Impact study of DMSP F-16 SSMIS radiances in NCEP global data assimilation system

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- Quality of SSMIS radiance data
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Introduction

- SSMIS: Special Sensor Microwave Imager Sounder
- DMSP F-16 SSMIS was launched on 18 October 2003
  - (F-17 SSMIS was also launched on 4 November 2006)
- SSMIS data will be major source for NWP in transition time from POES to NPOESS.

Schedule of Polar orbiting satellite

SSMIS will be on board these satellites

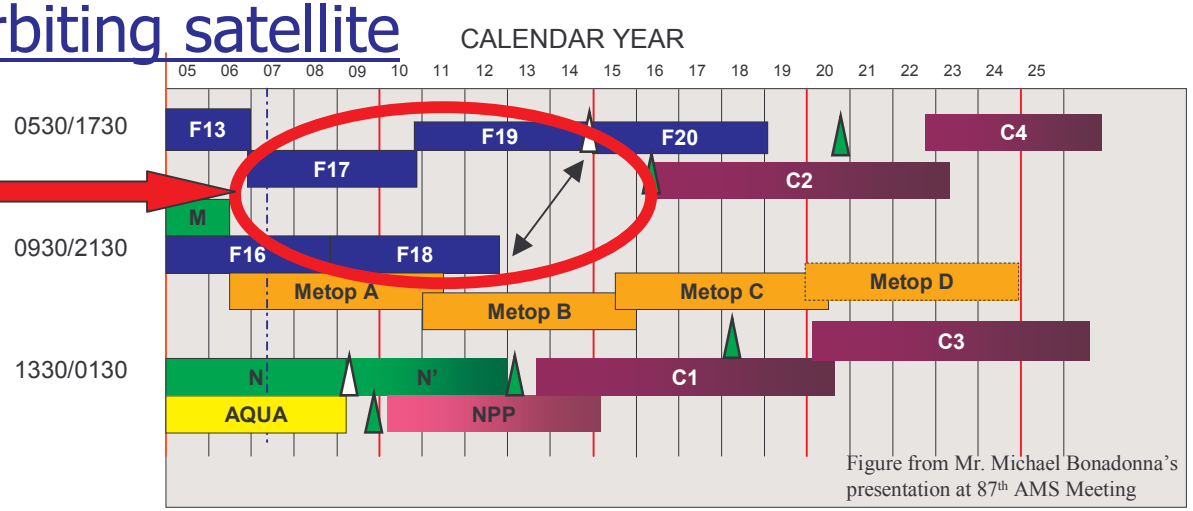


Figure from Mr. Michael Bonadonna's presentation at 87th AMS Meeting

SSMIS may be important for NWP for the next decade.

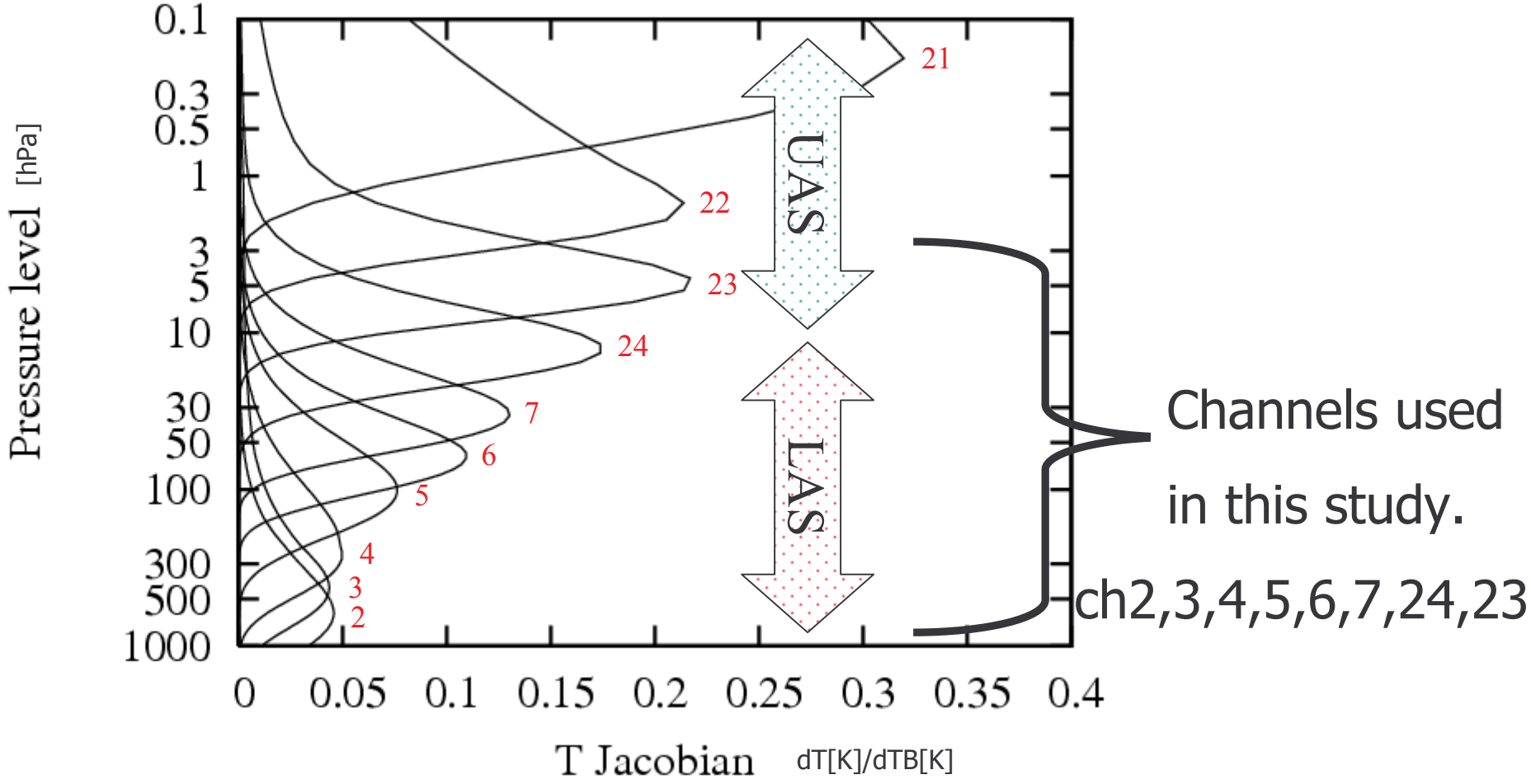
SSMIS

- Conical scaning instrument and successor of SSMI
- Four components of SSMIS instrument
  - Lower atmospheric temperature sounding channels **(LAS)**
    - (Freq. 50-60GHz, ch1-7,24)
  - Imager channels **(IMG)**
    - (Freq. 90-183GHz, ch8-11,17 and 18)
  - Environmental channels **(ENV)**
    - (Freq. 19-23GHz, ch12-16)
  - Upper atmospheric temperature sounding channels **(UAS)**
    - (Freq. 60-63GHz, ch19-23)

SSMIS has temperature sounding channels (LAS) along with window channels (ENV). ENV can be used for cloud detection.

But, as each component has different observation locations. Collocation (re-mapping) is necessary to use these components together.

SSMIS Temperature Jacobian for US Standard Atmosphere



SSMIS can bring atmospheric temperature information for NWP.

However…

- Since the launch, F-16 SSMIS has been suffering from calibration problems.
- The largest problems are solar contamination in the warm calibration target and an emissive antenna

Therefore,

- Pre-processed (re-calibrated) SSMIS radiance data are produced and distributed to several NWP centers by UKMO and NESDIS.

The purpose of this study is to investigate the quality of pre-processed (re-calibrated) SSMIS data and their impacts on analyses and forecasts in NCEP global data assimilation system.

Quality of SSMIS data

- F-16 SSMIS data available at NCEP (Mar. 2007)
  - **NRL calibrated data** (Original data, no collocation)
    - Distributed to Public via Internet (NOAA CLASS Server)

NRL Ta ➡ NRL Tb

  - **UKMO preprocessed data** (collocated on LAS)
    - Distributed to several NWP centers (ECMWF, NCEP, the Italian Met Agency and the Danish Met Service) pre-operationally.
    - UKMO assimilate the data in their operational system since Sep. 2006

preprocess

NRL Ta ➡ UKMO Tb

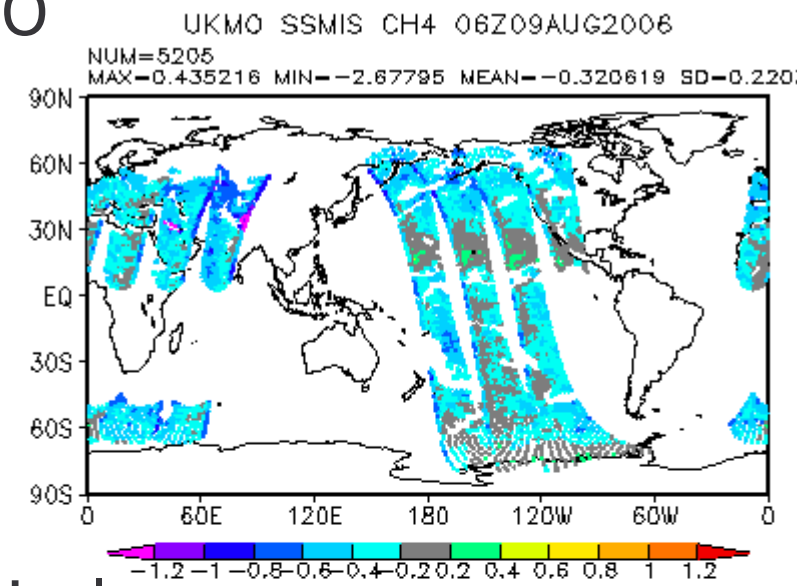
  - **NESDIS recalibrated data** (collocated on LAS)
    - Under development and evaluation at NCEP.

recalibrate

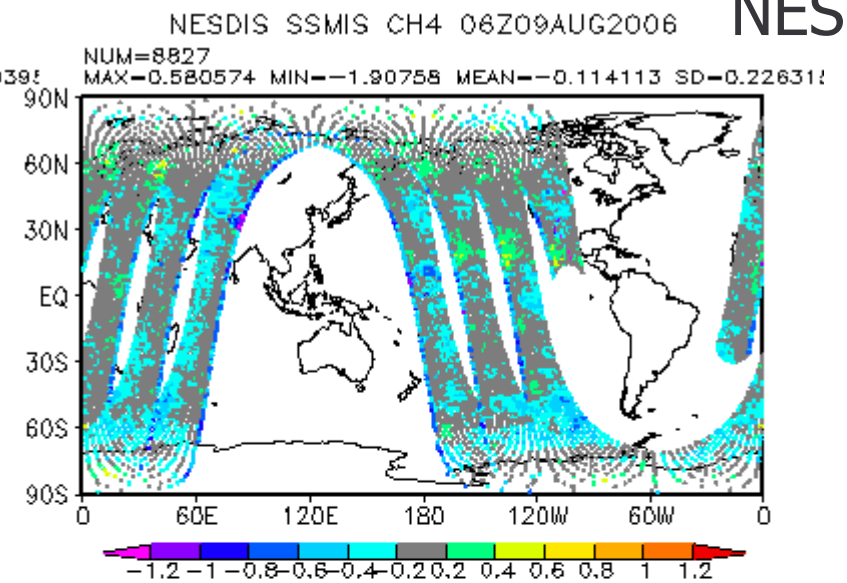
NRL Ta ➡ NEDSIS Tb

Comparison of SSMIS data
(ch4, brightness temperature O-B, w/o BC)

UKMO

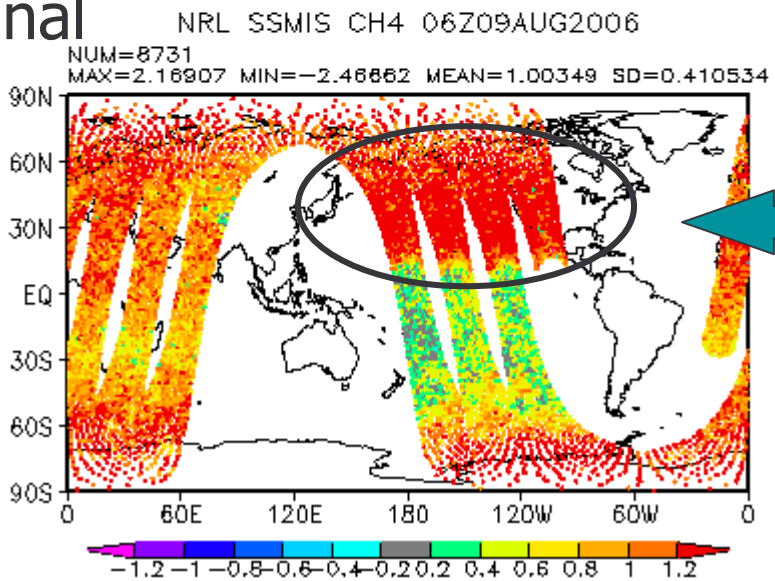


NESDIS



Original

NRL



Solar contaminations

Comparison of temperature sounding channels between SSMIS and AMSU-A

- SSMIS has conical scan
- AMSU-A has cross track scan
- Different FOV size, polarization

many difference

Frequency [GHz]	SSMIS channel number	Pol.	AMSU-A channel number	Pol.(at nadir)
52.800	2	V	4	V
53.596	3	V	5	H
54.400	4	V	6	H
55.500	5	V	8	H
57.290	6	RC	9	H
59.400	7	RC		
60.792668	24	RC		
60.792668	23	RC		

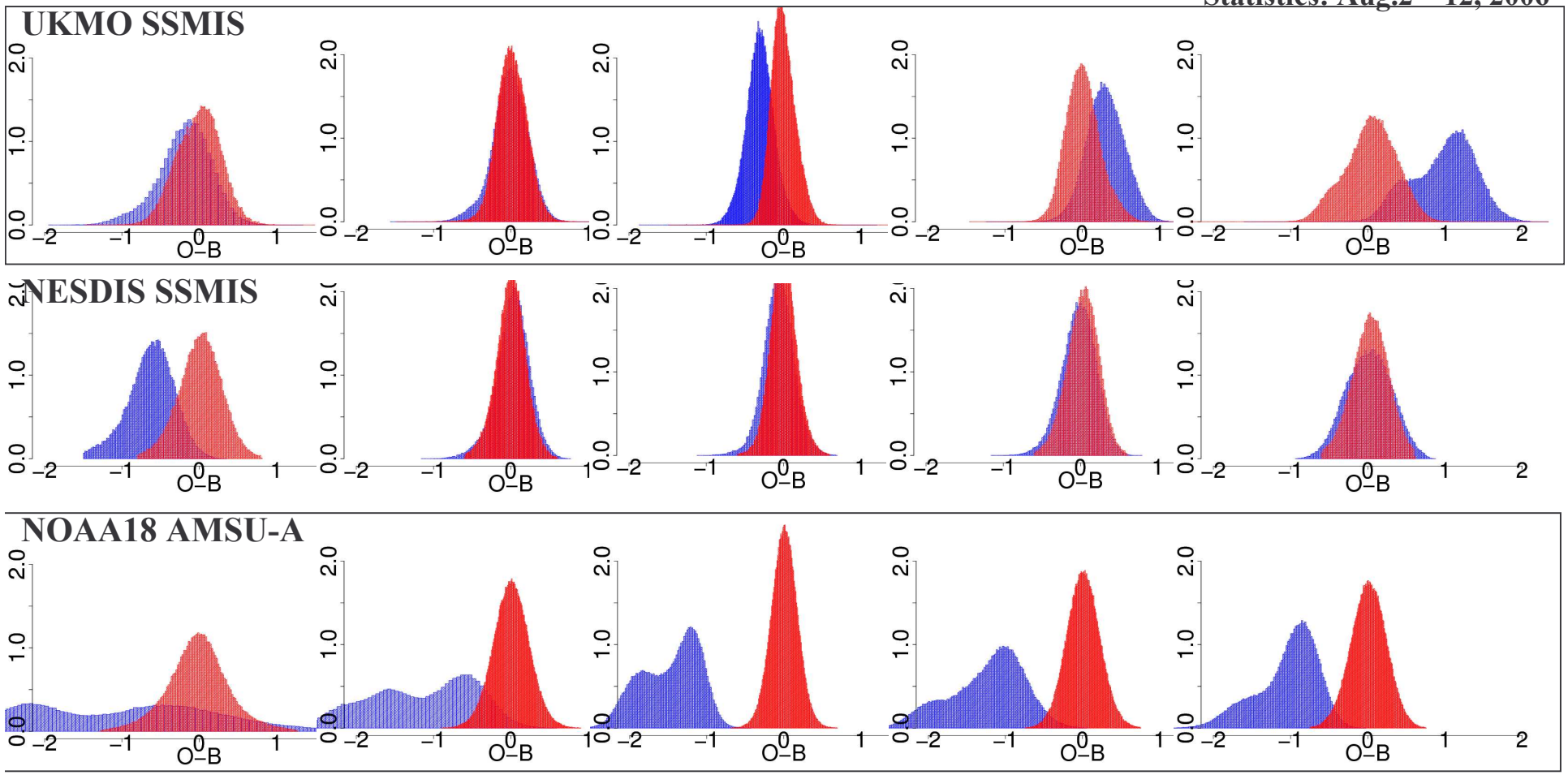
The comparison in the same frequency is just a rough estimate of SSMIS data quality

O-B histograms for QC passed data (global ocean data only)

Red: w BC

Blue: w/o BC

Statistics: Aug.2 – 12, 2006

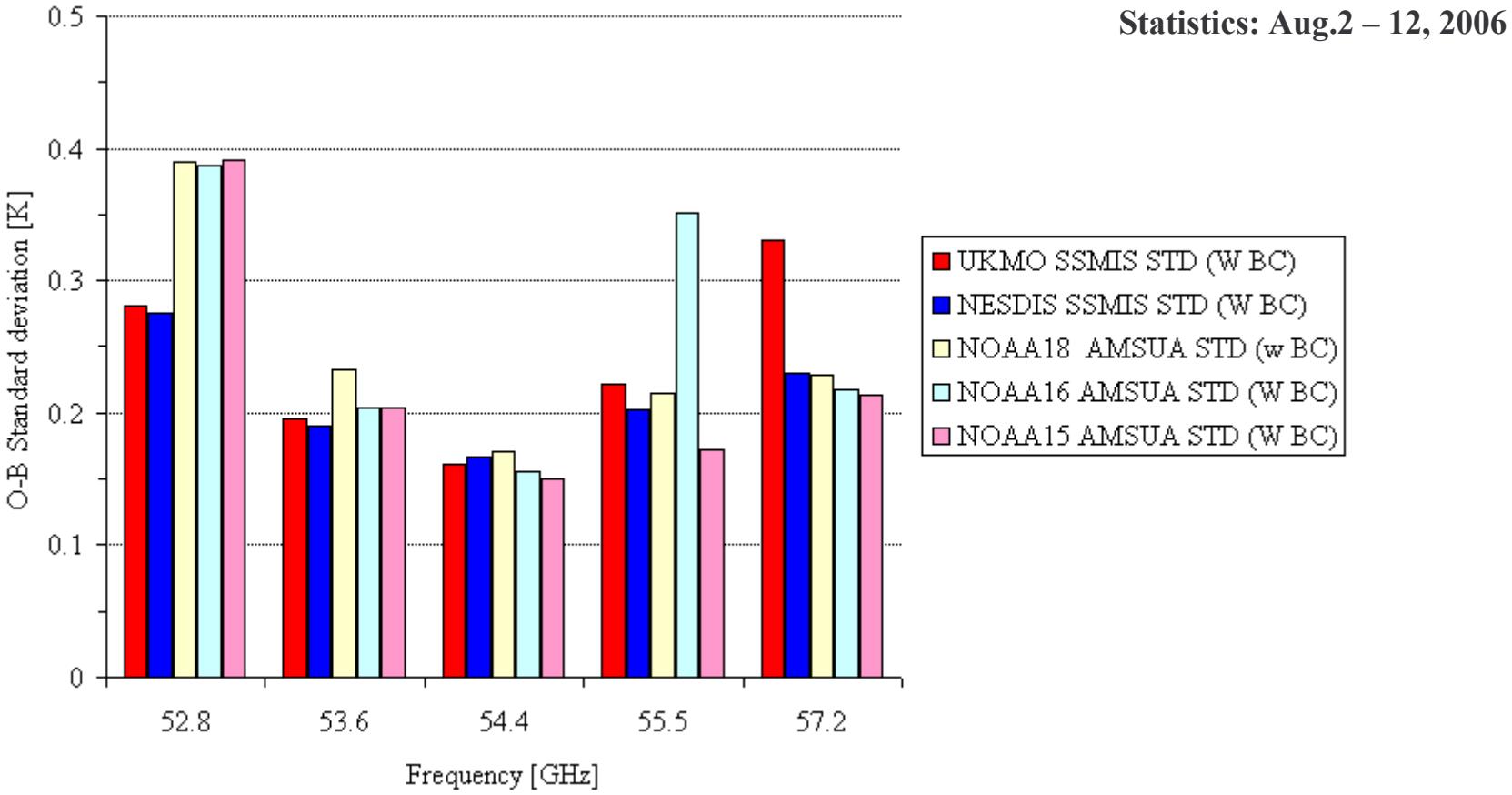


Weighting function Peak

700hPa 400hPa 300hPa 100hPa 70hPa

Current AMSU-A bias correction scheme can be used for SSMIS.

