Global Forecasting System (GFS)

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Outlines

- Operational NWP Model Overviews
- Initial condition for GFS model
- Operation run of GFS

Operational NWP Model Overviews

Models are either regional or global

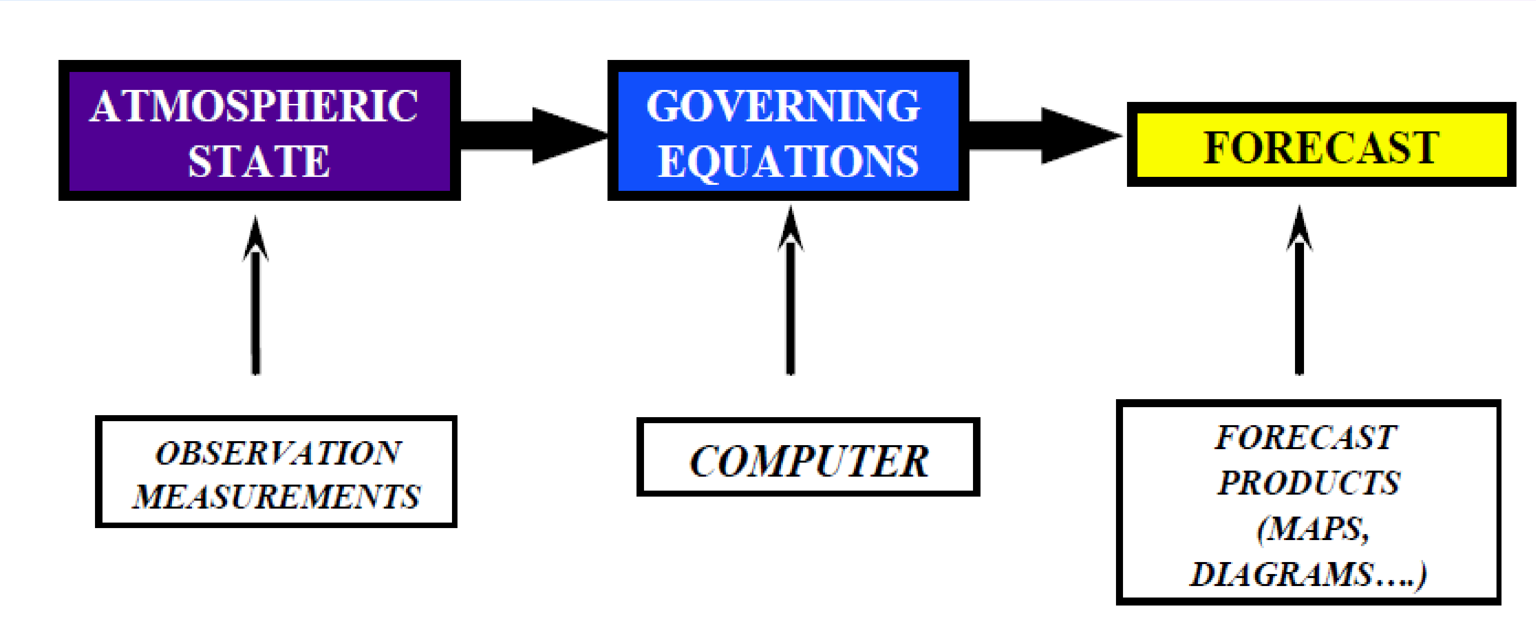
Regional (Meso-scale) Models

	Model	Owner
1.	ETA	(NCEP)
2.	RUC	(NCAR/NCEP)
3.	MM5	(PSU / Air Force, etc.…)
4.	GFDL	(NCEP and GFDL Lab)
5.	COAMPS	(Navy)
6.	WRF	(NCEP)

Global Models

	Model	Owner
1.	GFS	(USA, NCEP)
2.	JMA	(JAPAN)
3.	GEM	(Canada)
4.	ECMWF	(European Union)
5.	UKMET	(United Kingdom)
6.	NCUM	(NCMRWF)
7.	IMDGFS	(INDIA)

NUMERICAL WEATHER PREDICTION

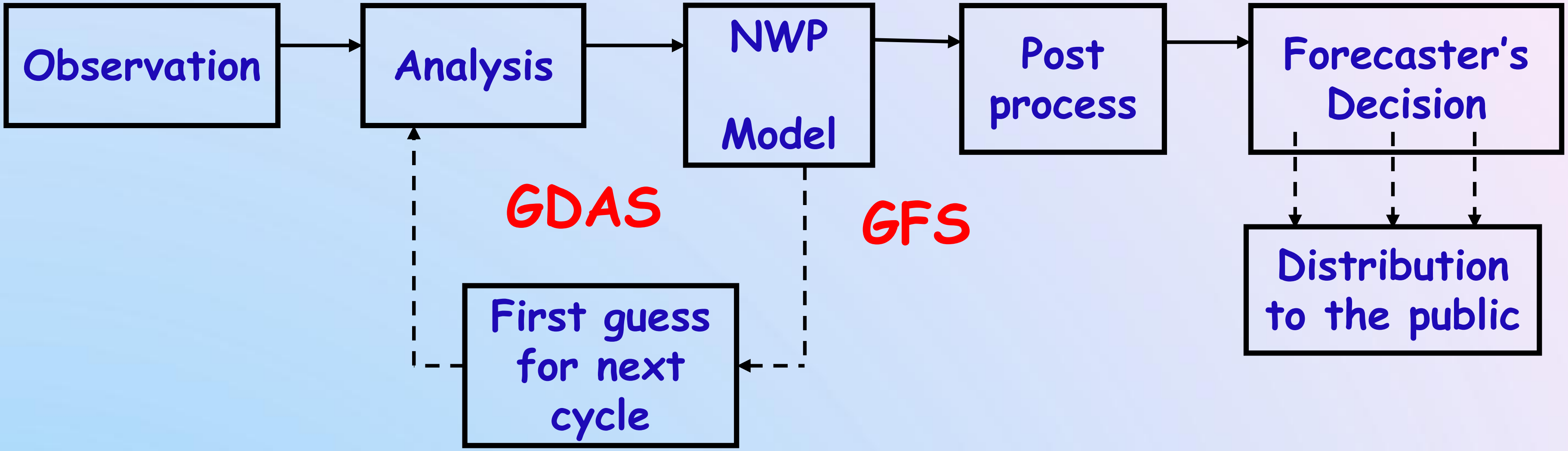


- *Numerical weather prediction* is an initial value problem.
- If we know the initial condition of the atmosphere, we can solve the differential equations to obtain new values of those variables at a later time (i.e., make a prediction).

$$A^{\text{forecast}} = A^{\text{initial}} + F(A)\,\Delta t$$

where F(A) stands for the combination of all kinds of forcing that can occur.

Operational NWP system at IMD



Observation

Analysis

NWP Model

Post process

Forecaster's Decision

GDAS

GFS

Distribution to the public

First guess for next cycle

The operational NWP systems consists of the following steps:

1) Collection Of Weather Information (OBSERVATION)
2) Analysis,
3) Numerical Weather Prediction,
4) Post-processing model output,
5) Forecaster's Decision
6) Actual Use of the Forecast by the Public.

Data assimilation

DATA ASSIMILATION-PRACTICAL VIEWS

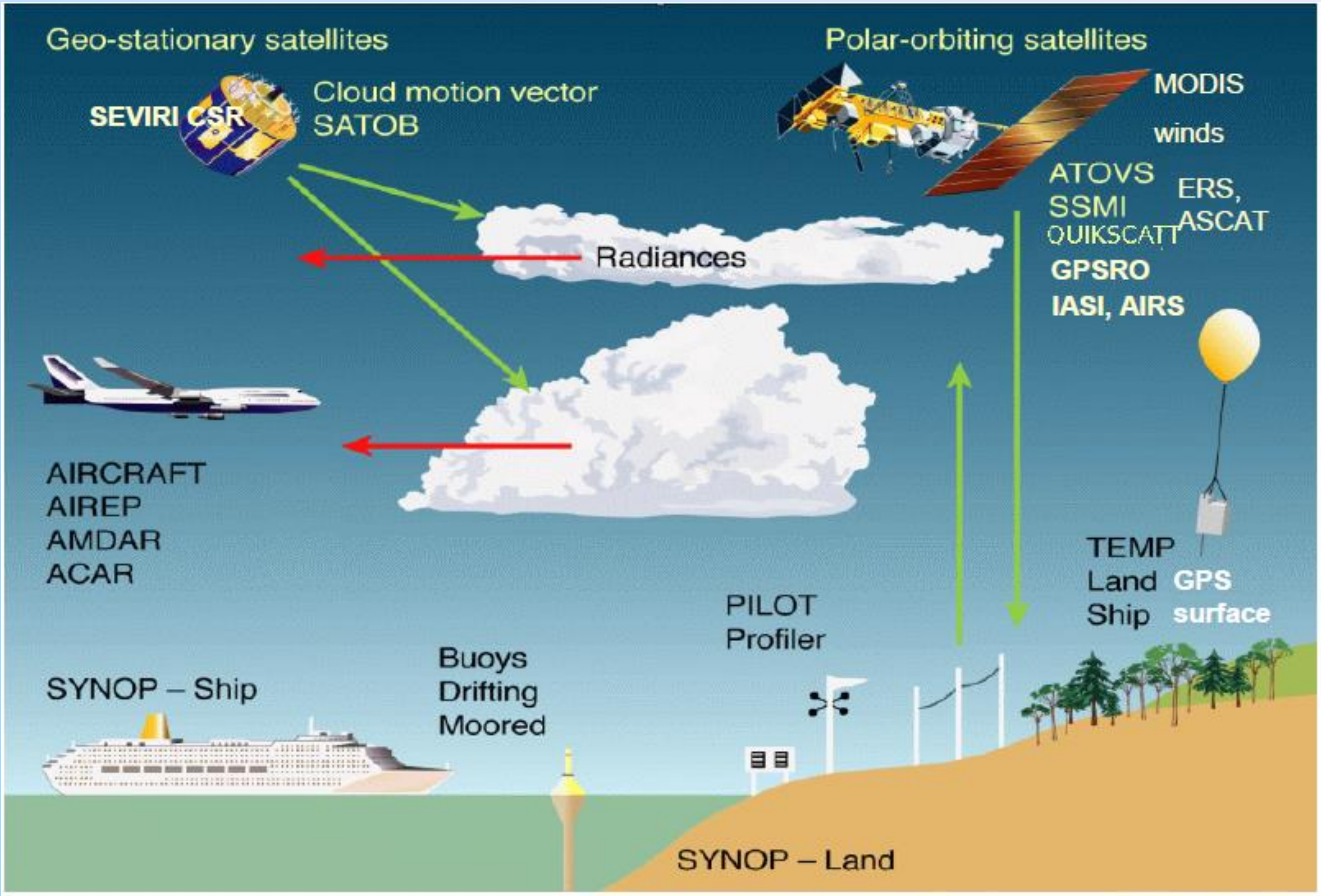
DATA ASSIMILATION

- To make a (NWP) forecast we need to know the current state of the atmosphere and the Earth's surface (land and oceans).
- NWP modelling centre around the world use *data assimilation* to estimate initial conditions for the forecast model from meteorological observations.
- The purpose of data assimilation is to determine a best possible atmospheric state using observations and short range forecasts.
- The quality of nwp forecasts depends on better use of information received in real-time from the global observing system, which consists of numerous satellite instruments, weather stations, ships, buoys, and other components
- Data assimilation is typically a sequential time-stepping procedure, in which a previous model forecast is compared with newly received observations, the model forecast state is then updated to reflect the observations.
- The update step in this process is usually referred to as the *analysis/IC*; the short range model forecast used to produce the analysis is called the *background/first guess field*.

Types of observations Assimilated in DAS

Observation category	Name of Observation.
Surface	Land surface, Mobile, Ship, Buoy (SYNOPs)
Upper air	TEMP (land and marine), PILOT (land and marine), Dropsonde, Wind profiler
Aircraft	AIREP, AMDAR, TAMDAR, ACARS
Atmospheric Motion Vectors from Geo-Stationary Satellites	AMV from Meteosat-7, Meteosat-9, GOES-11, GOES-13, MTSAT-1R, MODIS (TERRA and AQUA),INSAT3D
Scatterometer winds	ASCAT winds from METOP-A satellite,
NESDIS / POES ATOVS Sounding radiance data	1bmhs,1bhirs3, 1bhirs4
Satellite derived Ozone data	NESDIS/POES, METOP-2 and AURA orbital ozone data
Precipitation Rates	NASA/TRMM (Tropical Rainfall Measuring Mission) and SSM/I precip. rates
Bending angles from GPSRO	Atmospheric profiles from radio occultation data using GPS satellites
NASA/AQUA AIRS & METOP/ IASI brightness temperature data	IASI,AIRS,AMSR-E brightness temperatures

Observations used in NWP models



Satellite radiance data assimilated in GDAS

Sensor	Data type	Satellites
AMSU-A	Radiance ----	Aqua,Metop-A, N15, N18,N19
AMSU-B	Radiance ----	N15, N16, N17
MHS	Radiance ----	Metop-A, N18. N19
HIRS/3	Radiance ----	N16, N17
HIRS/4	Radiance ----	Metop-A, N18, N19
AIRS	Radiance ----	Aqua
AMSRE	Radiance ----	Aqua

SOURCE of data for DA

Conventional data

Source: GTS

1.Bathy (sub-surface buoy)
2. Buoy
3. Metar
4. Satob
5. Ship/Mob/AWS
6. Synop
7. Sonde

