Observation Processing for NWP -I

Different formats of data and their interchangeability. Decoding and quality control of GTS conventional/nonconventional observations

Indira Rani S.
NCMRWF, MoES

indirarani.s@gov.in, indira@ncmrwf.gov.in

Acknowledgements: Materials/contents from many sources

Components of Real-time Numerical Weather Prediction

Acquisition and Processing of Observations

Quality control and Monitoring of Observations

Data Assimilation

Dynamical Prediction Model

Post Processing and Visualizations

Application Models and Customization of Products

What is WIGOS?

World Weather Watch

GOS

GDPFS

GTS

WIGOS

GAW

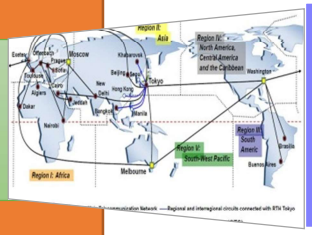
GCW

Hydro OS

GCOS

Partners

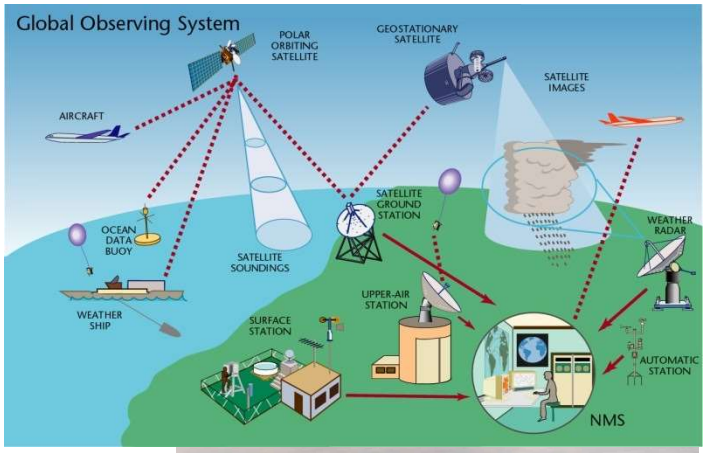
Co-sponsors

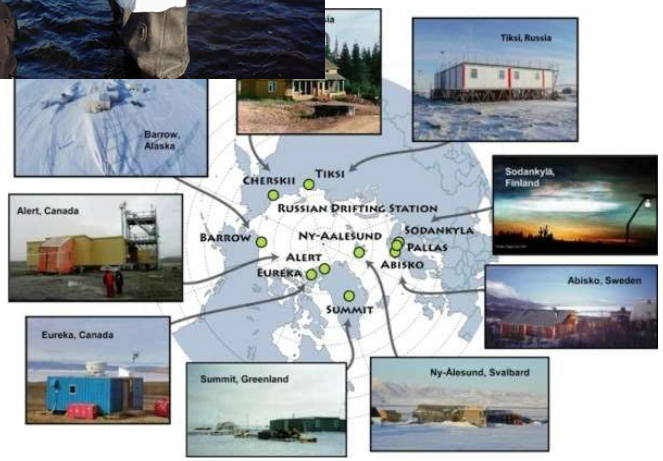


WMO Information System -WIS

WIGOS Component Systems

- Global Observing System (WWW/**GOS**)
- Observing component of Global Atmospheric Watch (**GAW**)
- WMO Hydrological Observations (including **WHYCOS**)
- Observing component of Global Cryosphere Watch (**GCW**)





Evolution of the observing system

Satellites

Upper-air soundings

Surface observations

log(number of observations)

ECMWF

D. Dee

1890 — Manual stations, limited data exchange

1938 — First radiosonde networks, systematic soundings

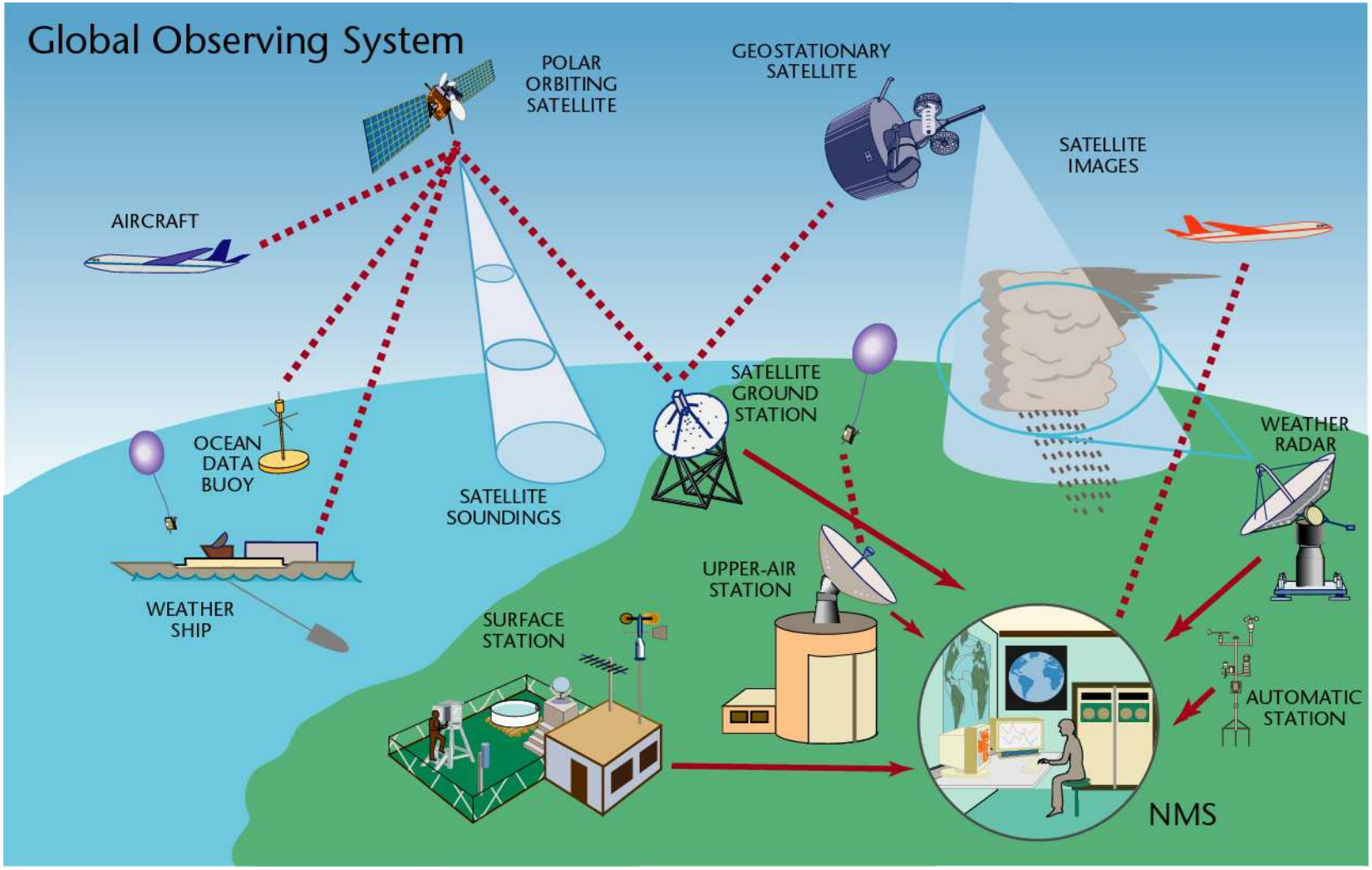
1957 — International Geophysical Year: radiosonde network enhanced, especially in the Southern Hemisphere

