Assimilation of GNSS radio occultation data at JMA

Hiromi Owada and Masami Moriya

Japan Meteorological Agency

Outline

- Progress made since the last IROWG
  - Metop-B/GRAS data were added in the global NWP system on November 28, 2013
  - Replacement to bending angle data assimilation in the global NWP system on March 18, 2014
- Impact of the RO data utilization in the global NWP system
- Development for RO data assimilation in the mesoscale NWP system
- Summary

PROGRESS MADE SINCE THE LAST IROWG

History on the use of GNSS RO data
in the JMA global analysis

Satellite	Period of operational use (Available for experimental use)	Current status of provided data
CHAMP	22 Mar. 2007 ~ 20 Nov. 2007	No dissemination
GRACE-A	30 Nov. 2009 ~ 04 Dec. 2009 18 Dec. 2012 ~	Operational use Refractivity: ~ 17 Mar. 2014 Bending angle: 18 Mar. 2014 ~
Metop-A	30 Nov. 2009 ~	
Metop-B	28 Nov. 2013 ~	
COSMIC	01 Nov. 2010 ~	
TerraSAR-X	18 Dec. 2012 ~	
C/NOFS	18 Dec. 2012 ~ 06 Nov. 2013	No dissemination
SAC-C	(20 Dec. 2010 ~ 2 Aug. 2011)	
TanDEM-X	(01 Jul. 2014 ~)	Validating for the operational use
GRACE-B	(12 Aug. 2014 ~)	

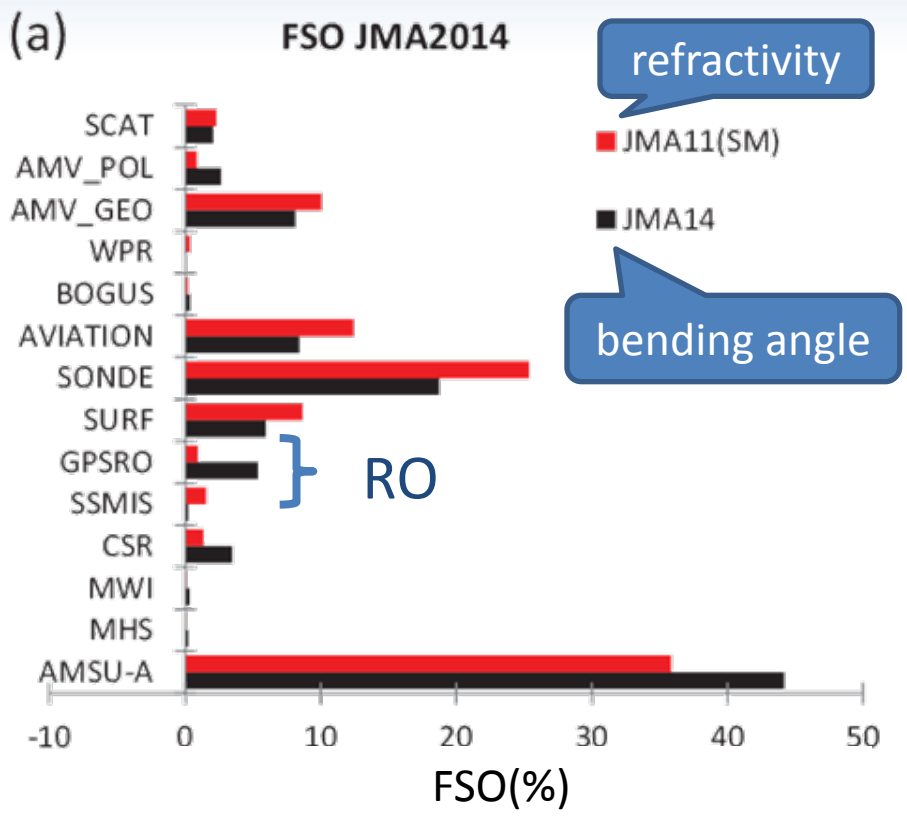
As of March 2015

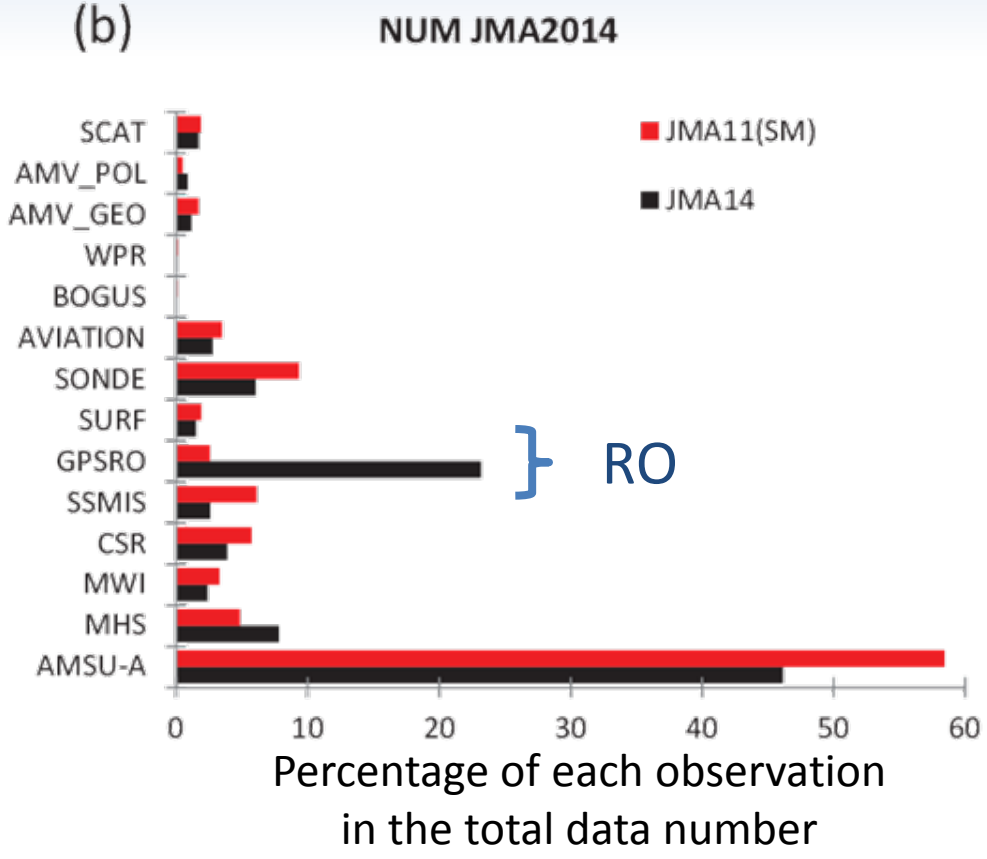
Replacement to bending angle data assimilation in the global NWP system

- Refractivity data assimilation (previous operation)
  - Vertical thinning : 500m
  - Upper limit of data usage : 30km
  - Code of observation operator: original
  - Observational error: defined independently in five latitudinal bands (60–90N, 20–60N, 20S–20N, 60–20S, 90–60S) as a function of height for each satellite based on statistics of O-B
- Bending angle data assimilation (current operation)
  - No vertical thinning
  - Upper limit of data usage: 60km
  - Code of observation operator: 1D operator in ROPP
  - Observational error: depends on impact height "h" only
    - 1% of observed bending angle for h > 10 km
    - linear variation from 20% at h=0 km to 1% at h=10 km
    - Lower limit of 3 micro rad.