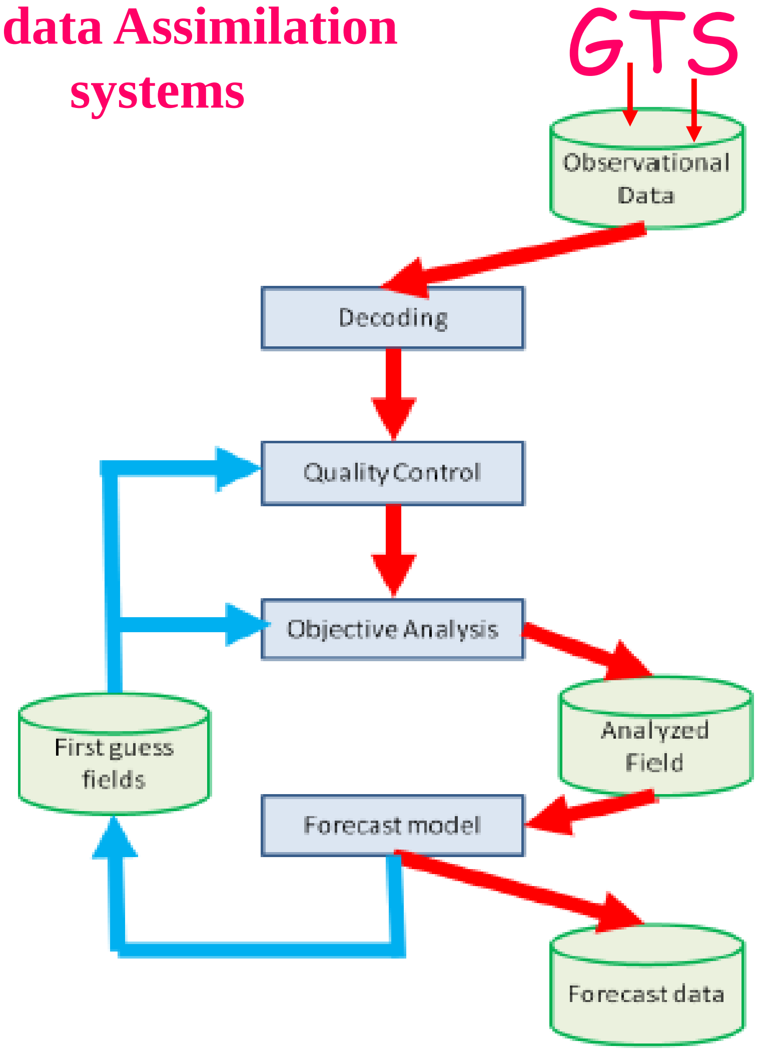
Non-Conventional data

Source: ftp

1. Satellite Radiance/AMV
2. Aircraft DATA
3. RADAR reflectivity data

Data Assimilation: Initial condition for NWP Models

Major components of the data Assimilation systems


GTS
Observational Data
Decoding
Quality Control
Objective Analysis
Analyzed Field
First guess fields
Forecast model
Forecast data

- Observational data received from the GTS are decoded and Quality Controlled.
- First guess from forecast models are used as a reference of the present atmospheric conditions.
- Analysis is carried out on the grid of the forecast models.
- The atmospheric fields analysed from the data assimilation systems are used as initial conditions of forecast models.

GLOBAL DATA ASSIMILATION SYSTEM (GDAS)

Data required for GDAS

INPUT :

1) FIRST GUESS FILED (from 6-hourly GDAS F/C)
2) PREPBUFR FILE (conventional data from GTS)
3) SATELLITE. RADIANCE/AMV/PROFILE DATA: (non-conventional data from NESDIS .i.e AMSU-A,AMSU-B, HRS3,HRS4,MHS,AIRS,AMSRE, IASI,GPSRO,GOES,TRMM)
4) SURFACE ANALYSIS FILES (from NCEP i.e. SST, SNOW, ICE)
5) BIAS CORRECTION FILE (from previous analysis cycle)
6) CLIMATOLOGY FILES (fixed)

spectral and transmittance coefficient for satellite radiance data

Real time Data required for GDAS Analysis : 00UTC

INPUT

CONVENTIONAL + NON-CONVENTIONL DATA

FIRST GUESS FILED

1. gdas1.t00z.bf00
2. gdas1.t00z.bf03
3. **gdas1.t00z.bf06**
4. gdas1.t00z.bf09
5. **gdas1.t00z.sgesprep**
6. gdas1.t00z.sgm3prep
7. gdas1.t00z.sgp3prep

SURFACE ANALYSIS FILES

1. gdas1.t00z.sstgrb
2. gdas1.t00z.snogrb
3. gdas1.t00z.engicegrb

CONVENTIONAL

gdas1.t00z.prepbufr

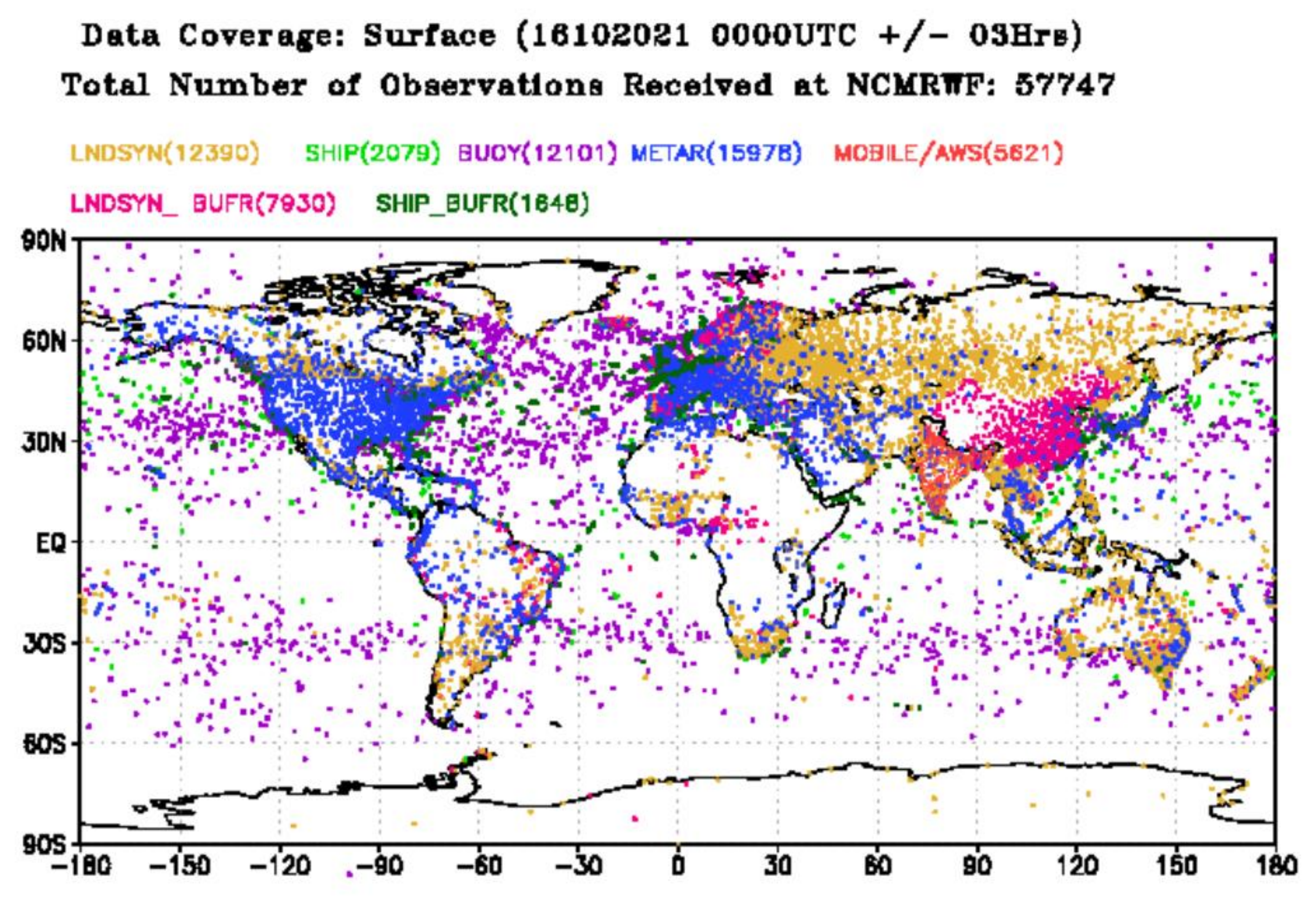
SATELLITE DATA

gdas1.t00z.1bamua.tm00.bufr_d
gdas1.t00z.1bamub.tm00.bufr_d
gdas1.t00z.1bhrs3.tm00.bufr_d
gdas1.t00z.1bhrs4.tm00.bufr_d
gdas1.t00z.1bmhs.tm00.bufr_d
gdas1.t00z.airsev.tm00.bufr_d
gdas1.t00z.amsre.tm00.bufr_d
gdas1.t00z.goesfv.tm00.bufr_d
gdas1.t00z.gpsro.tm00.bufr_d
gdas1.t00z.mtiasi.tm00.bufr_d
gdas1.t00z.osbuv8.tm00.bufr_d
gdas1.t00z.sptrmm.tm00.bufr_d

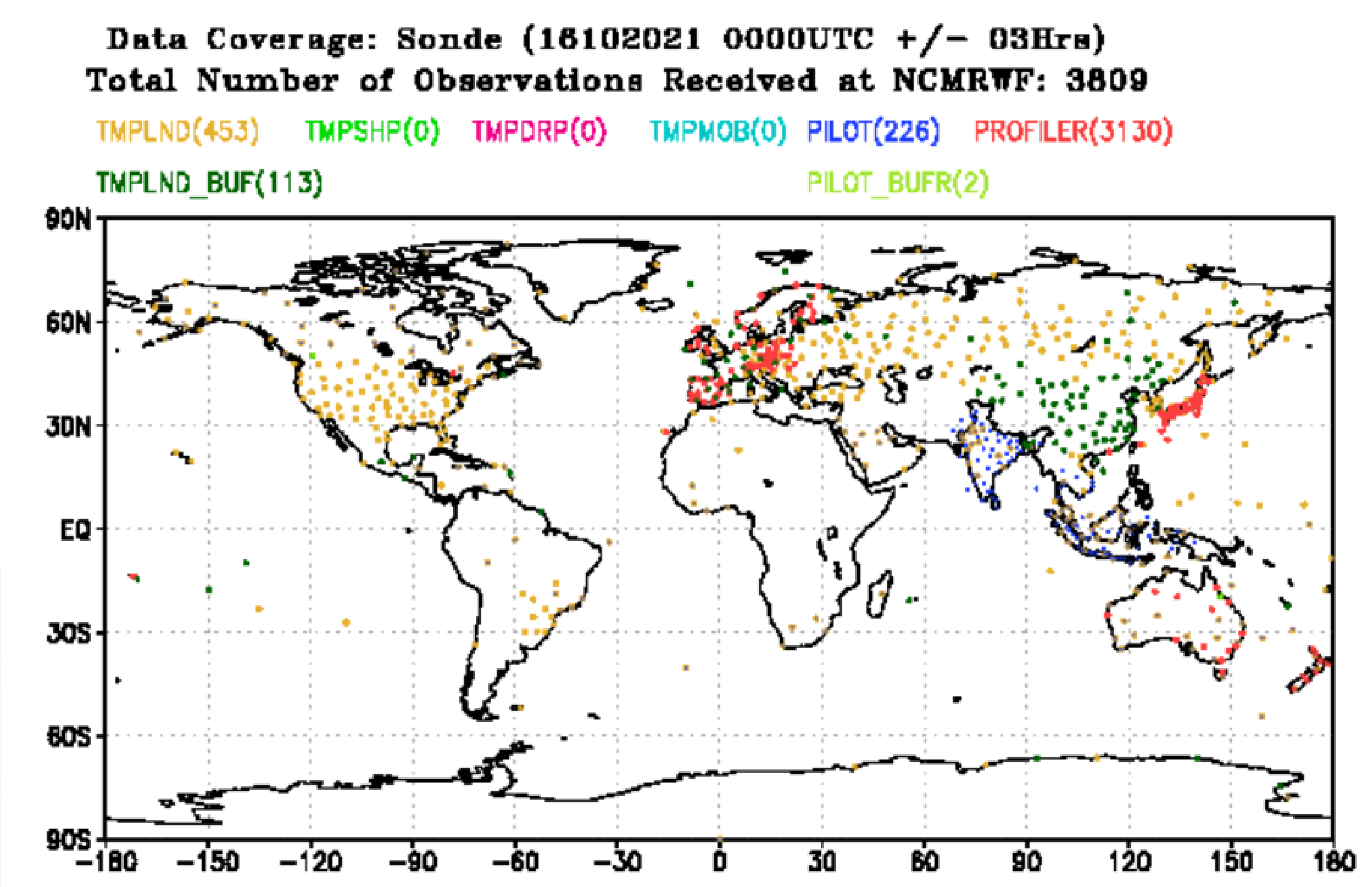
BIAS CORRECTION FILE

gdas1.t00z.satang
gdas1.t00z.abias

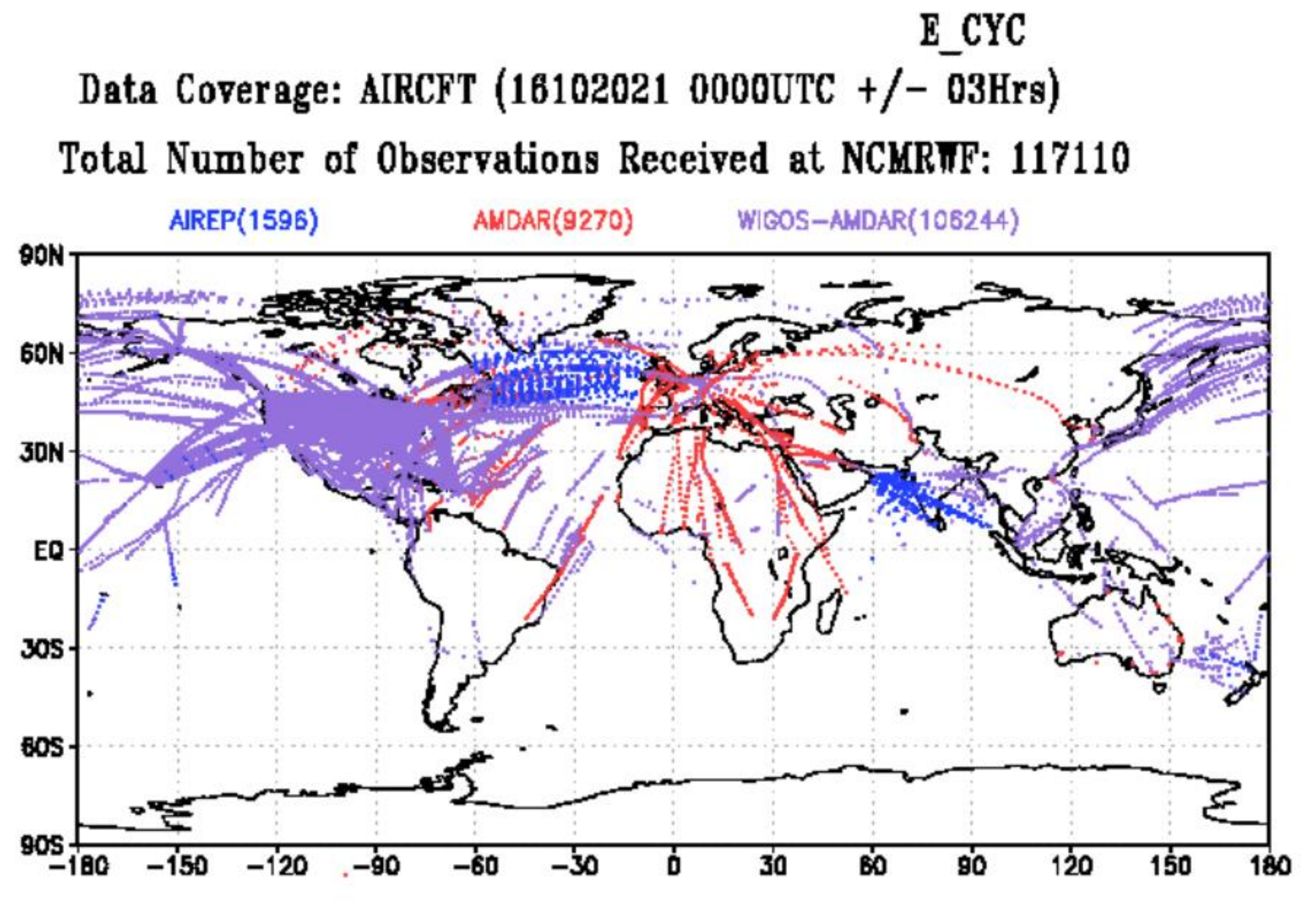
INPUT: CONVENTIONAL DATA (SURFACE)