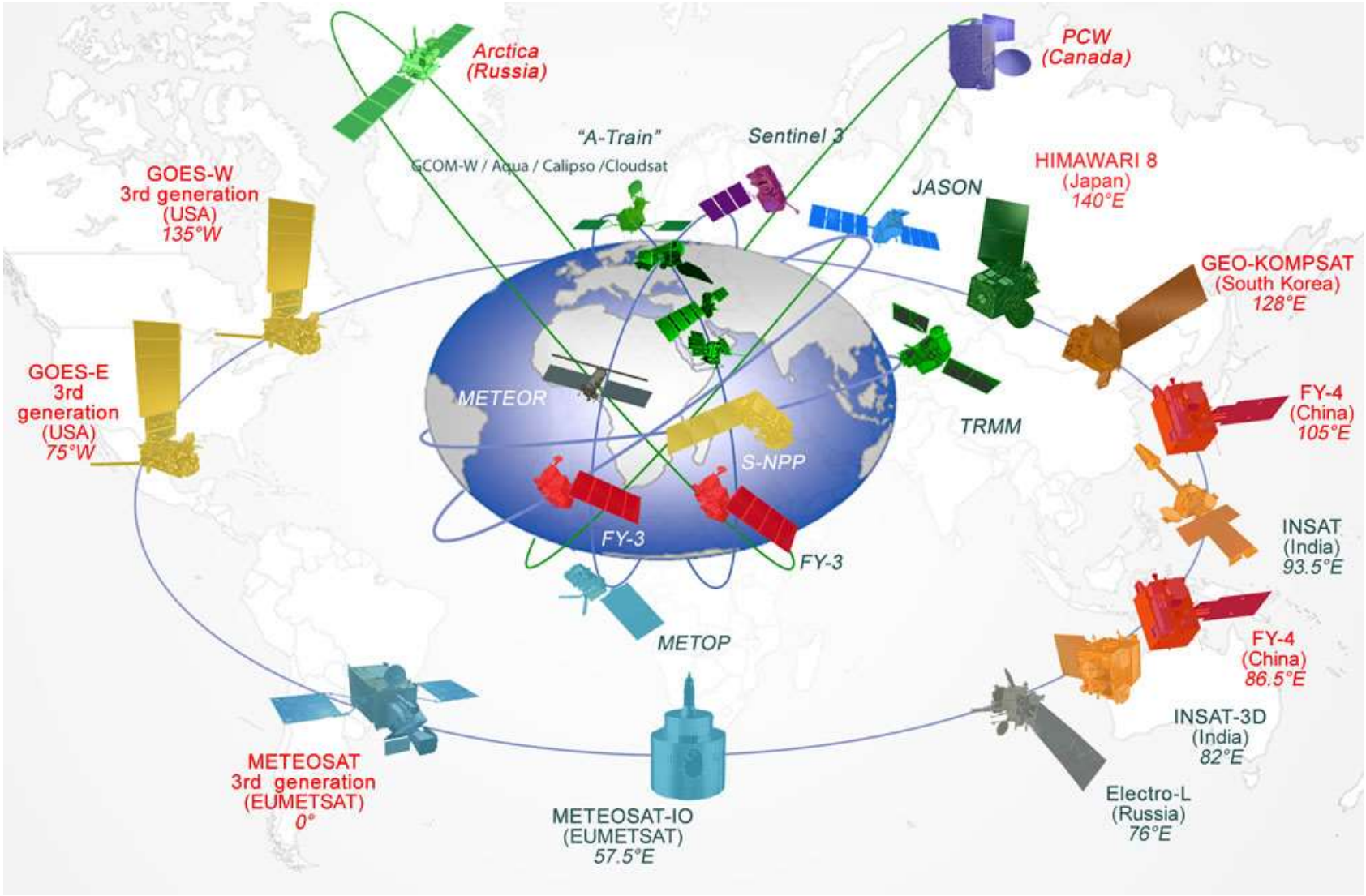
1973 — First operational satellite soundings (NOAA-2)

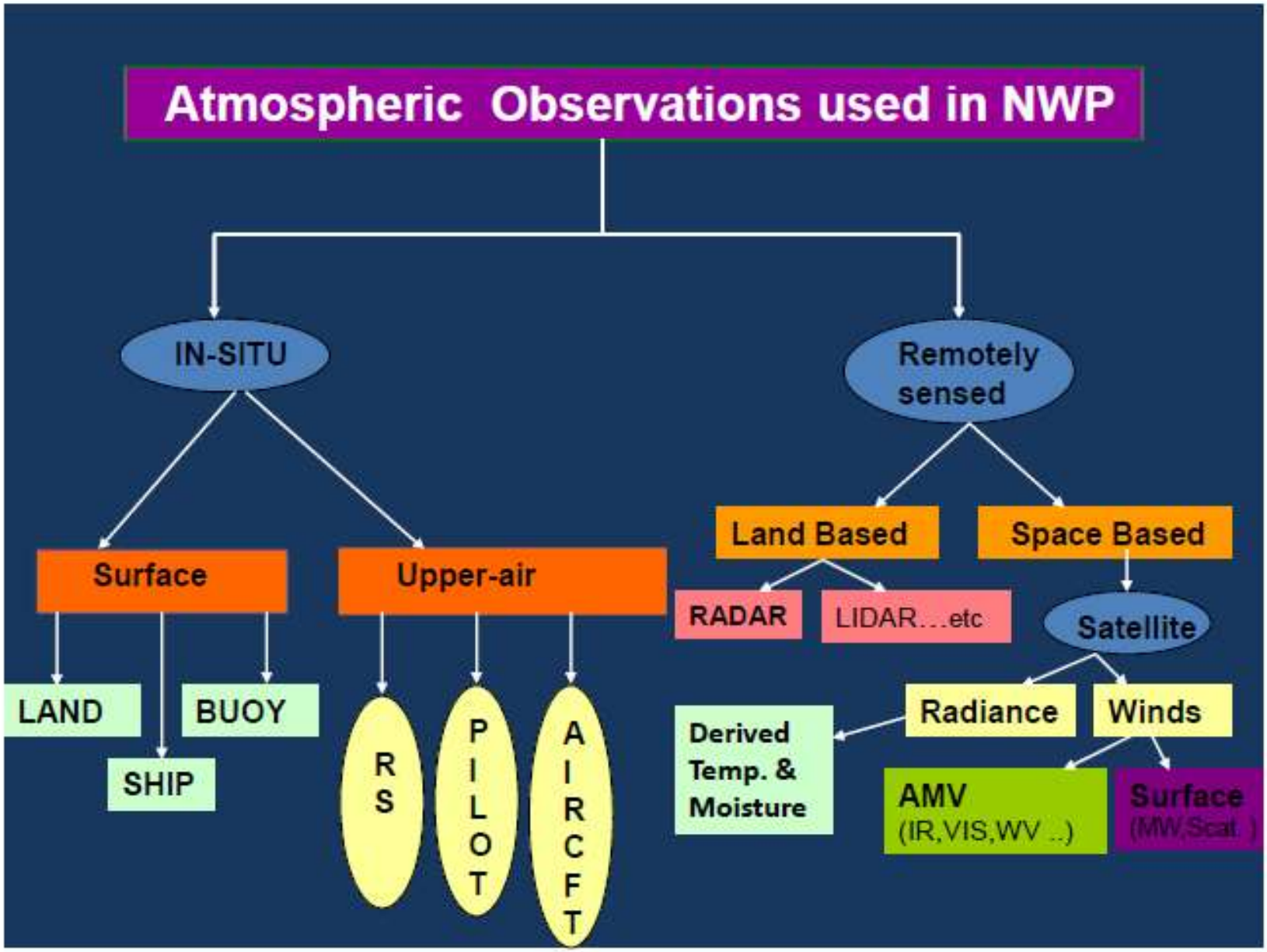
1979 — Improved sounding from polar orbiters; Winds from geostationary orbit; More data from commercial aircraft; First drifting buoys

Today — More satellites, aircraft, buoys, ocean gliders and drifters. Fewer radiosondes, but probe higher. Better knowledge of instruments. More obs. per hour.

2100 — *Opport-unity sensors : cell phones, UAVs, vehicles, rooftops, …*


Global Observing System
POLAR ORBITING SATELLITE
GEOSTATIONARY SATELLITE
SATELLITE IMAGES
AIRCRAFT
SATELLITE GROUND STATION
OCEAN DATA BUOY
SATELLITE SOUNDINGS
WEATHER RADAR
UPPER-AIR STATION
WEATHER SHIP
SURFACE STATION
AUTOMATIC STATION
NMS