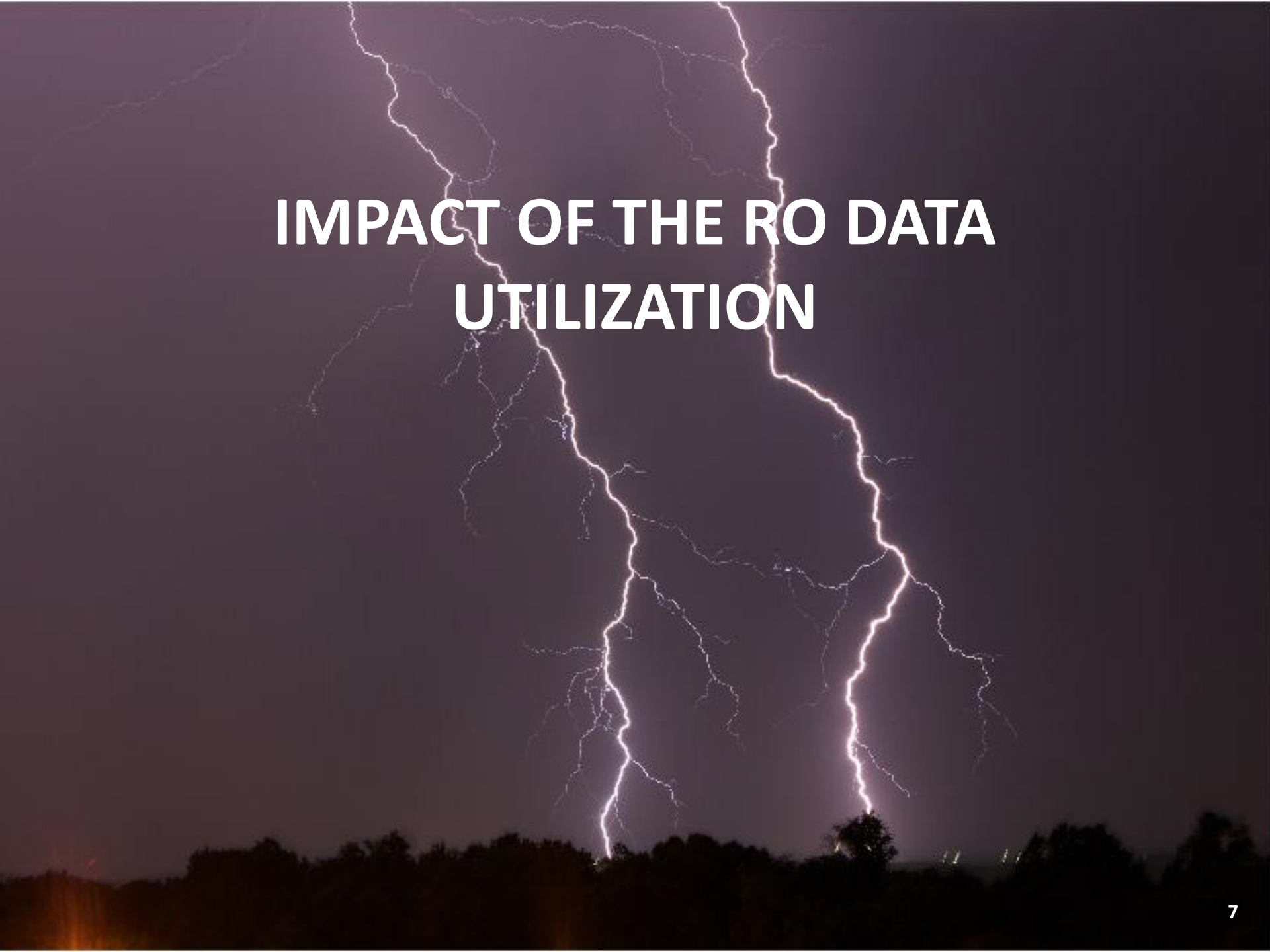
FSO in JMA's global model

FSO: Forecast Sensitivity to Observations





Ishibashi (2015)

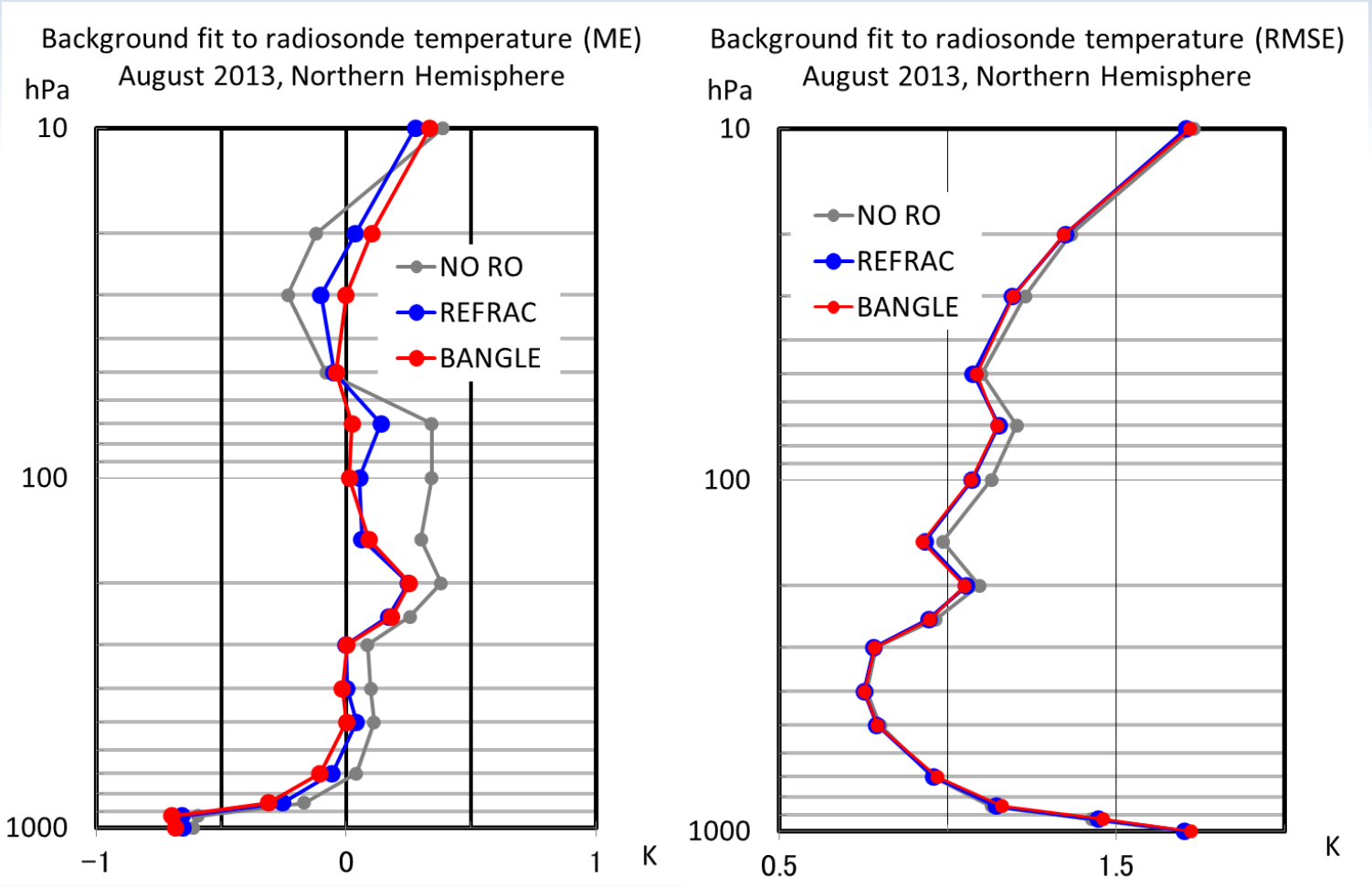


IMPACT OF THE RO DATA UTILIZATION

Observing system experiments to identify the impact of RO data assimilation

- Periods of the cycle experiments
  - August 2013: 10 July – 11 September,2013
  - January 2014: 10 December,2013 – 11 February,2014
- REFRAC
  - Refractivity data assimilation
  - Settings for assimilating RO data corresponds to the previous operational ones (vertical thinning, upper limit of data usage and observational error)
- BANGLE
  - Bending angle data assimilation
  - Settings for assimilating RO data corresponds to the current operational ones
- NO RO
  - Without RO data assimilation

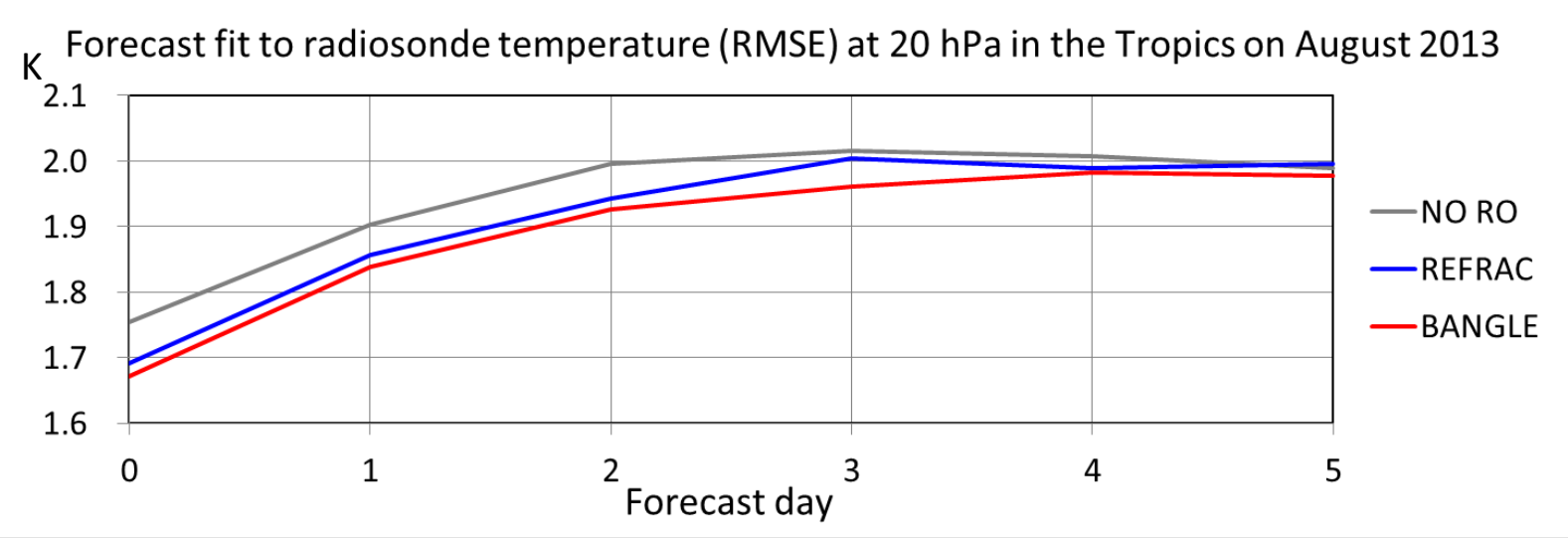
Background fit to radiosonde temperature

