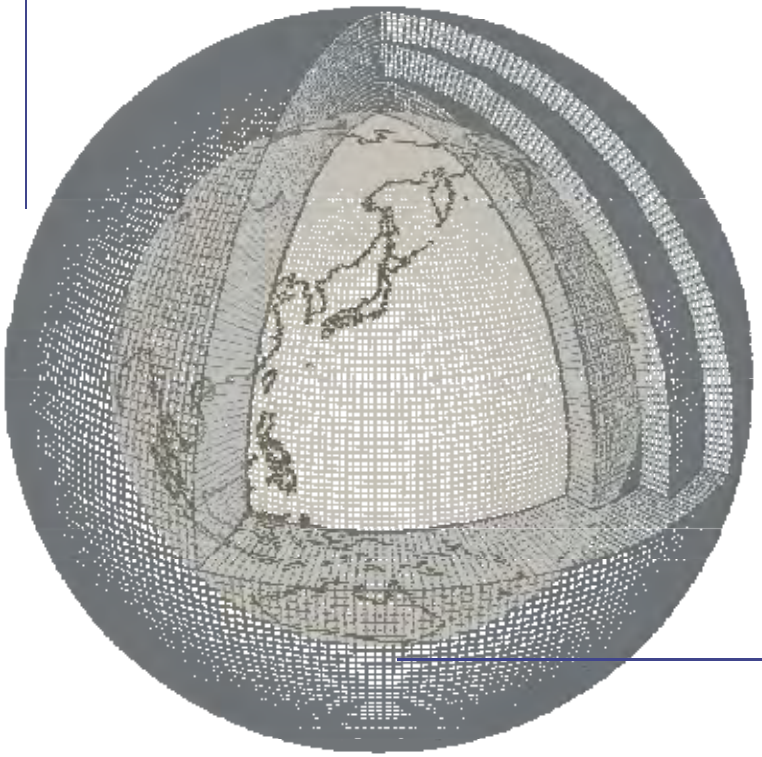
The Impact of Observational data on Numerical Weather Prediction



Hirokatsu Onoda
Numerical Prediction Division, JMA

Outline

- Data Analysis system of JMA

  in Global Spectral Model (GSM) and Meso-Scale Model (MSM)

- The impact of assimilated observations

  global view of the impact of observations on the quality of the forecast

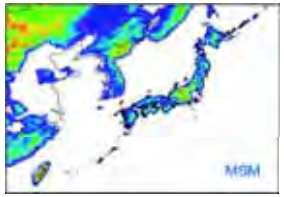
- Quality Control and inappropriate observation for NWP system

- Global Data Monitoring Report

Specification of NWP Models

JMA operates the following NWP deterministic models:

1) The Global Spectral Model (GSM) for the short and medium range forecast up to nine days ahead to cover the entire globe,
2) The Mesoscale Model (MSM) for warnings and the very short-range forecast of precipitation to cover Japan and its surrounding areas.

	Domains and topography	Grid size and/or number of grid, Vertical levels/top	Forecast hours (Initial time)	Initial condition
GSM	 Globe	0.1875 deg. (TL959), 60 / 0.1hPa	84 hours (00,06,18 UTC) 216 hours (12 UTC)	4D-Var analysis
MSM	 Japan and its surrounding areas	5km / 721x577, 50 / 21,800m	15 hours (00,06,12,18 UTC) 33 hours (03,09,15,21 UTC)	4D-Var analysis

Details of data use on NWP system

Observation type	Instrument	Global Analysis 650,000	Mesoscale Analysis 820,000
Conventional 20%	SYNOP	Pressure	Pressure
	AMeDAS*		Rain (Analyzed Rain)
	Ship, Buoy		sure
	RAOB		sure, Wind, Temperature, Relative Humidity
	Aircraft	Wind, Temperature	Wind, Temperature
Ground based remote sensing	Wind profiler	Wind	Wind
	Radar		Radar reflectivity (Analyzed Rain), Doppler velocity
	GPS		Total precipitable water
Satellite 80%	VIS IR radiometer	AMV, Radiance (clear sky)	AMV
	IR MW sounder	Radiance (clear sky)	Radiance (Temperature)
	MW imager	Radiance (clear sky)	Radiance (TPW, Rain rate)
	Scattrometer	Surface wind	Surface wind
	GPS-RO**	Refractivity	

Importance is still high

* Automated Meteorological Data Acquisition System ** GPS radio occultation

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Departure of observation and background

Definition of words

Background : forecast from previous analysis

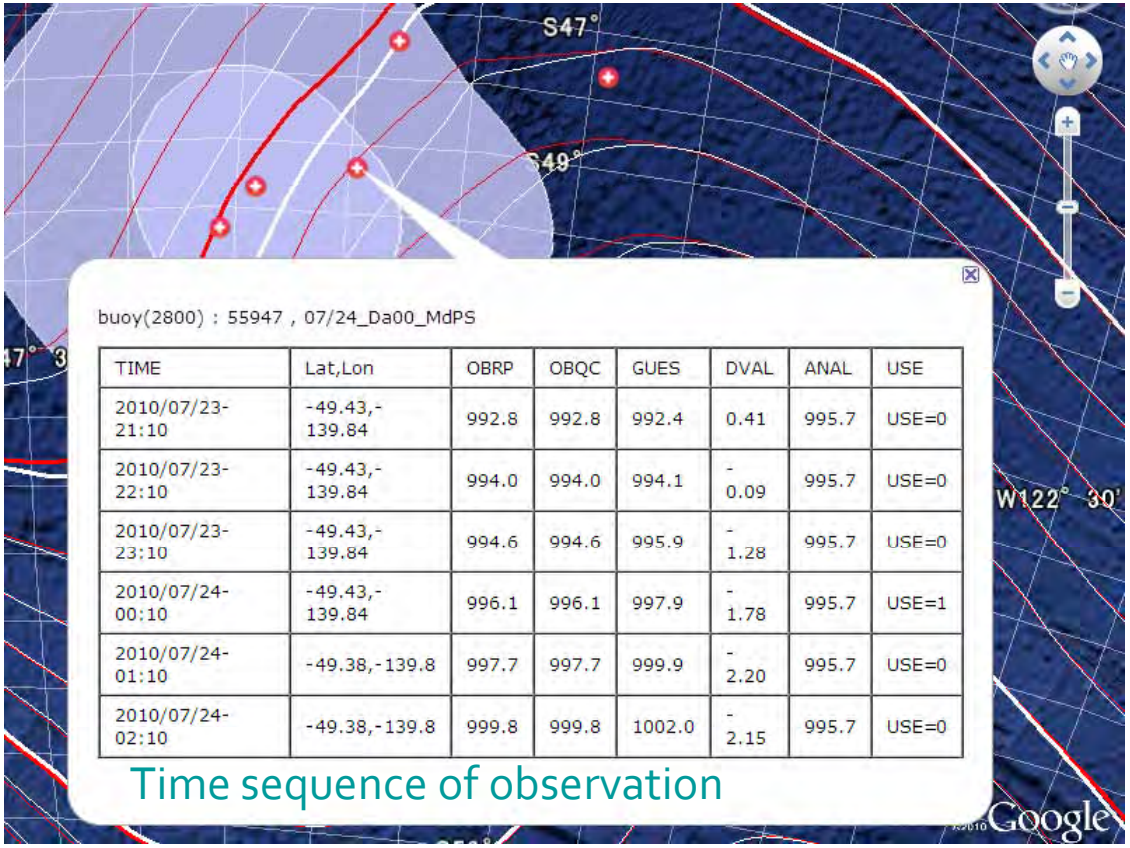
i.e. in GSM,

12UTC's background is 06UTC's 6-hour forecast.

O-B : (**O**bservation) – (**B**ackground)

usable for an index of the precision of the forecast or the observation

Basis of Data Analysis system



buoy(2800) : 55947 , 07/24_Da00_MdPS

TIME	Lat,Lon	OBRP	OBQC	GUES	DVAL	ANAL	USE
2010/07/23-21:10	-49.43,-139.84	992.8	992.8	992.4	0.41	995.7	USE=0
2010/07/23-22:10	-49.43,-139.84	994.0	994.0	994.1	-0.09	995.7	USE=0
2010/07/23-23:10	-49.43,-139.84	994.6	994.6	995.9	-1.28	995.7	USE=0
2010/07/24-00:10	-49.43,-139.84	996.1	996.1	997.9	-1.78	995.7	USE=1
2010/07/24-01:10	-49.38,-139.8	997.7	997.7	999.9	-2.20	995.7	USE=0
2010/07/24-02:10	-49.38,-139.8	999.8	999.8	1002.0	-2.15	995.7	USE=0

Time sequence of observation

White line : Background (input)
Red point : Observation (input)
Red line : Analysis (output)
Colored area : Increment (output)
*quantity of revision by analysis

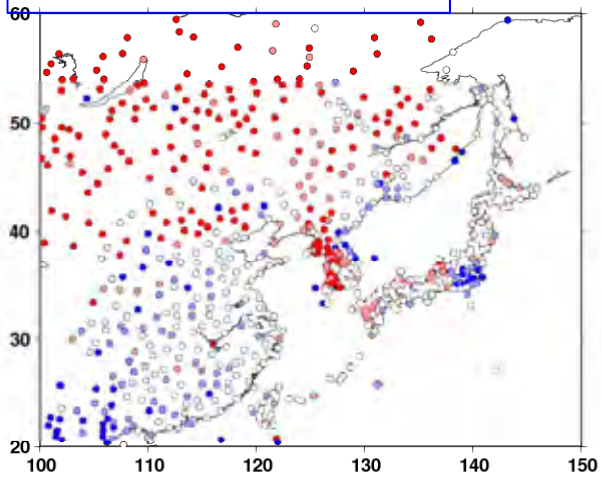
Schematic view of data analysis system (mean sea-level pressure)

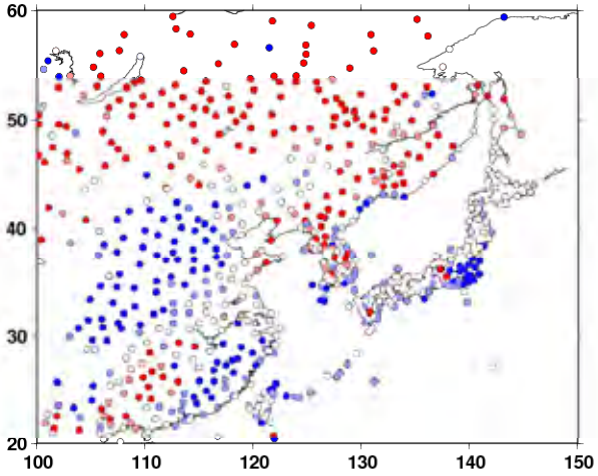
In data analysis system,

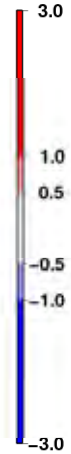
observation revise the error of the model based on departure of observation and background (O-B).

Experiment without ground-based conventional observation (SYNOP, Radiosonde) #1

OPERATIONAL





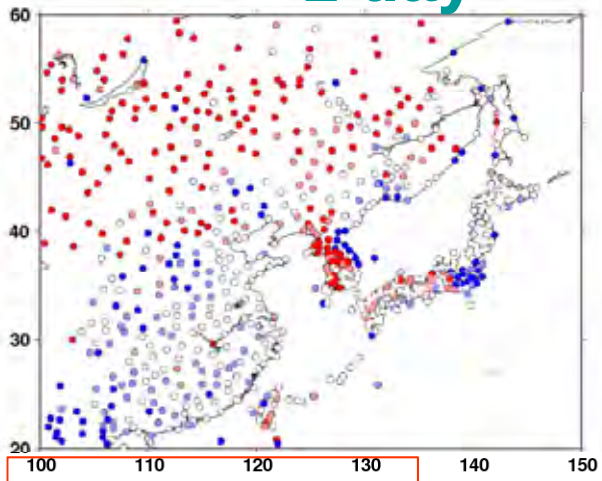


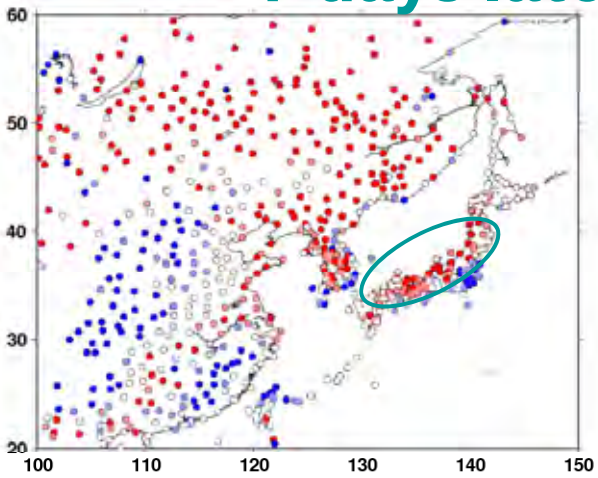
Mean Sea-Level pressure O-B at SYNOP stations.