Standard deviation of O-B for QC passed data (global, ocean only, with BC)



For lower tropospheric channels(52.8GHz), quality of SSMIS data is better.
NOAA16 AMSU-A 55.5GHz (ch 8) has bigger std than others.
UKMO SSMIS STD 57.2GHz (stratosphere channel 6) has a big std.
Generally, preprocessed (recalibrated)SSMIS data are comparable with AMSU-A.

Assimilation experiments

- **Experiment with UKMO SSMIS data**

  August 2 – October 7, 2006

  (December 2, 2006 – February 10, 2007)

- **Experiment with NESDIS SSMIS data**

  August 2 – October7, 2006

Design of experiments

- Analysis: GSI 3D-Var (Sep. 2006).
- Forecast model: NCEP global forecast model (Dec. 2006).
- Resolution: T382L64.
- Added new data: SSMIS brightness temperature (T sounding channels 2,3,4,5,6,7,23,24)
- Assimilation period: Aug. 2 – Oct. 7, 2006
- Forecast: every day 00Z initial, 168 hour forecast
- Experiment name
  - Prd: control
  - Pre: Test with UKMO SSMIS
  - Prg: Test with NESDIS SSMIS
- Both experiments use NCEP operational data set.
- Only Cloud-Clear data were used. 160km thinning.
- Operational radiance bias correction scheme was used.

QC of SSMIS data

- Selected channels (ch2,3,4,5,6,7,24,23)
- Thinning with 160 km distance
- Removal of flagged data (bad data and rain data) for UKMO SSMIS data
- Removal of cloud affected data by using a retrieval of cloud liquid water
- Gross error check

Usage

Ch2: ocean only, clw<0.2 kg/m^2

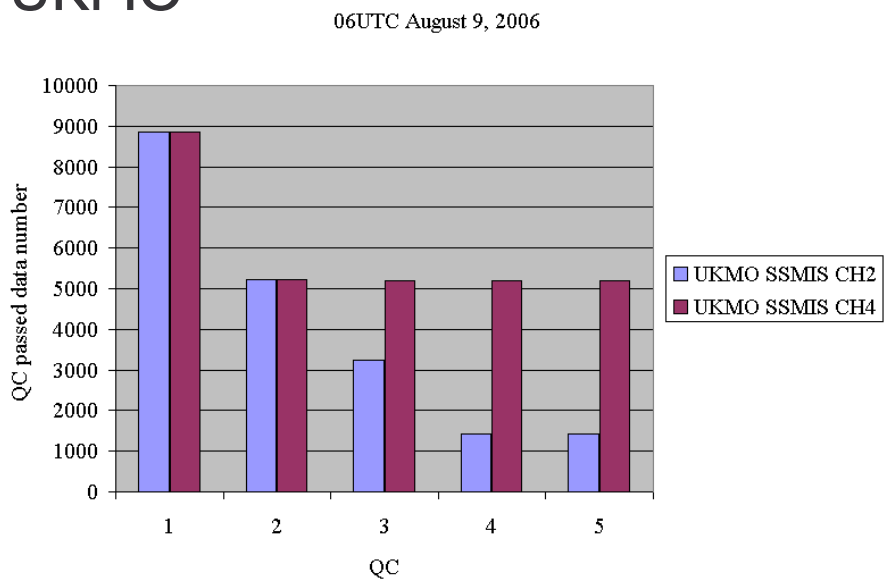
Ch3: ocean or land (alt.<2000m), clw < 0.6 kg/m^2

Ch4: ocean or land (alt.<4000m), clw < 0.6 kg/m^2

CH5,6,7,24,23: all qc passed data

QC passed data

UKMO



CH2: 15% data were used after QC

CH4: 60% data were used after QC

QC1: After thinning

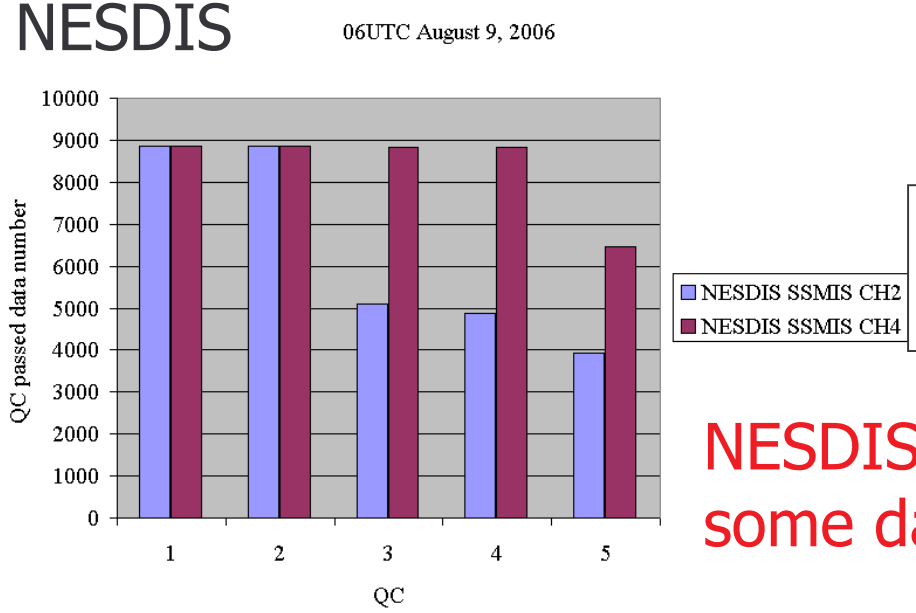
QC2: Solar contamination and rain flag

QC3: land ice QC

QC4: Cloud QC

QC5: gloss error check

NESDIS



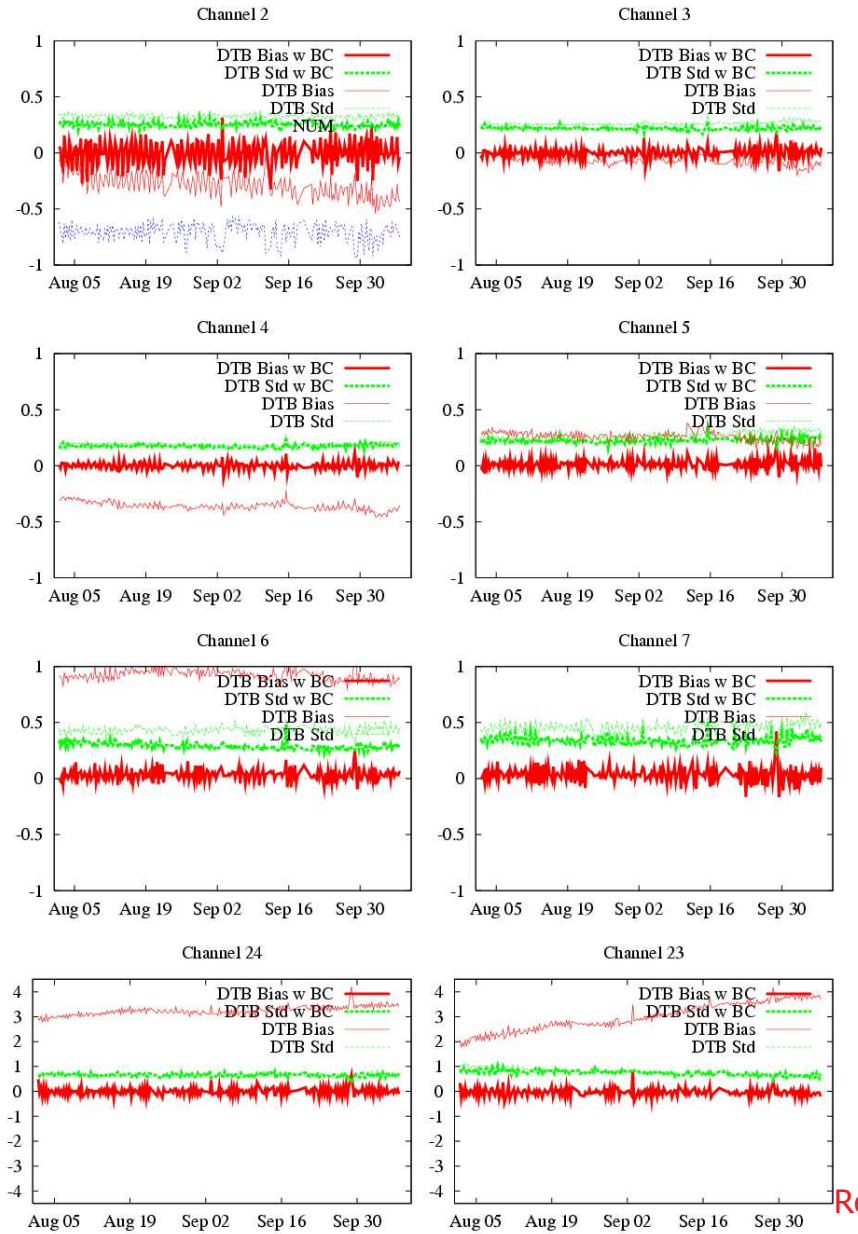
CH2: 44% data were used after QC

CH4: 72% data were used after QC

NESDIS correction algorithm can save some data from the solar contamination.

Bias correction

Time sequence of O-B (UKMO SSMIS)



- Same formula as other radiance data (AMSU-A)

  <u>Scan dependent + air-mass dependent</u>

  5 predictors for linear regression of air-mass dependent part

  Constant, Scan angle (=0 for SSMIS), Cloud liquid water, Weighted laps late (dt*dtau), (dt*dtau)^2

  Coefficients are optimized as analysis variables in GSI.

In general, SSMIS radiance bias correction works properly.

Assigned observation error

Ch2-7: 0.5K,Ch24,23: 1.0K

Red: Bias

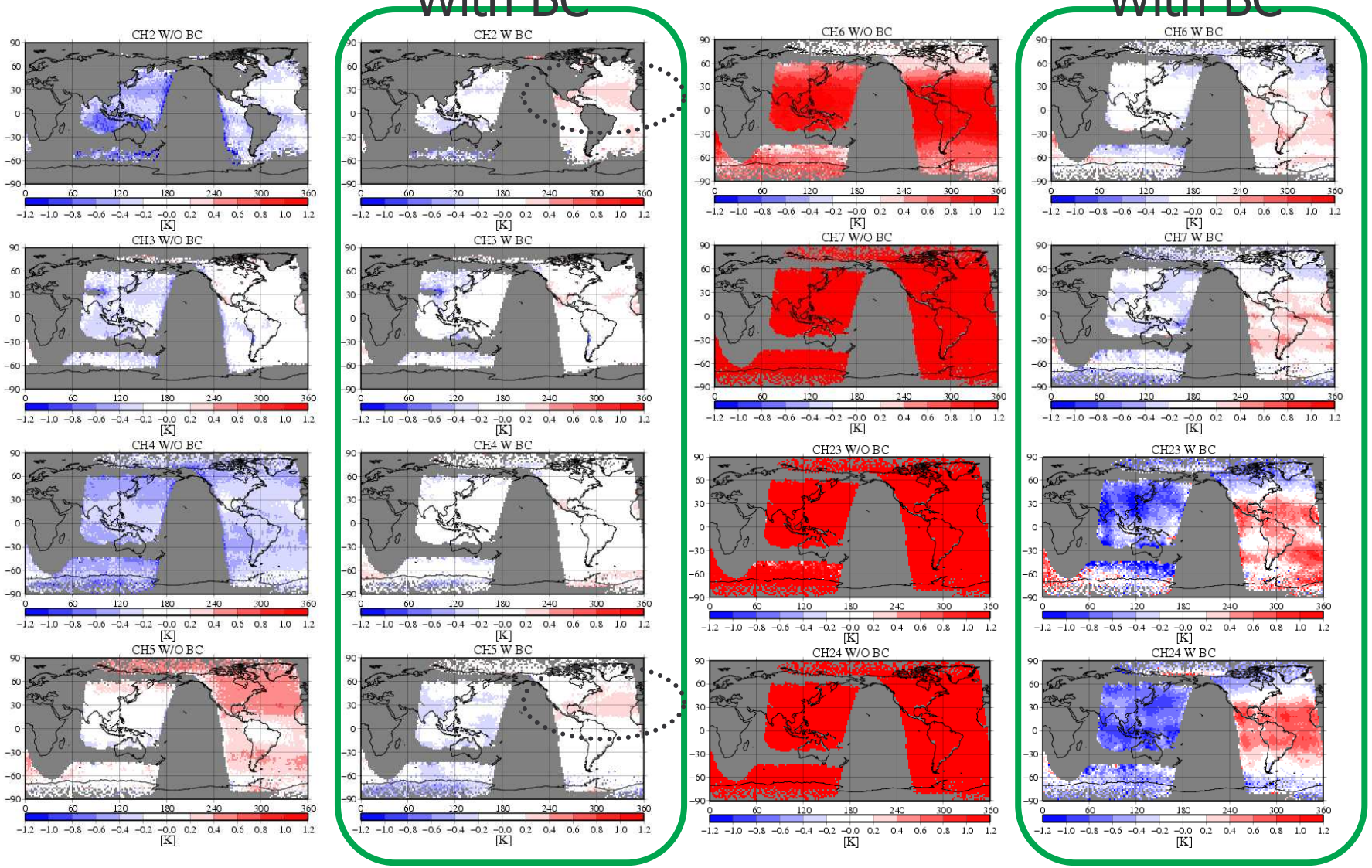
Green: Standard deviation

Mean O-B distribution for 00UTC analysis

UKMO
SSMIS

With BC

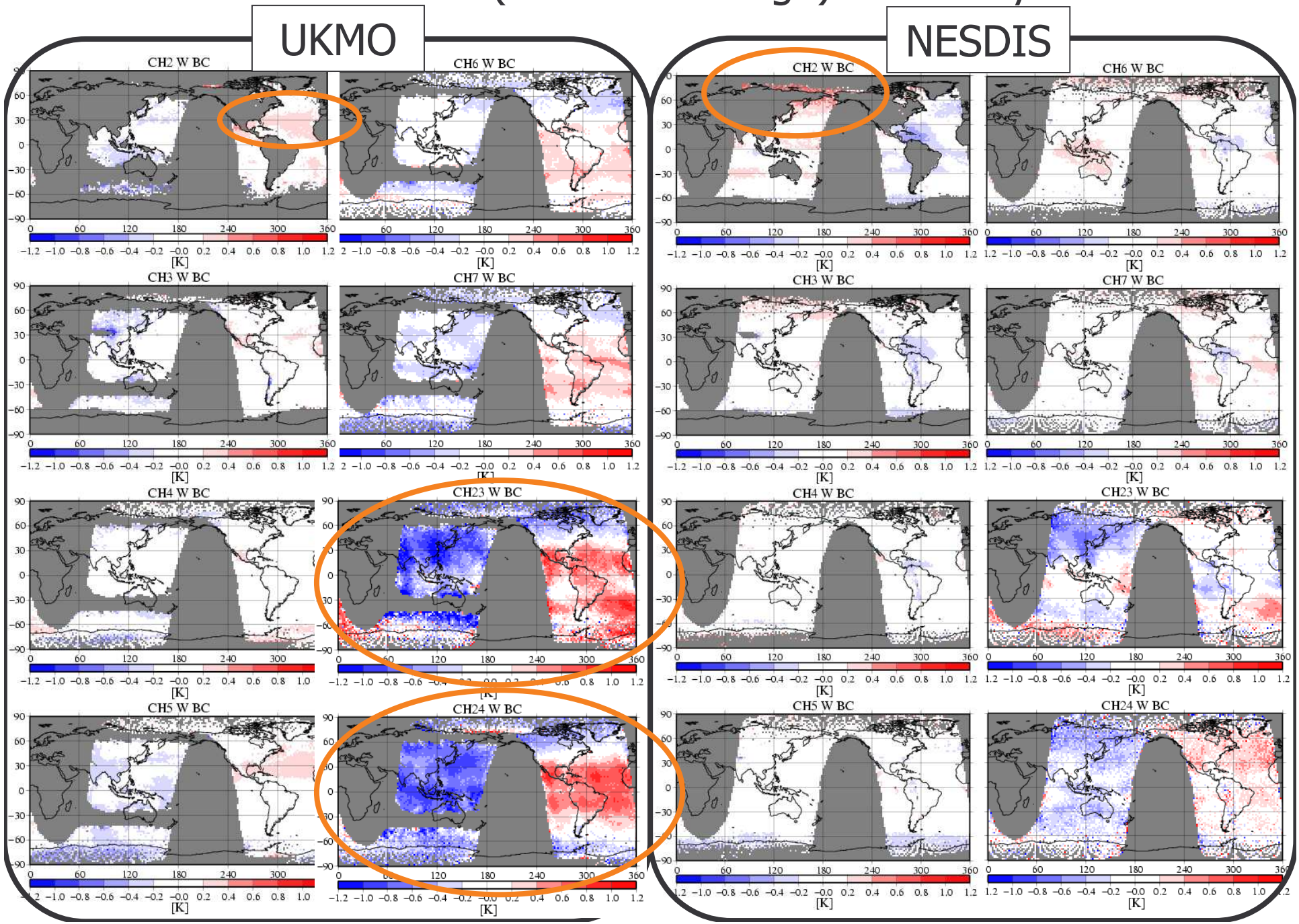
With BC



Ch2 and 5 have remaining bias around 30N in ascending orbit.

CH6,7,23 and 24 have unbalanced bias between ascending and descending.