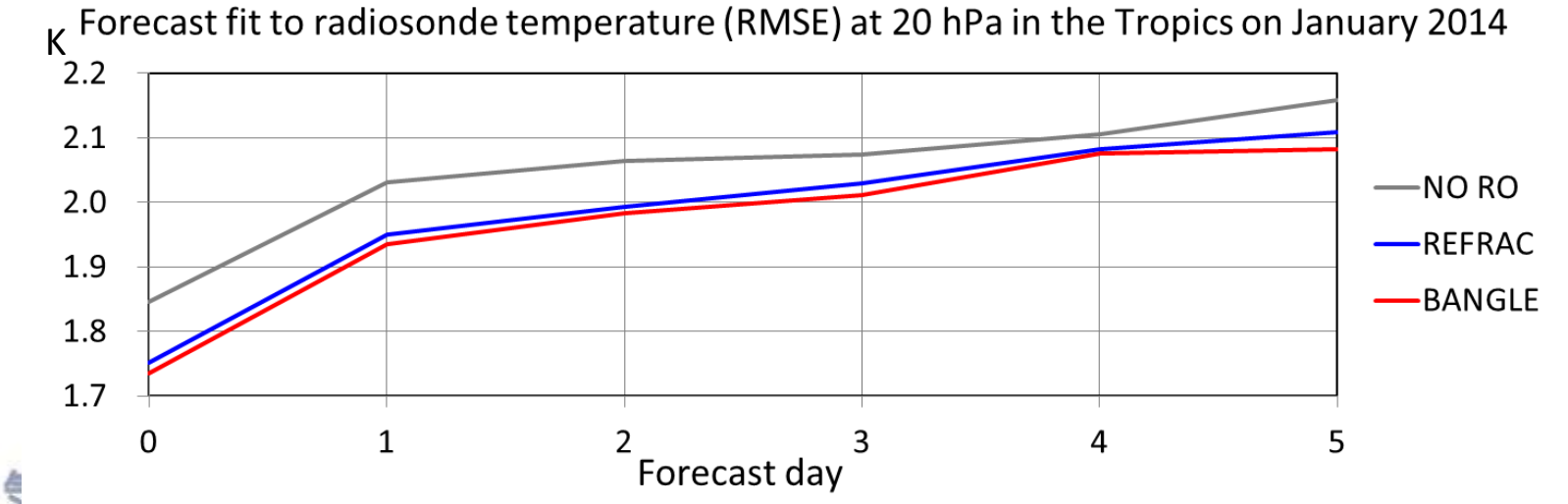


Mean error (left) and root mean square error (right) of background (6 hour forecast) fit to radiosonde temperature measurements in the Northern Hemisphere in August 2013.

Forecast fit to radiosonde temperature

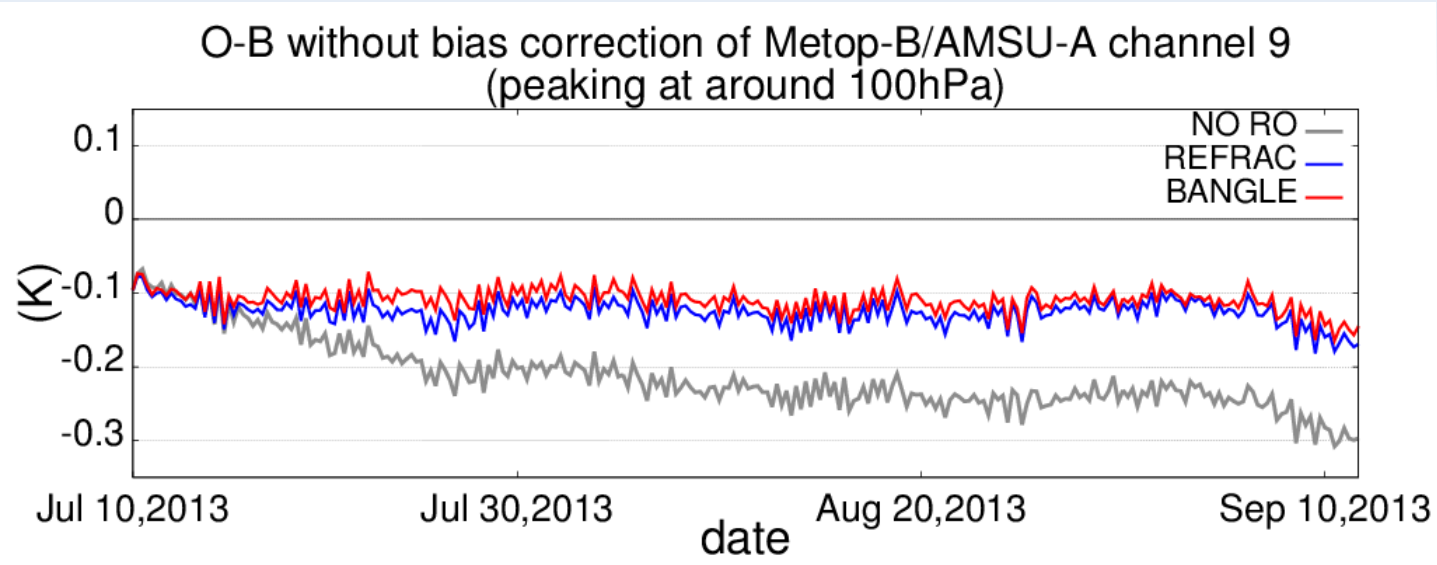
RMSE of temperature forecast at 20 hPa in the Tropics

