BIMSP

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SPECIAL ISSUE

ABSTRACTS

received for

National Symposium on "Cloud and Precipitation Processes"



To be Jointly Organized by

Indian Meteorological Society, Pune Chapter (IMSP)

And

Savitribai Phule Pune University (SPPU), Pune

(In association with IITM Pune & IMD Pune)

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Indian Meteorological Society Pune Chapter (IMSP)

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3. Promotion of application of Meteorology and allied sciences to various constructive human activities

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Annual Monsoon Workshop (AMW-2019) and National Symposium on "Cloud and precipitation processes"

To be Jointly Organized by: Indian Meteorological Society, Pune Chapter (IMSP) and Savitribai Phule Pune University (SPPU), Pune
(In association with IITM Pune & IMD Pune)

❖ About IMSP and Annual Monsoon Workshop (AMW-2019):

The Indian Meteorological Society, Pune Chapter (**IMSP**), a Chapter under Indian Meteorological Society, is one of the largest and active chapters in the country. About 600 members are actively associated with India Meteorological Department (IMD), Indian Institute of Tropical Meteorology (IITM), various departments of Savitribai Phule Pune University, CDAC, IISER and other institutions. IMSP is one of the most important platforms for the meteorological stalwarts, for forwarding their experience and science to the next generation, even after their retirement. In order to keep a pace with time-to-time developments in the field of Meteorology, this Chapter organizes a sizable number of popular lectures by eminent meteorologists from India and abroad and more thematic programs focusing on popularization of Meteorology among the general public and basic academic institutions like schools, colleges, etc. **As a regular activity, IMSP conducts 'Monsoon Workshop' every year**. **This year, SPPU will join hands with IMSP to organize AMW-2019.** The behaviour and unique features of the monsoon season are discussed thoroughly during the Annual Monsoon workshop. The workshop provides meteorologists, working in the operational services and research, an opportunity to present various features of the monsoon in their varied point of view. In addition, weather scientists share their views & knowledge on the changing trends in the monsoon activity and its implications on various issues related to climate change. Behaviour & unique features of monsoon 2019 will be discussed thoroughly in **AMW-2019**.

❖ About the National Symposium on "Cloud and precipitation processes":

Although the term 'monsoon' refers to the consistent seasonal reversal in the wind direction over a region, the most significant feature of direct influence to us are the clouds and precipitation. It is well-established that monsoon rainfall undergoes intra-seasonal oscillations on the order of days to several weeks, as well as inter-annual variations. In addition, the precipitation also occurs from transient convective and meso-scale systems in highly localized pattern, with influence from the topography/ orography of the region. This further adds to the spatio-temporal variability of clouds and precipitation. The precipitation systems are observed to have large diurnal variations as well as variations in the frequency of occurrences, cloud base heights and durations. The processes involved and the controls on the formation of convective and stratiform systems, their organization and precipitation/ decay in the monsoon regime are highly complex. Improving the understanding on the role of atmospheric dynamics, dynamical and microphysical processes in monsoon clouds and correctly representing them in the numerical models are crucial for improving the monsoon forecast.

Long-term rainfall records over India indicate that Indian summer monsoon has become more extreme in the recent years. Intense short period rainfall causing floods and excessive dry spells

leading to droughts have risen markedly. Some of the extreme precipitation events in this decade have caused very devastating floods and landslides, which terribly affected human life, agricultural operations, infrastructure and transportation. Notable among them are the Uttarakhand floods in 2013, Kerala floods in 2018 and Maharashtra floods in 2019. In the year 2019, floods were experienced by Maharashtra, Madhya Pradesh, Bihar, Uttar Pradesh, Uttarakhand, Meghalaya, Assam, West Bengal, Kerala, Gujarat, Karnataka and many other states of the country (even in Rajasthan). Severe flood situation prevailed in Maharashtra, especially over Sangli & Kolhapur area (for the period 4-10 August 2019), Mumbai, Pune, etc. Mumbai has experienced floods in 2005, 2017 & 2019. Monsoon 2019 produced a large number of extreme rainfall events, making the seasonal total much higher than expected and also extending in time. Analyses have revealed that monsoon variability has amplified in the recent decades, with weakening of the moderate rainfall and a simultaneous rise in the magnitude and frequency of extreme rainfall events. Climate models predict that the frequency of extreme events, both in rainfall and dry conditions, are expected to increase over India in the warming world. Some of the important questions to answer are: **How will the frequency of extreme events change in the future? where and when they will occur?** and how far the global warming is responsible for the extremes?

Better understanding of the Cloud and precipitation processes, especially studies on controls and processes involved, and correctly parameterizing them in numerical models are crucial to improve the predictability of monsoon in general, as well as that of the occurrence of extreme rainfall events. Substantial research activities have taken place in the recent decades on these aspects, in terms of both observational and numerical modelling efforts. Nevertheless, the problems are getting more complicated in the warming world, with every monsoon season offering new challenges. The national symposium will provide an ideal platform to present and discuss recent findings on the monsoon clouds and extreme precipitation from observational as well as numerical modelling studies, especially flooding events in different parts of the country during recent years.

❖ **Invited Talks, on following themes, will be delivered by keynote speakers and experts:**

- Observing monsoon clouds: high altitude, air craft, radar and remote sensing.
- Ice nuclei and its role in cloud microphysics.
- Numerical modelling aspects of monsoon clouds.
- Historical perspective on extreme rainfall events over India from observations.
- Floods over various states of our country in 2019
- Why extreme events, and what we know/ don't know on the extreme events of the decade.
- Forecasting extreme weather events.

❖ **A special session** on **'Cloud Microphysics: Observational and Numerical Modelling aspects'** will be held as part of the National Symposium in **the honor of Prof. P. Pradeep Kumar**, a renowned cloud physicist who superannuated from Savitribai Phule Pune University in November, 2019.

Themes for the National Symposium:

Theme-1: Clouds and its characteristics:

- Characteristics of the monsoon clouds and rain-formation mechanisms.
- Microphysical characteristics of monsoon clouds.
- Aerosol-Cloud interaction and their impacts on monsoon.
- CCN and Ice Nuclei observations and parameterizations in numerical models.
- Cloud and precipitation parameterization for monsoon simulations.
- In Situ and remote sensing observations of monsoon clouds and precipitation.
- Observations of Orographic and other clouds.

Theme-2: Extreme weather events:

- Observational evidence for trends and changes in extreme events.
- Floods over various states of our country: Findings on severe flood situations over Sangli Kolhapur, Mumbai & Pune of Maharashtra, over Uttarakhand, Kerala & other states and other extreme precipitation events.
- Predictability of extreme weather events, especially extreme rainfall events.
- Investigations on mitigation and adaptation measures related to extreme rainfall events.

Theme-3: Ocean-atmosphere coupling & extreme events

- The role of oceans in extreme events
- The role of atmosphere in extreme events
- Study of extreme events through ocean-atmosphere coupled models

Theme-4: Climate change impacts

- Historical changes in monsoon rainfall characteristics.
- Global warming and extreme weather events.

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Theme-1 (Th1): Cloud-and-its-Characteristics

Th1-A001

Entrainment Rate and Mass-Flux Parameterization in Monsoon Cumulus Clouds

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Abstract:

Several Large Eddy Simulations (LES) with varying environmental humidity is used to investigate the entrainment and detrainment rates and convective mass-flux in monsoon continental cumulus clouds. The main purpose of the study is to make parameterization of the entrainment and detrainment rates in monsoon clouds over arid land (rain shadow region), useful for the large-scale atmospheric models. A systematic decrease in cloud liquid water path (LWP) is noted in the drier environments as clouds become shallower due to decrease in positive buoyancy in the cloud core. Updraft and downdraft velocities in the sub-cloud layers are strengthened in the drier environments which affects the in-cloud updraft strength. The most important finding of the present study is the effect of environmental humidity on the entrainment (and detrainment) rate and the convective mass-flux. The study found that a decreasing environmental humidity leads to a decrease in both the entrainment rate and the convective mass-flux but an increase in the detrainment rate. The relationships established between the entrainment parameters and the environmental relative humidity (RH) can be used in large-scale model parameterization.

Th1-P002

An innovative model to forecast 'Rainy days (clouds) cyclone emergence in Arabian Sea' months in advance based on relative daily movements in geo-centric solar system

Bhairavi Shah& Dhansukh Shah (Patron Member IMSP)

Abstract:

Moon is the satellite of the earth. Moon and Sun have impact on tide and ebb of oceans on the earth. Further there are eclipses of Sun and Moon on new moon or full moon. Accordingly, there should be 12+12 =24 eclipses in the year; however, we observe 2 to 7 eclipses in the year. These two matters are predicted months to years in advance of the event. Accordingly, if we consider topography of the area with various phenomena and aspects of Sun, Moon and planets it is possible to forecast 'RAINY DAYS (CLOUDS) CYCLONE EMERGENCE in the seas. For this purpose, we undertook a research programme for Saurashtra area of Gujarat State in INDIA (Area of more than 60,000 square kilo meters of Saurashtra), Guj. State has about 1,600 K.m of sea shore. We started research with past few decade data of rainfall, floods and cyclones as well as the ephemeris of those days. Accordingly, we find many positive results. Which are summarized here under:

It is the established fact (1) The day & night come about because the earth is spinning on her axis. (2) The seasons come about because of the inclination 23 1/2◦of the earth's axis to plain of its orbit. " Now It is observed that:"

(1) Changes in the daily weather are associated with various daily relative aspects and Phenomena of sun, moon and other planets of Geo-Centric solar system.

(2) The study of rainfall data with the relative movements in GEO-Centric Solar Systems indicates strong co-existing relation on the behavior of rainfall. There may be dozens of parameters to be identified with actual data. The work of verifications is under process. Following are some of the eye-catching observations short-listed.

- The changes in daily weather are associated with various relative combinations of aspects and phenomena occurring in daily movements in Geo- Centric Solar System.
- *The declination of mercury in the end of May or beginning of June determines onset of* monsoon in Saurashtra region. The positions of mercury determine cloud formation and off shore trough in west coast of India.
- Venus has profound effect on monsoon behavior. It determines positions of monsoon behavior.
- Certain positions of mars, mercury and Venus causes heavy to very heavy rains, sometimes resulting in floods.
- Certain positions of sun, mercury with Saturn and/ or Mars has effect on cyclone appearances.
- The detail effects of outer planets Jupiter, Saturn, Uranus and Neptune is under study. It is understood that these outer planets have effect on monsoon behavior.

Important words: topography, Geo-centric Solar system, rainy days, cyclone

Th1-P003

Comparison of Disdrometer Rain Rate with Cloud Penetration Depth of Celiometer laser during Monsoon 2018 and 2019 over Pune

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Abstract:

Present study investigates rain rate in mm/hr. observed by Disdrometer with the cloud penetration depth observed by ceilometer. Penetration depth data is retrieved from the Ceilometer CBME80B which uses a laser with 980 nm wavelength. The data is collected every 30 s and for this study it is averaged for every one minute. Rain Rate in mm/hr. were obtained from OTT Parsivel Disdrometer, which collects the data every 10 s and for this study we have averaged the data for every one minute. Both instruments are co-located at the Department of Atmospheric & Space Sciences, Savitribai Phule Pune University (18.5° N, 73.8° E and 560 m above sea level).

The rain rate has been grouped into light which is less than 2.8 mm/hr, moderate which falls in the range 2.8 to 7.6 mm/hr and heavy which is greater than 7.6 mm/hr. Observations for June, July, August and September (JJAS) have been considered for two years i.e. 2019 which was an Extreme monsoon year and 2018 which was a normal monsoon year.

The minimum penetration depth of the Ceilometer laser was around 30 m from the cloud base, while the maximum penetration depth was about 250 m. In general, the rain rate should be inversely proportional to the Ceilometer laser penetration depth. For heavy rain rate events this has been found to be valid with the only exception being the month of July 2019. However, for light and moderate rain rates it is seen that for most of the months the rain rate shows increase with laser penetration depth for year 2018 and vice-versa for 2019 suggesting different drop size distribution of rain due to different aerosol and cloud properties. Thus, the drop size distribution inside the cloud is one of the important factors for determining the attenuation of the Ceilometer laser beam.

Th1-P004

The Impact of Modified Fractional Cloud Condensate to Precipitation Conversion Parameter in Revised Simplified Arakawa-Schubert Convection Parameterization Scheme on the Simulation of Indian summer monsoon and Its Forecast Application on an Extreme Rainfall Event Over Mumbai

Malay Ganai[1], R. P. M. Krishna[1], Snehlata Tirkey[1], P. Mukhopadhyay[1], M. Mahakur[1] , and Ji-Young Han[3]

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Abstract:

The impact of modified fractional conversion parameter (from cloud condensate to precipitation) in the revised simplified Arakawa-Schubert (RSAS) convection scheme in Climate Forecast System version 2 on the simulation of Indian summer monsoon (ISM) is examined. While the default fractional conversion parameter is constant in RSAS, the modified parameter has the form of an exponential function of temperature above the freezing level, whereas below the freezing, level it is kept constant. The model simulation indicates RSAS with modified conversion parameter (RSAS_mod) shows a better fidelity in capturing the mean monsoon features over the ISM region. The spatial distribution of precipitation shows notable improvement over the ISM region. Most of the global general circulation models has a tendency to grossly overestimate (underestimate) the convective (large-scale) rainfall over the ISM region, which has somewhat improved in RSAS_mod simulation. It is suggested that reduced rate of conversion of cloud condensate to convective precipitation above the freezing level leads to suppression of convective precipitation, which further increases the detrained moisture from the upper-level, resulting enhancement in large-scale precipitation. Further, improvement has been noted in outgoing longwave radiation, wind circulation, total cloud fraction, and dynamical and thermodynamical processes in RSAS_mod simulation. The modified conversion parameter helps in improving the feedback between moisture and convective processes through better lower tropospheric moistening. In addition to mean summer monsoon, the RSAS_mod indicates its potential in predicting an extreme rainfall event over Mumbai in high-resolution global forecast system at T1534 horizontal resolution. However, its fidelity needs to be further tested for more number of heavy rainfall events.

Th1-P005

Single-Particle Analysis of Airborne Aerosol Particles from the Rain Shadow Region of Western Ghats

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Abstract:
Regional heterogeneity in aerosol concentration influences monsoon rainfall in the Indian subcontinent. Here we report single-particle analysis of airborne aerosol particles from the rain shadow region of the Western Ghats during 2015 southwest monsoon. Samples were collected using a research aircraft as part of the Cloud-Aerosol Interaction and Precipitation Enhancement Experiment (CAIPEEX). Collected particles were characterized for morphology, mixing state and chemical composition using High-Resolution Transmission Electron Microscopy (HR-TEM) coupled with Selected-Area Electron Diffraction (SAED) and Energy-Dispersive Xray Spectroscopy (EDS). Realtime data of aerosol, cloud condensation nuclei (CCN) and cloud droplet measurements complement the HR-TEM/EDS results. 98% of the detected particles were in submicron size. Based on chemical composition and morphology, analyzed aerosol particles were grouped into Metal particles (Fe, Co and Cr rich), Sea Salts, Silicates and Carbonaceous particles. The majority of the particles sampled were heterogeneous and internally mixed with two or more aerosol species, thus indicating multiple sources and atmospheric aging. Silicates (up to 73%) were the dominant species in samples collected during non-rainy days. Samples collected during rainy days contained a higher concentration of sea salts (up to 50%). There are clear indications for the presence of pollution aerosol signature in the cloud layer, which are indeed found as aged particles and as aggregates. The internally mixed carbonaceous particles were found with metal and sea salt during the days with enhanced cloud growth and precipitation. The spatial heterogeneity and mixing state associated with sampled aerosols are discussed in this study with an emphasis on vertical variation of its size and number concentration.

Keywords: Airborne aerosols, TEM, Morphology, Aerosol composition, Mixing state, Monsoon

Th1-P006

EFECT OF HIGH-LEVEL METEOR SHOWERS ON ARESOL NUMBER DENSITY

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Abstract:

Atmospheric aerosols are the suspension of particles in air. Aerosols play active role in altering the radiation budget of the earth's atmosphere. In the present work, study of high level meteor shower (Zenith Hourly Rate > 10) was done to know the effects of meteor showers on Aerosol Number Density per dm^3 (AND). Aerosol measurements have been carried out at Kolhapur (16°42′N, 74°14′E) using the Semiautomatic Twilight Photometer to study the association between vertical distribution of the atmospheric AND and different types of clouds.

After event of High-Level meteor showers, we find a peak of AND on the following morning, or the following evening. This Peak lies mostly in between altitude of 50-60km which clearly shows, the sudden increase in AND. In few cases, this peak found below 50km, which shows, deep penetration of meteor particles. Further, looking at AND-Altitude graphs for days after the meteor showers, altitude of these peaks moves slowly down, also AND of peak reduces slowly, and width broadens. It slowly diffuses in our atmosphere. Further, after the events we see cloudy sky, within 3-4 days of the event, which shows many of these particles become cloud condensation nuclei (CCN) and lead to cloud formation. Observing cloudy days soon after the meteor event, confirms this. Two of such events discussed below.

Looking at the 2011, Ursids event (23 December), we observed AND peak at date 25th, at 60.65kms, with AND 5199 and width 6.58km. After which on 26th peak shifts at 55.23kms, and on 27th morning peak reaches below 50km level with several peaks in altitude range of 35-50kms, with AND ranging between 700-2000 and at evening the cloudy sky observed.

Similarly, looking at the 2009, Eta Aquarids event (6 May), we observed two AND peaks at 7th morning (at 44.48kms and 46.35kms, with AND 1137 and 1979 respectively). While at 7th evening we see peaks ranging at 41-46kms, with AND 968-760, (Highest peak at 41.17kms). By 7th morning, the sky became cloudy.

Keywords: aerosols, remote sensing, meteor showers, twilight technique, clouds

Th1-P007

Ground-based and air borne observations of microphysical properties of monsoon clouds over Western Ghats, India

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Abstract:
The microphysical properties of monsoon clouds over Western Ghats, India are studied using ground based and aircraft observations of monsoon 2015. Cloud Aerosol Interaction and Precipitation Enhancement Experiment (CAIPEEX) phase III campaign done in monsoon 2015 was over Western Ghats region where High Altitude Cloud Physics Laboratory (HACPL), was the base station. Ground based observations were taken from HACPL (Lat: 17.92º N, Lon: 73.66º E). In this work, microphysical properties of monsoon clouds i.e., passing through ground and vertical distribution have been studied using Cloud Droplet Probe (CDP) observations (deployed at HACPL and on-board flight). Microphysical properties such as Cloud droplet number concentration (CDNC), Liquid water content (LWC), Median volume diameter (MVD), Effective diameter (ED) and Cloud droplet mean diameter (D_m) has been studied on temporal and altitude scale.

Using 104 hours (12th June 2015 to 4th August 2015) of CDP observations obtained from HACPL it is seen that, CDNC and LWC have higher magnitude during the month of June. MVD and ED were almost within the same range throughout the observational period and exhibited similar variation with MVD slightly higher than ED. D_m ranged from 5 µm to 15 µm. In general a clear intra-seasonal variation is seen in all the microphysical properties and even showed the presence of cloud with larger and smaller droplets over the study region.

Vertical distribution of cloud microphysical properties has been studied using CAIPEEX aircraft observations. During this campaign (July 2015), 25 research flights (RF) were conducted over the Western Ghats, out of which 06 RF flew over within HACPL, i.e. ±0.1 degree. From the obtained data set, the distribution from ~ 1.8 km to 3 km has been obtained. In general the vertical distribution has shown that, CDNC is within 10 to 130 cm^{-3}, LWC from 0.2 to 1.0 g m^{-3}. D_m from 5 to 25 µm, ED from 6 to 28 µm and MVD from 10 to 30 µm. Detailed analysis and statistics will be presented.

Th1-P008

Pre-monsoon cloud characteristics as seen from ceilometer observation of a high altitude site in Western Ghats, India

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Abstract

Pre-monsoon cloud characteristics obtained from Ceilometerobservations of aHigh Altitude Cloud Physics Laboratory, (HACPL, 17.92°N, 73.66°E, and 1348 m above mean sea level (MSL)),is presented here. HACPL, Mahabaleshwar,is situated at windward side of Western Ghats. In this work, ceilometer derived Cloud Base Height (CBH), cloud depth and Backscattering Coefficient (β) for the period April to May, 2019 was analyzed.

During this season single layer, two layered and three layered clouds were observed over the study region. Categorization of retrieved bases of cloud base height has showed the presence of low level, mid-level and high level clouds. Clear diurnal variation in cloud base height is visible from the analysis. On comparing the CBH with observed CBH of transition to monsoon period (June month) showed the presence of smaller base clouds during monsoon. Clear association of cloud base height was seen with pre-monsoon convective event. Detailed statistics and results will be provided.