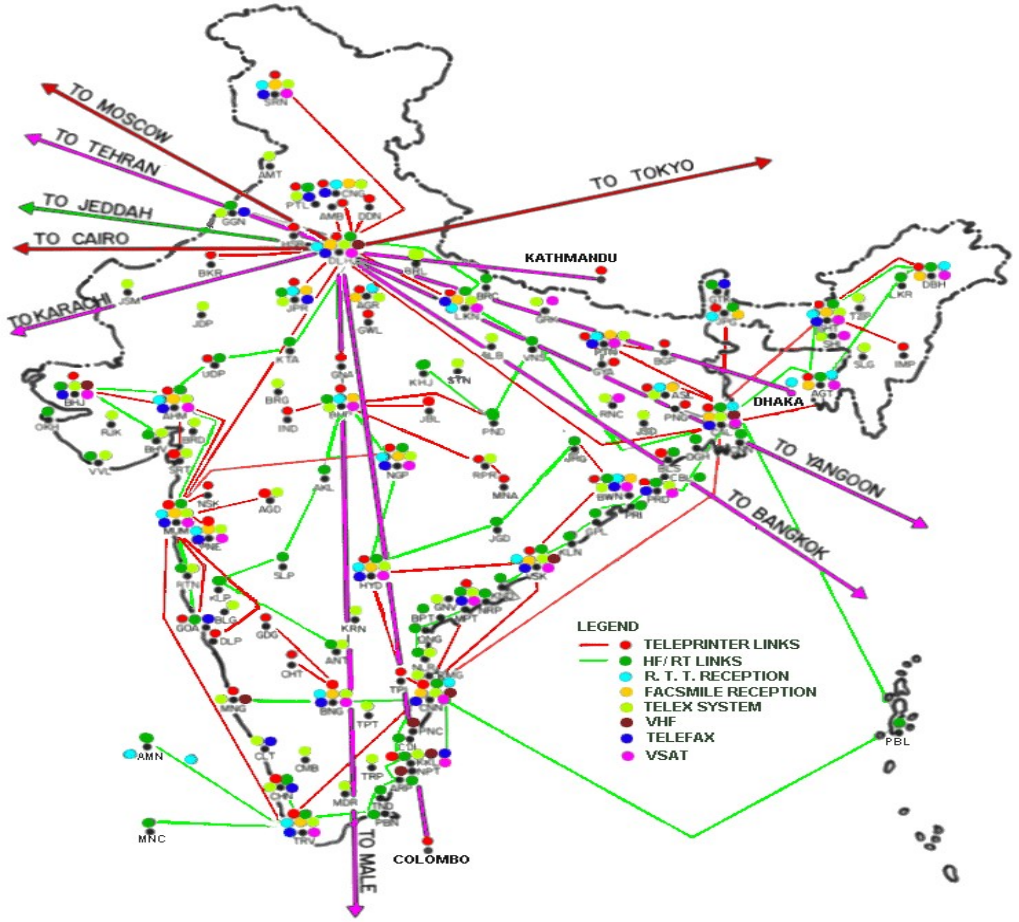

Arctica
(Russia)
PCW
(Canada)
"A-Train"
GCOM-W / Aqua / Calipso /Cloudsat
Sentinel 3
JASON
HIMAWARI 8
(Japan)
140°E
GOES-W
3rd generation
(USA)
135°W
GEO-KOMPSAT
(South Korea)
128°E
GOES-E
3rd
generation
(USA)
75°W
METEOR
TRMM
FY-4
(China)
105°E
S-NPP
INSAT
(India)
93.5°E
FY-3
FY-3
METOP
FY-4
(China)
86.5°E
INSAT-3D
(India)
82°E
METEOSAT
3rd generation
(EUMETSAT)
0°
METEOSAT-IO
(EUMETSAT)
57.5°E
Electro-L
(Russia)
76°E


Atmospheric Observations used in NWP
IN-SITU
Remotely sensed
Surface
Upper-air
Land Based
Space Based
RADAR
LIDAR…etc
Satellite
LAND
BUOY
SHIP
RS
PILOT
AIRCFT
Derived Temp. & Moisture
Radiance
Winds
AMV (IR,VIS,WV ..)
Surface (MW,Scat.)

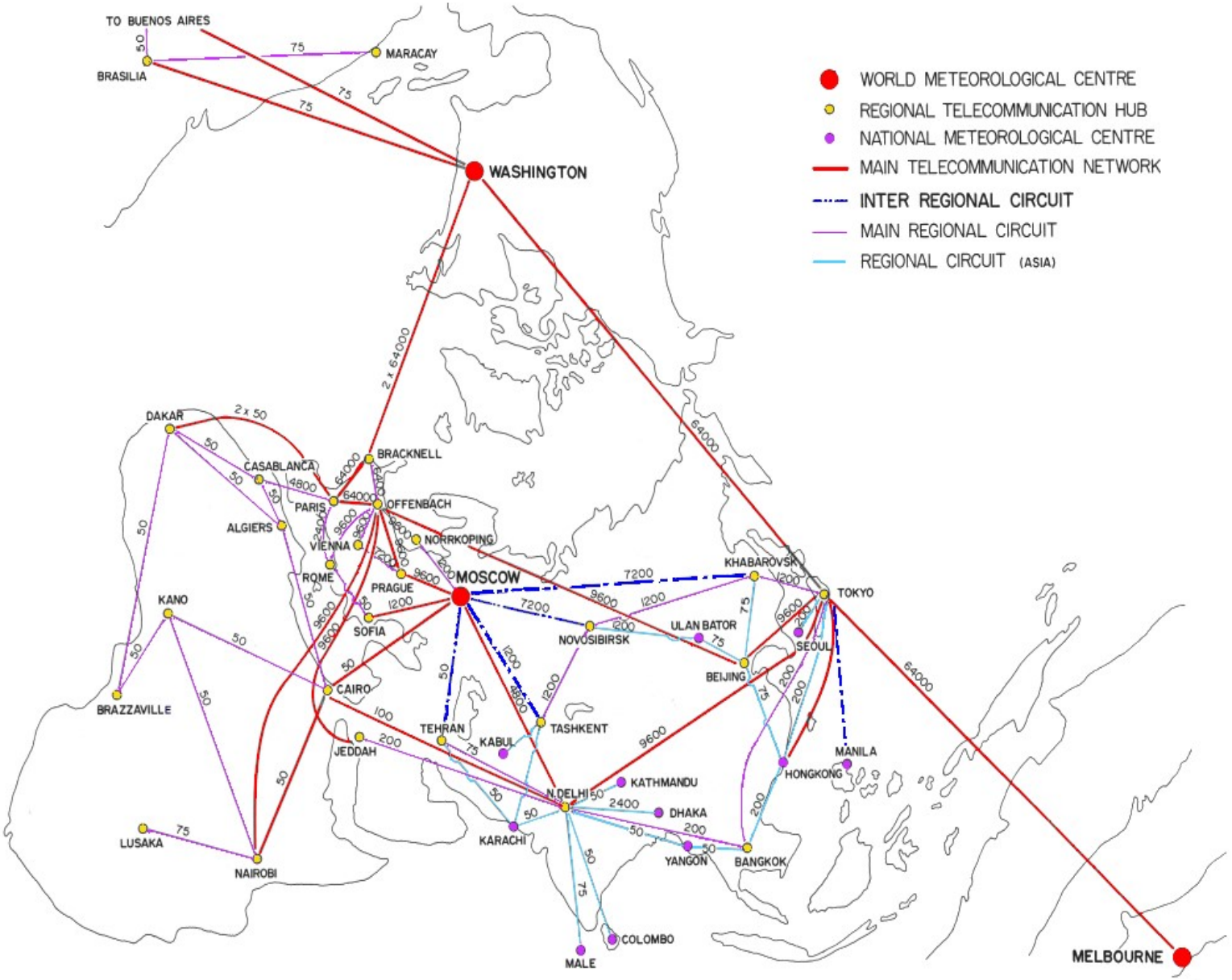
Global Telecommunication System:

Global communication satellites transmit these data sets by collecting them from land based communication networks spread over various countries and transmit the global observational data in real time to the various weather center.

