Evaluation of Satellite Data Assimilation in the ARW WRF Mesoscale Model System

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& UCAR/AFWA

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Overview

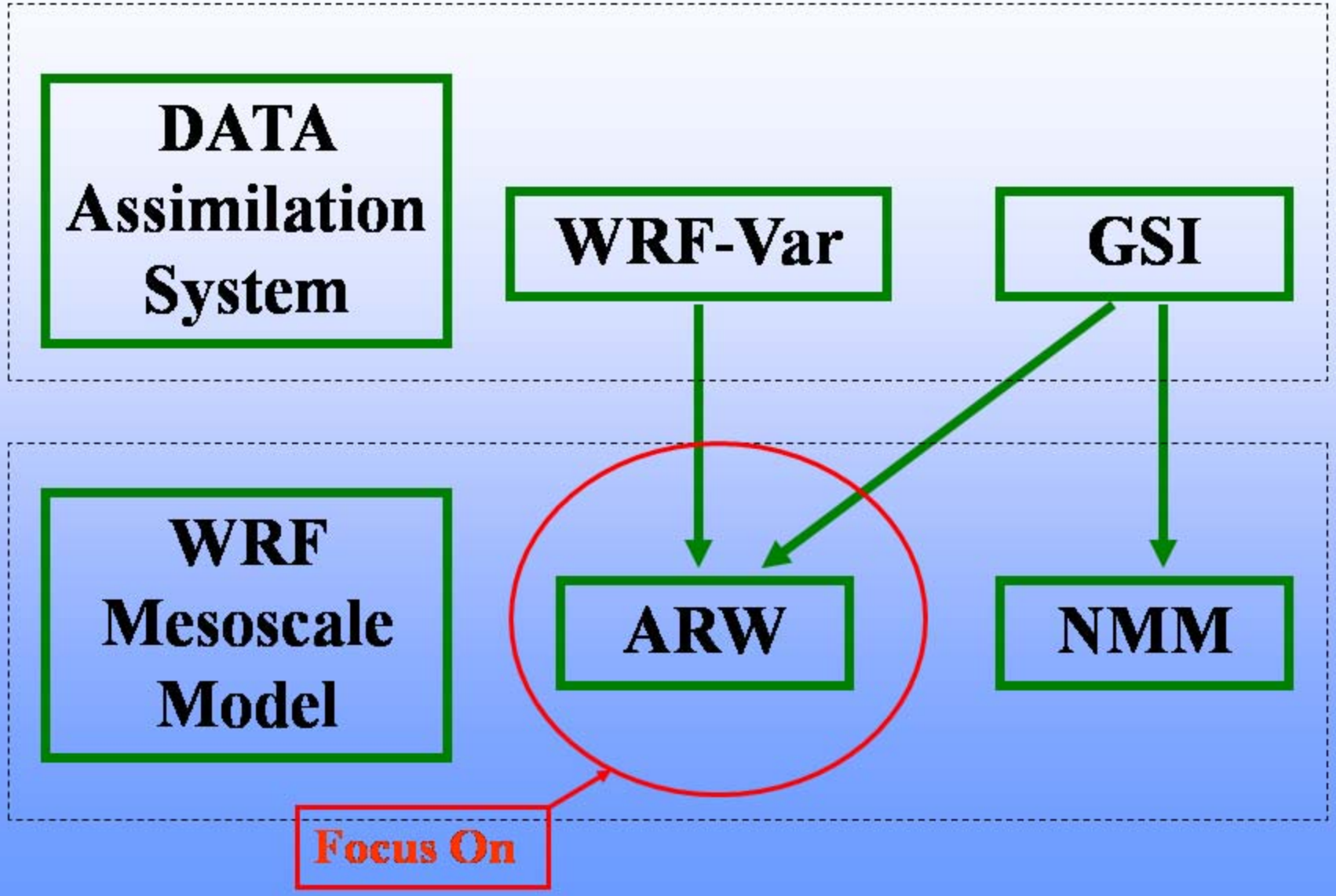
1 Current Status of Data Assimilation System for Regional Model

2 Experiments

- 2.1 ATOVS radiance application in Hurricane Katrina case study
- 2.2 ATOVS and SSM/IS radiance application in the real time forecasts over the AFWA T44 Domain
- 2.3 ATOVS and SSM/IS radiance application in the real time forecasts over the AFWA T46 Domain
- 2.4 ATOVS radiance application in the flash flood forecasts over the East Asia

3 Summary

1 Current Status



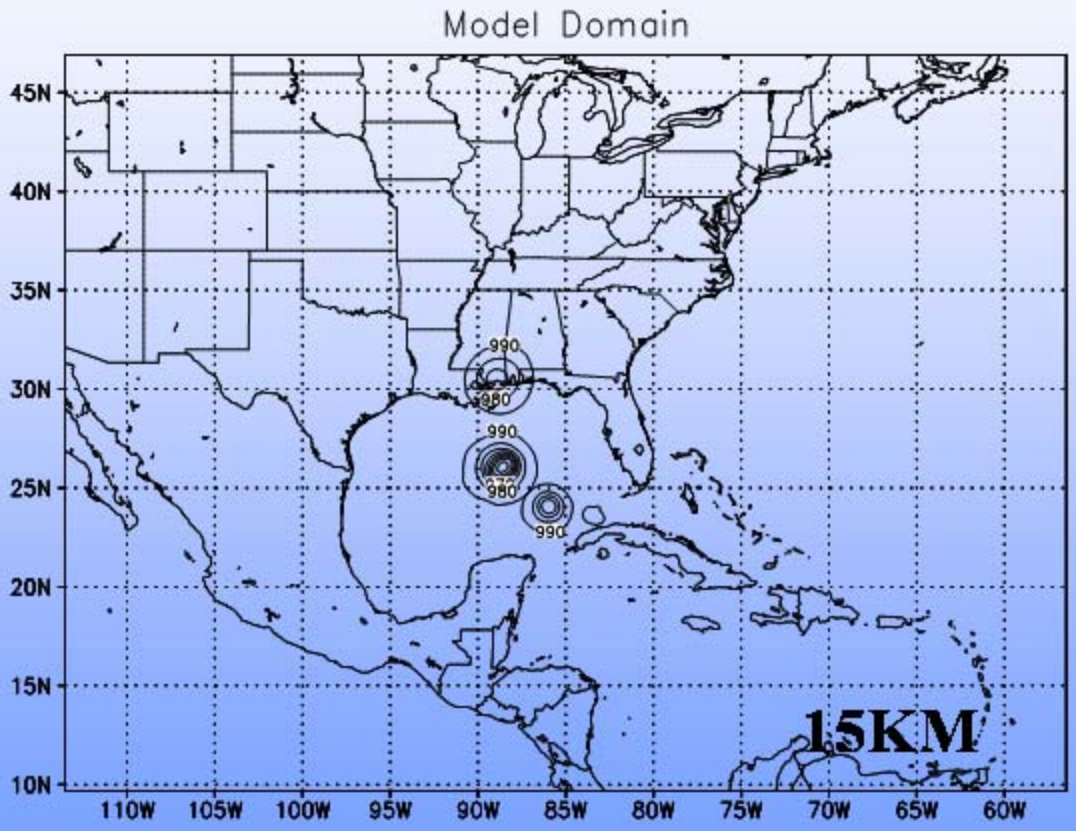
2 Experiments

2.1 **ATOVS radiance application in Hurricane Katrina case study (2005)**

EXP1 : Impact of ATOVS radiance data assimilation on the forecasts of Hurricane Katrina with GSI analysis system.

EXP2 : Comparison of forecasts in WRF-Var and GSI systems

EXP1 : Impact of ATOVS radiance data assimilation on the forecasts of Hurricane Katrina with GSI analysis system.



Period: August 27-30, 2005

Forecasts: 72 hours
Initial Time : 00Z27Aug2005

Boundary condition : NCEP reanalysis

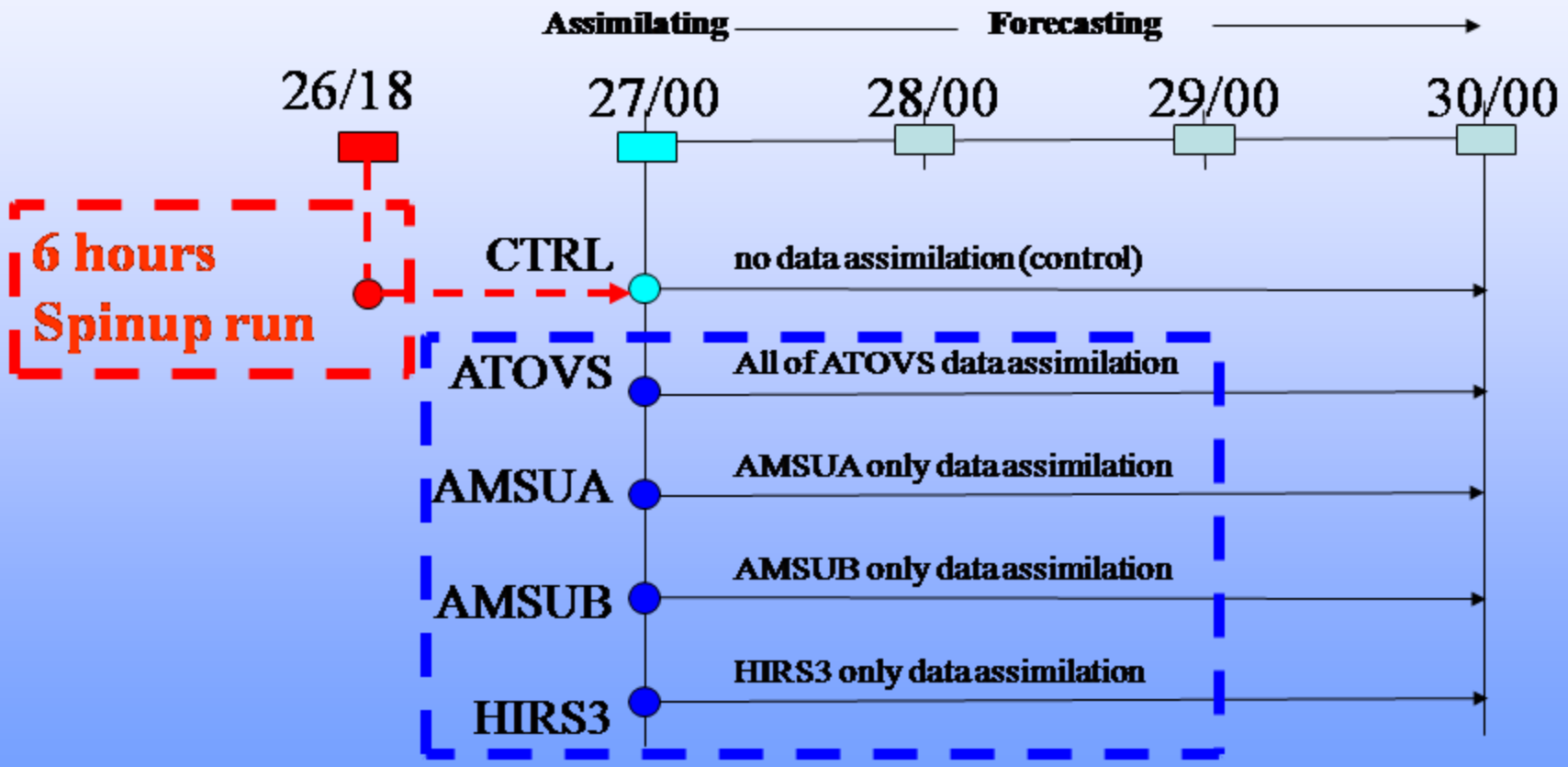
Domain: South of America
Model resolution : 15km

Satellite Data: AMSU-A/B and HIRS3

Data assimilation system: GSI with old version of CRTM

EXP1

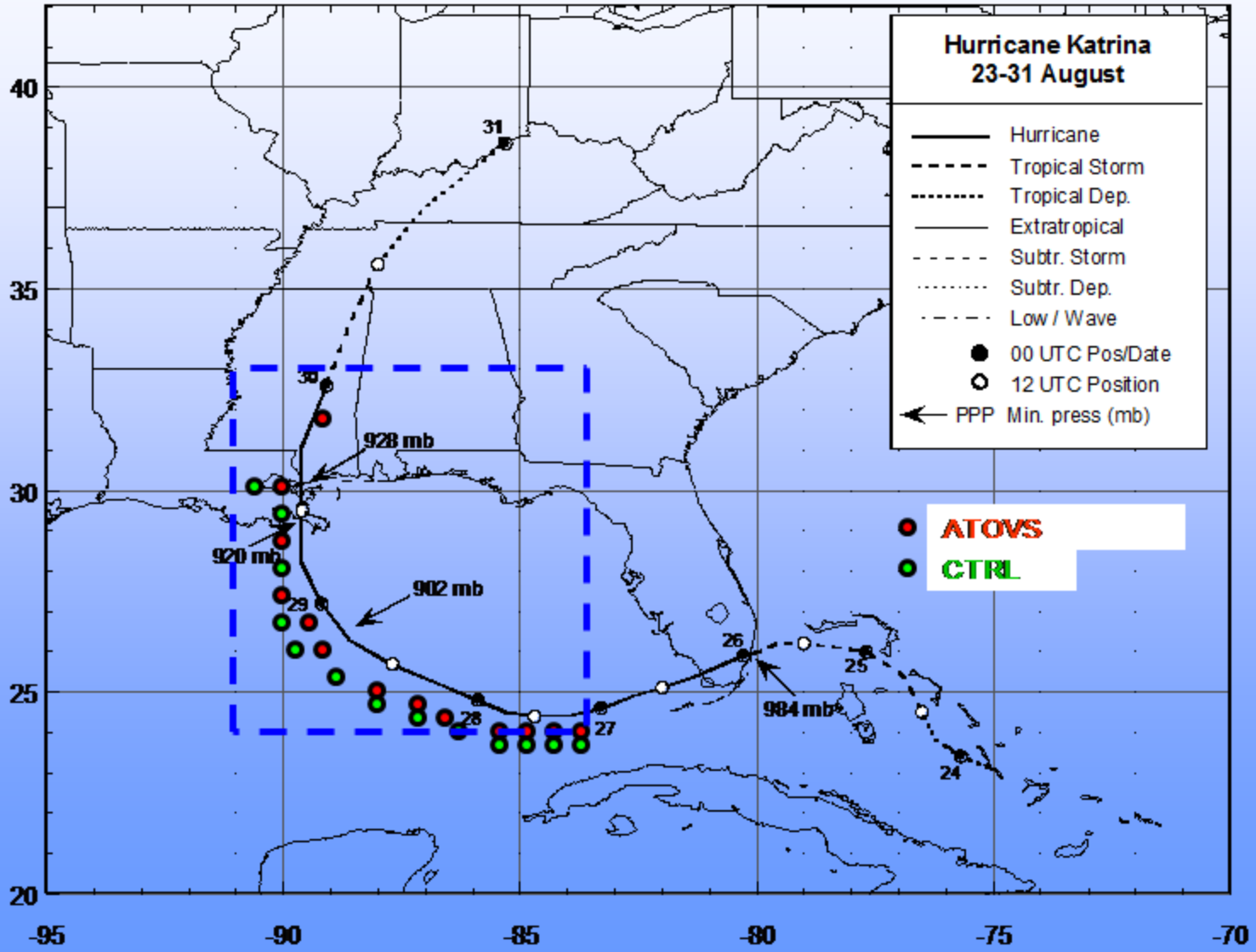
Experimental Design



EXP1

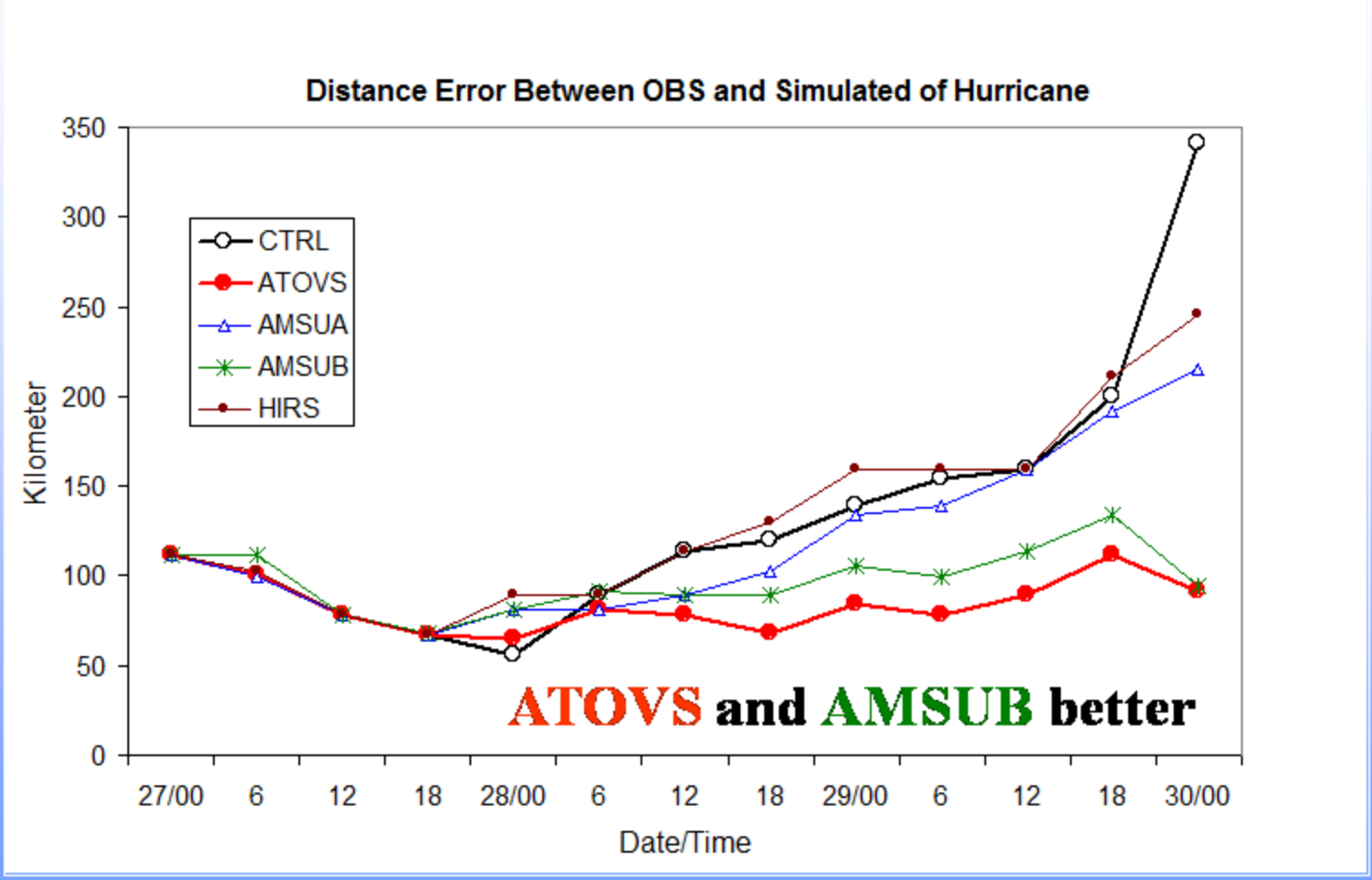
Track of Hurricane Katrina Simulated initial at UTC 00 AUGUST 27 2005