Term of experiment:
from 20th Dec 2009
to 09th Feb 2010

1 day

7 days later

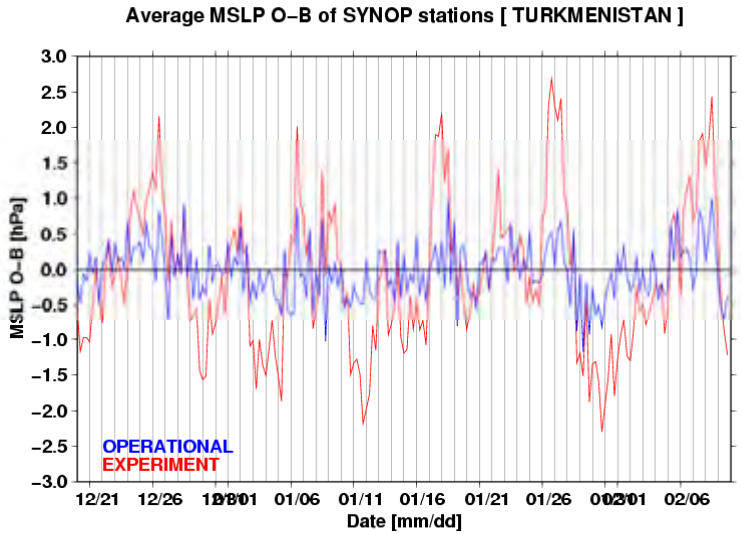


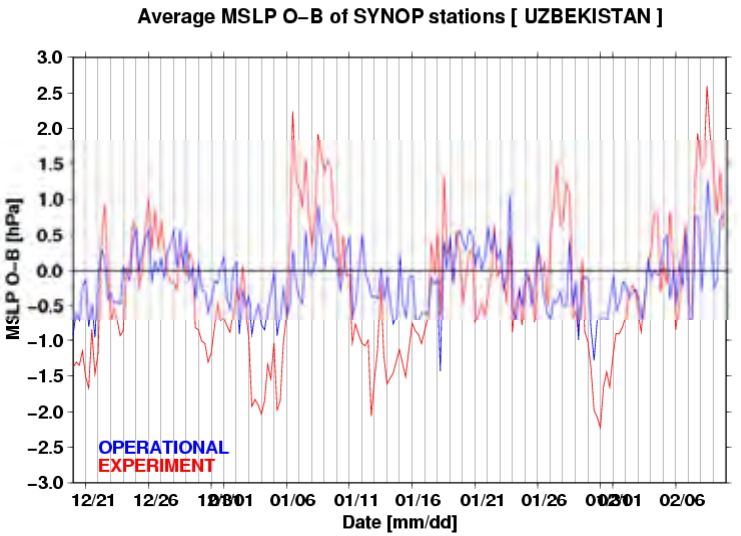


Difference of O-B increased through the analysis-forecast cycle. Continuous observation is important for forecast field.

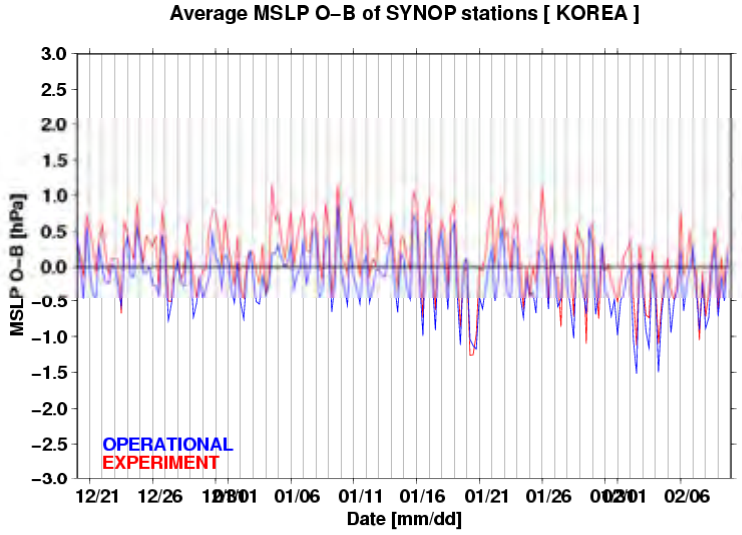
EXPERIMENT

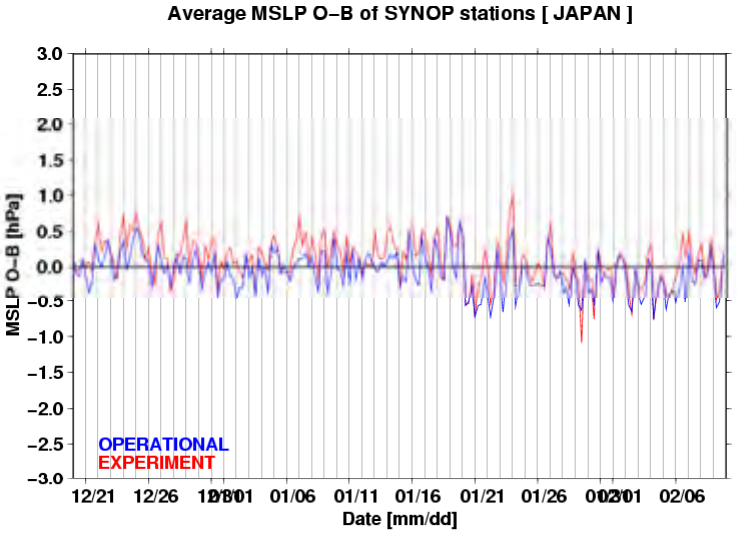
Experiment without ground-based conventional observation (SYNOP, Radiosonde) #2





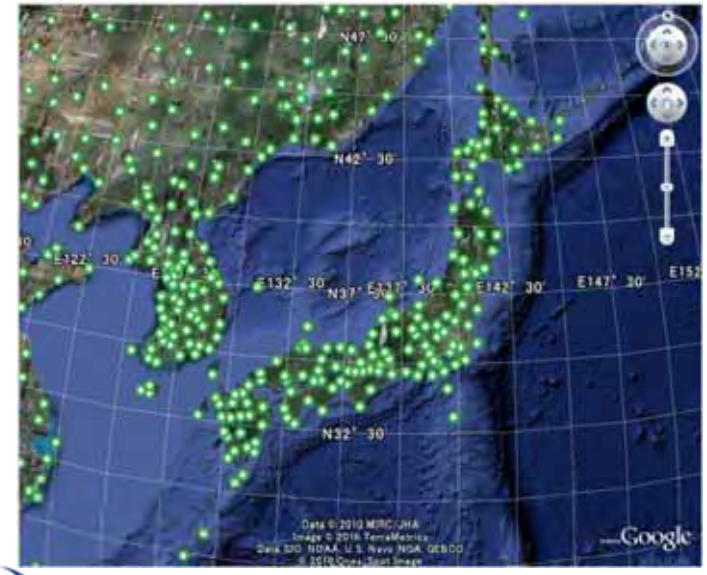
Large difference between OPERATIONAL and EXPERIMENT

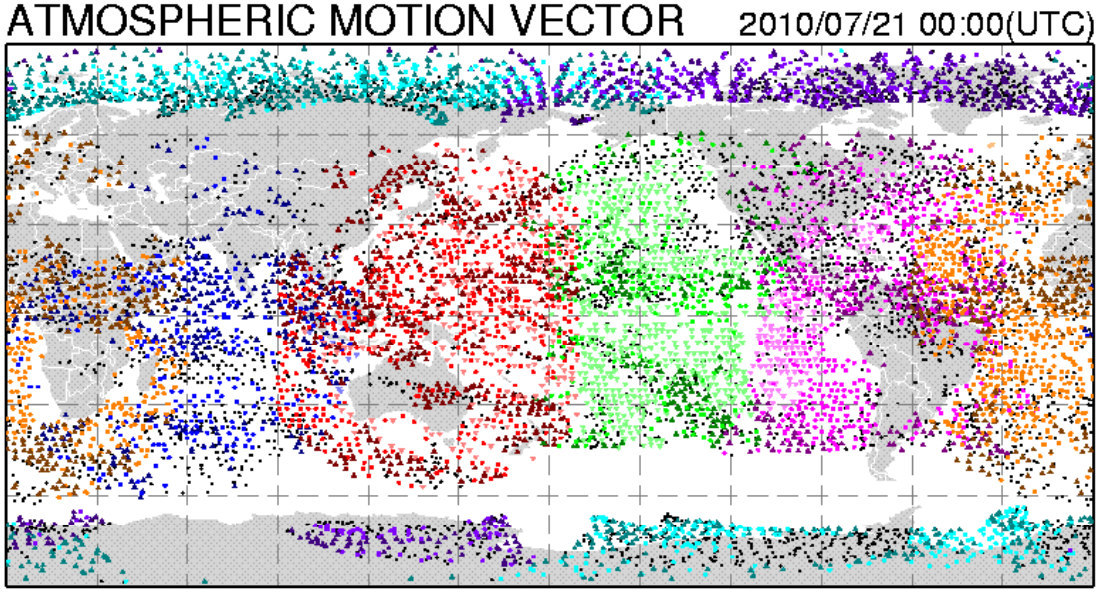




Small difference between OPERATIONAL and EXPERIMENT

Experiment without ground-based conventional observation (SYNOP, Radiosonde) #3





MTSAT-1	GOSE-11	GOSE-13	Meteosat-7	Meteosat-9	Terra	Aqua
IR[●]: 521	IR[●]: 227	IR[●]: 491	IR[●]: 252	IR[●]: 767	IR[●]: 334	IR[●]: 569
VS[▼]: 202	VS[▼]: 546	VS[▼]: 176	VS[▼]: 6	VS[▼]: 5		
WV[▲]: 559	WV[▲]: 220	WV[▲]: 270	WV[▲]: 316	WV[▲]: 507	WV[▲]: 513	WV[▲]: 772
NOUSE[●]: 307	NOUSE[●]: 666	NOUSE[●]: 828	NOUSE[●]: 357	NOUSE[●]: 605	NOUSE[●]: 483	NOUSE[●]: 798
ALL: 1589	ALL: 1659	ALL: 1765	ALL: 931	ALL: 1884	ALL: 1330	ALL: 2139

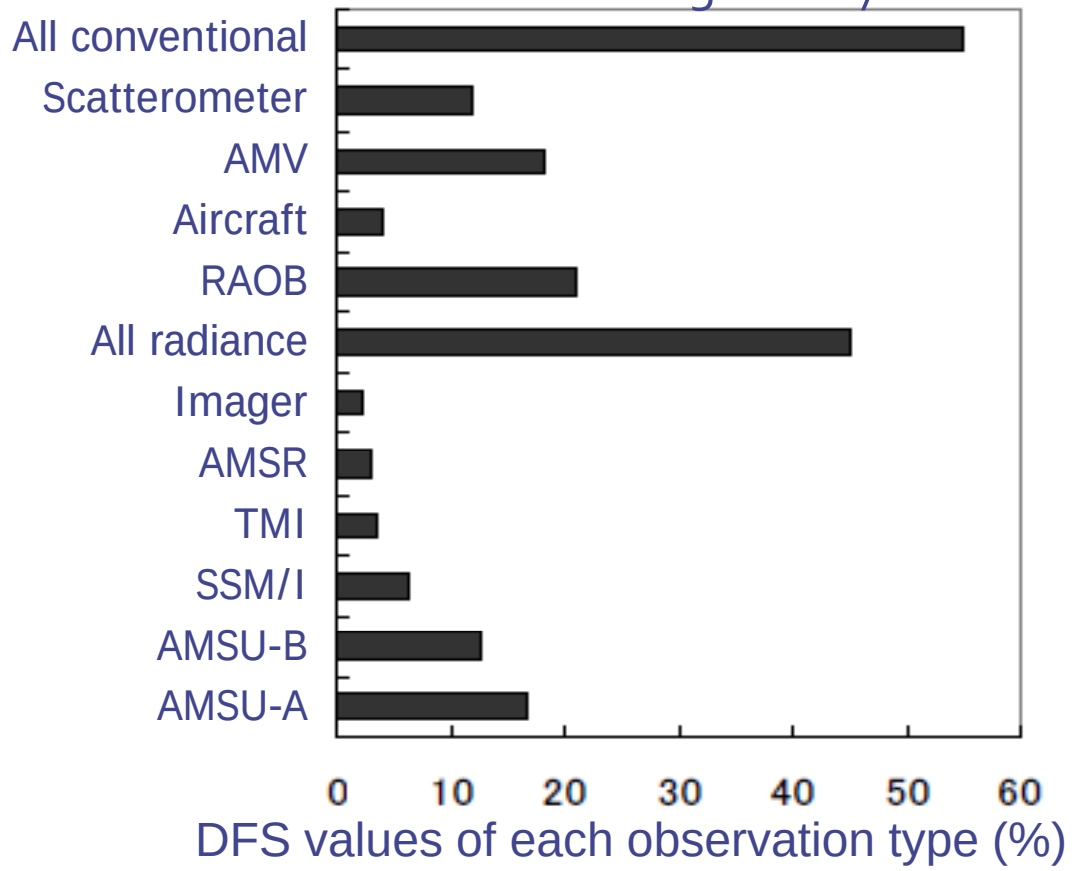
- Density of the observation point may be important.
- Satellite observation makes the land a weak point.