Bias corrected O-B (2month average) 00Z analysis time



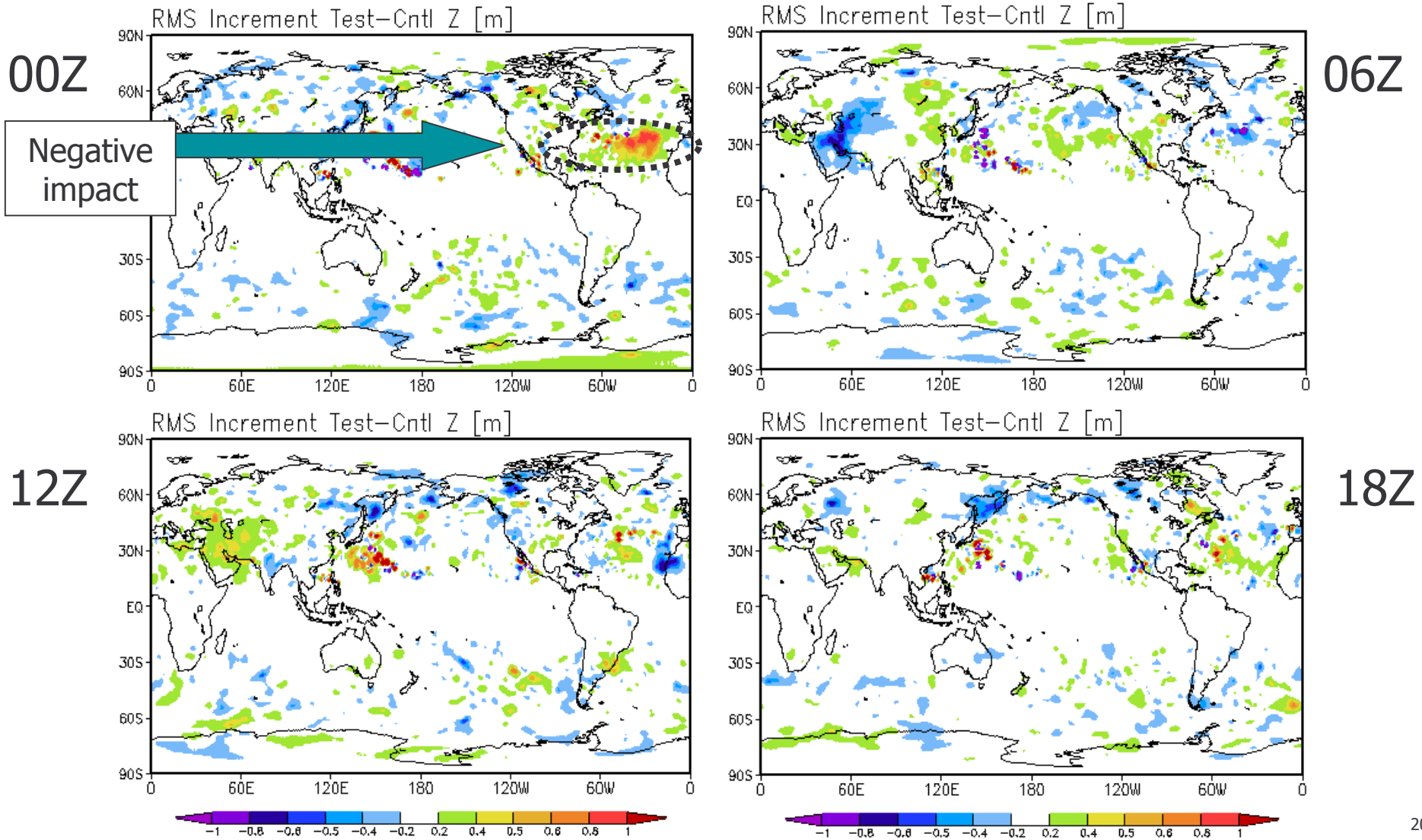
Assimilation Experiments

- Impact on analysis

Impacts on analysis

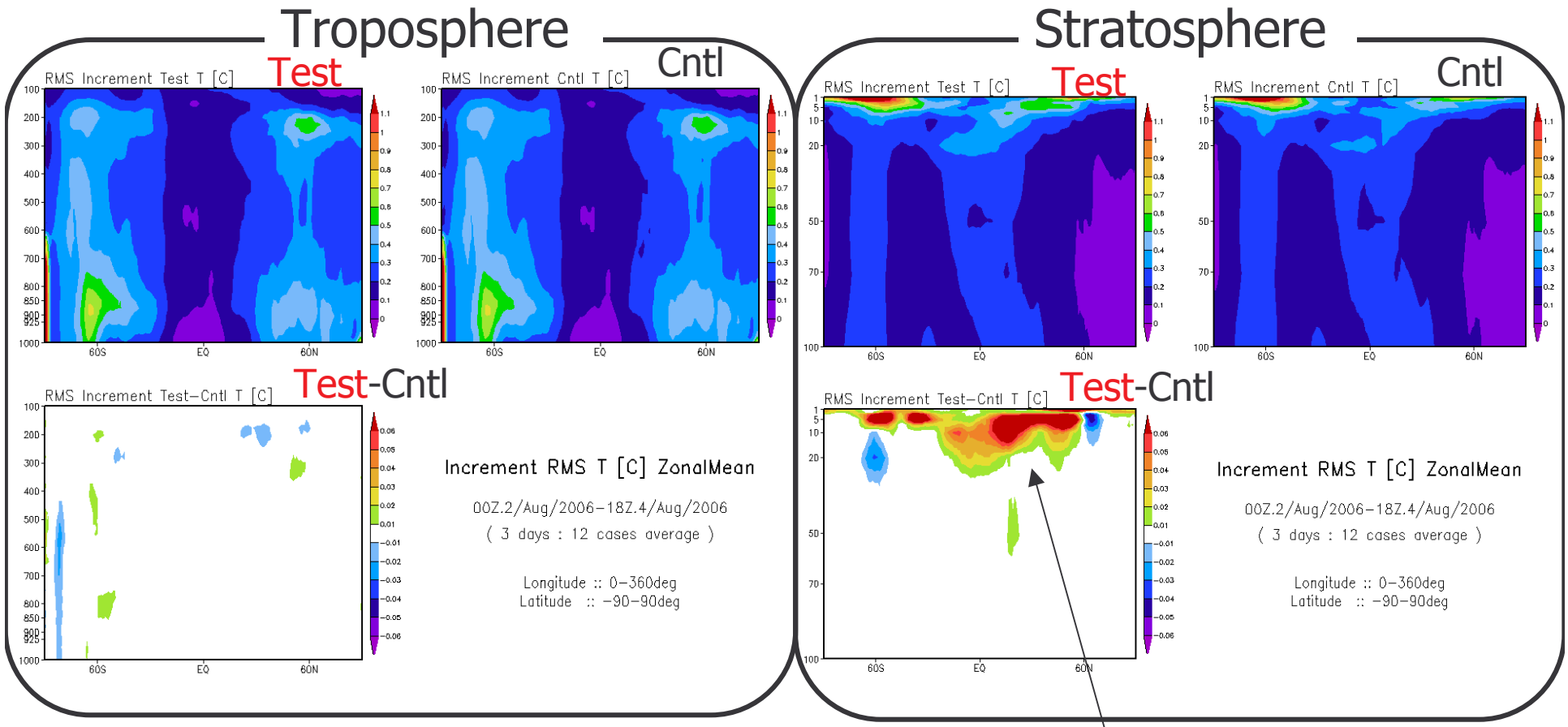
UKMO SSMIS

- Difference of RMS of Z500 analysis increment Test – Cntl (52 cases average, Aug.10-Sep.30)



UKMO SSMIS

RMS temperature analysis increment (Zonal average of the first 3 day analysis)

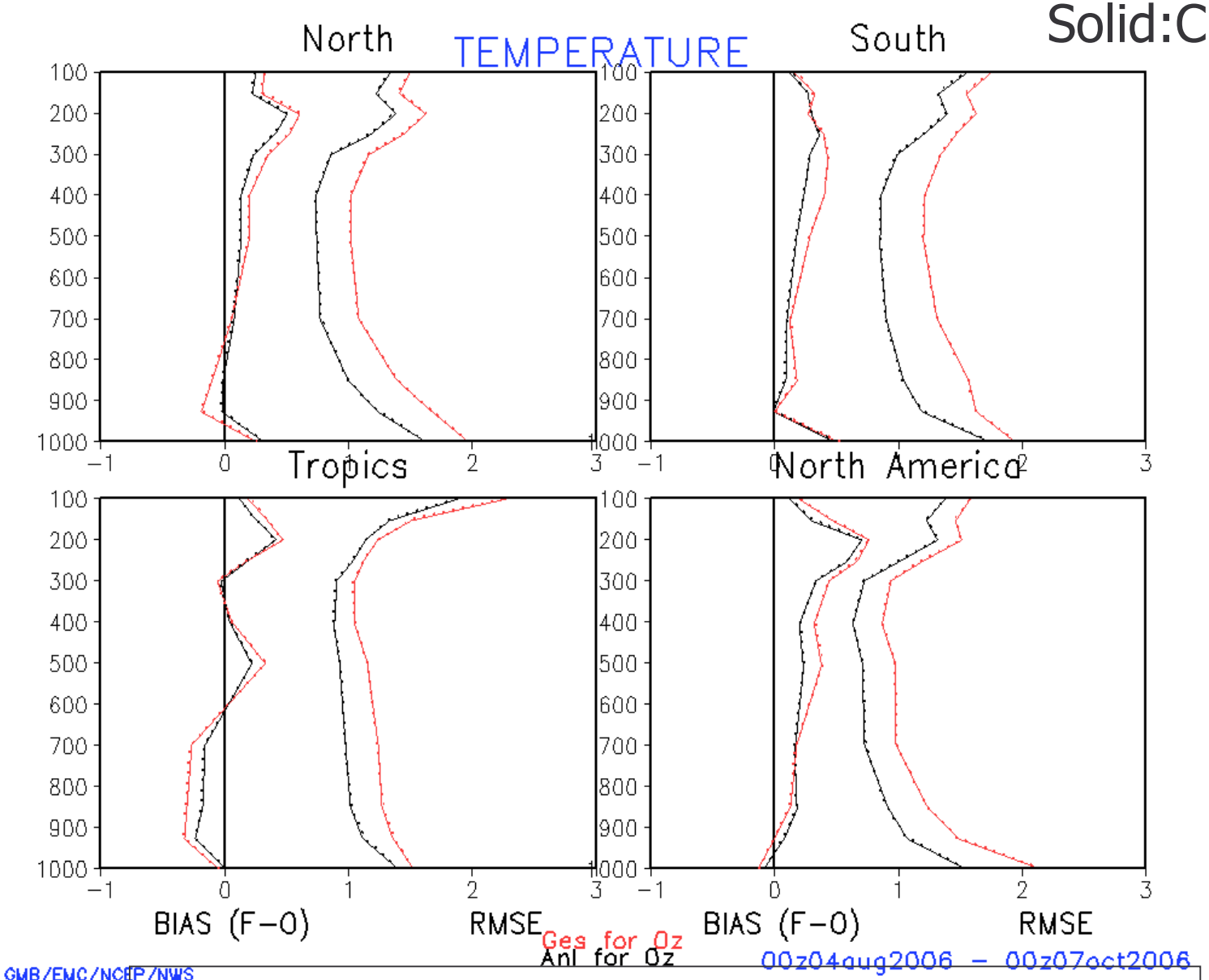


Negative impact in upper stratosphere

Fits to RAOB

Dotted:Test

Solid:Cntl



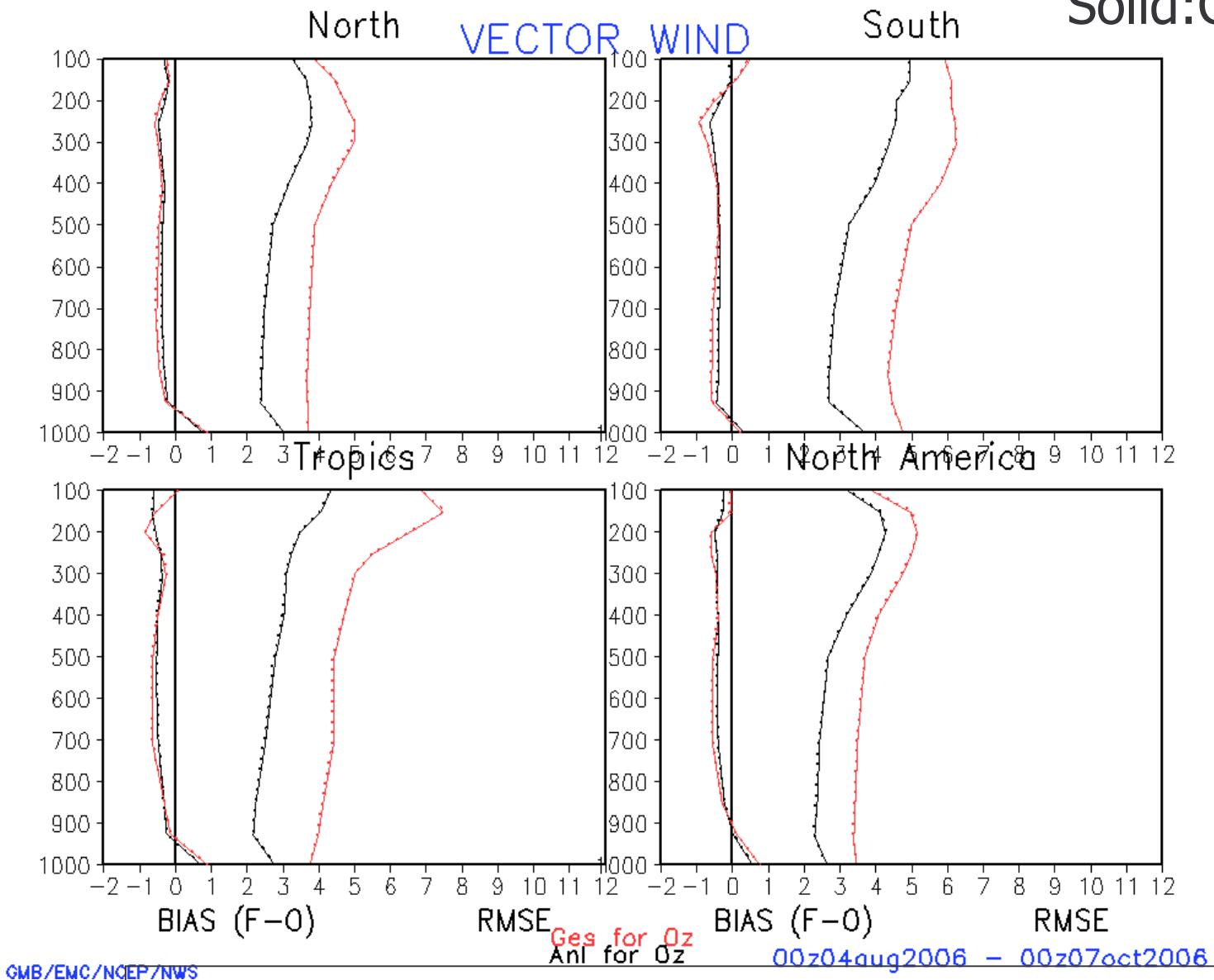
UKMO
SSMIS

Impacts on analysis and guess are small.

Fits to RAOB

Dotted:Test

Solid:Cntl



UKMO
SSMIS

Impacts on analysis and guess are small.

Assimilation Experiments

- Impact on forecast

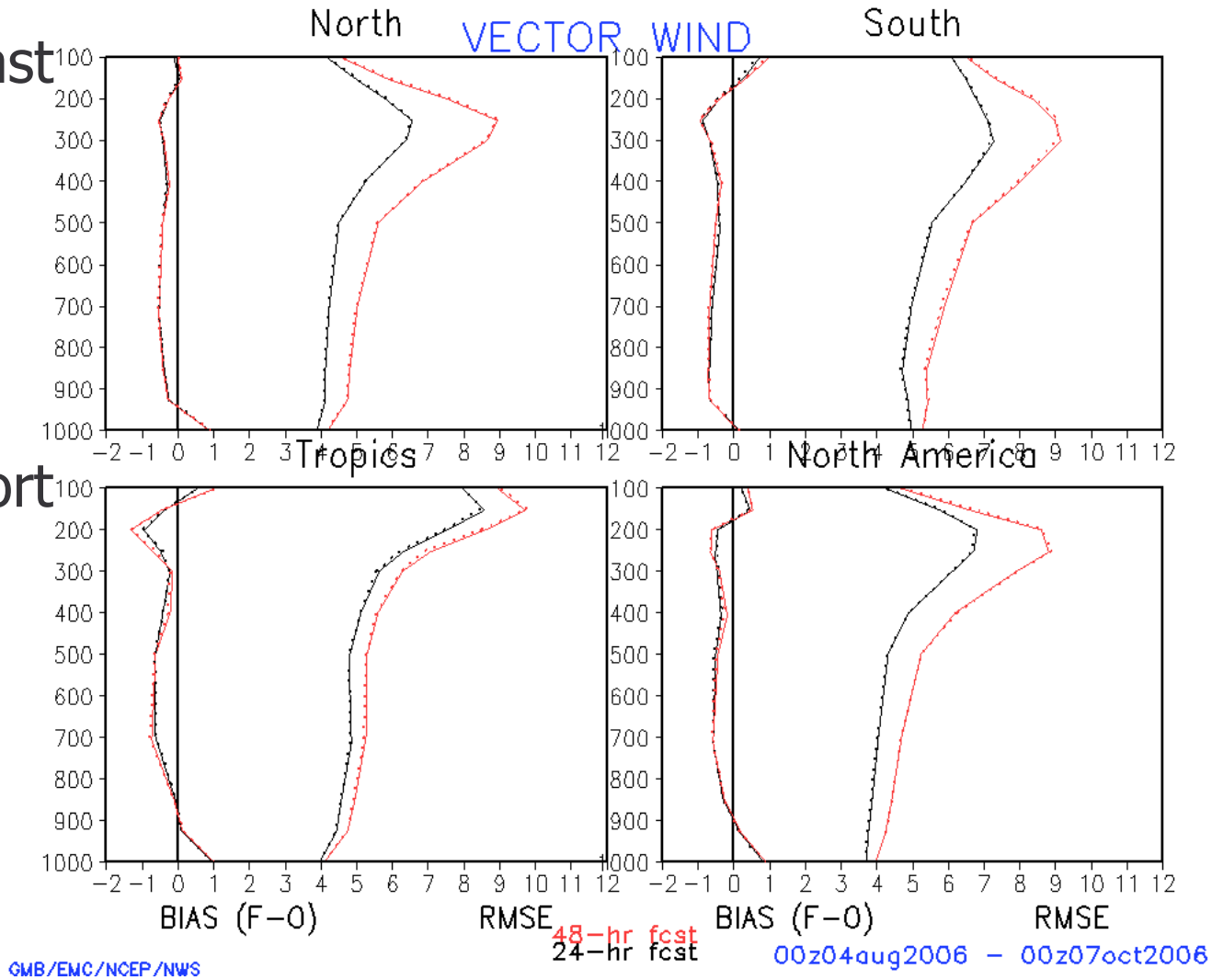
Fits to RAOB, 1day, 2day forecast

Dotted:Test

Solid:Cntl

Red: 1day forecast

Black: 2day forecast

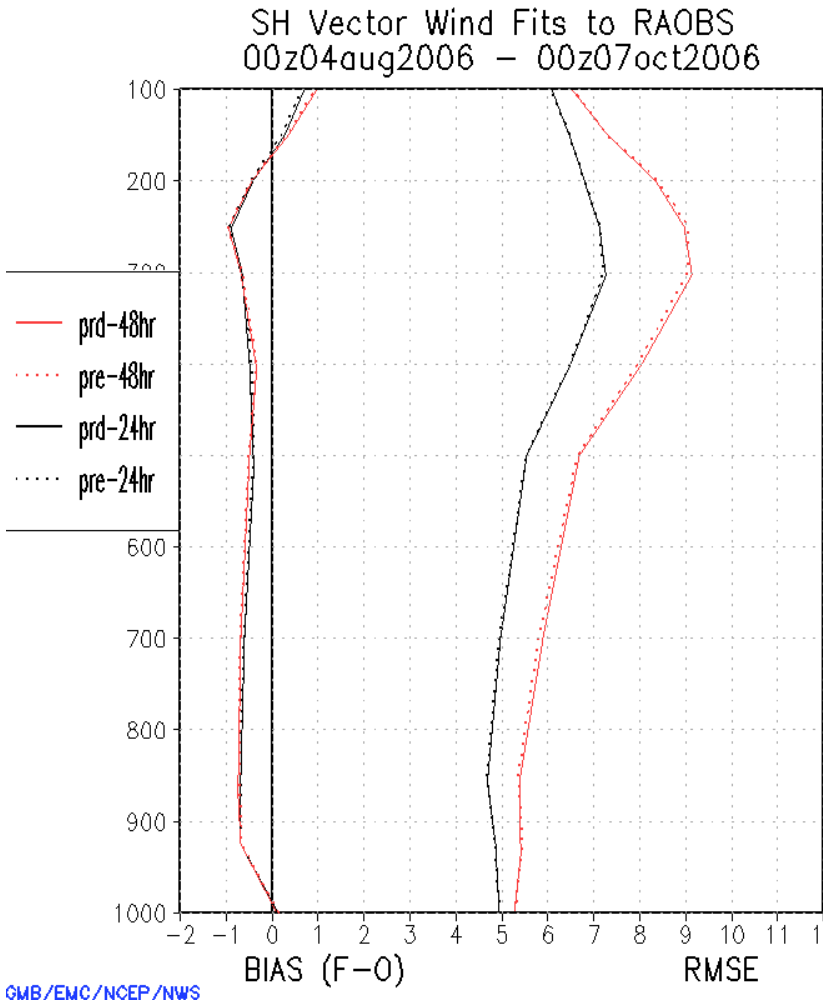


Small impact on short range forecast

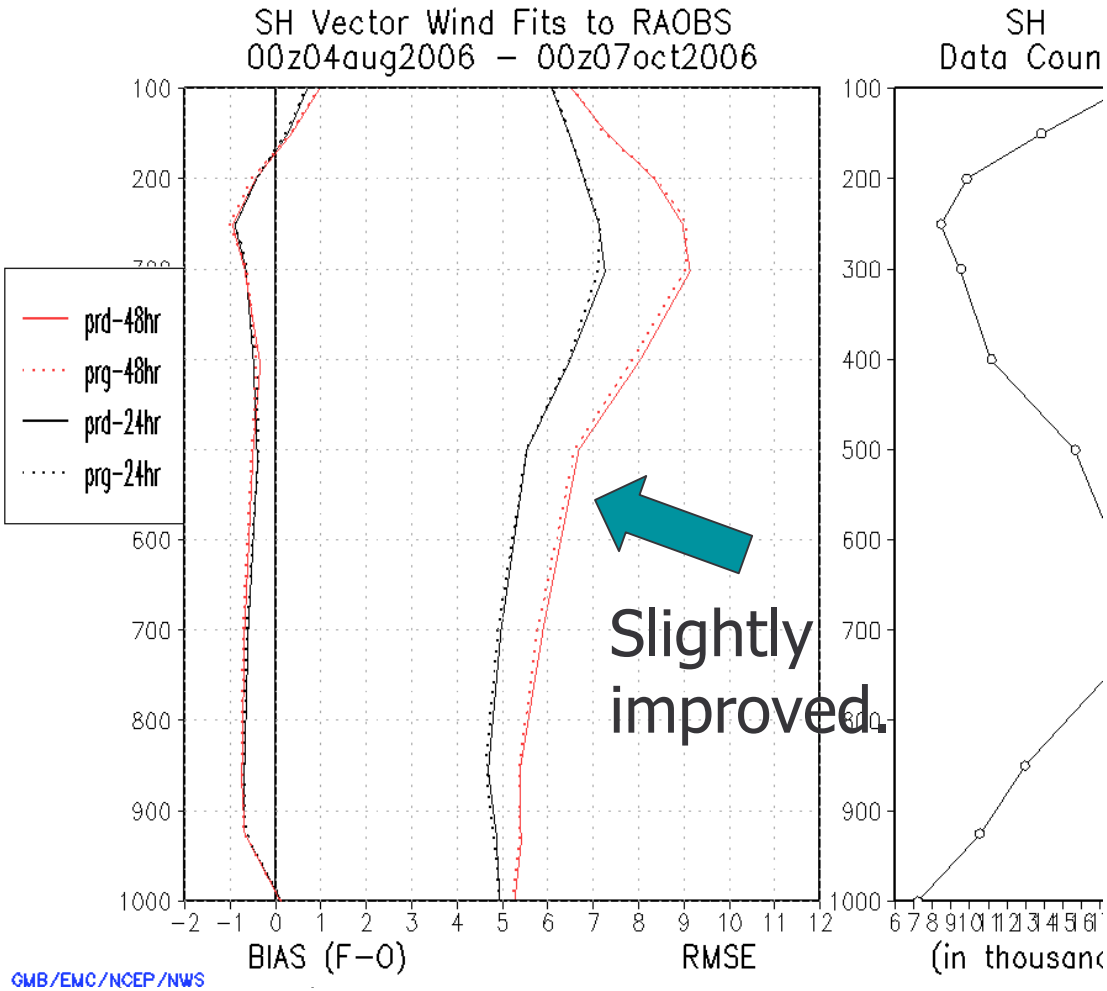
UKMO
SSMIS

Fits to RAOB 1day,2day forecast (S.H. vector wind)