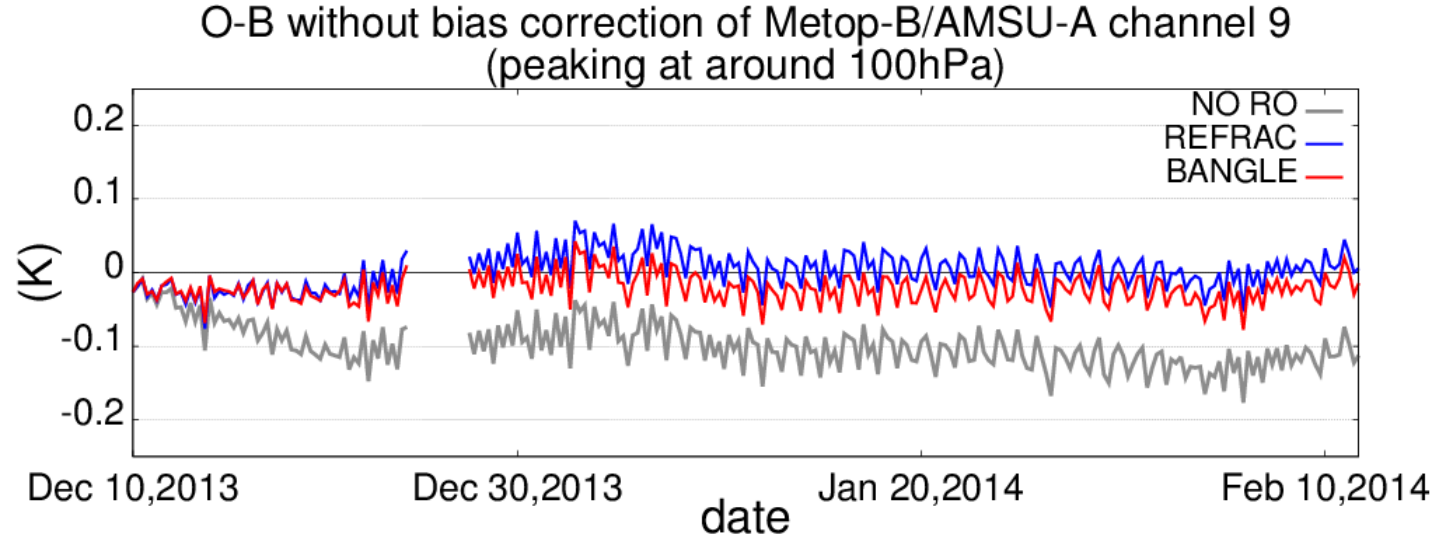




Time series of O-B of AMSU-A channel 9

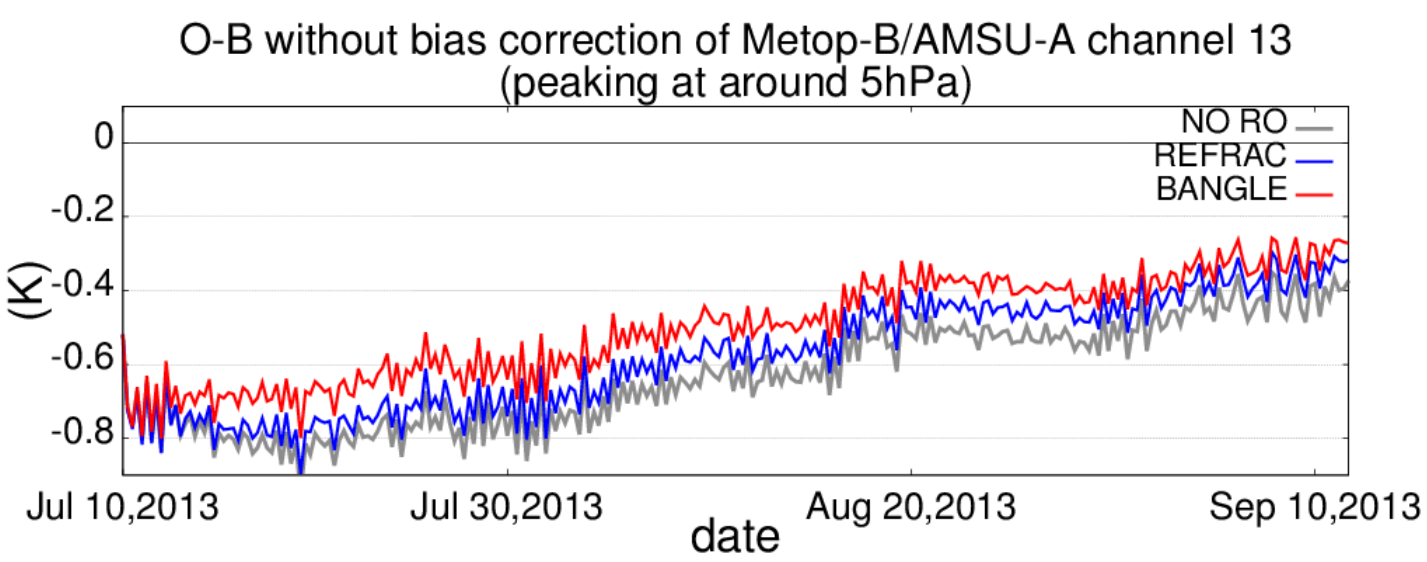
during the period of cycle experiments

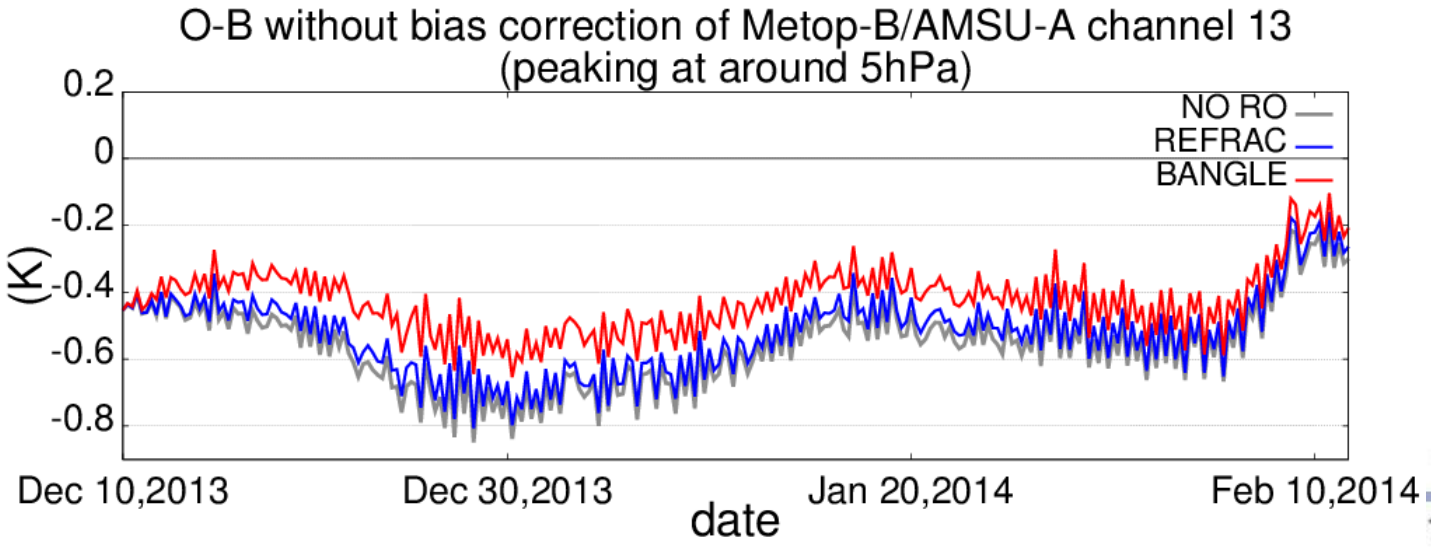




Time series of O-B of AMSU-A channel 13

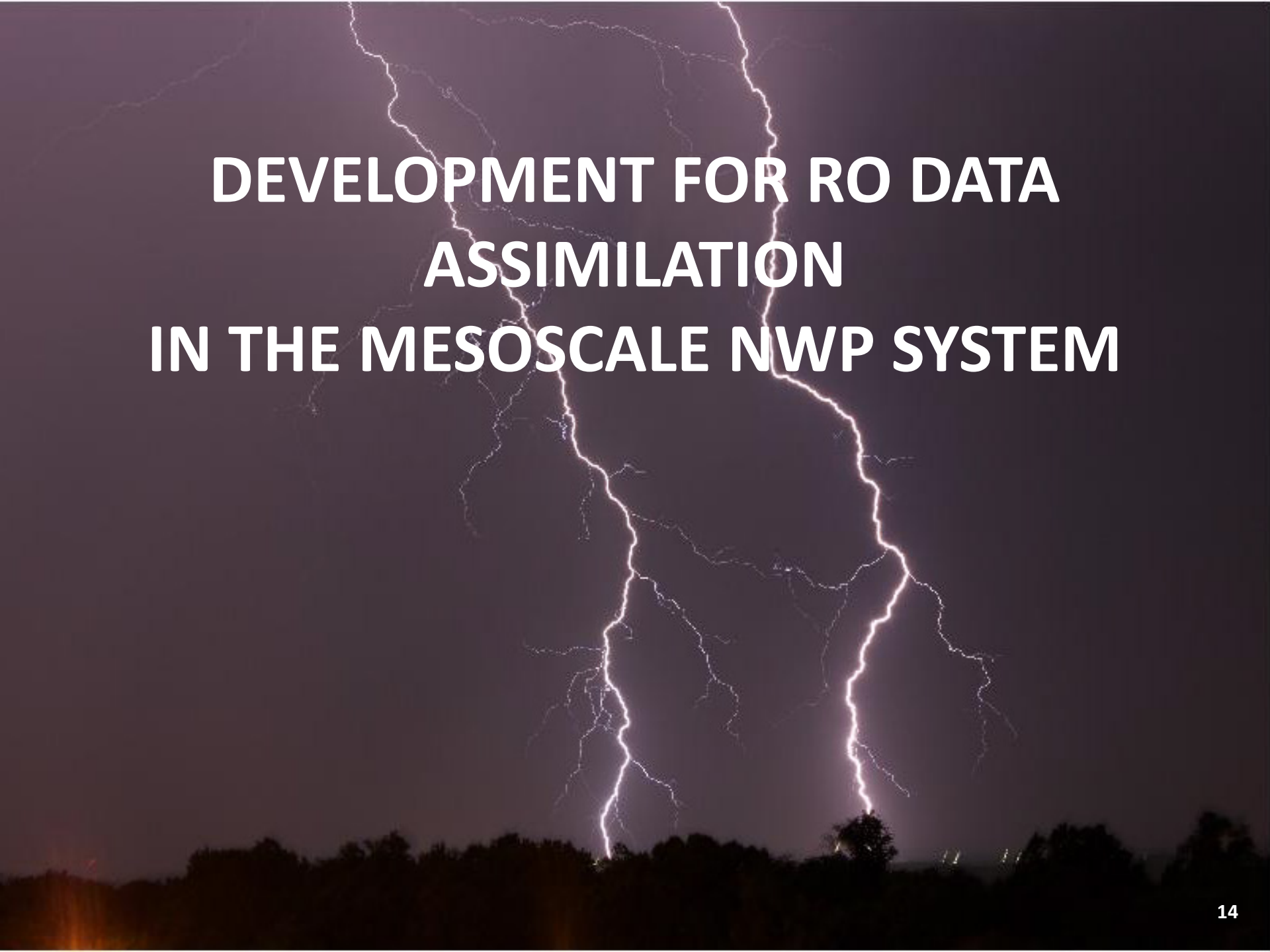
during the period of cycle experiments





Summary on the experiments

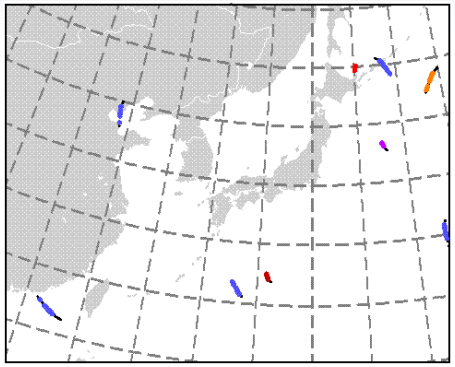
- Both BANGLE and REFRAC reduced large biases in the background (6 hour forecast) relative to radiosonde observations which appeared in the upper troposphere and stratosphere in case of NO RO
- The improvement of the stratospheric temperature forecasts in BANGLE was larger than in REFRAC. This is because the background of BANGLE was improved by assimilating RO profiles above 30 km



DEVELOPMENT FOR RO DATA ASSIMILATION IN THE MESOSCALE NWP SYSTEM

Coverage of RO data available in the JMA mesoscale analysis

26 July, 2014



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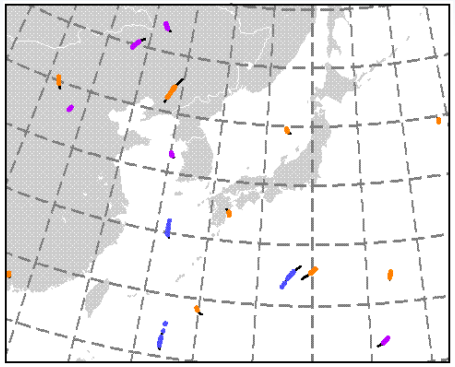