Th1-P009

Atmospheric Aerosols and Different Types of Meteor Showers

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Abstract:

Atmospheric aerosols are minute particles (10^{-9} to 10^{-4} m) suspended in various layers of Earth's atmosphere. During meteor showers, huge amount of cosmic debris called meteoroids enters into the Earth's atmosphere. These particles contributes to aerosols in the mesosphere. One attempt is made to study correlation between the mesospheric Aerosol Number Density per dm^3 (AND) and Meteor Showers of medium-level (ZHR in between 2-10). Another attempt is made to find out impact of low-level meteor showers (ZHR<2) also.

Semiautomatic Twilight Photometer is capable of giving the qualitative picture of aerosol vertical distribution from about 6 km to a maximum of 350 km. During the course of the study, the measurement of the atmospheric aerosols carried out by using semiautomatic twilight photometer during the period of 2009 to 2011 at Kolhapur (16°42′N, 74°14′E).

Results indicates that there is gradual increase in AND as we come downwards from higher altitudes. It also reveals that whenever there is peak of meteor showers, AND changes significantly. Due to addition of minute particles (meteor showers debris i.e. aerosols); AND at mesosphere is boosted up and increases than its average value. With respect to time, this increased AND shifted to lower altitudes and coming to troposphere, they contributes in cloud formation. On an average after 12-24 hours increased AND again dropped down to its average value at corresponding altitudes. Few of such events discussed below.

In case of medium-level meteor shower Alpha Centaurids (7 February 2009 with ZHR 5), it was noticed that during peak period of meteors AND increases rapidly at the altitude of 140km; also dropped to its average value after certain time.

In case of low-level meteor shower 'Xi corona Borealids (15 January 2011), it was observed that during peak period there is sudden increase in AND at different height in the mesosphere. Two days after these aerosols dispersed in the mesosphere showing higher aerosol loading. Beta Herculids (13-Feb-2011) meteor shower, also showed similar results.

Many of earlier workers have studied about High-level meteor showers. This is the first attempt to study medium-level and low-level meteor showers.

Keywords: aerosols, remote sensing, meteor showers, twilight technique, clouds

Th1-P010

Association of Solar flares with Thermospheric aerosols and clouds

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Abstract:
Atmospheric aerosols present in the atmosphere known to affect the overall climate change. The present study is focused on the thermospheric aerosols and its correlation with solar activity. Solar activity in connection with solar flare was studied. The relation between solar phenomenon and its effect on the aerosols and the climate was studied.

Semiautomatic Twilight photometer was developed for the measurements of atmospheric aerosols. Observations of Aerosol Number Density (AND) for different layers of the Earth's atmosphere were taken at Kolhapur, Maharashtra (16 ◦41' 28.7052" N 74◦ 14' 41.5140" E). The data was analysed to study vertical distribution of aerosols in connection with solar flares, one of the solar activities.

Solar flares eject stream of highly energetic particles through the Sun's corona into the outer space. These particles can affect the Earth's magnetosphere. If the ejection is in the direction of the Earth, particles associated with this disturbance can penetrate into the upper atmosphere. These partials oscillate between poles many times and when the energy become sufficiently low, they trapped by the Earth's gravitational field. It is well known that, they can cause bright auroras, and may even disrupt long-range radio communication.

In the present study, one attempt is made to study thermopsheric Aerosol Number Density per dm3 (AND) in association with some intense solar flares. The study focuses on the solar flares dated 15 February 2011 and 9 March 2011. These flares were of intensity X2.2 and X1.1 respectively. After 4-5 days from these flares increase in the AND at the altitude of 300kms was noticed. These particles slowly slides down showing increased AND at 250kms after 2-3 days. Again sliding down of these particles up to the altitudes of 200km and 150kms was also detected. Some flares are so energetic that increased AND in the lower atmosphere also observed, and high-level cloud formation seen.

However, at present the definite relation between the solar flares and different types of clouds could not be established with so few data events, this is the innovative attempt.

Keywords: aerosols, thermosphere, solar flares, twilight technique, clouds

Th1-P011

Effects of Coronal Mass Ejections on Earth's Thermosphere

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Abstract:

Aerosols, one of the most important constituents of the Earth's Atmosphere, are fine particles that are suspended in various layers of the atmosphere. The particles in the Thermosphere are continuously subjected to a high-energy stream of charged particles and radiation from the Sun, in the form of Coronal Mass Ejections (CMEs), and also from interplanetary and intergalactic cosmic rays. A CME is a type of solar phenomena in which a significant amount of highly energized plasma and an accompanying magnetic field is released from the sun. Although protected by the magnetic field, these particles penetrate the shield and enter the earth's atmosphere causing the ionization of the upper atmosphere and the formation of radioactive nucleoids in the same. These ions then affect the total electron content, aerosol density, cloud formation rate and various other factors that drive our atmosphere.

In order to observe the effects of incoming high-energy particles in the thermosphere, the data of concentration of aerosols in the atmosphere, measured in terms of Aerosol No. Density (AND) per cm^3, was taken using Semi-Automatic Twilight Photometer, which works on the principle of Mie Scattering, from Kolhapur (16°42′N, 74°14′E). To detect an earth-directed CME, High-Energy Proton flux data was taken from GOES-13 satellite of NASA and NOAA. These data sets were then analyzed in order to observe the effects. The analysis showed the increase in the AND during the proton events along with the occurrence of Twilight Airglow at 315-350 km altitude. The wavelength of Twilight Airglow observed was 620 nm which tells that the Twilight Glow was the result of the ionization of the atomic oxygen layer present in the thermosphere region due to high-energy particles. This increase in the AND resulted in an increased rate of cloud formation along with the occurrence of contrails and high-altitude clouds. This work is one of the first attempts to study the thermosphere region and the effects on aerosol due to high-energy particles of extraterrestrial origin.

Th1-P012

Study of Upper Stratospheric Aerosol Loading

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Abstract:

Aerosols measurements were carried out at tropical station Kolhapur (16º42′N, 74º 14′E) during the period of 1 January 2009 to 31 December 2011 by using semiautomatic twilight photometer. One attempt was made to study upper stratospheric (altitudes in between 30-50 kms) aerosol loading.

Upper stratospheric aerosol loading showed day-to-day variability but there was no specific trend for monthly variability for all the three years. One noticeable point was that for the entire three years upper stratospheric aerosol loading was lowest for the month of February, the period free from strong meteor activities; whereas maximum for the month of December, the period followed by Orionids, Leonids and Geminids activities. Minor variations were observed in the months of March and April, the period of weak meteor showers. The considerable fluctuations were detected in the period of strong meteor activities. The conclusion drown from these observations is that, the upper stratospheric aerosols completely depends on an influx of meteor matter including sporadic celestial dust particles and meteor showers. During meteor showers, large amounts of dust particles intrude into the mesosphere. These dust particles perturb the middle and upper atmosphere and contribute to additional scattering in the atmosphere.

The height resolution of semiautomatic twilight photometer is ~400 meters for upper stratosphere. Hence, very small-scale features are visible for the aerosol vertical profiles. Therefore, upper stratospheric aerosol loading showed large amount of peaks on the graph of AND vs. Altitude. Monthly variations of these peaks were studied. They also showed similar type of variations as explained above.

Keywords: aerosols, remote sensing, meteor showers, twilight technique, stratosphere

Th1-P013

Application of machine learning in cloud microphysics

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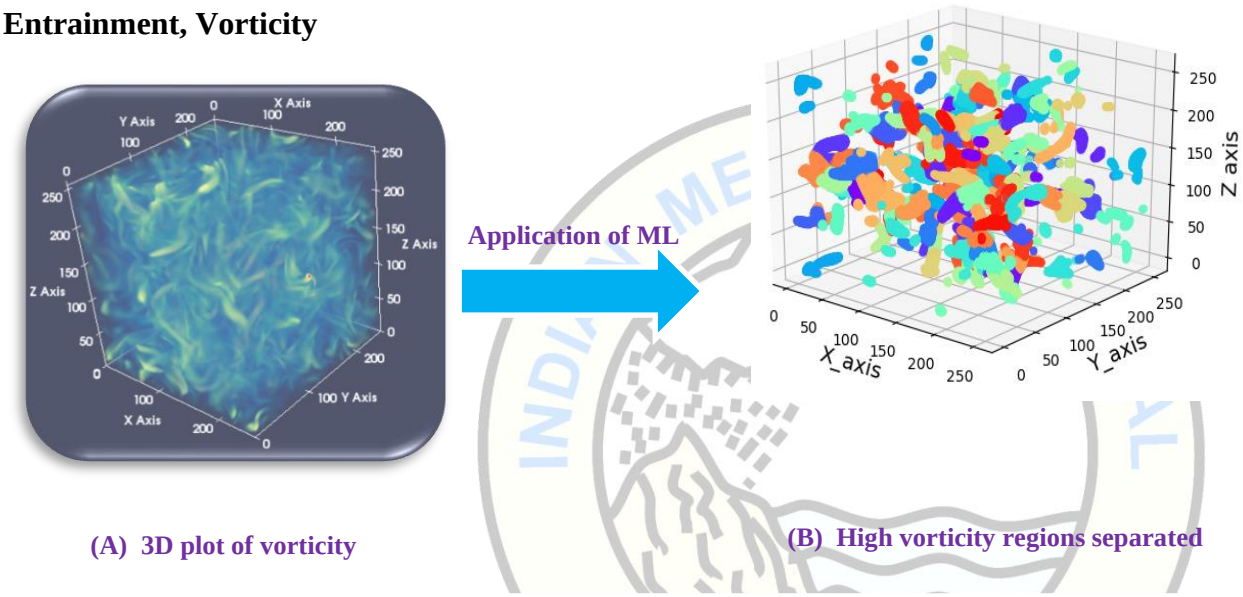
Abstract:

The mixing between cloudy and ambient dry air takes place through turbulent entrainment process. It modifies the cloudy volume and the interface as well. Entrainment and mixing process give rise to regions with certain characteristics, like high vorticity or low vorticity, negative or positive vorticity and high or low or high velocity etc. Identifying and locating such regions in a certain domain through visualizations can be slow and tedious, making the analysis of droplet characteristics and physics of the flow a very time consuming job. So, to examine the droplet characteristics in high and low vorticity regions in Direct Numerical Simulation of cloud in turbulent flow environment, we have used an unsupervised machine learning algorithm. It gives the locations of the regions in form of coordinates, which is easier and more reliable for further application in the study of droplet characteristics such as droplet size spectra and degree of mixing in selected regions.

Keywords: DNS, Clouds, Machine Learning (ML), Entrainment, Vorticity



(A) 3D plot of vorticity **(B) High vorticity regions separated**

Fig. : The panel (A) depicts the vorticity plot in a domain of size (25.6 cm)^3. The selection of high vorticity regions using machine learning algorithm has been shown in panel (B).

Th1-P014

Study of aerosol and cloud characteristics during dry and wet conditions over Delhi

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Abstract:

Atmospheric aerosols arising from the variety of natural and anthropogenic emission sources have huge impact on our climate system through direct and indirect effects. Aerosol direct effect from scattering and absorption of solar radiation continuously modifies the Earth's radiation budget and, at the same time, through aerosol indirect effect, it alters the cloud microphysics and precipitation efficiency and thus the cloud life time. Due to recent climate change and global warming issues, study of atmospheric aerosols and its interaction with clouds become essential on regional levels as well. The present study aims to understand the spatio-temporal variability of aerosol optical and cloud microphysical properties and their possible association with each other during the dry and wet conditions over Delhi, one of the highly polluted urban mega cities in the world using MODIS level-3 data from the Terra and Aqua satellites for 15 years period from November 2004 to October 2019.

The highest recorded value for annual mean of dry season aerosol optical depth (AOD) in 2016, which ranged from 0.49 to 0.90 while for wet season, it varied from 0.73 to 0.98 with the highest recorded value in 2019. During the study period, the mean Angstrom exponent (AE, a proxy for dominant aerosol sizes) ranged from 1.52 to 1.69 for both dry and wet seasons. The analysis showed variation of annual mean of seasonal water vapor (WV) ranged 4.48 to 5.69 cm in wet season while 1.34 to 1.83 cm in dry season. High value of WV observed during the wet season is due to high temperature and precipitation in this season. The correlation between AOD and WV is found to be positive in both seasons, with relatively higher correlation in the wet season (0.39). From the observation, the results showed the annual mean cloud liquid water path (CLWP) and cloud effective radius liquid (CERL) varied from 21.32 to 42.83 g/m^2 and 15.91 to 18.46 μm in dry seasons respectively, while in wet seasons, these values varied from 29.26 to 80.81 g/m^2 and 15.27 to 17.58 μm. Furthermore, investigation showed annual mean of cloud fraction (CF) and cloud optical depth (COD) varied from 0.33 to 0.49 and 2.11 to 5.42 in dry seasons, respectively while in wet seasons, it varied from 0.33 to 0.68 and 3.09 to 8.14. AOD showed positively correlated with CF, which was relatively highly correlated during the wet season (0.62) compared to dry season (0.15). The annual mean cloud top pressure (CTP) and cloud top temperature (CTT) ranged from 864 to 760 hPa and 288 to 279 K, respectively in the dry season, while in wet season, it varied from 746 to 581 hPa and 292 to 276 K, respectively. Interestingly, AOD showed a positive correlation with CTP and CTT in dry season (0.49 and 0.52); however, a negative correlation was observed in wet season (-0.59 and -0.53). It could be due to increase in anthropogenic aerosols, which may change CTT and humidity profile by induced secondary circulation.

Th1-A015

Tropospheric Aerosols and Different Types of Clouds

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Abstract:

Aerosols (the suspended particles in the air) are responsible for the majority of atmospheric phenomena. In the present study, semiautomatic twilight photometer was operated for three consecutive-years viz., 2009-2011. This is an inexpensive but very sensitive instrument for remote sensing of vertical distribution of the tropospheric aerosol number density per cm^3 (AND).

Detail study of AND vertical profiles from 6 to 7 km gives pre-information about occurrences of high level cloudy days. The results acquired reveal that one peak was detected three days prior to the high level cloudy sky days. This peak was found to be moving downwards with an average speed of the order of ~0.2 to 0.3 km per day for the two subsequent days after perceiving it. The AND at 6 km was increased (~1000 particles per cm^3) at former to the high-level cloudy sky conditions. On the clear sky days following cloudy sky conditions, the values of AND at ~6 Km was found lower (~260 to 300 particles/cm^3) in most of the cases.

Middle and low level clouds were frequently observed following with high level clouds. In very rare cases, middle level cloudy days were noticed separately after any clear sky days. The sudden increase in the aerosol loading, in between 6 and 7 km at any day followed by sudden decrease at subsequent day could be a precursor of middle level cloudy days.

The contrail is also one type of clouds. The results acquired reveal that one or two broad aerosol layers noticed in between 8 to 12 km on the AND vertical profiles at any day could be a forerunner of the contrail occurring at subsequent day.

Optically thin cirrus layers were frequently observed just below the tropopause. These clouds were invisible for normal eyes. Using twilight technique existence of thin invisible cirrus clouds in the field of view of the twilight photometer can be discovered. The increased aerosol loading in between 8 to 11 km at any day was responsible to create favourable conditions for the invisible cirrus clouds development on the next day.

Keywords: aerosols, clouds, twilight photometer, remote sensing, weather

Th1-P016

STRATOSPHERIC JUNGE LAYER AND DIFFERENT TYPES OF CLOUDS

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Abstract:

Atmospheric aerosols are the fine solid particles or liquid droplets suspending in air. Aerosols play a crucial role in the environmental aspect of a region since it has been observed to affect cloud formation. Aerosols are observed in all different atmospheric levels viz. Troposphere, Stratosphere, Mesosphere and Thermosphere.

The aerosol layer found in the stratosphere, often known as the Junge layer is found at a height of around 15-25 km from the earth's surface. Aerosol vertical profiles were utilised to measure the maximum aerosol number density (AND), their corresponding altitudes and the thickness of Junge layer. The trend observed amongst these quantities was examined for data sets ranging over two years Set1: 2009-10 and Set 2:2010-11 with regards to the seasonal changes.

The sky was almost clear in January and March. In February all, the three types of clouds were observed frequently. It was observed that the altitude of Junge layer peak for clear sky day, preceding the high level cloudy sky day lowered down to ~11 Km and increased up to ~19 Km on the clear sky day following the high level cloudy sky day.
Middle and low level clouds were frequently observed following with high-level clouds. It implies that the CCN particles perturb downwards. In very rare cases, middle level cloudy days were noticed separately after any clear sky day. It was detected that the altitude of Junge layer peak decreased one day before the low-level cloudy days, value of, AND increased near about three times the normal values.
In winter, fog or dewdrops were observed. Fog is also one type of cloud in contact with ground. The AND of Junge layer peak increased nearly three times for clear sky days prior to the days on which fog or dew drops were observed.
The annual variation of the altitude of the peak of Junge layer shown that, this layer appeared to be drifting downwards as the monsoon season approached. The annual variations of the altitudes of the peaks of Junge layer and the AND of Junge layer peaks showed opposite phase relation.

Keywords: Junge Layer, Stratosphere, Aerosol, clouds

Th1-A017

Study of Aerosol-Cloud interaction on precipitation system using spaceborne radars

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Abstract

The present study investigates the indirect effect of aerosols on precipitation clouds over Indo-Gangetic Plains (IGP) and Western Ghats (WG) region. We used radar reflectivity from Cloudsat Cloud Profiling Radar (CPR) and Global Precipitation Mission (GPM) precipitation features database to classify single layer warm clouds and mixed phase clouds during the 2014-2017 monsoon period, respectively. The aerosol optical depth (AOD) (proxy for aerosol concentrations) was extracted from level 3 MODIS datasets. Results over the IGP region shows the suppression of warm rainfall, while rainfall intensity is increased in mixed phase clouds due to dominancy of ice processes. We further looked at the relationships between 20, 40 dBZ echo top height with AOD. The significant positive (negative) correlation was observed over IGP (WG) region. The results show aerosols enhance the cloud top height and increases the cold rain in mixed phase clouds. The present study adds value to existing studies by examining the potential of both Ku and W band spaceborne radars on cloud-precipitation-aerosol systems.

Keywords: Clouds, aerosol, radar, GPM, Cloudsat

Th1-P018

Surface controls on the Planetary Boundary Layer height during different monsoon scenarios over a rain shadow region

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Abstract

The Planetary Boundary Layer (PBL), the lowest part of the troposphere, interacts with the earth's surface and plays a dominant role in the weather and climate of a region. The vertical transport of momentum, heat and moisture are affected by turbulent mixing in the PBL, and thus controls the low-level cloud development. The PBL height and turbulent mixing exhibit large variations at diurnal and seasonal scales, which also has large spatial differences. The surface conditions and forcing mechanisms over the Indian sub-continent changes significantly in relation to monsoon circulations and rainfall, which in turn affects the PBL characteristics. For numerical weather and climate modelling, air pollution and agro-meteorological applications, quantitative understanding on the PBL height evolution and its various controls are very important.

In our study, PBL heights are estimated using air temperature and humidity from radiosonde and microwave radiometer. The micrometeorological observations on a 50 meter tower are used to study the surface controls on PBL height. The observations are taken from the Cloud Aerosol Interaction and Precipitation Enhancement Experiment (CAIPEEX) ground based observations conducted at Solapur, a rain shadow location in Maharashtra, by the Indian Institute of Tropical Meteorology, Ministry of Earth Sciences. The Convective Boundary Layer (CBL) heights are calculated from microwave radiometer observations using parcel method and compared with radiosonde CBL heights. The Brunt-Vaisala frequency method is used for the detection of stable boundary layer heights. Diurnal and seasonal variations of CBL evolutions are investigated in for one complete year during 2018-19. The dependence of PBL height evolution on the surface fluxes, namely net radiation, sensible and latent heat fluxes are investigated in detail for different monsoon scenarios.

Th1-P019

Investigation of Black Carbon Direct Radiative Forcing over India

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Abstract:

In India, there is large uncertainty as to estimate of loading of black carbon (BC), direct radiative forcing (DRF) and climate response because, lack of countrywide monitoring and coarse emission inventory of BC in early years. Here we used emission inventory (EDGAR-HTAPs) of BC to investigate its loading and optical depth (AOD) at 550 nm and DRF using weather research forecasting model coupled with chemistry (WRF-Chem). The model framework consists of 2 interactive domain. The outer most domain covers the Asian region with 45 km resolution whereas inner domain cover mainly the Indian geographical region with a finer resolution of 15 km x 15 km. The levels of BC simulated by the model has been validated by the pan-India observational network of MAPAN (Modelling Atmosphere Pollution and Network) project. Model simulated pattern of AODs is found to be smaller than from satellite and AERONET. Preliminary model results suggest a significant bias in simulated results of BC and DRF against observation. The model is being fine-tuned. Initial results and model capability will be discussed in this paper.