Succeeded



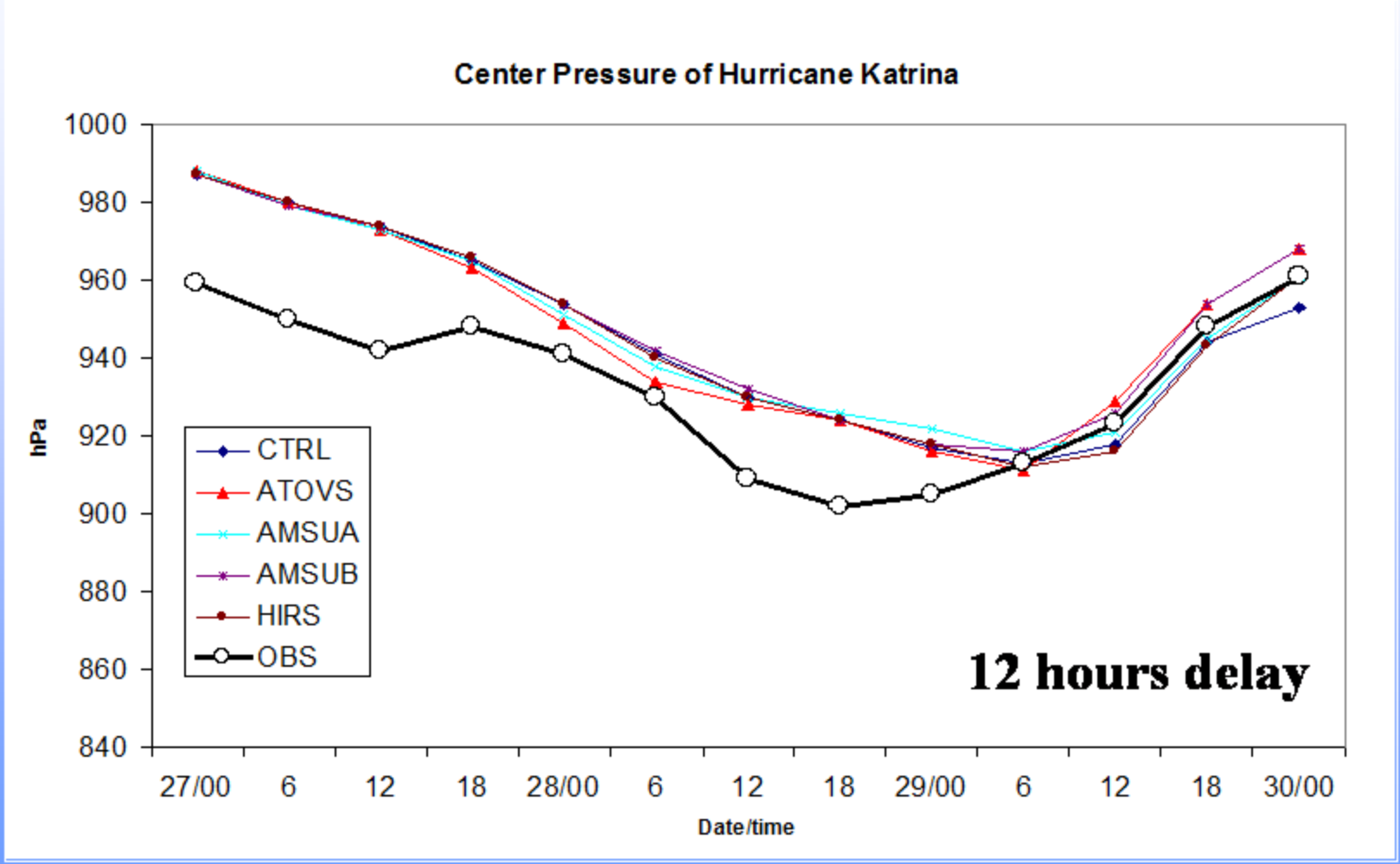
EXP1

Track Error



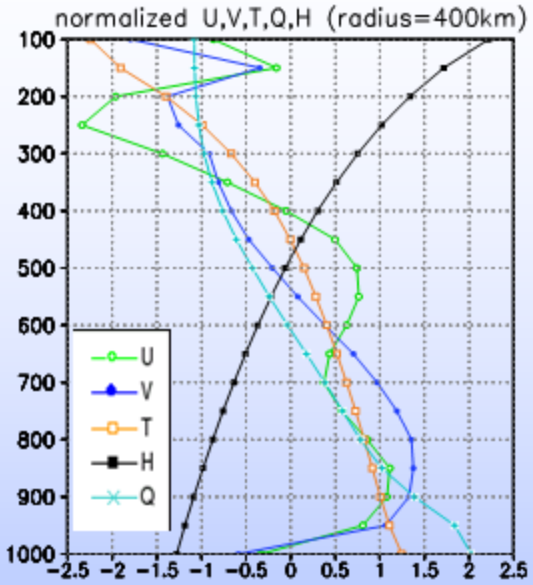
EXP1

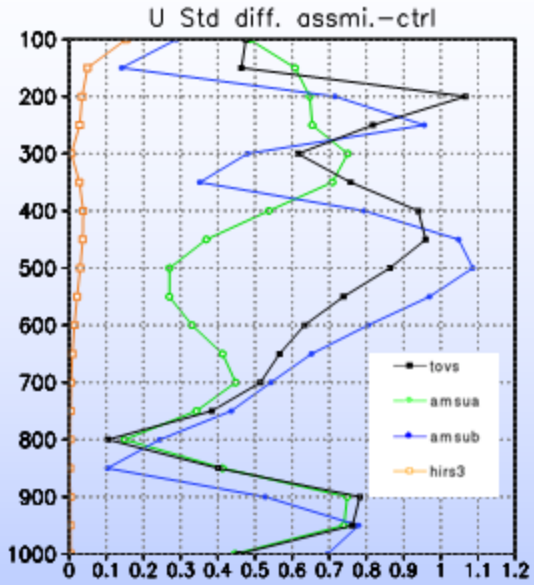
Pressure of hurricane center

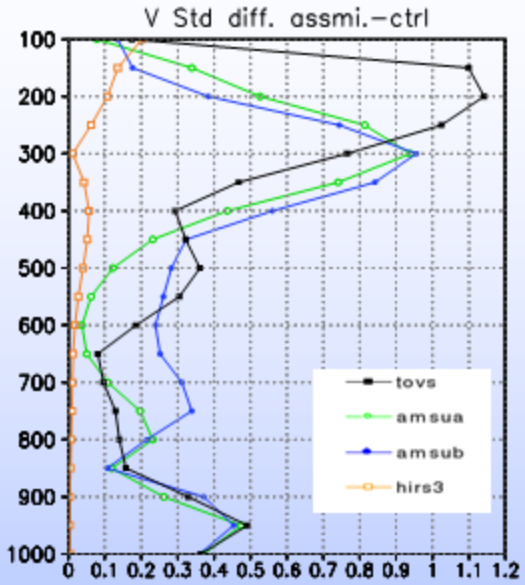


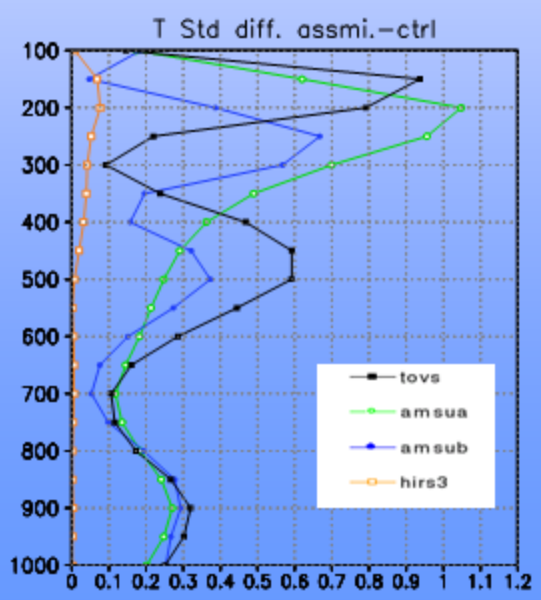
EXP1

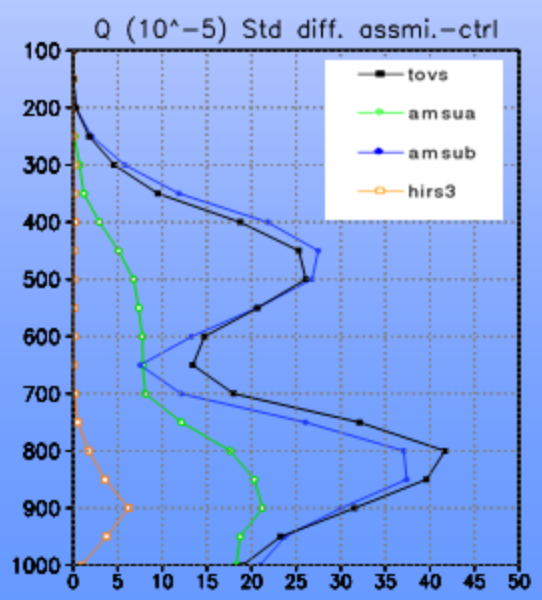
Impact on Initialization

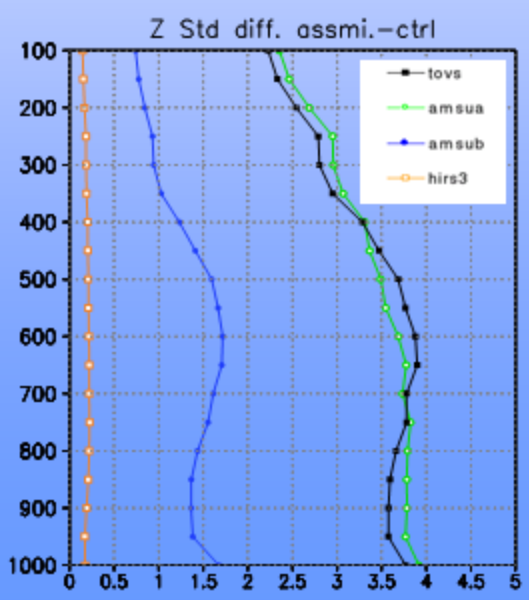












EXP2 Comparison of WRFVAR with ARW WRF/GSI Regional Data Assimilation System in Prediction of Katrina Hurricane

Model design is same as EXP1

Period: August 27-30, 2005

Forecasts: 72 hours, Initial Time : 00Z

Domain: South of America
Model resolution : 15km

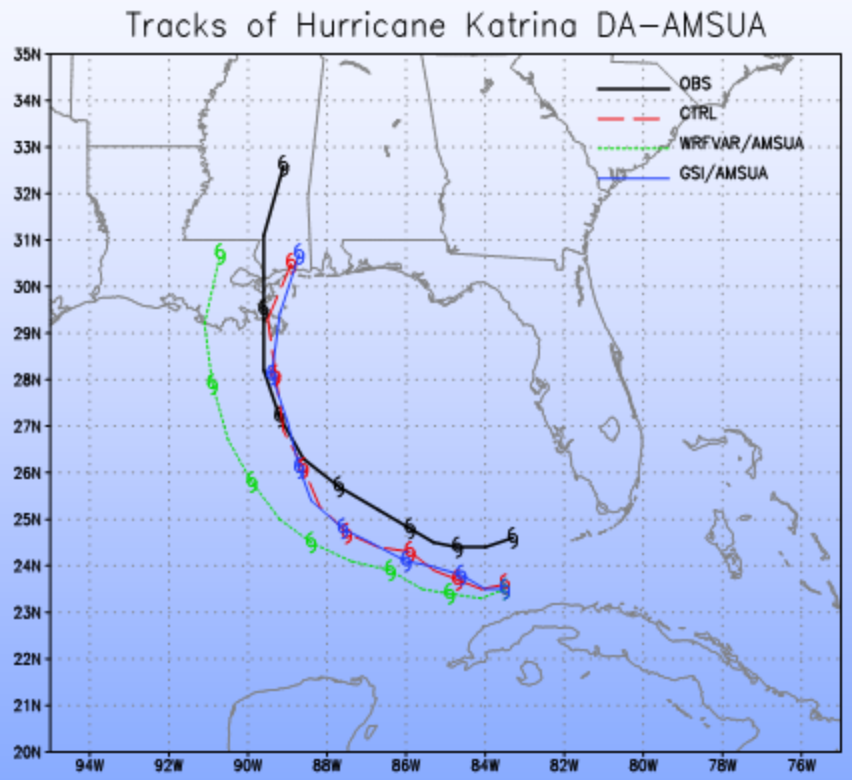
Satellite Data: AMSU-A/B and HIRS3

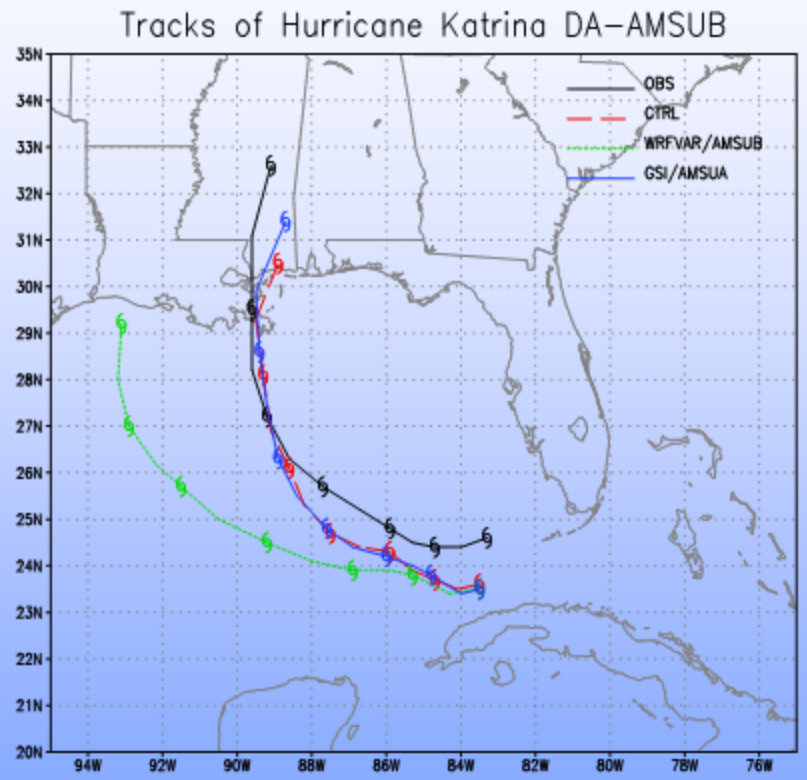
Data assimilation system:

1) WRF-Var with RTTOV 7
2) GSI with old version of CRTM

Note : WRF-Var and GSI used here is old version by 2~3 years ago

EXP2


Tracks of Hurricane Katrina DA-AMSUA
OBS
CTRL
WRFVAR/AMSUA
GSI/AMSUA
35N
34N
33N
32N
31N
30N
29N
28N
27N
26N
25N
24N
23N
22N
21N
20N
94W
92W
90W
88W
86W
84W
82W
80W
78W
76W


Tracks of Hurricane Katrina DA-AMSUB
OBS
CTRL
WRFVAR/AMSUB
GSI/AMSUA
35N
34N
33N
32N
31N
30N
29N
28N
27N
26N
25N
24N
23N
22N
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94W
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90W
88W
86W
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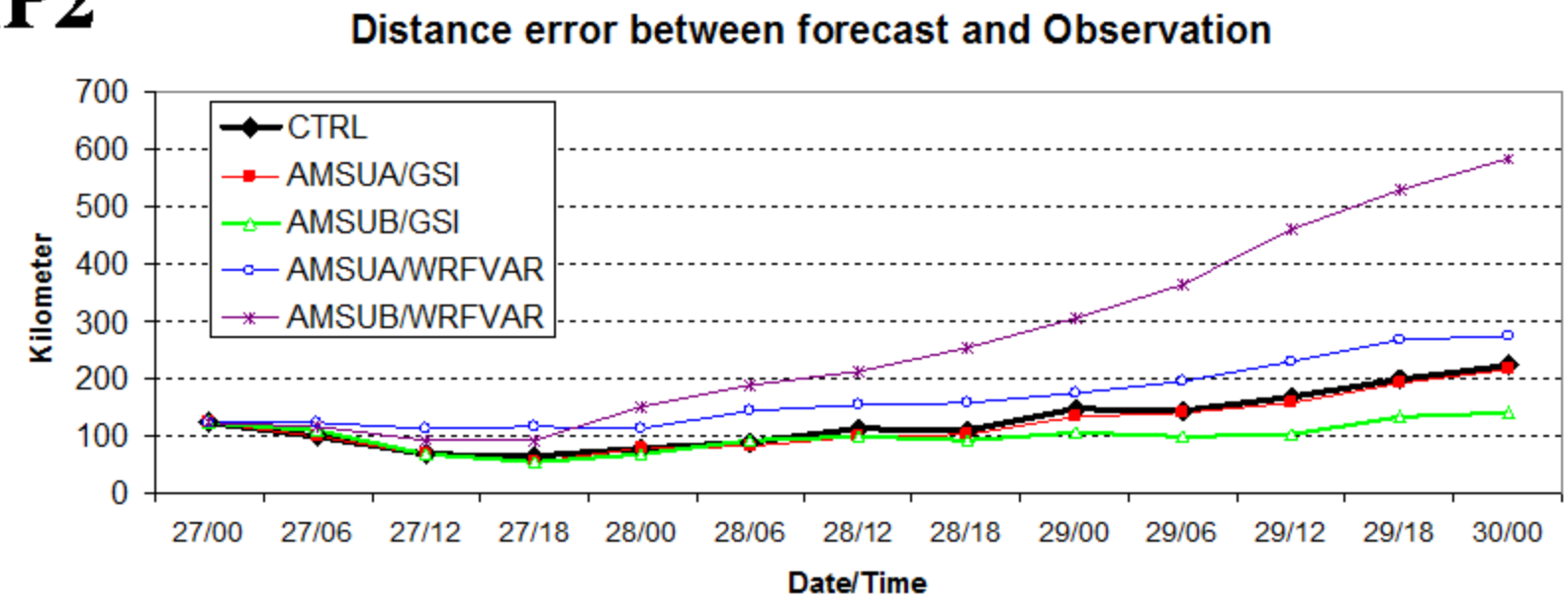
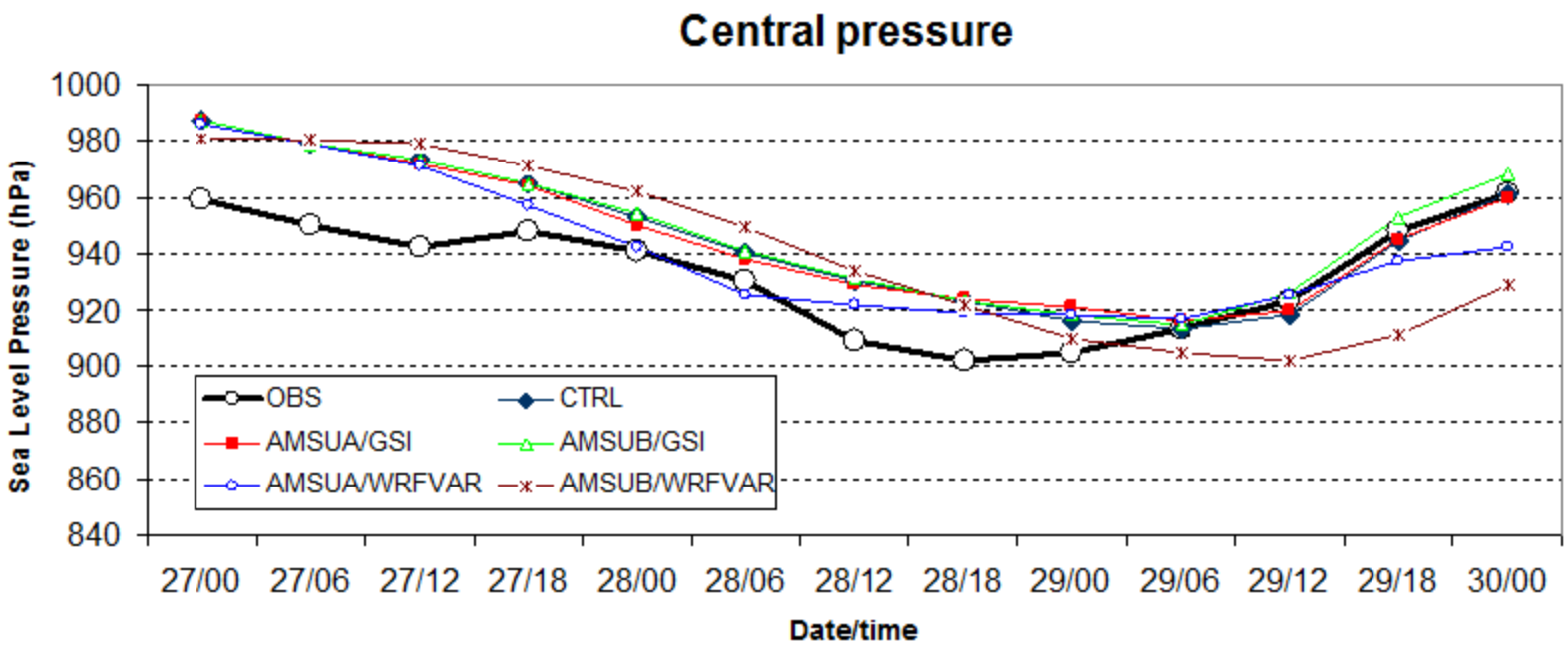
82W
80W
78W
76W

EXP2


Distance error between forecast and Observation
Kilometer
700
600
500
400
300
200
100
0
CTRL
AMSUA/GSI
AMSUB/GSI
AMSUA/WRFVAR
AMSUB/WRFVAR
27/00
27/06
27/12
27/18
28/00
28/06
28/12
28/18
29/00
29/06
29/12
29/18
30/00
Date/Time


Central pressure
Sea Level Pressure (hPa)
1000
980
960
940
920
900
880
860
840
OBS
CTRL
AMSUA/GSI
AMSUB/GSI
AMSUA/WRFVAR
AMSUB/WRFVAR
27/00
27/06
27/12
27/18
28/00
28/06
28/12
28/18
29/00
29/06
29/12
29/18
30/00
Date/time

EXP2

Summary

By the radiance data assimilation using the old version of WRFVAR and GSI analysis system, we didn't exactly catch up the track of the Hurricane Katrina, but at least, a positive impact can be found in GSI system

Please notice that the reason for the failed to catch up the track of hurricane movement is very complicated. It is not determined only by initial condition. The location of hurricane center in the first guess filed, model resolution, option of physical processes including microphysics, cumulus convection and radiation parameterization are very important for prediction of hurricane activities.