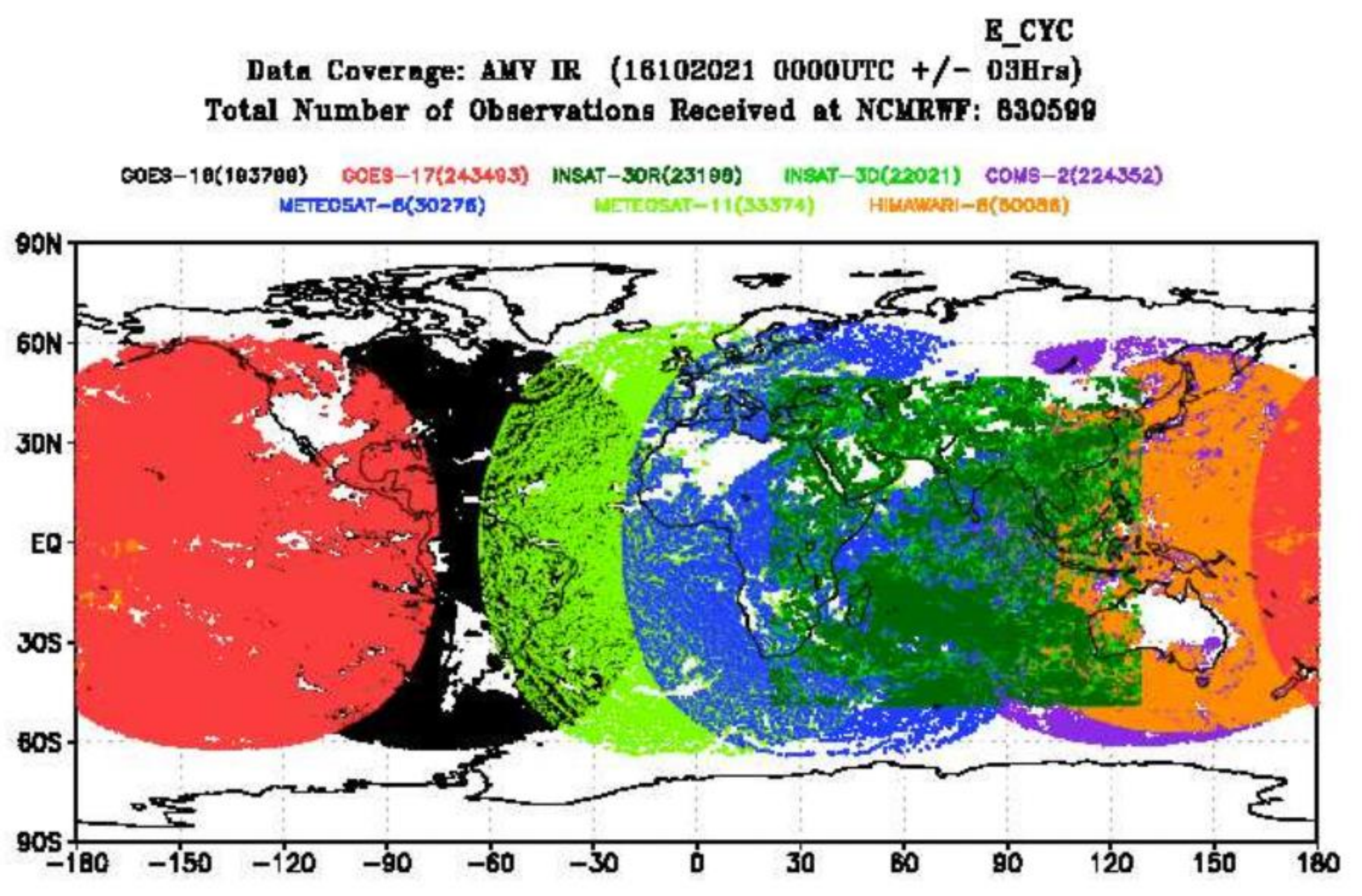
INPUT: CONVENTIONAL DATA (UA)



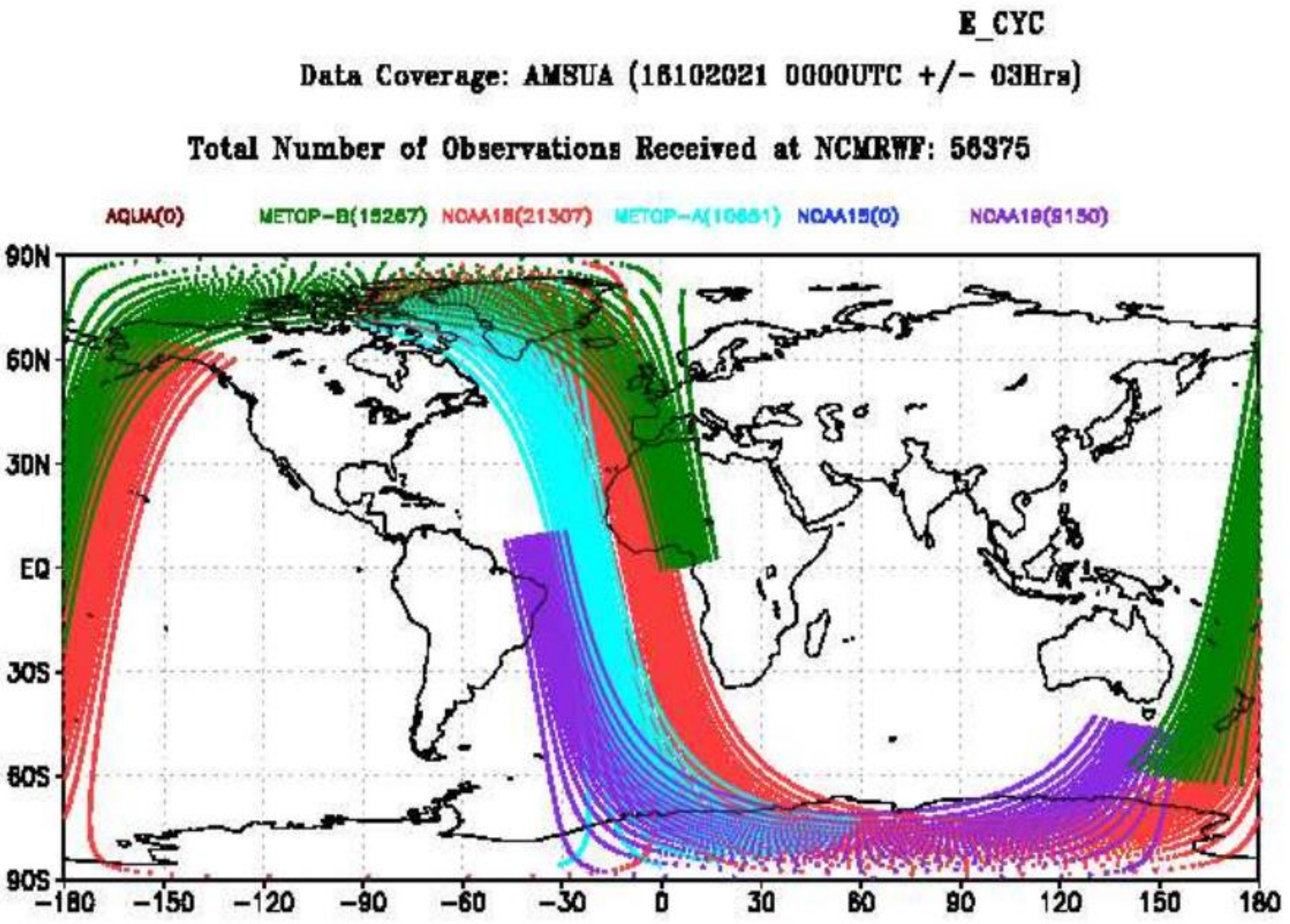
INPUT: NON-CONVENTIONAL DATA (AIRCRAFT)



INPUT: NON-CONVENTIONAL DATA (AMV)



INPUT: NON-CONVENTIONAL DATA (SAT RADIANCE)



DAILY SURFACE ANALYSIS DATA FOR GDAS

Sea surface Temperature (SST)

Daily SST (sea surface temperature) analysis that assimilates observations from past seven days is used (NESDIS at NCEP)

Sea Ice

Sea-ice analysis from the Marine Modeling Branch at NCEP , available daily.

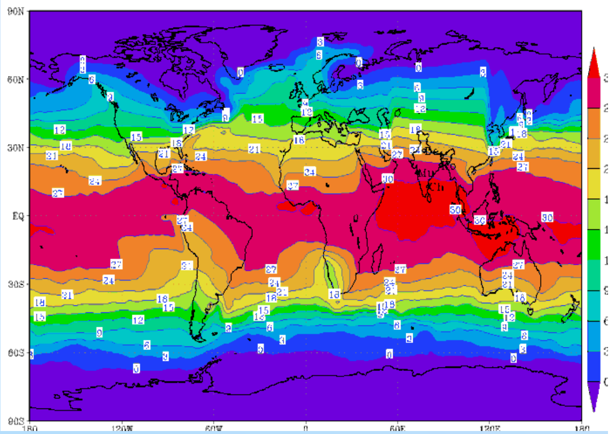
Snow Cover

Snow cover analysis from NESDIS at NCEP daily.

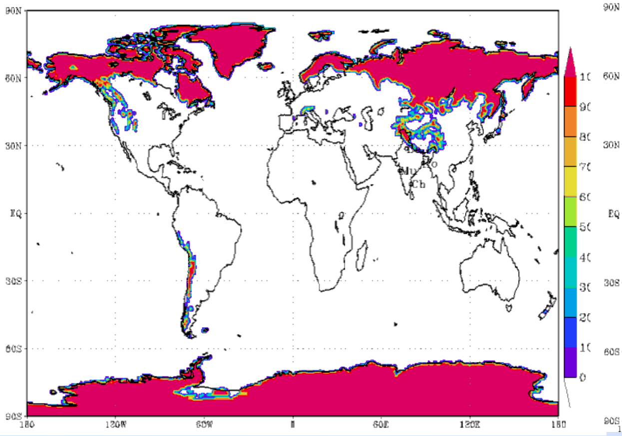
(through ftp)