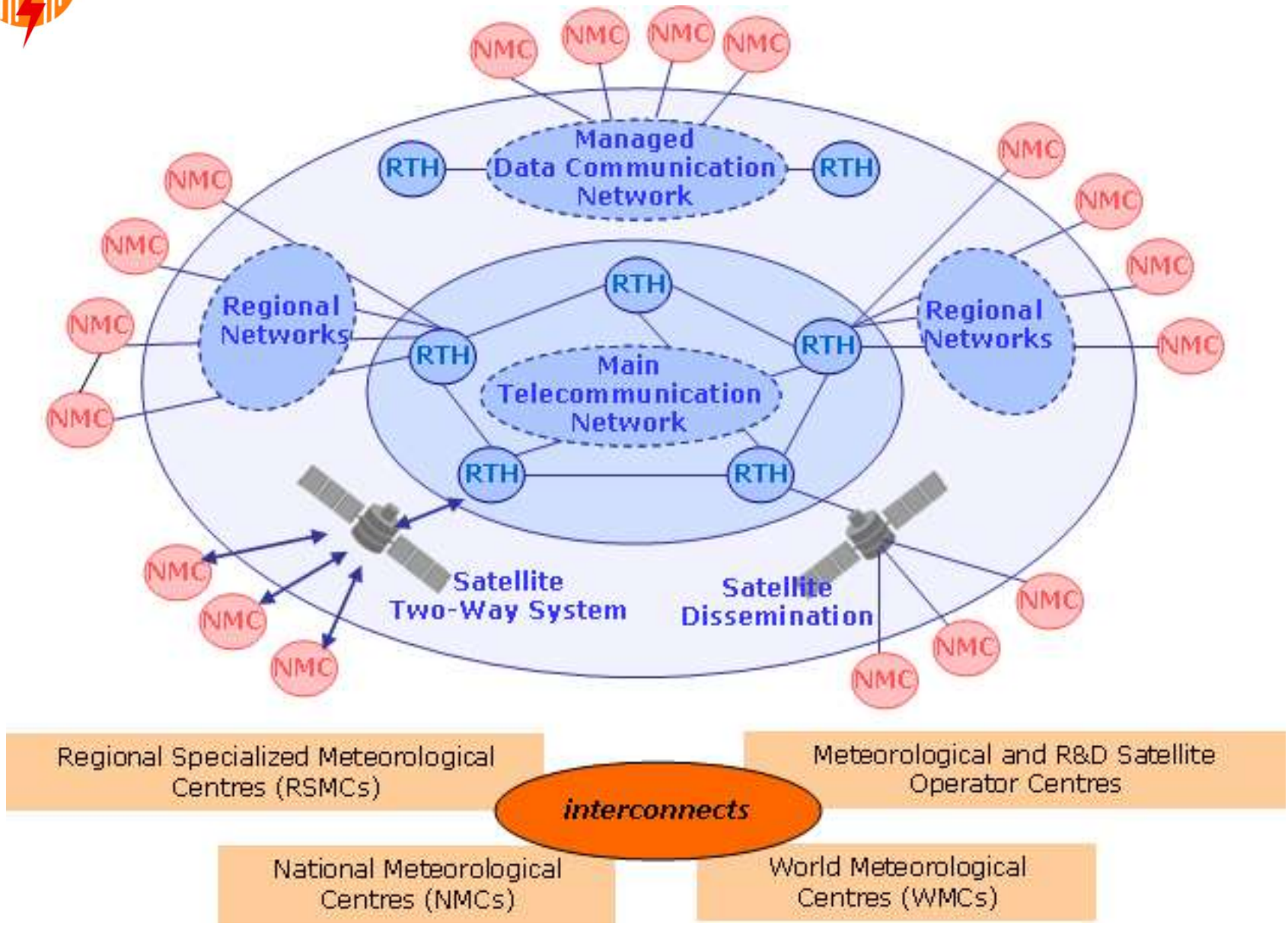
This service is a part of Global Telecommunication System (GTS) of World Meteorological Organisation (WMO).



Structure of the Global Telecommunication System



Structure of the Global Telecommunication System



Courtesy WMO

Six Regional Associations of WMO	
Region	Area
1	Africa
2	Asia
3	South America
4	North and Central America
5	South-West Pacific
6	Europe

- France (Regions I, III, IV, and VI)
- United Kingdom (Regions I, IV, V, and VI)
- Colombia (Regions III and IV)
- Kazakhstan (Regions II and VI)
- Netherlands (Regions IV and VI)
- Portugal (Regions I and VI)
- Russian Federation (Regions II and VI)
- Spain (Regions I and VI)
- United States of America (Regions IV and V)
- Venezuela (Regions III and IV)

Weather Report and its transmission

When the meteorological observations have been completed and the results recorded, this information has to be transmitted to a meteorological centre. The message must be prepared in a form suitable for transmission over a communication system, generally known as a weather report.

It is desirable to reduce the length of the message for the rapid and efficient transmission of the weather report. A system of meteorological codes has been developed for the transmission of weather report.

The receiver has to decode the weather report to get the actual weather information. Sound understanding of the coding practices are necessary.

International codes are developed for the exchange of weather report between NMC

WMO codes

Common procedures for data representation and transmission are based on the concept of using codes designed by WMO

It helps to

- reduce the length of messages,
- avoid language problems and
- facilitate automatic processing.

Mainly two types of code

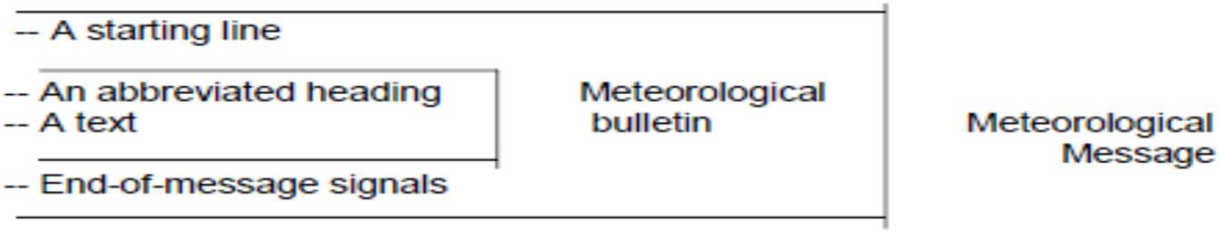
- ASCII (SYNOP, TEMP etc..)
- Binary (BUFR, GRIB etc..)

BUFR --- table driven code (mainly observations)

GRIB --- gridded fields (analysis/forecast ..)

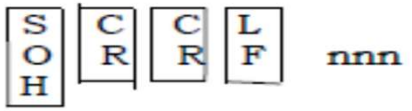
ASCII Code

A routine meteorological message transmitted on the GTS comprises of:

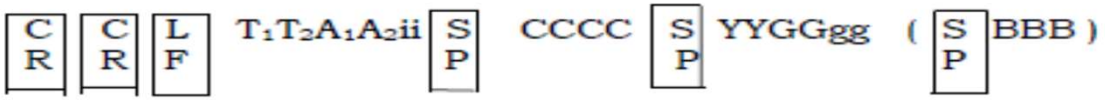


Using International Alphabet No. 5, a message looks like

Starting Line :



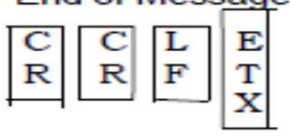
The abbreviated heading of the bulletin is in the following format.



where,

$T_1T_2A_1A_2ii$	Data designator,
CCCC	International four-letter location indicator
YYGGgg	International date-time group.
BBB	Indicator for delayed reports/correction/amendments.

End of Message :



Legend:
Start of heading (Signal 0/1)
Carriage return (Signal 0/13)
Line feed (Signal 0/10)
Space (Signal 2/0)
End of text (Signal 3/13)
= Separator (Signal 3/13)

T1T2A1A2ii (WMO Volume C1 - Catalogue of Meteorological Bulletins)

T1 is taken from WMO Manual 386 table A. It is an alpha character that designates the general code form of the contents of the bulletin (Coded or plain text).

T2 is taken from WMO Manual 386 tables B1 through B6 depending on the designator T1 in table A. It is an alpha character that designates the data type.

A1 is taken from WMO Manual 386 tables C1 through C6 depending on designator T1 in table A (U.S. National practice through C9). It is an alpha character that designates the geographical area the content of the bulletin covers.

A2 is taken from WMO Manual 386 tables C1 through C5 depending on designator T1 in table A (U.S. National practice through C9). It is an alpha character that designates the geographical area, or may define the forecast period.

ii is taken from the WMO Manual 386 paragraph 2.3.2.2 definition, or from table D1 or D2 depending on designator T1 in table A (U.S. National practice table D3 replaces D2). It is a numeric set of two characters. Go to the WMO message structure for more details on this group.