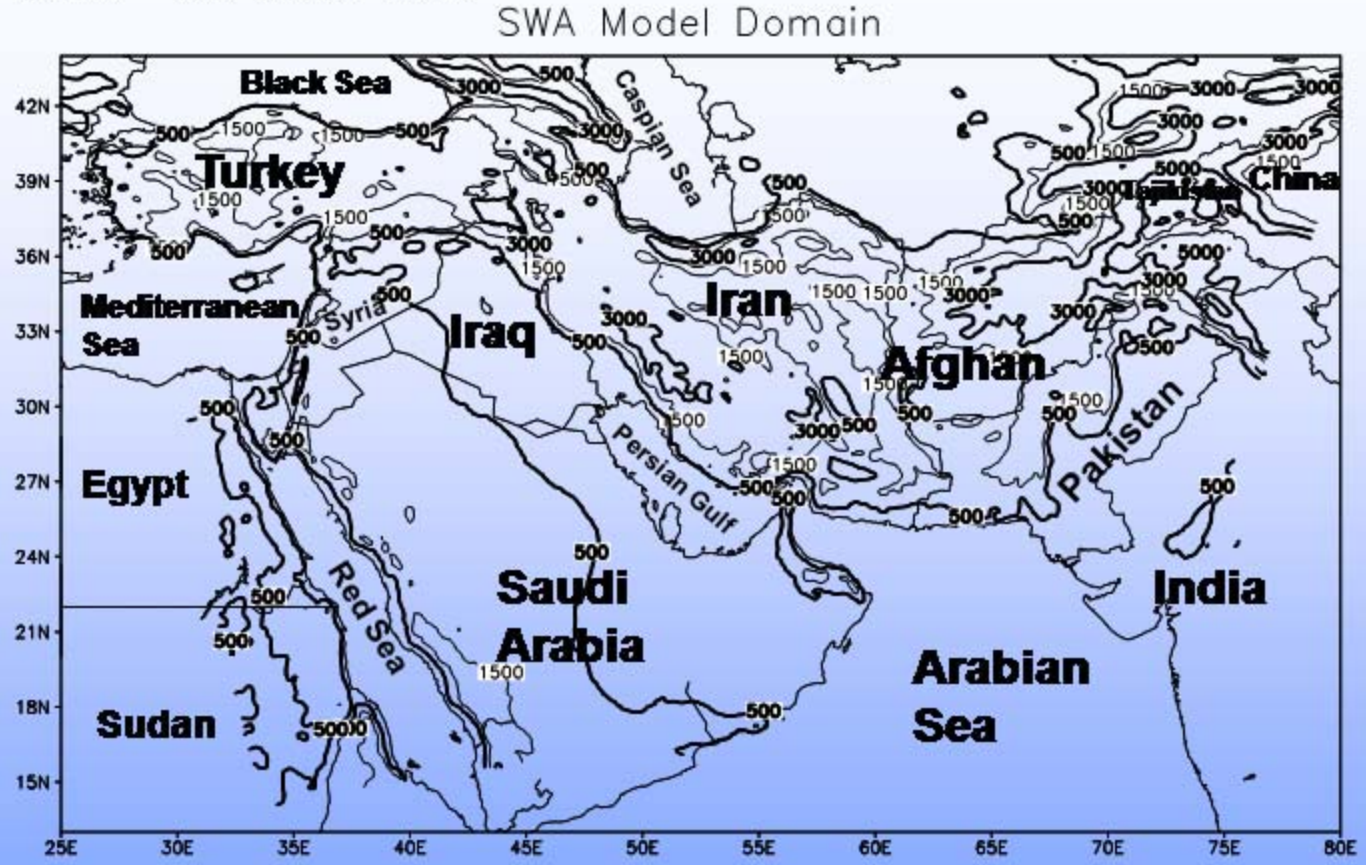
ii) ATOVS and SSMIS radiance application in the real time forecasts over AFWA T44 Domain

EXP3 : Comparison the forecasts with ATOVS radiance data assimilation by WRF-Var and GSI system during May 1~31, **2006**

EXP4 : Precipitation forecasts with ATOVS radiance data assimilation by GSI system during January 1~31, **2007**

EXP5 : Impact of SSM/IS radiance data assimilation on weather forecasts by GSI system during May 1~31, **2007**

EXP3 Comparison of ATOVS radiance data assimilation with WRF-Var and GSI



Period: May 1-31, 2006

Forecasts: 48 hours

Initial Time : 00Z

Boundary condition : NCEP GFS forecast data

Domain: Southwest of Asia (T44)

Model resolution : 15km

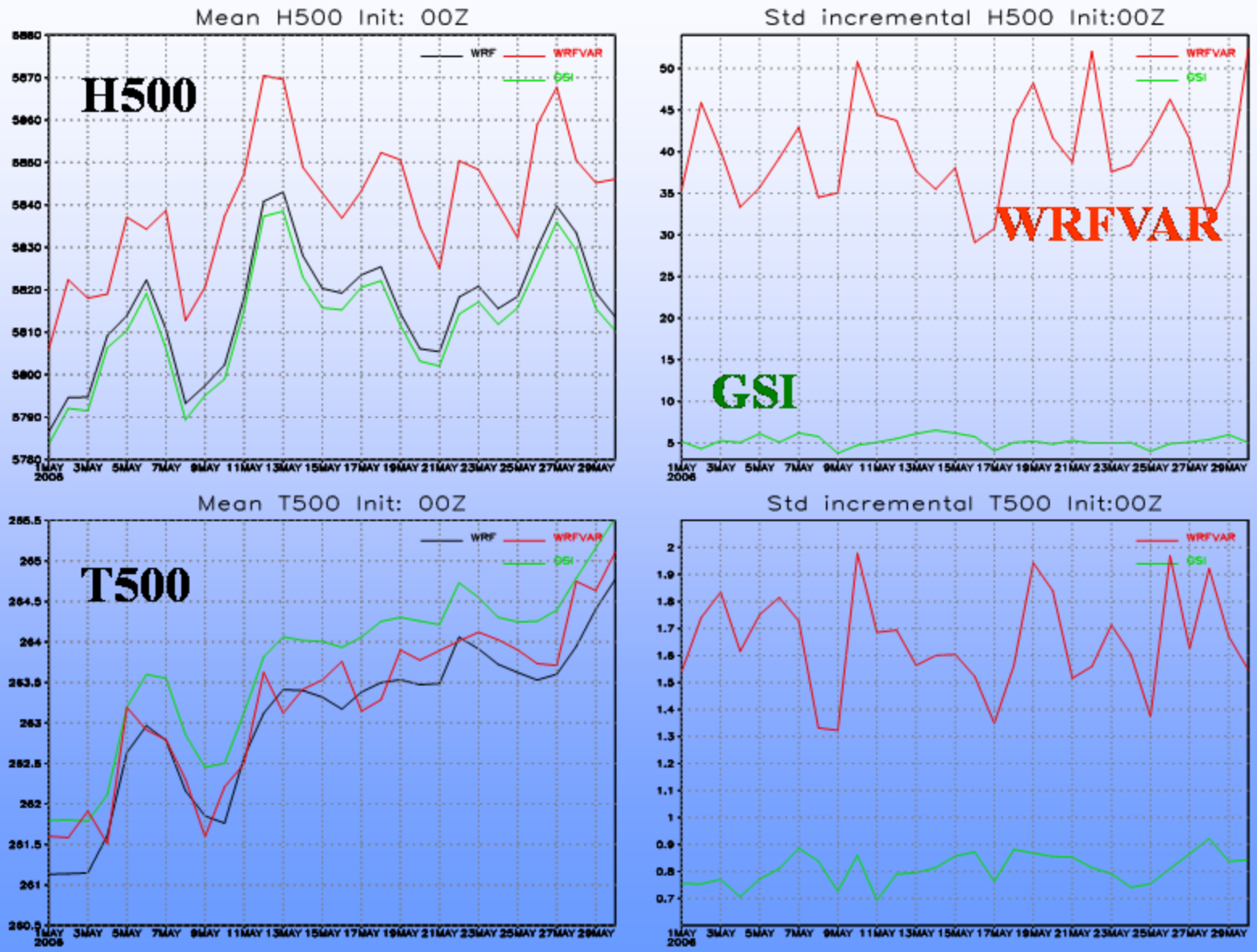
Satellite Data: AMSU-A/B and HIRS3

Data assimilation system:

1) **WRF-Var with RTTOV 7**
2) **GSI with old version of CRTM**

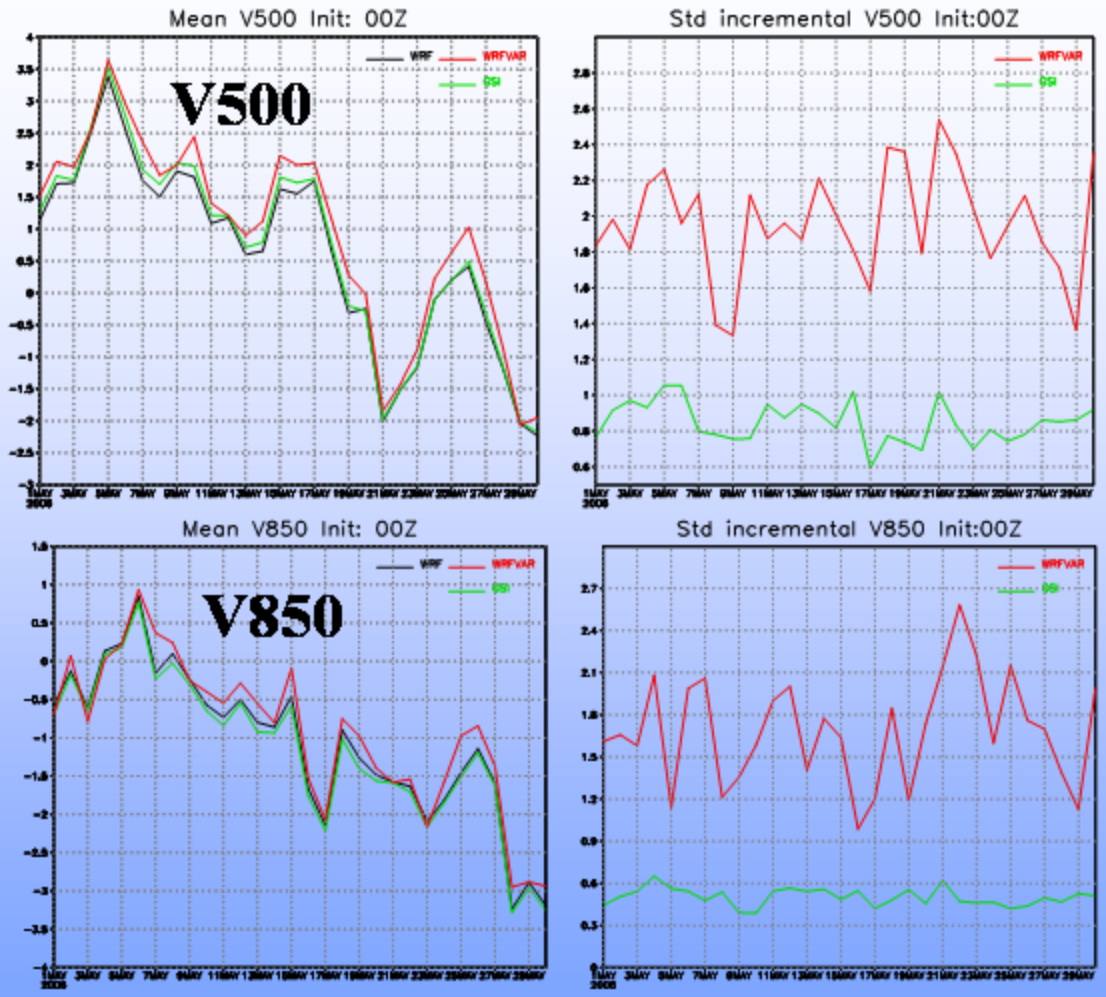
EXP3

Initial Condition (spatial mean)



EXP3

Initial Condition (spatial mean)

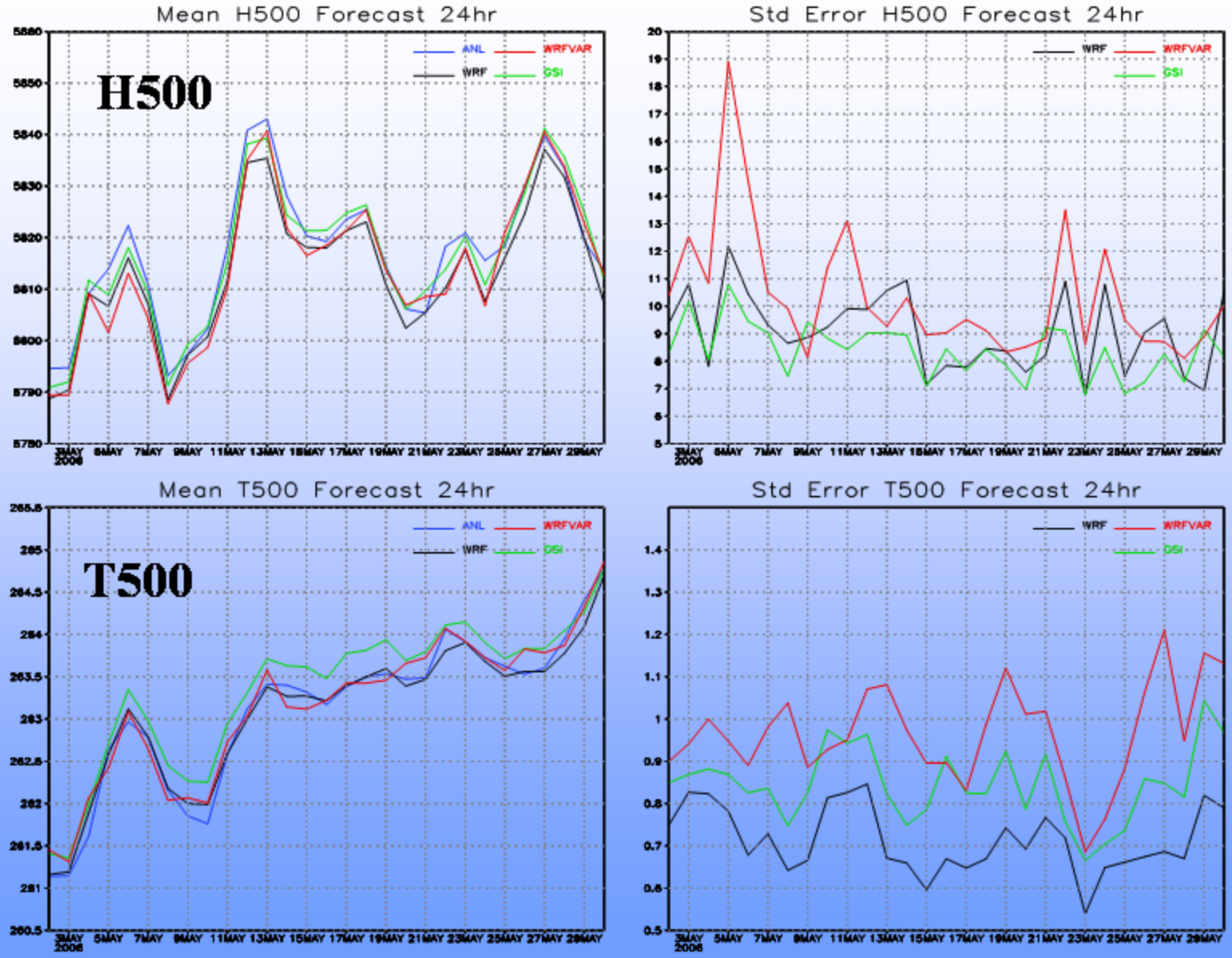


The initial value was modified significantly by the WRFVAR system, the standard deviation between data assimilation and original analysis variable in WRFVAR is about 2-3 times the value in GSI system.