DAILY SURFACE ANALYSIS OF SST AND SNOW

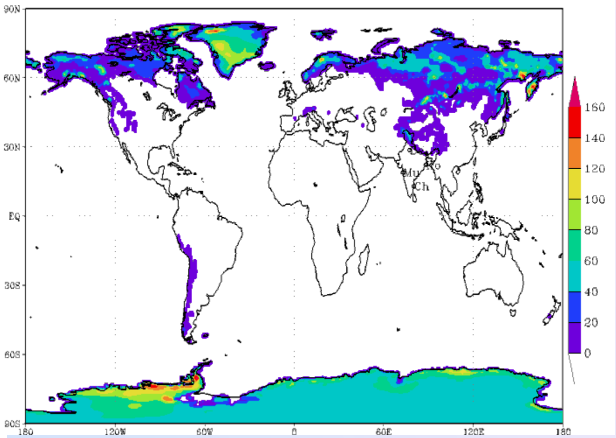
January: SST



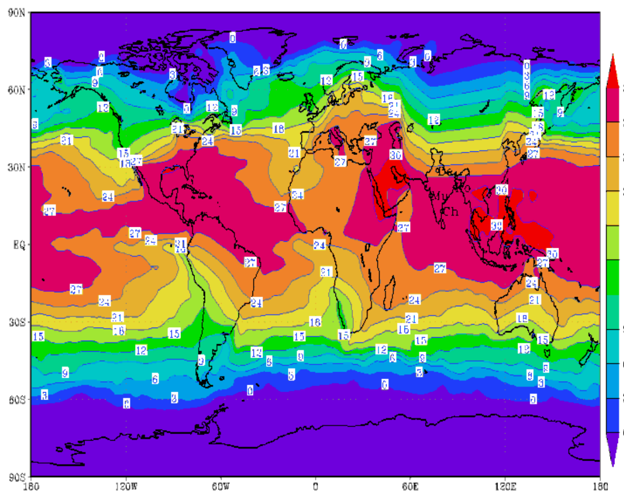
SNOW COVER %



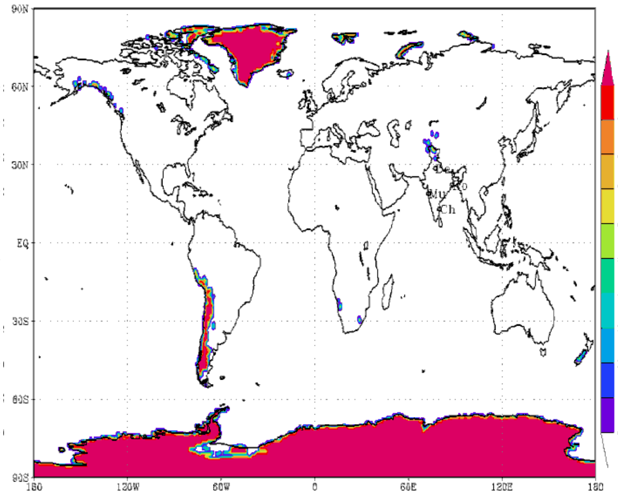
ACCU SNOW KG/m2



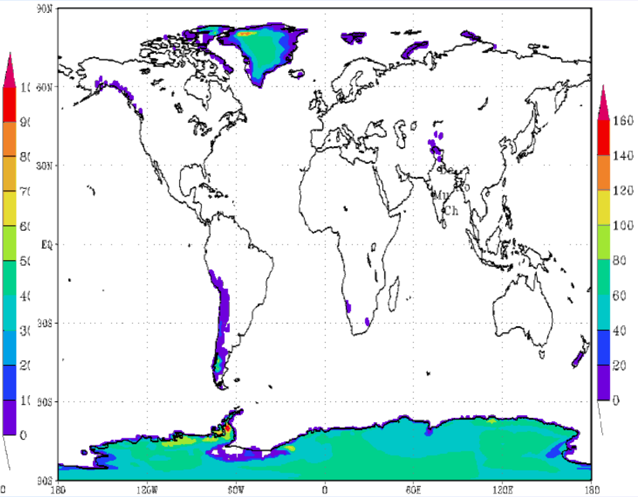
July: SST:



SNOW COVER %



ACCU SNOW KG/m2



GDAS Analysis output:

Initial condition for GFS model Run

1. SFCANL (surface Analysis fields)
2. SIGANL(Upper Air Analysis fields)

Initialisation

- Objectively analysed values of different field variables at the grid points (IC) are most likely to contain error.
- Errors in the data may physically be interpreted as an imbalance between different forces, caused due to interpolation method used in objective analysis.
- This imbalance may results in the generation of spurious waves, which may amplify with time and propagate into the forecast region and thus may spoil the forecast.
- Thus it is essential to eliminate such spurious wave by removing such errors from the objectively analysed data. This is known as initialisation.

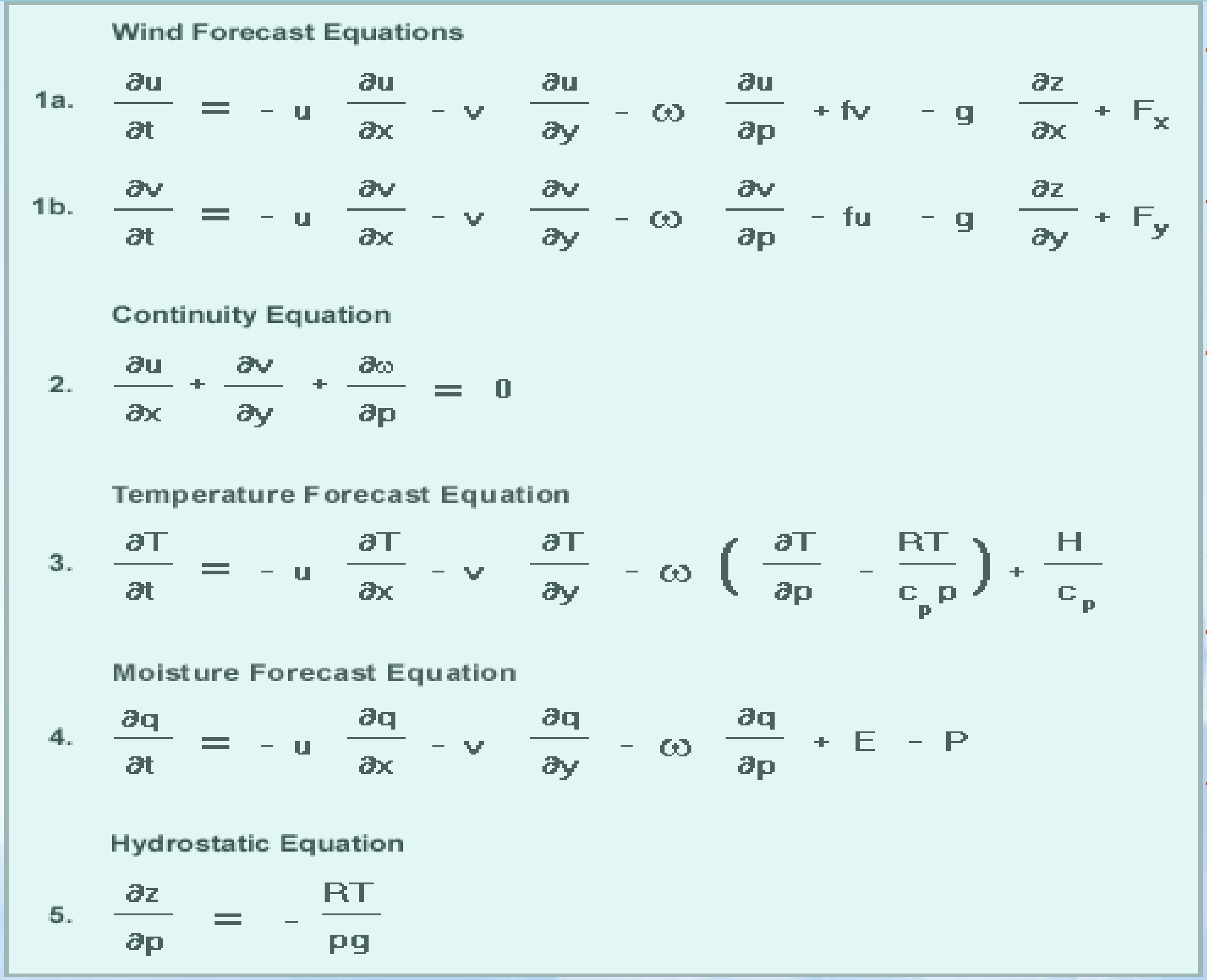
NUMERICAL WEATHER PREDICTION
-PRACTICAL VIEWS

NUMERICAL WEATHER PREDICTION

Governing equations

- Conservation of momentum (u,v) (Newton's 2'd law)
  - *2 Equations for accelerations of wind* ($F = Ma$)
- Conservation of mass & water (q)
  - 1 equation for conservation of air (mass continuity)
  - 1 equation for conservation of water
- Conservation of energy (T)
  - 1 equation for the first law of thermodynamics
- Relationship among p, V, and T
  - 1 equation of state (ideal gas law)

NUMERICAL WEATHER PREDICTION



Wind Forecast Equations

1a. $$\frac{\partial u}{\partial t} = -u\frac{\partial u}{\partial x} - v\frac{\partial u}{\partial y} - \omega\frac{\partial u}{\partial p} + fv - g\frac{\partial z}{\partial x} + F_x$$

1b. $$\frac{\partial v}{\partial t} = -u\frac{\partial v}{\partial x} - v\frac{\partial v}{\partial y} - \omega\frac{\partial v}{\partial p} - fu - g\frac{\partial z}{\partial y} + F_y$$

Continuity Equation

2. $$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial \omega}{\partial p} = 0$$

Temperature Forecast Equation

3. $$\frac{\partial T}{\partial t} = -u\frac{\partial T}{\partial x} - v\frac{\partial T}{\partial y} - \omega\left(\frac{\partial T}{\partial p} - \frac{RT}{c_p p}\right) + \frac{H}{c_p}$$

Moisture Forecast Equation

4. $$\frac{\partial q}{\partial t} = -u\frac{\partial q}{\partial x} - v\frac{\partial q}{\partial y} - \omega\frac{\partial q}{\partial p} + E - P$$

Hydrostatic Equation

5. $$\frac{\partial z}{\partial p} = -\frac{RT}{pg}$$

Eqn 1a: calculates east-west component of the wind (u)

Eqn 1b: calculates north-south component of the wind (v)

Eqn.2: keeps track of the air entering or leaving the box. If more air is coming in than going out, decides how much air rises or sinks (w)

Eqn.3: calculates the effects of adding or taking away heat (T)

Eqn 4: keeps track of water in all forms and how much is changing to or from vapor, liquid, or ice (q)

Eqn 5: calculates the air temperature, pressure, and density (p)

The five equations shown here , are derived from the complete set of conservation of momentum, mass, energy, and moisture laws

Numerical methods

- The above mentioned equations form a set of nonlinear partial differential equations (PDE) which does not have an analytical solution and can only be solved numerically.

- For solving it, different numerical approximations methods are used,

  For Example,

  1) Finite Differences or

  2) Spectral Technique

Data Representation in GRID point and spectral model

❖ Most NWP models solve the forecast equations using data represented as gridded values or in spectral form

NWP Model Types based on data representation:

1. Grid point Model (ex. WRF,MM5,ARPS..)
2. Spectral Model (ex. GFS,ECMF,JMA)

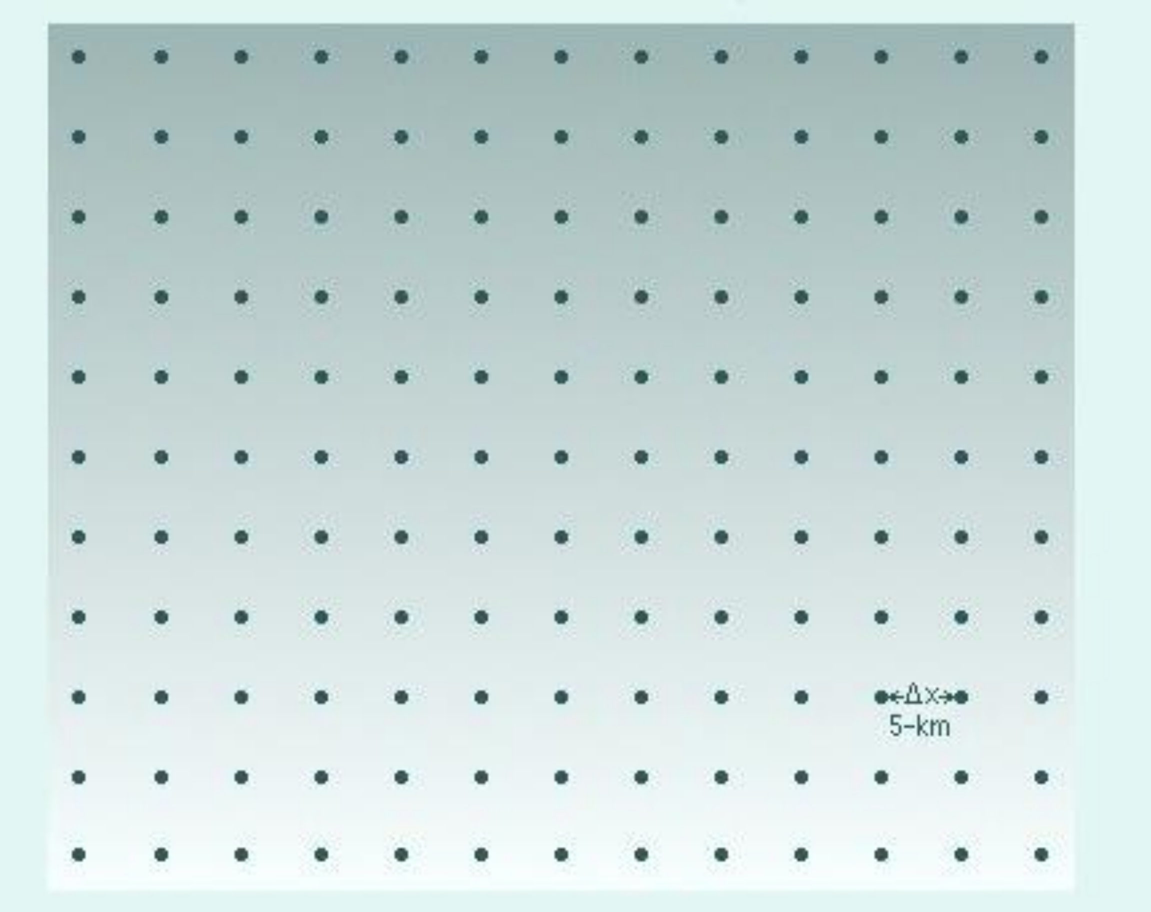
❖Grid point and spectral models are based on the same set of primitive equations.

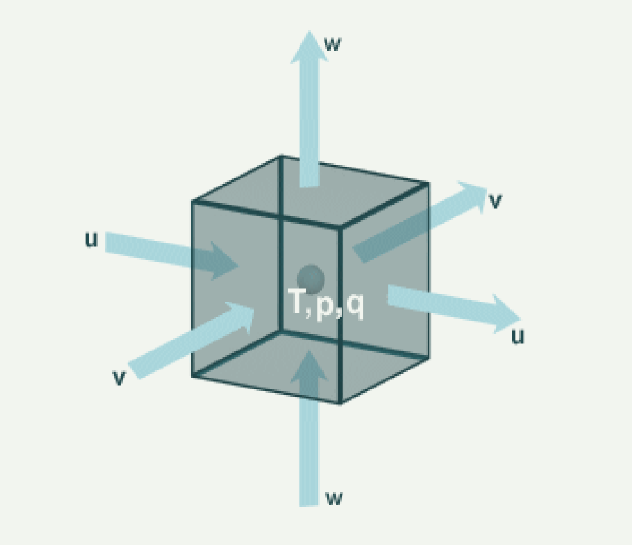
❖However, each type formulates and solves the equations differently.

❖The differences in the basic mathematical formulations contribute to different types of errors in the model .