UKMO SSMIS



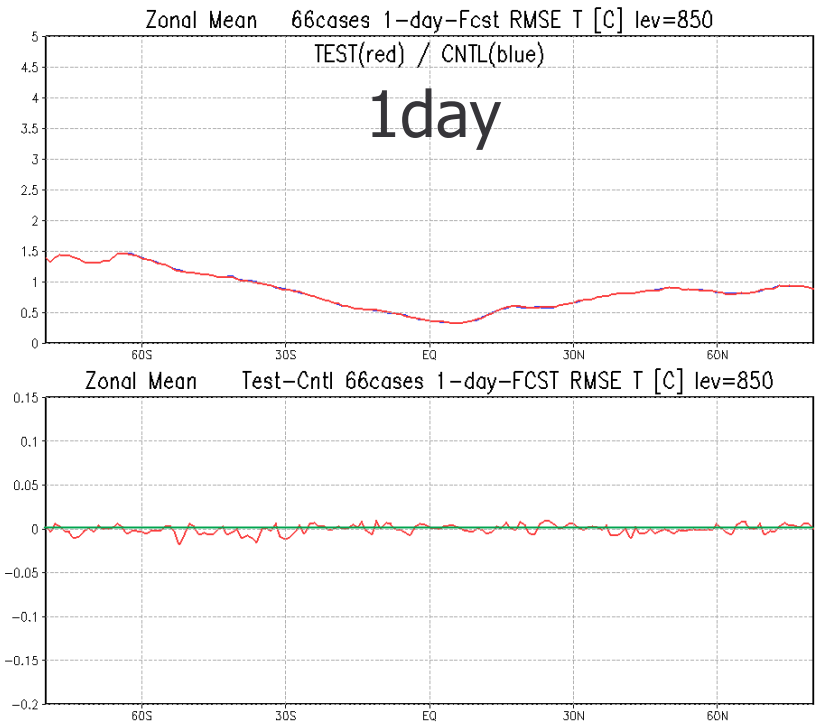
NESDIS SSMIS

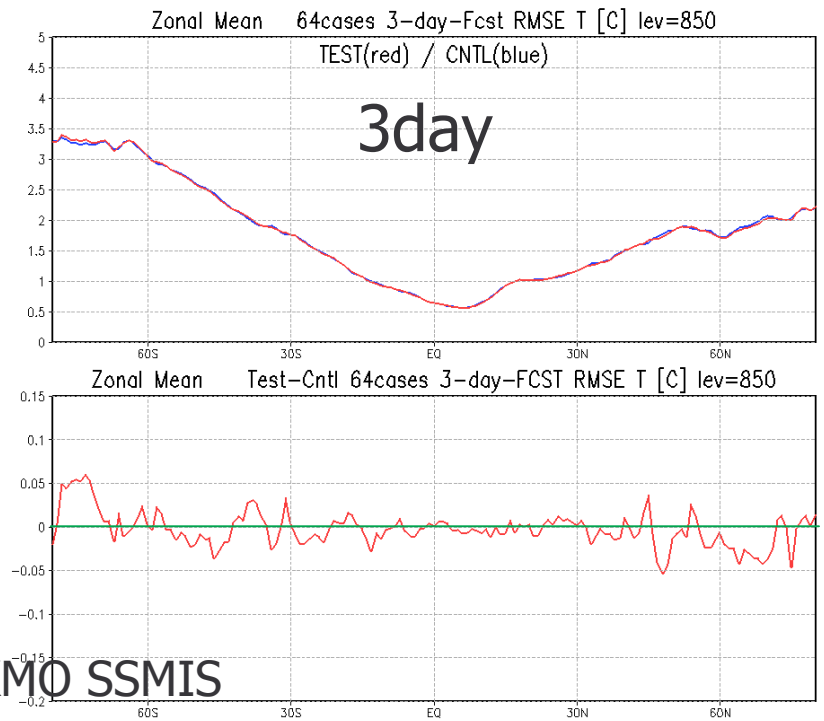


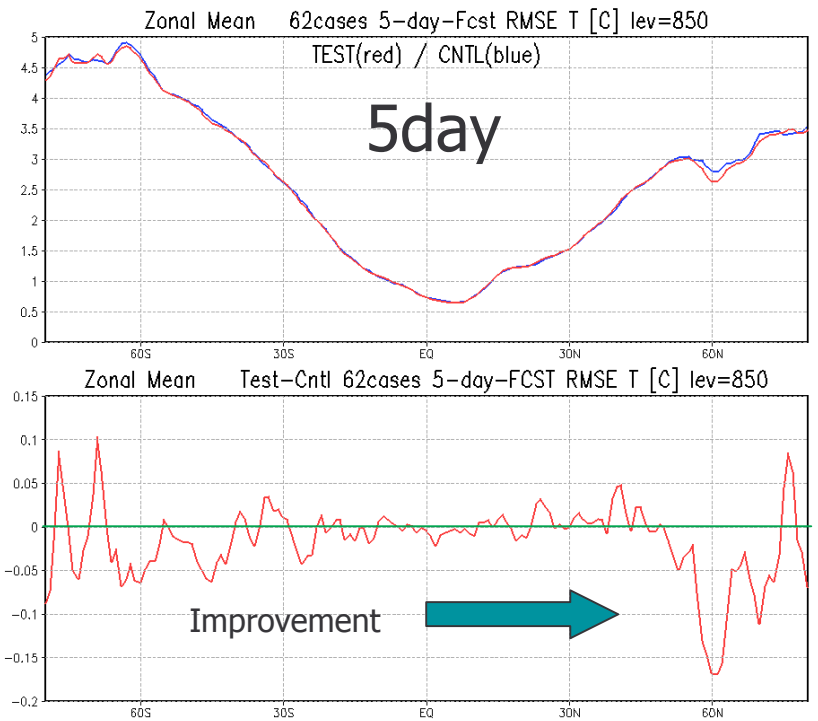
Slightly improved.

Dotted : Test, Solid Cntl

T850 1-day, 3-day, 5-day forecast Zonal mean RMSE and difference(Test-Cntl)



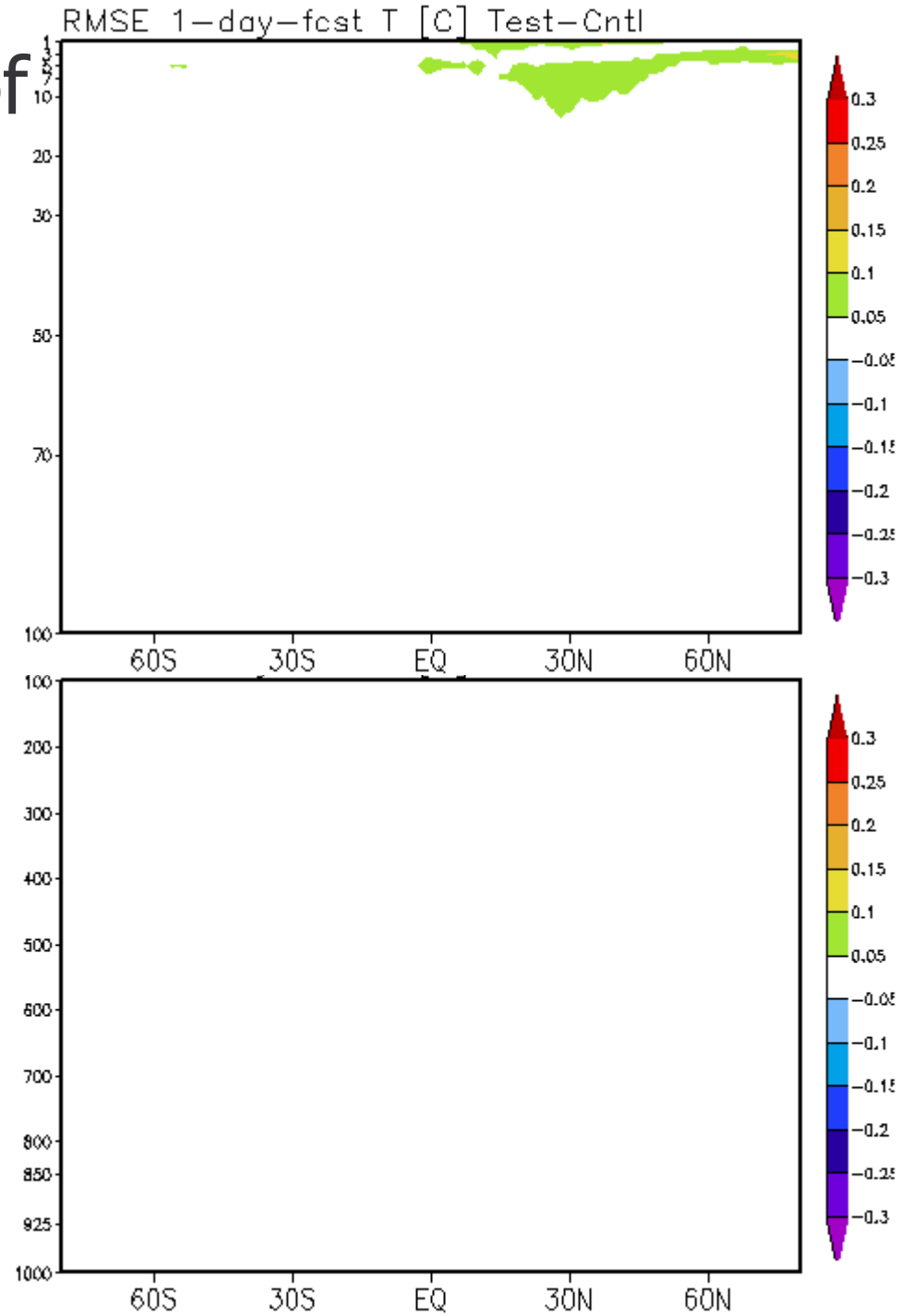




Zonal mean of RMSE of Temperature forecast (Test-Cntl)

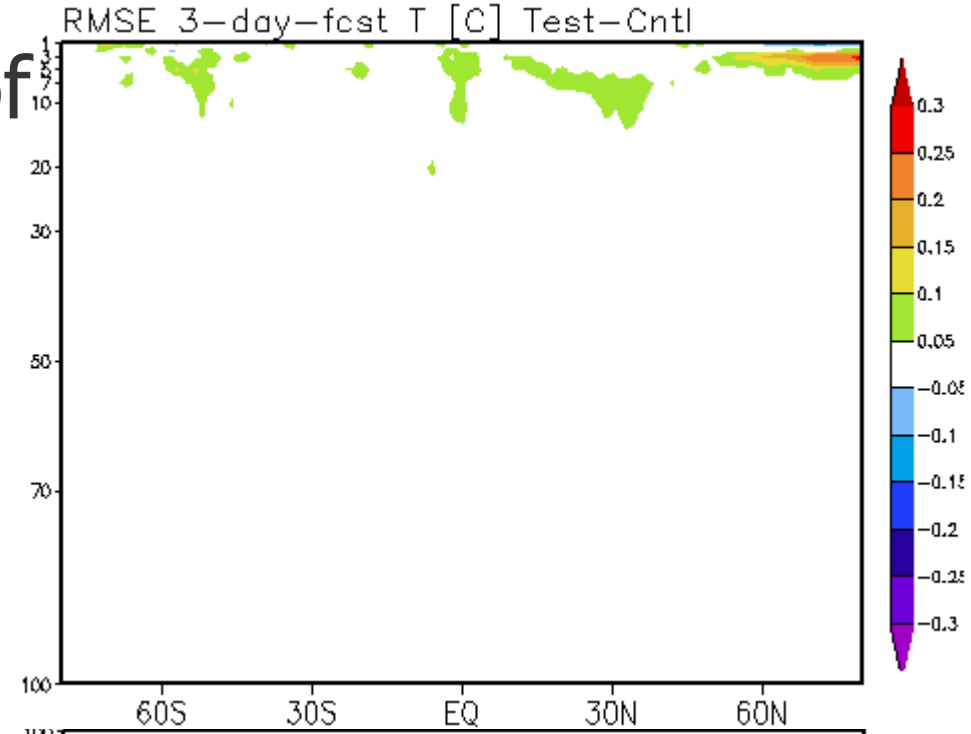
- 1-day forecast
- From Aug. 2 –
- 66 cases average

Blue color means improvement

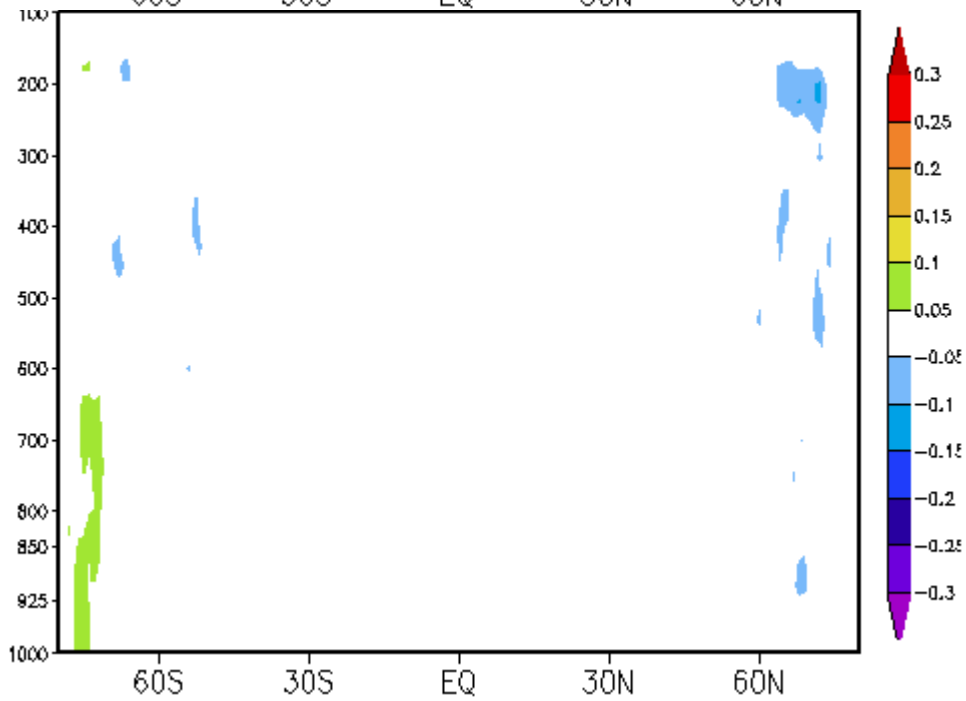


Zonal mean of RMSE of Temperature forecast (Test-Cntl)

- 3-day forecast
- From Aug. 4 –
- 64 cases average

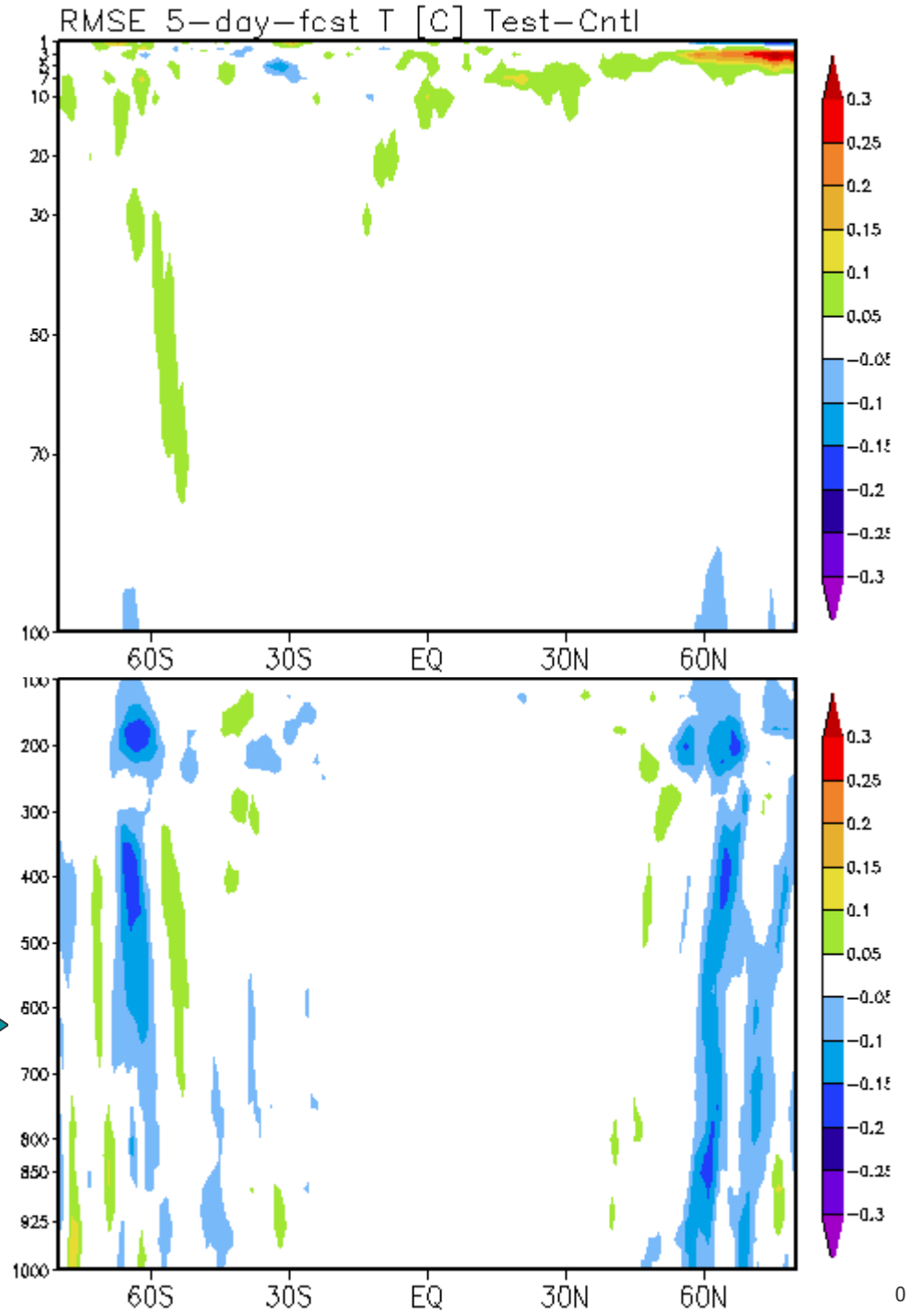


Blue color means improvement



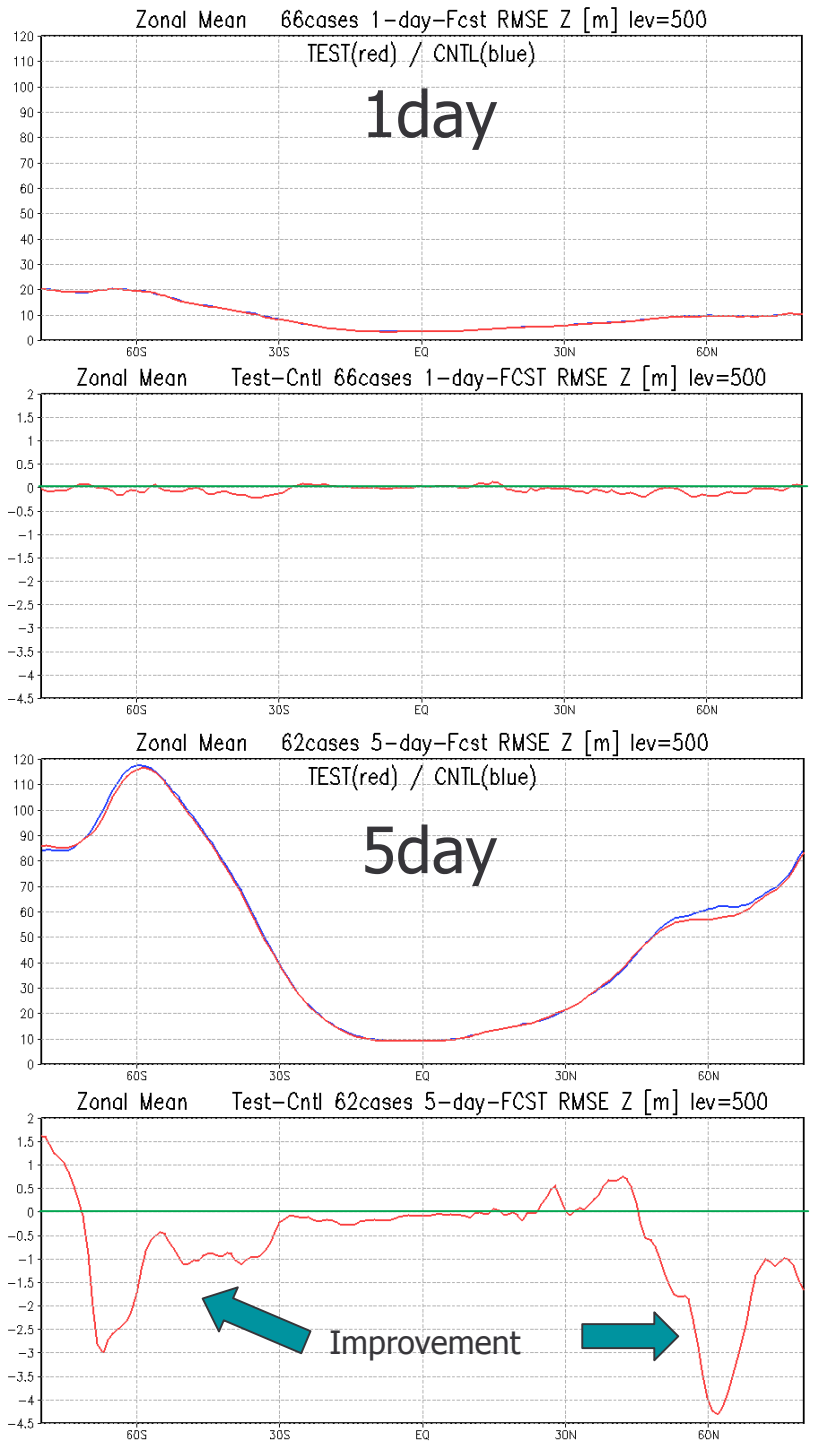
Zonal mean of RMSE of <u>Temperature forecast</u> (Test-Cntl)