For more information : Weather-Communications-Codes.pdf (udxf.nl)
https://library.wmo.int/doc_num.php?explnum_id=10235

FM-12 SYNOP/FM-13 SHIP

b. LIST OF CODE FORMS WITH NOTES AND REGULATIONS

FM 12–XIV Ext. SYNOP **Report of surface observation from a fixed land station**

FM 13–XIV Ext. SHIP **Report of surface observation from a sea station**

FM 14–XIV Ext. SYNOP MOBIL **Report of surface observation from a mobile land station**

CODE FORM:

SECTION 0 $M_iM_iM_jM_j$ { D . . . . D**** or $A_1b_wn_bn_bn_b$** } $YYGGi_w$ { Iiii* or $99L_aL_aL_a$ $Q_cL_oL_oL_o$**** } $MMMU_{La}U_{Lo}$*** $h_0h_0h_0h_0i_m$***

SECTION 1 i_Ri_xhVV Nddff (00fff) $1s_nTTT$ { $2s_nT_dT_dT_d$ or 29UUU } $3P_0P_0P_0P_0$

{ 4PPPP or $4a_3hhh$ } 5appp $6RRRt_R$ { $7wwW_1W_2$ or $7w_aw_aW_{a1}W_{a2}$ } $8N_hC_LC_MC_H$ 9GGgg

SECTION 2 $222D_sv_s$ ($0s_sT_wT_wT_w$) ($1P_{wa}P_{wa}H_{wa}H_{wa}$) ($2P_wP_wH_wH_w$) (($3d_{w1}d_{w1}d_{w2}d_{w2}$)

($4P_{w1}P_{w1}H_{w1}H_{w1}$) ($5P_{w2}P_{w2}H_{w2}H_{w2}$)) ({ $6I_sE_sE_sR_s$ or ICING + plain language })

($70H_{wa}H_{wa}H_{wa}$) ($8s_wT_bT_bT_b$) (ICE + { $c_iS_ib_iD_iz_i$ or plain language })

SECTION 3 333 (0 . . . .) ($1s_nT_xT_xT_x$) ($2s_nT_nT_nT_n$) ($3Ejjj$) ($4E'sss$) ($5j_1j_2j_3j_4$ ($j_5j_6j_7j_8j_9$))

($6RRRt_R$) ($7R_{24}R_{24}R_{24}R_{24}$) ($8N_sCh_sh_s$) ($9S_PS_Ps_ps_p$)

(80000 (0 . . . .) (1 . . . .) . . . .)

SECTION 4 444 N'C'H'H'C_t

SECTION 5 555 Groups to be developed nationally

The code form is divided into a number of sections as follows:

Section number	*Symbolic figure group*	*Contents*
0	—	Data for reporting identification (type, ship's call sign/buoy identifier, date, time, location) and units of wind speed used
1	—	Data for global exchange which are common to the SYNOP, SHIP and SYNOP MOBIL code forms
2	222	Maritime data for global exchange pertaining to a sea, or to a coastal station
3	333	Data for regional exchange
4	444	Data for national use for clouds with base below station level, included by national decision
5	555	Data for national use

WMO-306 Vol A,B,C - Manual on codes

FM-12 SYNOP/FM-13 SHIP

b. LIST OF CODE FORMS WITH NOTES AND REGULATIONS

FM 12–XIV Ext. SYNOP **Report of surface observation from a fixed land station**

FM 13–XIV Ext. SHIP **Report of surface observation from a sea station**

FM 14–XIV Ext. SYNOP MOBIL **Report of surface observation from a mobile land station**

CODE FORM:

SECTION 0 $M_iM_iM_jM_j$ {D . . . . D**** or $A_1b_wn_bn_bn_b$**} $YYGGi_w$ {IIiii* or $99L_aL_aL_a$ $Q_cL_oL_oL_oL_o$****} $MMMU_{La}U_{Lo}$*** $h_0h_0h_0h_0i_m$***

SECTION 1 i_Ri_xhVV Nddff (00fff) $1s_nTTT$ {$2s_nT_dT_dT_d$ or 29UUU} $3P_0P_0P_0P_0$

{4PPPP or $4a_3hhh$} 5appp $6RRRt_R$ {$7wwW_1W_2$ or $7w_aw_aW_{a1}W_{a2}$} $8N_hC_LC_MC_H$ 9GGgg

SECTION 2 $222D_sv_s$ $(0s_sT_wT_wT_w)$ $(1P_{wa}P_{wa}H_{wa}H_{wa})$ $(2P_wP_wH_wH_w)$ $((3d_{w1}d_{w1}d_{w2}d_{w2})$

$(4P_{w1}P_{w1}H_{w1}H_{w1})$ $(5P_{w2}P_{w2}H_{w2}H_{w2}))$ ({$6I_sE_sE_sR_s$ or ICING + plain language})

The code form is divided into a number of sections as follows:

Section number	*Symbolic figure group*	*Contents*
0	—	Data for reporting identification (type, ship's call sign/buoy identifier, date, time, location) and units of wind speed used
1	—	Data for global exchange which are common to the SYNOP, SHIP and SYNOP MOBIL code forms
2	222	Maritime data for global exchange pertaining to a sea, or to a coastal station
3	333	Data for regional exchange
4	444	Data for national use for clouds with base below station level, included by national decision
5	555	Data for national use

Discussion: Example of ASCII coded observation report

What is BUFR (FM 94 BUFR)

• Binary representation of meteorological data or Binary Universal Form for data Representation

• Continuous bit stream made of sequence of octets.

• Table driven code

• Self descriptive code

• Machine independent

• Compression available for improved transmission speed

BUFR FORMAT (consists of a continuous binary stream comprising of 6 sections)

• Indicator section
• Identification section
• Optional section
• Data description section
• Data section
• End section

All sections are padded with “0”s if needed to occupy even number of octets.

Section 0 – Indication

Octet number	Meaning
1 - 4	BUFR four letters in CCITT IA5
5 - 7	Total length of bufr message in bytes
8	Bufr Edition number

Section 2- Optional section

Octet number	Meaning
1 - 3	Length of section
4	Set to zero
5-	Reserved for local ADP centre

Section 1 – Identification section

Octet number	Meaning
1 – 3	Length of section
4	BUFR master table
5	Originating sub-centre
6	Originating centre
7	Update sequence number
8	Presence of section 2 flag
9	Data category (Table A)
10	Data sub-category
11	Version number of Master tables used
12	Version number of local table used
13	Year of century
14	Month
15	Day
16	Hour
17	Minute
18-	Reserved for local use by ADP Centres

Section 3- Data description section

Octet number	Meaning
1 - 3	Length of section
4	Set to zero (reserved)
5 - 6	Number of data subsets
7	Flag (compression)
8 -	Collection of data descriptors

F type	X category	Y entry
2 bits	6 bits	8 bits

- F = 0 Element Descriptor – Bufr table B
- F = 1 Replication descriptor
  - → X = number of descriptors to repeat
  - → Y = number of times the descriptors are repeated
- F = 2 Operator Descriptor – Bufr table C
- F = 3 Sequence Descriptor – Bufr table D

Section 4- Data section

Octet number	Meaning
1 - 3	Length of section 4
4	Set to zero (reserved)
5-	Binary data as defined by sequence descriptors

Section 5- End section

Octet number	Meaning
1 - 4	7777 Coded according to CCITT IA5

BUFR Tables

- Table A - Data category
- Table B - Classification of elements
- Table C - Data descriptor operators
- Table D - List of common sequences

Table A- Data Category

- Used in the Section 1 (element 9) of the BUFR message
- Example:

Code figure	Meaning
0	Surface data - land
1	Surface data – sea
2	Vertical soundings (not satellite)
…	
31	Oceanographic data

Table B- Classification of Elements

	Element Name	Unit	Scale	Reference	#bits
•	005001 Latitude (high accuracy)	Degree	5	-9000000	25
•	007003 Geopotential	m**2/s**2	-1	-400	17
•	002019 Satellite instruments	Code table	0	0	11
•	008001 Vertical sounding signifi	Flag Table	0	0	7
•	001006 Aircraft flight number	CCITTIA5	0	0	64

- → (obs. * 10**scale – Reference) is encoded into #bits bits
- → For coded or flagged values, the element descriptor indicates the number of the table discribing the codes/flags.
- 0 - Table B entry
  - → 05 - Location (horizontal 1) class
  - → 01 - Identification
  - → 08 - Significance qualifiers

Table C- Data Descriptor Operators

- 201yyy - Change data width
- 202yyy - Change scale
- 203yyy - Change reference value
- 222000 - Quality information

Table D- List of common sequence

- Table D can contain sequences of table B entries, Table D entries and Operators. It is not needed but saves a lot of space.

→301027 301001 WMO block and station
002011 Radiosonde type
002012 Radiosonde computational method
301011 Date
301012 Time
301022 Lat/Long and station height

For more details:

https://library.wmo.int/doc_num.php?explnum_id=10722

Discussion: Example of BUFR coded observation report

Decoders are set of structured software (mainly in FORTRAN and C)
for decoding different WMO FM codes

Input - data in WMO FM codes
Output - generally in BUFR format
fixed files e.g. WMO station directory, bufr tables etc.