Grid Point Models

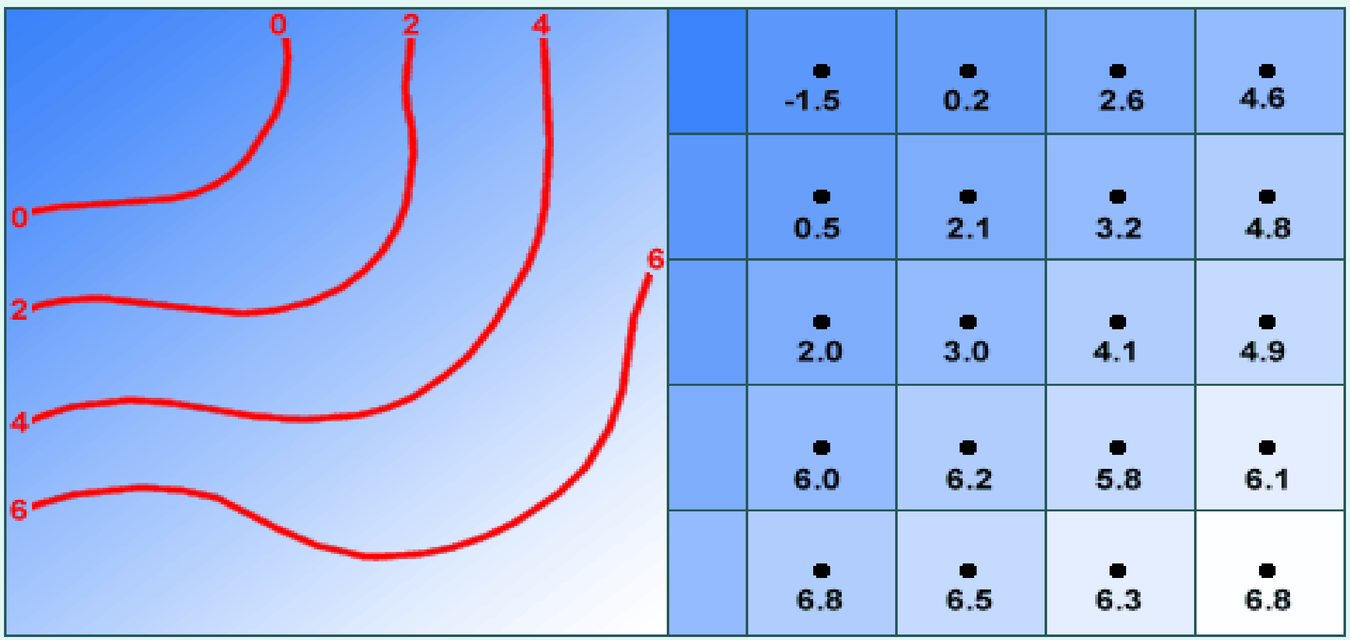
- Horizontal resolution is defined as the distance between grid points.





Example of 3-D Grid Box in a Grid Point Model

Grid Point: Data Representation (T)



	-1.5	0.2	2.6	4.6
	0.5	2.1	3.2	4.8
	2.0	3.0	4.1	4.9
	6.0	6.2	5.8	6.1
	6.8	6.5	6.3	6.8

Actual smooth and continuous temperature field in degrees C (similar to spectral model representation)

Grid point model representation of the same temperature field in degrees C

In the real atmosphere, T, P, wind and moisture vary from location to location in a smooth and continuous way.

The values at the grid points actually represent an area average over a grid box.

Spectral Models

- Horizontal resolution is a function of wave number

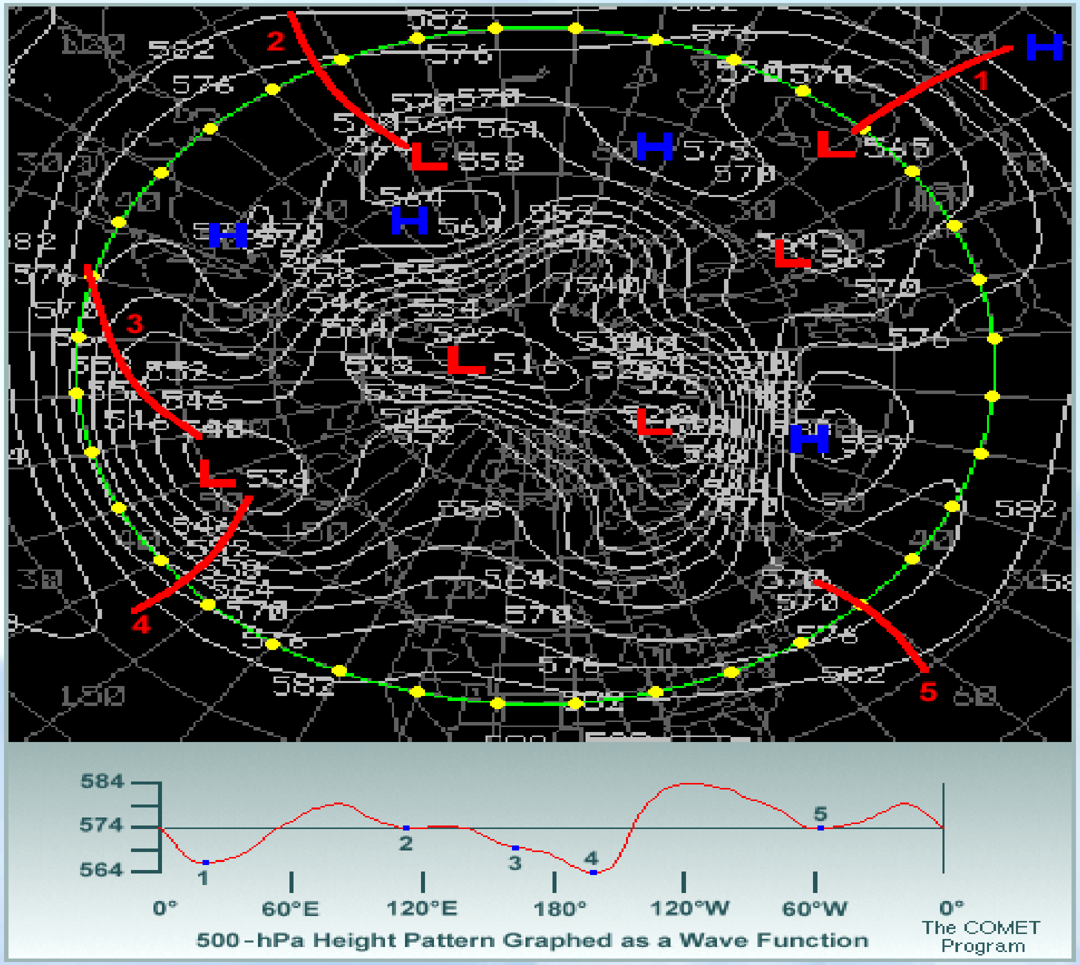
$$\Delta X \approx \frac{360^{\circ}}{3N}$$

- Higher numbers (more waves) indicate finer resolution

- The more waves used to represent the data, the more computing power required to carry out the calculations

- Terrain representation and associated weather are improved when the number of waves is increased

Data Representation in Spectral Model:

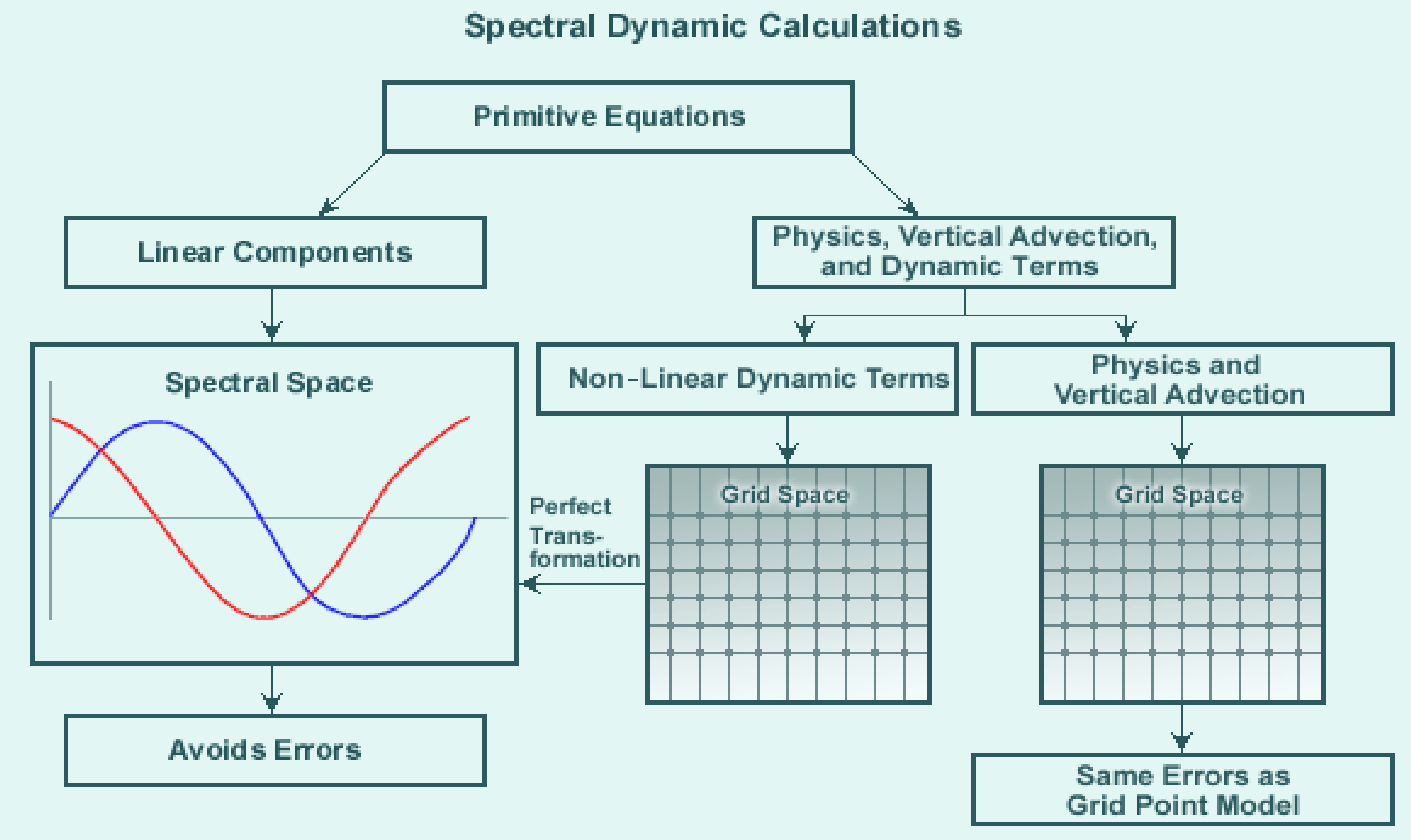


❖Spectral models represent the spatial variations of meteorological variables (such as geopotential heights) as a finite series of waves of differing wavelengths.

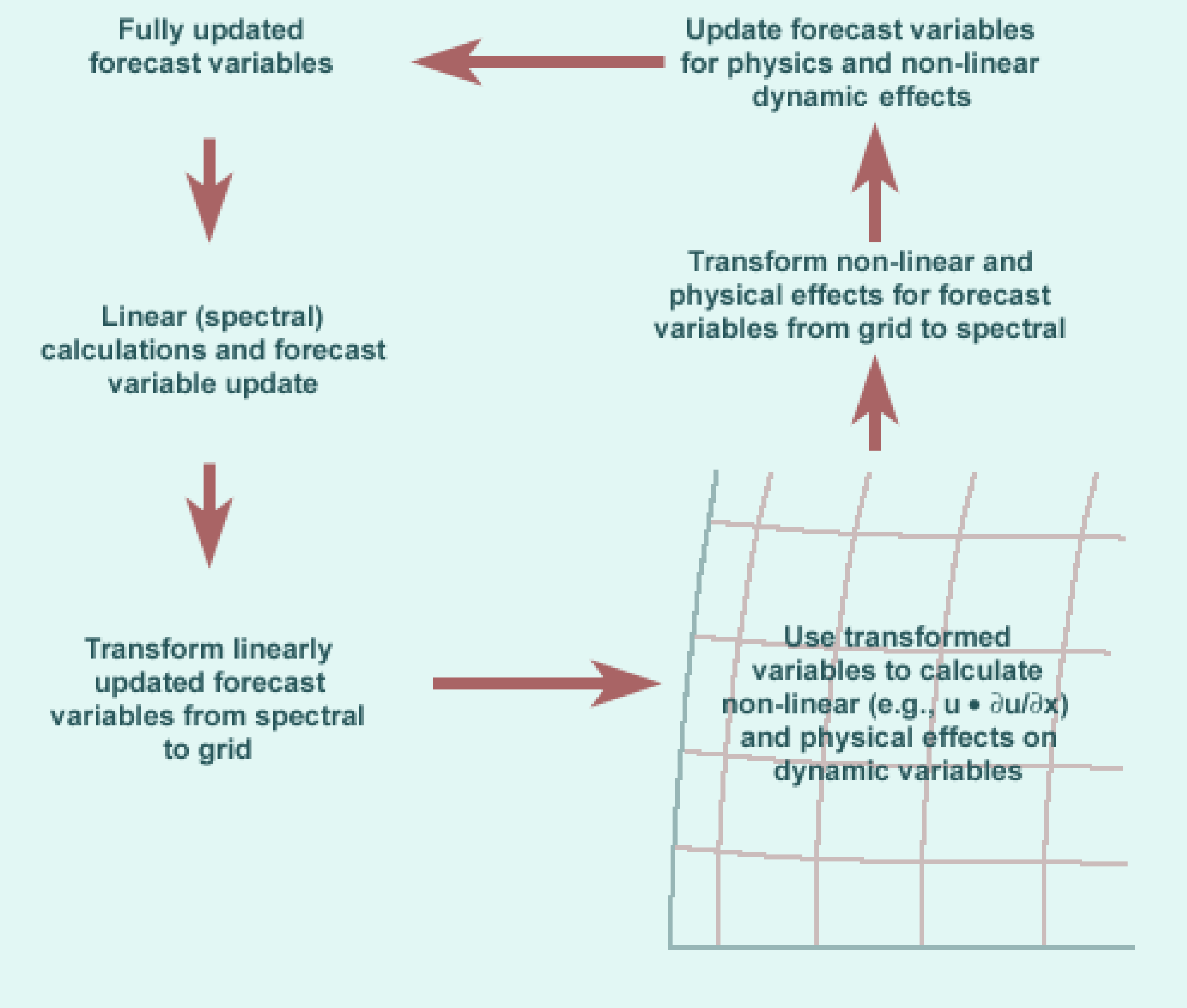
❖It takes a minimum of five to seven points to reasonably represent a wave and, in this case, five or six waves can be defined with the data.