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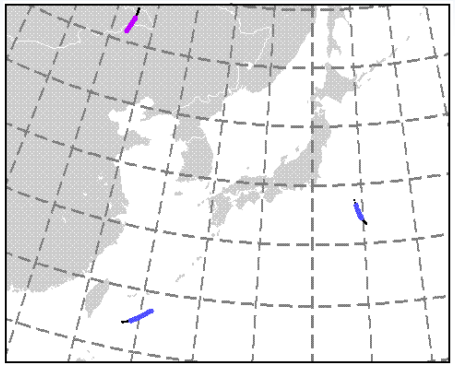

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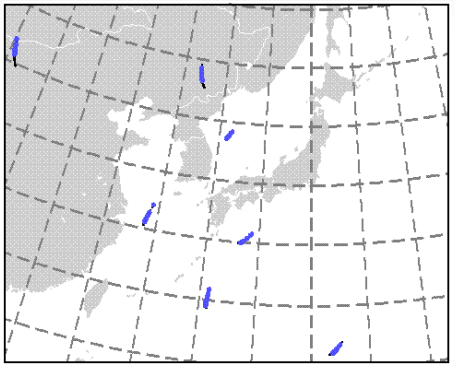

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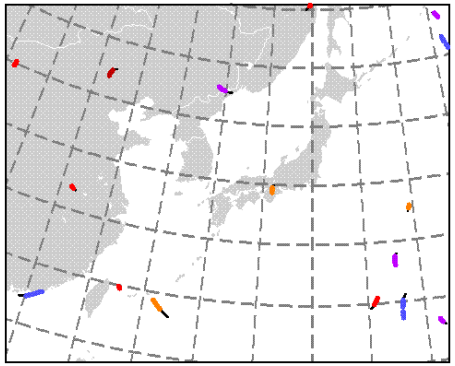

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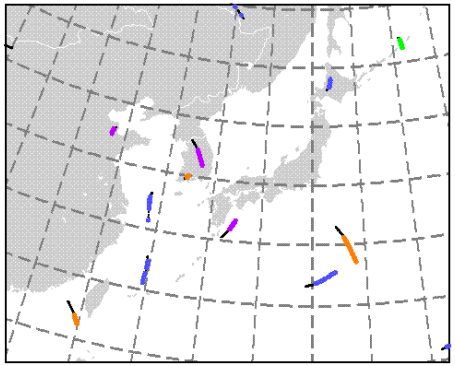

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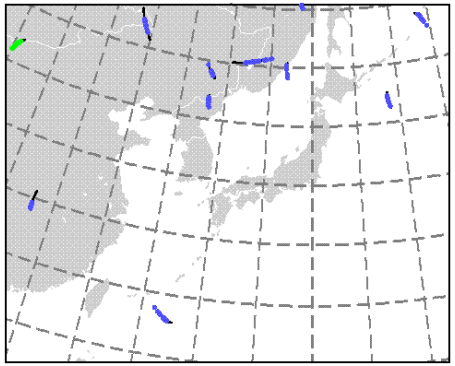

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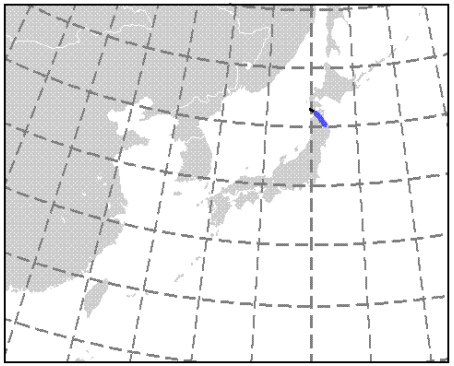


21UTC

● COSMIC ● TerraSAR-X ● Metop-A

● GRACE-A ● TanDEM-X ● Metop-B

Comparison of four analysis (1/4)

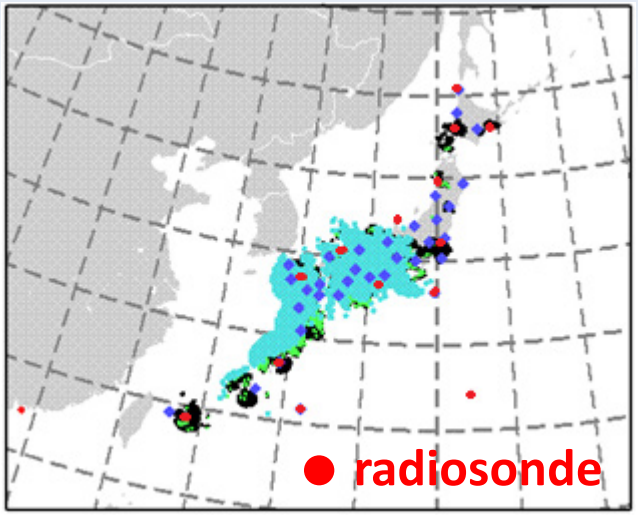
Purpose and setting

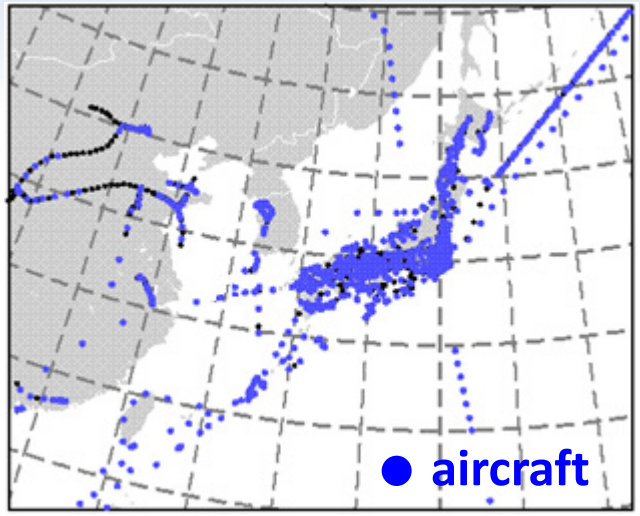
- To verify the effect of RO data assimilation compared with the radiosonde and aircraft observations in the mesoscale NWP system
- Comparison of each one-shot analysis with “Control” at the 13 radiosonde stations in Japan

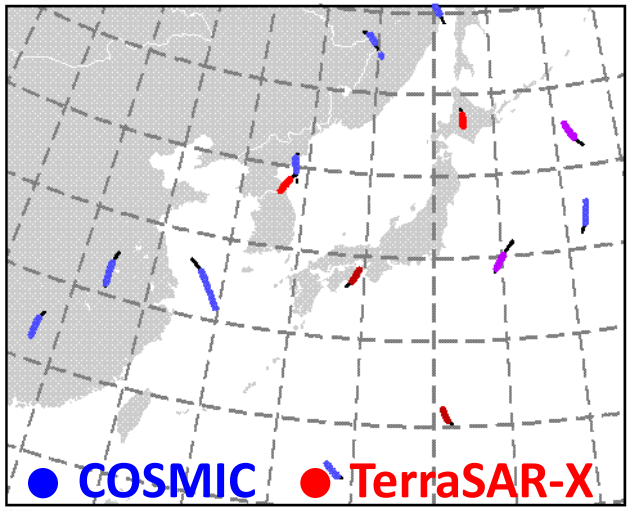
	Radiosonde (temp. and humidity)	Aircraft (temp.)	Bending angle	Refractivity
“Control”	NO USE	NO USE	NO USE	NO USE
“Sonde”	USE	NO USE	NO USE	NO USE
“Aircraft”	NO USE	USE	NO USE	NO USE
“Bangle”	NO USE	NO USE	USE	NO USE
“Refrac”	NO USE	NO USE	NO USE	USE

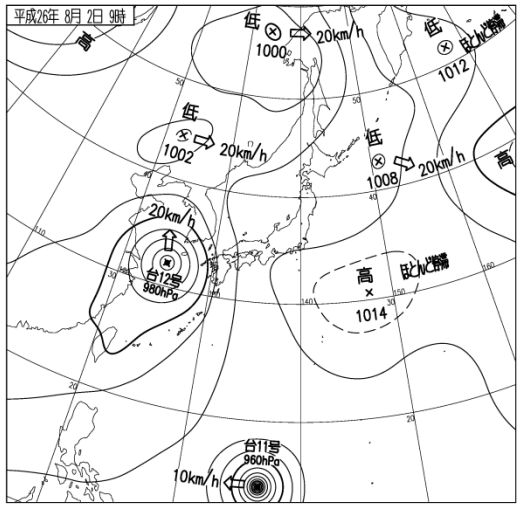
Comparison of four analysis (2/4)