DFS (Degrees of Freedom for Signal)

Which type of data had the greater influence?

Langland and Baker suggest
to estimate the observation impact.

Investigated by JMA



Large DFS means large impact to forecast.
Small DFS means small impact to forecast.

Conventional data still plays important roll.

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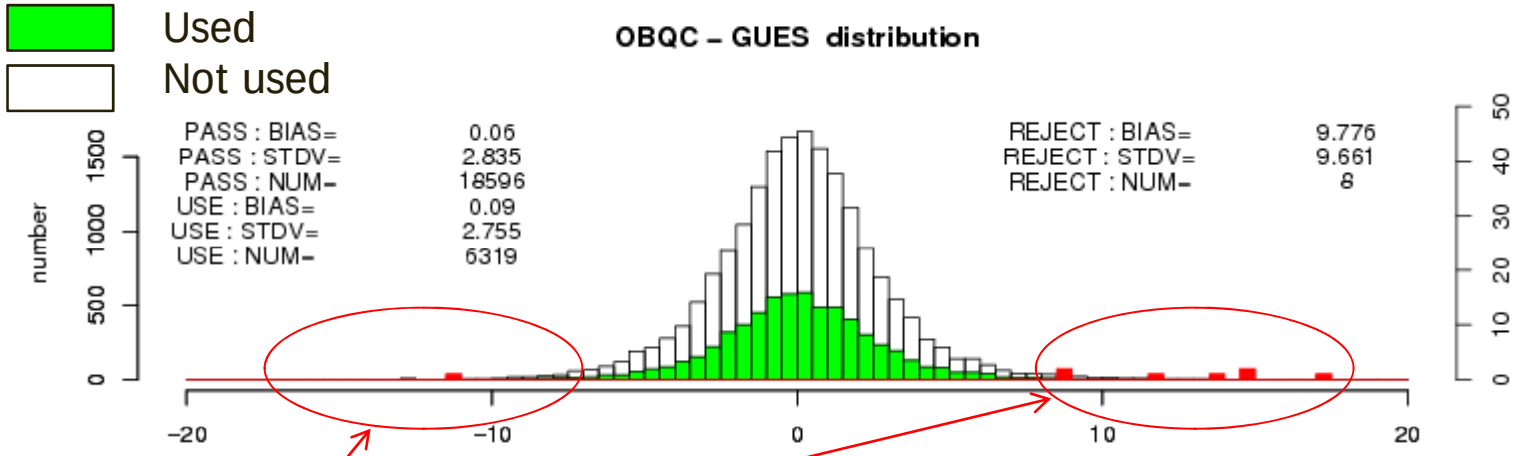
Quality Control (QC) of observational data

Observational data includes false report or deviating from a background.



Δu for Wind Profilers, 1 ～ 10 October 2009, 900～800hPa

To reject these data,
JMA perform **Quality Control (QC)**.

Real-time QC (automatic)
Non real-time QC (manual)

Real-time QC

First Step

- climatologically check
- ship/flight path check
- bias correction
- wind correction
- T lapse rate
- interpolation (T,RH,wind)
- hydrostatic check
- ice (freezing)
- wind shear
- sea-level correction

Etc.

Second Step

- Gross error check

Reject rough error
human error
instrumental malfunction
communication error
etc.

- Spatial consistency check

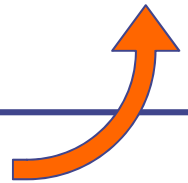
Compare with surrounding observations

Etc.

Non real-time QC

Sometimes, data of low quality pass real–time QC.

→ real-time QC is not perfect.

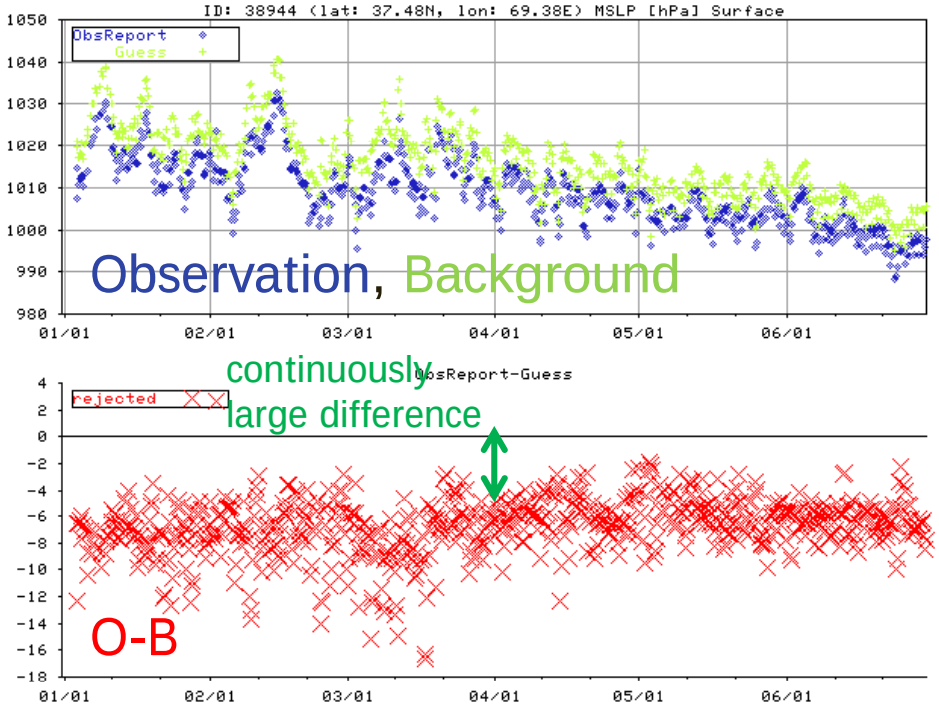


Blacklist is managed for these case.

- Blacklist needs careful monitoring, and is updated when
  [add]
  Platforms (stations, airplanes, ships, etc.) found to report biased or erratic observations
  [remove]
  The quality has returned to an accepted standard

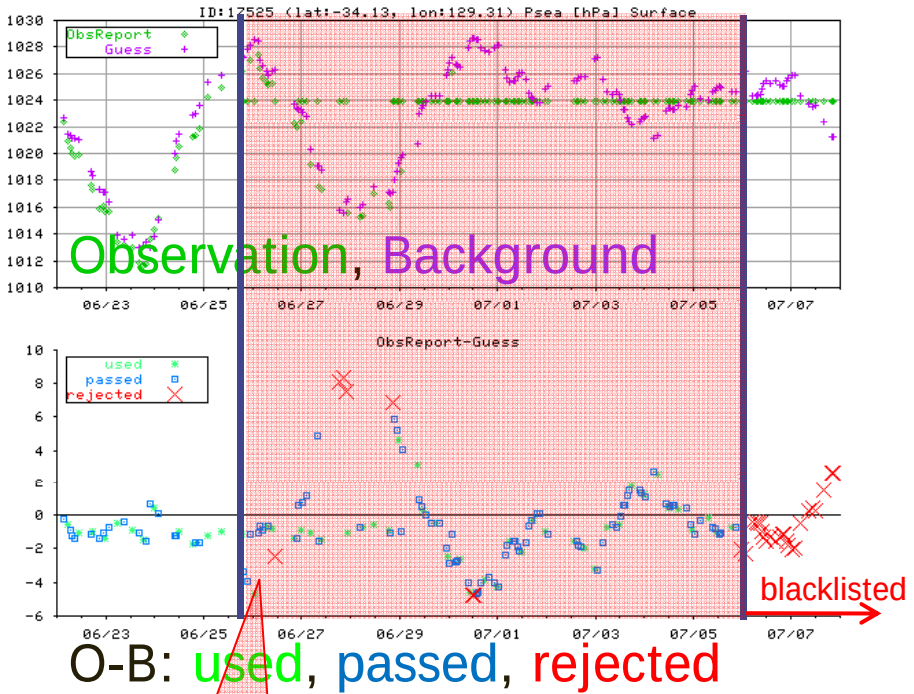
- Blacklisted observations are rejected before real-time QC procedures.

Examples
SYNOP,SHIP,BUOY : trouble of instrumentation



Time sequence of Mean Sea-Level pressure of SYNOP (WMO-ID:38944) from January to June 2010.

Easy case to reject in real-time QC.

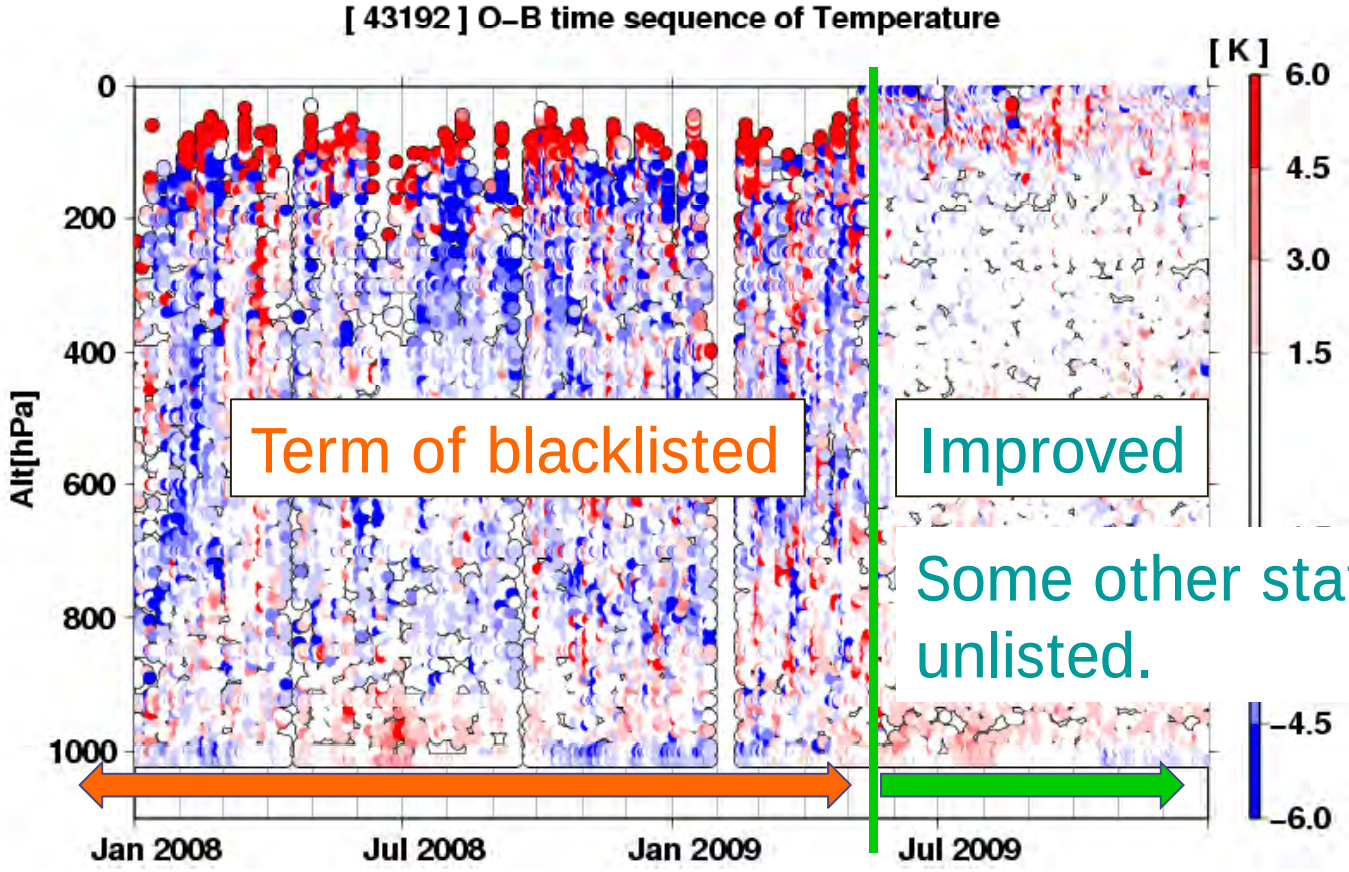


Time sequence of Mean Sea-Level pressure of Buoy (Call sign:17525) from 22nd June to 8th July 2010.