Th1-A020

Diffusional growth of cloud droplets in homogeneous isotropic turbulence: Scaled-up DNS

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Abstract:

A novel methodology to use the Direct Numerical Simulation (DNS) to study the impact of isotropic homogeneous turbulence on the condensational growth of cloud droplets for larger domains is attempted. As shown by previous DNS studies, the impact of turbulence increases with the computational domain size, that is, with the Reynolds number, because larger eddies generate higher and longer-lasting supersaturation fluctuations that affect growth of individual cloud droplets. The traditional DNS can only simulate a limited range of scales because of the excessive computational cost that comes from resolving all scales involved, that is, from large scales at which the turbulent kinetic energy (TKE) is introduced down to the Kolmogorov microscale, and from following every single droplet. The novel approach is referred to as the 'scaled-up DNS'. The scaling-up is done in two parts, first by increasing both the computational domain and the Kolmogorov microscale, and second by using super-droplets instead of real droplets. To ensure proper dissipation of TKE and scalar variance at small scales, molecular transport coefficients are appropriately scaled-up with the grid length. For the scaled-up domains, say, meters and tens of meters, one needs to follow billions of real droplets. This is not computationally feasible, and so-called super-droplets are applied in scaled-up DNS simulations. Each super-droplet represents an ensemble of identical real droplets, and the number of real droplets represented by a super-droplet is referred to as the multiplicity attribute. After simple tests showing validity of the methodology, scaled-up DNS simulations are conducted for five domains, the largest of 64^3 m^3 volume using a DNS of 256^3 grid points and various multiplicities. All simulations are carried out with vanishing mean vertical velocity and with no mean supersaturation, similarly to past DNS studies. As expected, the supersaturation fluctuations as well as the spread in droplet size distribution increase with the domain size, with the mean droplet radius variance increasing in time t as $t^{1/2}$ as identified in previous DNS studies. Scaled-up simulations with different multiplicities document numerical convergence of the scaled-up solutions. The results are compared with a simple stochastic model that calculates supersaturation fluctuations based on the vertical velocity fluctuations updated using the Langevin equation.

Th1-A021

Sensitivity experiments with surface temperature and impact on cloud processes using cloud resolving simulations

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Abstract:

North east monsoon gives a significant portion of annual rainfall and thus plays a crucial role for southern peninsular India. In this study, we have studied the role of surface heating on the cloud processes over the coastal and inland area. Typically, the surface temperature observations are not available and is either taken from a large scale model or an estimate from other observations of energy budget are used in the simulations. A change of surface temperature has indeed modified the conditions favourable for deep cloud development and prevalence of mixed phase processes. This has indeed impacted precipitation from these clouds; by the amount, intensity and duration of precipitation.

The observations conducted during the CAIPEEX experiment showed contrasting microphysical characteristics for these clouds. On 24th October 2011 i.e. on the onset date of north east monsoon 2011, CAIPEEX aircraft took in-situ measurements of clouds over coastal and inland region near Vijayawada, Andhra Pradesh. This study investigates and compares the microphysical properties of these observed clouds with an idealized simulations performed over coastal and inland domain. A thermodynamic profile showed a sandwiched dry layer over both regions around 5000 meters AMSL. Seven days HYSPLIT back trajectory analysis at lower level showed the continental origin and at upper level showed marine origin of air mass. Two separate simulations are conducted, one for the inland location and another for the coastal area. Preliminary results shows that the cloud droplet number concentration is higher at base of cloud in a coastal case and is higher near upper part of cloud in an inland case. Also, it is observed that the enhancement in surface heating is helping clouds to grow deeper, which results in early formation of graupel and thus increased accumulated precipitation. Further inferences are made from these simulations and will be discussed in the presentation.

Th1-P022

Aerosol Characteristics of an Elevated Haze layer using Aircraft Observations

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Abstract:

The vertical profile of condensation nuclei (aerosols) and cloud condensation nuclei (CCN) for a day (during the monsoon break phase) over the rain shadow region of Western Ghats is presented. The boundary layer had weak westerlies while the dry continental northerly air mass produced an inversion layer above it. This continental air mass also brings in more aerosols which forms a layer of haze at altitudes between 4 and 5km. The CCN concentration at 0.36% supersaturation also increased with altitude. Filter analysis of these aerosols using High Resolution Transmission Electron Microscopy (HR-TEM) coupled with Energy Dispersion Spectroscopy (EDS) were performed on the aerosol samples collected. The samples showed signatures of pollution and marine aerosols at lower levels (1-2km). Aged Tar balls and soot particles mixed with some crustal matter was found in the haze layer. The filter analysis was found to be consistent with the back trajectory analysis. CCN closure study was also performed on the aerosol measurements.

Th1-P023

Importance of Hallet-Mossop process in monsoon clouds

Gayatri Kulkarni, S. Patade and Thara Prabhakaran

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Abstract:

There has been a lot of research for the past 40 years on discrepancy between ice crystal number concentration and ice nuclei particle concentration (e.g.,Mossop and Hallett, 1974; Mossop,1985; Rangno and Hobbs, 2001;Crawfordet al., 2012). The ice crystal number was found by almost four orders higher than the ice nuclei number (Cooper and Vali,1981; Auer et al., 1969). To explain this enhancement, variety of secondary ice nucleation mechanisms were proposed, for example, the rime splintering mechanism also known as the Hallet-Mossop (HM) Process (Hallett and Mossop, 1974). It occurs between -3 and -8 ^{o}C cloud temperature zone and highly effective at -5^{o}C when large ice particles collide with cloud droplets. Modelling studies allow further insights on HM process in different thermodyanamic framework and their roles in ice multiplication process. We present simulatuons to understand the importance of HM process on monsoon clouds in different environments. It is seen that HM process was responsible for a significant contribution of small ice crystals concentration which later grow further due to vapour deposition, aggeragation and riming. These aspects result in more precipitation when HM process is active. Impact of HM on the large scale precipitation over the Indian region is shown in this study. Also, the atmospheric moisture play an important role in the ice multiplication process, therefore, contribution of HM process in monsoon clouds is more significant.

Th1-P024

Radar-derived Storm-to-large scale environment relationships: Observational constraints on the assumptions of Convective parameterization schemes in Numerical models

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Abstract:

Radar-derived storm scale convection holds an important place in the scale hierarchy of tropical deep convective cloud systems as storms occupy major fraction and contribute to more than 90% of the convective precipitation. Nevertheless, accurately representing them in climate models requires an understanding of the relationships between the states of convective cloud ensemble and the large-scale environment. We investigate this relationship using 9 wet seasons of radar observations in a tropical station located at the eastern flank of Indian Summer Monsoon Trough. We find several key characteristics of convective storms are related with their own unique environments. The larger positive moisture convergence is associated with increased convective precipitation through increasing convective precipitation area. Numerous Convective storms are likely to occur in moist mid- tropospheric conditions, albeit those cells are less intense. On other hand, in a relatively drier mid-tropospheric conditions storms are observed to be fewer but more intense. CAPE is observed to affect cell area and cell number in a disproportionate way such that it has a stronger influence on intensity than areal mean property. Though our findings are statistically robust, we acknowledge significant variability in the relationships. Storm scale Convection bears a more systematic relationship with large-scale environment measures related to large-scale convergence compared to instability/energetics. The degree of randomness in the storm-to-large scale relationship is found to be decreasing as a function of the increasing large-scale forcing itself. This explains the empirical outlines that convective systems embedded within the large scale dynamical features like Monsoon Trough, depends strongly on the synoptic conditions with less departure from the mean state i.e. less stochastic in nature. We also found that storm scale convection exhibits selective nature in the large-scale environment with a stochastic to quasi-equilibrium transition. The observed results provide information on relationships between convective state cloud and large scale environment that is much implicative and instructive for the convective parameterization in climate models. The degree of randomness in the storm-to-large scale relationship enable us to go for the stochastic framework of spectral convective parameterization schemes that incorporates statistics of convective cloud ranging from single storm cell to mesoscale convective systems in the cloud resolving models.

Details of work will be presented during the final Proceedings of the conference.

Th1-P025

Observational characterization of cold rain process in the Indian Summer Monsoon

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Abstract:

Cold rain process refers to the formation of precipitation from mixed-phase and ice phase clouds. Mid-level mixed-phase clouds are cloud systems characterized by the presence of both supercooled liquids and ice crystals typically found between 0º and -40º isotherm in the atmosphere. The study of mixed-phase clouds is essential because of its importance in precipitation formation, cloud life cycle, and radiation budget. This observational work uses high-resolution cloud radar, Ka-band scanning polarimetric radar (KaSPR), located at a tropical site in Indian Western Ghats. Vertical looking measurements of the radar are studied to understand the cloud vertical structure during the Indian summer monsoon(ISM) and the role of mixed-phase clouds in the precipitation process. The mixed-phase clouds found in the height range of 5.3-10.8 km are analyzed using the reflectivity factor (Z) profiles and CFAD analysis, particularly under changing the ISM spell or vigour. The occurrence of mixed-phase clouds is high during transition time compared to the active and break phase. Since the mixed-phase clouds occur between low-level and high-level clouds, it can be affected by both, which is evident from the cloud vertical structure. This can be due to the combined effect of cloud environment interaction through turbulence and dehumidification. In the case of high-level clouds, a descending cirrus type cloud base can reach up into a mixed-phase region height of 6 km with a descending rate in the range of 0.6-1.0 m s-1 with cloud top height sustained around 13 km. Moreover, the study shows an increase in ice water content in the mid-level clouds during ISM active phase. The qualitative role of cloud microphysics and cloud dynamics will be brought out and discussed in the forthcoming Annual Monsoon-2019 Workshop and National Symposium on "Cloud and Precipitation Processes," that is the main focus regarding the cloud radar inferred monsoon clouds measurements.

Th1-P026

A Study on Characterization Of The Sky-Conditions Using Ground-Based Solar Radiation Measurements Over Western Himalayan Region Tehri Garhwal Uttarakhand, India

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Abstract:

In this study, a simple method is proposed to characterize the sky and cloud conditions by using ground based observations of solar radiation. Among the standard meteorological parameters, solar radiation is the most affected by cloud cover. The solar radiation in the atmosphere has many constituents. To understand sky and cloud conditions for the purpose of this study as the spacious effect of clouds and other atmospheric constituents on the diffuse fraction of solar radiation (D/G), the ratio between the global to Extra-terrestrial radiation (K_T), and the transmissivity (T_t), measured at the earth's surface. Using global and diffuse solar radiation data to classify sky conditions into several classes is suggested. This method is applied to one year (1 October 2018 to 31 August 2019) solar radiation data and human based observations at Himalayan Clouds Observatory (HCO), Swami Ram Tirtha (SRT) Campus (30˚34' N and 78˚41' E), Hemvati Nandan Bahuguna (HNB) Garhwal University of Tehri Garhwal, Uttarakhand, India at an altitude of 1706 m (amsl). Also measurements of the CCN Concentration in these sky conditions. Most errors are explained by limitations in the database; therefore further work is under way with a more suitable database.

Keywords: CCN, Global and Diffuse solar radiation, Sky conditions, Cloud conditions.

Th1-P027

Variation Of Cloud Condensation Nuclei (CCN) Concentration At The High Altitude Observation Site In Garhwal Himalayan Region Of Uttarakhand, India

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Abstract:

Continuous observation of Cloud Condensation Nuclei (CCN) concentration was carried out at the high-altitude site of the central Himalayan region from August 2018 to June 2019. It is regarded as Himalayan Cloud Observatory (HCO) and established at Swami Ram Tirtha (SRT) Campus (30˚34' N, 78˚41' E, 1706 m AMSL) of Hemvati Nandan Bahuguna Garhwal University, Tehri Garhwal, Uttarakhand. CCN concentration was measured at four different levels (0.2, 0.5, 0.8, and 1.0%) of supersaturation (SS). Monthly as well as seasonal variation is observed for CCN concentration. The highest value of CCN was recorded for premonsoon season caused by heavy aerosol loading due to the aggregated contribution of transported dust, forest fire and local sources, and the lowest during the monsoon season due to wet deposition and scavenging processes. Two prominent peaks observed for diurnal variation of almost all seasons except for the premonsoon. The first one during the morning hours and another in the evening hours. Monthly average value of CCN concentration (at 0.5% SS) ranges from 1099.1 to 3843 cm^{-3}. Showing a significantly wide range of variation in daily averaged value from the minimum value of 43.84 cm^{-3} to maximum concentration up to 17000 cm^{-3}. The extreme values of concentration correspond to the special weather events that occurred at the observation site such as heavy rainfall, snowfall and forest fire. Local source contribution in the variation of CCN concentration is investigated by finding its dependency on the background meteorological parameters including temperature, humidity, wind speed and direction. Long-range transport of air mass from different regions also contribute to the excessive loading of aerosol over the observation site.

Keywords: CCN, Aerosol, Garhwal Himalayan region, Air-mass back trajectory.

Th1-P028

Study on Diurnal And Seasonal Variation Of Sulphur Dioxide (So_2) Concentration In The Atmosphere Of Alaknanda Valley (Srinagar) In Garhwal Himalayan Region, India

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Abstract:
A study for assessment and management of sulphur dioxide (SO_2) concentration in ambient air of Srinagar was carried out in Hemvati Nandan Bahuguna Garhwal University (HNBGU), Chauras Campus Srinagar (Garhwal) Uttarakhand, India. The continuous ground-based observations are taken to understand temporal variation in concentration of SO_2 (Ecotech Serinus 50 Suphur dioxide analyzer) along with the meteorological parameters (Temperature, Humidity, Wind Speed, Wind Direction, and Precipitation) by Davis Vantage Pro2. The behavior of meteorological parameters and SO_2 concentration was investigated and analyzed by correlation coefficients during the July 15, 2018 to March 31, 2019. The maximum monthly of SO_2 concentration (6.07 ± 1.30 μ g/m^3) was recorded in February 2019, due to extensive agricultural residue burring, anthropogenic activities (Solid wood burning, traffic, construction etc.), whereas the minimum monthly of SO_2 concentration (1.74 ± 1.14 μ g/m^3) was recorded in July 2018 mainly attributed due to wet deposition/ precipitation. In the case of diurnal variation, higher values of SO_2 concentrations (4.94 ± 1.82 μ g/m^3) was reported at 19:00 hr local time due to long range transportation of pollutants from Indian Gangetic Plan (IGP) as well as second highest SO_2 concentration (4.84 ± 1.74 μ g/m^3) at 12:00 hr due to Photochemical activities and intense traffic. The minimum SO_2 concentration (4.39 ± 1.39 μ g/m^3) was observed at 06:00 hr local time due to low human activities in early morning hours. In our observations, SO_2 show strong and positive correlation with temperature (r=0.65) and wind speed (r=0.75), whereas humidity (r= - 0.72) and wind direction (r= - 0.67) shows strong negative correlation with SO_2

Keywords: SO_2, meteorological parameters, wet deposition, photochemical activities etc.

Th1-P029

Seasonal Variation in UV irradiance at village Atigre, Kolhapur

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Abstract:

The highly advanced Microtop II ozonometer has been used for the measurement of ozone over Atigre village near to Kolhapur. Micrometer II ozonometer contains the five optical filters (five channels) for solar irradiance measurements at five different wavelengths (305.5 nm, 312.5nm, 320.5nm, 936 nm and 1020 nm). Out of five, sequentially first three filters are used to measure the ultra-violet (UV) irradiance which are coming from the sun. The UV irradiance a measured in the form of voltage by the photodiodes incorporated in the instrument. Atigre village (16.74°N latitude, 74.37°E longitude, 604 meters altitude above sea level) is placed at low latitude stations and it is a unique station for the atmospheric study since it is covered by many small as well as large scale industries and urban activity. In this work, we have studied the variabilities in the UV irradiance and it's seasonal, daily and diurnally variability for the considered time periods. The inverse relationship between the ozone and UV irradiance is very well known. The increase in UV irradiance indicates the loss of stratospheric ozone concentration. We observed that the UV irradiance is decreased from monsoon to winter and then after it increased towards the summer season. The apparent position of the sun is also responsible for such variation. We also found that the UV irradiance varies daily representing synoptic variation in the ozone and the effects of the weather conditions on the ozone. We have considered some days in a particular month to represent the diurnal behavior of the UV irradiance. The characteristic bell shaped UV irradiance diurnal structure is obtained which shows the seasonal variation in its amplitude. We have discussed the possible mechanism for variation of UV radiations in the Kolhapur region.

Theme-2 (Th2): Extreme-weather-events

Th2-P001

Extreme rainfall over the Gujarat State – A word of caution

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Abstract:

Nowadays, in view of the climate change scenario due to global warming, extreme rainfall events have proved to be one of the most popular topics in contemporary climatology as variation in their occurrence and intensity in a short time result in serious floods causing destruction to human lives, ecology, live stocks and environment therein, leading to great economical loss of the region and country as well. Hence such extreme climatic events are considered as the potential climatic change evidence and catching researchers' attention.

Gujarat, the westernmost state of India, located along the Arabian Sea coast experience diverse climatic conditions receive heavy rainfall in short duration or in a single month during the monsoon season. However, extreme rainfall analysis for 1871 to 2019 showed that most of the stations in Gujarat state experienced 1-day extreme rainfall events almost in all the monsoon months with maximum frequency in July and lowest in June month. Decadal variation (Fig.1) showed increased frequency in 1941-1950, 1951-1960 and 1961-1970 decades but recording highest frequency in the month of July, 2011-2019 decade/duration has not only recorded highest frequency (117) of extreme 1-day rainfall but more than 23 stations recorded > 60 cm of 1-day extreme rainfall. Many stations surpassed their previous 1-day extreme rainfall indicating climate change impact on the rainfall distribution over the state.

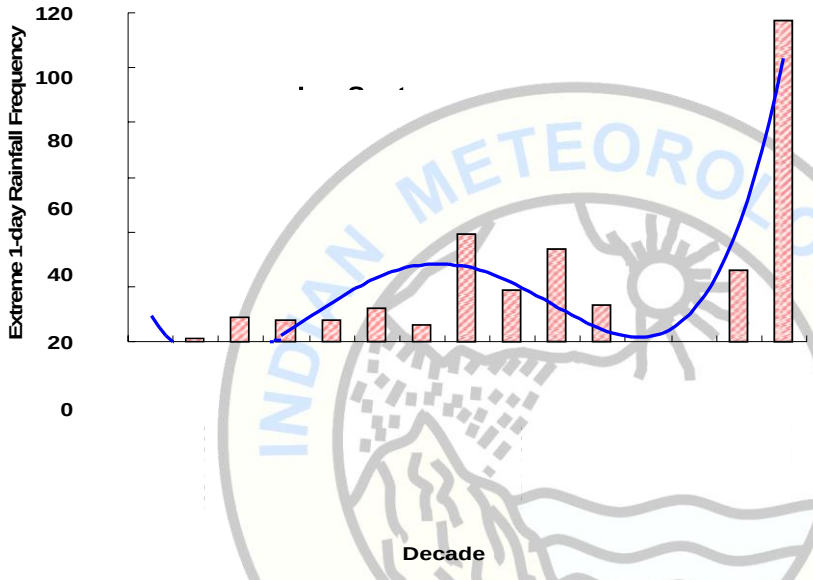

Fig.1: Decadal variation of extreme one-day rainfall frequency over the Gujarat state

These extreme events during 2011-2019 are found to be correlated with the most severe rainstorms of 23-30 Sept 2013, 23-25 Jun 2015, 24-26 Jul 2017 and 09-11 Aug. 2019. The resultant floods, caused severe loss of lives and damage to properties. It is interesting to note that although 2019 rainstorm was having its extension almost over the entire state; heavy rain centers with > 40 cm of rainfall were located in South Kuchchh and North Saurashtra region. Due to the increase number of such disasters and their high impact on economy and human life, the information about extreme rainfall at the state level will be useful for the state administration, planners and design engineers for estimation of design flood and flood mitigation.

Th2-P002

Extreme rainfall events recorded over Sriharikota and a typical heavy rainfall event without significant weather phenomena

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Abstract"

Extreme rainfall event is one of the weather concerns causing flash floods, crop damage, public inconvenience, transport disturbances and so on. Some of these events are associated with low pressure systems and prolonged land based trough of low pressure, are with prior indication and intimation. Some events are with summer severe convective activity associated with thunderstorm and heavy rainfall. These events are with limited lead time to cope up with risk reduction and necessary protection measures. But very rarely, extreme rainfall events occur without any notable weather phenomena and giving no indication. These events are very localized and can not be caught by the regular model predictions. Apart from the laid down definitions and statistical indices, the physical impact is taken into consideration while assessing the severity of an extreme rainfall event.