ECMWF BUFRDC: https://confluence.ecmwf.int/display/BUFR/BUFRDC+Home

ECMWF eCcodes: https://confluence.ecmwf.int/display/ECC/Releases

NCEP decoder: https://www.nco.ncep.noaa.gov/sib/decoders/

Python toolkit for WMO BUFR decoder: https://pybufrkit.readthedocs.io/en/latest/

More information: https://rda.ucar.edu/#!BUFR

List of decoders implemented at NCMRWF

	Type of Observations	Decoder Name	WMO Code Name
1	Upper air sounding	dcusnd	TEMP & PILOT
2	Land surface	dclsfc	SYNOP & SYNOP MOBIL
3	Marine surface	dcmsfc	SHIP
4	Drifting buoy	dcdrbu	BUOY
5	Sub-surface buoy Obsn.	dcbthy	BATHY & TESAC
6	Aircraft observations	dcacft	AIREP & AMDAR
7	Automated Aircraft Obsn	dcacft	BUFR (ACARS)
8	Airport Weather Obsn	dcmetr	METAR
9	Satellite winds	dcsaob	SATOB
10	High density satellite winds	dceums	BUFR (winds from EUMETSAT & Japan)
11	Wind profiler observation	dcprof	BUFR (wind profiler from US/Europe/Hongkong)
12	Surface pr. Analysis (Aust.)	dcpaob	PAOB

Observation pre-processing

- The observations arrive via GTS and are stored in a decoded format in a database.
- Prior to the data assimilation the observations are extracted from the data base.
- These data undergo some rudimentary quality control, e.g. a check for the observation format and position, for the climatological and hydrostatic limits as well as for the internal and temporal consistency, etc.
- Then an observation file suitable for assimilation is created in an observation preprocessing module.
- This entails format conversions, change of some observed variables, like calculation of relative humidity from dry and wet bulb temperatures, as well as assignment of observation error statistics.
- The resulting file contains all the observational information from the data window (currently six hours) and is an input for the NWP assimilation system.
- The observation screening then selects the best quality and unique observations.
- After the assimilation step a feedback file is created using the preprocessing software.

Bias correction

The feedback files are extensively used for monitoring the performance of the observing and assimilation systems.

Feedback file is used to determine the bias corrections for some observing systems, eg: for TEMP temperature observations, satellite radiances, scatterometer winds, AMVs, etc.

Bias correction is a very difficult task as there is no fixed reference point with respect to which the bias should be corrected.

Due to the risks involved, often a policy of “conservative bias correction” has been adopted, i.e. removing for instance only a half of the bias appearing in the observations.

The biases change in time due to changes in observing and assimilation systems and therefore the bias correction has to be updated from time to time.

The bias correction is calculated with an off-line code using feedback files as input.

Screening of conventional observations

1. Preliminary checks of observations :

- Completeness of the report (eg: mass observations from SYNOP and TEMP (Surface pressure and geopotential height), observation error)
- Blacklisting: controls the selection of variables, vertical range, orographic rejection

2. Background quality control

- performed for all the variables that are intended to be used in the assimilation
- background departure is considered as suspect when it exceeds its expected predefined value.

3. Vertical consistency of multi-level reports

- duplicate levels are removed from the reports
- if consecutive layers (more than 3) are found to be of suspicious quality, then these layers are rejected
- in the case of geopotential observations all the layers above the suspicious layers are rejected

4. Removal of duplicated reports

- searching pairs of co-located reports of the same observation types and then checking the content of these reports
- The pair-wise checking of duplicates results in a rejection of some or all of the content of one of the reports.

Screening of conventional observations contd...

5. Redundancy check

- active reports that are co-located and originate from the same station.

- For land SYNOP and PAOB/TEMP reports, the report closest to the centre of the screening time window with most active data is retained whereas the other reports from that station are considered as redundant.

- For SHPSYNOP and DRIBU (BUOY) observations the redundancy check is done in a slightly modified fashion. These observations are considered as potentially redundant if the moving platforms are within a circle with a specified radius in terms of latitude, and retains the observation closest to the screening time window.

- All the data from the multi-level TEMP and PILOT reports from same station are considered at the same time in the redundancy check. The principle is to retain the best quality data at the significant levels (i.e. the turning points of the sounding) and closest to the centre of the screening time window.

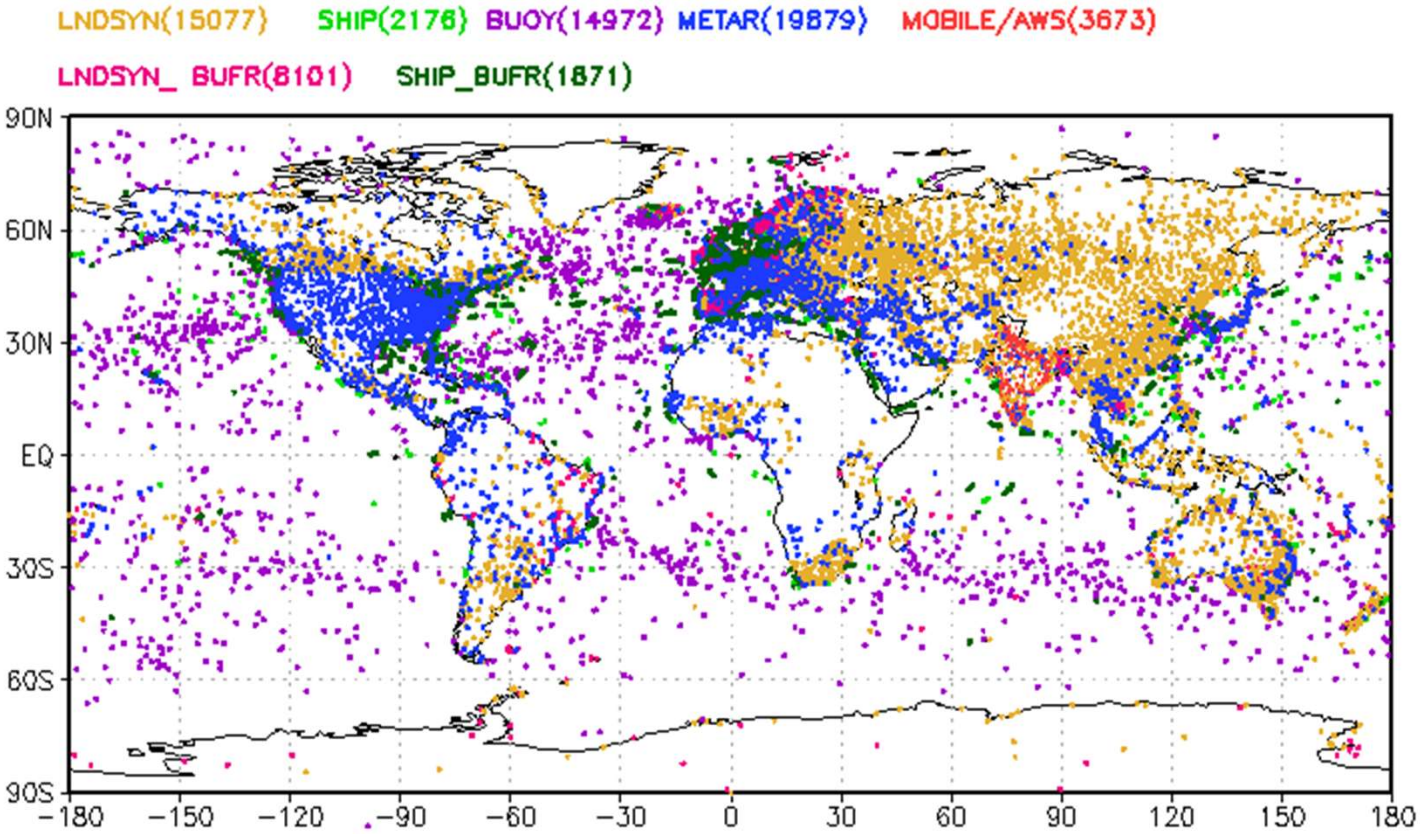
- One such datum will however only be retained in one of the reports. A wind observation, for instance, from a sounding station may therefore be retained either in a TEMP or in a PILOT report, depending on which one happens to be of a better quality.