The results seem that the GSI has a reasonable modification for the initialization

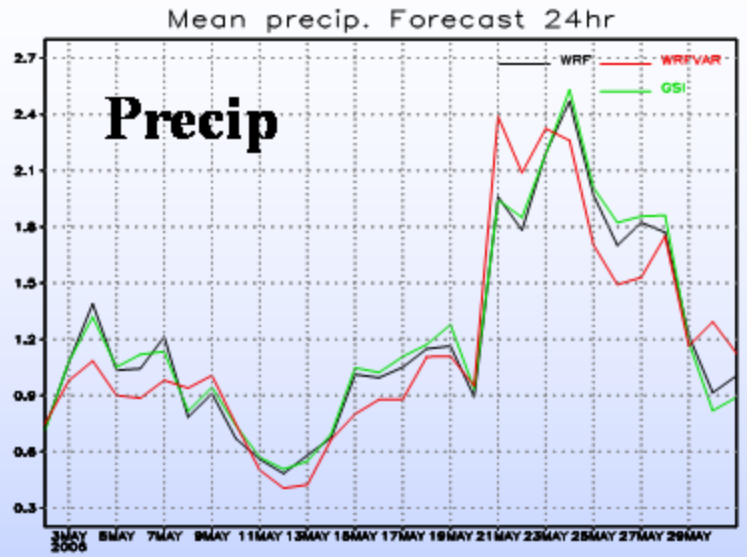
EXP3

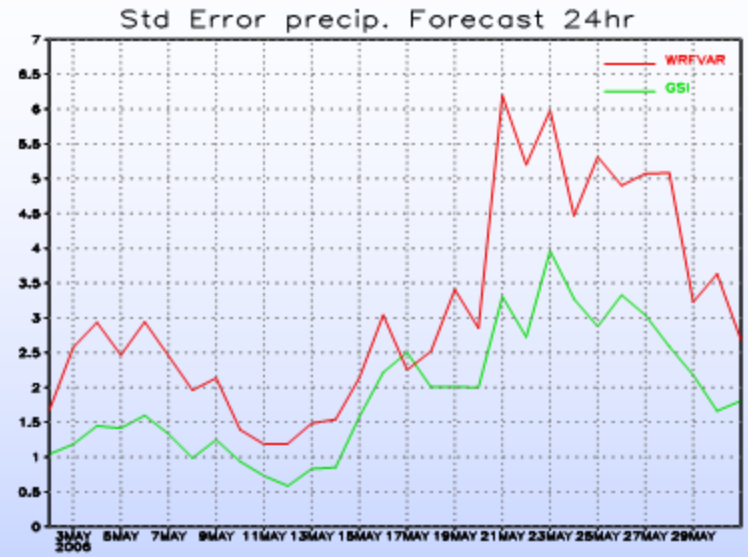
24-hour forecast (spatial mean)

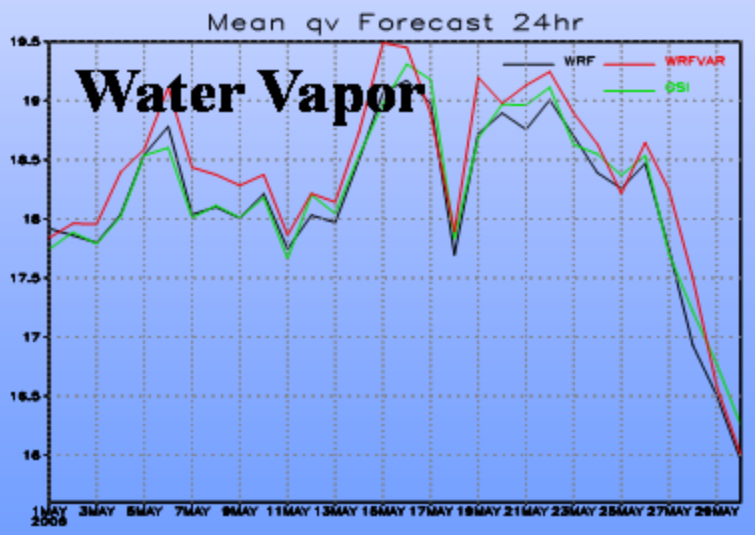


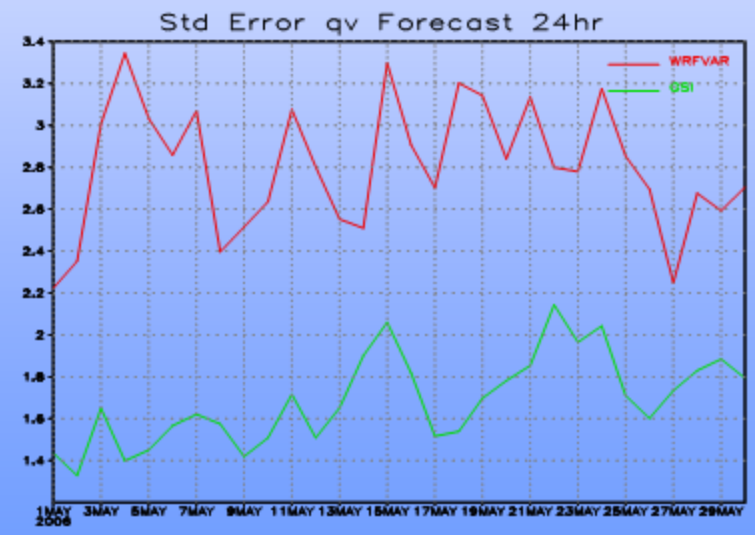
EXP3

24-hour forecast (spatial mean)









The precipitation and total water vapor forecasts, the bigger forecast error appears in WRFVAR data assimilation system.

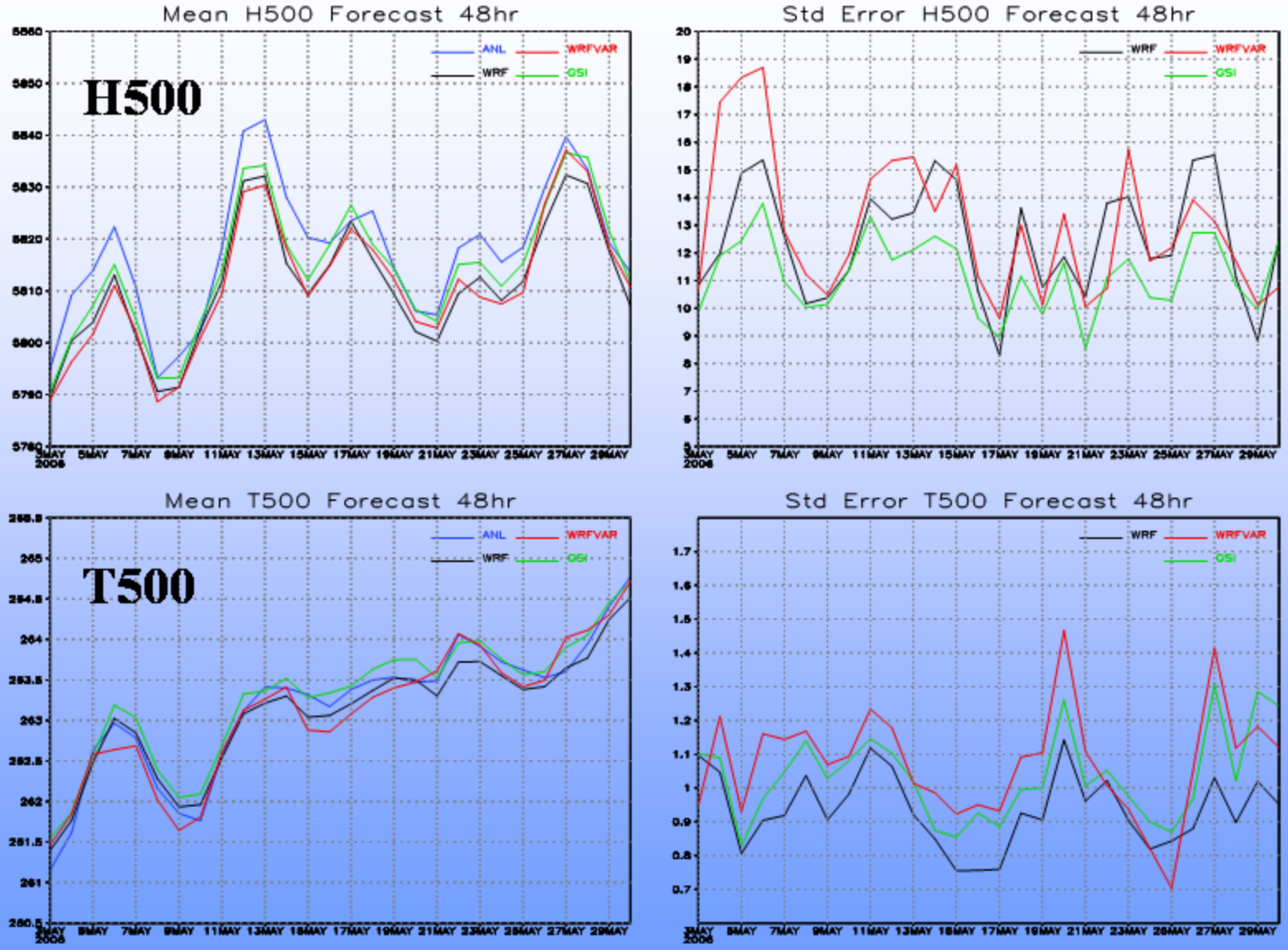
EXP3

24-hour Forecasts Summary

For the forecasts of Height and temperature and wind components on 500 hPa or 850 hPa, the forecast error between forecasting and analysis with WRFVAR data assimilation is much bigger than that in GSI system.

EXP3

48-hour forecast (spatial mean)



EXP3

48h Forecast Summary

Compared to the 24h forecasts, the 48h forecasts error didn't show the big difference in GSI and WRF-Var.

EXP3

Summary

1) Under an appropriate options of the physics parameterization, ARW WRF fine scale model has a strong capability to make 24h or 48h forecasts over the southwest Asian (SWA) areas.
2) The radiance data assimilation impact substantially on the initialization of ARW WRF model, the difference (data assimilation minus original analysis) in the height, temperature and wind initial fields indicated a big difference between GSI and WRFVAR system. GSI has a reasonable results.
3) The 24-hour forecasts show a better result by the GSI data assimilation.

EXP4 Precipitation forecasts with ATOVS radiance data assimilation by GSI system during January 1~31, 2007

Model domain is the same as EXP3

Period: Jan. 01 ~ 31, 2007.

Forecasts: 48 hours, Initial Time : 00Z

Domain: Southwest Asia

Model Resolution : 15 km

First Guess Field: NCEP GFS forecasts

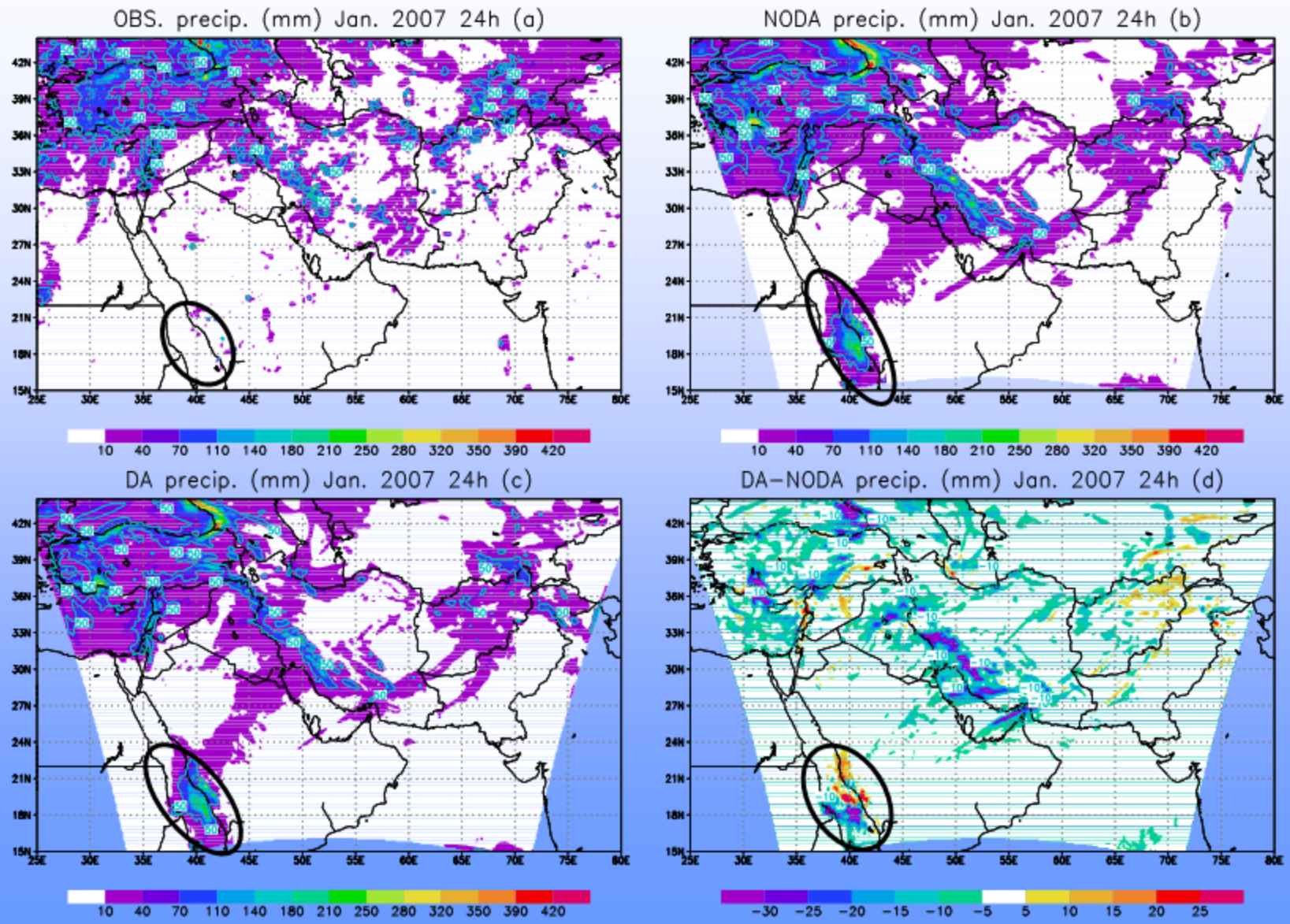
Satellite Data : AMSU-A/B and HIRS3

Data Assimilation System: GSI with new version of CRTM

EXP4

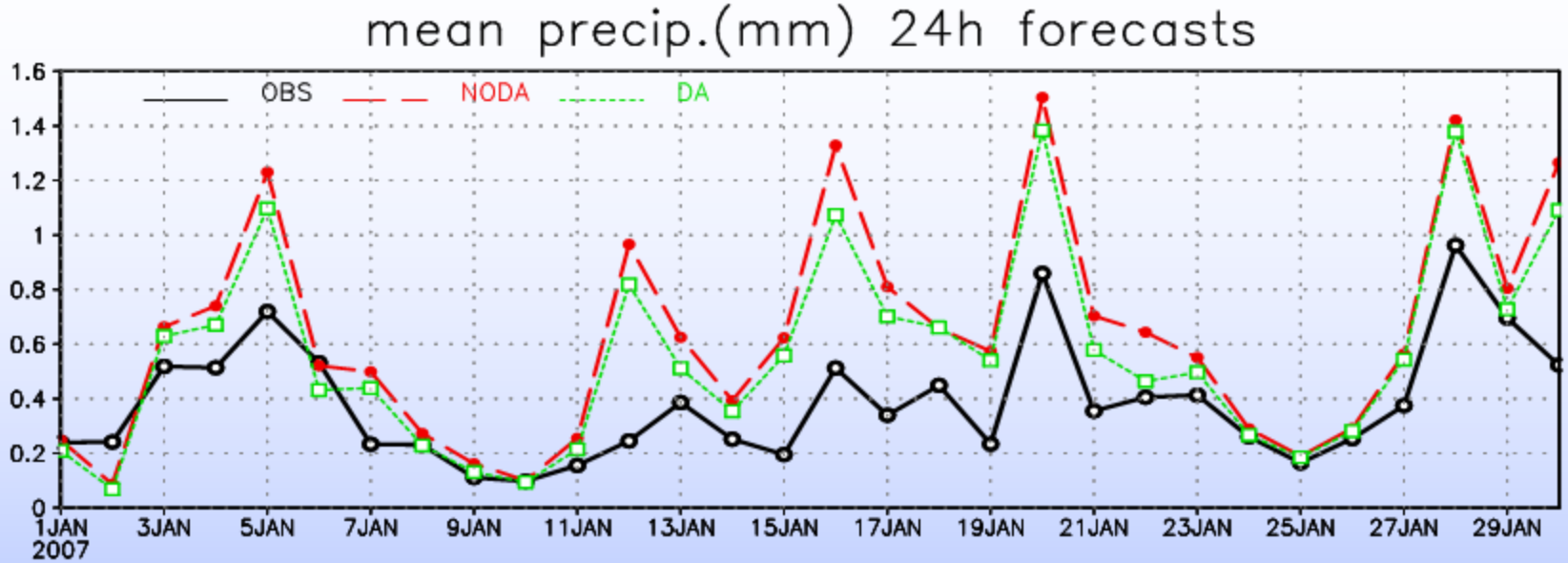
24 h Forecasts

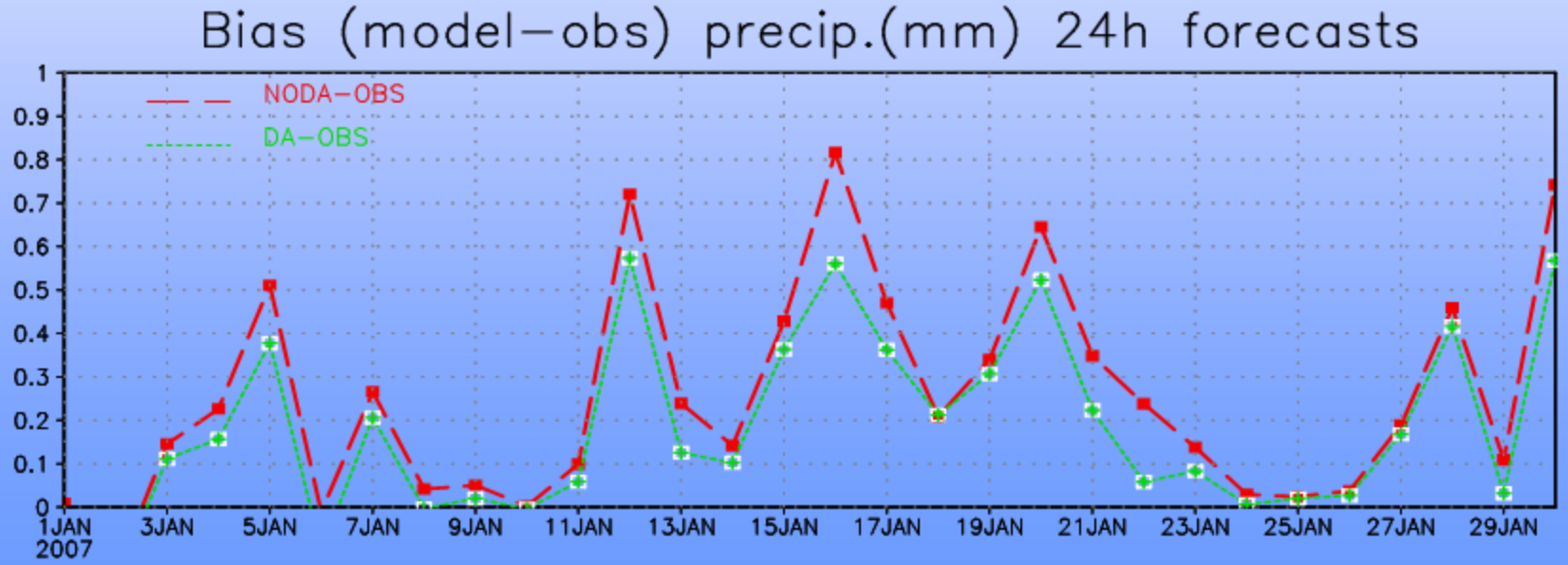
Observational precipitation data is from FEWS/CPC supported by Pingping Xie and Tim Love