Sriharikota (13.7°N & 80.2°E), Space Port of India, is a tropical coastal station experiencing rainfall events, during middle of April through September to beginning of January covering pre-monsoon convective showers to the end of northeast monsoon. Using the daily rainfall records and available hourly rainfall records, from 1975 onwards, extreme rainfall events over Sriharikota are identified based on the statistical normals and duration of rainfall.

Case studies of very typical extreme rain events over Sriharikota are selected and presented here with details. One particular extreme rainfall event, a typical localized, on 9th January 2002 with a continuous down pour for three hours in the afternoon, in the absence of any notable weather phenomena, is presented here with available details.

Th2-A003

Deterministic and Probabilistic Approaches in Predicting Tropical Cyclones: Very active season of 2019 over North Indian Ocean

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Abstract:

The Global Forecast System (GFS T1534) was implemented at India Meteorological Department (IMD), New Delhi for the forecast up to 10 days with effect from June 2016. The model is run operationally, two times a day (00, 06, 12 and 18UTC) at T1534 (~ 12 km). Another globally highest resolution ensemble based model i.e. Global Ensemble Forecast System (GEFS T1534) was also implemented at IMD with effect from June 2018. This model is run with 00UTC initial condition everyday with 21 ensemble members (20 members and 1 control) at ~ 12km resolution for generating forecast for next 10 days. Near real time sea surface temperature (NSST) is used to provide ocean state.

In 2019, the North Indian Ocean was very active resulting in total 8 cyclones: 5 in Arabian Sea (AS) and 3 in Bay of Bengal (BoB). Most of these cyclones are of very severe intensity. The objective of the present study is to evaluate the skill of these two modelling systems in predicting the track and intensity of tropical cyclones in the year 2019 over North Indian Ocean (NIO). The models forecast for these eight cyclones at various lead times are verified with the IMD observations. Deterministic model GFS is able to well capture the track and intensity of most of the cyclones at minimum 3 days lead time. The strike probability prediction derived from GEFS provides the information about the landfall uncertainty. The predicted intensity by ensemble model shows large spread implying the uncertainty in the intensity prediction. Prediction of intensity with reasonable accuracy is not yet achieved and needs more understanding of the underlying physical processes involved in it. These modelling systems could capture the tracks, more specifically the recurving tracks of cyclones like Vayu and Maha at 2-3 days lead time but prediction of recurving tracks with even longer lead time is still a challenge.

Th2-P004

Meteorological Drought Prediction of North West and West Central Homogeneous Monsoon Regions of India based on Hydro-Climatic Inputs using Genetic Programming

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Abstract:
Prediction of droughts plays a significant role in planning utilization of water resources of a region and deciding drought mitigation plans. Predicting of droughts happens to be a difficult task due to inherent complexities in modelling climatic systems. The paucity of rainfall results in meteorological drought. It further leads to agricultural drought and hydrologic drought. Large-scale atmospheric circulation patterns show marked influence on Indian Summer Monsoon Rainfall. Hence, signals obtained from the large-scale atmospheric circulation patterns in form of their indices are used for the development of drought prediction models in this work. Signals of atmospheric circulation patterns viz. El Nino Southern Oscillation (ENSO), Equatorial Indian Ocean Oscillation (EQUINOO), Atlantic Multi decadal oscillations (AMO), Indian Ocean Dipole (IOD) and Multivariate ENSO Index (MEI) are used for prediction of meteorological drought over 'North West' and 'West Central' 'Homogeneous Monsoon regions' of India.
Analysis of wet period and dry period is carried out by using 'SPI Index' (Mckee et al.1993). The SPI index is a statistical assessment of rainfall and it gives dry period and wet period along with intensity, duration, and frequency in various time scales as 3, 6, 9, 12 and 24 months. The droughts are classified suitably based on SPI Index. AI tool 'Genetic Programming' (GP) is advantageously used to establish the complex nonlinear relationship between Standardized Precipitation Index (SPI-6) as drought index and aforesaid atmospheric indices along with monthly anomaly rainfall. Koza (1992) defines GP as a domain-independent problem-solving approach, in which computer programs are evolved to solve problems based on the Darwinian principles of reproduction and 'survival of the fittest'. Genetic Programming generates millions of programmes by combining input data and algebraic operators. The work shows that GP derived SPI-6 drought index forecasting models, using monthly rainfall anomaly and large-scale climatic inputs are able to predict SPI-6 drought indices. Out of 14 models of one month lead time prediction, the combinations of ENSO and EQUINOO gives good correlation coefficients 0.851 and 0.734 for training and testing respectively for West Central India. The correlation coefficients are 0.797and 0.690 for training and testing respectively for North West India.

Keywords: **Meteorological Drought Prediction,** ***Standardized Precipitation Index (SPI), EL Nino-Southern Oscillation (ENSO), Equatorial Indian Ocean Oscillation (EQUINOO), Genetic Programming (GP)***

Th2-P005

The characteristic features of a Severe Dust Storm as observed by Dual-Polarised Doppler Weather Radar and other Instruments over New Delhi

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Abstract:

Over the past few years, rise in global temperature has set new records and that is leading to the increase in the number of extreme weather events. India also witnessed an increase in the severity and frequency of the dust storm and thunderstorm which is a common phenomenon for the northern and north-eastern part of India in the recent years. The dust storm that occurs during the pre-monsoon month of March-June every year is one of the principal sources of pollution that originate from the Arabian Peninsula and Thar Desert region of Indian sub-continent. On the view of that the present paper tried to study a severe dust storm event which has occurred over New Delhi and adjoining areas on May 30, 2014 by using C-band Doppler Weather Radar and other surface based observation along with the synoptic large-scale features.

The satellite data (MODIS) over the region reveals an increase in Aerosol Optical Depth (AOD) and decrease in Angstrom Exponent (AE) on that particular day when taken into consideration for the 10 days into concern thereby putting the mentioned date in Centre. The analysis has also been complemented with the diurnal variation of surface based PM2.5 and PM 10 where the severe increase of both the parameters are noticed during 17:30 hours on May 30, 2014. The wind direction over the region reveals the domination of wind from 270° - 300° implicating the source from north-western part of India.

The characteristic features of dust storm have also been portrayed through the C-band Dual-polarised Doppler Weather Radar placed at the Mausam Bhavan in New Delhi. The reflectivity as high as 40 dBZ are observed in the patch from north-western to eastern direction. The vertical profile of radar reflectivity also reveals the presence of clouds of higher reflectivity from 4 km onwards which strongly suggests the presence of liquid water content in that level for the dust storm. The features of dual-polarised parameters for that particular event have also been studied in details along with the variation of vertical profile of relative humidity and temperature from radiosonde data for the mentioned event.

Th2-A006

Unusual Lifecycle of Indian Monsoon-2019 using Meteorological Information System (MIS)

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Abstract:

In Meteorological Information System (MIS), customized weather information (charts/maps, numerical data and text) is prepared in such a way that it is directly useful to end-user meteorologists. Emphasis is placed on visualization of 3D structure of weather systems rather than stereotype display of routine charts of atmospheric parameters. Presently detailed information has been developed about life-cycle of the Indian monsoon-2019 using global 2.5°-grid cell daily pressure, precipitable water, and level-wise (1000-100-hPa) temperature, geopotential height and wind. A structured five-stage approach has been developed to determine real-time start/finish of effective monsoon rains across India. The five stages are: i. determination of start/finish of effective global atmospheric thermal condition (GATC); ii. preparation of charts showing level-wise global weather regimes (GWRs), streamlines and globally-conditioned wind-speed (GC-W); iii. preparation of chart showing area under effective Indian monsoon condition (IMC); iv. determination of start/finish of effective IMC over individual subregion/location; and v. determination of start/finish of effective Indian monsoon rains. Details of the five stages have been described. Maps showing normal 3D structure of the GATC, the GWRs and area under effective IMC have been prepared and described. Yearwise (1979-2019) start/finish of effective monsoon rains across 19 subregions of the country has been reported. Normally, effective GATC starts on 28 May and finishes on 28 September; effective IMC starts earliest on 30 May over southeastern India and latest on 19 June over northwestern region; and effective IMC finishes first on 9 September from extreme northern region and latest on 26 September from East Coast. Effective monsoon rains start normally 2 days after start of effective IMC across the country, and finish 4 days before effective IMC. Details for monsoon-2019 are as:

- Start of effective GATC 17 June and finish 1 October
- Daily charts prepared - Level-wise (1000-100-hPa) GWRs, unconditioned streamlines and globally-conditioned wind speed (GC-W); and Area under effective IMC
- Table for 19 subregions prepared - Start and finish dates of effective IMC

Slower rate of cooling of the SH was main cause of weaker early phases of the monsoon. Chief features of other important phases of monsoon-2019 compared to normal have also been discussed.

Th2-P007

On 3D Structure of General and Monsoon Circulations during Extreme Rains Events across Subtropical Asia

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Abstract:

There is wide spread apprehension that frequency and intensity of extreme rain events is increasing over subtropical Asia. To understand underlying mechanism of interaction between Eurasian westerlies and Indo-Pacific easterlies, four extreme rain events across subtropical Asia have been selected for investigation: Pakistan, 27-30 July 2010; Uttarkashi, 2-8 August 2012; Kedarnath, 16-17 June 2013 and Jammu & Kashmir, 3-6 September 2014). By considering equatorially conditioned (EC) temperature and geopotential height, globally-conditioned (GC) windspeed and unconditioned streamlines, levelwise (1000-100-hPa) charts of global weather regimes (GWRs) have been prepared. Further, by considering equatorially conditioned pressure and precipitable water, charts of area under effective Indian monsoon condition have been prepared. It is amply clear that interaction between Eurasian westerlies and Indo-Pacific easterlies occurs when mid-high latitude cool-low regime and tropical warm-low regime occurs side-by-side that is without any other transition regime between them. Normal and departure-from-normal of 3D structure of actual general and monsoon circulations during the four events have been documented. Normal features during the Kedarnath event (16-17 June 2013) are: *1000–850-hPa layer*- cross-equatorial flows after sweeping Indian subcontinent, collide/confluence/converge with Eurasian westerlies across Tibetan convergence zone; *700–500-hPa layer*- Eurasian westerlies enter into Indian domain and make exit towards east Asia-Pacific; and *400–100-hPa layer*- upper tropospheric anticyclone well-developed over subtropical Asia and outflows are spread all around. And chief features of departure-from-normal were:

- Troposphere was warmer-and-thicker over major parts of the globe (south subtropic through north subpolar) with warmest-thickest over Tibet-China.
- Tropospheric temperature and thickness downward slopes from Tibet-China to globe, two hemispheres and different climatic zones were highly significant.
- Changes in global atmospheric conditions were such that after intense interactions between Eurasian westerlies and Indo-Pacific easterlies over Indian domain, warm-moist air-masses were forced to make exit towards north mid-high latitudes via western slopes of Tibet-Himalaya where squeezing of large-thick moist air-stream, cool-low and warm-low regimes contrast and orographic as well as pumping-suction effects caused heavy rains.
- The ejected airflows from western Tibet-Himalaya caused warmer-thicker troposphere over large parts of northern mid-high latitudes (eastern Russia-North America). Lesser outflows from Tibet-China anticyclone were directed southwards, consequently troposphere was cooler-thinner over southern mid-high latitudes.

Th2-P008

Distribution of rainfall in different intensity ranges during southwest monsoon period in the Western Ghats

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Abstract:
In this paper the long-term trend analysis is carried out during southwest monsoon rainfall over different regions of the Western Ghats (WG). The WG is one of the important biodiversity hotspot in Asia. The WG region is classified into four different regions in different latitudes namely R1 (9^o N-11^o N; 76^o E-77^o E), R2 (12^o N-15^o N; 75^o E-76^o E), R3 (16^o N-18^o N; 73.5^o E-74.5^o E) and R4 (18^o N-21^o N; 73^o E-74^oE) for the study during the period 1951 to 2015. Our result shows the trend in the south west monsoon mean rainfall shows negative trend all over the study regions. Further, rainfall data is classified in to the six intensity bins such as dry (0-10%), low (10-60%), moderate (60-90%), heavy (90-95%), very heavy (95-99%) and extreme (> 99%). The rainfall data used for the present study is daily gridded IMD data with a spatial resolution of 0.25 X 0.25 latitude – longitude. We analyses the trends of different rainfall intensity bins over this four region in addition to the number of rainy days and their relative contribution for the all the regions.

The dry rainfall intensity bin has a positive trend in the regions R1 and R3 and negative trend in the R2 and R4 regions. The low rainfall intensity bin has negative trend in the regions R1 and R4 and positive trend in R2 and R3 regions. The moderate rainfall intensity class has negative trends in the R1, R3 and R4 regions and has positive trend in the R2 region. The heavy rainfall intensity bin and very heavy rainfall intensity bin has negative trends in the all the four regions. The extreme rainfall intensity bin has negative trend in R1 and R2 and positive trend in R3 and R4 regions. The extreme rainfall intensity bin trend is increases from the low latitude to high latitude i.e. from the region R1 to R4. The dry rainfall intensity bin days has a very low contribution in the rainfall which is negligible. The low rainfall intensity bin occurs half of the total rainy days which contributes only 20% of the total rainfall. The moderate rainfall intensity bin occurs 30% of the total rainy days and that contributes about 45% of the total rainfall. The heavy rainfall intensity bin occurs 5% of the total rainy days, which contributes about 14% of the total rainfall. The very heavy rainfall intensity bin occurs 4% and contributes about 15% of the total rainfall. The extreme rainfall intensity bin occurs only 1% of the total rainy days and the contribution from the 1% rainy day is more than 6% of the total rainfall.

Th2-P009

IMPACT OF SOUTH – WEST MONSOON IN PUNE CITY

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Abstract:

The aim of the study is to know about the impact that the South-West monsoon has on the city of Pune due to the fluctuating monsoon. To achieve this, research study was carried out in exploring the factors which are contributing for this variation in amount of precipitation. For instance, improper urbanization and industrialization in the states such as that of Maharashtra is happening in a haphazard manner owing to the uncontrolled burst in population in the cities and town. To ascertain the impact caused due to heavy rainfall this study was initiated. Data of population of Pune city was collected as it is our study area for research. Based on the analysis it was clear that there is a drastic increment in last three decades. A survey was conducted and responses from people across the city were collected regarding the management of rain water as well as the issues faced during peak rainfall and it was analysed to evaluate the impact.

For analysis and identifying the regions that were most affected, SPSS (Statistical Package for the Social Sciences) tool has been used. The survey responses collected were analysed using SPSS and various parameters have been compared to identify the relevant ones. Based on the analysis of the data obtained from the survey it is concluded that in many regions proper rain water management strategies are not adopted and also rain water harvesting technique is not installed. This results in various problems like water logging, traffic congestion and improper drainage. If the authorities don't take stringent measures and people are not adopting sustainable water management strategies then situation will go very worse and it may lead to flood and spreading of fatal diseases. It is high time to take some immediate measures, some of the remedial measures are suggested which can be implemented ultimately improving the situation to a certain extent.

The output obtained is conclusive on identifying the parameters that have crucial impact on the city during monsoons and if corrected, can bring a change in the rain water management strategies adopted and make Pune a better city to live in.

Keywords : South-West monsoon, migration, rain water harvesting

Th2-P010

A case-study of an extreme rainfall event of Mumbai on September 04, 2019 as observed by Radar and other surface-based instruments

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Abstract:

A large segment of the population across the world resides in the coastal cities due to the strategic advantages of the places with respect to tropical climate and convenient trade opportunities through sea route. Likewise, Mumbai, situated on the west coast of Indian subcontinent is considered to be one of the most populous coastal urban city of the world that experiences heavy rainfall spells during the pre-monsoon and monsoon months from the clouds originating over the eastern and western part of the region respectively. In view of that the present paper tried to study in details the vertical structure of clouds and microphysical characteristics of precipitation during one of the severe rainfall event of September 04, 2019 over the city of Mumbai. The Joss-Waldvogel Disdrometer placed at IMD campus in Santacruz along with S-band Doppler Weather Radar placed at Colaba has been used for the present study. The paper also tried the highlight the large-scale atmospheric features persisting over the region during that severe rainfall spell.

The IMD record of rainfall reveals that the day experienced a rainfall spell of 210 mm in just 6-hours during 9:00AM -15:00PM on September 04 thereby submerging the city. Two peaks of rain rate are observed during the 09:30 and 11:20 hrs which are also complemented with clouds of higher reflectivity of 30-35 dBZ ranging upto 5.5 km. The spatial variation of radar shows the clouds of higher reflectivity approaching towards Mumbai from the north-western part during the first peak of rainfall while the second peaks are supplemented by the higher reflectivity clouds originating from the western and south-western part. The details study related to the large-scale features has also been done will be portrayed in the details presentation.

Th2-A011

Extreme weather events and its impact on agriculture in Kolhapur district

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Abstract:

Kolhapur district comes in 24th Meteorological subdivision of India and Sub montane Agroclimatic Zone of Maharashtra. Annual average rainfall of Kolhapur is 1069.5 mm, Annual mean Tmax and Tmin is 31.4 and 18.9˚C respectively while annual mean temperature is 25.1˚C. Normal onset and withdrawal of Monsoon is on 22st and 41st of Meteorological week. Extreme events for maximum temperature at Kolhapur during 1989 to 2019 shows that highest Tmax was recorded on 6th May, 2013 which was 42.1 ˚C, from 1989 there was only one event when Tmax remained >=42 and <43 ˚C while there were 596 events when temperature remained in between 36 and 37˚C while there was only 15 events when Tmin remained>= 6 and < 8 ˚C while for 128 times temperature remained >= 8 and < 10 ˚C. Rainfall data showed that out of 30 years there was 5 moderate drought years while 7 excess rainfall years. The highest recorded rainfall in 207 mm on 26th July 2005. Panchganga river and its tributaries are the major source of irrigation to crop in Kolhapur district. These extreme weather events affected the Crop production in Kolhapur. The heavy rainfall recorded from 30th July 2019 till 9th August 2019 resulted in flood situation in Kolhapur district. About27,000 ha of cropped area is badly damaged due to heavy flood situation. Sugarcane, Rice and Pulse crop was affected thousands of cattle's are died in 2019 flood which declined the milk production of Kolhapur district. Kolhapur district faced record breaking severe flood condition affected milk and sugar industry thus affected socioeconomic condition of farmers.

Key words: Extreme weather, flood, Kolhapur, heavy rainfall.

Th2-P012

Extreme Weather Events And Its Impact On Agriculture And Allied Sectors In Kolhapur District

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Abstract:

Kolhapur district comes in Sub montane Agroclimatic Zone of Maharashtra. Annual average rainfall of Kolhapur is 1069.5 mm. Extreme events for maximum temperature at Kolhapur during 1989 to 2019 shows that highest Tmax was recorded on 6th May, 2013 which was 42.1 ˚C, from 1989 there was only one event when Tmax remained >=42 and <43 ˚C while there were 596 events when temperature remained in between 36 and 37˚C while there was only 15 events when Tmin remained>= 6 and < 8 ˚C while for 128 times temperature remained >= 8 and < 10 ˚C. Rainfall data showed that out of 30 years there was 5 moderate drought years while 7 excess rainfall years. The highest recorded rainfall in 207 mm on 26th July 2005. Panchganga river and its tributaries are the major source of irrigation to crop in Kolhapur district. These extreme weather events affected the Crop production in Kolhapur. The heavy rainfall recorded from 30th July 2019 till 9th August 2019 resulted in flood situation in Kolhapur district. About27,000 ha of cropped area is badly damaged due to heavy flood situation. Sugarcane, Rice and Pulse crop was affected thousands of cattle's are died in 2019 flood which declined the milk production of Kolhapur district. Kolhapur district faced record breaking severe flood condition affected milk and sugar industry thus affected socioeconomic condition of farmers.

Key words: Extreme weather, flood, Kolhapur, heavy rainfall.

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Th2-P013

Observation of Atmospheric Potential Gradient during Disturbed Weather Conditions

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Abstract:

Potential gradient was measured at University of Kashmir, Srinagar (34° 03' N, 74° 51'E, 1585 m amsl) for a period of 1 year (march 2018- February 2019) as well as the meteorological parameters were obtained for the same period from the nearest IMD station. The annual mean diurnal variation of PG represents a typical double-maxima pattern with the primary maximum at 0900-1000 LT and the secondary maximum at 1900-2000 LT which is in accordance with the measurements at different continental stations. For the present study the effect of a range of disturbed meteorological conditions such as thunderstorms, rain, snow, fog etc causing PG changes has been selected. It was observed, that changes in weather have a very strong effect on the potential gradient observations. During disturbed weather conditions, potential gradient variations on time scales of minutes to hours occur, as cloud and precipitation carry electric charges. Although the greatest absolute PG variability occurs during a thunderstorm, the relative variability during non-thunderstorm activity can also be pronounced. During rain, the electric field was observed to increase drastically as rain particles can carry negative electric charge and when they come in contact with the field mill sensor the electric charge gets transferred to the sense plates causing large deviations in the potential gradient. An increase in PG values was seen during snow showers as snow carries positive charge but the change was more gradual compared to changes caused by rain. Its response under fair weather or turbulent phases of weather become a promising source of investigation and may prove to be vital in early warning systems.