Difficult case to reject in real-time QC.

Inappropriate data were used in operational.

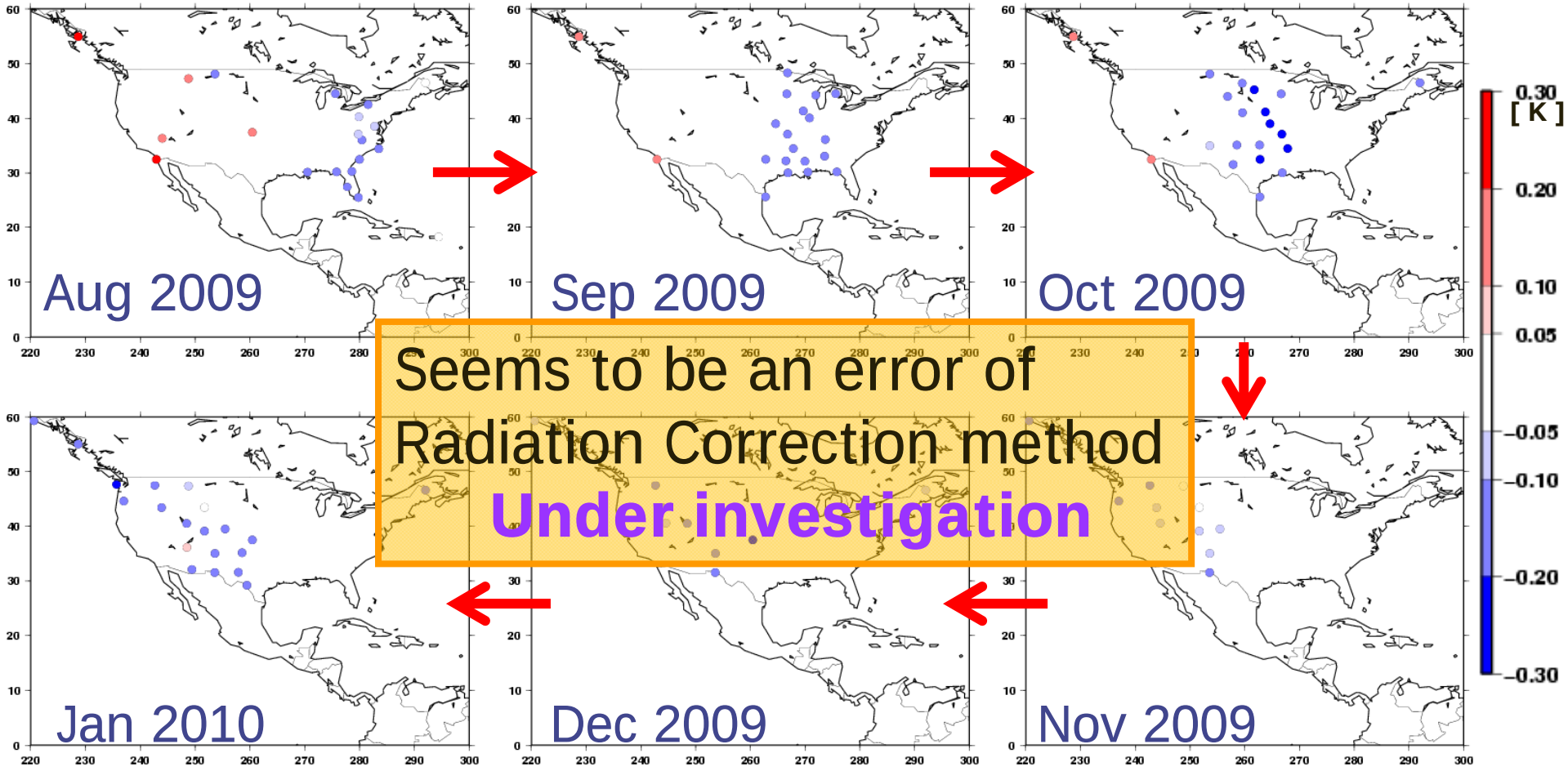
Radiosonde :
Quality of Indian Radiosonde observations has improved



Time sequence of temperature O-B vertical profile from Jan 2008 to Dec 2009 at WMO-ID:43192 .

At spring 2009, O-B became small suddenly.
Supplier of instrument has changed.

Radiosonde : Moving bias of US radiosonde observations

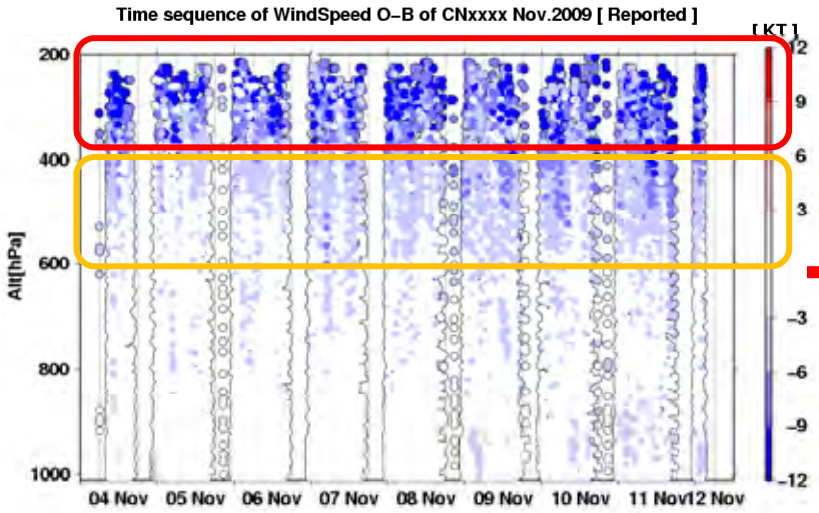


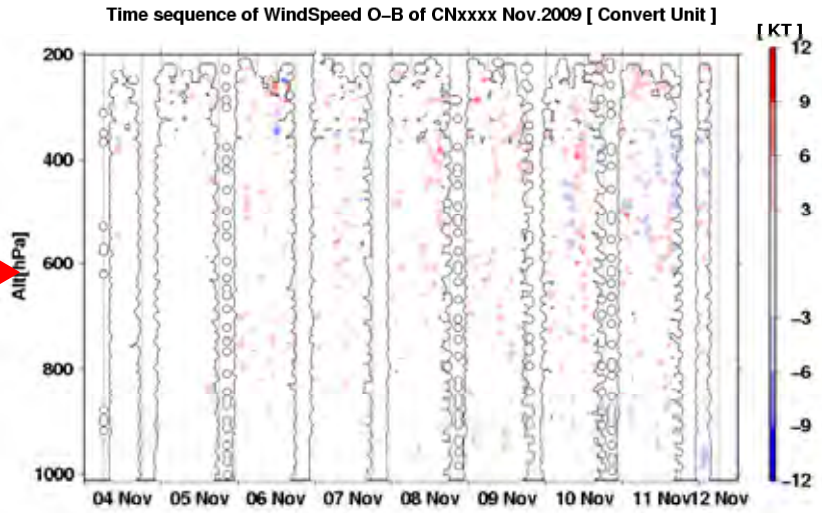
Seems to be an error of Radiation Correction method

Under investigation

Monthly average of T200 O-B from Aug 2009 to Jan 2010.
Negative values (lower observations) moving westward.

Aircraft : Mistake of the report format





Wind speed O-B profile of
CNxxxx (xxxx : number) at China.
There is negative bias in upper air.
Term: 4^{th} – 12^{th} Nov 2009

Large biased observation was rejected
Small biased observation was used
in operational system.

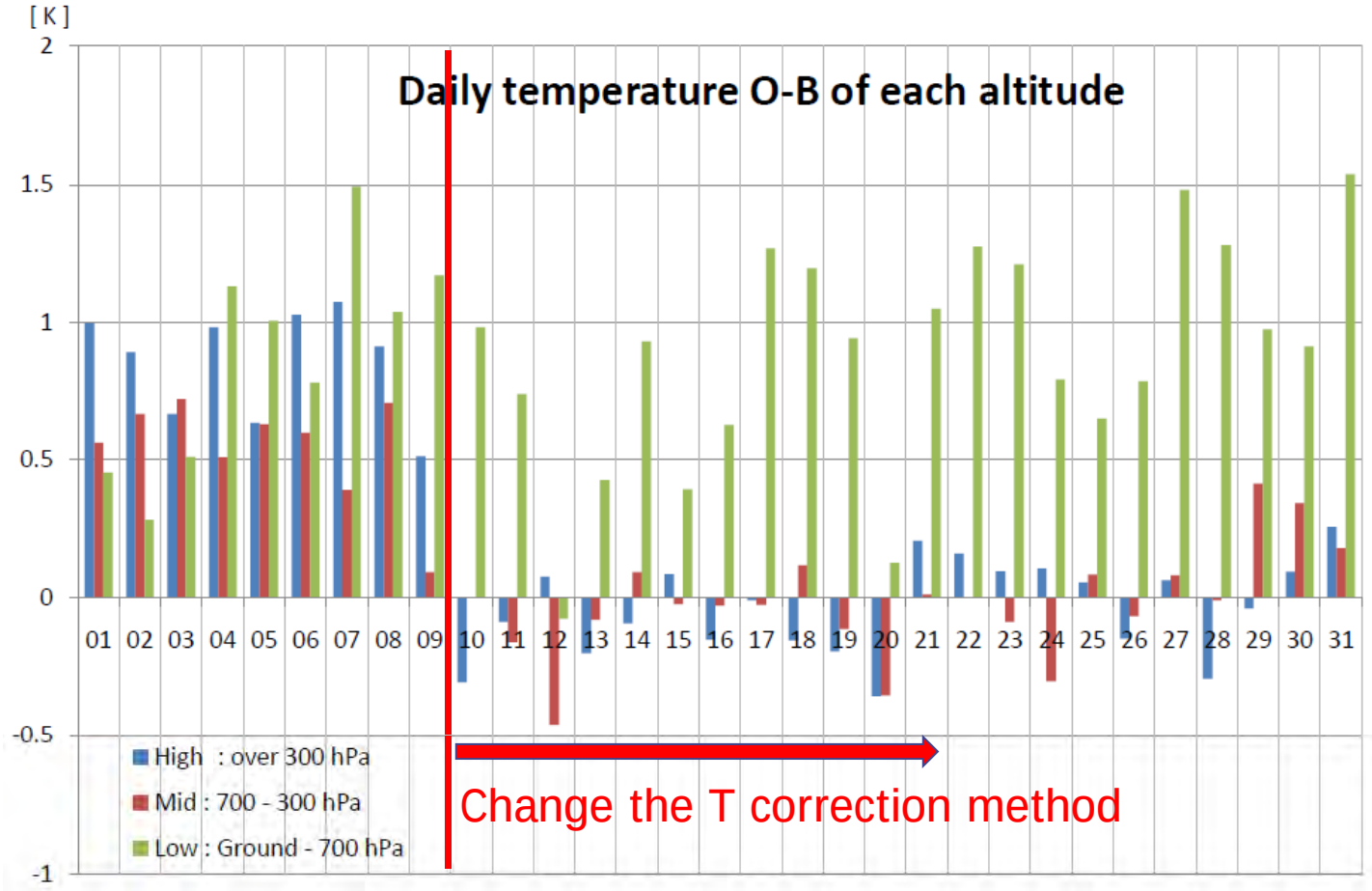
By the later investigation:

Convert unit of wind speed
from [m/s] to [Knot].
(Suppose that
reported unit were "m/s".)

↓

Negative bias is disappeared.
The guess might be right.