EXP4

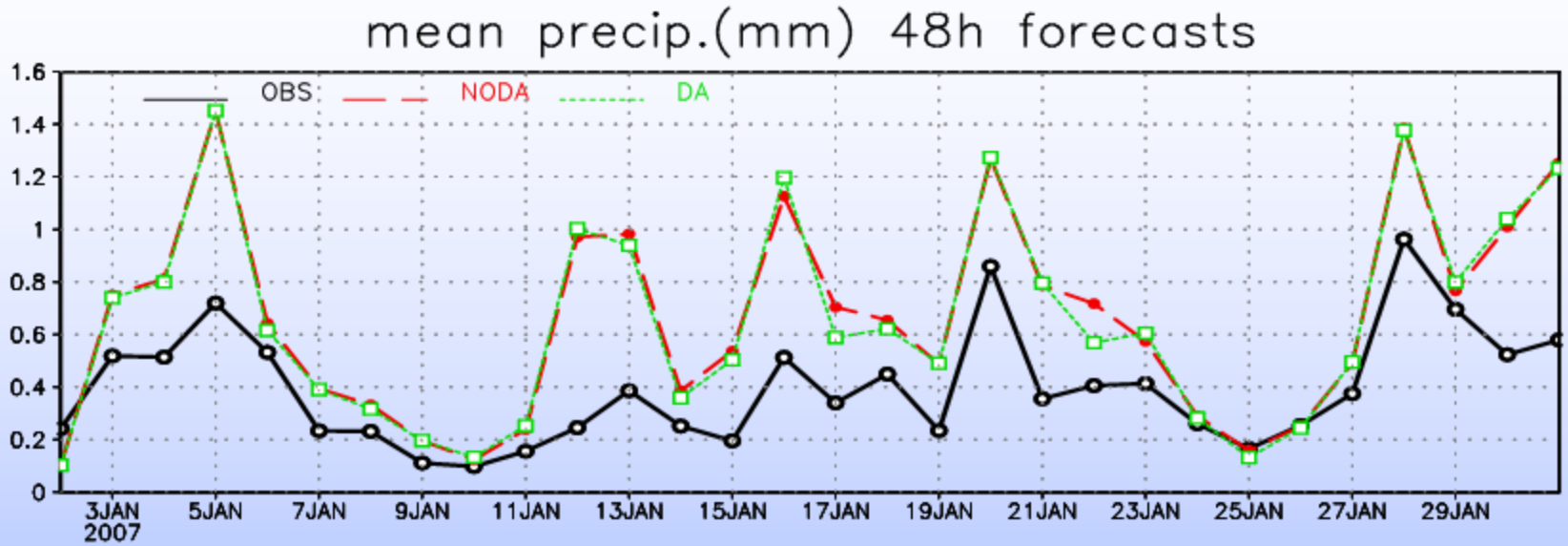
24 h Forecasts

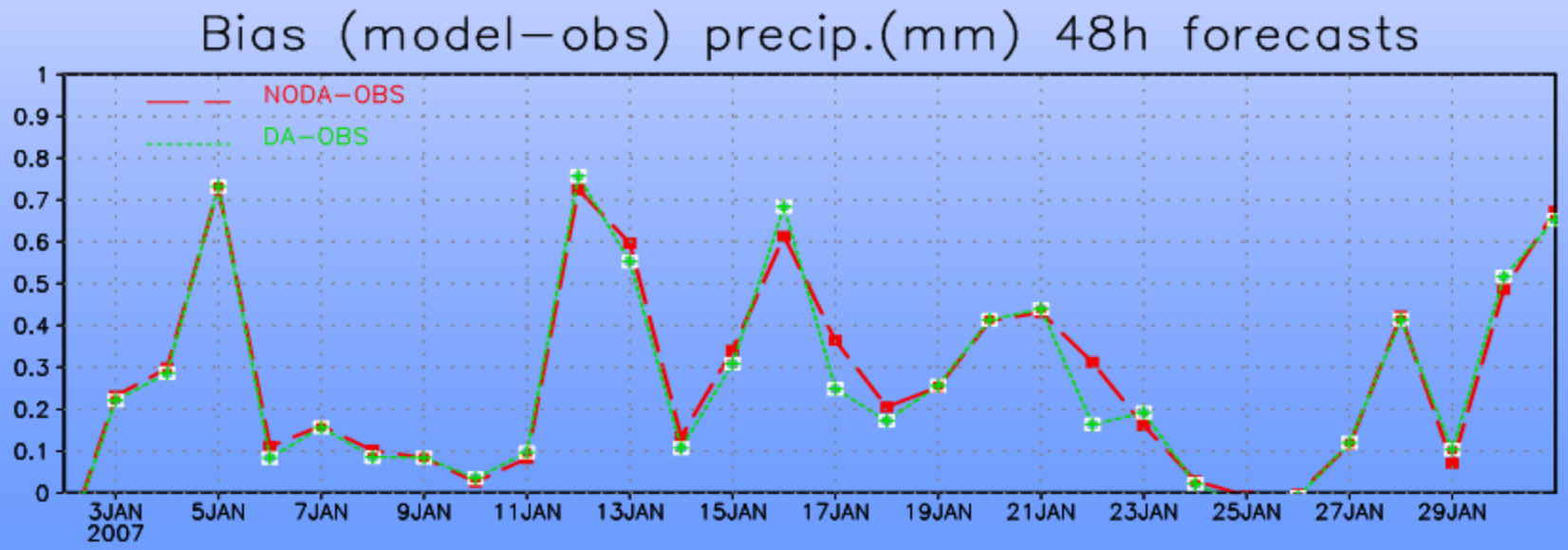




EXP4

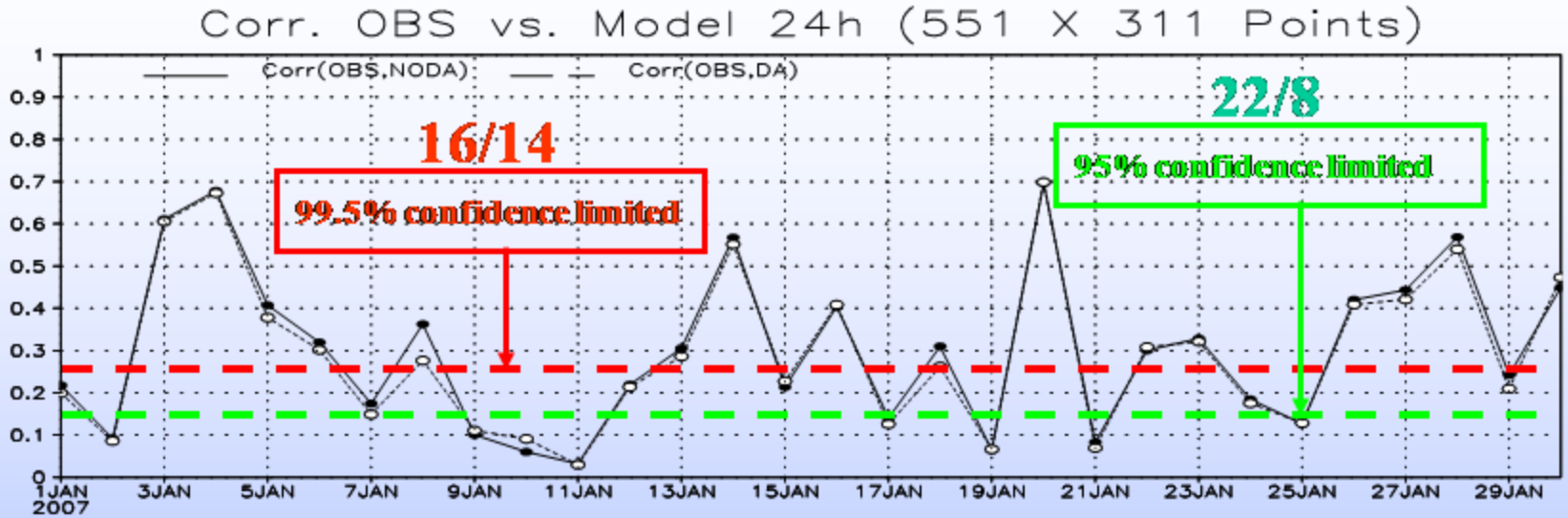
48 h Forecasts

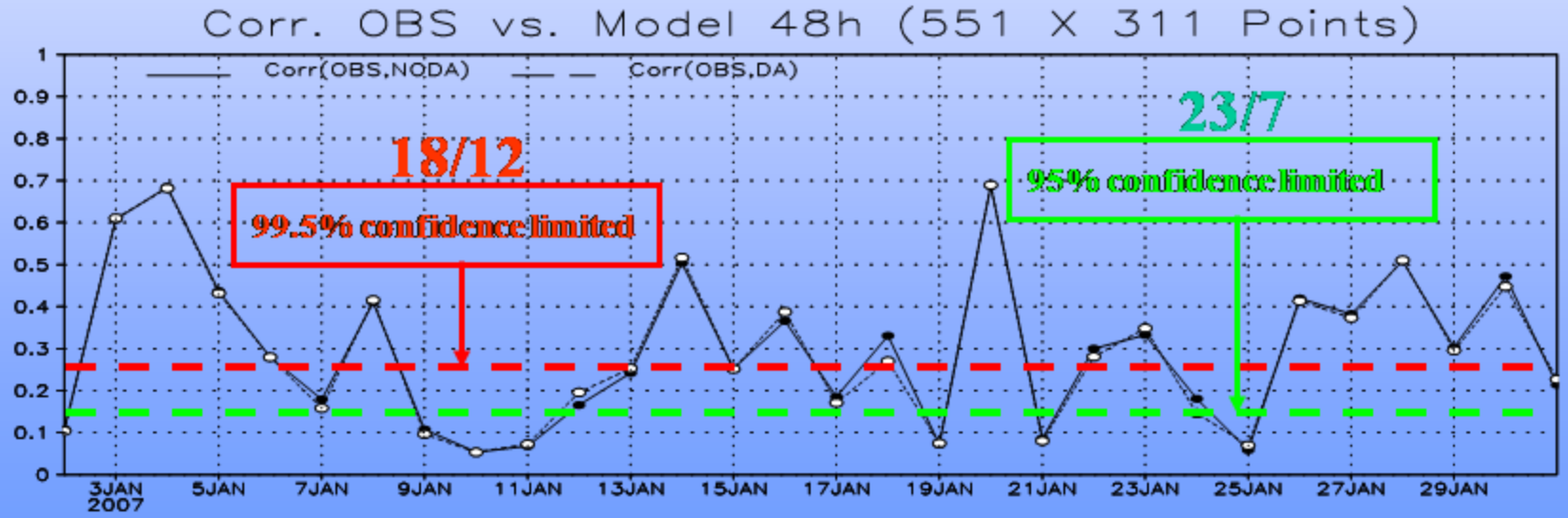




EXP4

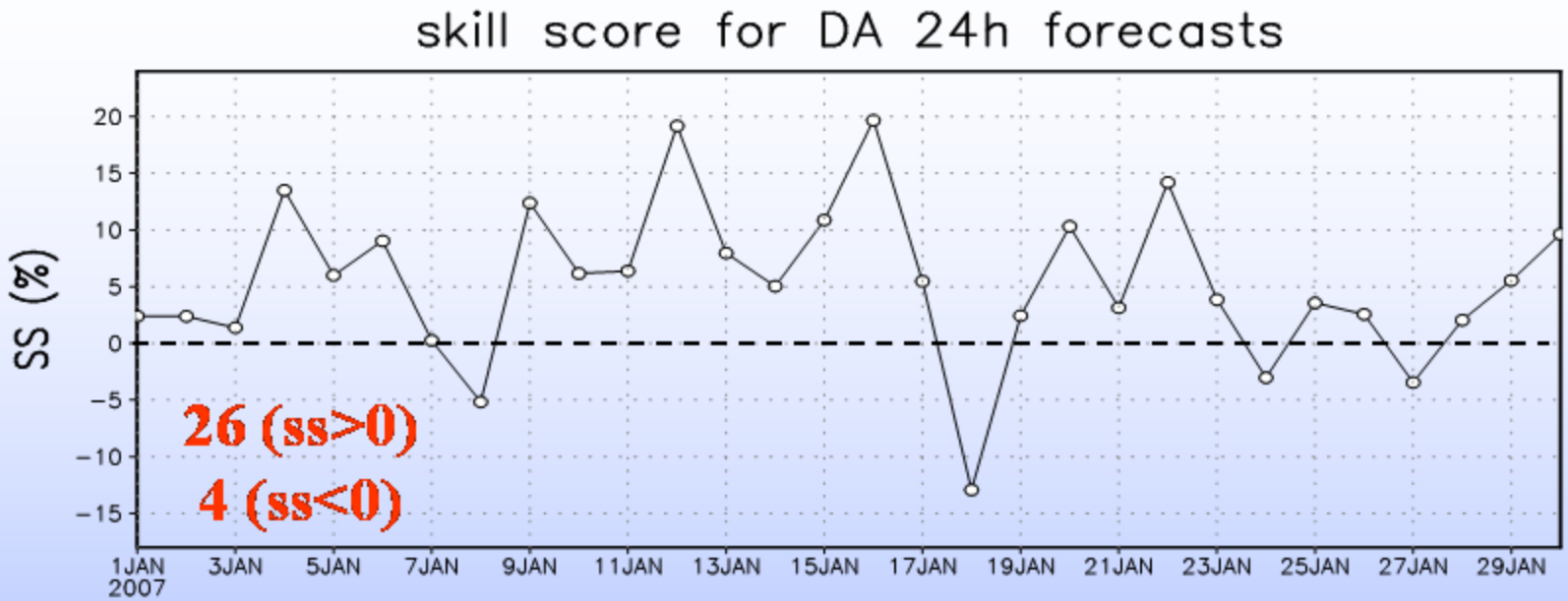
Spatial Correlation of OBS & Model

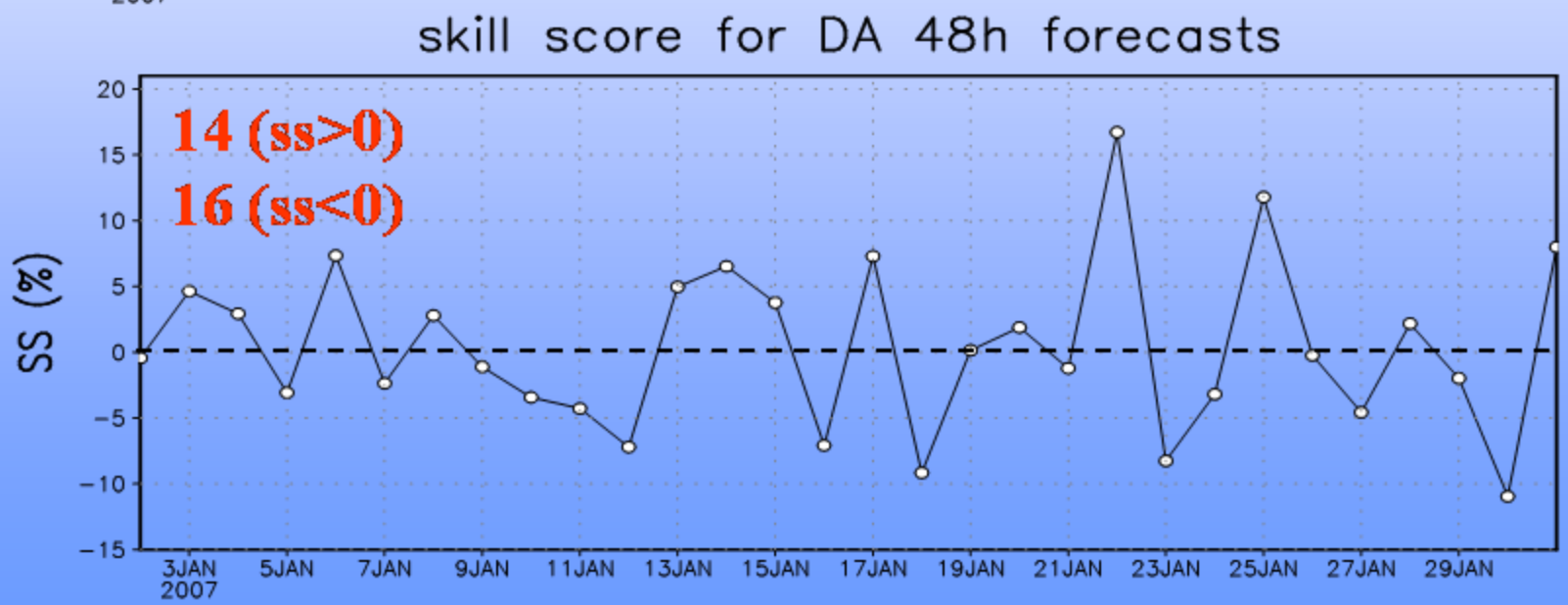




EXP4

Mean Square Error Skill Scores





EXP4

Summary

1) The ARW WRF fine scale model (15 km) has a strong capability to reproduce the observation, especially for precipitation on the 24 hr or 48hr forecasts over the southwest Asian (SWA) areas, and the model captured almost all rainfall peaks occurring over this region. But the amount of rainfall has been overestimated in the order of 40% by the model.

2) The satellite data assimilation (here only AMSU-A/B and HIRS3 is being used) indicated somehow a capability to reduced the bias of model forecasts. The another evidence worth to be noticed that the time length of effectiveness is within 24 hours after the radiance has been assimilated.

EXP5 : Impact of SSMIS radiance data assimilation on weather forecasts by GSI system

Period: May 01 ~ 31, 2007.