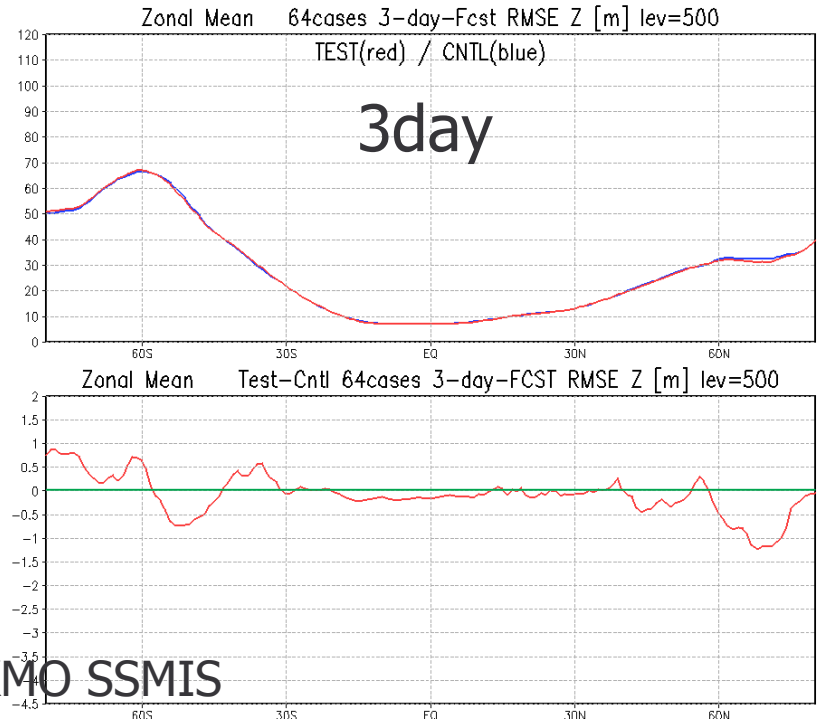
- 5-day forecast
- From Aug. 6 –
- 62 cases average



Blue color means improvement

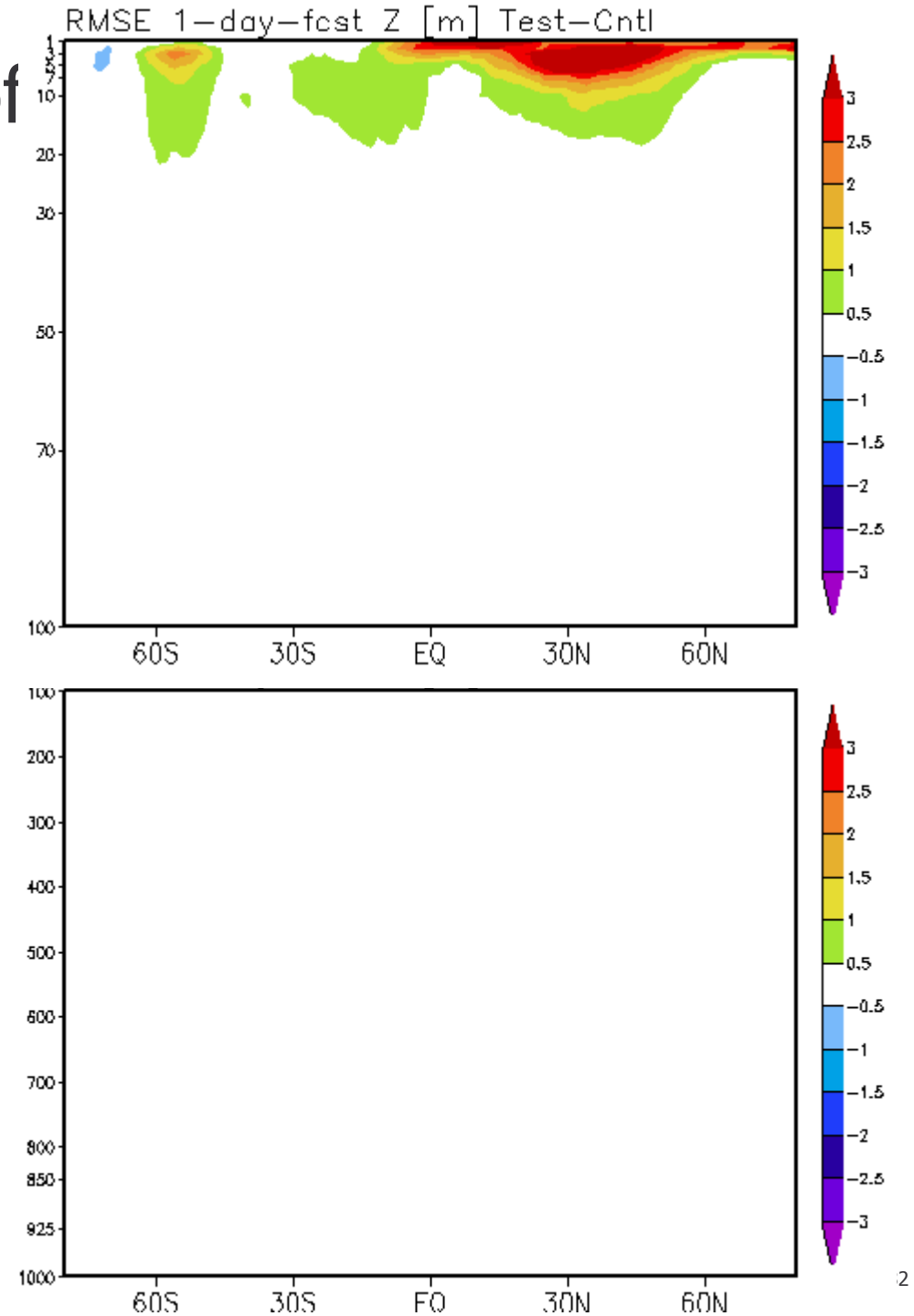
Z500 1-day, 3-day, 5-day forecast Zonal mean RMSE and difference(Test-Cntl)





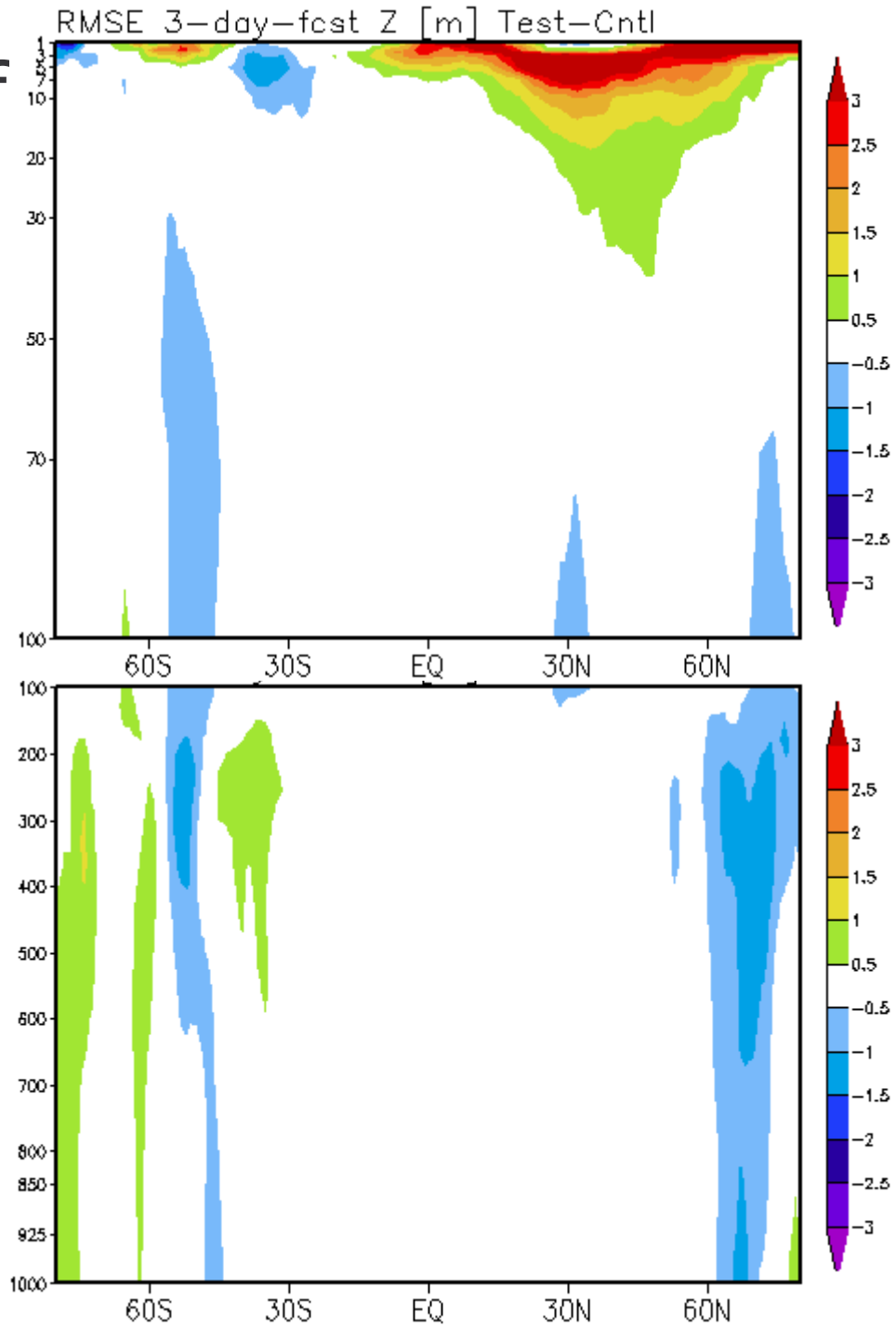
Zonal mean of RMSE of Geopotential height forecast (Test-Cntl)

- 1-day forecast
- From Aug. 2 –
- 66 cases average



Zonal mean of RMSE of Geopotential height forecast (Test-Cntl)

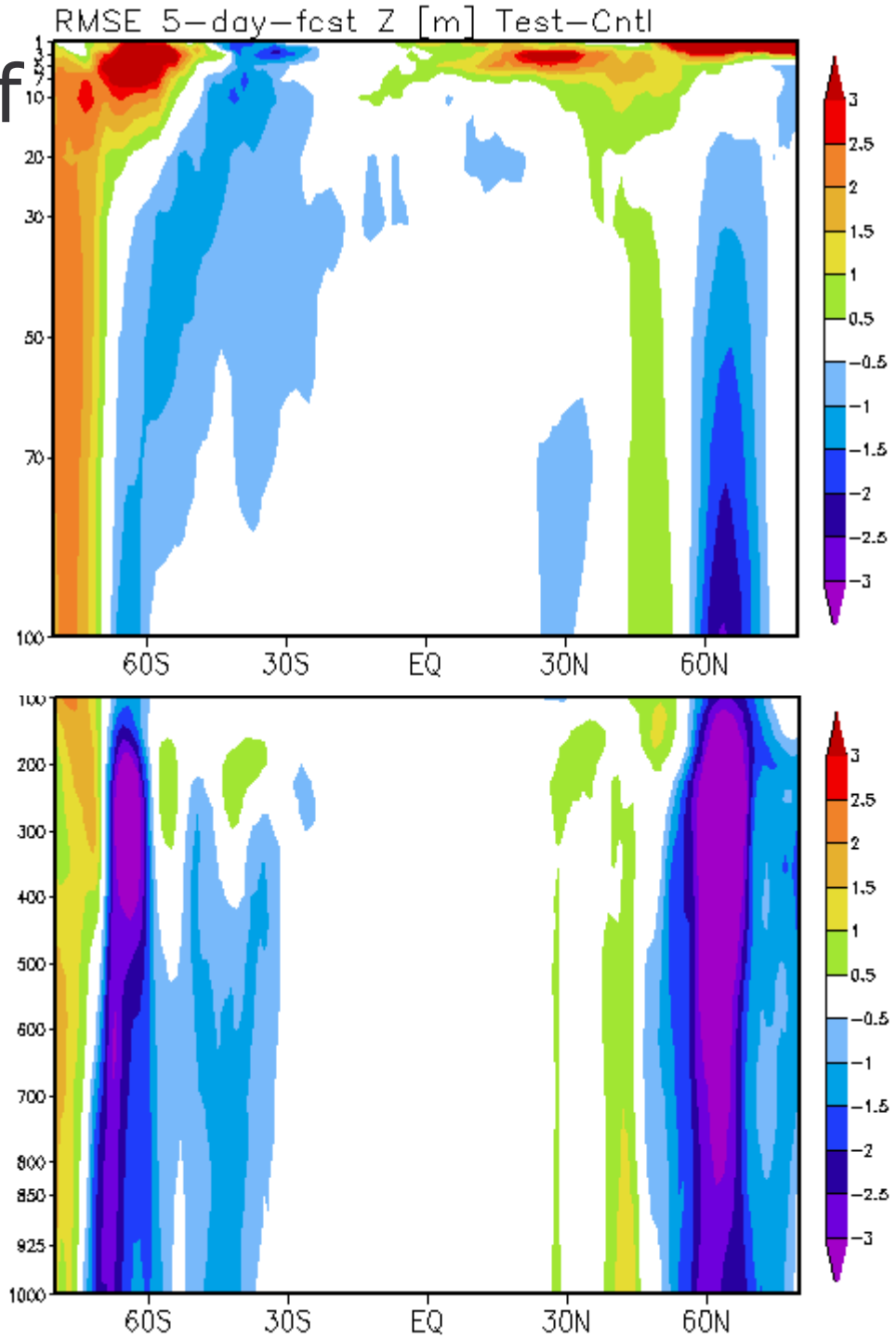
- 3-day forecast
- From Aug. 4 –
- 64 cases average



Blue color means improvement

Zonal mean of RMSE of Geopotential height forecast (Test-Cntl)

- 5-day forecast
- From Aug. 6 –
- 62 cases average



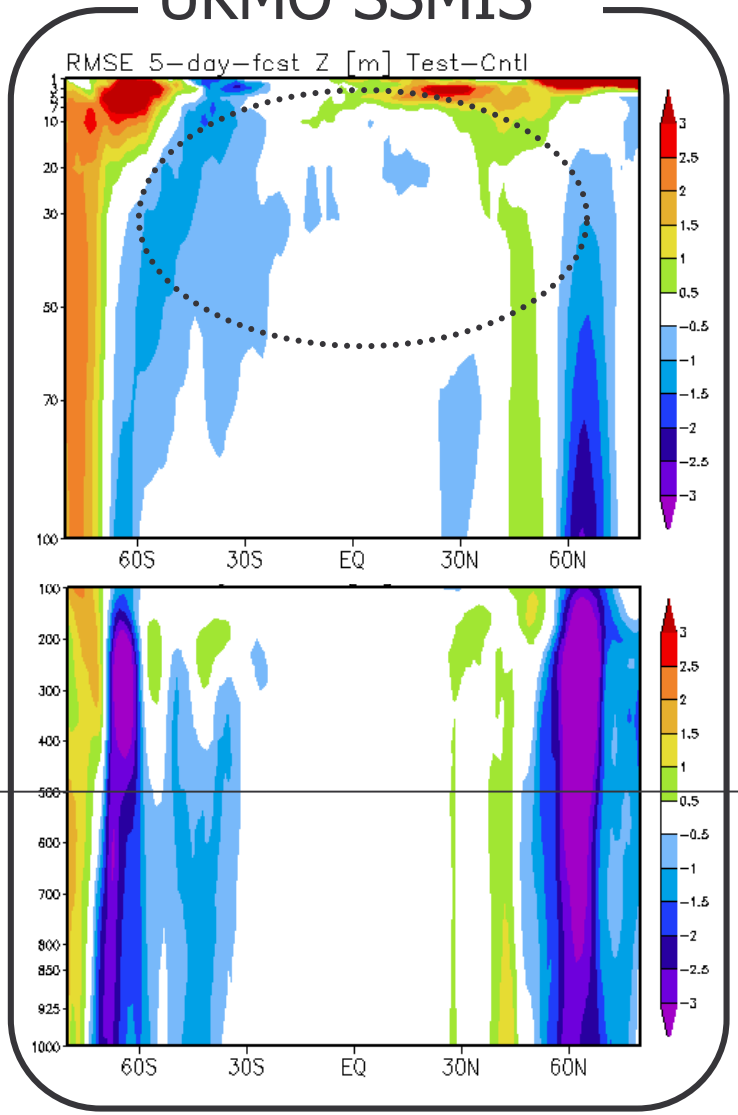
Blue color means improvement

5day Z forecast zonal averaged RMSE difference (Test-Cntl)

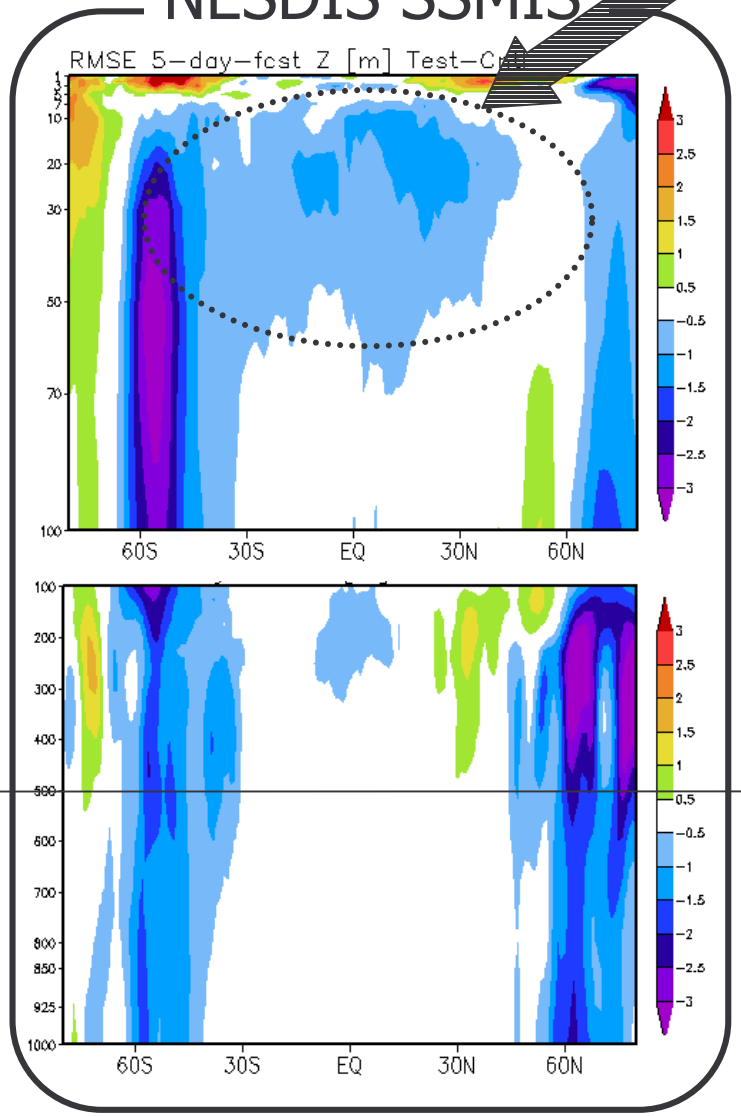
Blue color means improvement.