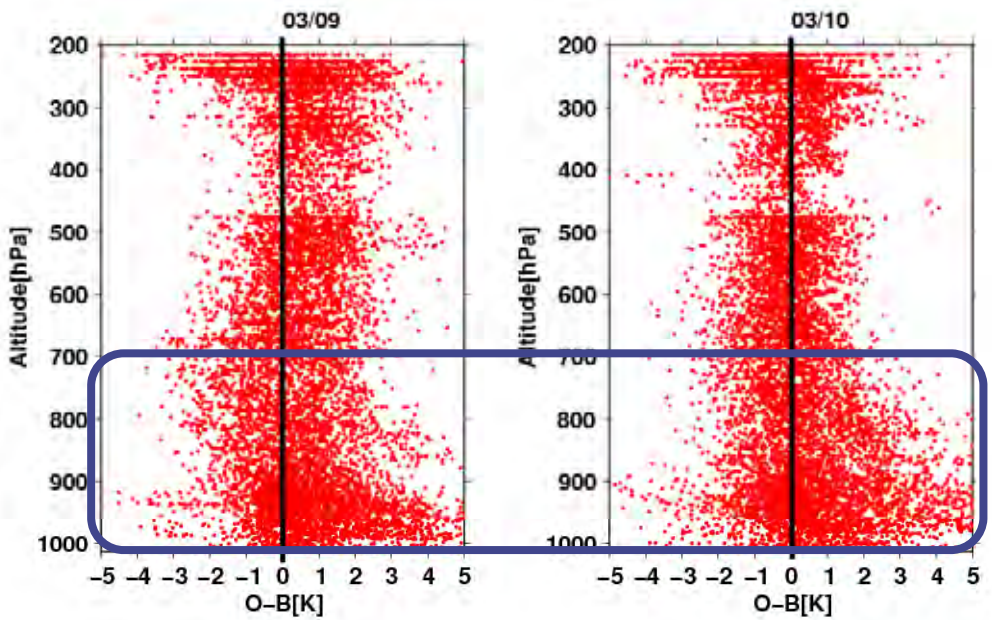
Aircraft : The change of correction method by airline



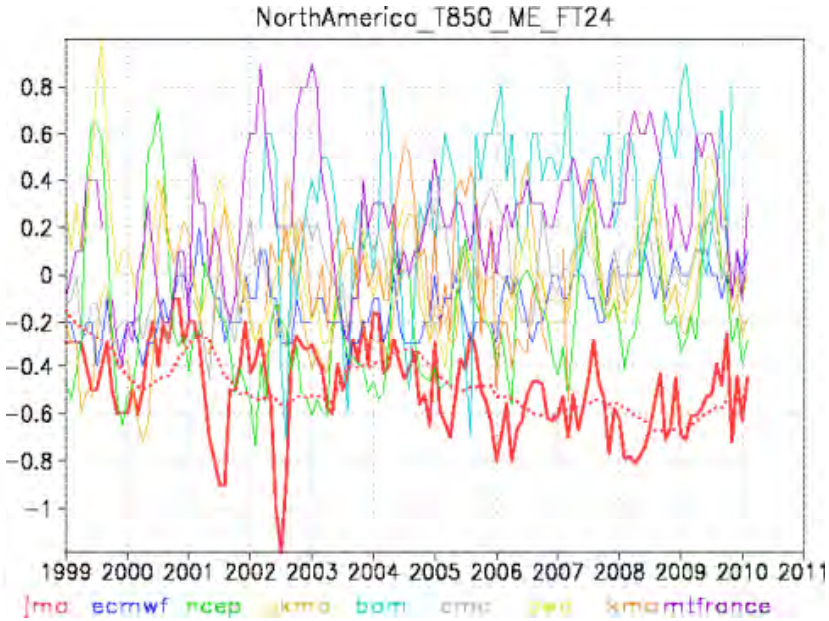
Southwest Airline (SWA; USA) changed the method of temperature correction from 10th Mar 2010.
86 airplanes correspond to this case.

Improvement of O-B is found especially High and Middle(Mid) altitude.

Is it Observation error or Model error ? #1



Temperature O-B scatter plot at 9th and 10th March 2010.
Many points came to gather in the graph center.



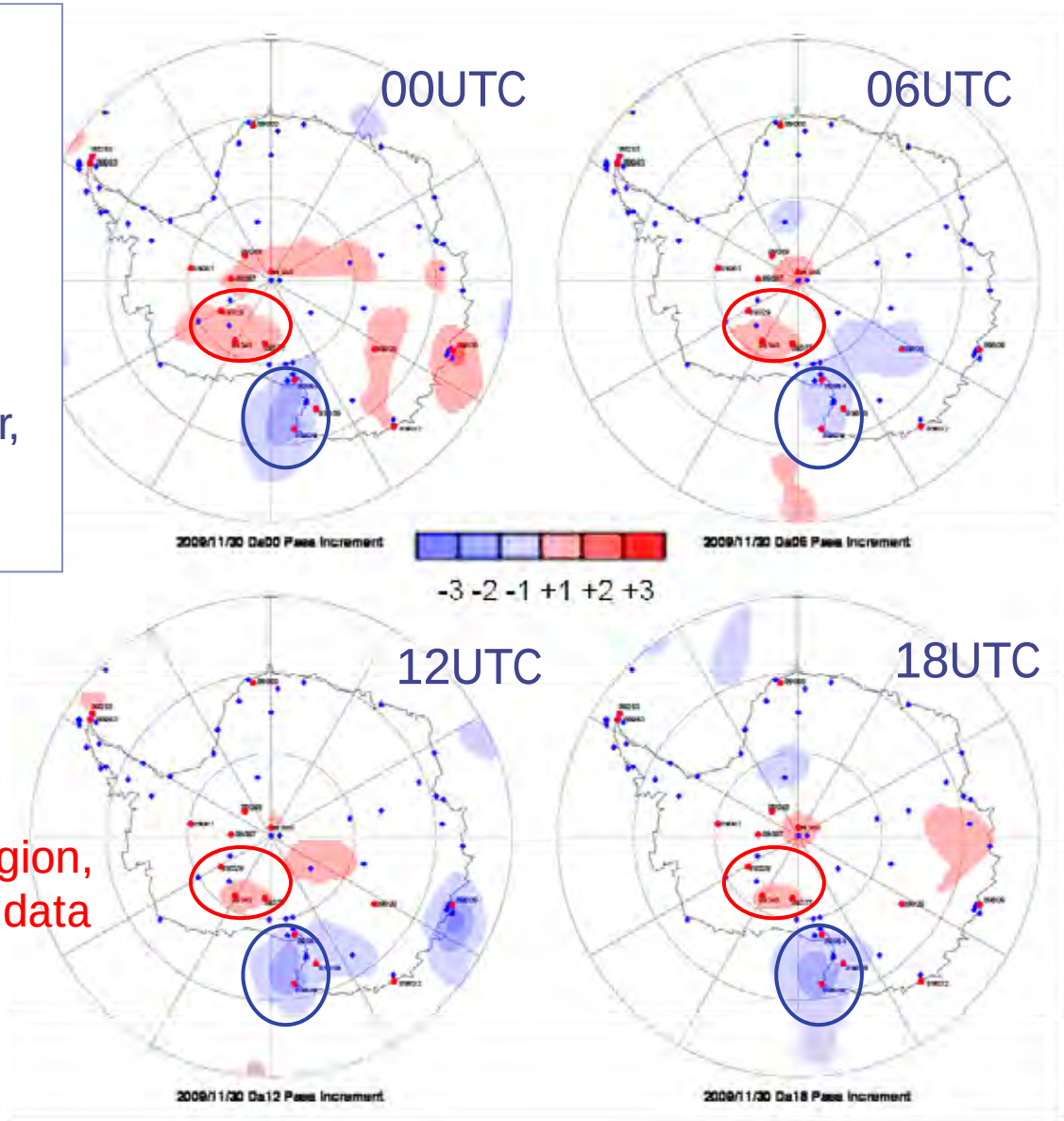
Inter-comparison of T850 at North America for forecast time 24h.
JMA (red line) may have lower bias of temperature.

There are not many changes at lower altitude.

Is it Observation error or Model error ? #2

Increment (quantity of revision by analysis) map of Mean Sea-Level pressure on Antarctica at 00,06,12,18 UTC analysis, 30th Nov 2009.

It seems to be a model error, because some stations suggest similar O-B.



Antarctica is data sparse region, real-time QC hard to reject data with large difference from background.

Summary

- The ratio of conventional data has become **small**,
  but the importance is still **high**.

- **Continuous observation** and **the maintenance of the network** are necessary.

- **QC** plays an essential part in maintaining the quality of the initial value and forecast field.

- QC is composed real-time and non real-time QC.
  Blacklist is kept for non real-time QC.
  Important to be careful to **the changes of the data tendency**.
  The correct format and **unbiased** reporting is needed.

- Difficult to discriminate
  whether **errors are related to observation or to the model**.

Request to Observation from NWP system

Good product of weather forecasting needs good analysis.
Good analysis needs good observation.
Good observation needs the cooperation of many people.

- We need to keep **high quality** observation **for NWP system.**
  - Continuous observation
  - Maintenance of the dense observation network
  - Recovery from instrumental malfunction (as soon as possible)
  - The correct format reporting
  - Unbiased observation
  - Information when the station changes (latitude, altitude, height …)
    - * information of position is extremely important.
  - Information of the instrumental changes

- High quality observation **enables to be better forecast**.
  - enables to make good analysis
  - enables to use inspection of models

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Data monitoring report

JMA publishes following reports ;

- Monthly Global Monitoring Report

  JMA reports suspected observations of low quality through our NWP system once a month.

- Report on the Quality of Land Surface Observations in Region II (Asia)

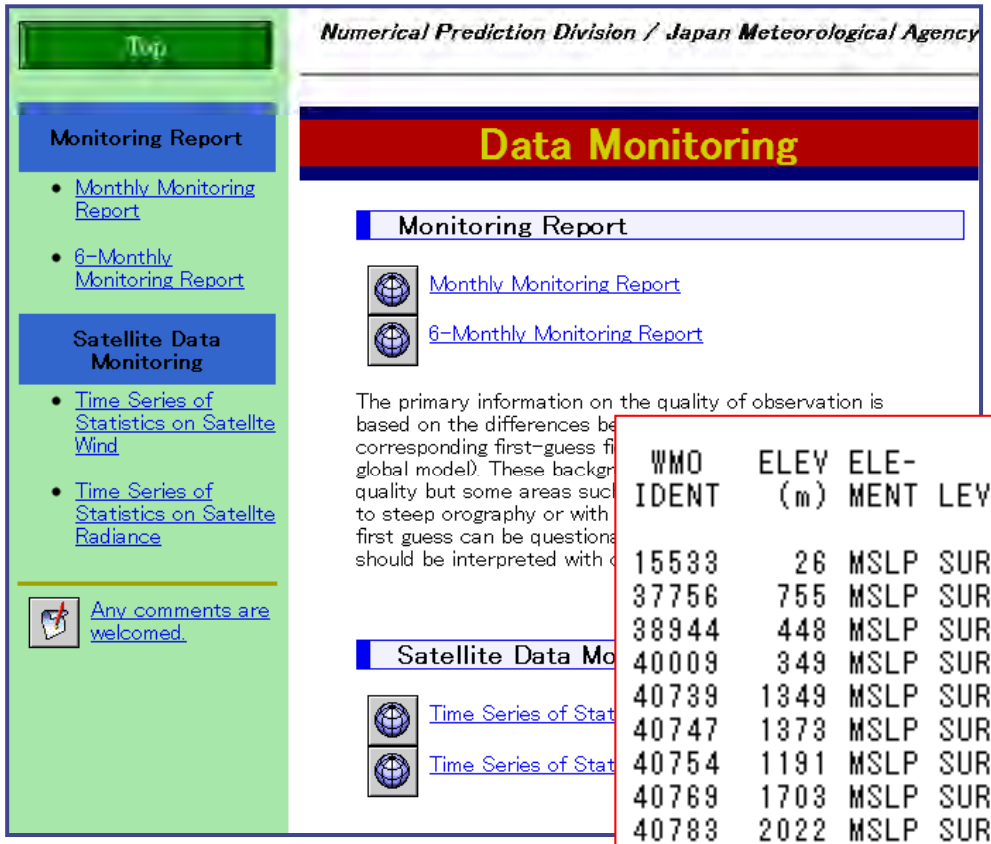
  RSMC Tokyo publishes it in a half year as a lead center for monitoring the quality of land surface observations.