Forecasts: 48 hours, Initial Time : 06Z

Domain: Southwest Asia

Model resolution : 15 km

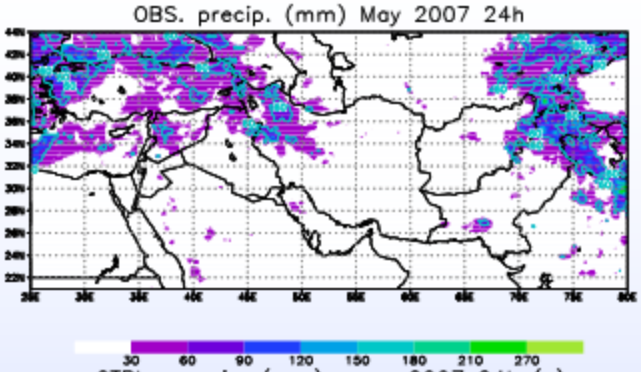
First guess field : NCEP GFS forecasts

Satellite data: 1) SSM/IS radiance

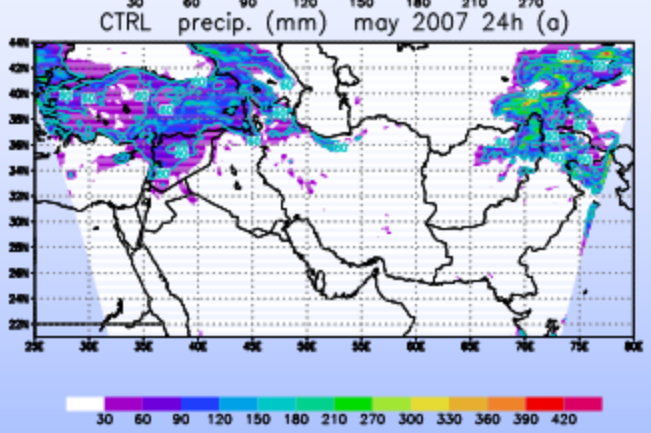
2) AMSU-A/B and HIRS3 radiance

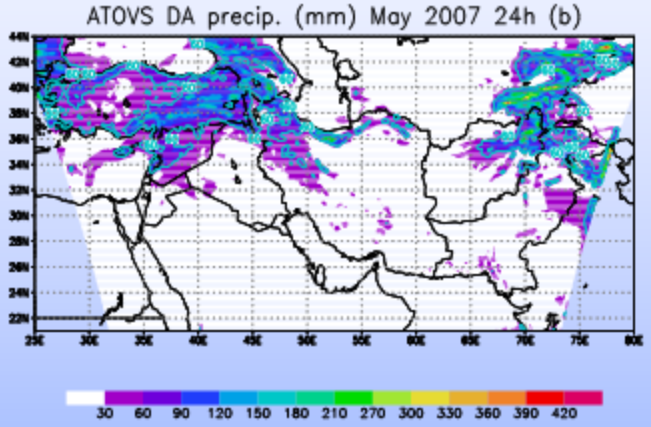
exp1 ~ Control experiment : No data assimilation
exp2 ~ ATOVS : Conventional prebufr data, AMSU-A/B and HIRS3 radiance data assimilation
exp3 ~ NESDIS: NESDIS SSM/IS LAS radiance plus data in exp2
exp4 ~ UKMO : UKMO SSM/IS LAS radiance plus data in exp2

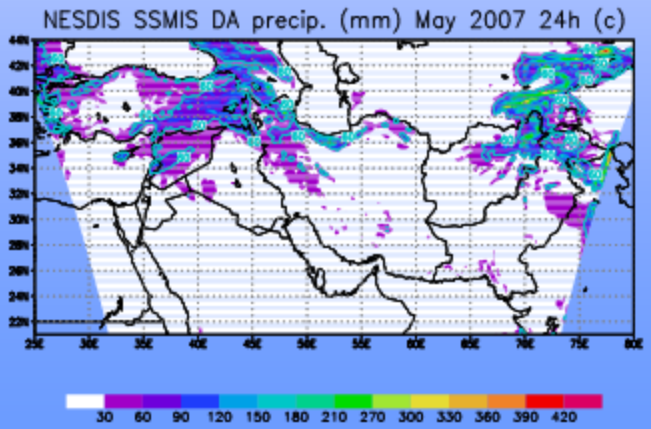
EXP5

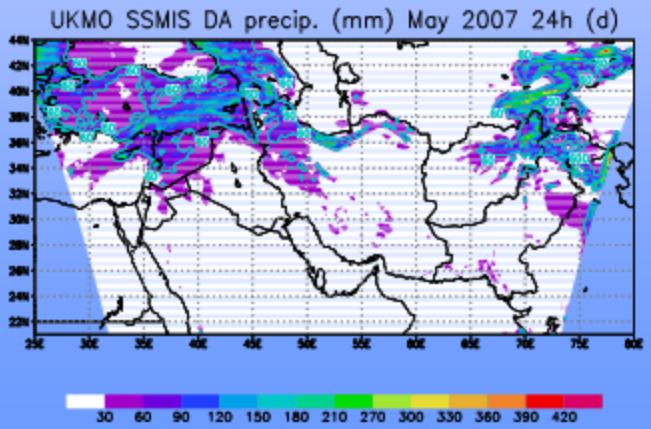


Observational precipitation data is from FEWS/CPC supported by Pingping Xie and Tim Love



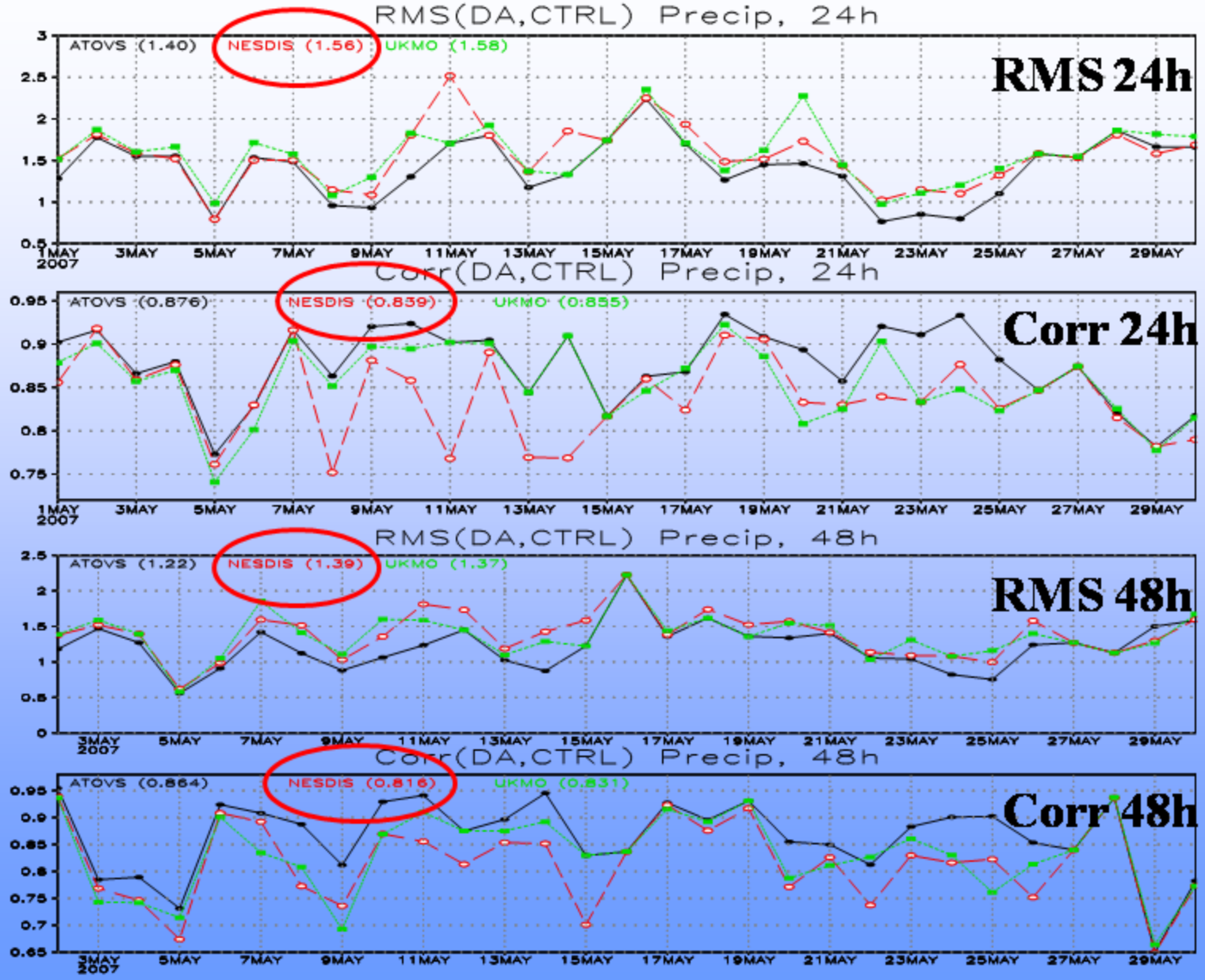






EXP5

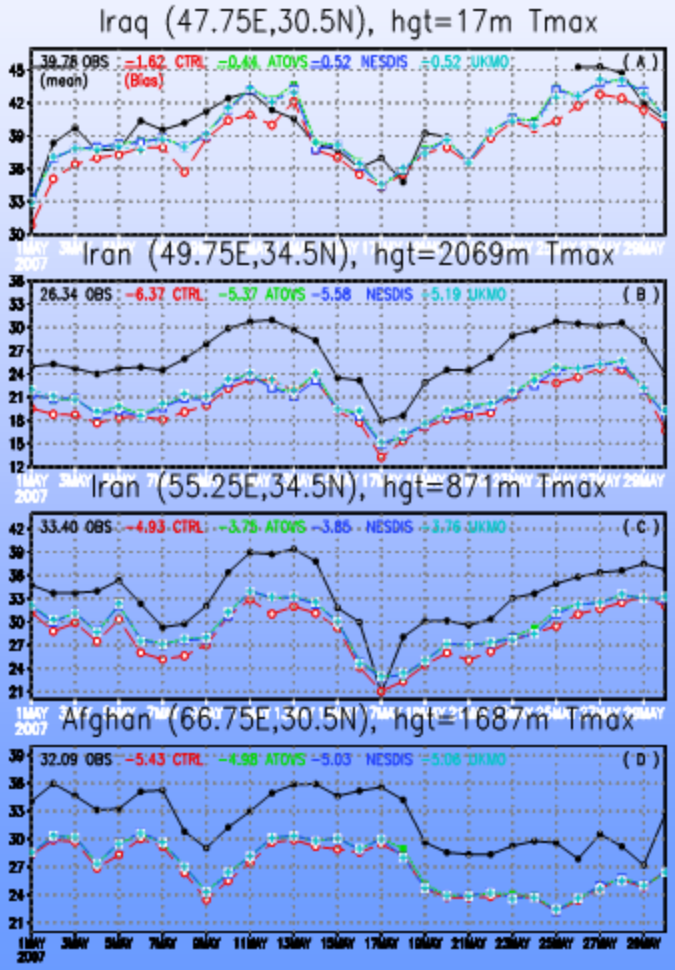
Precipitation

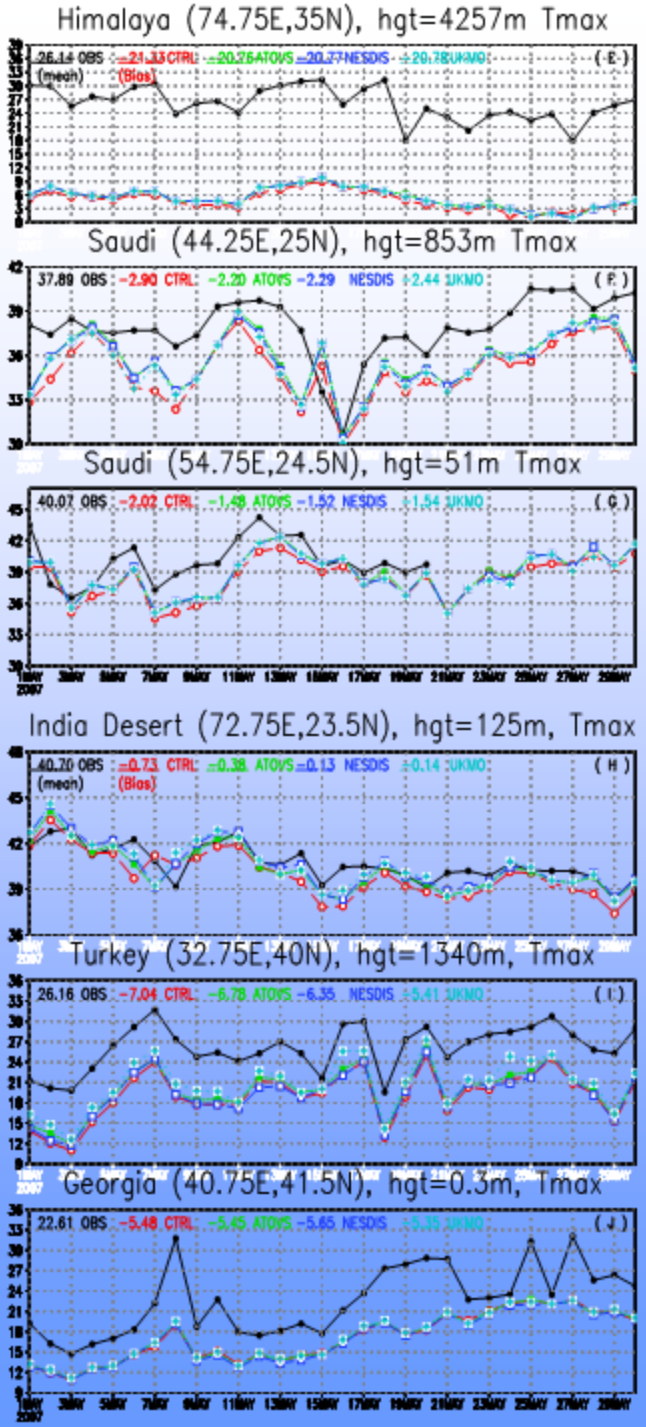


More SSM/IS data being assimilated with ATOVS did not improve the precipitation forecasts, UKMO looks better

EXP5

The observational data is from GTS/CPC supported by Pingping Xie



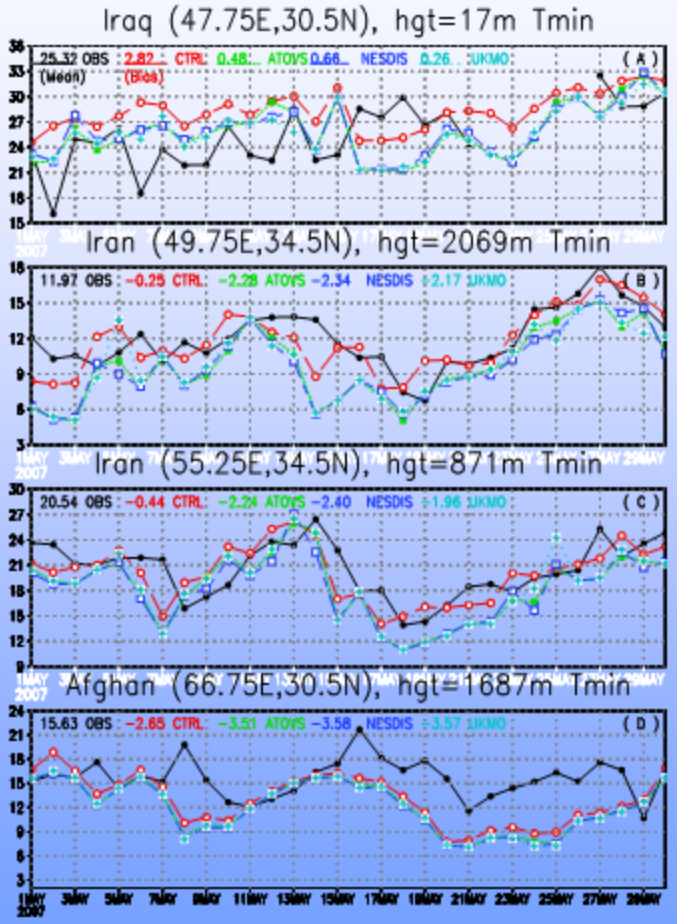


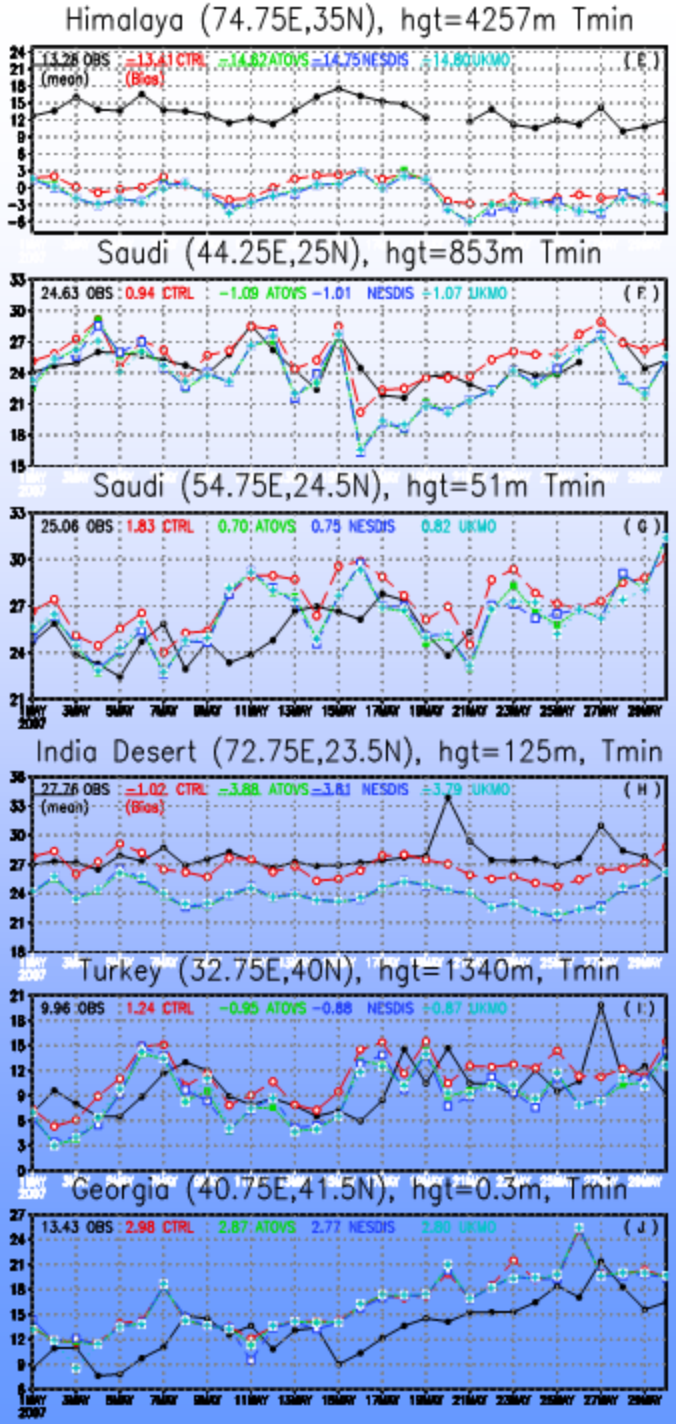
In the selected 10 observatory stations, all model forecasts of maximum temperature is lower than the observational counterpart by ~2.0 C except for the high mountain Himalaya station, in which the forecasts completely failed, but in the other station, the forecasts are reasonable.

The forecast error get improved somewhat through the satellite data assimilation, unfortunately, plus SSMIS data assimilation, the improvement is NOT significant.

It is worth to notice that the corrected UKMO SSMIS data assimilation don't got a significant improvement of forecasting comparing to uncorrected NESDIS SSMIS data assimilation

EXP5





Compared to the forecasting of maximum temperature, the forecasts of minimum temperature is closer to the observational temperature, but the forecasts are not always lower than the observation.

However, the forecast error do not get improved after the satellite data assimilation whether only ATOVS data or plus SSM/IS data

EXP5 Summary

1) AWR WRF model reproduced somehow temperature distribution, but the model maximum temperature is always colder than the observation by ~2 C, the worst error occurs over the high mountain areas. The biggest error appeared over the Himalaya mountain.

2) The forecasts with radiance data assimilation get a positive impacts for Tmax and Tmin.

3) Comparing to the forecasts in only ATOVS data assimilation, plus SSM/IS radiance data assimilation did not show any significant improvement for the temperature forecasts. The corrected UKMO SSM/IS radiance don't get a better results than the uncorrected NESDIS radiance forecasts.