Spectral models use continuous wave functions to represent data.

Spectral Dynamic Calculations



Grid Point Physics Calculations in Spectral Models



Fully updated forecast variables

Linear (spectral) calculations and forecast variable update

Transform linearly updated forecast variables from spectral to grid

Use transformed variables to calculate non-linear (e.g., $u \bullet \partial u/\partial x$) and physical effects on dynamic variables

Transform non-linear and physical effects for forecast variables from grid to spectral

Update forecast variables for physics and non-linear dynamic effects

Grid Calculations in Spectral Models

GFS Model

- Numerical Properties
- Physical Properties

Numerical Properties of GFS model

1 .Horizontal Resolution of GFS

- In spectral models, the horizontal resolution is designated by a "T" number

For example, T80,T254 and T382,T574,T1534

` T ` indicates number of waves used by a spectral model.

The approximate grid spacing / resolution for a spectral model can then be represented as

$$\Delta X \simeq \frac{360^{\circ}}{3N}$$

For example:

For a T80 model, the maximum grid spacing for equivalent accuracy of about

$$\Delta X \simeq \frac{360^\circ}{3N}$$

$$\Delta X \simeq \frac{360^\circ}{3 \times 80} \simeq 1.5^\circ \sim 160 \text{ km}$$

- For GFS T382

= 360/3x382

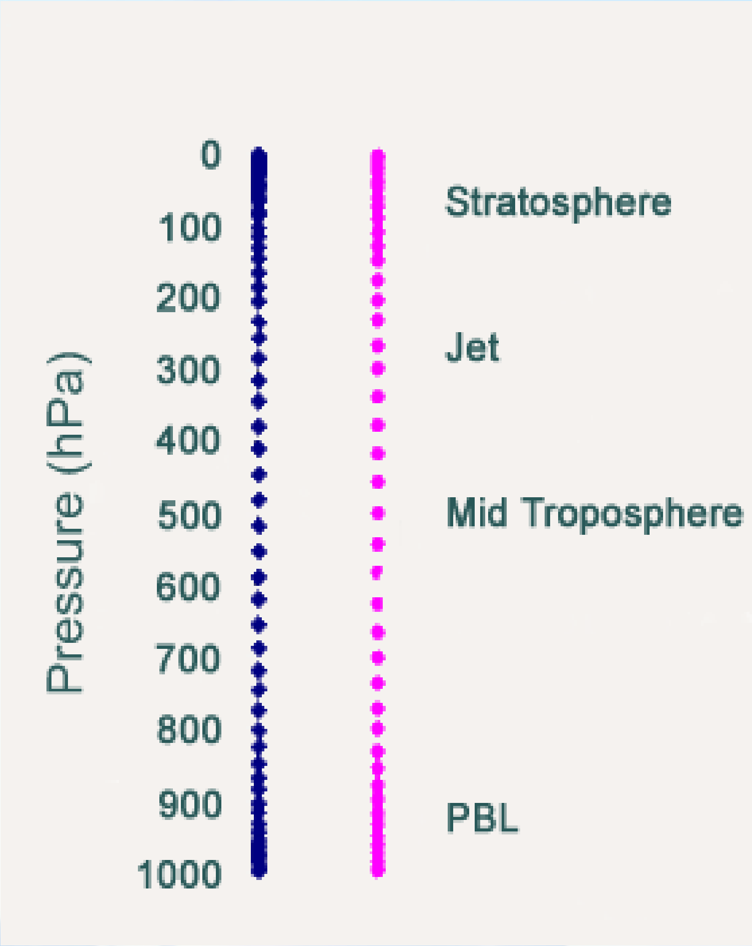
= 0.31 deg ~ 35 km

- **For GFS T574**

= 360/3x574

= 0.21 deg ~ 25 km

2. Vertical Resolution of GFS



GFS :- 64 sigma-p layers

- ✓For a surface pressure of 1000 hPa,
- ✓There are 16 levels in the lower Troposphere (below 800 hPa)
- ✓13 layers in the middle troposphere (800-350 hPa)
- ✓8 levels are at jet-stream level (350-150 hPa)
- ✓ 27 levels above 150 hPa in the stratosphere ,

- ☐sigma up to 70 hPa.
- ☐concentrated in the PBL and near the tropopause

3. Model Domain and Boundary Conditions

- Model domain refers to a model's area of coverage.
- Global models, which by nature cover the entire earth, have only vertical boundaries and no lateral boundaries.
- Vertical boundary values can be obtained from a variety of sources;

a) Data assimilation systems (GDAS),i.e. Forecast values from a previous cycle

b) climatology values

(for example in the surface for lower BC : soil moisture, sea surface temperature, and vegetation type)

4. Initialization

- Initialization is not necessary for GFS model, because the GSI (GRIDPOINT STATISTICAL INTERPOLATION) analysis scheme eliminates the unbalanced initial state.

5. Time Integration Scheme(s)

- The main time integration is leapfrog for nonlinear advection terms.
- One time step loop is divided into : Computation of the tendencies of divergence, log of surface pressure and virtual temperature and of the predicted values of the vorticity and moisture (grid)
- Semi-implicit for gravity waves & zonal advection of vorticity and moisture

Time step $\Delta t = 3600/(T/20)$ (sec)

Where T =Triangular Truncation

The time step for T382L64 is 3 minutes
and for T574L64 is 2 minutes

Dynamical/Physical Properties of GFS model

Dynamical/Physical Properties of GFS model :

Atmospheric Dynamics

Primitive equations with

1. Vorticity (u,v)
2. Divergence (u,v)
3. Virtual Temperature (t)
4. Specific Humidity (q)
5. Surface Pressure (p)
6. Cloud Condensate

as dependent variables.

Model Physics

Convection:

✓Penetrative convection is simulated following Pan and Wu (1994), which is based on *Arakawa and Schubert(1974)* as simplified by Grell (1993) and with a saturated downdraft.

Planetary Boundary Layer

✓A new scheme based on the *Troen and Mahrt (1986)* paper was implemented on 25 October, 1995

Model Physics

Planetary Boundary Layer and vertical diffusion (PBL)

- Nonlocal PBL scheme originally proposed by Troen and Mahrt (1986) and implemented by Hong and Pan (1996)
- First order vertical diffusion scheme
- PBL height estimated iteratively from ground up using bulk Richardson number
- Diffusivity calculated as a cubic function of height and determined by matching with surface fluxes
- Counter-gradient flux parameterization based on the surface fluxes and convective velocity scale.
- Recent update – stratocumulus top driven vertical diffusion scheme to enhance diffusion in cloudy regions when CTEI exists
- For the nighttime stable PBL, local diffusivity scheme used.
- Exponentially decreasing diffusivity for heat and moisture
- Constant background diffusivity of 3 m2/s for momentum

Model Physics

Shallow convection parameterization

- Until July 2010, the shallow convection parameterization was based on Tiedtke (1983) formulation in the form of enhanced vertical diffusion within the cloudy layers.

- In july 2010, a new massflux based shallow convection scheme based on Han and pan (2010) was implemented operationally.

- Model code still contains the old shallow convection scheme as an option (if you set old_monin=.true.) with an option to limit the cloud top to below low level inverstion when CTEI does not exist.

Model Physics

Mass flux based shallow convection scheme

- Detrain cloud water from every updraft layer
- Convection starting level is defined as the level of maximum moist static energy within PBL
- Cloud top is limited to 700 hPa.
- Entrainment rate is given to be inversely proportional to height and detrainment rate is set to be a constant as entrainment rate at the cloud base.
- Mass flux at cloud base is given to be a function of convective boundary layer velocity scale.

Deep convection parameterization

- Simplified Arakawa Schubert (SAS) scheme is used operationally in GFS (Pan and Wu, 1994, based on Arakawa-Schubert (1974) as simplified by Grell (1993))

- Includes saturated downdraft and evaporation of precipitation
- One cloud-type per every time step

- Until July 2010, random clouds were invoked.

- Significant changes to SAS were made during July 2010 implementation which helped reduce excessive grid-scale precipitation occurrences.

Model Physics

Updated deep convection scheme

❖ No random cloud top – single deep cloud assumed

❖Cloud water is detrained from every cloud layer

❖ Specified finite entrainment and detrainment rates for heat, moisture, and momentum

❖Similar to shallow convection scheme, in the sub-cloud layers, entrainment rate is inversely proportional to height and the detrainment rate is set to be a constant equal to the cloud base entrainment rate..

❖Above cloud base, an organized entrainment is added, which is a function of environmental relative humidity.

Horizontal Diffusion

Scale-selective, second-order horizontal diffusion after *Leith (1971)* is applied to vorticity, divergence, virtual temperature, and specific humidity and cloud condensate

Gravity-wave Drag

Gravity-wave drag is simulated as described by *Alpert et al. (1988)* is used

Radiation

The long wave (LW) radiation in GFS is handled by Rapid Radiative Transfer Model *(RRTM) developed at AER (Mlawer et al. 1997)*

The short wave (SW) radiative transfer parameterization is based on Chou's work (1992).

Surface Characteristics

- Over oceans the surface Albedo depends on zenith angle.
- Soil type and Vegetation type data base from GCIP is used.
- Vegetation fraction monthly climatology based on NESDIS NDVI 5-year climatology is used.
- Roughness lengths over oceans are determined from the surface wind stress after the method of Charnock (1955).
- Over sea ice the roughness is a uniform 0.01 cm.
- Roughness lengths over land are prescribed from data of Dorman and Sellers (1989) which include 12 vegetation types.

Surface Fluxes

❖Surface solar absorption is determined from the surface albedos, and longwave emission from the Planck equation with emissivity of 1.0 (see Surface Characteristics).

❖The lowest model layer is assumed to be the surface layer (sigma=0.996) and the Monin-Obukhov similarity profile relationship is applied to obtain the surface stress and sensible and latent heat fluxes.

❖Land surface evaporation is comprised of three components: direct evaporation from the soil and from the canopy, and transpiration from the vegetation. The formulation follows Pan and Mahrt (1987).

Land Surface Processes

- Soil temperature and soil volumetric water content are computed in two layers at depths 0.1 and 1.0 meters by a fully implicit time integration scheme (Pan and Mahrt, 1987).

- A climatological deep-soil temperature is specified at the third layer of 4 meters for soil and a constant value of 272 K is specified as the ice-water interface temperature for sea ice.

- The vegetation canopy is allowed to intercept precipitation and re-evaporation. Runoff from the surface and drainage from the bottom layer are also calculated.

Ozone:

- Ozone is a prognostic variable that is updated in the GSI analysis and transported in the model.

- The sources and sinks of ozone are computed using zonally averaged seasonally varying production and destruction rates provided by NASA/GSFC (climatology).

OPERATIONAL RUN OF GFS T1534L64

GFS Model at IMD

- Global Forecast System (GFS, adopted from NCEP USA) at T382 resolution was implemented at IMD HQ on IBM based High Performance Computing Systems (HPCS) in may 2010.

- From may 2012 , GFS T382 has been replaced by the upgraded version of GFS T574 (version *GSM 9.1.0*)

- Currently, the new version GFS T1534 is made operational, it was implemented in the operational mode during the year 2018

- The Global Forecasting System (GFS) is a primitive equation spectral global model with state of art dynamics and physics .

GFS T1534 Model

- Global Forecast System is the full global scale numerical weather prediction system – It includes both the global analysis (GDAS) and forecast components (GFS)
- The Global Forecast System (GFS-T1534) model run operationally at India Meteorological Department (IMD) four times in a day (00,06,12 & 18 UTC) to give forecast up to 10 days.
- The forecast model has a resolution of approximately 12 km in horizontal and has 64 levels in the vertical.
- The dynamical core of the GFS is based on semi-Lagrangian (SL) spectral global model with state of art dynamics and physics .