Th2-A014

Extreme hydro-meteorological Events and Urban Development

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Abstract:

Extreme weather events in particular heavy rains and floods cause huge losses to economic growth of the country. India receives nearly 4000 billion M3 water from rains and snowfall annually. However, it shows fret seasonal and spatial variability and is concentrated in the summer monsoon season.

Even during summer monsoon season, short (1-2 days) spells of extreme rainfall can exceed even monthly normal rainfall (of the station), and cause natural hazards, which can turn into a disaster. These disasters are increasing & affecting adversely major urban areas. The area and persons affected by floods may increase due to reasons such as deforestation, urbanization and population growth (IPCC AR-4). An analysis of recent data (1998-2007) of Disastrous Weather Events (DWE , IMD) indicated 34 cases of heavy rains, 71 cases of severe floods, 70 cases of moderate floods, 30 cases of cloud bursts, 88 cases of flash floods over the Indian region. We discuss the important features reported in recent decade – damage, economic losses and lives lost in these disastrous events.

The paper presents some of these aspects and stresses the need for stainable way of development of cities, balancing the needs of various stake holders via-a-vis the environment. The study will be extended up to 2018 after the data can be available for presentation in this symposium.

Th2-P015

INSAT – 3D Satellite Measured Cloud Top Temperatures Associated with Intensity Changes of Tropical Cyclones over North Indian Ocean

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Abstract:

Recently there were two cyclonic storms developed over North Indian Ocean (NIO) during Monsoon 2019. VSCS Vayu developed during onset in the month of June and VSCS Hikka during withdrawal in the month of September. Both formed and rapidly intensified over Arabian Sea. Prediction of rapid changes in the Tropical Cyclones (TCs) is a challenge and it is important to understand the cloud characteristics of such storms. As TCs occurs over ocean, satellite data fills the gap in the coverage of observational data and are the best tool for monitoring the status, development, maturity, and decay of TCs.

In this paper, variations of INSAT-3D satellite measured cloud top temperatures as well as rainfall associated with Vayu and Hikka over NIO is studied. Aim is to understand the relation of cloud top temperature using Infrared (IR) Brightness Temperature (BT) and rainfall with intensity changes of TCs. Variations in cloud top temperature is an important element of TC dynamics and has relevance with structure and intensity changes. Variations in IR BT associated with cloud top temperature is evaluated using average temperatures within a fixed radius or annulus. Also, variations in the areal extents from centre of TC clouds are studied using cloud-top temperatures below specific thresholds. Variations of IR BT in TC seems to have a large influence on the development of deep convection which results in heavy rainfall and storm surge during a life of TC. Hence, this is the area which needs to be explored further. Analysis of variations of IR BT, rainfall and intensity of TC will enhance our understanding and this can be applied for better prediction of TCs in NIO. This will be helpful for many sectors like agriculture, fishery, marine industries, solar power plants, wind farms etc.

Th2-A016

Study of Cloud Condensation Nuclei (CCN) behaviour in relation to fog occurrences over Delhi

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Abstract:

Comprehensive field campaigns dedicated to fog life cycle observation were conducted during the winters of 2015-2016 at the Indira Gandhi International Airport (IGIA), Delhi, as a joint mission by Indian Institute of Tropical Meteorology (IITM), Pune and India Meteorological Department (IMD), Ministry of Earth Sciences. In order to study the impact of variations in Cloud Condensation Nuclei (CCN) in different fog events, 3 major dense fog events are analyzed here. It is found that the smaller particle size CCN contributes more to the total CCN count as compared to the large particle size ones. A sharp increase in CCN count is observed a few hours prior to the commencement of fog episode. Increased amount of moisture (RH>80%) is also observed during the intense fog events discussed here.

Th2-P017

Changes in large-scale circulations over Indo-Pacific region and its association with 2018 Kerala extreme event

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Abstract:

In the present study we have investigated characteristics of recent extreme flood in Kerala during August 2018. The changes in large-scale circulations over Indo-Pacific region and their association with regional circulation resulting extreme rainfall in Kerala are analyzed in the present study. The west Pacific subtropical high (WPSH) is one of the large scale circulations over Indo-Pacific region. The geopotential height, sea level pressure and surface winds from NCEP-NCAR reanalysis (2.5x2.5 degree resolution) data sets are used to study the abnormal changes of WPSH during 2018 summer monsoon period. Further analysis of high resolution daily rainfall data set, available from Indian Meteorological Departments (IMD), reveals that variability of WPSH during this period modulates the regional rainfall over south India. The extreme rainfall event (8-19 August 2018) over Kerala, particularly southern part of Kerala experienced excesses rainfall of about 80-100 mm/day. The northward shift and intensification of WPSH during the extreme event tends to form a cyclonic circulation over north-west Pacific. In addition to this, there is a blocking high over East Asia. The outflow from blocking high along with northward transport from the equatorial Indian Ocean tend to induce organised convection and subsequently leads to extreme rainfall over Kerala region. The patterns of regional features such as outgoing longwave radiation, updraft and sea surface temperature over the west equatorial Indian Ocean during August 2018 are favourable for the organisation of convective clouds and moisture transport towards the southern parts of India.

Th2-P018

Assessment of extreme weather event at Raichur and Yadgir Districts of Northern Karnataka during 2019-20; A case study

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Abstract:

Kalyana Karnataka (Northern part of Karnataka) is extremely vulnerable to impact of climate events. Every year it faces extreme weather events either in the form of severe drought or floods along with extreme high temperature summer months, which have severe impacts on crop production and socio-economic status of farming families and results in huge revenue losses. Here's a look at recent flood at Raichur and Yadgir Districts of Karnataka and also Maharashtra due to heavy rainfall during 2019-20. The banks of the Krishna River in Raichur and Yadgir districts experienced one of the worst floods since time immemorial. Many villages, private and public properties were affected in this flood apart from creating problem for the land and vegetation resources along the river course. The team of scientists from University visited affected area, assessed the damage and recommended the protection measures for natural resources especially with regard to land, water and vegetation resources. This flood started in the month of August first week and continued till the third week of the month. As a result of release 6.3 lakh cusecs of excess water from Almatti and Narayanpur dams which are located at upper stream side, 5,521 residents from 72 villages were shifted in three taluks *i.e.*, Raichur, Devadurga and Lingsugur of Raichur district. Also, 104 residents from six islands have been evacuated to safer places. A total of approximately 24,056 hectares of agriculture land had been damaged due to the flood. Of which, 13674 hectares paddy, 6459 hectares cotton, 3108 hectares redgram and 744 hectares of bajra were damaged. In such scenario making agriculture system adoptable to changing climate conditions, timely dissemination of weather based Agro-advisory services plays a pivotal role in taking measures to re-build the eco-system and conserve soil and water.

Key words: Flood, Rainfall, Vegetation and Soil conservation

Th2-P019

The unprecedented heavy rainfall event of August 2019 in the Upper Krishna River Basin of Maharashtra-A ARCGIS Purview

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Abstract:

Heavy Rainfall Event during the month of August 2019 in the Upper Krishna Basin of Maharashtra has been analysed using ArcGIS interface. A very intense rainspell occurred over sub divisions of Maharashtra namely Konkan and Madhya Maharashtra during 3rd – 6th August 2019 leading to devastating floods over many districts in of Southern part of Madhya Maharashtra such as Satara, Sangli and Kolhapur. . Situations worsened with the upstream dams being in their full capacity were released samultaneously.

The Study area includes three districts of Maharashtra- Kolhapur, Sangli and Satara. A brief account of seasonal rainfall of 3 districts, their temporal changes, extreme rainfall events during 1951-2018 are analysed and compared with Aug. 2019 event. Meteorological situations during the heavy rainfall period are also examined. Hydrological model has been implimented to generate flood in a small watershed of Kolhapur district and compared with the actual discharge data during the flood situation of 4-6 Aug. 2019.

Th2-P020

Prediction Of River Basin Yield Using Local And Global Climate Parameters

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Abstract:

Global and local climatic parameters influence the distribution of precipitation over continents. The spatiotemporal distribution of rainfall and the depth of rainfall over a river basin influences the river basin yield. This study deals with the prediction of the river basin scale yield of "Upper Bhima River basin" from Maharashtra State of India.

Maharashtra has constructed 26 Major dams along with 39 Medium dams 480 Minor projects in Upper Bhima River basin. Hence, inflow, outflow, spill, water uses and losses of all reservoirs have been taken into consideration while calculating the actual monthly yield of Upper Bhima river basin. The information about large scale circulation patterns viz. El Nino-Southern Oscillation (ENSO) index, Equatorial Indian Ocean Oscillation (EQUINOO) index, Multivariate ENSO Index (MEI) and local climate input viz. Outgoing longwave radiation (OLR) is used to predict the river basin scale yield. The recent Artificial Intelligence (AI) tool –'Genetic Programming (GP)'is adopted for developing prediction models.

Total eighteen different combinations of input variables are attempted for the development of monthly river basin yield models to arrive at the best input variable combination for the best predictions with different lead times. Also, four combinations of input variables are tested for prediction of seasonal and annual yield before the onset of monsoon.

The genetic programming approach of developing prediction models is found to capture the complex relationship between the river basin scale yield and the various climate inputs. The observed and predicted monthly and seasonal river basin scale yield were found to match well with each other with a correlation coefficient (r) =0.75, whereas annual observed and predicted yield shown the r=0.82, which appears appealing for such a complex water resources system.

Keywords: River Basin-scale yield, ENSO, EQUINOO, MEI, OLR, Genetic Programming

Th2-P021

Study on variations in TCO, AOT, and PWC by ground-, satellite- and model-based observations

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Abstract:

A Microtops II (Microprocessor-based Total Ozone Portable Spectrometer) has been deployed to continuously measure the total column ozone (TCO), precipitable water content (PWC) and aerosol optical thickness (AOT) at Atigre village (16.74° N, 74.37° E, 604 meters above sea level, masl) located on the southeastern slope of Indian western Ghats. The Microtops II ozonometer measurements during the period from September 2017 to June 2018 were analyzed along with the retrieved products of Ozone Monitoring Instrument (OMI) and Moderate Resolution Imaging Spectroradiometer (MODIS) onboard NASA's Terra satellites and also the ERA-interim reanalysis model. We found that the TCO (or PWC) data from the OMI (or MODIS) and the ERA reanalysis model data products are very well matched. The measurements showed strong seasonal variability such that TCO was lowest in the winter season but increased in the summer season, and both PWC and AOT were lowest in the post-monsoon season and increased in the summer season. In continuous ERA-interim reanalysis TCO observations, we found the three types of periodicities in the daily mean TCO as well as PWC (i) The weekly (7 days), (ii) quasi-biweekly (14 to 16 days), (iii) Madden Julian Oscillations (MJO) (30 - 60 days) oscillations. These oscillations are depending on the periodic weather changes in the troposphere. We also observed that the average day to day variability in daily mean TCO observations in the observational period is to be about 1.4%, 1.1%, 2.62% in the Microtops II ozonometer, ERA-interim reanalysis and OMI data respectively. We found the positive correlation in between daily mean AOT and PWC in all seasons (except monsoon), which is maximum in the winter season showing the hygroscopic nature of aerosols. The sources of water vapor and aerosol at our location is also studied using back-trajectory analysis. The distinctive non-negligible diurnal structures in TCO, PWC and AOT are observed for different seasons.

Th2-P022

Tahsil-wise Maximum Heavy Rainfall Events Monthly Variation in Pune Districts

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Abstract:

Department of Agriculture Meteorology, College of Agriculture, Pune studied the Tahsilwise maximum heavy rainfall events variation in Pune Districts. Rainfall Data used is daily rainfall data of 38 years i.e. 1980-2018 Tahasilwise. Study is useful for preparation of Block Level Agroadvisory in our AMFU (Agro Meteorological Field Unit) Pune under GKMS (Gramin Krishi Mausam Seva) scheme sponsored by IMD New Delhi. Analysis is carried out by Software Weathercock developed by CRIDA, Hyderabad for calculation of extreme event we consider the 50 mm and above rainfall received in single day of particular month and particular year. Whole year from January to December considered for calculations. Out of 14 tahsils Ambegaon (28.2), Baramati (41), Daund (31),Haveli(30.7), Indapur (29.3) Purander (25.8) and Shirur (51.7) recorded more extreme rainfall events in September month with more number of years. Five Tahsils i.e. Bhor (39.6), Mulshi (44.8), Khed(35.8), Vadgaon Maval (33.3) and Velhe (33.3) recorded more extreme rainfall events in July month with more number of years. Pune city (20.5) is recoded in month October and Junnar (28.2) tahsil recorded in August month with more number of years. This is useful for suggesting cropping pattern, crop selection and crop management i. e. for giving Agroadvisory on value added weather data basis. Which is useful for Farmers for saving on their inputs and increase in their outputs\Yield.

Key words: Extreme event, Rainfall, Pune Tahsilwise.

Theme-3 (Th3): Ocean-atmosphere-coupling-extreme-events

Th3-A001

Modulations in the Indian Summer Monsoon rainfall associated with Atlantic Nino and El Niño-Southern Oscillation

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Abstract:

Emerging role of the Atlantic Niño in modulating Indian Summer Monsoon (ISM) rainfall on interannual timescale is highlighted in the recent years. Atlantic Niño peaks generally in boreal summer (June-July and August) and could exert strong influence on ISM rainfall. It is noted in the previous studies that Atlantic Niño can co-occur with El Niño-Southern Oscillation (ENSO) in the Pacific. In this study, individual and combined impact of Atlantic Niño and ENSO on ISM rainfall variations is examined. The National Oceanic and Atmospheric Administration (NOAA) Extended Reconstructed Sea Surface Temperature (ERSST) and the twentieth century reanalysis (20CR) datasets are utilized in this study. Using Atlantic Niño (ATL3) and Niño 3.4 indices, pure positive Atlantic Niño (PAN), pure negative Atlantic Niño (NAN), PAN-co occurred with La Niña and NAN-co occurred with El Niño years are selected. Composite analysis is used to study the circulation and rainfall patterns over ISM region associated with Atlantic Niño year and data used for the period of 1901 to 2014. It is noted that during PAN (NAN) years rainfall anomalies over the southern and central India is negative (positive) and positive over the northeastern parts of India. Low and upper level circulation changes associated with PAN or NAN is primarily responsible for rainfall patterns over the Indian subcontinent. In response to Pure PAN events, low level winds over the central and southern Indian region triggers anticyclonic circulation. This circulation pattern causes negative rainfall anomalies in the central and southern Indian region and positive rainfall over the northeast India. In case of Pure Negative Atlantic Niño stronger Southwesterlies from Arabian Sea to Indian land region result positive precipitation in the southern and central India region and negative anomalies in northeastern parts. These circulation patterns are altered by ENSO during Atlantic Niño-ENSO co-occurrence years and as result changes in rainfall patterns are observed over ISM region.

Th3-P002

Interannual variability of surface air-temperature over north India during winter season

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Abstract:

Climate variability over the north Indian region in winter season is important as it has large impacts on human life. Cold waves, pollution and fog etc. are some of those which have direct influence on society. In this study, variability in the surface air-temperature (SAT) over north India during winter has been examined for the period of 1900 to 2015, with a special emphasis on El Niño-Southern Oscillation (ENSO). Air temperature data from the India Meteorological Department (IMD) and winds, Sea Level Pressure, soil moisture, and surface fluxes from the twentieth century reanalysis (20CR) are used for analysis. It is found that extreme warm and cold SAT over north India is not only associated with ENSO years but also associated with normal years. Detailed analysis suggests that 50% (~ 30%) of El Niño (La Niña) years have displayed warm (cold) SAT over north India during winter season. During La Niña (El Niño) years, positive (negative) shortwave radiation (SWR) is mainly responsible for warm (cold) SAT over the north India. In the other years, SWR is weak or out of phase with SAT and the results are supported by precipitable water content and cloud cover. During normal years, dry soil moisture favors the warm SAT over north India. In case of El Niño years, low-level winds from Bay of Bengal helped to warm SAT over this region. During cold years all three cases are associated with wet soil moisture. Further, low-level and upper level circulation changes during ENSO and non-ENSO years also played an important role in maintaining cold/warm events. Further, we have also examined the frequency of cold waves and variability over the north Indian region. Role of large scale circulation in triggering these cold waves are also explored.

Th3-P003

Westerly wind events and El Niño evolution in the last century: An observational perspective

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Abstract:

The formation of El Niño is associated with the westerly wind events (WWE) in the western to central Pacific and is considered as a one of the genesis of the El Niño formation. In the present study the temporal and spatial evolution of WWE during last hundred years are studied and it's corresponding behavior of the formation of El Niño is explored. , To identify WWE, European Reanalysis 20 Century(ERA-20C) daily zonal wind data for the period 1900-2010. In addition to this Extended Reconstructed Sea Surface Temperature(ERSSTv5) data set is used to estimate Niño indices as well as to understand the eastern and central Pacific SST anomaly evolution associated with El Niño. Analysis brought out that the regional and temporal features of WWE varies, hence they are classified in western Pacific, central Pacific and eastern Pacific WWE. It is noted that the central and eastern Pacific WWE contributes noticeable to the formation of the canonical or modoki El Niño. The frequency of these events are found to be high during the period of 1950-2010 as compared to 1900-1950, mostly during the fall and winter season. In line with this, spatial patterns of SST variability displayed strong modulations in central Pacific along with eastern Pacific in recent era than earlier, when higher magnitude of SST variability was confined to eastern Pacific. This spatial pattern of SST variability in central Pacific is consistent with occurrence of more El Niño Modoki events than earlier. Our results suggest that five El Niño events are formed without the WWE during the study period, out of which four events are El Niño Modoki and one canonical El Niño. Above analysis supports that the temporal and spatial evolution of WWE during the last century may contributes to the central and eastern Pacific thermal structure variability.

Th3-A004

The role of river discharge and ocean dynamics on the freshening episode in the north Bay of Bengal

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Abstract:

Daily time series of salinity measurement recorded at 15 ºN and 90 ºE in the Bay of Bengal (BoB) from a Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction buoy for the period of 2007 to 2018 is used to study the freshening episodes in the BoB. Season wise analysis of the number of freshening episodes at 15ºN reveals that the maximum freshening episodes have occurred during the winter (DJF). In many cases freshening is not confined to surface, its vertical extent is reported up to 40m. Episode of fresh and salty water are found in DJF 2015 -2016, which is studied in detail in the present study to understand role of ocean dynamics. Soil Moisture Active Passive (SMAP) satellite data are used to confirm the observed oscillation of salinity. Analysis of precipitation data from buoy and satellite confirmed that oscillation is not associated to precipitation in the BoB. During this period upper ocean mixed layer and isothermal layer modulated accordingly, supporting the coherent oscillation happening of the barrier layer. One dimensional Price-Weller-Pinkel model forced with the observed forcing and initiated with observed temperature and salinity profile at 15ºN buoy location is used to study the role of local forcing to upper ocean salinity oscillation. In addition to the above, to know the contribution of river runoff, Ekman transport is estimated using daily wind fields from TropFlux. This analysis reveals that freshening is due to advection of Irrawaddy river fresh water towards the buoy location through Ekman transport. Oscillation of salinity is coherent with the northerly winds oscillation during the study period. Present study concludes that ocean dynamics associated with the winter wind forcing can lead to upper ocean salinity oscillation in the north east BoB, which could modify upper ocean vertical structure and response to local air-sea interaction.

Th3-A005

Impact Of Madden Julian Oscillation Over the Indo-Pacific Region

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Abstract:

The most dominant mode of variability on the intraseasonal timescale over the tropics is Madden Julian Oscillation (MJO), characterized by the eastward-moving atmospheric circulation coupled with the convective system. MJOs in fact have influence on the interseasonal and interannual events as well. However, the impact of MJO propagation on the upper ocean parameters are not understood well. In this study, we examine the intraseasonal variation of upper-ocean salinity, temperature, and zonal currents as a response to MJO. We have used the ARGO and NCEP Global Ocean Data Assimilation(GODAS) reanalysis upper ocean salinity and temperature, and OSCAR surface zonal currents for detailed analysis. The OSCAR surface currents is a satellite derived product available on a 1/3-degree grid resolution. This study examines the upper ocean variations over the Indian Ocean (IO) and the western Pacific (WP) from 1992-2019 for November-April months as MJO is more active in boreal winter. With the help of daily RMM values of MJO from the Australian Bureau of Meteorology, we found that the average amplitude value of active MJO phases from 1992-2019 over the IO (i.e. phase 2 and 3) has increased and that over the western Pacific region (i.e. phase 6 and 7) has reduced. The changes in the amplitude have been observed from the year 2000. While comparing the average amplitudes, we found that phase 3 is dominant over 2 in IO and phase 7 is dominant over 6 in WP. In the boreal winter period of 2000-19, we found that the salinity over the WP has reduced by 0.05 psu as compared to 1992-1999 and over IO it has reduced by 0.025 psu. The temperature has increased slightly over WP however no significant changes are seen over IO. From the spectral analysis of zonal current over 2S-2N, we infer that its amplitude has reduced significantly over the recent years. The results show that during recent years, the changes in MJO strength has affected the upper ocean salinity and temperature. And the impact of these variations can also be seen on the zonal currents extending the impact to the neighbouring areas as well.