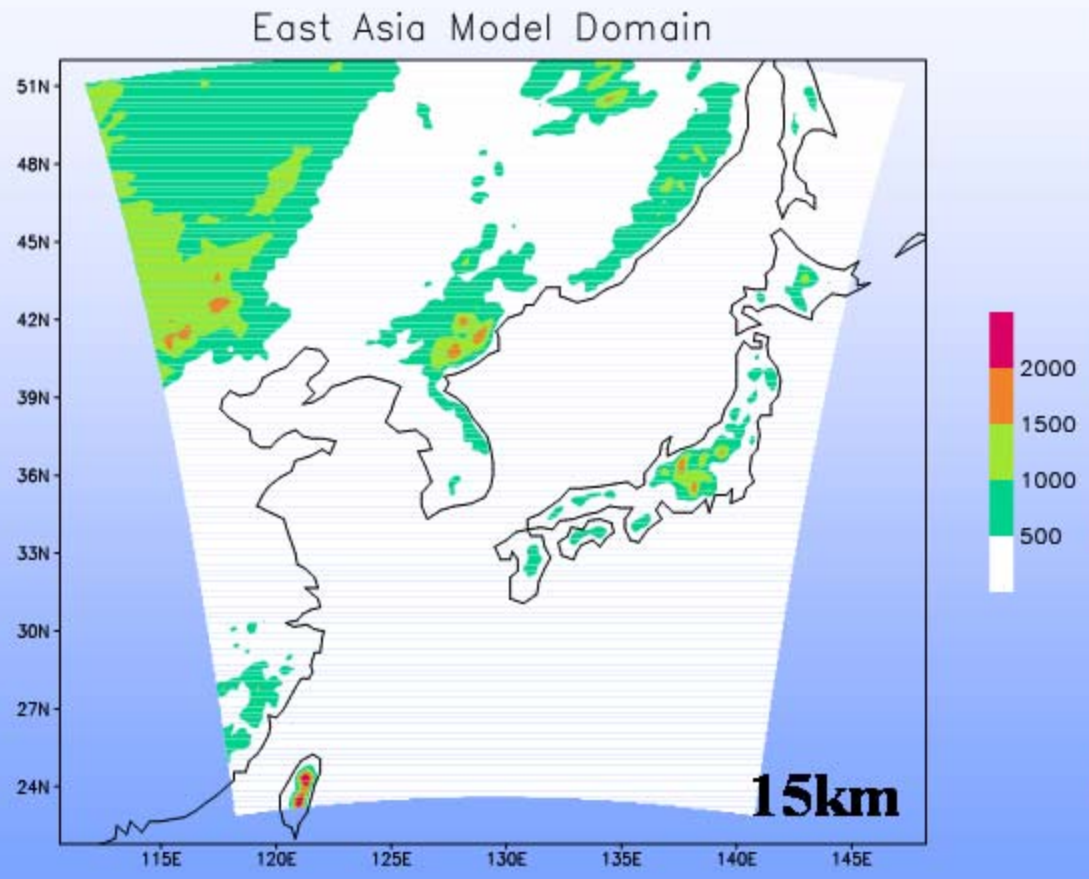
4) The SSM/IS temperature sounding radiance (LAS) using in WRF forecasts will improve limitedly the temperature forecasts over the Southwest of Asia areas.

iii) ATOVS and SSMIS radiance application in the real time forecasts over the AFWA T46 Domain

EXP6 : Comparison the impacts of AMSU-A radiance data assimilation in WRF-Var and GSI system

EXP7 : Comparison the impacts of AMSU-A and SSM/IS LAS radaince data assimilation in GSI system

EXP6 : Comparison the impacts of AMSU-A radiance data assimilation in WRF-Var and GSI system



Period: July 1-14, 2007.

Forecasts: 24 hours, Initial Time : 00Z

Domain: East Asia
Model resolution : 15km

Conventional data : NCEP prebufr observational data

Satellite Data: AMSU-A

Data assimilation system:

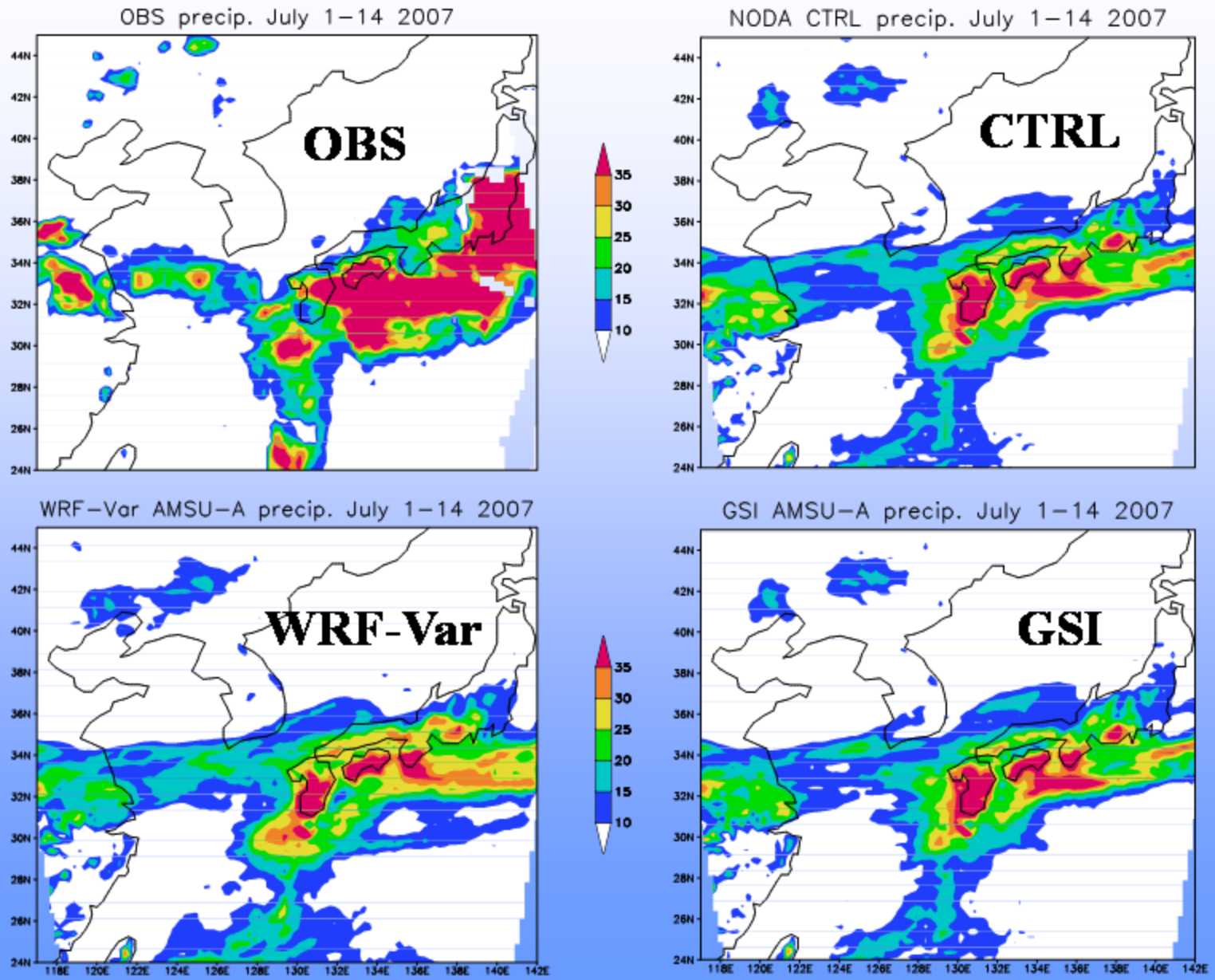
1) **WRF-Var with CRTM**
2) **GSI with new CRTM**

WRF-Var experiment completed by zhiquan Liu (NCAR)

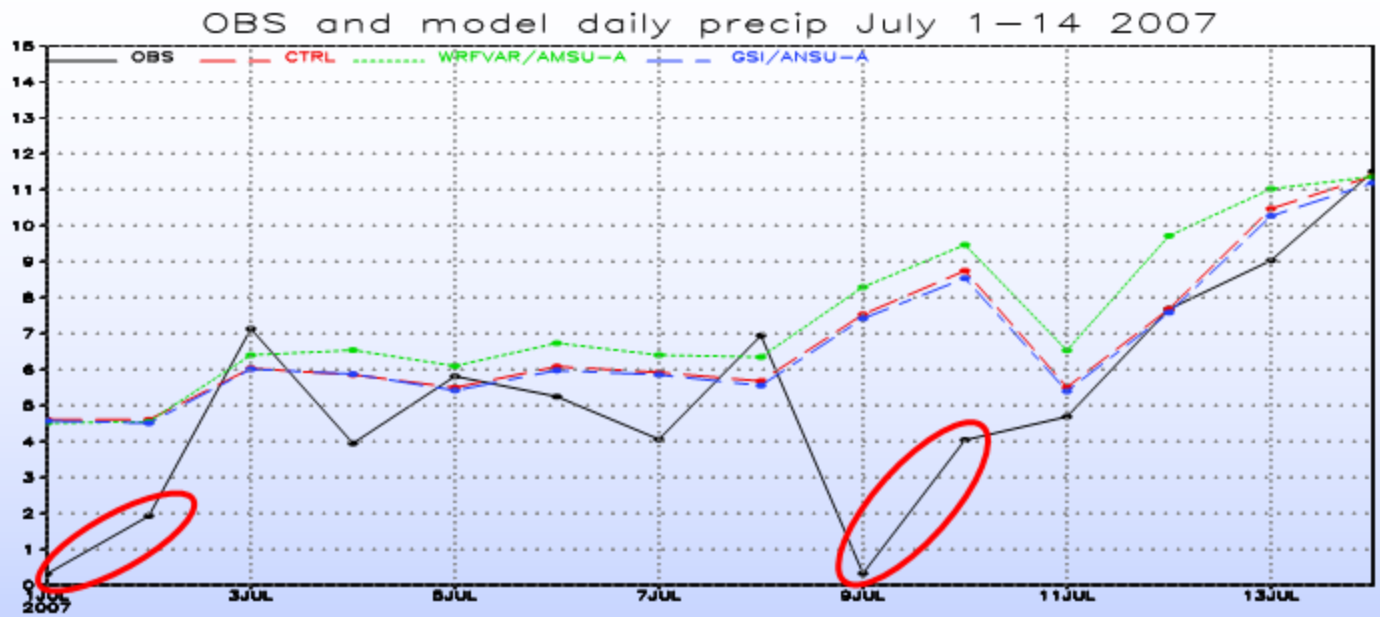
EXP6

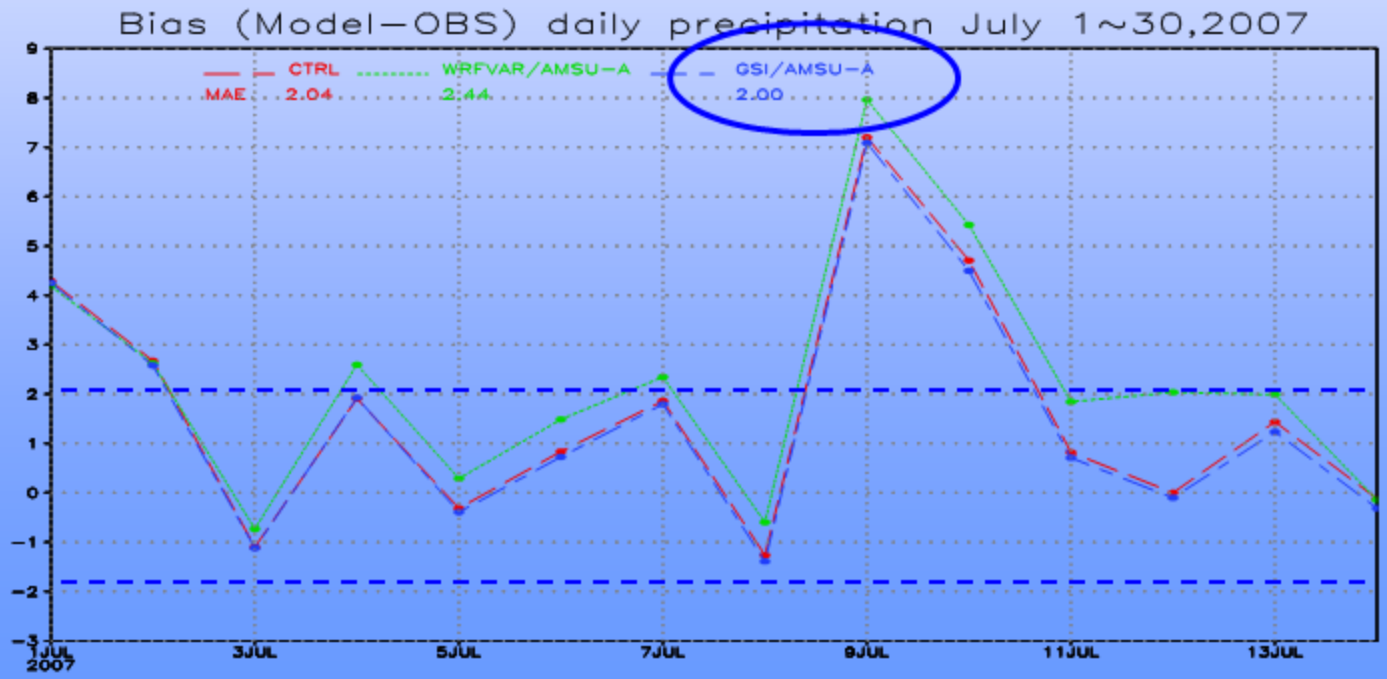
Observational precipitation is from CPC CMORPH 0.25 degree 3-hourly

Forecasting precipitation pattern is quite good



EXP6





The forecasts get improved by GSI, but the improvement is not significant.

GSI better

EXP7 : Comparison the impacts of AMSU-A and SSMIS LAS radiance data assimilation in GSI system

Model Domain is the same as EXP6

Period: July 1-31, 2007.

Forecasts: 24 hours; Initial Time : 00Z

Domain: East Asia

Model resolution : 15km

Boundary condition: NCEP GFS real time forecasts

Satellite Data: AMSU-A (channel 4-6,8-9) and SSM/IS LAS (channel 2-6) with the same frequency

Data assimilation system: GSI system with new CRTM

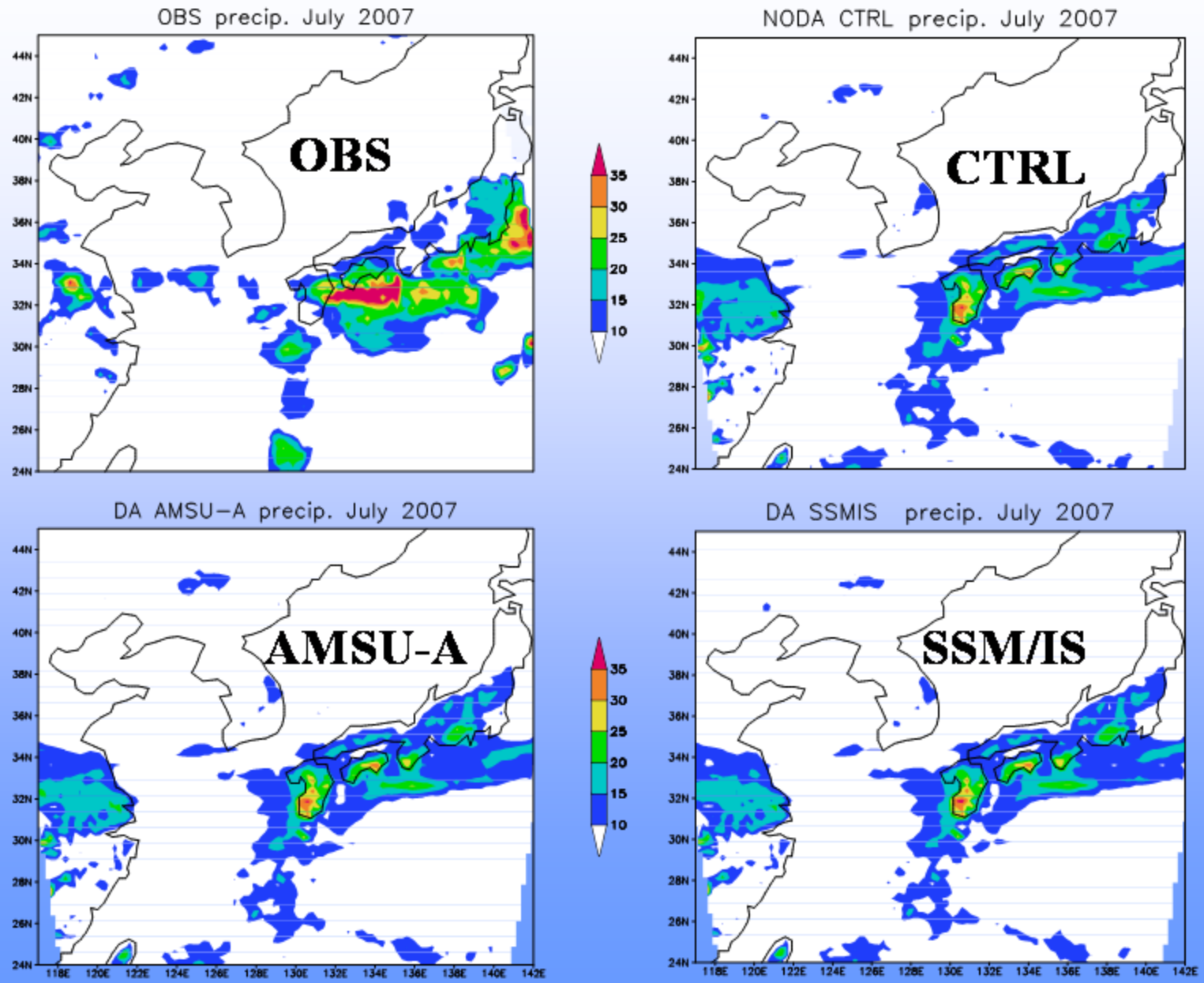
exp1 : control experiments, no data assimilation

exp2 : AMSU-A only data assimilation

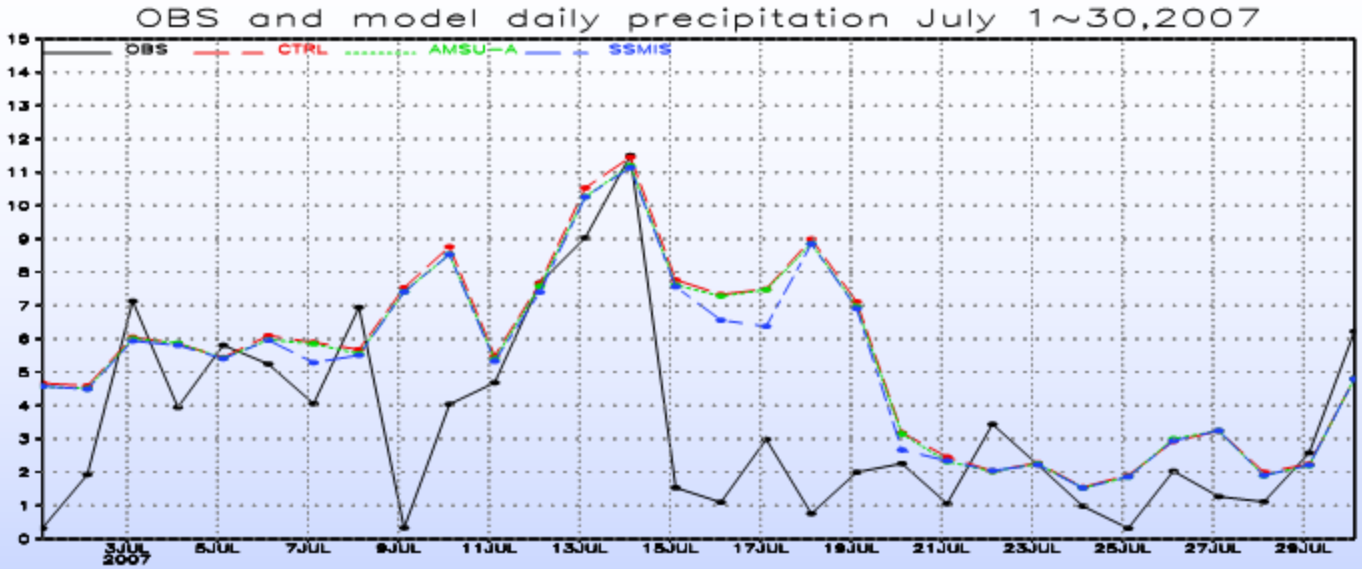
exp3 : SSM/IS LAS only data assimilation