Using these reports,
we want you to make use for maintenance of the high quality observation.

website

These reports are shown in following Website.
Anyone can access without a password.

http://qc.kishou.go.jp



WMO IDENT	ELEV (m)	ELE-MENT	LEVEL	NUM OBS	NUM GRS	% GRS	% REJ	SD	BIAS	RMS
15533	26	MSLP	SUR	120	0	0	0	0.8	-4.3	4.4
37756	755	MSLP	SUR	94	0	0	24	1.8	4.5	4.8
38944	448	MSLP	SUR	117	0	0	100	1.3	-6.3	6.4
40009	349	MSLP	SUR	112	1	1	0	1.5	-4.2	4.5
40739	1349	MSLP	SUR	104	0	0	0	2.2	-4.2	4.7
40747	1373	MSLP	SUR	48	0	0	2	2.1	-4.2	4.7
40754	1191	MSLP	SUR	106	0	0	2	1.9	-4.3	4.7
40769	1703	MSLP	SUR	88	0	0	2	3.5	-4.0	5.3
40783	2022	MSLP	SUR	48	0	0	2	3.4	-4.6	5.7
40800	1550	MSLP	SUR	102	0	0	2	3.2	-5.0	5.9

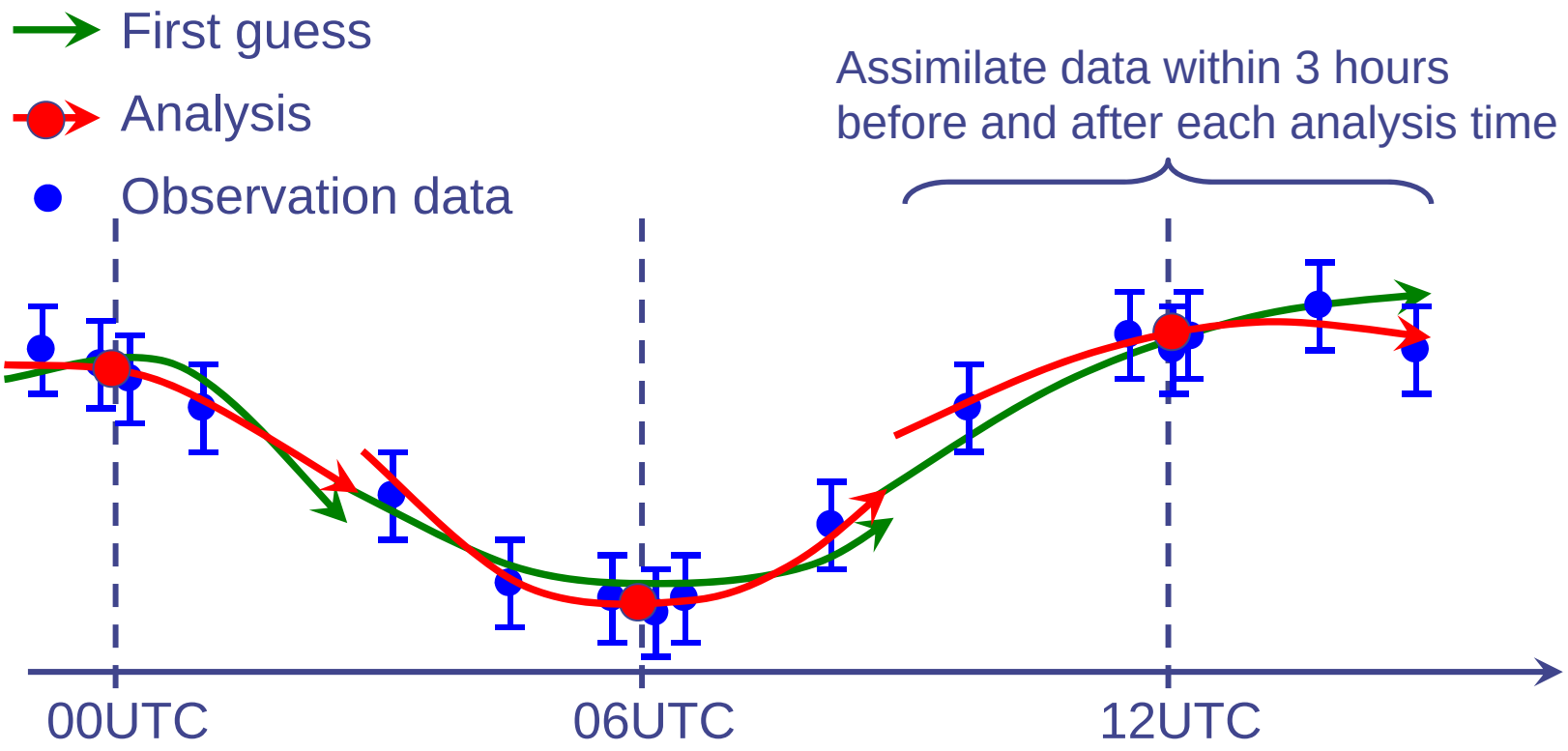
Thank you for your attention.

Please be careful to avoid heat strokes.

Contact us
E-mail : qc@naps.kishou.go.jp

Additional slides

Four-Dimensional Variational Analysis (4D-Var)



Forecast from previous analysis is used as a first guess.

Departure between model trajectory and observations over 6-hour assimilation window are measured (cost function).

Then, model trajectory that minimizes the departure is sought. Analyzed field at target analysis time is obtained as forecast field at that time.

Observation Impact Methodology (Langland and Baker, 2004)

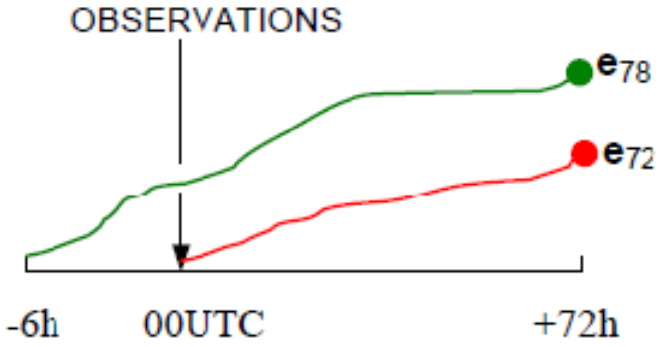


Fig. 1: Observations are assimilated at 00UTC, creating ICs for a new trajectory, which has forecast error $\mathbf{e}_{72}$. The old trajectory starts from 18UTC (-6h), and has forecast error $\mathbf{e}_{78}$. It also provides the background for the analysis at 00UTC.

Observations are assimilated in a 6-h update cycle. If there are no observations at 00UTC, **e**72 will be equal to **e**78.

The difference in forecast error norms, (**e**78- **e**72), is due to the combined impact of all observations assimilated at 00UTC

Using sensitivity gradients from two forecast trajectories, we can estimate the forecast error difference, $^{TM}\mathbf{e}f = \mathbf{e}72 - \mathbf{e}78$, using following equation.

$$\delta \mathbf{e}_f = \left\langle (\mathbf{y} - \mathbf{H}\mathbf{x}_b), \frac{\partial J_{72/78}}{\partial \mathbf{y}} \right\rangle$$

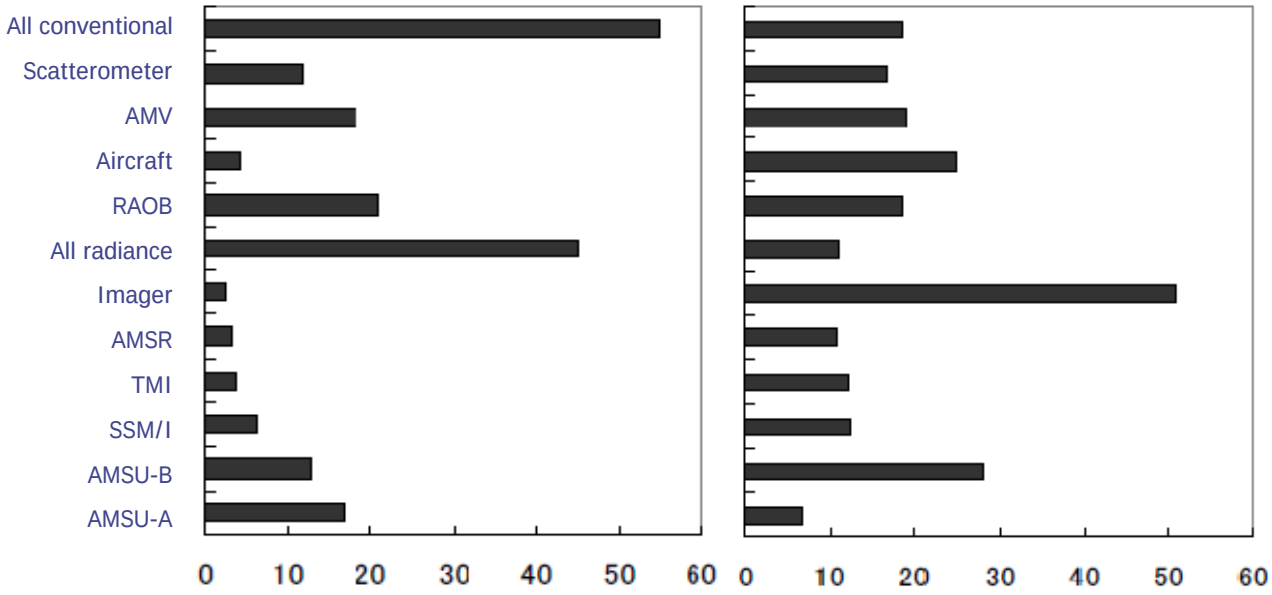
The quantity ($\mathbf{y} - \mathbf{H}\mathbf{x}b$) is the observation departure from the background state, and **H** is an operator that performs spatial interpolation of the background into observation space.

DFS (Degrees of Freedom for Signal)

The global observation impact can be considered as the sum of contributions made by all individual observations.

Best Linear Unbiased Estimator (BLUE) approach ;

- Define a linear estimator
- Impose the condition to be unbiased



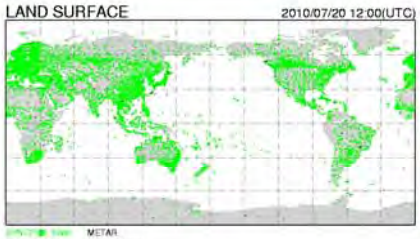
DFS values per obstype (%)

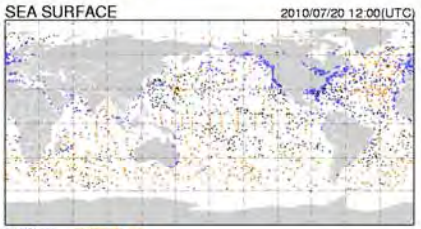
per one report (‰)

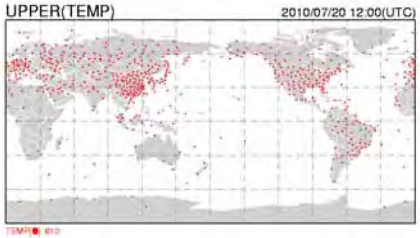
These results were investigated in JMA (Ishibashi, JMA)

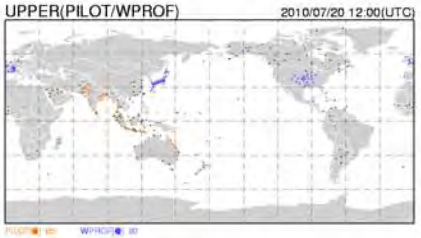
Data coverage map (global)

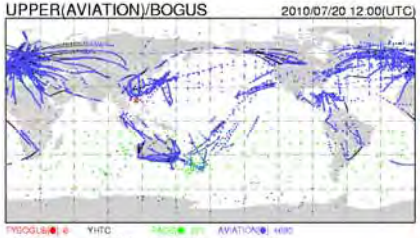
JMA GLOBAL ANALYSIS – DATA COVERAGE MAP – 1 (Da12ps): 2010/07/20 12:00(UTC)

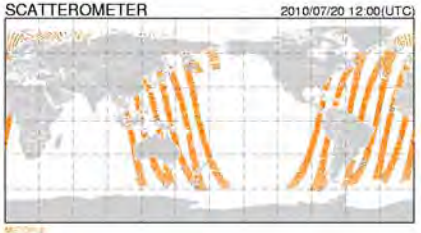


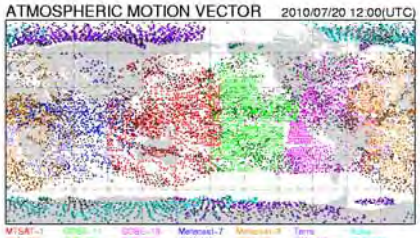


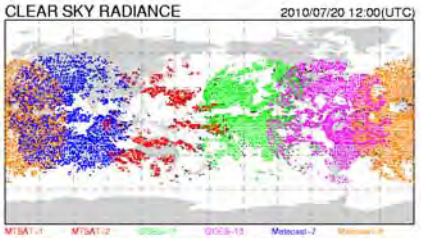




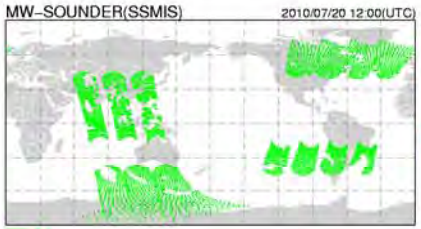


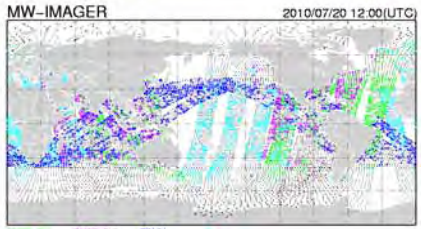


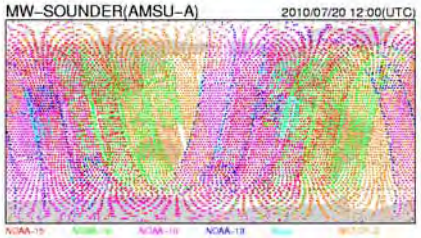


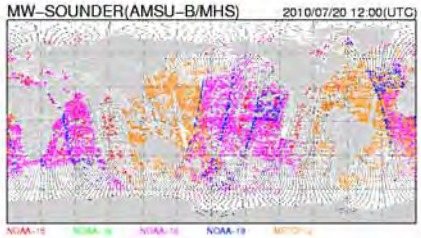


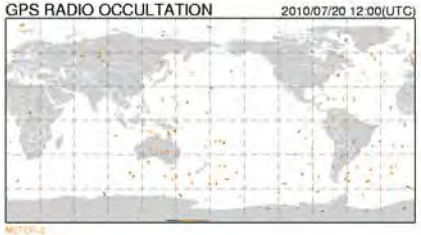
JMA GLOBAL ANALYSIS – DATA COVERAGE MAP – 2 (Da12ps): 2010/07/20 12:00(UTC)