Data coverage and weather map







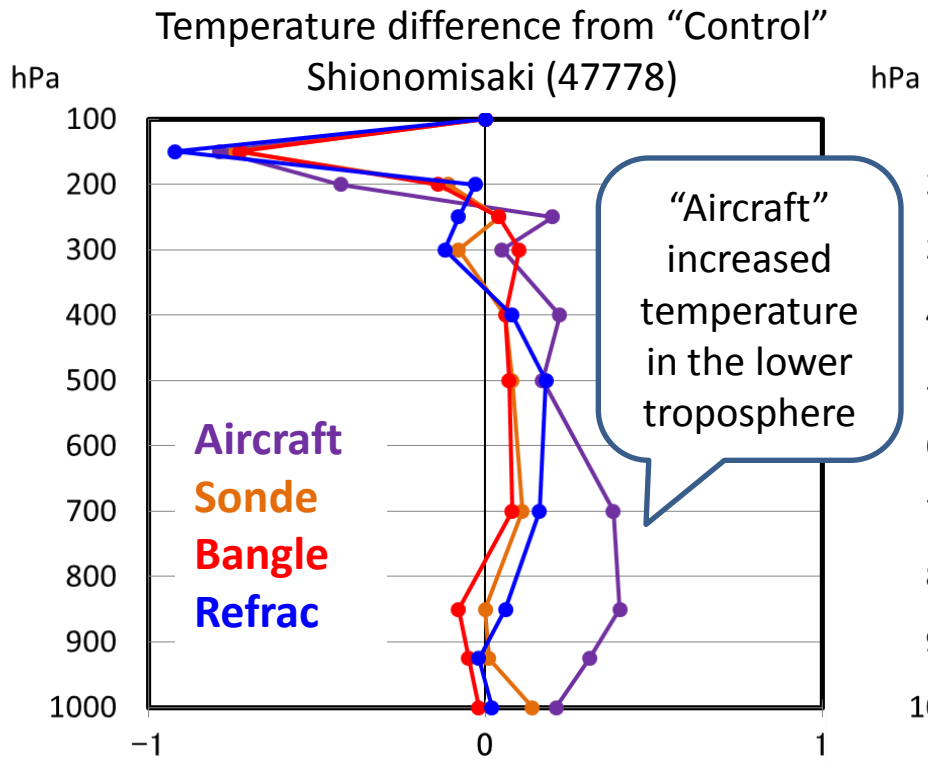


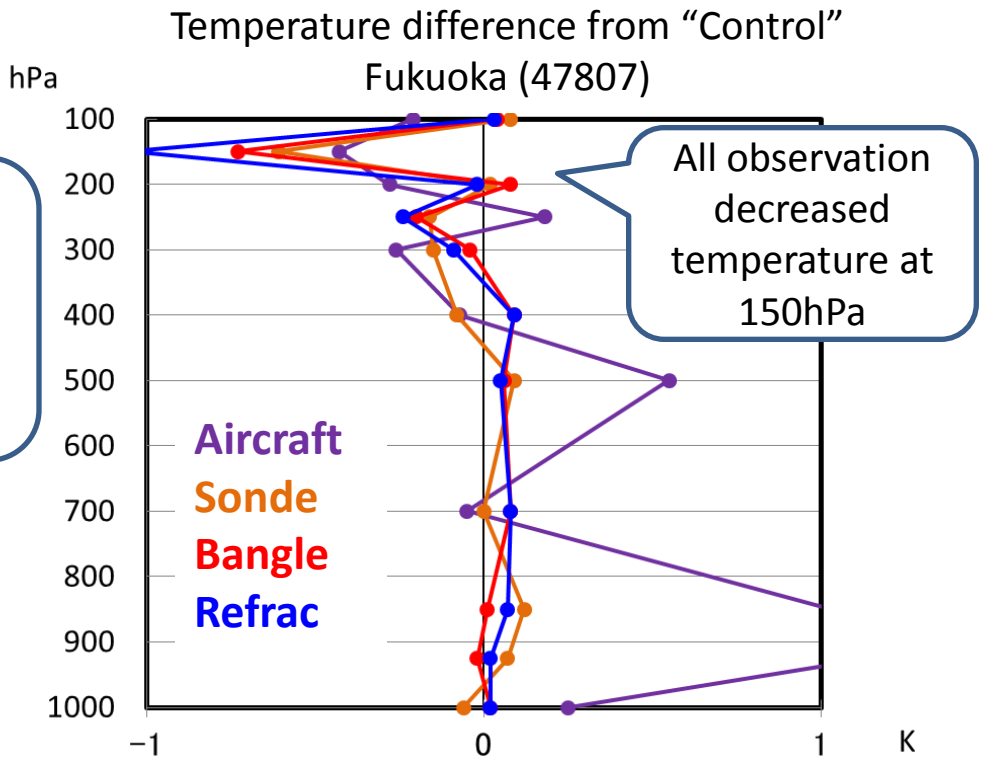
00UTC
2 August, 2014

Comparison of four analysis (3/4)

Difference from control analysis

- Each profile of temperature difference from “Control” at Shionomisaki (47778) and Fukuoka (47807)

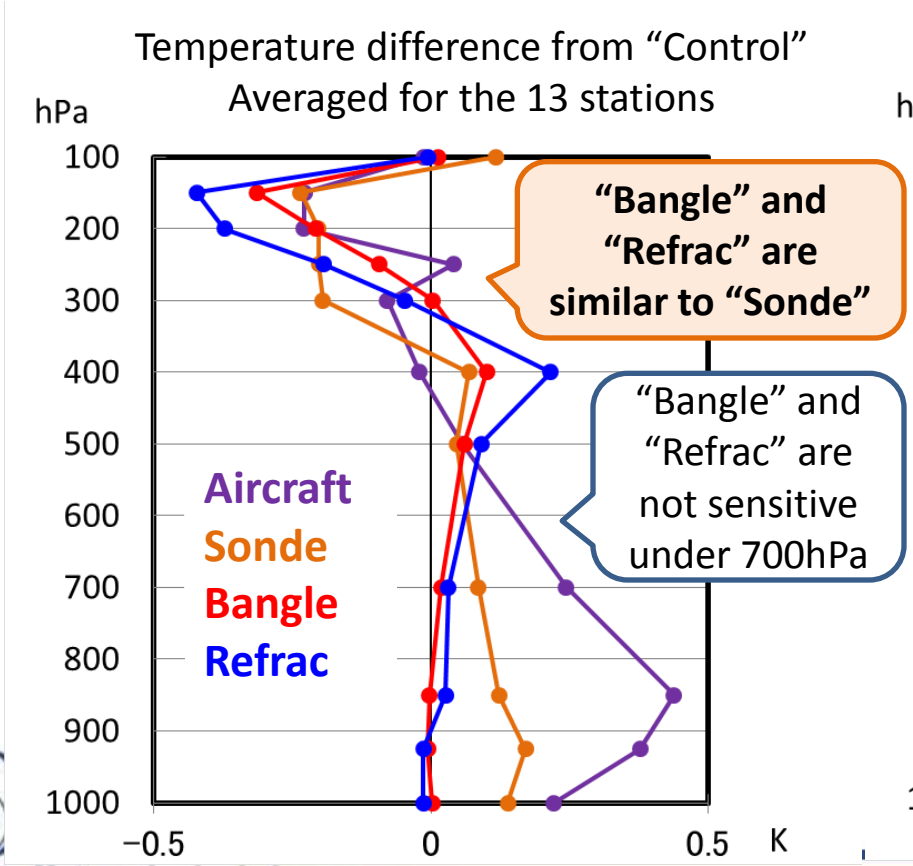


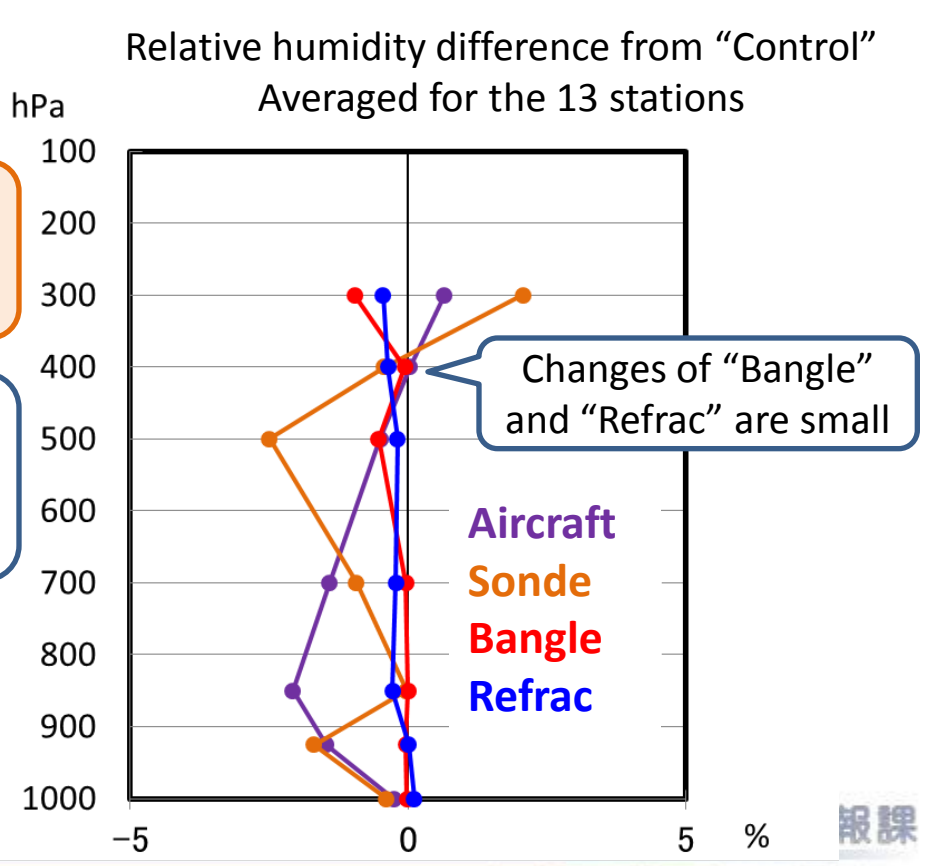


Comparison of four analysis (4/4)

Difference from control analysis

- Averaged profiles of temperature difference from “Control” for the 13 radiosonde stations in Japan





Summary (1/2)

- Progress made since the last IROWG
  - Metop-B/GRAS data were added
  - Replacement to bending angle data assimilation
    - There were also some changes such as removal of vertical thinning and expansion of the observation height up to 60 km
    - 1D observation operator in ROPP was introduced
    - In the recent adjoint sensitive studies, FSO of RO in JMA's global model was increased after the replacement to bending angle data assimilation
  - New data from GFZ are available
    - We are ready to use TanDEM-X and GRACE-B data

Summary (2/2)

- Impact of the RO data utilization
  - RO data reduced biases in the background relative to radiosonde observations which appeared in the upper troposphere and stratosphere
  - Temperature forecast in the stratosphere was improved by adding the use of RO profiles above 30km
- Development for RO data assimilation in the mesoscale NWP system
  - RO data is expected to have an impact similar to radiosonde observations.
  - We are testing RO data assimilation in the JMA's mesoscale NWP system

Acknowledgement

We would like to thank GFZ for providing GRACE, TerraSAR-X and TanDEN-X data, EUMETSAT for Metop data, UCAR for C/NOFS data, NSPO and UCAR for COSMIC data and ROM SAF for ROPP.