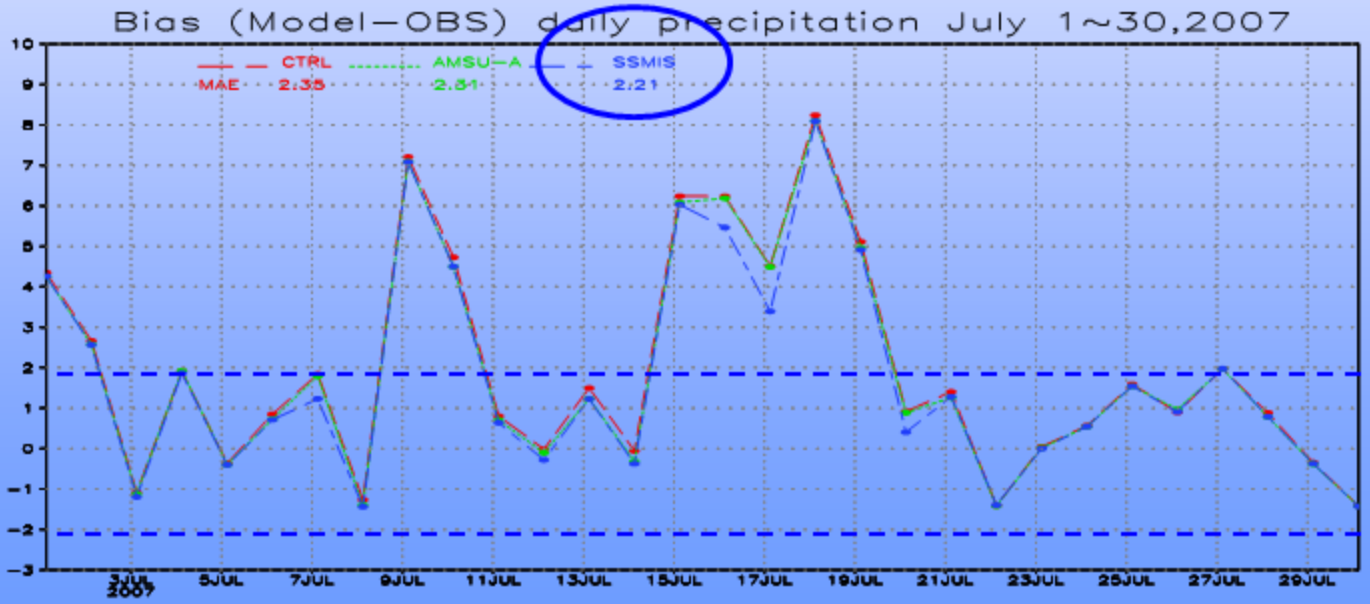
EXP7

Forecasting precipitation pattern is quite similar



EXP7



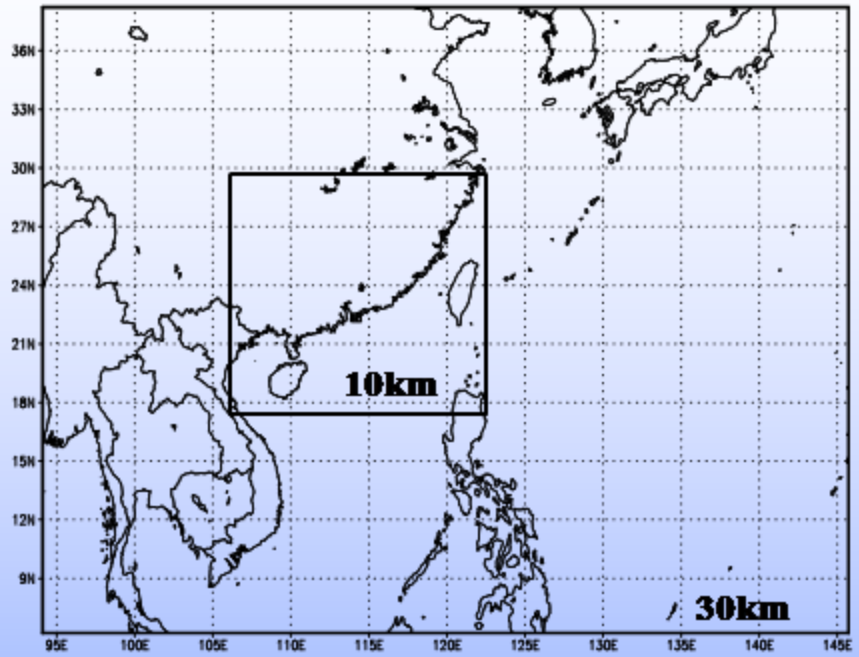


The forecasts get improved with AMSU-A or SSM/IS data assimilation by GSI.

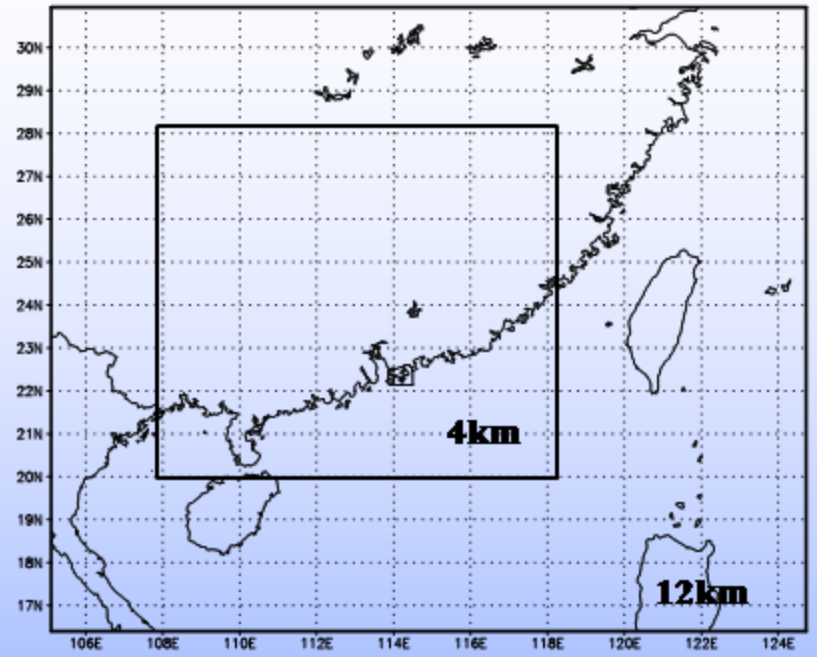
SSM/IS better

EXP8 ATOVS radiance application in the flash flood forecasts over the East Asia

Course domain 30km



Course domain 12km



Period: June 20-21, 2005.

Forecasts: 24 hours, Initial Time : 06Z

Domain: Southeast of China

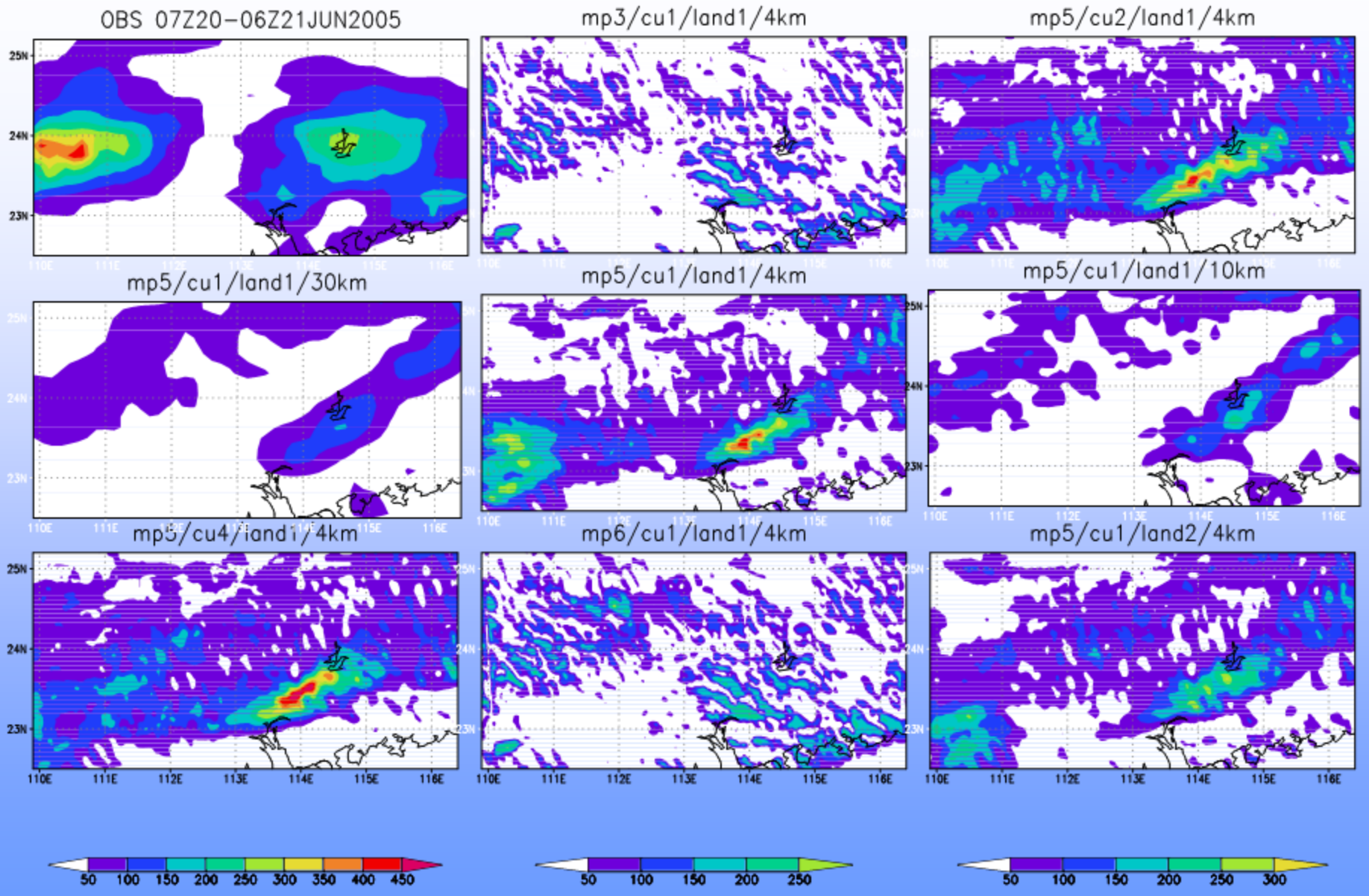
Model resolution : 30/10 km and 12/4 km nested domains

Boundary condition : NCEP reanalysis data

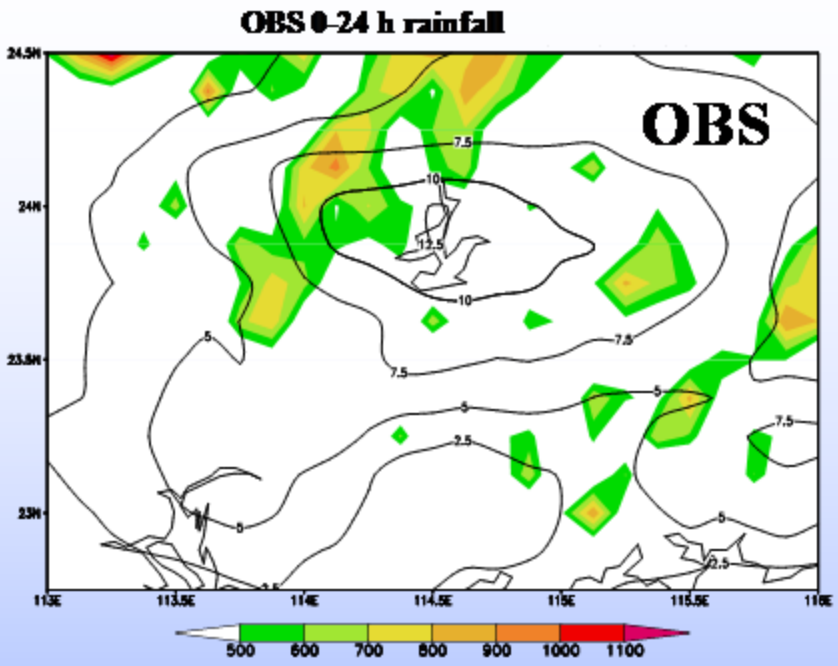
Satellite Data: AMSU-A/B and HIRS3 radiance

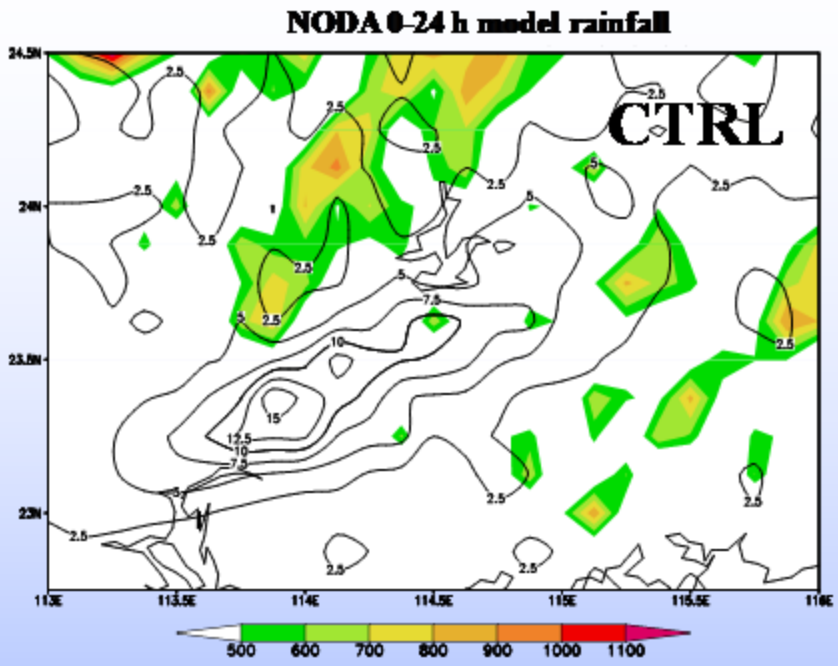
Data assimilation system : GSI with CRTM

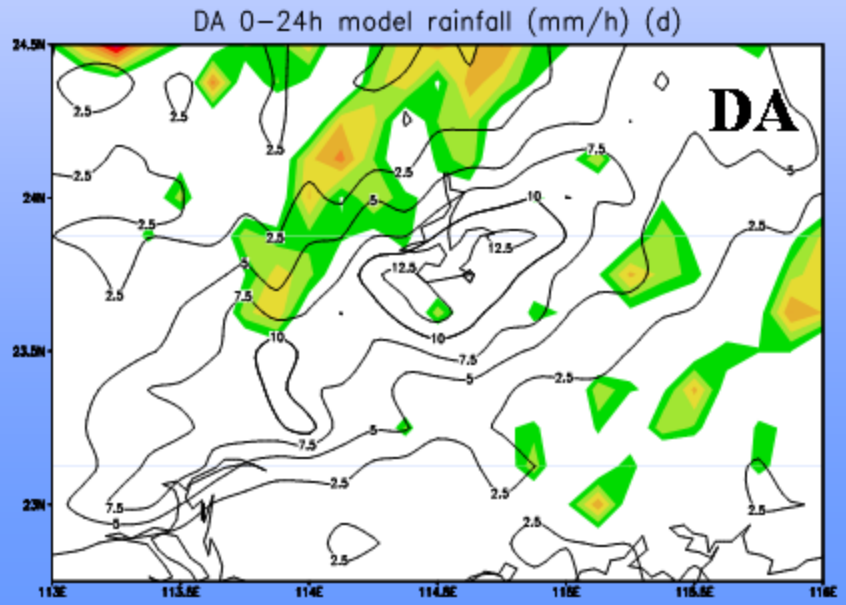
EXP8


OBS 07Z20-06Z21JUN2005
mp3/cu1/land1/4km
mp5/cu2/land1/4km
mp5/cu1/land1/30km
mp5/cu1/land1/4km
mp5/cu1/land1/10km
mp5/cu4/land1/4km
mp6/cu1/land1/4km
mp5/cu1/land2/4km
25N
24N
23N
110E
111E
112E
113E
114E
115E
116E
50 100 150 200 250 300 350 400 450
50 100 150 200 250
50 100 150 200 250 300

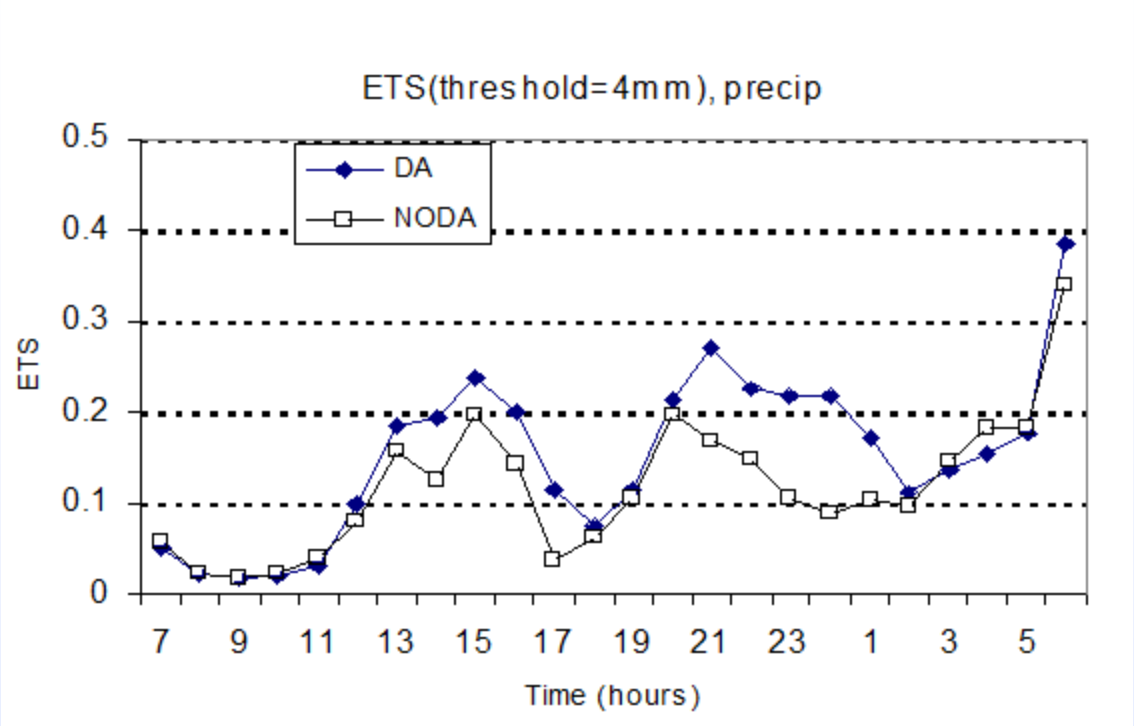
EXP8


OBS 0-24 h rainfall
OBS
24.5N
24N
23.5N
23N
113E
113.5E
114E
114.5E
115E
115.5E
116E
500
600
700
800
900
1000
1100


NODA 0-24 h model rainfall
CTRL
24.5N
24N
23.5N
23N
113E
113.5E
114E
114.5E
115E
115.5E
116E
500
600
700
800
900
1000
1100


DA 0-24h model rainfall (mm/h) (d)
DA
24.5N
24N
23.5N
23N
113E
113.5E
114E
114.5E
115E
115.5E
116E

EXP8



ETS is a little higher in DA

Summary

- ARW WRF model has a strong capability to reproduce observation, but the forecasts are sensitive to various sources of error including the representation of model initialization, physical processes, representation of local properties such as orography, as well as spatial resolution of model simulation.
- The accuracy of forecasts get improved slightly by the ATOVS and SSM/IS data assimilation, but its improvement is not significant whatever the GSI or WRF-Var is being used.
- GSI shows a little better performance
- WRF-Var combining with both RTTOV and CRTM radiative transfer models has gotten a significant progress for satellite data assimilation, its performance is comparable to that in GSI for ATOVS radiance data assimilation
- Both WRF-Var and GSI systems are being developed, the final conclusion is probably too earlier, we have more work to do in the future.

Future Work

- Help to implement the SSM/IS radiance in WRF-Var system
- Help to implement the Windsat radiance in GSI firstly and then WRF-Var

Thanks !

Question ?