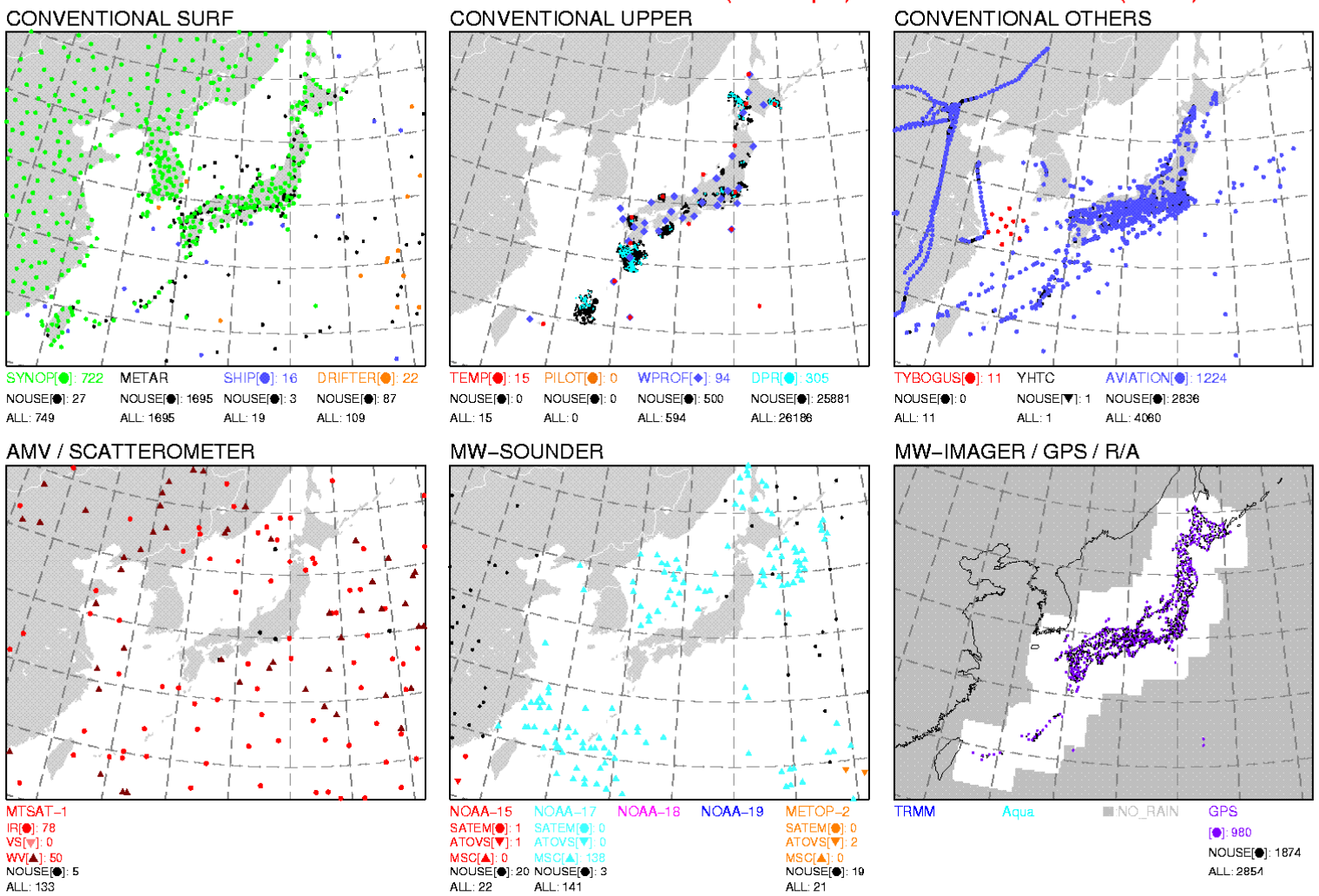








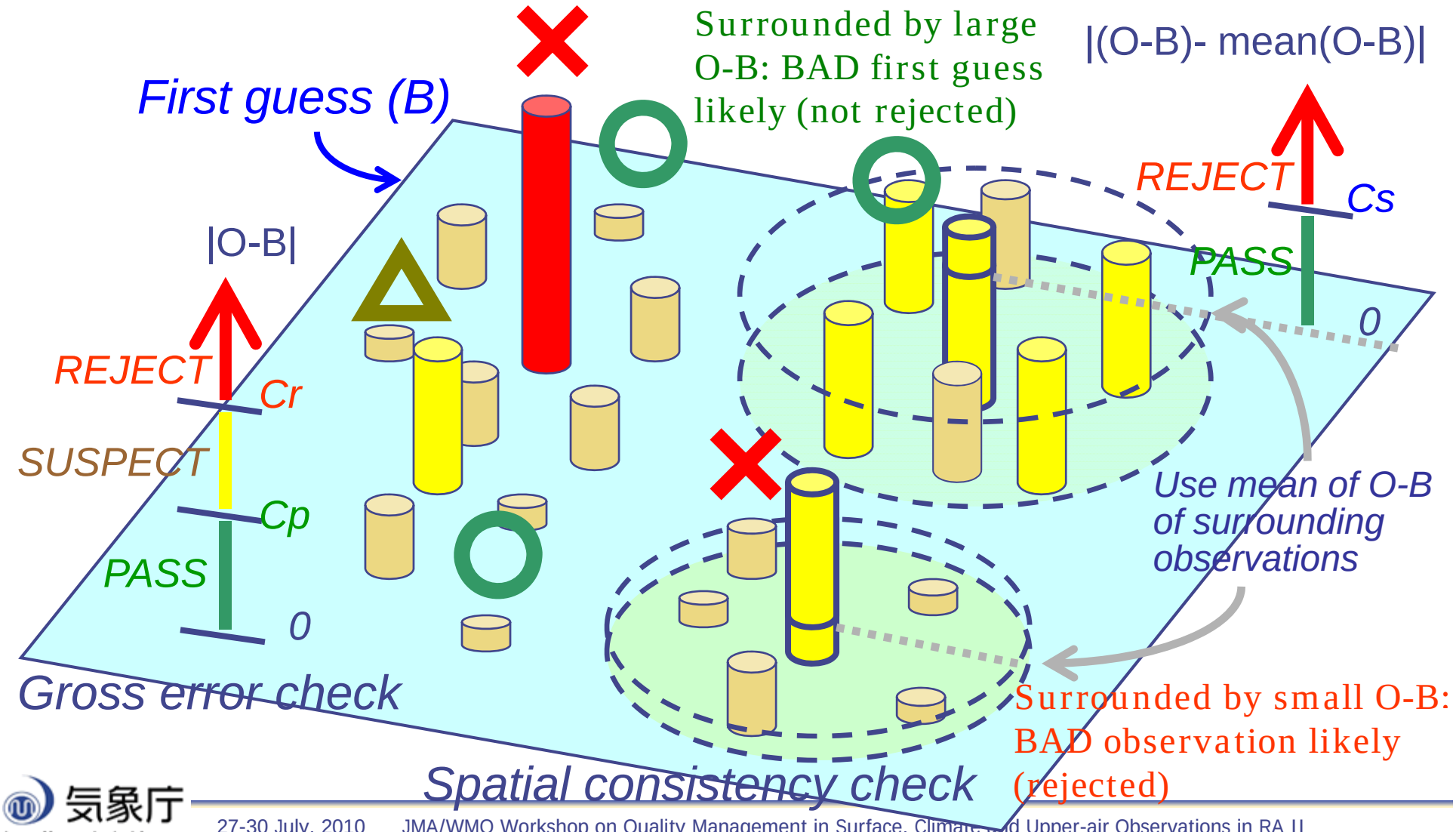
Data coverage map (regional)

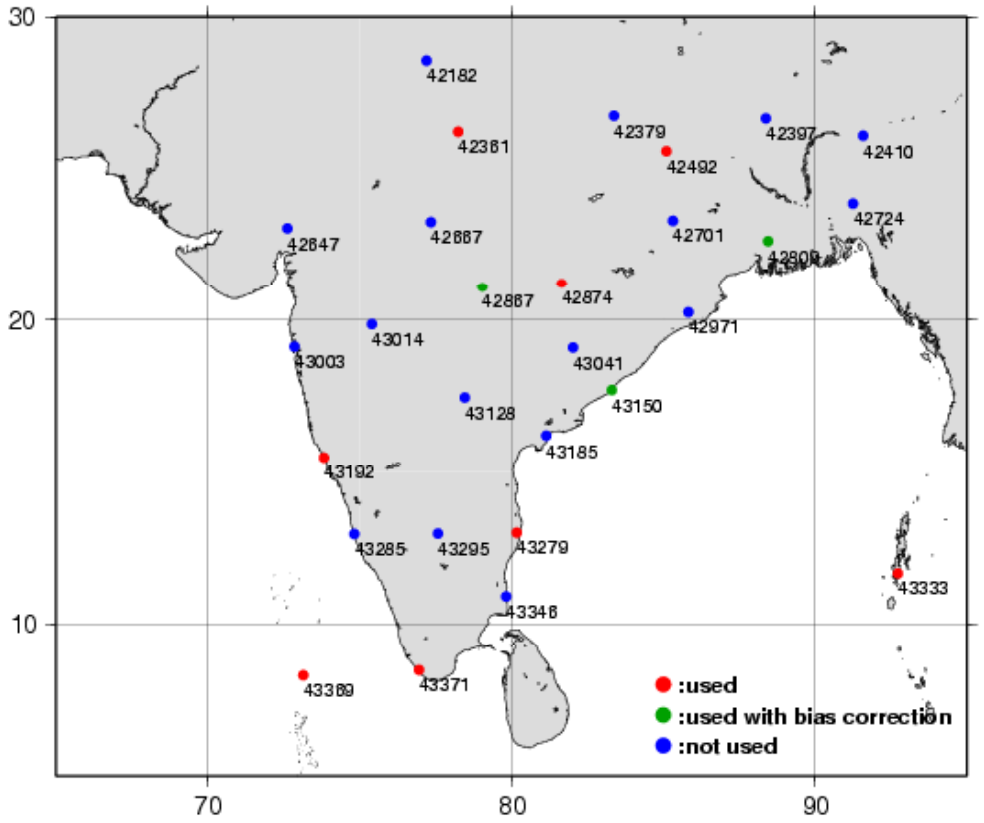


Gross error check, Spatial consistency check

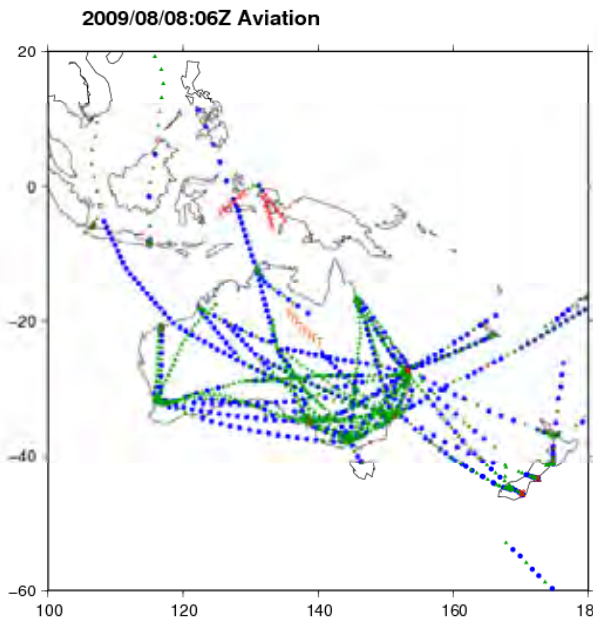
Check each obs

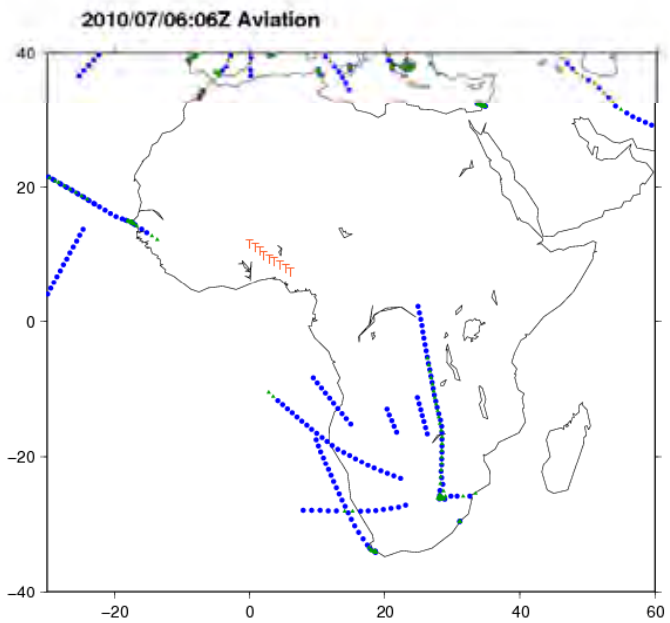
O-B are checked.