Much improvement in the stratosphere

UKMO SSMIS



NESDIS SSMIS



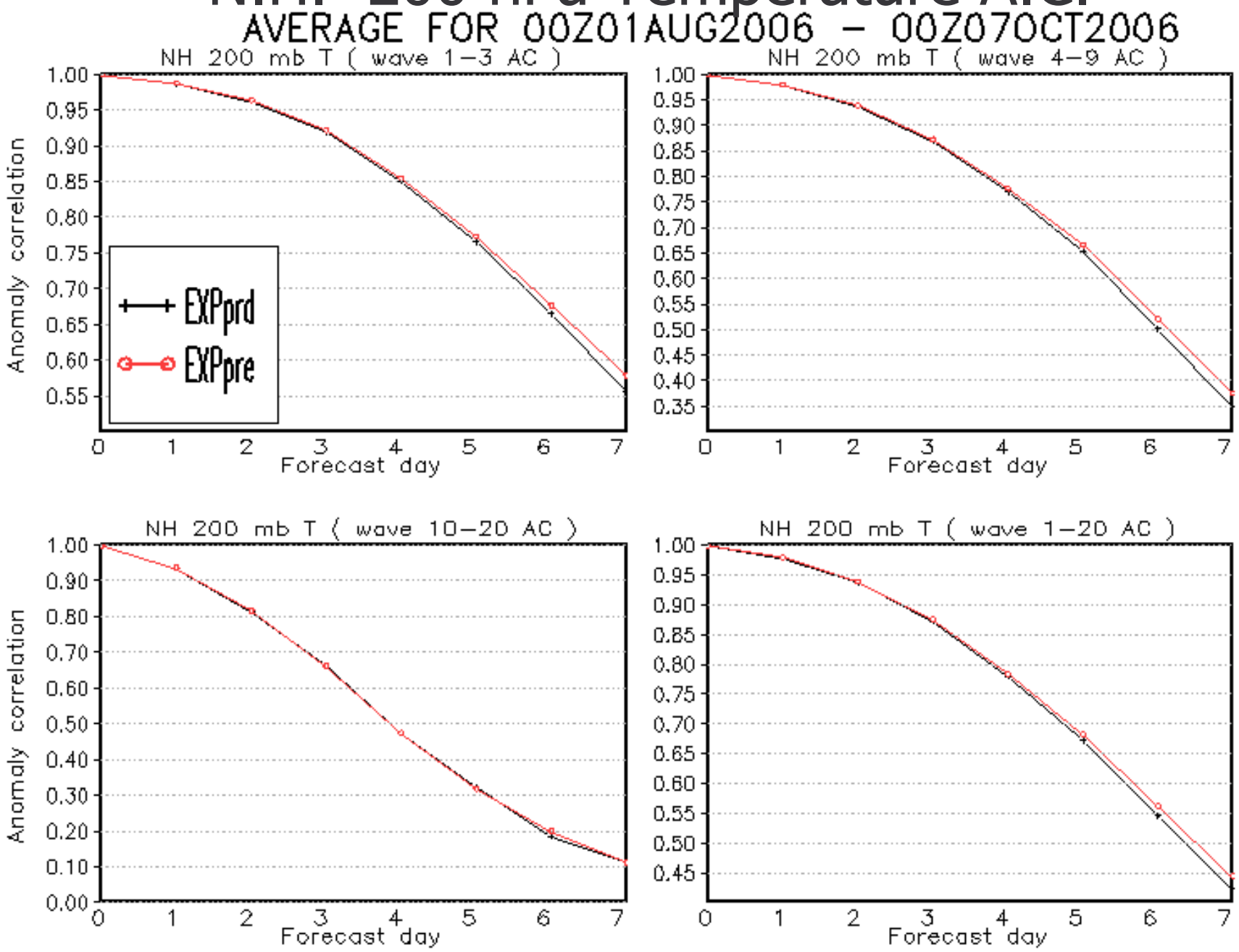
10hPa

100hPa

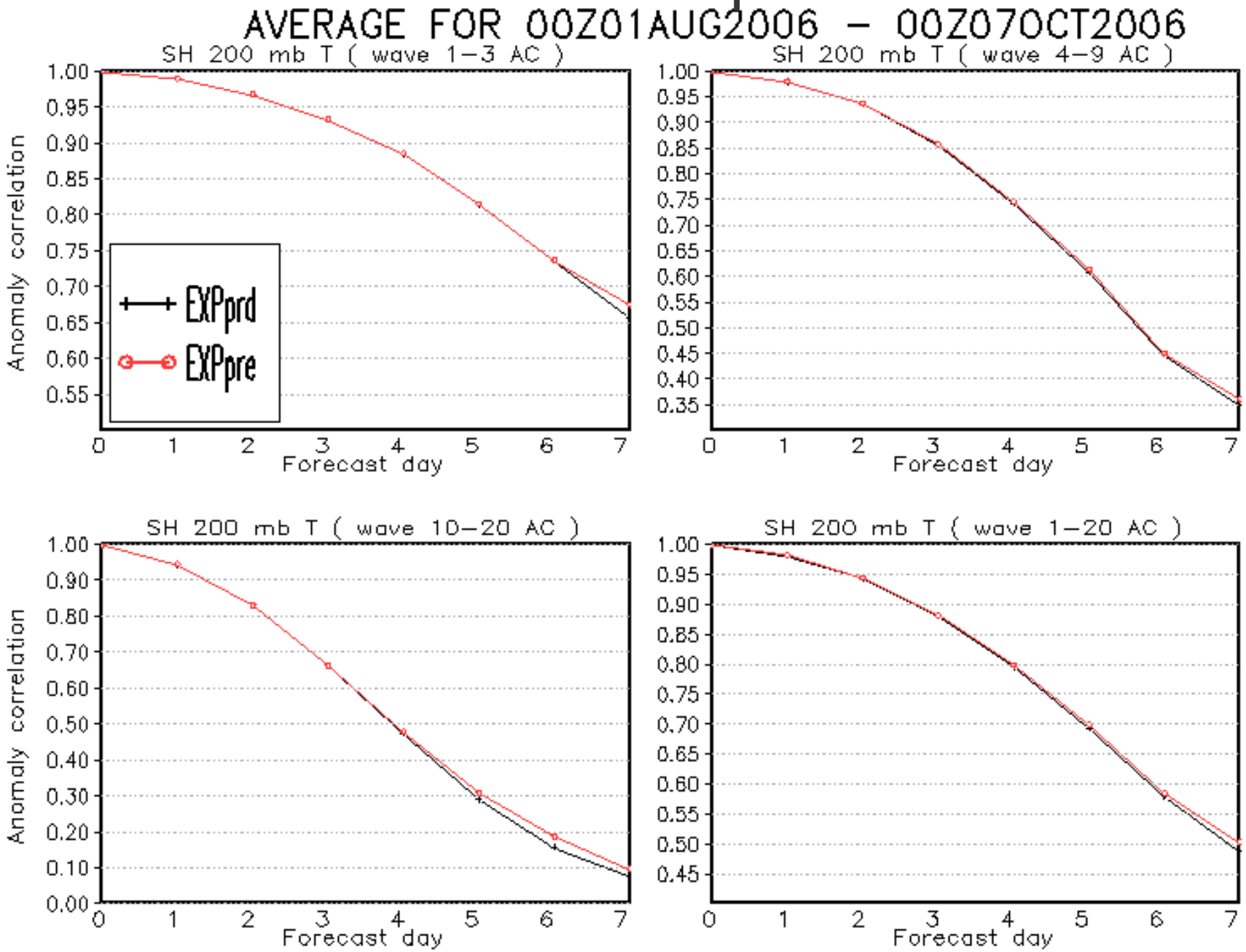
500hPa

1000hPa

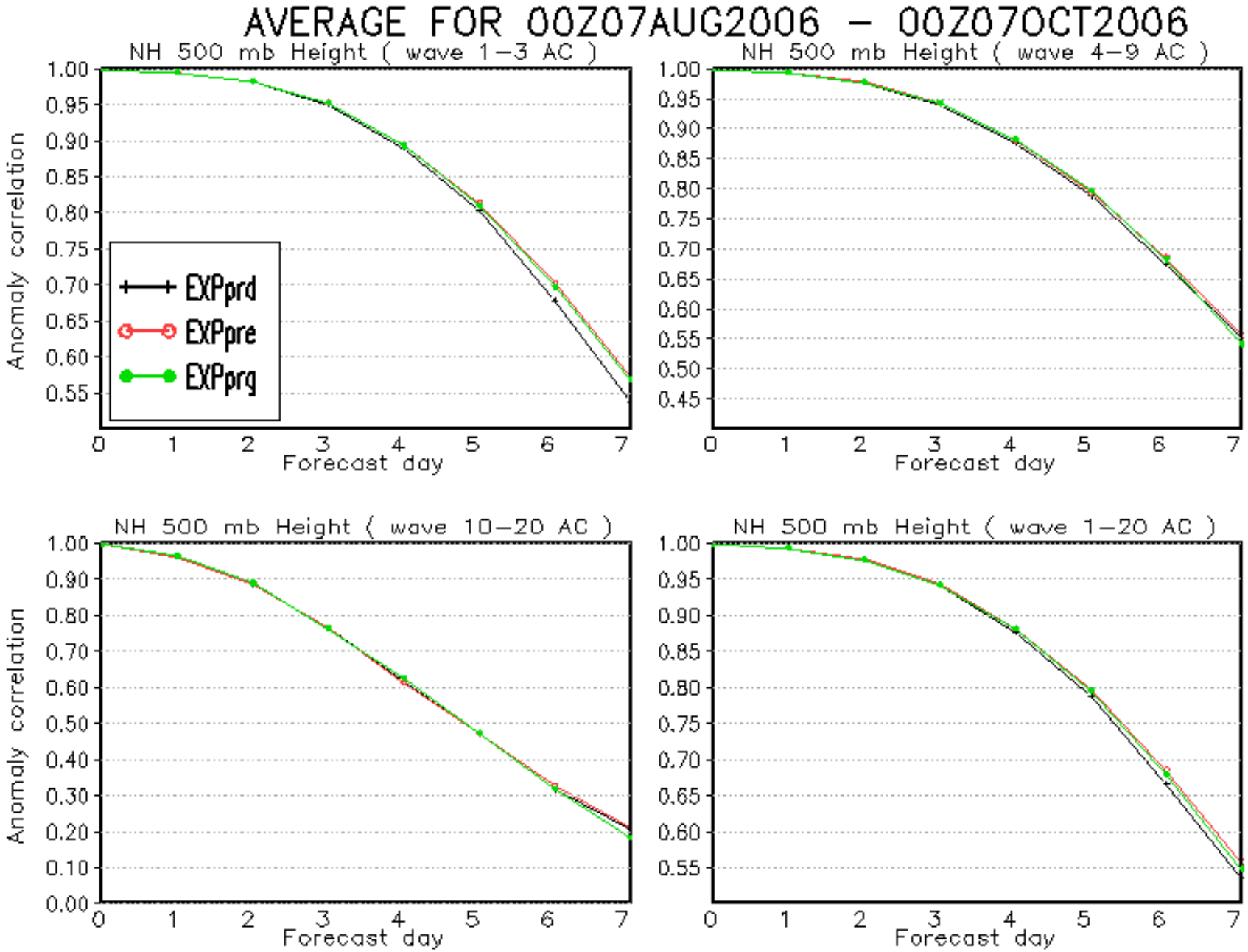
N.H. 200 hPa Temperature A.C.



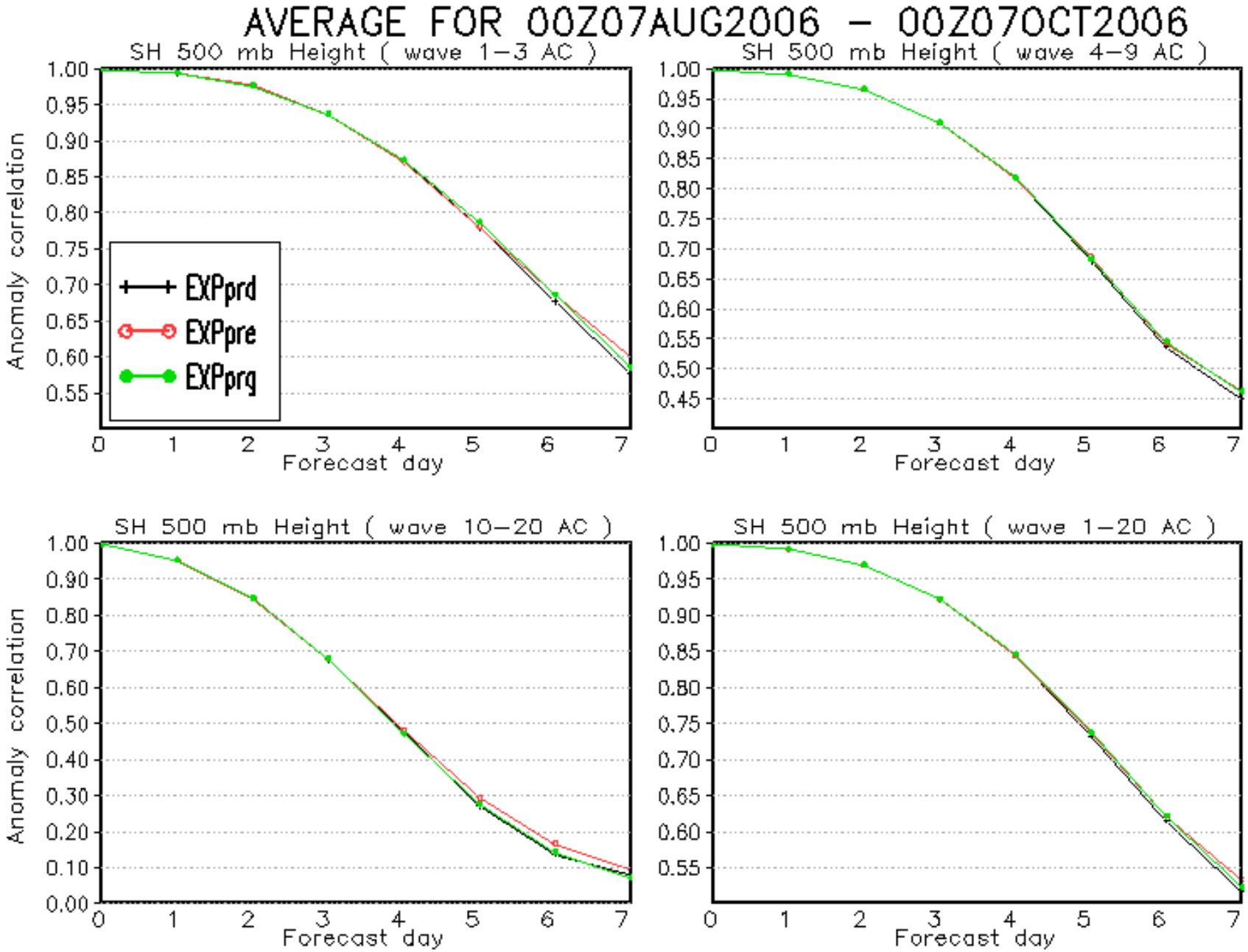
S.H. 200 hPa Temperature A.C.

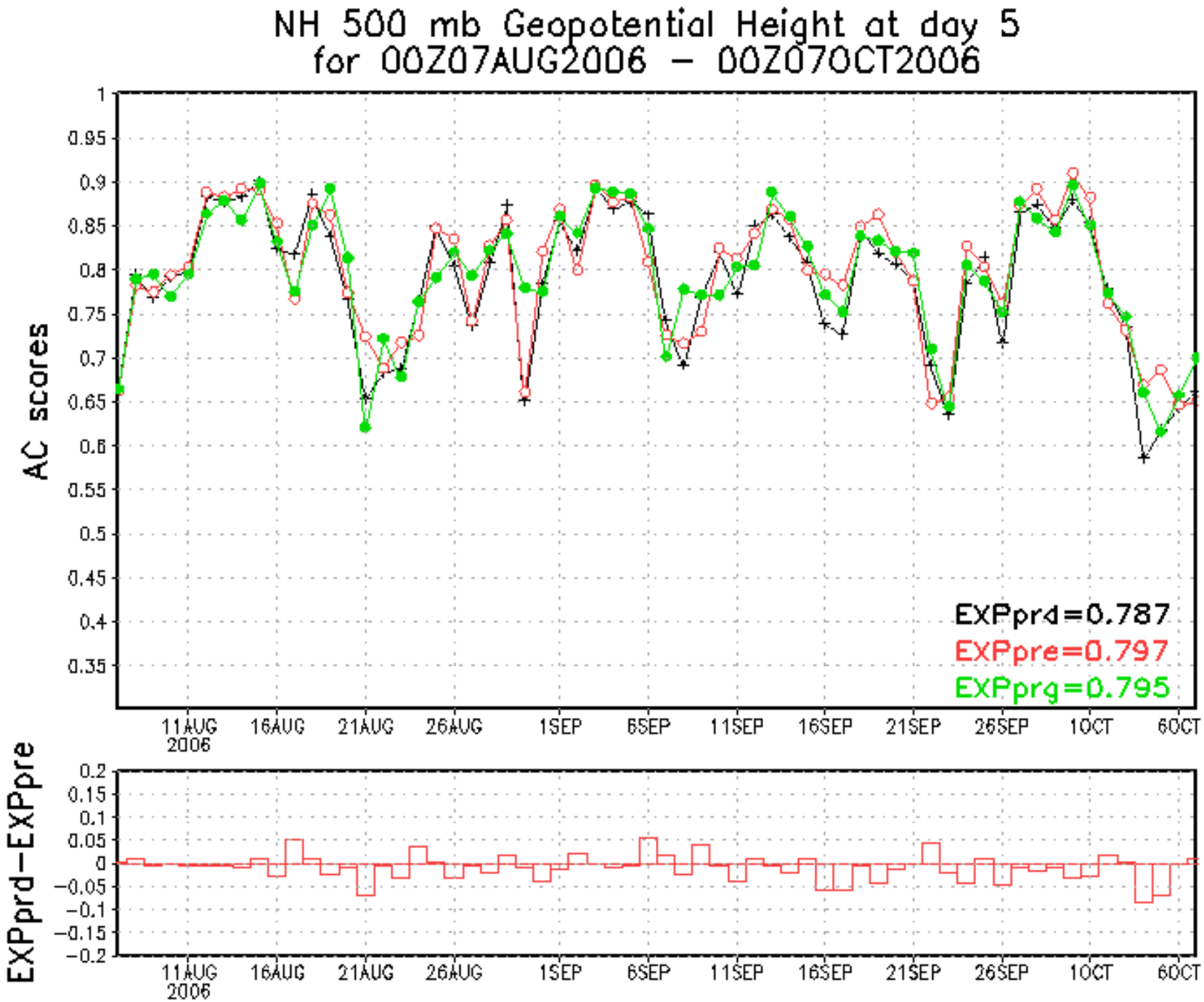


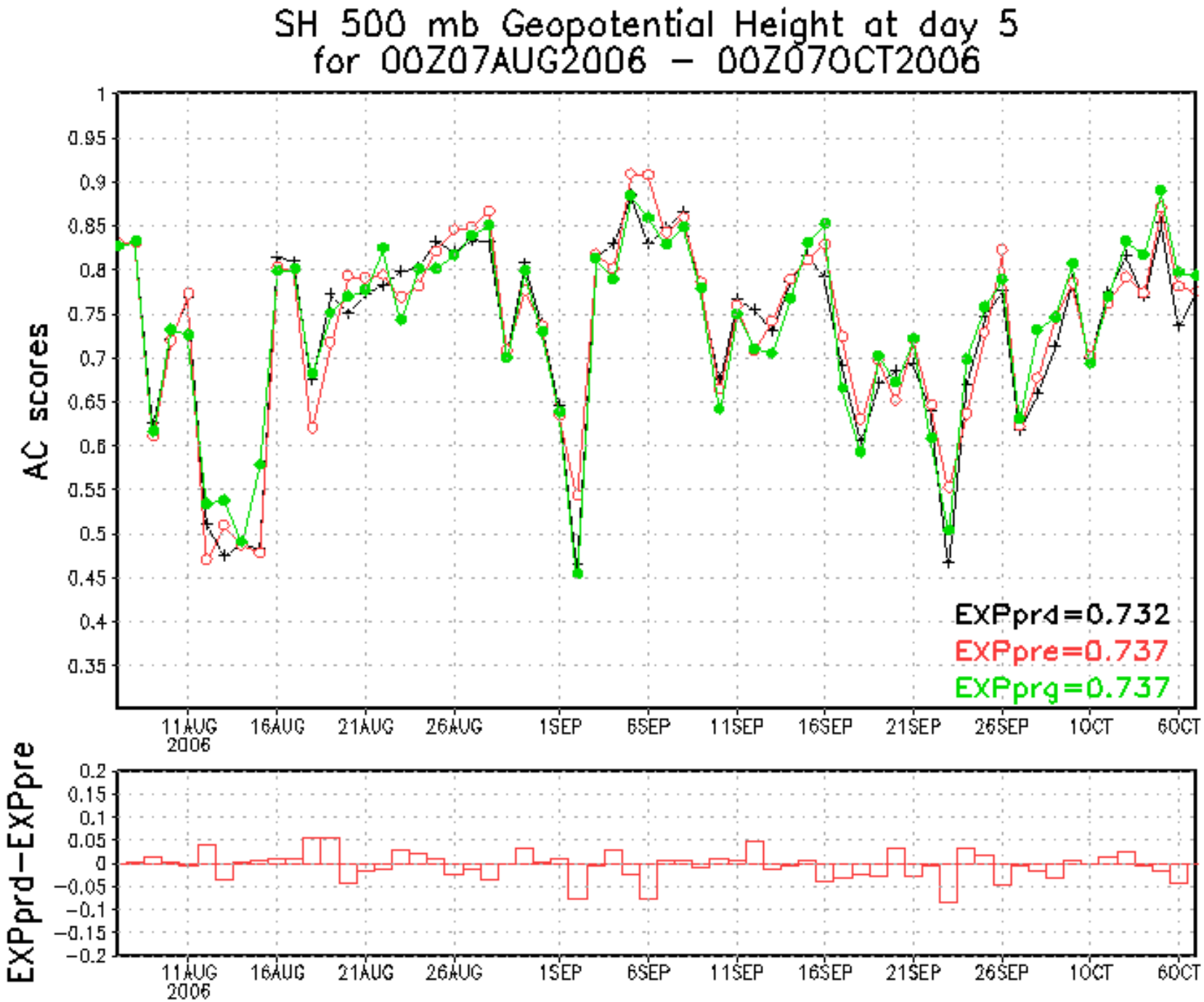
N.H. 500 hPa Geopotential Height A.C.