Screening of conventional observations contd…

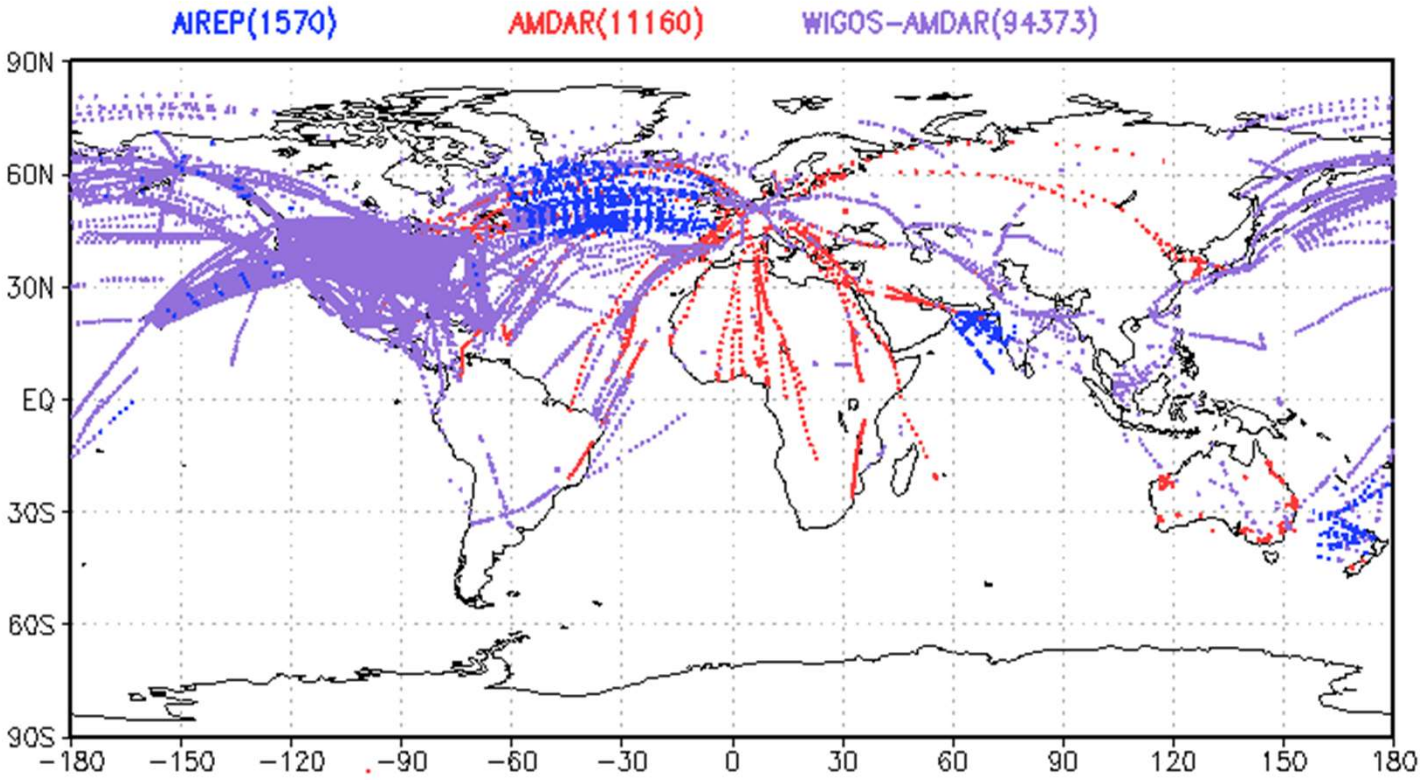
5. Thinning

- Horizontal thinning for some of the conventional observations (eg: Aircraft reports)
- A predefined minimum horizontal distance between the nearby reports from the same platform is enforced.
- Thinning of the Aircraft data is performed with respect to one airliner at a time.
- In this removal of redundant reports the best quality data is retained as the preceding quality control is taken into account.
- In vertical, the thinning is performed for layers around standard pressure levels thus allowing more reports for ascending and descending flight paths.
- **Thinning criteria is different for satellite radiances (will cover during the presentation "Satellite data processing for NWP")**