Evolution of NCEP GFS model since 1980

Year	Model	Horizontal Resolution/Vertical Layers	Forecast length	Note
1980	Spectral; Eulerian	R30L12	48h	Rhomboidal Truncation
1987	Spectral; Eulerian	T80L18	240h @ 00Z	MRF, triangular truncation
1991	Spectral; Eulerian	T126L18	240h @ 00Z	MRF
2000	Spectral; Eulerian	T170L42	384h	MRF/AVN, Prognostic ozone;
2002	Spectral; Eulerian	T170L42	384h 4x/day	RRTM LW
2002	**Spectral; Eulerian**	**T254/64**	**384h 4x/day**	**Now called GFS**
2007	Spectral; Eulerian	T382L64	384h 4x/day	Hybrid-sigma vertical coordinate, GSI analysis
2010	Spectral; Eulerian	T574L64	384h 4x/day	RRTM SW
2015	Spectral; Semi-Lagrangian	T1534L64	384h 4x/day	
2016	Spectral; Semi-Lagrangian	T1534L64 T574L64	384h 4x/day	4D Hybrid Ensemble-Var
2017	Spectral; Semi-Lagrangian	T1534L64	384h 4x/day	NEMS ; NSST
2019	FV3	13 km / 64	384h 4x/day	Increase resolution of ensemble DA from 35km to 25km;
2021	FV3	13 km / 127	384h 4x/day	One-way coupling to NCEP wave model

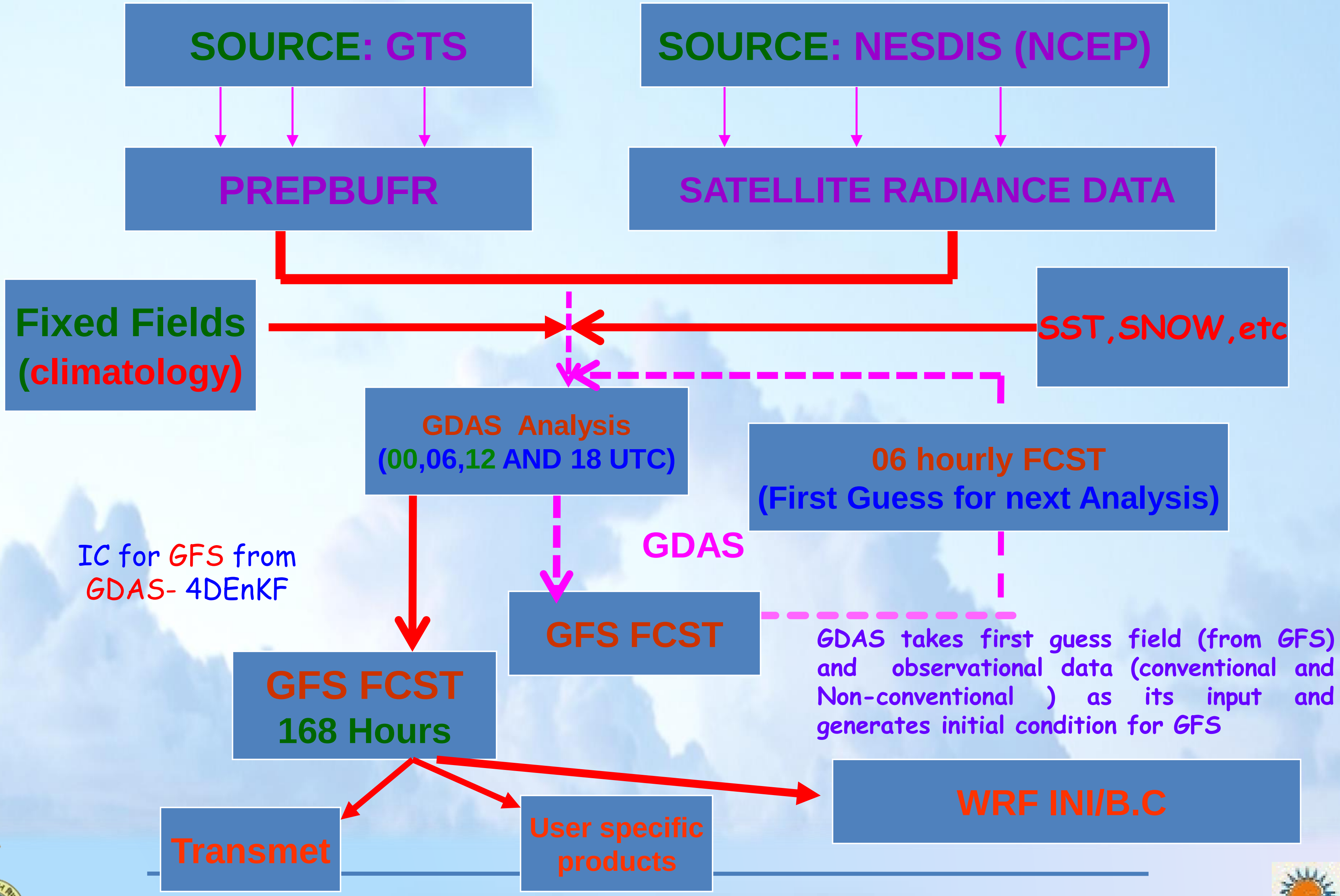
HIGH PERFORMANCE COMPUTING SYSTEM (HPCS)

- ❑ Two High Performance Computing (HPC) Systems Pratyush (4 peta flops) and Mihir (2.8 peta flops) installed at IITM, Pune and NCMRWF, Noida respectively have a total computing capacity of 6.8 peta flops.

- ❑ After the current augmentation, the total HPC capacity of the ministry of Earth Sciences of India has gone up to <u>8.0 Peta Flops.</u>

- ❑ The Ministry HPC system with a combined capacity of 8.0 Peta Flops is now placed at the 4th position after Japan, UK and USA for dedicated HPC resources for weather/climate community.

OVERVIEW OF GFS RUN at IMD



SOURCE: GTS

SOURCE: NESDIS (NCEP)

PREPBUFR

SATELLITE RADIANCE DATA

Fixed Fields (climatology)

SST,SNOW,etc

GDAS Analysis (00,06,12 AND 18 UTC)

06 hourly FCST (First Guess for next Analysis)

GDAS

IC for GFS from GDAS- 4DEnKF

GFS FCST

GFS FCST 168 Hours

GDAS takes first guess field (from GFS) and observational data (conventional and Non-conventional) as its input and generates initial condition for GFS

Transmet

User specific products

WRF INI/B.C

Data required for running the GFS Model

INPUT

Initial Condition :(from GDAS/GSI analysis)

1) SIGANAL. --- Sigma analysis file
2) SFCANAL --- Surface analysis file

Fixed Fields: (climatology)

1) Vertically dependent Fixed fields
2) Horizontally dependent Fixed fields
3) Completely independent Fixed fields

Vertically dependent Fixed Fields:

1. CO2 radiation at all 64 levels

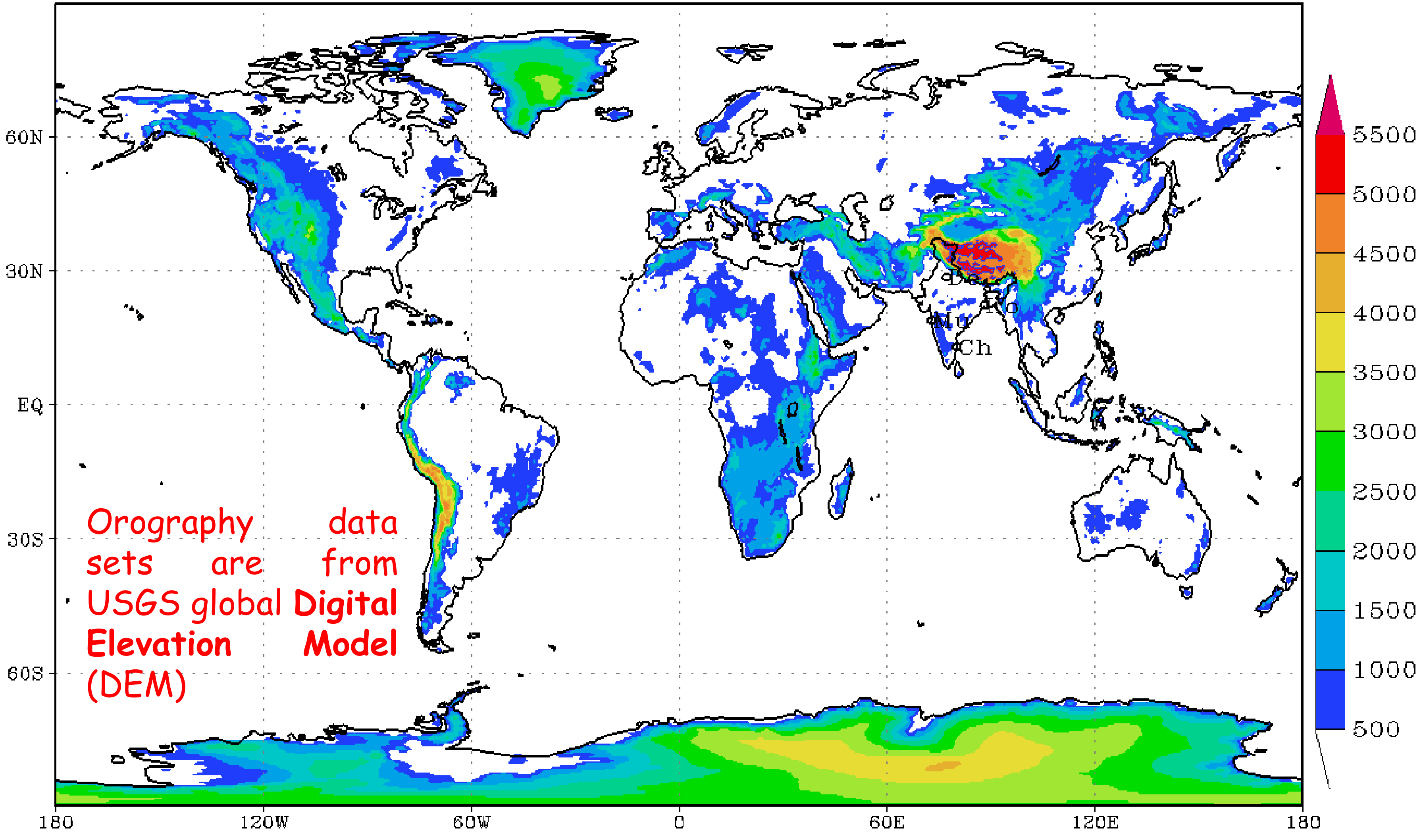
Horizontally dependent Fixed fields:

1. OROGRAPHY data
2. Mountain variance data

Completely independent Fixed fields:

1. Input cloud tuning file
2. Equivalent potential temperature
3. Ozone production climatology
4. Ozone destruction climatology
5. Ozone climatology
6. Glacier climatology
7. Maximum sea ice climatology
8. SST climatology
9. Snow climatology
10. Roughness climatology
11. Sea ice climatology
12. Deep soil temperature climatology
13. Vegetation fraction climatology
14. Albedo climatology
15. Vegetation type climatology
16. Soil type climatology
17. Soil moisture climatology
18. High resolution land mask
19. SST analysis
20. Sea ice analysis
21. Snow analysis
22. Aerosol climatology

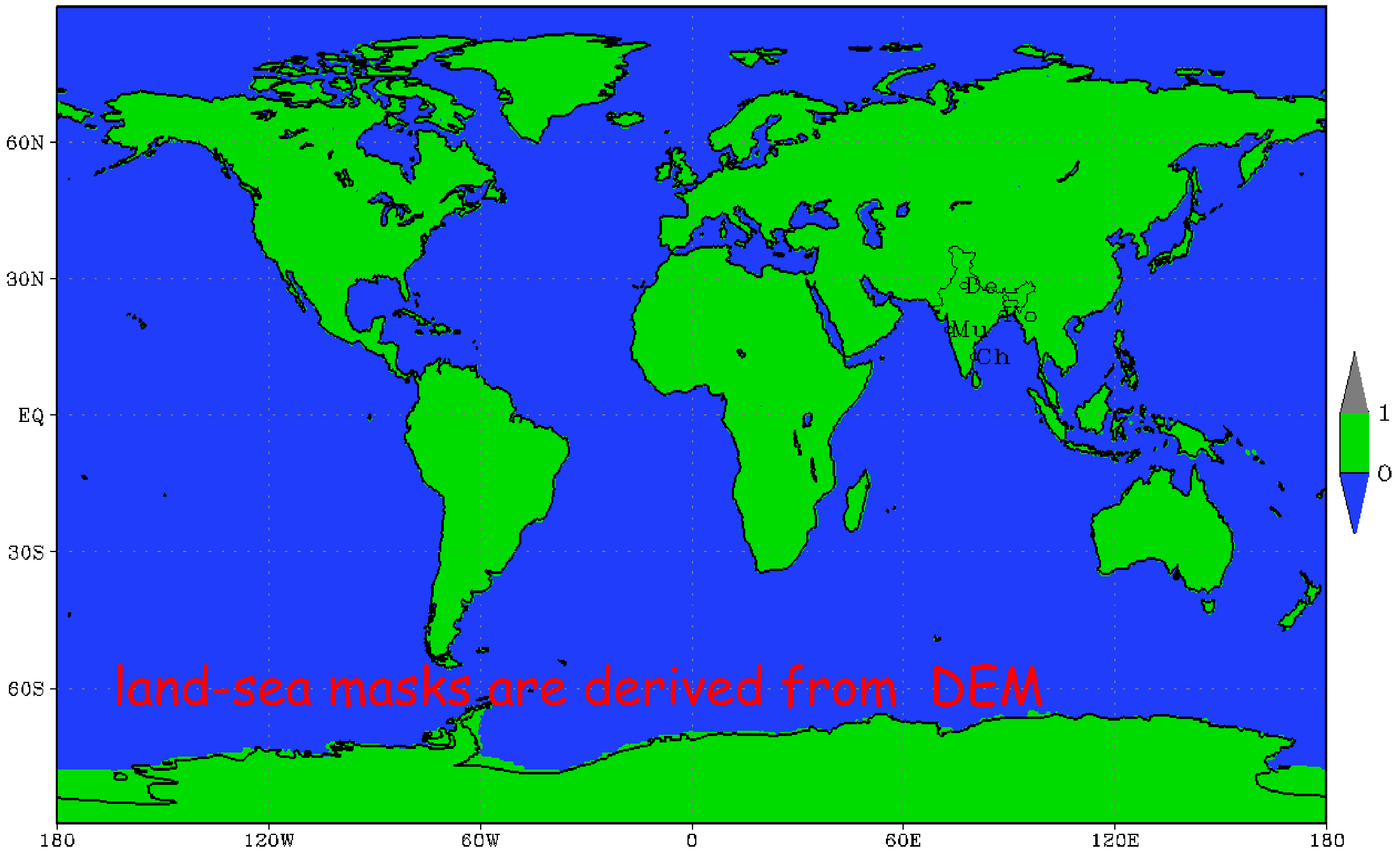
GLOBAL OROGRAPHY (meter) at T382L64 Resolution



Orography data sets are from USGS global **Digital Elevation Model** (DEM)

(Background does not depict political boundary)

surface Land cover (land=1;sea=0) (fraction) at T382L64 Res



land-sea masks are derived from DEM

(Background does not depict political boundary)