S.H. 500 hPa Geopotential Height A.C.

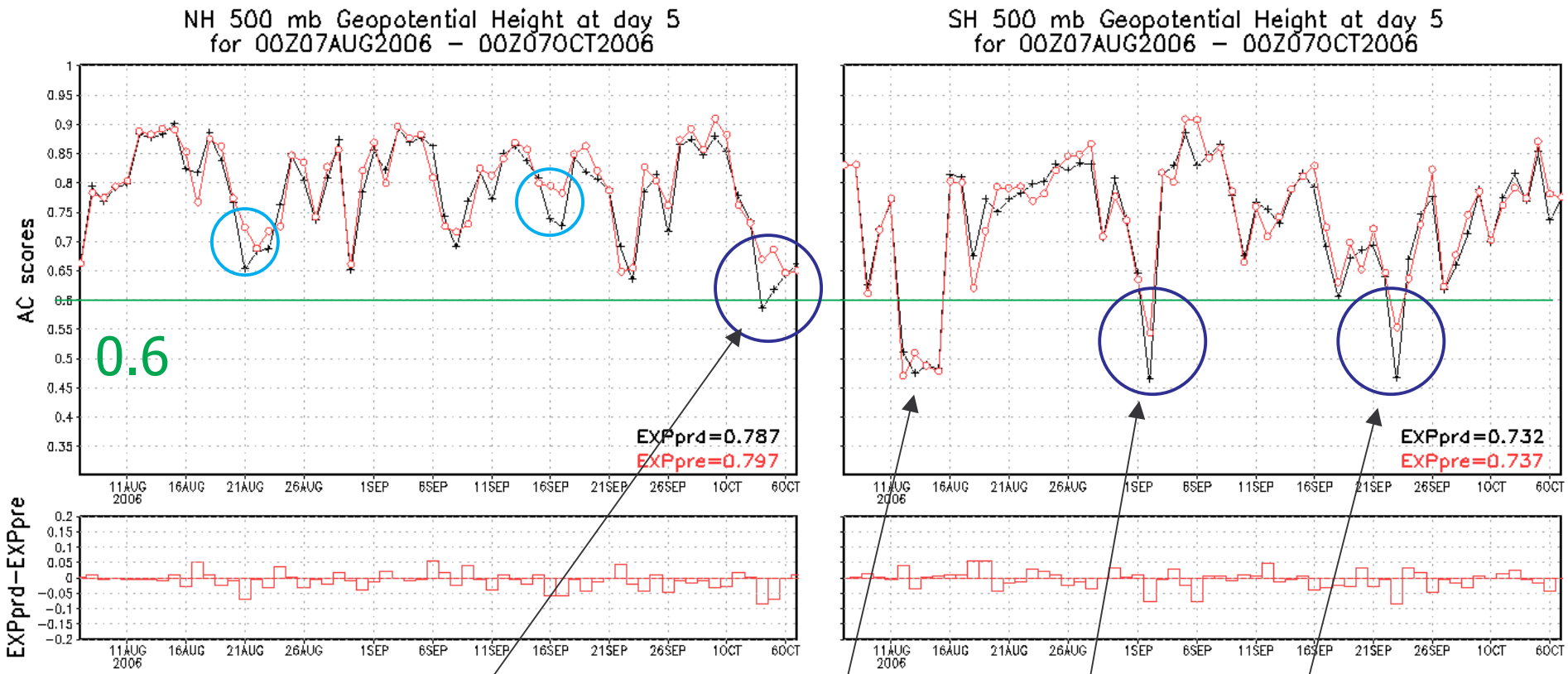



NH 500 mb Geopotential Height at day 5
for 00Z07AUG2006 – 00Z07OCT2006
AC scores
EXPprd=0.787
EXPpre=0.797
EXPprg=0.795
11AUG 2006
16AUG
21AUG
26AUG
1SEP
6SEP
11SEP
16SEP
21SEP
26SEP
1OCT
6OCT
EXPprd–EXPpre


SH 500 mb Geopotential Height at day 5
for 00Z07AUG2006 – 00Z07OCT2006
AC scores
EXPprd=0.732
EXPpre=0.737
EXPprg=0.737
11AUG 2006
16AUG
21AUG
26AUG
1SEP
6SEP
11SEP
16SEP
21SEP
26SEP
1OCT
6OCT
EXPprd–EXPpre

Time sequences of Z500 5 day forecast A.C.

"Forecast bust : A.C. dropping below 0.6 in 5day forecast"



Case1

Forecast bust

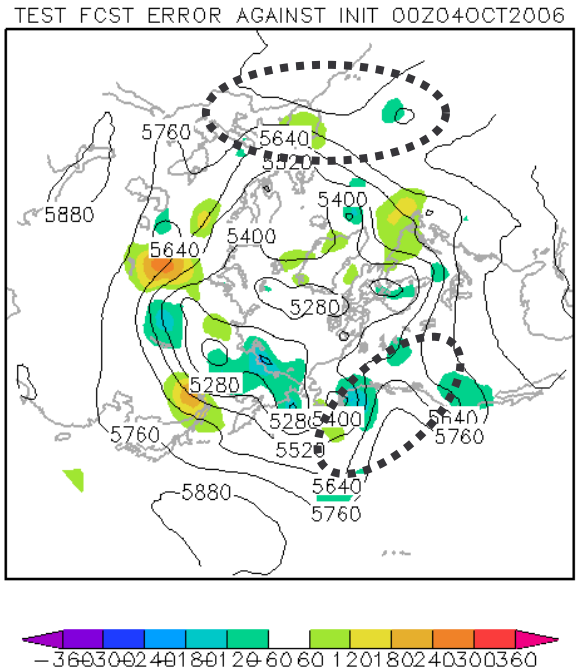
Case2

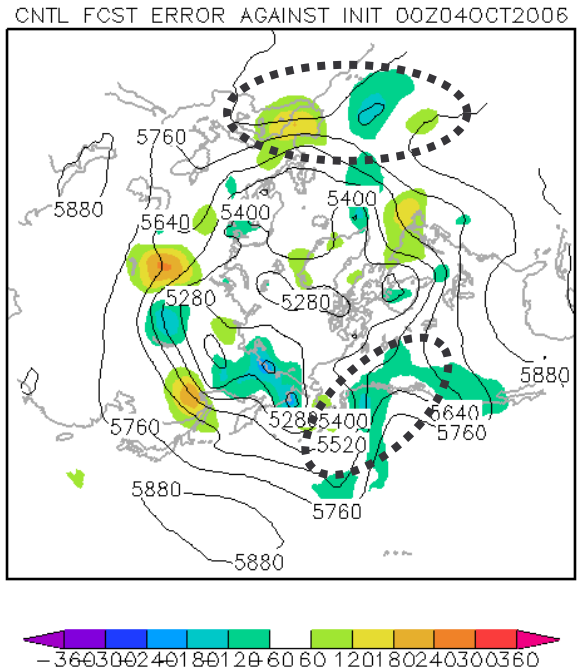
Case3

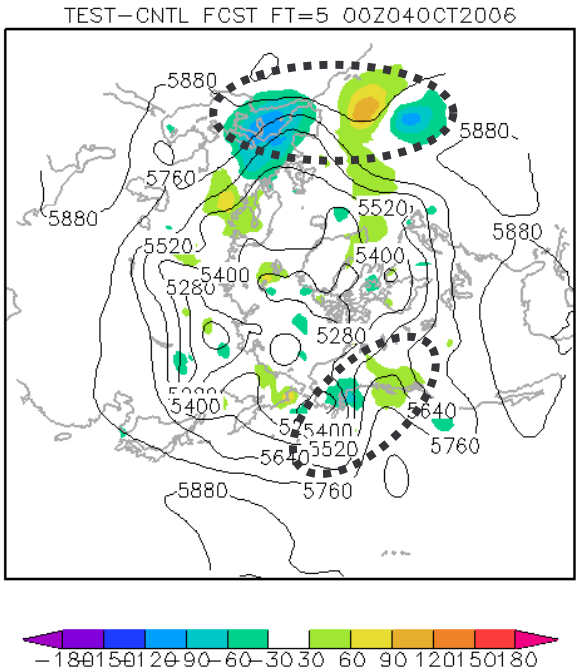
No improvement?

Forecast bust case 1 : 00Z04OCT 2006

N.H.







Test Forecast error

Contour : Test Z500 [m]

Shaded: Test(FT5)-Test(Init)

Cntl Forecast error

Contour : Cntl Z500 [m]

Shaded: Cntl(FT5)-Cntl(Init)

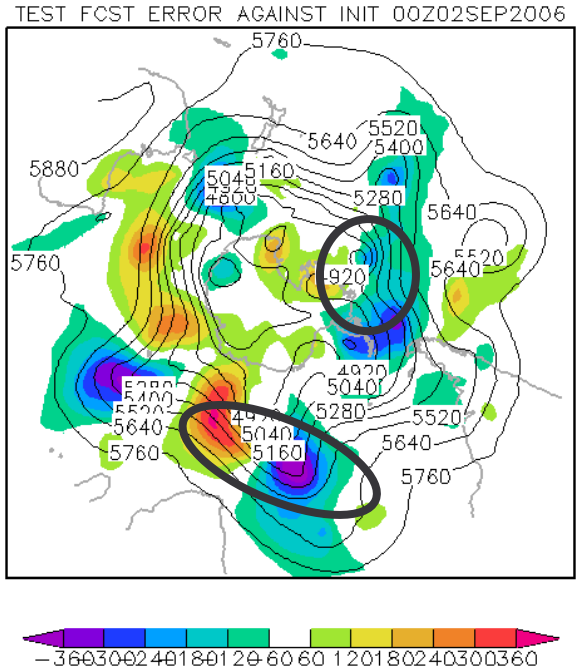
Forecast difference

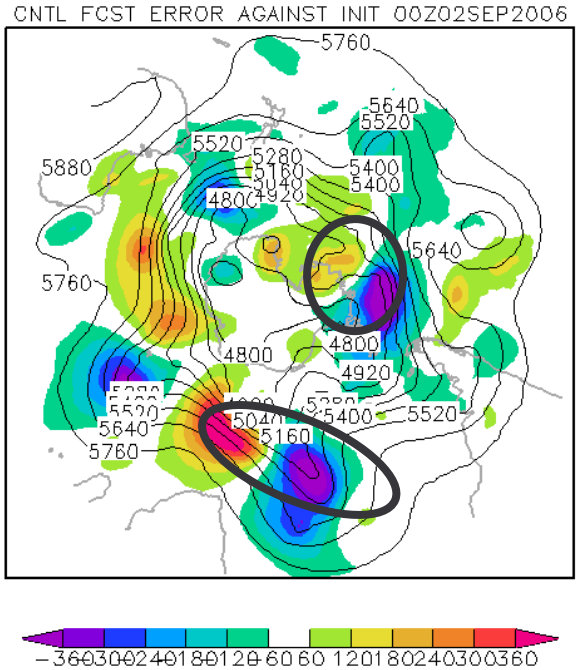
Contour : Init Z500 [m]

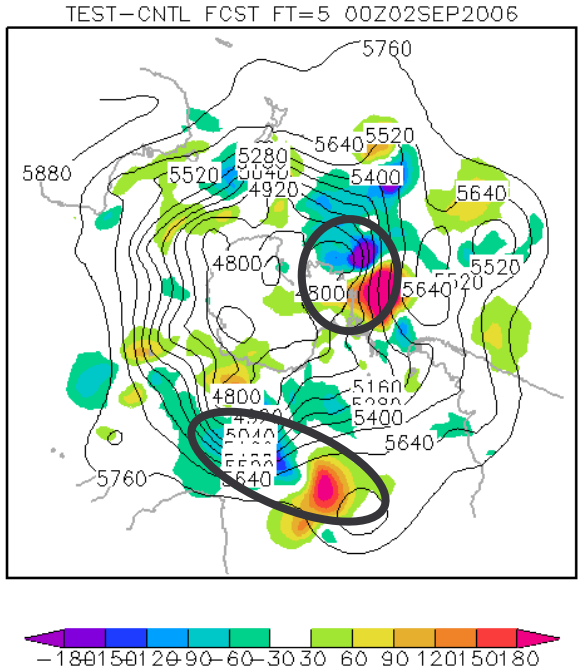
Shaded: Test(FT5)-Cntl(FT5)

Forecast bust case 2: 00Z02SEP 2006

S.H.







Test Forecast error

Contour : Test Z500 [m]

Shaded: Test(FT5)-Test(Init)

Cntl Forecast error

Contour : Cntl Z500 [m]

Shaded: Cntl(FT5)-Cntl(Init)

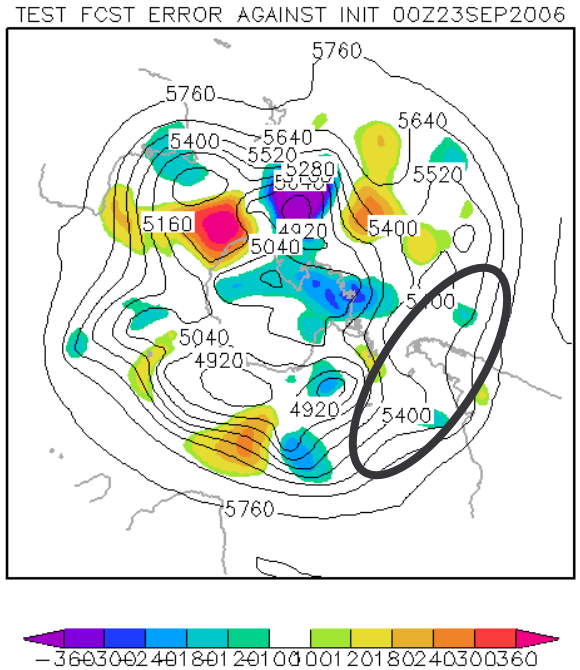
Forecast difference

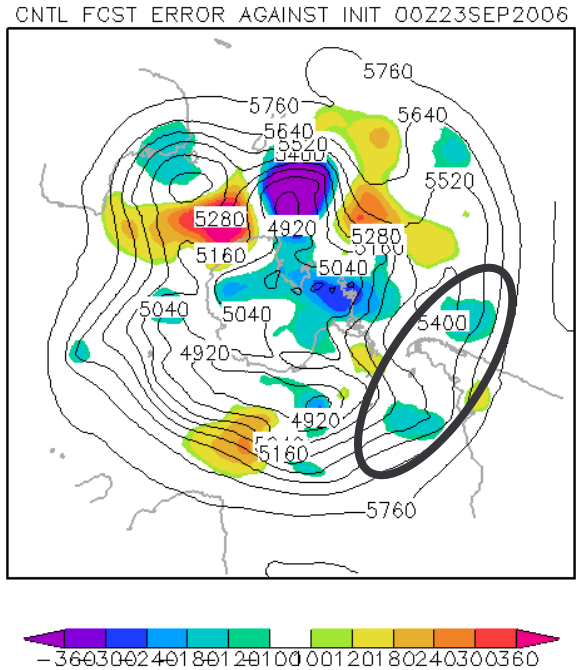
Contour : Init Z500 [m]

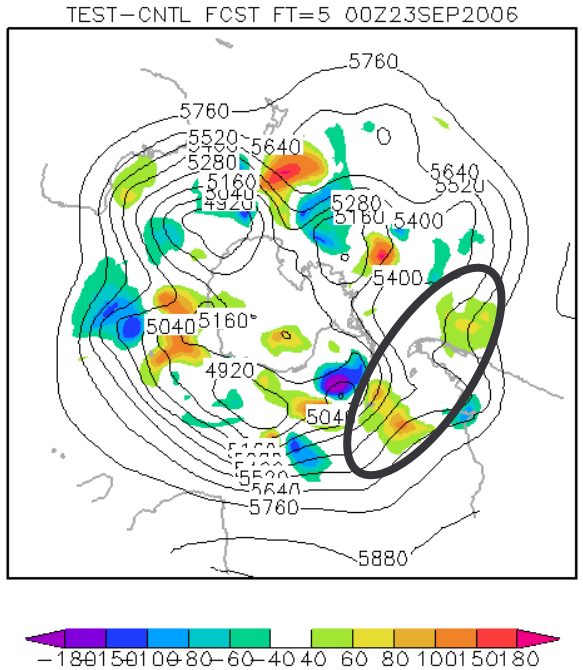
Shaded: Test(FT5)-Cntl(FT5)

Forecast bust case 3: 00Z23SEP 2006

S.H.







Test Forecast error

Contour : Test Z500 [m]

Shaded: Test(FT5)-Test(Init)

Cntl Forecast error

Contour : Cntl Z500 [m]

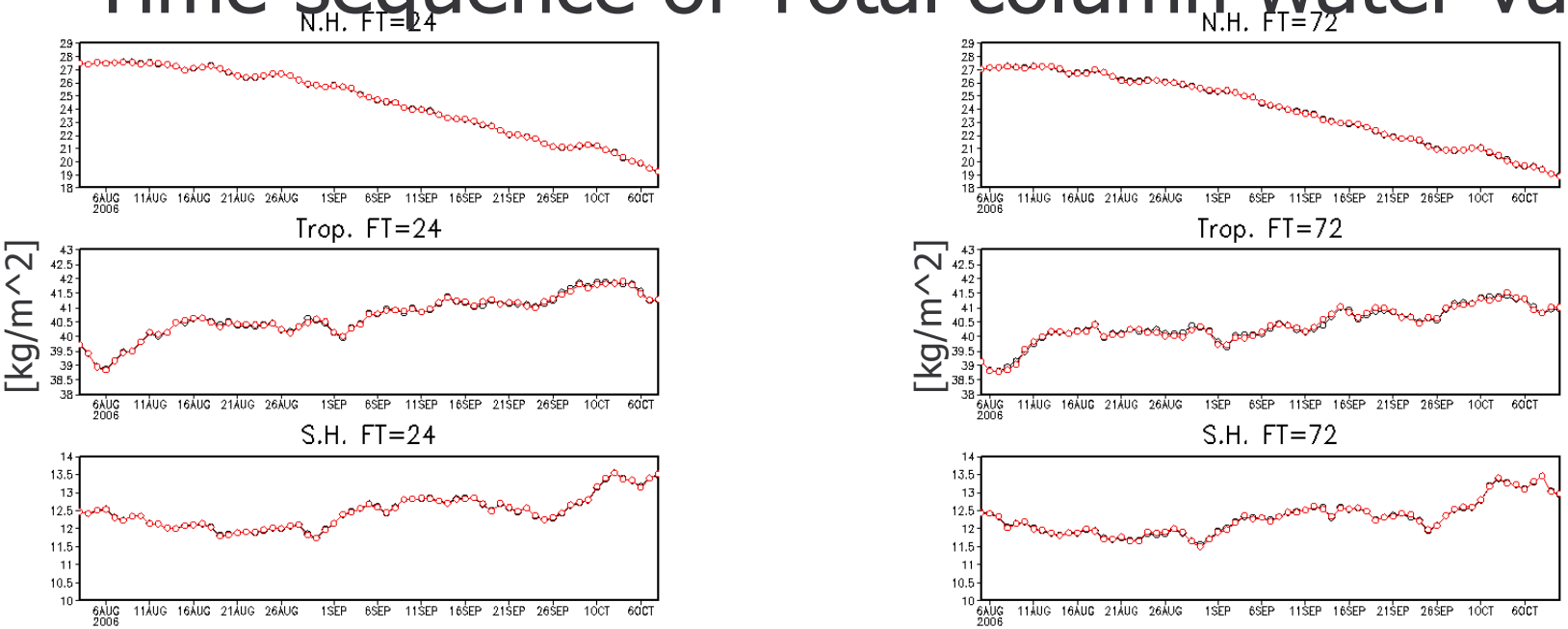
Shaded: Cntl(FT5)-Cntl(Init)

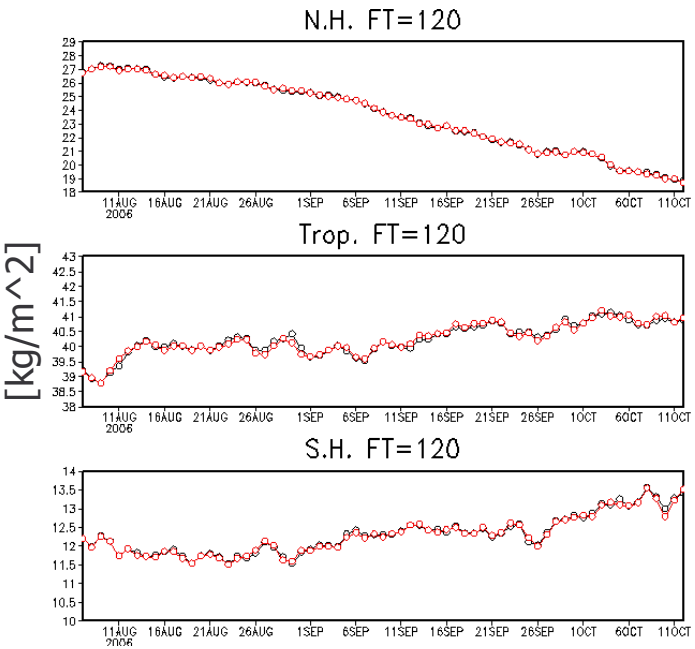
Forecast difference

Contour : Init Z500 [m]