Th3-A006

North India summer monsoon precipitation and east equatorial Indian Ocean clouds

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Abstract:

Generally, a strong north India summer-monsoon precipitation (NISP) is associated with anomalous upper troposphere ridge over northwest of India. This ridge triggers anomalous northerly winds over Tibetan Plateau and easterlies over India. The easterly anomaly over India reduces the tropospheric wind shear, while the northerly at Tibetan plateau allows frequent intrusions of high-latitude dry and cold meridional winds to interact with the lower-level relatively warm and moist easterly monsoonal flow, enhancing the NISP. The current study, using a suite of observations, reanalysis products and numerical model sensitivity experiments, explores the changes in NISP, and its association with the warming in the equatorial Indian Ocean.

In the recent two decades (1996-2017), the NISP has been exhibiting a decreasing trend with increased variability, much larger than the earlier period (1979-2000). A possible reason for this is due to the rise in warm sea surface temperature (SST) observed in the east equatorial Indian ocean, which shows a negative correlation to NISP. The current analysis indicates that the warmer SST induce strong convection, producing deep clouds and associated northward propagating off-equatorial Rossby gyres to the west of the equatorial eastern Indian ocean, spreading the tropospheric heating towards the northeast of India, thereby elevating the geopotential height. This creates upper troposphere low pressure anomaly at the northwest of India. These factors are consistent with the suppression of the NISP, resulting in the observed decreasing trend in the recent decades.

Th3-P007

North Indian Ocean cyclones of 2019 and associated upper ocean thermal structure

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Abstract:
The upper ocean is dramatically affected during tropical cyclones (TCs). Cyclones interact not only with the surface but also with the deeper oceans, the depth depending upon the strength of the wind mixing. Hence, it is necessary to consider the thermal structure of the upper ocean for cyclone studies.

In exploring the ocean's role in cyclone's intensification, it is necessary to consider not only sea surface temperature (SST), but the thermal structure of the upper-ocean column because cyclones interact not only just with the surface, but with the subsurface ocean. However, it has been difficult to explore the upper ocean thermal structure related issues because of the lack of subsurface observations, over the vast oceans. With the advancement in remote sensing and in situ ocean measurements it is now possible to study this subject with more reliable new observations.

In the present study we have analysed upper ocean response to storms of the year 2019. utilising daily Ocean Mean Temperature data (OMT) of different layers available from NRSC Bhuvan website and weekly data of currents, temperature, and SSHA from the Copernicus Marine Environment Monitoring Service (CMEMS). The season had eight cyclonic storms, six very severe cyclonic storms (VSCS) and one super cyclonic storm, becoming exceptionally active. Very severe cyclones Vayu and Hikka formed during the onset and withdrawal phase of monsoon respectively. We have considered here two extremely severe cyclonic storms: Fani and Maha and two VSCS: Vayu and BulBul which impacted our continent.

Preliminary analysis shows the reduction in OMT during the passage of cyclone. The maximum cooling observed in the wake of cyclone Fani and Maha is 4.0^{o}C and 4.5^{o}C respectively. The cooling of the layer up to 300m is found for Maha and up to 200m in the case of Fani. Drop in temperature is 4.5^{o}C at 50m during the passage of storm Vayu and 1.5^{o}C in case of Bulbul. Their impact is seen up to 200m. Decrease in Tropical Cyclone Heat Potential of 50 and 55 kJ/cm^2 is seen during passage of Fani and Vayu as revealed from satellite data. Further analysis will be explored in detail.

Th3-P008

Impact of ENSO on the onset, peak and withdrawal phases of Indian summer monsoon rainfall and their changes from early to recent decades

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Abstract:

The El Niño Southern Oscillation (ENSO) is an important coupled ocean-atmosphere phenomenon in the tropical Pacific and an important driver of the Indian summer monsoon variability. Here, we explore the impact of ENSO on the onset (June), peak (July-August) and withdrawal (September) phases of Indian summer monsoon by studying the changes in the ENSO-monsoon relationship from early decades (1951-1980) to recent decades (1986-2015). Considerable changes in the ENSO-monsoon relationship from the early to recent decades are observed in all the three phases. During El Niño events, the rainfall over most Indian regions is increased in recent decades during onset phase, but decreased during peak and withdrawal phases. On the other hand, the rainfall during La Niña events is decreased during onset and withdrawal phases and increased during peak phase. The changes in sea surface temperature (SST), low level circulations, and Walker circulation anomalies over the central Pacific and Indian Ocean are linked to the changes in the rainfall characteristics during ENSO events during all three phases, with most robust relationship during the onset phase.

Th3-A009

Impact of El- Niño and Easterly Wave activity on the occurrence of heavy rainfall events over South East peninsular India during NE monsoon season

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Abstract:

The catastrophic floods over southeast peninsular India during 2015 northeast monsoon season (NEM, October–December) avowed 400 lives, affected more than 4 million people and reported a loss of property worth 3 billion US dollars. In the present study, an attempt has been made to understand the mechanism of occurrence of heavy rainfall events over southeast peninsular India during NEM, with a special emphasize on 2015 heavy rainfall events. In presence of strong El Niño, basin-wide warming and low-level easterly winds were observed over tropical Indian Ocean during NEM-2015. It is noted that dominant easterly wave (EW) activity aided the intensification of already developing synoptic systems over Bay of Bengal (BoB) and led to occurrence of heavy rainfall events. This finding encouraged us to explore the association of El Niño, EW activity and heavy rainfall occurrences over southeast peninsular India during NEM for the period 1951–2015. It is noticed that ~43% of the heavy rainfall events during NEM are associated with El Niño, ~31% with La Niña and ~26% with neutral years, respectively. A 3–7-day band-pass filter is applied to the daily global reanalysis fields to elucidate the role of EW activity on heavy rainfall occurrences over the region during El Niño–Southern Oscillations (ENSO). Results indicate that EW activity over Indian Ocean plays a seminal role in occurrence of the heavy rainfall events during positive phase of the ENSO (El Niño), while it is found to be weak during negative (La Niña) and neutral phase. It is also revealed that significant above-normal sea surface temperature (SST) over BoB, strong west–east SST gradient between southwest BoB and tropical western Pacific Ocean and anomalous strong low-level easterly flow over tropical Indian Ocean during El Niño years offer favourable conditions for the initiation and westwards propagation of EWs.

Th3-P010

Modeling Surface Runoff in West Flowing River Basin of Kutch, Saurashtra and Marwar during contrasting monsoons

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Abstract:

The freshwater availability varies considerably over time & space and is stressed due to growing consumptive requirements. The study area is West Flowing River Basin of Kutch, Saurashtra and Marwar. The basin is located in western India covering Rajasthan, Gujarat & Diu and encompasses varied topography in the form of desert, salt marsh (rann), hills, plains and coastal areas.

The analysis focuses on the estimation of surface runoff using modified Soil Conservation Service Curve Number (SCS-CN) method for Indian Conditions, also known as the hydrologic soil cover complex method. The direct runoff has been calculated for 268 watersheds within a basin by using antecedent soil moisture conditions, soil, land cover and the curve number (CN) which characterizes the runoff potential of the soil land cover complex. The data used is available for water years 2004-05 to 2013-14.

The water availability within the basin is quantified using SCS-CN method in the watersheds of the basin during 2007 (excess) and 2009 (deficit) monsoons. In 2007, the calculated annual water availability varies from 0 to 903.48 MCM in watersheds and from 0 to 1130.47 in monsoon season with higher values towards southern part of the basin. In 2009, the calculated annual water availability ranges from 0 to 625.04 MCM in watersheds and from 0 to 729.29 MCM in monsoon season. The maximum runoff in both years was observed in southern coastal watersheds of Junagadh district, Gujarat. The spatial maps were generated to interpret the spatial variations of surface runoff during contrasting monsoons within the basin.

Theme-4 (Th4): Climate-Change-Impacts

Th4-P001

Drying of North India during Indian Summer Monsoon

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Abstract:

This study focuses on drying trend rainfall over North India during the Indian summer monsoon (ISM) from June through September (JJAS) as the major amount of rainfall is received during this season over here. All the previous studies have mentioned either considering North India along with a part of Central India or only Indo-Gangetic plains of North India. The circulation features over North India are different from that of Central India. Also, the study of rainfall during ISM over North India has been reported less than that of over central India. Therefore, the monsoon circulation is poorly understood over this region. The main objective of the present study is to understand the interannual variability of rainfall during ISM over North India. The present study has been carried out using 71 years (1948-2018) of data. We have found that most of the parts of North India showing a drying trend of rainfall during ISM (ISMR). To investigate the relationship of ISMR over North India with zonal and meridional components of wind and sea surface temperature (SST), the correlation and regression analysis is being carried out. It showed that the upper-level north-easterlies are playing a significant role in modulating ISMR over North India. At the lower-level, the moisture supply is coming from the Bay of Bengal to this region. The equatorial eastern Pacific Ocean SST has a significant negative correlation with ISMR over North India. It may be the reason which leads to decreasing in rainfall during the summer monsoon over North India.

Th4-P002

Variations in potential evapotranspiration over western Himalaya during the last two centuries inferred from tree ring-width records

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Abstract:

Tree ring-width chronologies of different species from the western Himalaya have been carried out in relation to climate variability / change. The 1st principal component (PC1) computed through tree ring chronologies of the western Himalaya is negatively correlated with temperature (TM), heat index (HT), and potential evapotranspiration (PET) but positively with the rainfall of the region during the spring season. Based on their relationship, it is observed that HT and PET's influence on tree growth had a stronger impact than temperature, which encourages reconstructing the spring season PET. The extended periods of low PET have been found at ending phase of Little Ice Age (LIA) during 1827-1845. The reconstruction showed that the advance of the glaciers over the western Himalaya might have an influence on the reduction of downward shortwave radiation on the earth's surface which might turn low temperature and low PET across the region. The highest PET was noticed in the entire reconstruction during 1921, which has been associated with the lowest tree growth over western Himalaya.

Th4-A003

Atmospheric aerosols and their impact on climate

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Abstract:

Aerosols (tiny suspended particles in the atmosphere) are in the forefront of climate studies since last three decades owing to the role they play in the Earth Atmosphere system by absorbing or scattering the incoming solar radiation thus warming or cooling the atmosphere and hence playing an important role in the Earth's radiation budget. Atmospheric aerosols are contributed by natural as well as anthropogenic sources. Their natural sources include volcanoes, dust, forest, vegetation and sea-spray. Natural sources, such as volcanic activity, produce synoptic scale effects; while other sources, such as wind-blown dust, sea-spray, convective and general circulations produce regional-scale effects in modulating the background aerosols. Anthropogenic aerosols are short-lived and mostly produce negative radioactive forcing. The major sources of anthropogenic aerosols are fossil fuel and biomass burning and these sources are also associated with degradation of the air quality and acid deposition. On a global scale, the natural sources of aerosols are more important than the anthropogenic aerosols, but regionally anthropogenic aerosols are more important. Moreover, aerosols influence the solar radiation both directly and indirectly through their various sizes and thus have different optical and physical properties. When aerosol particles are small, they act as cloud condensation nuclei and help in the formation of clouds and when sufficiently large in size, they scatter and absorb sun light. Although the dynamics change the aerosol size spectrum during their residence time, the particle population highly relies on the strength of their source and sinks mechanisms. As a result, concentrations of ambient aerosol differ to a great extent between urban and remote areas, and between industrialized and rural regions. The aerosols in the size 0.1-5.0 μm are considered as the most effective in attenuating the sunlight. Some experimental results will be discussed in the presentation.

Key words: Atmospheric Aerosols, Climate change, Solar radiations, Aerosols sources.

Th4-A004

Enso-Indian Summer Monsoon Rainfall Teleconnection in a Warming Environment

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Abstract:

An effort is made to identify a physically consistent change in the ENSO-Indian summer monsoon rainfall (ISMR) teleconnection with the help of long-term data from historical and RCP scenarios of CMIP5 models. It is shown that the correlation between ENSO and ISMR is likely to change from significantly negative to positive on a multi-decadal time scale with increase in the greenhouse gas (GHG) forcing. Through a combined empirical orthogonal function (CEOF) analysis, which is supported by the signal-to-noise maximizing EOF analysis, the effect of global warming is separated from the natural variability of ENSO. It is argued that the change in ENSO-ISMR correlation is due to persistent 'forced' increase in ISMR as a response to the global warming. It is suggested that the ISMR predictability is likely to get worse during the next 4-5 decades under high GHG forcing.

Th4-A005

Climate Change and Rice Crop Yield Sensitivity In Maharashtra State, India

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Abstract:

Climate Change has become a reality today. A country like India with its vast agrarian economy and a huge population, any change in climatic variables, would have a profound impact on agriculture and on public health. The scope of the present study is to examine the possible adaptability of agriculture to such a change in climate in the Indian context.

The study would comprise the entire nine agro climatic zones of Maharashtra covering representative seventeen districts in the state. The data collected at district level in Maharashtra state would for around 33years, (minimum number of years of timeline required to analyze the climate data for climate change as per world meteorological organization).The IMD data includes maximum temperature and minimum temperature, rainfall, and relative humidity morning and evening would be analyzed using different statistical techniques. The major food rice productivity would be analyzed for the sensitivity analysis with the help of *'Detrending Method'* and the Crop Simulation Model *'DSSAT'*. For the crop simulation model the soil data collected from NBSS & LUP would be analyzed in conjunction with the crop data to find out the *'soil moisture stress'*. Further, *'crop water stress' would be analyzed to check the crop sensitivity stage.* The *'crop diversification'* analysis plays an important role for giving advisories in districts subject to vagaries of climatic effect. The Remote Sensing & GIS Techniques would be used to carry image interpretation, data capture, spatial overlay analysis, neighborhood and proximity analysis.

Geographical distribution of vulnerable districts–prone to crop stress and their physical environment studied. The spatial distribution of rainfall, rainy days and temperature by considering various geographical factors like orographic, seasonality, land cover, land use and technology practices etc also analyzed to identify long term variations in Area, Production and Yield of Rice in major growing districts of Maharashtra. Expected Findings and Results: The *'intra'* and *'inter'* changes brought out by the analyzed data would be spatially represented by using GIS mapping tools, at the District level and to give a Macro visualization at State level. The data also would be represented in choropleth maps, probability maps, trend maps and flow maps, along with set of tables and graphs to support the text. The study examined the temporal variability and change in Tmax, Tmin, RF, RH I and RH II some of key parameters and its effect on rice productivity.

Key word – Climate Change, Detrending method, DSSAT Crop simulation model, Adaptation strategy.

Th4-A006

Wintertime rainfall variability over India and its homogenous regions

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Abstract:

Extensive studies on the Indian summer monsoon rainfall and its variability over the country and related phenomena has left a void for the research in winter months that is of prime importance considering the agriculture-driven economic developments. This study comprises of the variability analysis of the winter months (November to Februrary) rainfall over various homogenous regions (Northwest, Central Northeast, West Central, Northeast and Peninsular) of India defined by IMD over 143 years (1871-2014). Time series plot of the standardised rainfall of these regions on tricadal and decadal basis have been analysed and compared with the overall rainfall trend over the country. Further, Mann-Kendall trend test has been utilised for any monotonic significant trend (at 90% and 95% confidence level) and Sen's slope estimated. No significant long term trends were observed for the overall region but only short term epochs. But the 1st tricade (1955-1984) of All India, Northwest and west central have shown significant increasing trends of 0.04 mm/year (95% significance level), 0.05 mm/year (95% significance level), and 0.033 mm/year (90% significance level) respectively. Third tricade (1955-1984) of Central Northeast region showed significant decreasing trend with Sen's slope being 0.066 mm/year. However, the 2nd tricade (1985-2014) of the Northeast region depicted the significant decreasing trend of 0.05 mm/year (5% alpha level) that is a matter of concern regarding the present scenarios of changing climate in the world. The scantiest rainfall during the recent decade (2005-2014) relative to the previous decade was faced by the Northwest region with negative change of 110.9% followed by the Northeast region (negative change of 97%). Further, the Peninsular India depicted highest rainfall anomaly during the recent decade compared to all other decades. Also, SSA (Singular Spectrum Analysis) was applied to the time series to find the oscillatory components and thus, forecast for the coming years based on the past trends.

Th4-P007

Epochs/stages of rainfall variability in summer monsoon over all India and its homogeneous region

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Abstract:

The most important climate parameter, the rainfall has a high degree of variability on temporal and spatial scale, as compared to the other atmospheric indicators. Monsoon is a manifestation of seasonal variation of tropical circulation in response to seasonal variation of the solar radiation. This current study is based on the analysis of summer monsoon (JJAS) rainfall for India and its five homogeneous regions during 1871-2013. The rainfall analysis has been done for climatological variation, decadal and tricadal variation (i.e., the epochs of increasing/decreasing trends) over all India and its five homogeneous regions – North West, West central, North East, Central North East and Peninsular region. The overall rainfall trend from 1891-2010, all the regions except peninsular region showed a decreasing trend with maximum decrease in North East region. Furthermore, Mann-Kendall trend test has been utilised at 95% confidence level for all the five regions and observed that all the regions except peninsular region showed decreasing trend in third tricade (1951-1980), in fourth tricade (1981-2010), there was decreasing trend in all the 4 regions except North West and Central North East. The decadal analysis depicted that except for peninsular region and North West region, all other regions showed decreasing trend. The period 2001-2010 was really a matter of concern as the mean rainfall showed decreasing trend than the previous decades in all region signifying the reduced mean rainfall. In recent years the monsoon rainfall and distribution are irregular and unpredictable nature have caused extensive financial loss damage to lives and agriculture consequently leads to food insecurity issues. Knowledge and awareness of such variability can advantage to enhanced risk management systems in agricultural and other industries.

Key words: Indian summer monsoon, rainfall variability, trend analysis, Mann-Kendall trend test

Th4-P008

Inter-decadal modulation of IPOC mode and its impact on Indian summer monsoon rainfall in CMIP5 models

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Abstract:

In this study we have evaluated the performance of Coupled Model Intercomparison Project Phase 5 (CMIP5) models in simulating the inter-decadal variability of the Indo-Western Pacific Ocean Capacitor (IPOC) mode and its influence on Indian Summer Monsoon rainfall (ISMR). The Extended Reconstructed Sea Surface Temperature (ERSST), India Meteorological Department (IMD) precipitation and the National Oceanic and Atmospheric Administration 20th Century Reanalysis (NOAA-20CR) datasets for the period of 1901-2005 (observations) are used for analysis. Historical runs from the 22 CMIP5 models are used to assess the skill in capturing interdecadal modulations of IPOC and ISMR. The IPOC mode is extracted by performing Singular Value Decomposition (SVD) analysis based on tropical Indian Ocean (TIO) Sea Surface Temperature (SST) and Western North Pacific 850 hPa vorticity anomalies during summer season (June-July-August). Spatial correlation of SVD Principal Component-1 (PC-1) with ISMR showed south-west (positive) and north-east (negative) dipole precipitation anomaly pattern over the Indian region in observation. This rainfall pattern is mainly contributed by anomalous WNP anticyclone and TIO warming which are primary components of IPOC mode. Depending upon the 21-year sliding correlation coefficients between ISMR anomaly index and SVD PC-1, three epochs are selected in observations. It is found that the IPOC mode has strong influence on ISMR in Epoch-1 (1895-1926) and Epoch-3 (1976-2007), but its relationship with ISMR is weaker in Epoch-2 (1932-1972), suggesting clear inter-decadal modulations. Late decay of El Nino related warming signals over the central Pacific and presence of strong Pacific Decadal Oscillation (PDO) over the northern Pacific are found to be the main cause for disorganized IPOC mode in epoch-2 in observations. It is noted that majority of CMIP5 models are unable to represent the IPOC mode that affects the IPOC-ISMR teleconnection. In most of the models, disorganized WNP anticyclone is mainly provoked representation of poor IPOC mode and decadal modulations.