GFS Direct output in hybrid (sigma -p) levels

```
1)   -rwxr-xr-x   1 durai   staff   227083304 Mar 29 08:30 gdas1.t00z.sf00
2)   -rw-r--r--   1 durai   staff   116787028 Mar 29 08:30 gdas1.t00z.bf00
3)   -rwxr-xr-x   1 durai   staff    41591102 Mar 29 08:30 gdas1.t00z.sfluxgrbf00
4)   -rw-r--r--   1 durai   staff          56 Mar 29 08:30 gdas1.t00z.logf00
5)   -rwxr-xr-x   1 durai   staff   227083304 Mar 29 08:30 gdas1.t00z.sf03
6)   -rw-r--r--   1 durai   staff   116787028 Mar 29 08:30 gdas1.t00z.bf03
7)   -rwxr-xr-x   1 durai   staff    42943056 Mar 29 08:30 gdas1.t00z.sfluxgrbf03
8)   -rw-r--r--   1 durai   staff          56 Mar 29 08:30 gdas1.t00z.logf03
9)   -rwxr-xr-x   1 durai   staff   227083304 Mar 29 08:31 gdas1.t00z.sf06
10)  -rw-r--r--   1 durai   staff   116787028 Mar 29 08:31 gdas1.t00z.bf06
11)  -rwxr-xr-x   1 durai   staff    43068054 Mar 29 08:31 gdas1.t00z.sfluxgrbf06
12)  -rw-r--r--   1 durai   staff          56 Mar 29 08:31 gdas1.t00z.logf06
13)  -rwxr-xr-x   1 durai   staff   227083304 Mar 29 08:32 gdas1.t00z.sf09
14)  -rw-r--r--   1 durai   staff   116787028 Mar 29 08:32 gdas1.t00z.bf09
15)  -rwxr-xr-x   1 durai   staff    43450494 Mar 29 08:32 gdas1.t00z.sfluxgrbf09
16)  -rw-r--r--   1 durai   staff          56 Mar 29 08:32 gdas1.t00z.logf09
17)  -rwxr-xr-x   1 durai   staff   227083304 Mar 29 08:32 gdas1.t00z.sf12
18)  -rw-r--r--   1 durai   staff   116787028 Mar 29 08:32 gdas1.t00z.bf12
19)  -rwxr-xr-x   1 durai   staff    43426506 Mar 29 08:32 gdas1.t00z.sfluxgrbf12
20)  -rw-r--r--   1 durai   staff          56 Mar 29 08:32 gdas1.t00z.logf12
21)  -rwxr-xr-x   1 durai   staff   227083304 Mar 29 08:33 gdas1.t00z.sf15
22)  -rw-r--r--   1 durai   staff   116787028 Mar 29 08:33 gdas1.t00z.bf15
23)  -rwxr-xr-x   1 durai   staff    43493442 Mar 29 08:33 gdas1.t00z.sfluxgrbf15
24)  -rw-r--r--   1 durai   staff          56 Mar 29 08:33 gdas1.t00z.logf15
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26)  -rw-r--r--   1 durai   staff   116787028 Mar 29 08:33 gdas1.t00z.bf18
27)  -rwxr-xr-x   1 durai   staff    43526350 Mar 29 08:33 gdas1.t00z.sfluxgrbf18
28)  -rw-r--r--   1 durai   staff          56 Mar 29 08:33 gdas1.t00z.logf18
29)  -rwxr-xr-x   1 durai   staff   227083304 Mar 29 08:34 gdas1.t00z.sf21
30)  -rw-r--r--   1 durai   staff   116787028 Mar 29 08:34 gdas1.t00z.bf21
31)  -rwxr-xr-x   1 durai   staff    43703494 Mar 29 08:34 gdas1.t00z.sfluxgrbf21
32)  -rw-r--r--   1 durai   staff          56 Mar 29 08:34 gdas1.t00z.logf21
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```

GFS Post Process

GFS direct output in sigma level

Example GFS model.
gdas1.t00z.sf00

gdas1.t00z.bf00

Global post process Program

Output in pressure level (GRIB file)

gfs.t00z.pgrbf00

gfs.t00z.pgrbf24

Post Processing : Direct model products

Post processing : Generation of model products at the standard pressure level and at the given observation/forecast time .

There are two kinds of NWP model products namely;

(a) Direct model products and (b) Derived model products.

Direct model products

Directly available as model output are called direct model products, they are

1. WIND,
2. TEMPERATURE,
3. PRESSURE,
4. GEOPTENTIAL HEIGHT
5. HUMIDITY

Post Processing : Derived model products

The outputs such as vorticity, divergence, vertical wind shear, moisture flux, PWC, CAPE, CINE etc are called derived products.

Numerical expression of these derived products are

$$Divergence = \nabla.V = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}$$

$$Vorticity = \nabla x V = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}$$

$$Vertical\ wind\ shear: u200 - u850$$

Lower troposphere convergence (negative value of divergence), vorticity and vertical wind shear provide information on the intensity of a low pressure system.

GFS Output in Pressure levels

```
❖    -rwxr-xr-x    1 durai    staff    124581814 Mar 29 08:58 gfs.t00z.pgrbf00
❖    -rwxr-xr-x    1 durai    staff    136774022 Mar 29 08:58 gfs.t00z.pgrbf03
❖    -rwxr-xr-x    1 durai    staff    137107916 Mar 29 08:59 gfs.t00z.pgrbf06
❖    -rwxr-xr-x    1 durai    staff    137701452 Mar 29 08:59 gfs.t00z.pgrbf09
❖    -rwxr-xr-x    1 durai    staff    137638122 Mar 29 08:59 gfs.t00z.pgrbf12
❖    -rwxr-xr-x    1 durai    staff    137707438 Mar 29 08:59 gfs.t00z.pgrbf15
❖    -rwxr-xr-x    1 durai    staff    137817228 Mar 29 09:00 gfs.t00z.pgrbf18
❖    -rwxr-xr-x    1 durai    staff    137745754 Mar 29 09:00 gfs.t00z.pgrbf21
❖    -rwxr-xr-x    1 durai    staff    137361564 Mar 29 09:00 gfs.t00z.pgrbf24
❖    -rwxr-xr-x    1 durai    staff    137283596 Mar 29 09:01 gfs.t00z.pgrbf27
❖    -rwxr-xr-x    1 durai    staff    137735200 Mar 29 09:01 gfs.t00z.pgrbf30
❖    -rwxr-xr-x    1 durai    staff    138117438 Mar 29 09:01 gfs.t00z.pgrbf33
❖    -rwxr-xr-x    1 durai    staff    137956054 Mar 29 09:02 gfs.t00z.pgrbf36
❖    -rwxr-xr-x    1 durai    staff    138125784 Mar 29 09:02 gfs.t00z.pgrbf39
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❖    -rwxr-xr-x    1 durai    staff    138115020 Mar 29 09:03 gfs.t00z.pgrbf45
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❖    -rwxr-xr-x    1 durai    staff    137229130 Mar 29 09:10 gfs.t00z.pgrbf114
❖    -rwxr-xr-x    1 durai    staff    137172614 Mar 29 09:10 gfs.t00z.pgrbf117
❖    -rwxr-xr-x    1 durai    staff    137270588 Mar 29 09:11 gfs.t00z.pgrbf120
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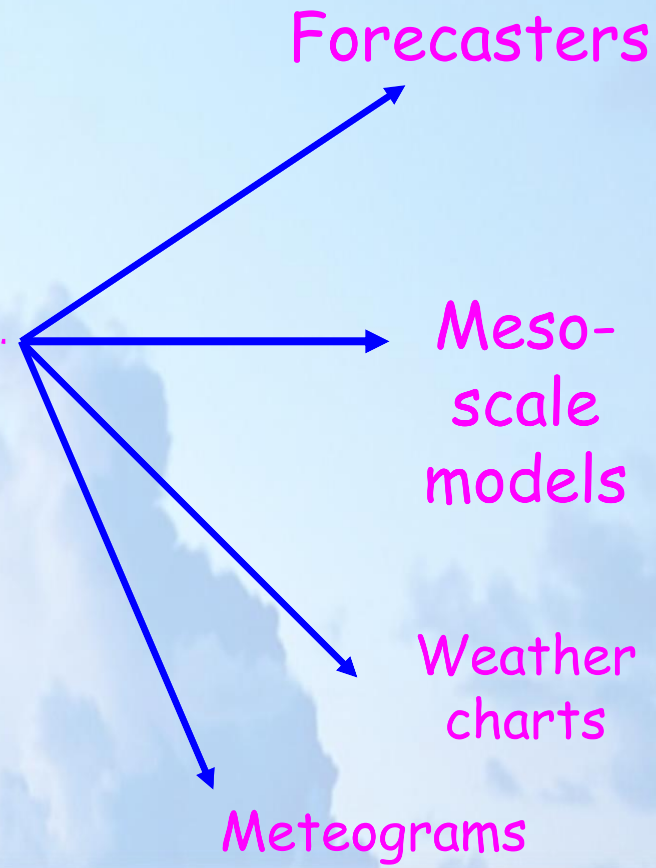


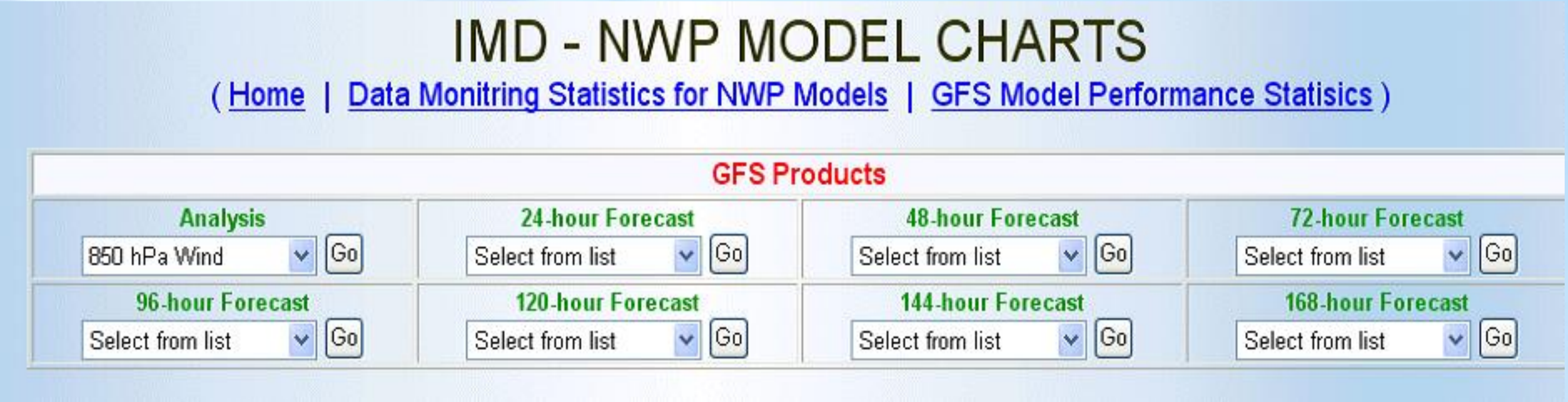
Forecasters

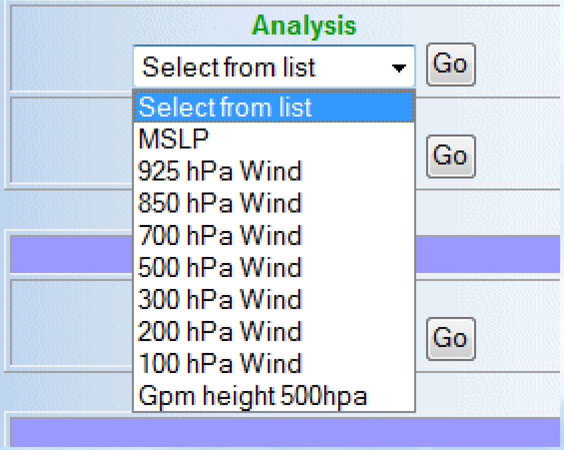
Meso-scale models

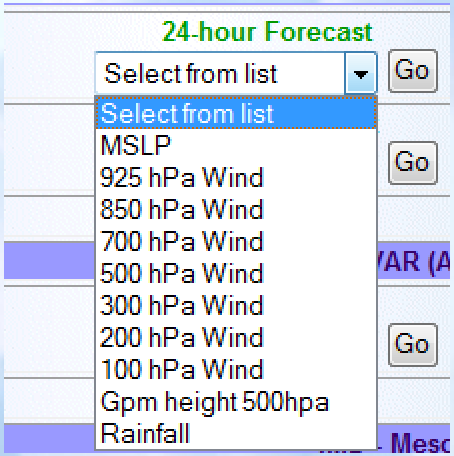
Weather charts

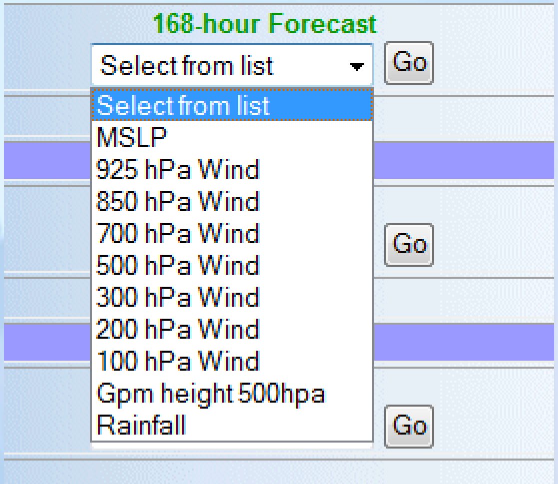
Meteograms

IMD GFS Products available in IMD web









Computer/Operating System :

IBM POWER6 in an AIX environment.

HIGH PERFORMANCE COMPUTING SYSTEM (HPCS)

- 1-D MPI scales well to 2/3 of the spectral truncation. For T574 about 400 MPI tasks.
- Open-MP threading performs well to 8 threads and still shows decent scalability to 16 threads.
- T574 scales to 400 x 16 = 6400 processors.

Computational Performance: GFS T382

Computing time in HPCS

Analysis CYCLE:

Number of compute node Used = 18

Number of processor used = 864

FOR ONE CYCLE (GSI Analysis) 15 minutes

GFS T382L64

(Resolution:0.35 X 0.35 degree lat./long)

Number of compute node Used = 20

Number of processor used = 960

LON=1152(grid point)

LAT=576(grid point)

Computation Time: 3 minutes for 24 hour f/c on IBM P6

Computational Performance :GFS T574

Computing time in HPCS

Analysis CYCLE:

Number of compute node Used = 18

Number of processor used = 864

FOR ONE CYCLE (GSI Analysis) 27 minutes

GFS T574L64

(Resolution:0.25 X 0.25 degree lat./long)

Number of compute node Used = 20

Number of processor used = 960

LON=1760(grid point)

LAT=880(grid point)

Computation Time: 10 minutes for 24 hour f/c on IBM P6

THANKS