BACKUP SLIDES

Operational NWP systems at JMA

Model	Global Model (GSM) & Analysis	Meso-scale Model (MSM) & Analysis	Local Forecast Model (LFM) & Analysis
Horizontal/vertical resolutions	TL959/100 (0.01hPa)	5km/50 (22km)	2km/60 (20km)
Forecast range (initial time)	84h (00,06,18UTC) 264h (12UTC)	39h (00,03,06,09, 12,15,18,21UTC)	9h (every 1 hour)
Data assimilation (inner loop resolution)	4D-VAR (TL319)	4D-VAR (15km)	3D-VAR (5km) Rapid Update Cycle
Assimilation window	6h (-3 to +3 hours)	3h (-3 to 0 hours)	1h (-30 to +30 minutes)
Data cut off time	Early Analysis : 2h20m Cycle Analysis : 11h50m(00,12UTC), 7h50m(06,18UTC)	50m	30m

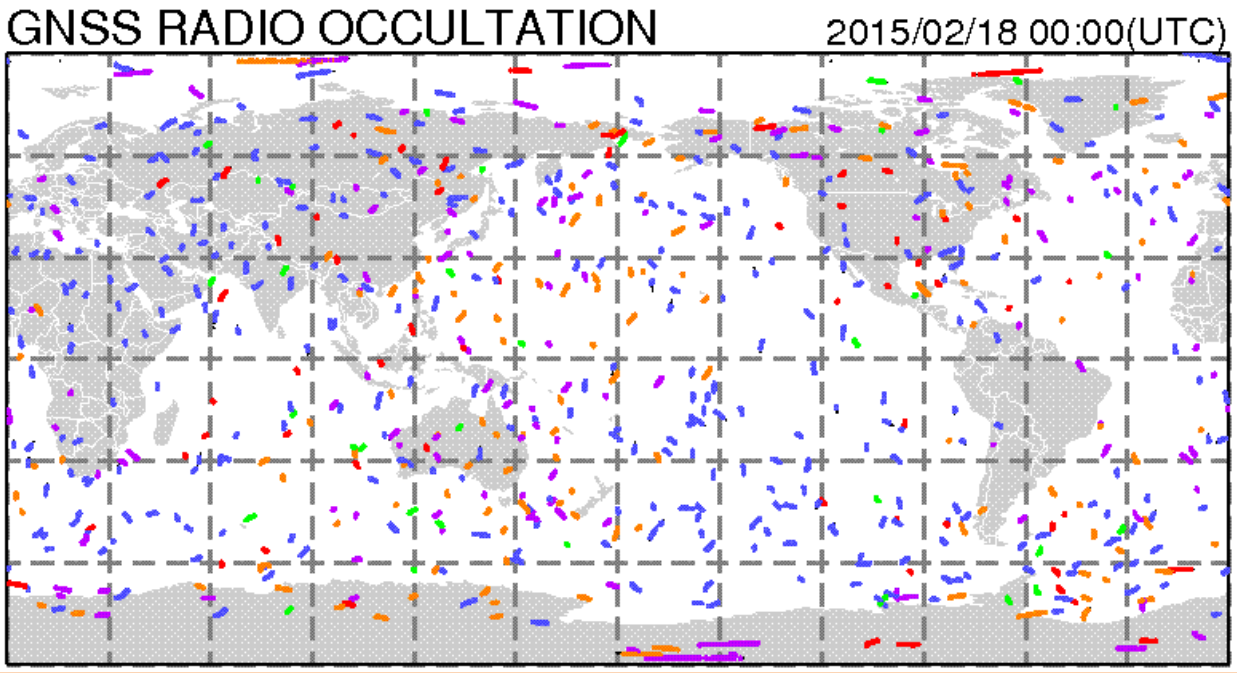
GNSS RO data are assimilated.

As of March 2015

Coverage of RO data assimilated at JMA

Bending angle data are assimilated into the global NWP system.

We are now validating data from TanDEM-X and GRACE-B for the operational use.