Th4-P009

Monsoon low level wind characteristics as seen from radiosonde observation of a high altitude site inWestern Ghats, India

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Abstract:

Monsoon dynamics play an important role in determining the amount of precipitation/rainfall across the country during the south-west monsoon. Many components of the monsoon system have a significant influence on monsoon variability over the Indian sub-continent. One of them is the strong cross-equatorial wind flow in the lower troposphere, which is known as the monsoon low level jet (MLLJ). In the present work, low level wind characteristics during monsoon season over a high altitude site, Mahabalehswar, has been studied using high resolution radiosonde observations. High Altitude Cloud Physics Laboratory (HACPL) placed at Mahabaleshwar (17.92° N, 73.65° E) is at a height of 1378 m above mean sea level (MSL) where daily radiosonde launch is taking place at 12 GMT . Monsoon Low-Level Jet (MLLJ) characteristics such as jet core, jet speed and depth has been analyzed for 03 years (2016-2018) of data set and compared with ECMWF (European Centre for Medium-Range Weather Forecasts) Re-Analysis (ERA) Interim datasets . The core speed, core height and depth of the low-level jet are ~ 15m/s, around height of 3km and 2.8km respectively. We have also estimated the vertical shear in zonal wind which showed clear altitude variability with positive shear below 3km and negative above that height. Detail analysis and statistics will be presented in conference.

Th4-P010

Indian Ocean Warming and Its Impact

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Abstract:

Sea surface temperature (SST) over Indian Ocean (IO) has been reported to increase by many folds. Present study aims to evaluate the warming over IO at different time scale. Inter-annual analysis of SST over IO for 69 years (1950-2018) using HadSST at 1° x 1° grid shows many significant features. 69 years mean and standard deviation shows that mean over North IO (NIO) is relative higher while high standard deviation is observed over south IO (SIO). Based on this two regions are selected for further analysis. One is equatorial region bounded by 5°N-5°S and other is SIO that is bounded by 30°S-50°S for longitude 30°E-140°E. Inter-annual variation over both region shows that SST is increasing. Among them Equatorial region depicts significant increase in SST after 1980. Hence for further analysis two epochs has been chosen Epoch one (1950-1980) comprises 31 years while second epoch (1981-2018) consists of 38 years. A significant increase of same pattern has also been observed in monthly as well as seasonal variation. In monthly and seasonal variation, it is observed that monsoon months encountered much warming than other season over equatorial IO (EIO). Further analysis has been done to understand the change between these two epochs. A basin wide significant warming with maximum of 0.6 °C over EIO has been observed. West SIO encounters 0.4°C increase while East encounters 0.6°C increase. Trend analysis of 69 years of SST shows that EIO is significantly increases with a rate of 0.015°C/year which means 0.15°C per decade. To understand the impact of SST warming over IO, Emperical Orthogonal Function has been evaluated which shows a significant change in both EOF 1 (Basin-wide mode) and EOF 2 (Dipole mode).

Th4-P011

On the trends in the frequency of monsoon lows and depressions and their association with Southwest monsoon rainfall

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Abstract:

Synoptic scale disturbances like depressions and lows formed over Indian region and adjoining seas during southwest monsoon season significantly influence the southwest monsoon rainfall temporally and spatially. Previous studies acknowledged the role of these systems during monsoon season and several studies estimated their contribution to seasonal rainfall. However, depressions are studied in greater depth than lows. Hence, it becomes important to investigate changes in their characteristics over a period of time and corresponding changes in rainfall patterns. This study investigates the trends in the frequency of monsoon depressions and lows formed over Bay of Bengal, Arabian Sea and Indian landmass over a period of 1901-2018, further divded in to shorter periods 1901-1950 and 1951-2018. The frequency of monsoon depressions(lows) shows significant decreasing(increasing) trend over Bay of Bengal during 1901-2018 as well as during 1951-2018. These trends were opposite during 1901-1950. However, the significant increasing trends in the frequency of both monsoon depressions and lows have been observed over Arabian sea for all periods, except in case of frequency of lows during 1901-1950 and that of depressions during 1951-2018. Changes in the frequency of both are insignificant over land. Number of days associated with systems follows the same trends as their frequency over the respective regions. It is also seen that the average life of depressions over all three regions is decreased from 1901-1950 to 1951-2018 whereas that of lows over every region is increased. These changes in the characteristics of monsoon depressions and monsoon lows modulated their contribution to monsoon rainfall over India especially over central India which is referred to as monsoon core zone(MCZ). Monsoon depressions(lows) are responsible for 20%-25%(20%-30%) of monsoon rainfall over during 1901-2018. However, during 1901-1950, the contribution of depressions(25-30%) was higher than that of lows(10-20%) whereas during 1951-2018, the contribution of depression decreased to 15-25% and that of lows increased to 25-35% which reaches up to 40% in some parts of Rajasthan.

Th4-P012

Evaluating the association between annual malaria incidence and El Nino Southern Oscillation (ENSO) in Odisha

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Abstract:
In the South- East Asia region of World Health Organization (WHO), the world's second highest populous country India contributes 2/3rd cases of malaria and most of the malaria-related deaths. The burden due to malaria differs in different parts of India with stable transmission in the northeast and unstable in the peninsular region; whereas well drained coastal areas and some mountainous regions above 1800m from sea level are free from malaria. However, with current climate trends and corresponding transmission windows, malaria free areas above 1800m have been suggested to become malaria prone under the changed climate conditions.

Odisha, a state in eastern India, has the highest reported malaria burden in the country, contributing 45% of total cases, albeit with only 4% of the Indian land mass and 3% of its population. A large part of Odisha has conditions that are conducive to malaria transmission, such as hilly forested areas with perennial streams, high humidity and medium-to-high rainfall.

A dynamical model (VECTRI) for malaria transmission which accounts for the influence of population and climatic conditions, malaria transmission dynamics is investigated for Odisha in India. The model is first run over the region, and then analysis is carried out for the period 15 years.

We have evaluated the association between annual malaria incidence and El Nino Southern Oscillation (ENSO) as measured by the Southern Oscillation Index (SOI) in five different districts of Odisha namely Kandhamal, Nayagarh, Bouda, Anugul, Dhenkanal, . Below normal incidence of malaria synchronized with a negative SOI (El Nino) and above normal incidence with a positive SOI (La Nina), which lead to dry and wet weather conditions, respectively. In most districts there was a positive relationship between SOI and annual malaria incidence, especially being *Anopheles culicifacie* is a major vector.

Keywords – VECTRI, El Nino Southern Oscillation (ENSO), Southern Oscillation Index (SOI)

Th4-P013

Temporal Rainfall Variability and its Correlation with Temperature over Ranchi, Jharkhand

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Abstract:
The extent to which rainfall amount varies across an area (spatial) or through time (temporal) is an important characteristic to determine the climate of an area. The discipline that covers this area in Meteorology/Climatology is known as "Rainfall variability". It is of two types: Areal (Spatial) and Temporal. The temporal variability of rainfall means variation of rainfall as time varies but the area of the location remains the same. The temporal variability of rainfall of a place helps in knowing the rainfall variability with time. Rainfall variability plays an important role in understanding climate change. In this fast growing world, urbanization and industrialization has led to the problem of global warming. As a result of this, there has been a drift rise in temperature. The present research work was taken over to analyse the temporal trend of Rainfall over Ranchi during 1975-2017 and to study its correlation with temperature over Ranchi, Jharkhand during1975-2009. To analyse the trend in rainfall over Ranchi, rainfall data from 1975-2017 was studied. The annual rainfall ranged from a minimum of 734.6 mm to a highest of 1771.335 mm. The mean, median, coefficient of variance and standard deviation was also found on the monthly, seasonal and annual basis. Through time series graphs of rainfall, a positive trend is detected in summer season while annual, winter and southwest monsoon rainfall appeared as a negative trend. On the other hand, by utilizing non-parametric tests such as Mann-Kendall trend test and Sen Slope, it was found that there was no significant trend at 95% confidence limit in any case. Through the study, it was found that there is a significant correlation of rainfall with temperature over the years 1975-2009. Although it was found to be negative in Summer, Monsoon and Annual data, whereas there was a positive correlation between rainfall and temperature during the winter season.

Th4-P014

Climate Change Effects on Spatio-temporal Distribution of Precipitation over West Central India: Statistical Downscaling Approach for Generating Future Scenarios

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Abstract:

Climate Change and hydrological studies focus on Rainfall as a one of the important parameters. This study focuses on assessment of future trends of spatio-temporal variation of precipitation over West Central region of India. Climate change plays an important role in forecasting weather patterns over various regions, which is caused due to solar radiation received by Earth, plate tectonics, and many geographical activities. It ultimately shows the impact on water resources and global hydrological cycle, which in turn affects surface as well as ground water.

Global temperature changes affect climate in different ways (IPCC 2013a Feng et al. 2014). General Circulation Models fail to capture the sub grid processes for some features of homogeneous monsoon regions. Rainfall patterns influenced by Climatic change, which is ultimately affecting the agriculture and water availability. Variation in spatiotemporal distribution of rainfall in due course of time may deteriorate the situation. To capture the Spatio-temporal variability of rainfall over study region, it is necessary to analyze the average rainfall of a region rather than finding the average rainfall at individual station points in study area. Therefore, to obtain projections of the climate change impacts at regional level i.e. over West Central region of India, downscaling is necessary.

The Statistical Downscaling Model (SDSM, version 4.2) is used for downscaling outputs of General Circulation Models (GCMs). Rainfall data of West central region of India is obtained from India Meteorological Department is used as predictand and National Centre for Environmental Prediction (NCEP) data are used as predictors from 1961 to 2001.HadCM3 with A2, B2 scenarios and CGCM3 of A1B, A2 scenario are used for period 1961–2099.The performance of the downscaling technique with SDSM is estimated by statistical parameters viz. Correlation Coefficient (CC), Standard Deviation (SD), Mean (μ) and Root Mean Square Error (RMSE) methods. Bias correction method has been applied for downscaled precipitation. The rainfall scenarios are generated for three epochs 2011-2040, 2041-2070 and 2071-2099 time scale. The scatter-plots and cross-correlations are used for verifying the reliability of the simulation. Downscaled future precipitation shows increasing trends for all scenarios.

Keywords: Climate change, Downscaling, NCEP, HadCM3, CGCM3, West Central India

Th4-A015

Long term variability of Indian Summer Monsoon (ISM) and its possible connection with El-Niño

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Abstract:

The interannual variability of Indian summer monsoon (ISM) is probably one of the most intensively studied phenomena in the research area of climate changes. This is because even relatively small variations of about 10% to 20% from the mean rainfall may have dramatic consequences for regional agricultural production. Southwest monsoon (JJAS) provides most of the annual rainfall to the Indian subcontinent. We have examined the long-term variability of Indian monsoon using precipitation from Global Precipitation Mission (GPM) during 2009-2018 in the context of El-nino. Warm sea surface temperature (SST) anomalies associated with super El Niño 2015 disappeared by early summer 2016 over the central and eastern Pacific. The preliminary result observes that southwest (JJAS) monsoon was stronger during 2009, 2011-14 and weaker during 2010, 2015 and 2016. This interannual variability is interpreted as El-nino southern oscillation index (ENSO) in the lower atmosphere. The factors that determine the year to year fluctuation in ISM rainfall are investigated with sea surface temperature (SST), zonal wind at 850 hPa, mean sea level pressure and Indo-pacific climate anomalies. It is noticed that low rainfall over central north India during southwest monsoon in the year 2015 and 2016 due to moisture divergence impacted by westward extension of ridge corresponding to western north pacific anticyclone. Results from a detailed analysis of these observations will be presented and discussed in the context of the climate variabilities.

Th4-P016

Analyzing change in dynamic patterns of Forest using FRAGSTATS and FORMIND model over Western Ghats, India

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Abstract:

Fragmentation leads to loss of biodiversity and reduction in water quality. Fragmentation activities often increase due to rapid urbanization and various anthropogenic activities. Remote sensing (RS) and Geographic Information system (GIS) are trending technology to analyze the fragmented landscapes using FRAGSTATS model. Fragmentation analysis is most crucial for analyzing the turbulences of forest community. This study has been focused to assess the fragmented landscapes in Konkan region of Maharashtra state over Western Ghats of India during the period: 1990 to 2018. FRAGSTATS model was used to extract the fragmented landscapes which correspond to Land use land cover (LU/LC) and Forest canopy density (FCD) mapping. From these, we can understand the differences which occurred from 1990 to 2018, which indicates the urban expansion and changes in land cover types, Total edge and edge density have also increased over the years. The results also revealed that there was a great spatial variability in the pattern of forest loss and land use land cover change. Since Field Inventories data are taken for estimating aboveground biomass, the biomass value is ranging from 203.90 to 295.02 ton/hectare, which shows a good amount of carbon stocks present in that area. Furthermore, this Inventory data sets and some previous data sets (from literature review) used for simulation of carbon stocks and fluxes using FORMIND model. The model simulates the forest succession are analyzed over 500 years, to assess the variability in forest model, we had 10 repeated simulation runs. The simulation is basically developed on the various plant functional types (PFT). The aboveground biomass was approx. 295 ton/h and it was increased in simulation forest model was 330 ton/h. The total basal area of the simulated data 38m^2/ha was close to the observed field data 40m^2/ha. According to the simulation model results, the forest was a strong carbon sink during 300 years of simulation, after that the simulation was balanced for all the parameters. The simulation results indicated that the model successfully reproduces measured basal area and aboveground biomass due to the fact that observed biomass through field inventory data were used to calibrate the model.

Th4-P017

Variability and trends in rainfall and temperature over Tamil Nadu

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Abstract:

Climate change happened on a worldwide scale, its impacts often vary across regions. Several studies have been conducted in recent years to detect possible climate trends and change worldwide. Most of these studies have focused on changes in temperature (maximum, minimum or mean) and precipitation only as changes in their pattern can affect agricultural production, water availability and ecosystems. The aim of this study was to explore the changes in the annual and seasonal rainfall and temperature using the long term time series data of Tamil Nadu. Trend analysis made through the non parametric Mann-Kendall test and Sen's slope estimator for historic climatic period (1981-2017) and future time scales such as near century (2010-2039), mid century (2040-2069) and end of century (2071-2099). ECMWF reanalysis Interim (ERA-I) data available at a 0.75° horizontal resolution was used as initial and boundary conditions in Weather Forecasting Model (WRF) model. All available satellite and in-situ observations in the region were assimilated into WRF using the consecutive re-initialization method to generate the historic climatic data. Dynamical downscaling of Global Circulation Model (CCSM4) was done at ACRC, TNAU, Coimbatore by employing Regional Climate Model (RCM) RegCM 4.4. The downscaled future data under RCP 4.5 and RCP 8.5 scenario and historical data used for the analysis. The results revealed that annual and seasonal maximum and minimum temperatures are predicted to have more variability and significant warming trend in the future. In future, the projected annual and seasonal rainfall tread indicated a mixed pattern over Tamil Nadu.

Key words: Rainfall, Temperature, Trend analysis, Mann-Kendall test, Sen's slope estimator

Th4-P018

Climate change projections for Tamil Nadu under RCP 8.5 using MIROC5 climate model

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Abstract:

Climate change sciences are rapidly expanding with the advent of new technologies which carried out throughout the globe. Climate models are used to project future climates based on scenarios given by the Intergovernmental Panel on Climate Change (IPCC). The Coupled Model Intercomparison Project (CMIP) is multi-model experimental framework utilized by the IPCC for bringing out information on changing climate. A research was carried out at Agro Climate Research Centre, Tamil Nadu Agricultural University, Coimbatore. The future scenario data of maximum temperature, minimum temperature and rainfall for entire Tamil Nadu were generated by climate model (MIROC5) to base period (1971-2000) near century (2011-2040), mid-century (2041-2070) and end century (2071-2099). The maximum temperature for Tamil Nadu is likely to increase in the range of 0.2 to 3.4°C while for the minimum temperature increase in the range of 0.1 to 4.0°C. The rate of increase in minimum temperature is higher than that of maximum temperature for Tamil Nadu. The seasonal variations of the maximum and minimum temperature were projected, Compared to North East Monsoon, the maximum and minimum temperature were projected higher during South West Monsoon. The deviation of rainfall was -6.0 per cent, 3.4 per cent and 4.7 percent during near, mid and end century respectively. On comparing the monsoon seasons, a noticeable increase in rainfall during NEM, and decrease in rainfall during SWM are projected for near, mid and end century in both RCP 8.5.

Keywords: MIROC5, Climate change projections, RCP 8.5, Tamil Nadu

Th4-P019

Study of Maximum and Minimum Temperature trends over Pune, Maharashtra (India)

Shama Anantharaman and Divya Surendran

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Abstract:

Climate change is one of the most important issues of present times. Of all the climatic elements, temperature plays a major role in detecting climatic change brought about by urbanization and industrialization. This study, therefore, attempts the analytical study carried out for Pune (Maharashtra) during the period 1985-2016 regarding all the seasons, pre-monsoon months i.e. March, April, May; monsoon months i.e. June to September; post-monsoon months i.e. October, November and December and winter months i.e., January and February. The long-term change in mean maximum temperature and mean minimum temperatures have been evaluated by MAKESENS rank statistics and linear trend. The analysis reveals significant increase in annual mean minimum and annual mean maximum temperature over Pune. Seasonal mean minimum and mean maximum temperature also shows significant increase. The increase is more pronounced in minimum temperature than in maximum temperature.

Th4-P020

Variability of Climate Indices over a tropical hill station Mahabaleshwar, Maharashtra

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Abstract:

Mahabaleshwar is located on the windward slope of the Western Ghats. It has a pronounced monsoon climate with the majority of rainfall (~ 6000 mm) received during the monsoon period (June–September). Climate indices reflect certain aspect of climate record that can be used to describe the state and the changes in the climate system of the study area. In this study, different climate indices are found out for Mahabhaleshwar station. Daily rainfall data of Mahabaleshwar from 1969-2019 (50 years) have been taken for calculating indices. For rainfall analysis, using ClimPact software following indices have been studied:

1. R10mm: No. of heavy rain days when precipitation is greater than 10mm
2. R20mm: No. of very heavy rain days when precipitation is greater than 20mm
3. Rnnmm: No. of days when precipitation is greater than 30mm
4. CDD: Max. number of consecutive dry days when precipitation is less than 1mm
5. PRCPTOT: Annual total wet day precipitation

From above mentioned indices (R10mm and R20mm), there is a significant decrease observed in heavy rainy days (R10mm) and very heavy rainy days (R20mm) during south west monsoon season (June-September) from 1969 to 2019.

Keywords: Mahabaleshwar, Heavy rainfall, Climate Variability, Climate Indices, ClimPact

Th4-P021

Effect of Manmade Activities on Aerosol Loading

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Keywords: -troposphere, Aerosol, temperature, humidity

Abstract:

Aerosol measurement have been carried out at Kolhapur (16°42'N, 74°14'E) by using semiautomatic twilight photometer to study the vertical distribution of the atmospheric aerosol number density per cm^3 (AND). In this ongoing study, one attempt was made to study the effect on vertical distribution of AND due to the increased manmade activities at road construction time in Kolhapur (During October 2009 - May 2).

The observations reveal that many types of aerosols introduced in the atmosphere at the road construction time remained suspended in the atmosphere for some hours to days. Hence, one new tropospheric aerosol layer (in between ~6 and ~9 km) was observed. This layer was the result of enhanced aerosol generation due to the primary production (bulk-to-particle conversion) and photochemical processes (secondary production) at the time of road construction activities. No such aerosol layer was observed before or after this period.

The AND of the newly observed tropospheric aerosol layer at road construction time and its altitudes for clear sky days showed day to day, monthly and seasonal variations with highest height in the month of October and lowest in the middle of March was observed. The considerable difference was observed in morning and evening altitudes of this layer. At evening this aerosol layer was observed at higher altitudes than morning for all the months.

The aerosols introduced in the atmosphere due to road construction work were heat-absorbing aerosols. Hence, increase in temperature at this period was observed. The atmospheric pressure was also increased. Relative humidity in the atmosphere was decreased. It is clear that man-made activities affects the tropospheric aerosol loading and there by affects the local climate.

Th4-P022

The Role of CO_2 In Precipitation of Monsoon Cloud

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Abstract

In atmospheric ambient air, **CO_2** is found to be 0.04%, but increment of it causes climatic changes producing adverse effect on environment and on the health of human being. Evidently **CO_2** as air pollutant raises the global warming due to its greenhouse effect which can damage the life on the earth at large time scale. The excess budget of **CO_2** in atmosphere may be used in enhancement of the precipitation of monsoon clouds. In order to understand the role of **CO_2** in precipitation of cloud, we conducted an experimental study and found that **CO_2** enhanced 16% rate of condensation of water vapor at NTP. The use of **CO_2** would help in two ways to reduce: (1) **CO_2** pollution in atmosphere and (2) flood and draught situations by uniform rain.