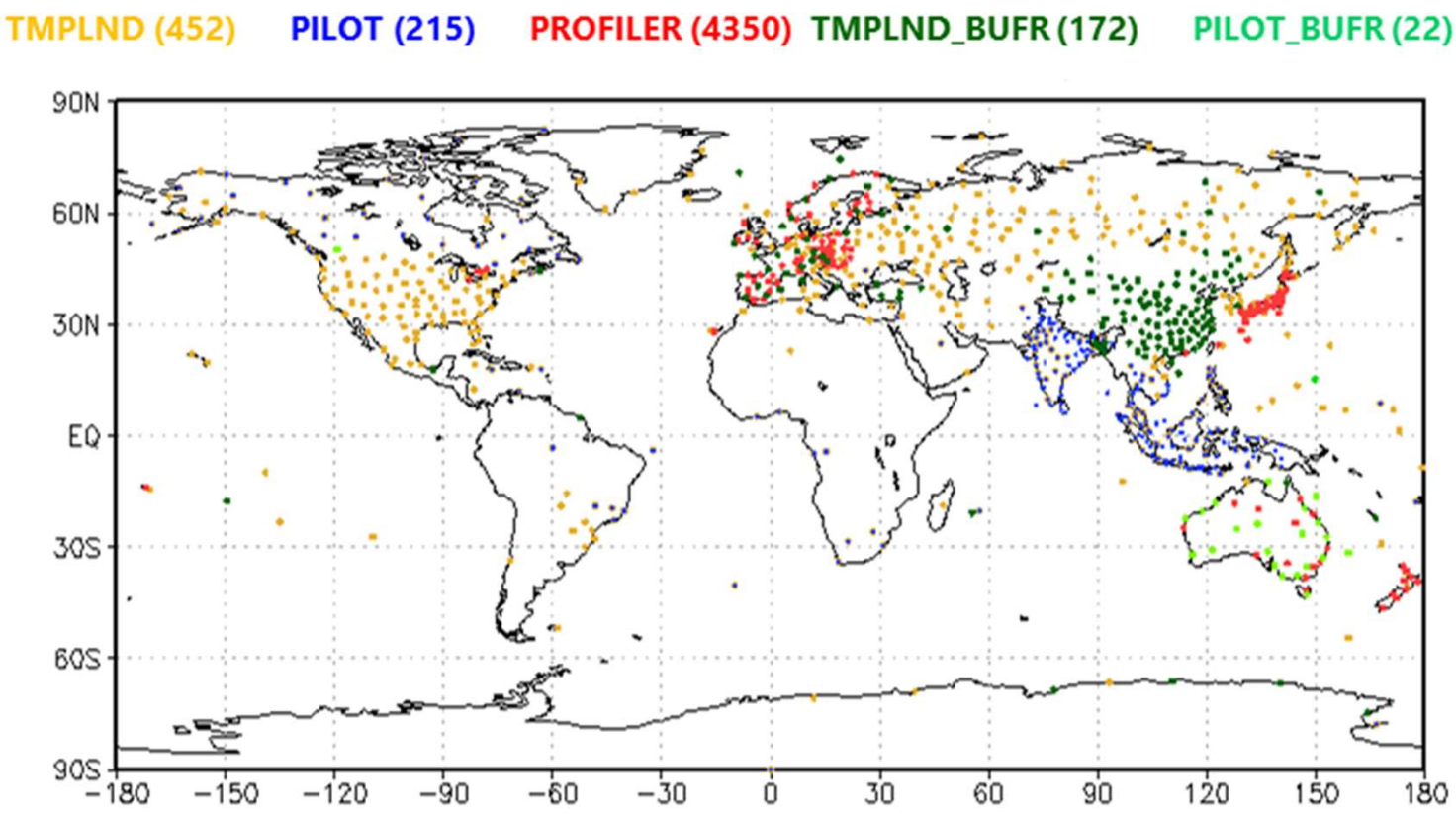
Surface Observation coverage



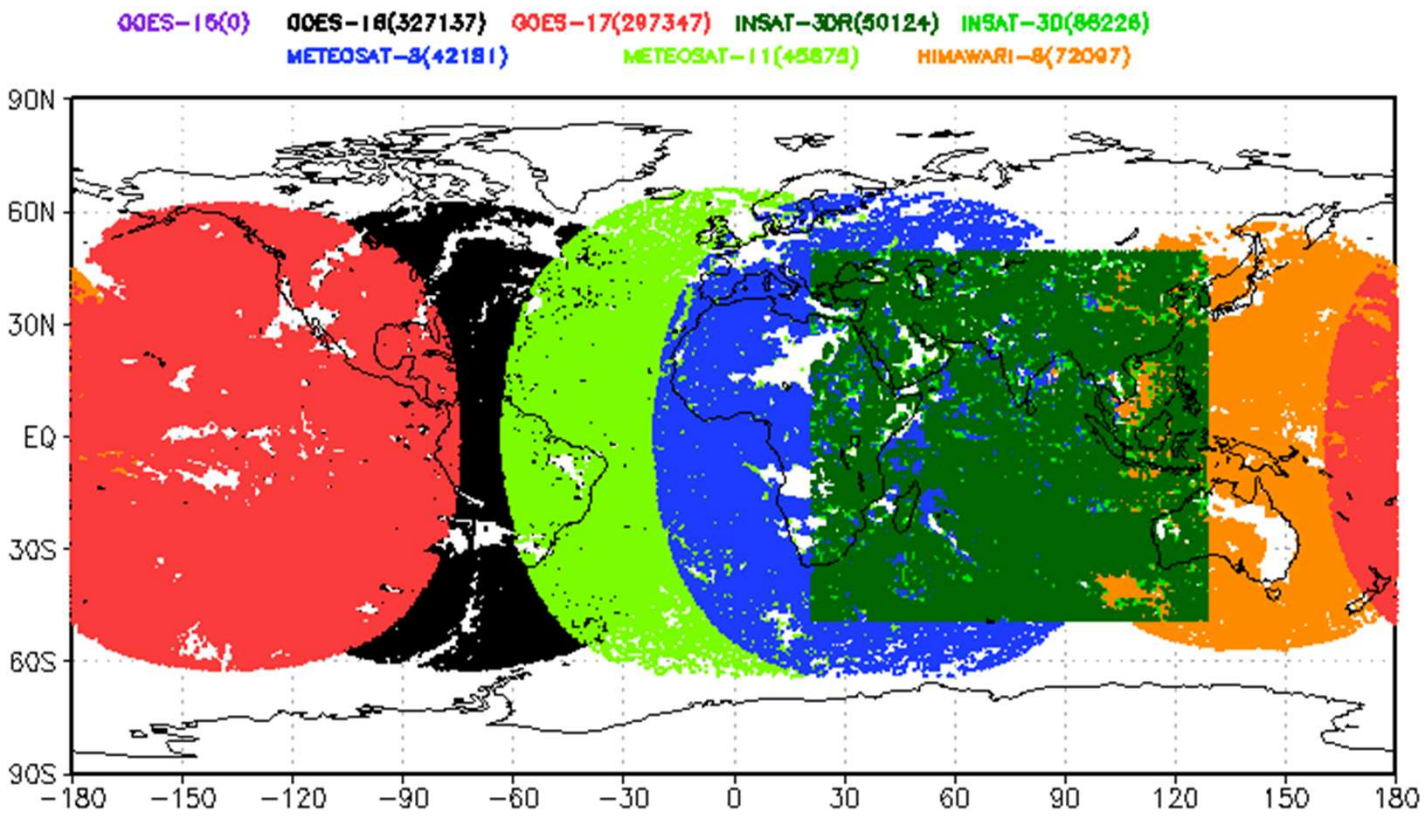
Aircraft Observation coverage



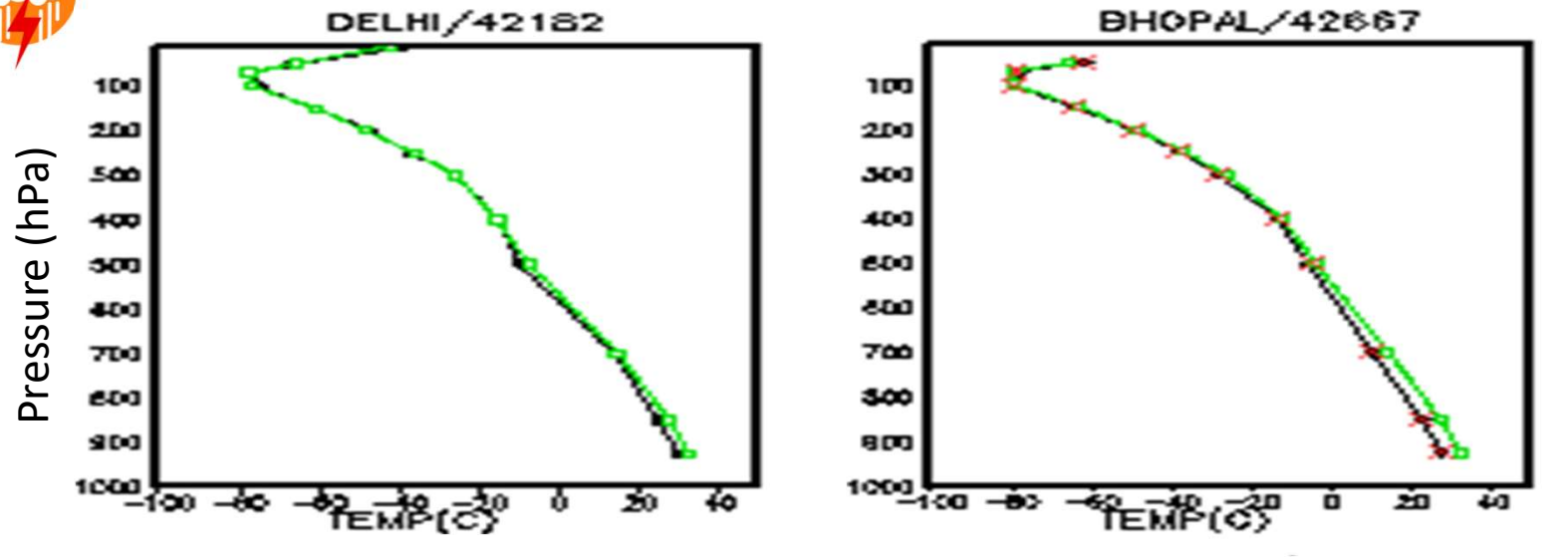
Upper air Observation coverage

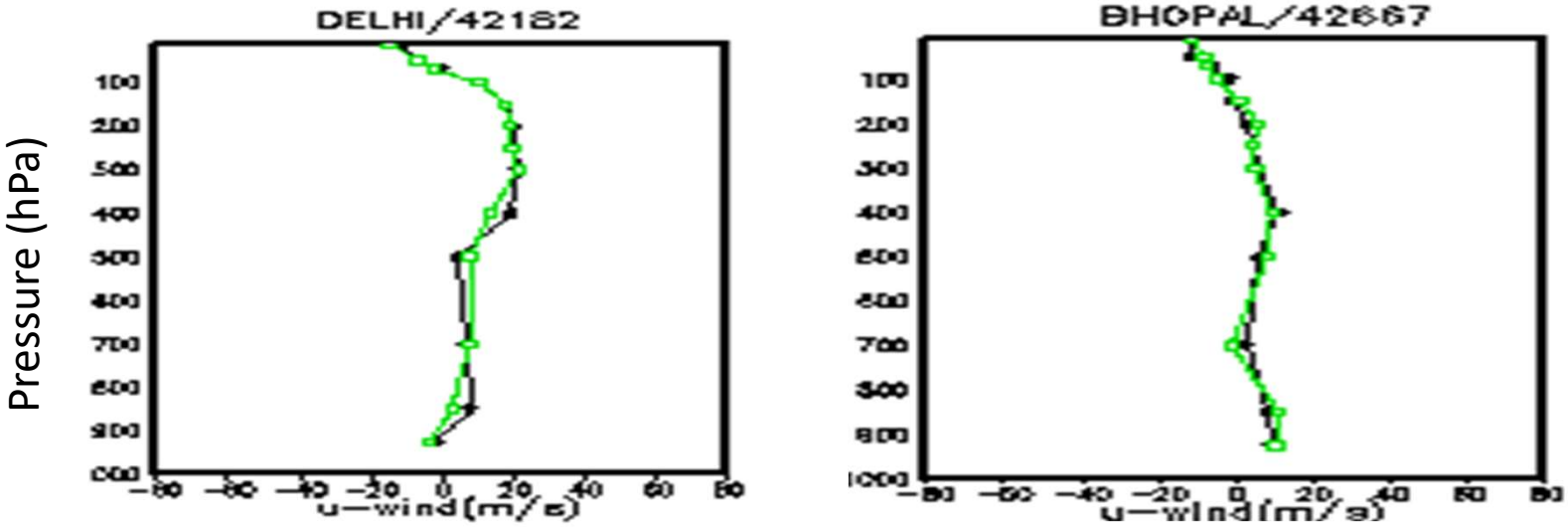


Geostationary satellite winds coverage



Radio sonde profiles





Observation **Model First Guess** **Rejection by data processing**

Observation Processing for NWP -II

Satellite radiance (brightness temperature) and GPSRO processing for NWP