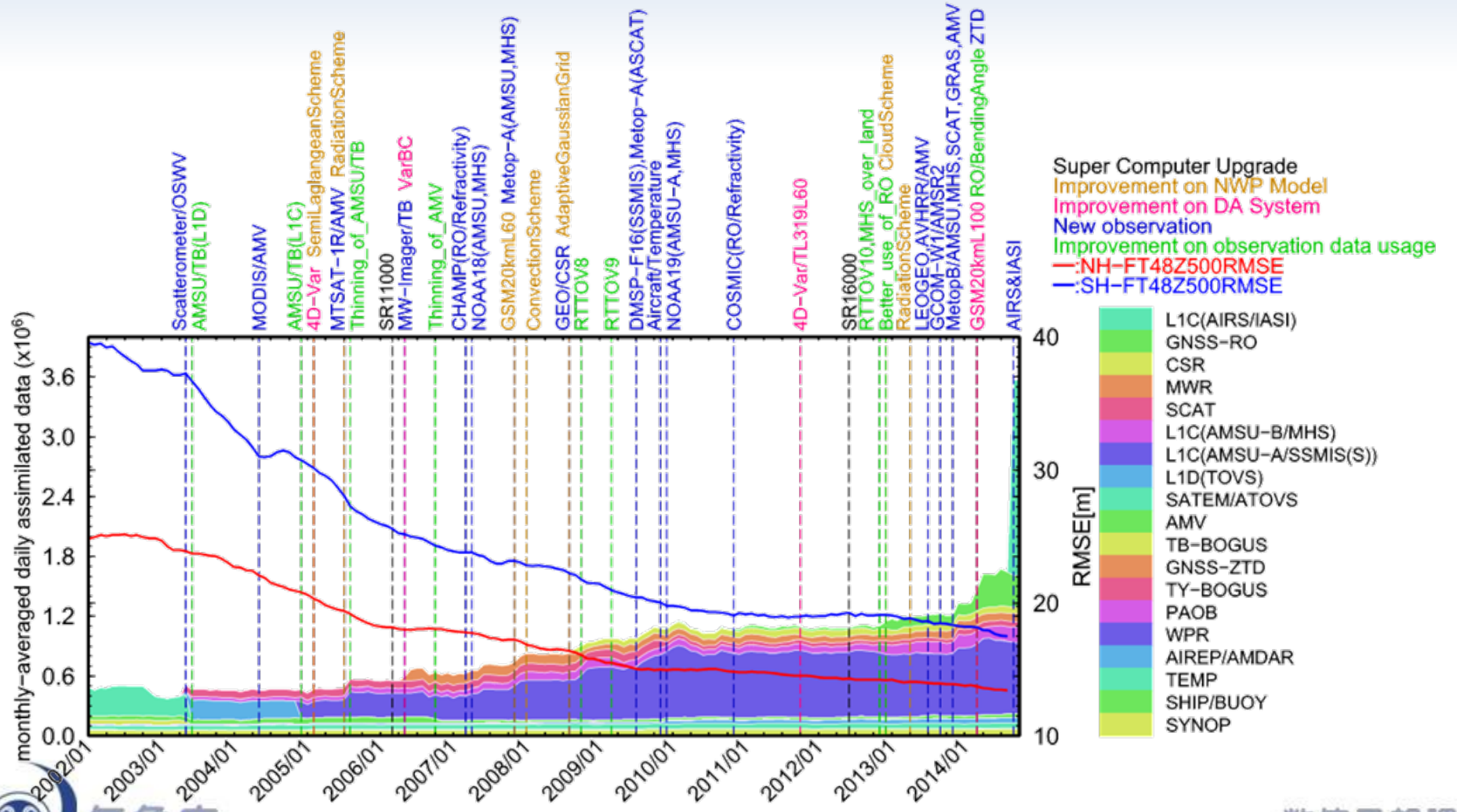


RO data assimilated in one cycle analysis

Satellites assimilated

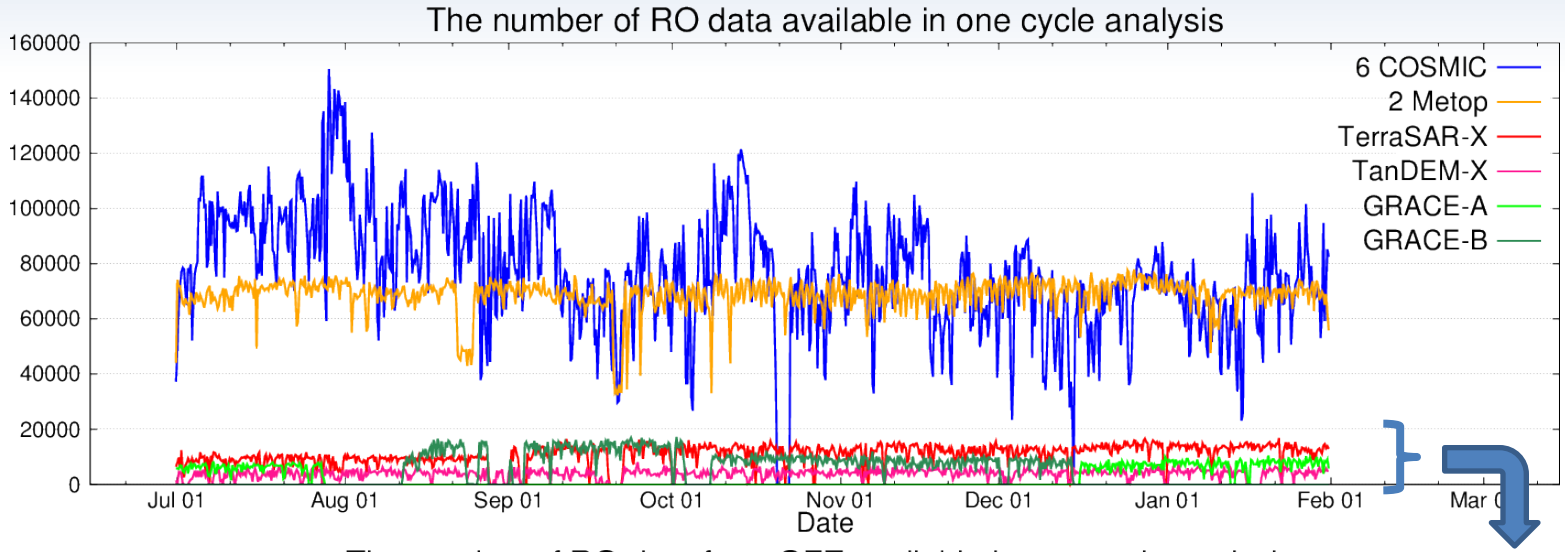
- COSMIC
- GRACE-A
- TerraSAR-X
- Metop-A
- Metop-B

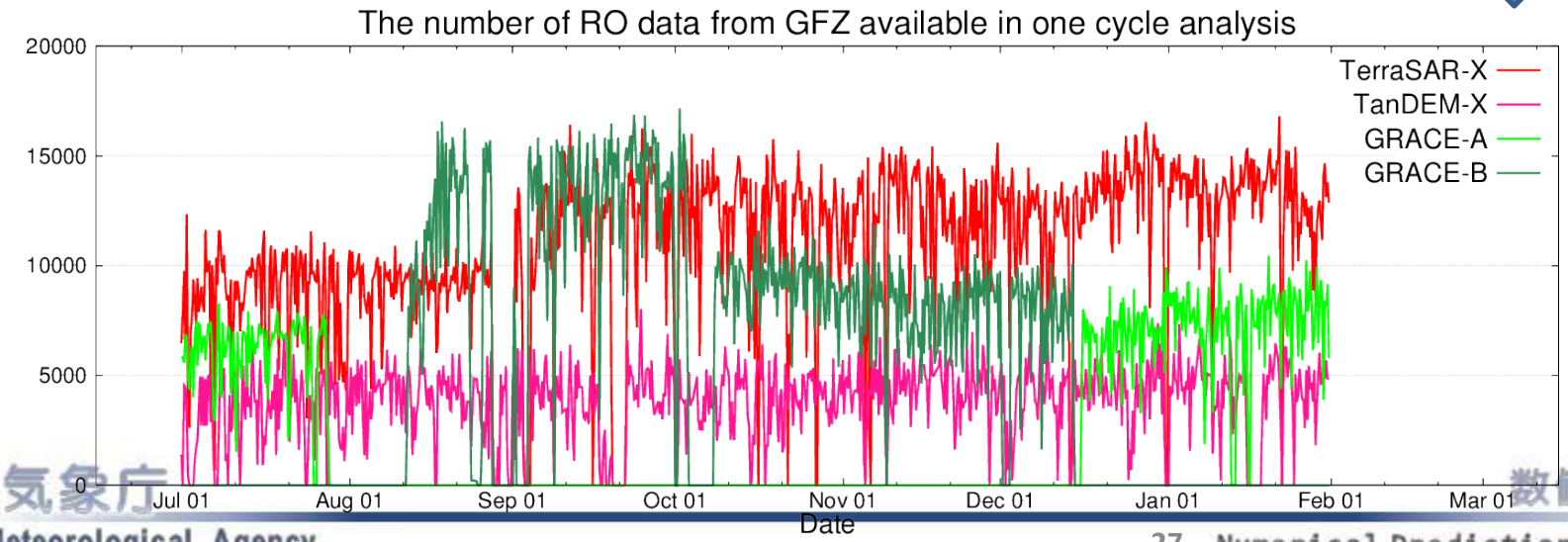
Number of data assimilated in the global NWP system at JMA



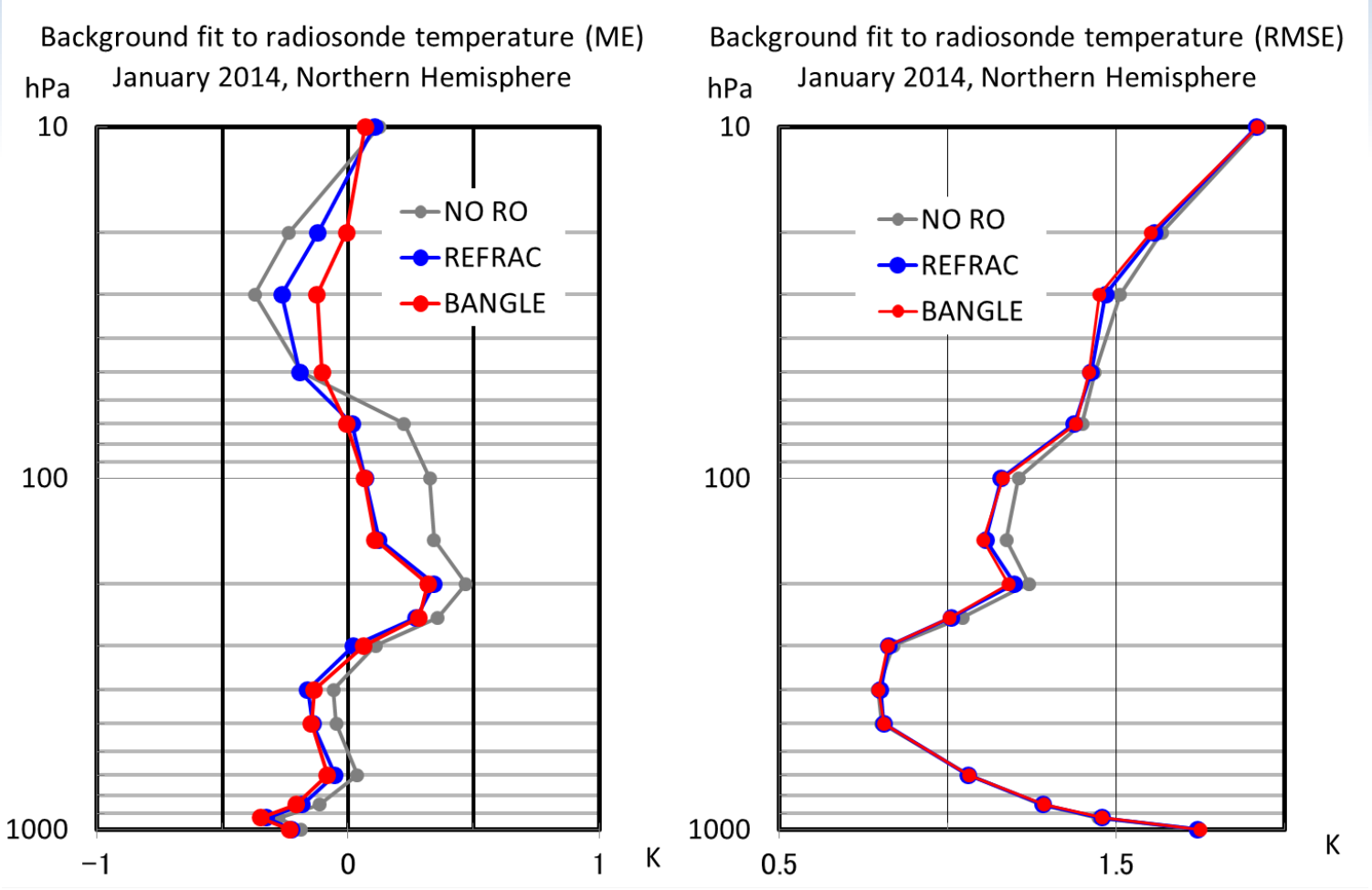
Time series of RO data number

Data period: 1 July, 2014 – 31 January, 2015





Background fit to radiosonde temperature



Mean error (left) and root mean square error (right) of background (6 hour forecast) fit to radiosonde temperature measurements in the Northern Hemisphere in January 2014.