Th4-P023

Trends Analysis of Rainfall over Pune during South-West Monsoon for the Period 1901-2019

Aradhana Kumari, Latha Sridhar, Divya E. Surendran, O.P. Sreejith and D. S. Pai

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Abstract:

Pune district is situated in the western part of the Maharashtra state of India and it is the second largest city in the Indian state of Maharashtra, after Mumbai. Pune forms a part of the tropical monsoon, shows seasonal variation in rainfall (RF) occurrences due to changing climate in the recent years. An attempt was made in this study to understand the trend of rainfall in Pune using 119 years (1901-2019) of station data. 80 % rainfall in the city occur during the monsoon season (Jun to Sep), and July is the wettest month of the year. Rainfall trend of Pune for the period 1901-2019 was observed significant positive for JJAS, June and August whereas other months of the season also showed increasing behaviour though not significant. Analysis is also done for heavy (RF between 64.5mm to 124.4mm) and very heavy (RF between 124.5mm to 244.5mm) rainfall. Trend in heavy and very heavy rainfall is calculated for the period 1901-2019, 1901-1970 and 1970-2019 for JJAS using Mann-Kendall test. The trend analysis of very heavy rainfall during JJAS over Pune revealed significant positive trend during 1901-2019. However, the trend was observed negative (statistically insignificant) for the period 1901-1970 and it is positive during 1971-2019 although not significant. The trend in very heavy rainfall showed positive insignificant trend for 1901-2019 as well as for 1901-1970 while it is negative insignificant for 1971-2019. The trends analysis of wet events (RF >=2.5mm) showed significant positive trend for the period 1901-2019 whereas for other two periods also, positive trend was observed though not significant. In the year 2019, 18 days of continuous rain was observed after 2004.

Keywords: **Pune, Rainfall, Wet Events, Trend**

Th4-P024

Assessment of the regional coupled model in simulating onset and withdrawal over India

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Abstract

The Indian Summer Monsoon (ISM) is expressed as a seasonal reversal of winds and northward migration of Intertropical Convergence Zone (ITCZ), that results in an active annual cycle of precipitation during June to September. The beginning of ISM rainfall over the southwest coast of India (Kerala) is referred to as "Onset". In contrast, it's retreating from the northwest part of India (Rajasthan) is regarded as "Withdrawal" of the ISM. The onset phase of ISM is a gradual process, but withdrawal is relatively accelerated process. In the present study, the performance of high-resolution regional atmospheric climate model (REMO) and Regional Coupled Atmosphere-Oceanic model (ROM) in capturing Onset and Withdrawal phase of ISM is studied. Under scenarios of increasing greenhouse gas concentration, models simulations are analyzed to study likely changes in onset and withdrawal characteristics in the present as well as the near future. For the present study, objective indices such as Onset Circulation Index (OCI) and All India Rainfall Onset and Demise (AIROD) index are used. The model simulations revealed that ROM is better in simulating the onset and withdrawal phase of ISM as compared to the REMO. Both models are showing systematic delayed biased when compared to IMD declared onset dates, but ROM is relatively better representing. The monsoonal seasonal length is explored to observe the effect of onset and withdrawal on ISM variability. The future projected simulation concludes that there will be a shift in climatological onset and withdrawal date, which will eventually affect the agricultural sector in terms of cropping patterns, yields and groundwater reservoirs.

Th4-P025

Variability and Trends of Rainfall over India during 1901-2019

Mahima, Arti Bandgar, O.P. Sreejith and D.S. Pai

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Abstract:

Indian Summer Monsoon has significant impact on agriculture, water resources and economic development of India. However, the intensity and duration of received rainfall is not uniform over all the four homogeneous regions of India (i.e. Northwest, Northeast, Central and South Peninsular India), due to their different geographical conditions and other influential climatic factors. Therefore, the study and analysis of the rainfall received over past years, as recorded by various stations over four homogeneous regions, becomes necessary. Also, recent studies have shown that climate shift has occurred at an unprecedented rate since 1980's, accelerated by extensive anthropogenic activities. This has caused a continuous rise in temperatures all over the globe since late 19th century (Source: IPCC Report,2018) resulting in extreme weather events, rising sea levels and diminishing Arctic Sea ice. It has been estimated that a huge population in India will be adversely affectedby extreme rainfall events, heatwaves, coastal flooding etc., due to the changing patterns of rainfall caused by ongoingclimate changes and this in turn will certainly impact agriculture and country's economy. Keeping this view in mind, this study aims to determine variability and trends of received rainfall in four different homogeneous regions of India on an annual as well as seasonal basis, using statistical analysis for different periods (1901-2019: Entire period and 1981-2019: Recent period). Attempt has been made to find out large scale factors responsible for the climate change over the homogeneous regions. For this study, area weighted station rainfall data available for theperiod 1901-2019 has been used.

This study highlights that for country as a whole, there is an overall significant decrease in received rainfall. Region wise NW India post-monsoon seasons has got significant (95%) decreasing amount of rainfall and Central India has shown significant decreasing trend (95%), during all seasons as well as annual rainfall. However, it is NE India has shown the most significant (99.9%) decreasing trend in annual and also in seasonal rainfall. In South Peninsular region, rainfall has decreased in monsoon season and an increasing trend is observed in pre-monsoon rainfall (95%). These results of rainfall trends indicate probable appearance of extreme weather conditions in future which may adversely impact agricultural yields, water resources, infrastructure and human life.

Keywords: rainfall trend, climate variability, homogeneous regions, southwest monsoon

Th4-P026

Adaptation measures to adapt to an uncertain micro-climate change

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Abstract:
In recent years, land use/land cover (LULC) changes due to urbanization affect local surface energy balance by changing the amount of solar energy reflected, the magnitude & duration over which absorbed energy is released as heat and impact local climate adversely. To control these adverse effects of LULC changes, various adaptation measures have been proposed is the main goal of this study. Since, mitigation of LULC changes is not possible, there is a need for effective adaptation measures to minimize these adverse effects of changes in surface temperature. Today, adaptation measures are very critical because increasing demands of people for better facilities is causing will cause continuous change in LULC. Till now, qualitative methods have been proposed to minimize these adverse effects but these methods are incapable to determine how much change is required to minimize a specified quantity of heat flux components. Therefore, quantitative methods for adaptation are required to overcome this limitation. In present research work monthly relative % changes in hourly surface energy balance (SEB) fluxes and surface temperature as compared to actual condition with original land use class at different percentages (10%, 25% and 50%) have been quantified and reduction of 0.17 to 0.21^{o}C in annual average maximum hourly surface temperature has been found from the optimum case of adaptation. Study is successful in demonstrating quantitatively that suitable adaptation measures related to LULC alterations are effective in limiting the adverse effects of micro climate change due to urbanization.

Keywords: Urbanization, Climate change, and Surface energy balance (SEB), Adaptation measure.

Th4-P027

The long term variation in the aerosol and water vapor over Kolhapur

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Abstract:

The aerosols and water vapor plays a vital role in the radiation budget, atmospheric chemistry and atmospheric electrical conductivity. Therefore, the present work is focused on their long term variability for the period of 1st Jan, 2008 to 31st Dec, 2017 which covers a decade. The data of aerosol optical depth (AOD) at 550 nm and PWC are considered for Atigre station from Moderate Resolution Imaging Spectrometer (MODIS) satellite which is available on the Giovenni website via Earthdata login. The aerosols are fine solid or liquid particles, suspended in the atmosphere and its influence observed locally, regionally, as well as globally. We have discussed its direct and indirect effect on the dynamics of the atmosphere. In addition to aerosols, to understand the cloud formation and photochemical smog formation we need to consider the variation in water vapor. We found that aerosols and water vapor show the strong positive relation while in few cases its shows moderate correlation. We have discussed in detail about this variability and source of aerosols. The present work will help in forecasting of the atmospheric models.

Th4-P028

Rainfall variability over Maharashtra during period of 1901 to 2015

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Abstract:

The rainfall data over four meteorological divisions (i) Konkan, (ii) Madhya Maharashtra, (iii) Marathwada, and (iv) Vidarbha in Maharashtra State for the longer period from 1901 to 2015 is considered to analyze the variability. The data are obtained from data.gov.in, which is free for public domain. This rainfall data is measured in different meteorological laboratories using series of rain gauge networks. There are total 36 meteorological subdivisions over India, we have considered above four regions which covers the whole Maharashtra State. The data contain monthly mean rainfall in mm during 1901 to 2015. This monthly mean time series shows characteristics of seasonal variation over all the subdivisions, where the rainfall is maximum in the monsoon season and minimum in the winter and summer month. The linear trend analysis technique is used to study the variations in rainfall for each subdivision during the data range. We found that the rainfall trend is negative over Marathwada and Vidarbha region having value -0.19 (±0.53) mm per year and -0.38 (±0.57) mm per year respectively. And it is positive over Konkan and Madhya-Maharashtra region having values 3.23(±1.33) mm per year and 1.25(±0.43) mm per year. The season wise trend analysis is also carried out for each subdivision. We have detected a number of normal, flood and drought years by calculating the normalized index (NI). These flood and drought years are also compared with the Elnino and La-nino episodes to study their effect on the rainfall. We found that the geographical and topographical effects are responsible for such rainfall distribution over different regions in Maharashtra. Our results may help to decide the policies regarding the agriculture sector in future in the same region.

Th4-P029

Trends in Changing Rainfall of Western Maharashtra

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Abstract:

Monthly rainfall series for all the 10 districts of Western Maharashtra. Statistical features of monthly rainfall series of each district are studied and then rainfall variability and trends of the monthly total rainfall for each of the districts are analyzed. The seasonality index was carried out for all the 10 districts. The changes in the seasonality index are noticed almost all the district of Western Maharashtra

We have analyzed the rainfall data of more than 100 years over Maharashtra, a large state in western parts of India which plays a significant industrial and agricultural contribution in the overall growth of India. The analysis includes variability of rainfall, trends in rainfall pattern and changes in spatial and temporal pattern of seasonality index. The impact of climate changes on temporal and spatial pattern over smaller spatial scales is clearly noticed in this analysis. Significant decreasing trends in monthly rainfall are being observed in many areas (districts) from the month of January to May with maximum decrease in February. These changing patterns are very crucial in agriculture or hydrological point of view. In spite of increasing trends in monsoon rainfall in many areas, the decreasing trends in the first five months of the year have resulted increase heating, and may have effect in shortage of soil moisture, ground water and lowering the ground water level.

Out of twelve months, August has shown very good for the state Maharashtra as most of the districts have shown increasing trends in August rainfall. Second good month is October. Analysis of seasonality index helps to have idea about the distribution of the rainfall among the months. The central parts of the state has seasonal rainfall regime having four months or rainy season indicating good for agriculture. The most warning situation for the agriculture and water sectors is the increasing trends in the seasonality index in most of the districts. Spatial analysis of both the trends in monthly total rainfall and trends in seasonality index will help the planners in all the sectors dependable in rainfall for better management and contingent crop planning.

Key words: Rainfall Trend

Th4-P030

Harvest rainwater by knowing the rainfall probabilities

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Abstract:

Rainfall data for last 40 to 49 years as per availability of nine places (1947-2005) was collected at Dry Farming Research Station, Solapur and used for analysis of this study. The rainfall analysis of the selected places comprising north, central and southern part of the scarcity zone of Maharashtra was carried out for Annual, Monthly, Seasonal, Weekly periods.

The northern part, representing Dhule is kharif oriented as evidenced by highest initial rainfall probabilities in MW 25 and 26 (> 55 %) and less variability. Delayed sowing of kharif crops can be possible in MW 30 and 31 as variability of kharif rainfall is less. (CV. 102 to 109 %), however, there after their is drastic increase in variability with low probability.

Analysis of rainfall of central part, representing Kopergaon, Rahuri and Chas indicated that, at Rahuri the rainfall probability was highest in MW24 (61 %) with less variability (CV. 86 %) indicated suitability for sowing of kharif crops can be undertaken. The sowing of rabi crops can be under taken in MW 39 having high probability (>60 %) and less CV(95%). At kopergaon the rainfall analysis indicated the critical situation for kharif as well as for rabi season showing more variability during the kharif ,coupled with long dryspells in kharif season. Chances of successful of kharif season at Chas were very meager due to high variability in MW 25 to 37 (CV. 118 to 222%).

Rainfall analysis of southern part representing Jeur , Mohol, Pandharpur, Padegaon and Solapur revealed the highest probability (>50%) of getting > 20 mm rainfall was observed in MW 38 to 40 with less varibility (CV.86 to 110 %) indicated rabi dominance. However kahrif crops can be possible in MW 25 at Solapur and MW 26 at Pandharpur as during these weeks there was less variability in rainfall (97 to 98 %). At Solapur under delayed onset of monsoon.

The sowing of kharif crops viz., Pearlmillet, Sunflower, Pigeon pea are recommended during this period. The mid season correction crop like sunflower is as recommended as contingent crop under late onset of monsoon i.e. in the month of late July and early August. However, MW 39 (24-30 Sept) with 75 percent assurance indicates maximum assurance of rainfall in rabi season. The rabi crops like winter sorghum, safflower and gram are recommended during this period on residual soil moisture. This study is helpful to the farmer in planning of field crops according to the rainfall pattern in dryland areas

Key Words: Rainfall, probability, variability,

Th4-P031

Rainfall Analysis using ITK- method

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Abstract:
Rainfall analysis of nine different places of scarcity zone was carried out. The rainfall data as per the availability of last 40 to 49 years was used for Nakshtrawise and Decadal analysis for Drought Prone Areas of Maharashtra

In northern part at Dhule, >50 mm rainfall was received in Mrugashira to Magha nakshtra with less variability (CV. <100). In central part, the rainfall in Mrugashira nakshtra at Kopergaon and Rahuri and Aaridra nakshtra at Kopergaon have less variability (CV < 100) in kharif season. Where as, Purva, Uttara and Hasta nakshtra in rabi season has less variability at Rahuri and Chas (CV < 100). In southern part, at all the selected places the Mrugashira nakshtra has less variability (CV. <100 %). Where as, Punarvasu and Pushya nakshtra at Mohol, Aaridra nakshtra at Pandharpur, Aaridra, Punarvasu and Aashelsha at Padegaon and Aaridra to Pushya nakshtra at Solapur has less variability.

In norhtern part at Dhule, Mrugashira to Purva nakshtras have the highest probability (>50%) while, Purva nakshtra has the highest initial probability (73%). In central part, the highest initial probability (>50%) of rainfall in Mrugashira nakshtra was only at Rahuri , where as the probability of rainfall in Purva to Hasta nakshtra at Rahuri and Chas indicated rabi cropping can be under taken at Rahuri and Chas.

In southern part, the initial probability of getting >50% rainfall was in Mrugashira nakshtra at Mohol in kharif season only. While, it was in Uttara and Hasta nakshtra at Jeur and Padegaon, Purva, Uttara and Hasta nakshtra at Mohol and Solapur and Purva and Hasta nakshtra at Pandharpur indicating that rabi cropping can be under taken in these nakshtras. Further, it is interesting to note that the mid season correction or contingent crop planning can be under taken in Pushya and Aashlesha nakshtra at Solapur.

Key Words: Nakshatra, Rainfall, probability, Variability, Cropping pattern

Bits and Bytes Crossword

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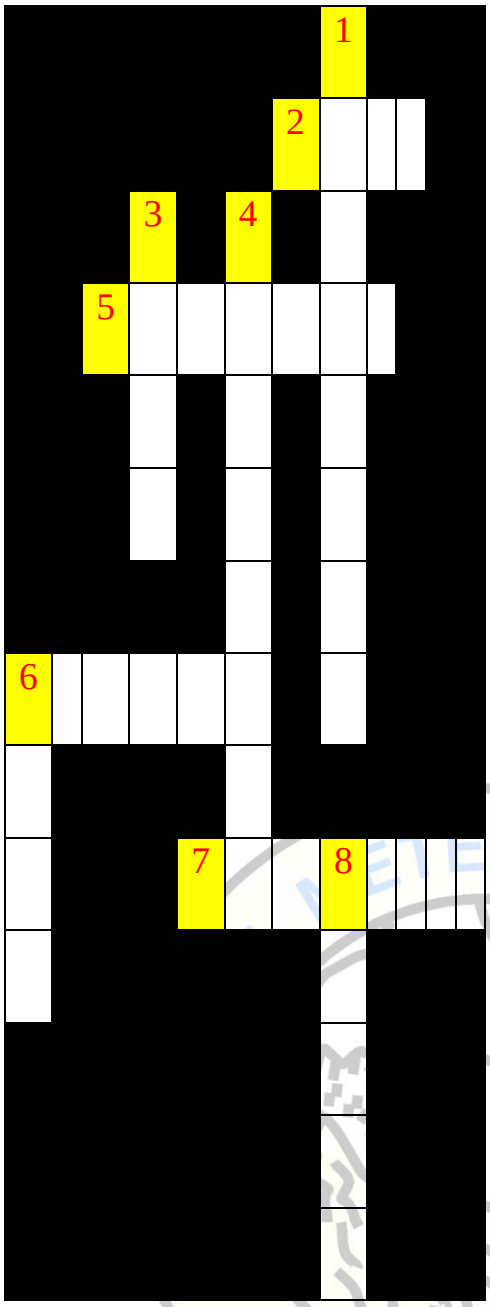


Clues Across

2 To store the world 'FORTRAN90' you would need ------ bytes of computer's space.

5 Since computers can only store binary numbers, all data has to be in this format.

6 The unit of storage of computer data consists of 0s and 1s and is known as ------.

7 The unit of storage for computer data is 1024 of 4 down.

Clues Down

1 The unit of storage for computer data is 1024 of 7 across.

3 8 of these make a byte.

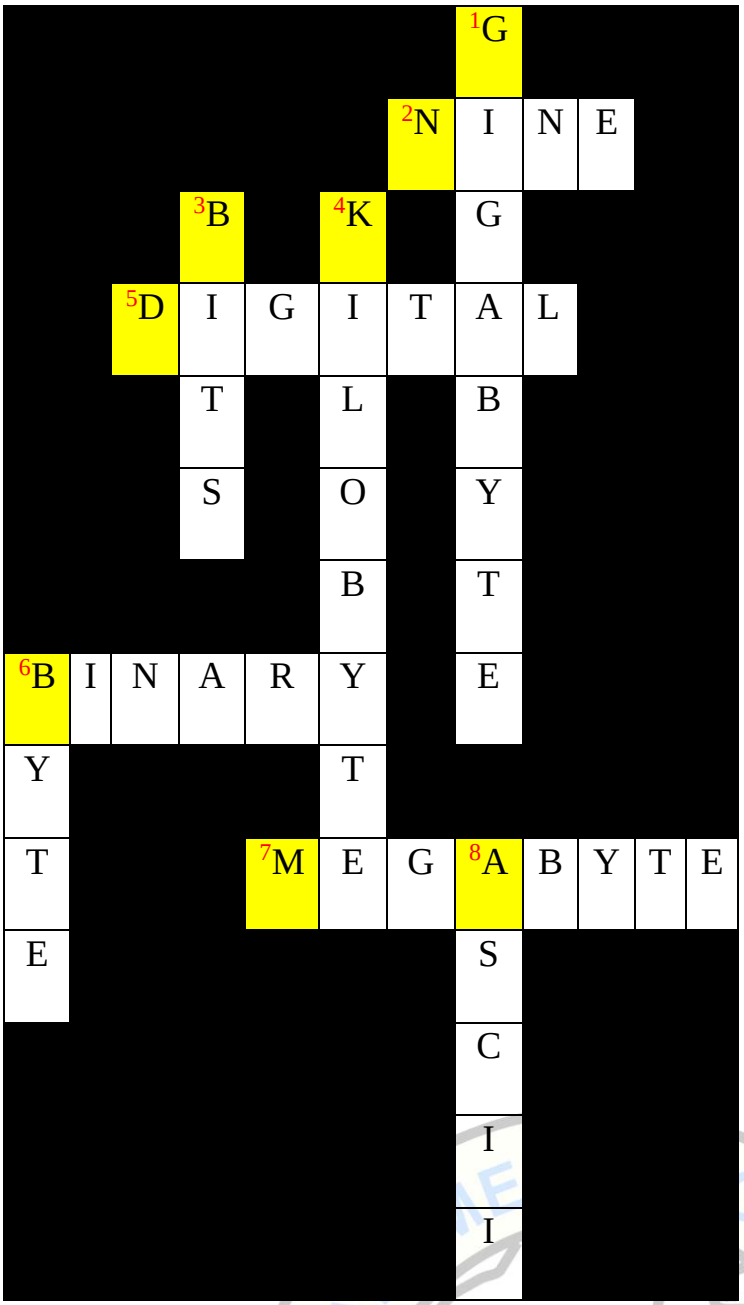
4. 1024 bytes.

6 This store one character or letter.

8 Letters or numbers are used for storing the computer- code

.

Solved Bits and Bytes Crossword


1G
2N I N E
3B 4K G
5D I G I T A L
T L B
S O Y
B T
6B I N A R Y E
Y T
T 7M E G 8A B Y T E
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