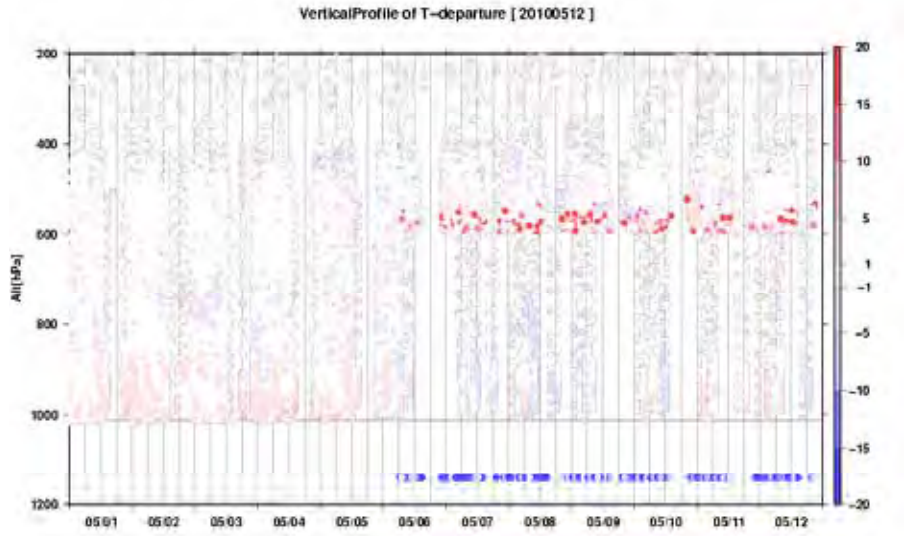


Recent status of Indian Radiosonde use.





Track-check error of Aircraft observation.



Temperature O-B profile of HLxxxx (xxxx : number).

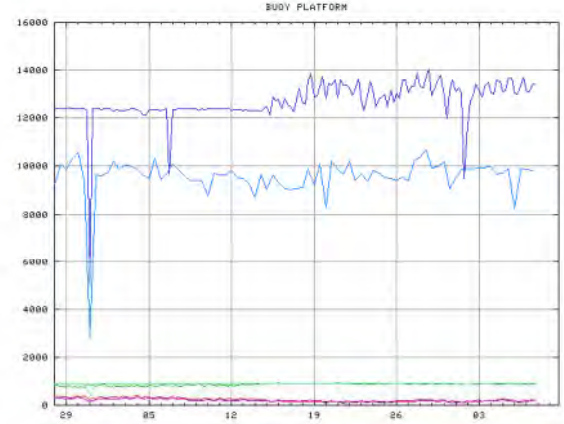
NUMBER of REJECTED DATA (CDA)

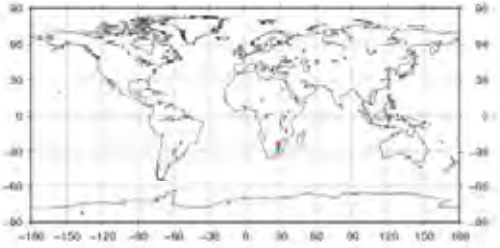
2010 05 28 00UTC - 2010 07 07 18UTC

Global Analysis (Cycle, Early)

-- : Reported of Cycle
-- : Rejected of Cycle (at least 1 lev 1 elem
-- : Used of Cycle
-- : Reported of Early
-- : Rejected of Early (at least 1 lev 1 elem
-- : Used of Early

DataType: BUOY/PLATFORM
ImageSize: 640*480 y-range: auto : auto Draw Reset
Plot kind:
☑Reported of Cycle ☑Rejected of Cycle ☑Used of Cycle
☑Reported of Early ☑Rejected of Early ☑Used of Early

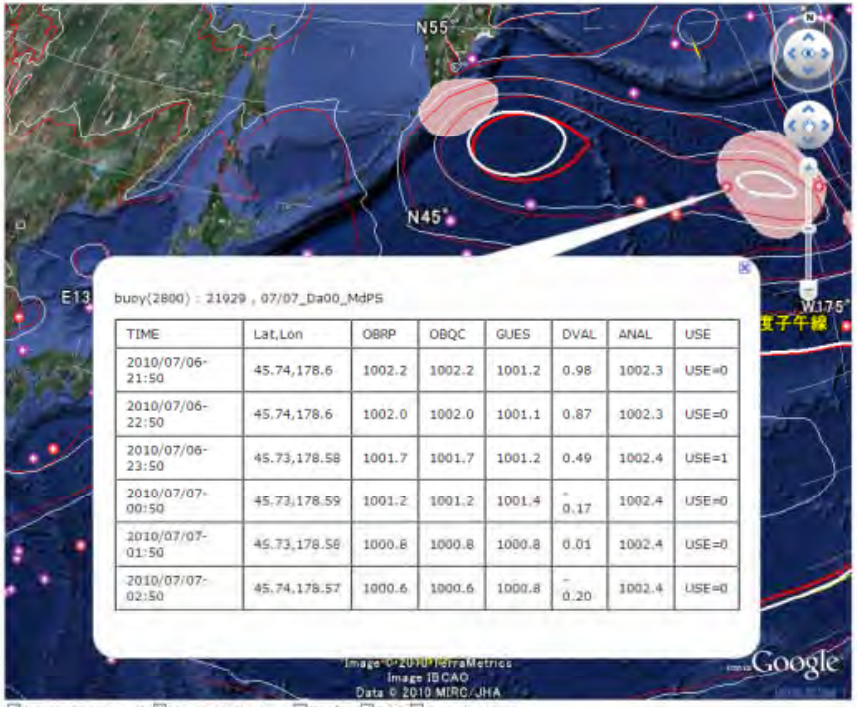




threshold = 2.5 hPa
update : 2010/07/02

Station

QC MONITOR 3D update :: 2010/07/08-02:16



buoy(2800) : 21929 , 07/07_Da00_MdPS

TIME	Lat,Lon	OBRP	OBQC	GUES	DVAL	ANAL	USE
2010/07/06-21:50	45.74,178.6	1002.2	1002.2	1001.2	0.98	1002.3	USE=0
2010/07/06-22:50	45.74,178.6	1002.0	1002.0	1001.1	0.87	1002.3	USE=0
2010/07/06-23:50	45.73,178.58	1001.7	1001.7	1001.2	0.49	1002.4	USE=1
2010/07/07-00:50	45.73,178.59	1001.2	1001.2	1001.4	-0.17	1002.4	USE=0
2010/07/07-01:50	45.73,178.58	1000.8	1000.8	1000.8	0.01	1002.4	USE=0
2010/07/07-02:50	45.74,178.57	1000.6	1000.6	1000.8	-0.20	1002.4	USE=0

☑Navigation Control ☑Mouse Navigation ☐Border ☑Grid ☐Overview Map

clear all file [custum] [help]

Assimilation Monitor date :: 2010/07/07
◉Da00 ○Da06 ○Da12 ○Da18
○Ea00(latest 2010/07/08)
A:Analysis(red),G:Guess(white),I:Increment

☑Psea(A)	☑Psea(G)	☑Psea(I)
☐Z500(A)	☐Z500(G)	☐Z500(I)

Observation(Conventional)

☐SYNOP	☑SHIP	☑BUOY
☐TEMP	☐WPR	
☐AIREP	☐AMDAR	☐AMDAR-B

NWP forecast initial :: 2010/07/08 12UTC
◉ft+00 ○ft+12 ○ft+24 ○ft+36
○ft+48 ○ft+60 ○ft+72 ○ft+84
Psea

☐JMA	☐ECM	☐UKM	☐NCP
☐CMC	☐DWD	☐BOM	☐KMA

Z500

☐JMA	☐ECM	☐UKM	☐NCP
☐CMC	☐DWD	☐BOM	☐KMA

Non-Realtime
Blacklist Status 2010/04/02

☐SHIP	☐BUOY	☐TEMP(T)

Sonde BiasTable

☐2010/04	☐2010/05	☐2010/06

Dictionary 2010/03/01

☐SYNOP	☐UPPER	☐METAR
☐MOBIL		

mean O-B map -- from 0704_00z to 0708_18z

ID: 4260
CALLSIGN: EU0707

Pressure categories:
b1 : Pres. ≥ 300hPa
b2 : 300hPa > Pres. ≥ 500hPa
b3 : 500hPa > Pres. ≥ 700hPa
b4 : 700hPa > Pres. ≥ 850hPa
b5 : 850hPa > Pres. ≥ Surface

mean O-B (O) threshold (T):
b1 : 0 < |3.0K
b2 : |3.0K ≤ 0 < |2.0K
b3 : |2.0K ≤ 0 ≤ +2.0K
b4 : +2.0K < 0 ≤ +3.0K
b5 : +3.0K < 0

mean O-B (O) threshold (DD):
b1 : 0 < |60°|
b2 : |60°| ≤ 0 < |30°|
b3 : |30°| ≤ 0 ≤ +30°
b4 : +30° < 0 ≤ +60°
b5 : +60° < 0

mean O-B (O) threshold (FF):
b1 : 0 < |10.0m/s|
b2 : |10.0m/s| ≤ 0 < |5.0m/s|
b3 : |5.0m/s| ≤ 0 ≤ +5.0m/s
b4 : +5.0m/s < 0 ≤ +10.0m/s
b5 : +10.0m/s < 0

*The number in the cell expresses the number of the report.

T [Temperature]

b5	0	4	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
b4	0	20	16	0	0	0	0	0	0	0	19	0	0	0	19	0	0	16	0	21
b3	0	11	8	0	0	0	0	0	0	0	14	0	0	0	14	0	0	13	2	16
b2	0	5	4	0	0	0	0	0	0	0	5	0	0	0	6	0	0	14	27	6
b1	0	4	3	0	0	0	0	0	0	0	6	0	0	0	7	0	0	33	11	6
time	00	06	12	18	00	06	12	18	00	06	12	18	00	06	12	18	00	06	12	18

DD [Wind direction]

b5	0	3	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0
b4	0	20	16	0	0	0	0	0	0	0	19	0	0	0	19	0	0	19	0	21
b3	0	11	8	0	0	0	0	0	0	0	14	0	0	0	14	0	0	13	2	16
b2	0	5	4	0	0	0	0	0	0	0	5	0	0	0	6	0	0	14	27	6
b1	0	4	3	0	0	0	0	0	0	0	6	0	0	0	7	0	0	33	11	6
time	00	06	12	18	00	06	12	18	00	06	12	18	00	06	12	18	00	06	12	18

FF [Wind speed]

b5	0	3	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0
b4	0	20	16	0	0	0	0	0	0	0	19	0	0	0	19	0	0	19	0	21
b3	0	11	8	0	0	0	0	0	0	0	14	0	0	0	14	0	0	13	2	16
b2	0	5	4	0	0	0	0	0	0	0	5	0	0	0	6	0	0	14	27	6
b1	0	4	3	0	0	0	0	0	0	0	6	0	0	0	7	0	0	33	11	6
time	00	06	12	18	00	06	12	18	00	06	12	18	00	06	12	18	00	06	12	18