Shaded: Test(FT5)-Cntl(FT5)

Time sequence of Total column water vapor





Red: Test

Black: Cntl

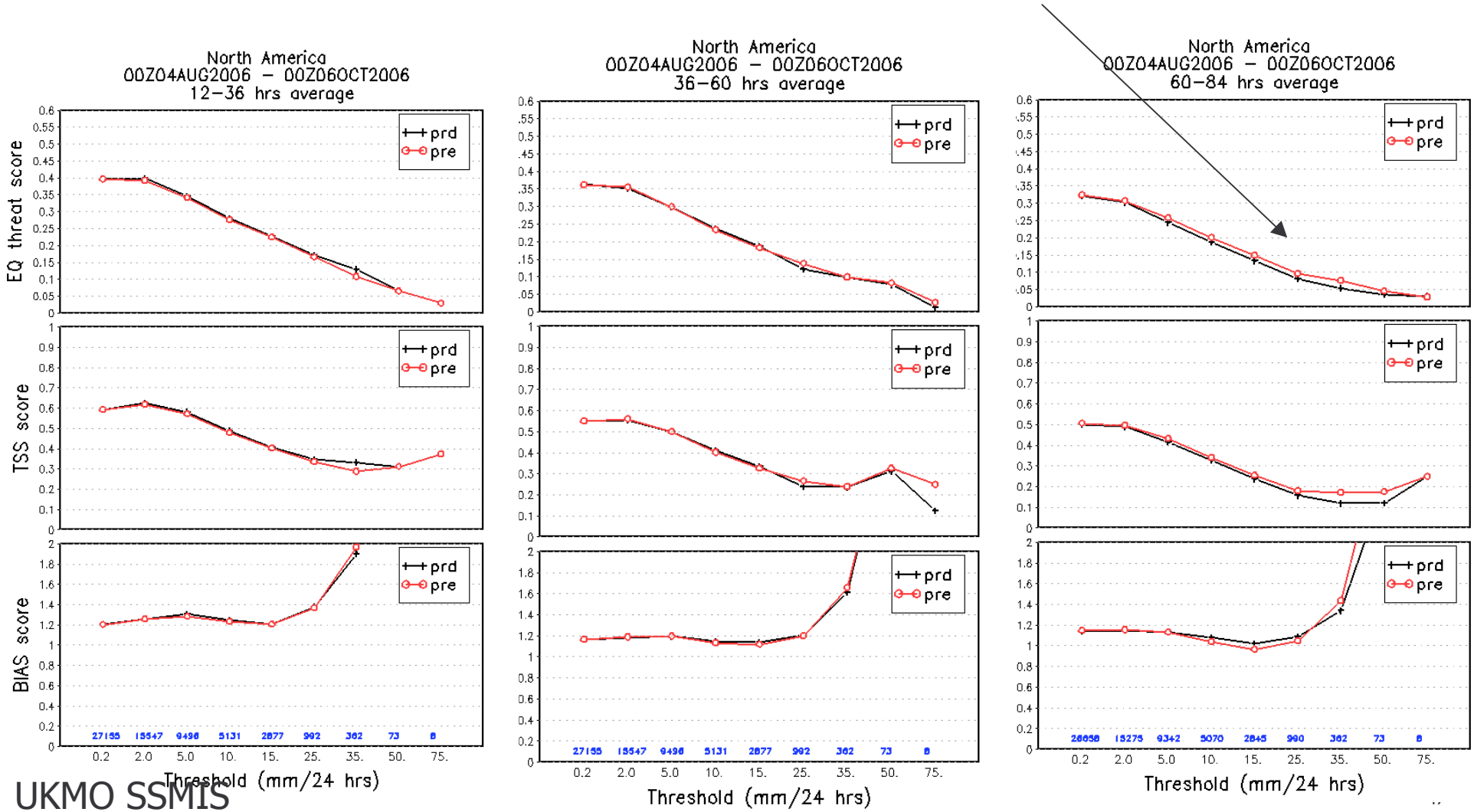
Impact on moisture field is small.

CONUS Precipitation Verification

Red: Test

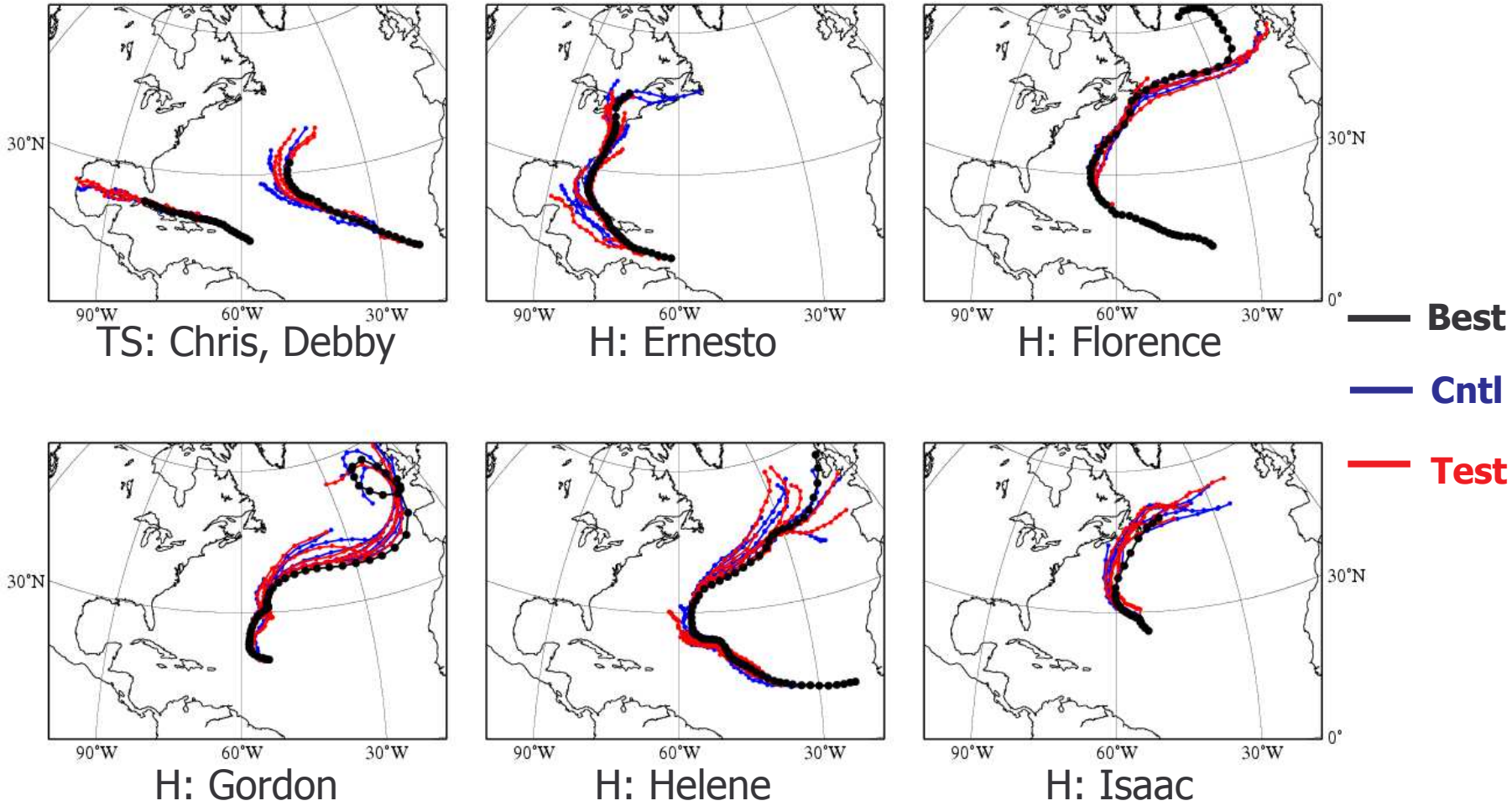
Black: Cntl

- Slightly improved in 60-84hr forecast



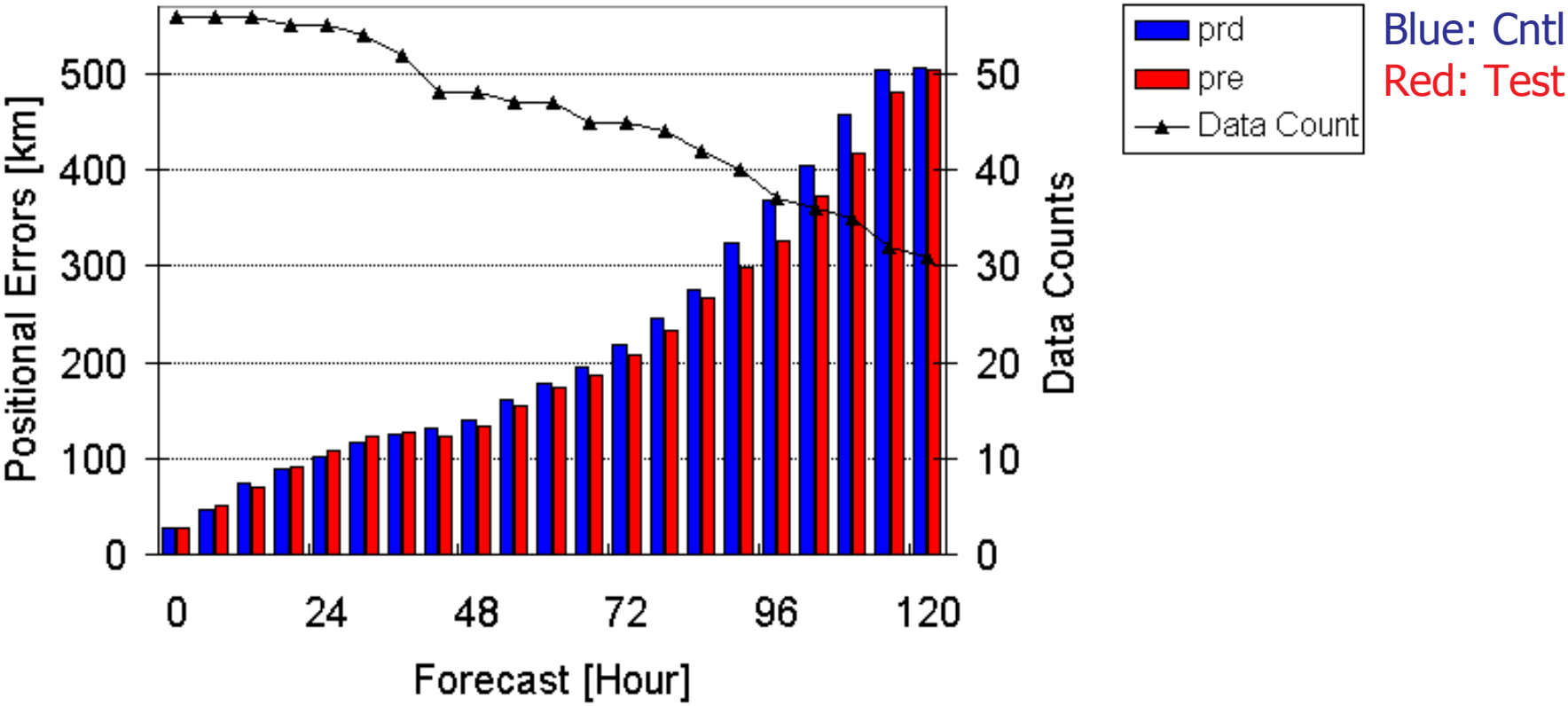
UKMO SSMIS

Forecast of tropical cyclone and hurricane in the Atlantic Ocean



2 Tropical cyclone and 5 Hurricane from Aug. 1 to Oct. 2, 2006.

Hurricane & Tropical cyclone track forecast verification



About 50km improvement of position forecast at 96 hour forecast.

Conclusions

- Preprocessed UKMO SSMIS data and recalibrated NESDIS SSMIS data have comparable quality with AMSU-A data
- Assimilation experiments with cloud cleared SSMIS radiances (UKMO and NESDIS) in GSI were carried out.
- Impacts on analysis
  - Neutral in average fields. The data around 30N in ascending orbit make negative impacts on 500hPa height analysis increment. But it does not affect forecast accuracy so much. Negative above 10hPa due to unbalance bias in stratosphere channels. (UKMO SSMIS)
- Impacts on forecast
  - Positive: A.C. of Z500,Z1000(not shown), T200 A.C. for both hemisphere, RMSE of T,Z (1000-10hPa)
  - Neutral: Vector Wind(Trop. not shown), Fits to RAOB (most of element,1day,2day),TPW
  - Negative: Above 10hPa,T,Z (UKMO SSMIS)
- Precipitation (In 60-84hr forecast, slightly positive on North America)
- Small improvements for hurricane track prediction after 48hour forecasts (about 50km improvement in 96-hour forecast).
- In NCEP GDAS, assimilation of preprocessed (recalibrated) SSMIS data can improve forecast accuracy especially in medium range forecasts.

Final comments

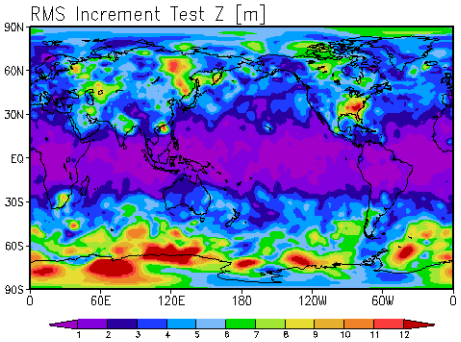
- Assimilations of corrected SSMIS radiances data show positive impacts on 500hPa height forecast score whichever SSMIS data is used (UKMO or NESDIS).
- In the stratosphere, much improvement was found from NESDIS SSMIS data.
- Correction algorithm (UKMO,NRL and NESDIS) should be merged and make an unified correction algorithm.
- Operational NWP center desire one well-calibrated SSMIS data in real time base.
- Clean SSMIS data (F17-F20) must be valuable for NWP in the next decade.

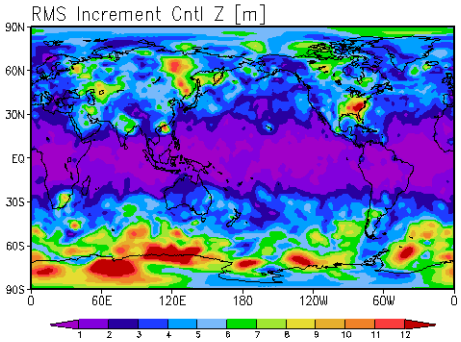
Backup slides

RMS geopotential height analysis increment (Zonal average of the first 3 day analysis)

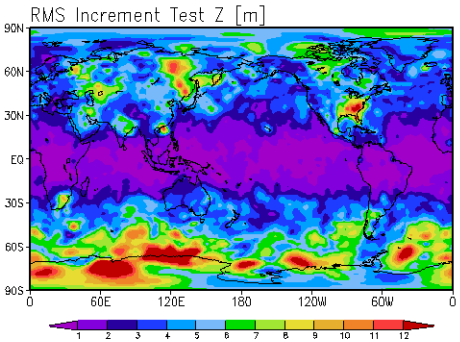
500hPa height

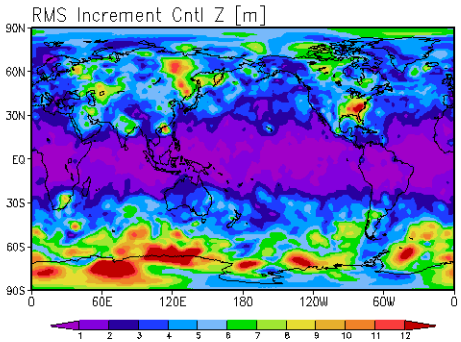
UKMO

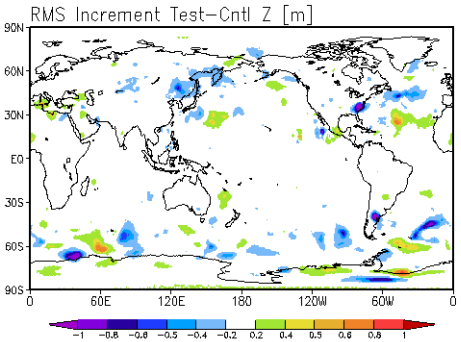




NESDIS





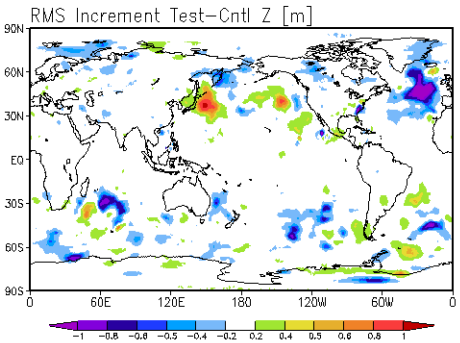


Increment RMS Z [m] lev=500

00Z.2/Aug/2006−18Z.4/Aug/2006

(3 days : 12 cases average)

Longitude :: 0−360deg
Latitude :: −90−90deg



Increment RMS Z [m] lev=500

00Z.2/Aug/2006−18Z.4/Aug/2006

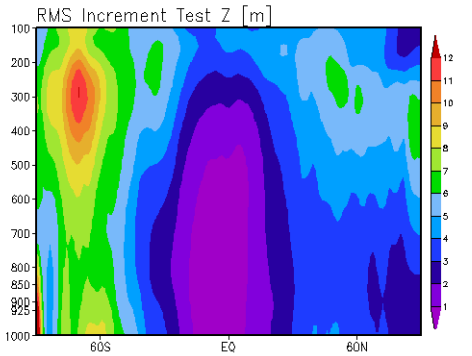
(3 days : 12 cases average)

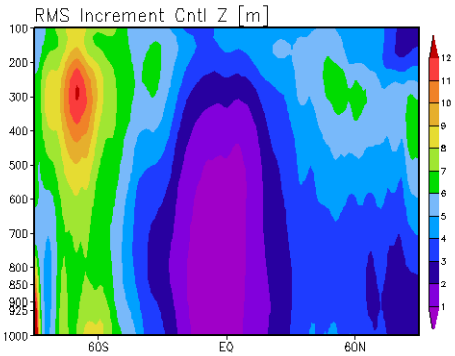
Longitude :: 0−360deg
Latitude :: −90−90deg

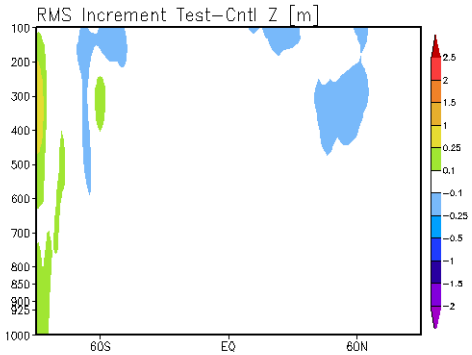
Difference of zonal mean RMS increment for geopotential height

Increment = analysis – background (6-h forecast)

UKMO







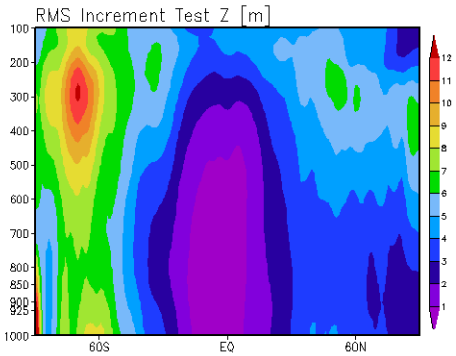
Increment RMS Z [m] ZonalMean

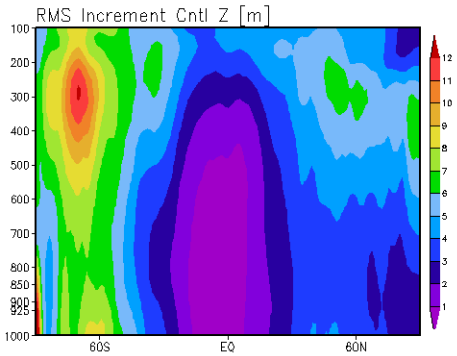
00Z.2/Aug/2006−18Z.4/Aug/2006

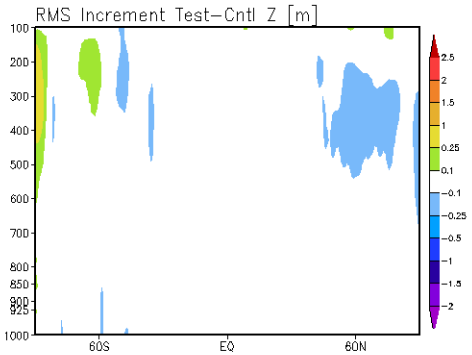
(3 days : 12 cases average)

Longitude :: 0−360deg
Latitude :: −90−90deg

NESDIS







Increment RMS Z [m] ZonalMean

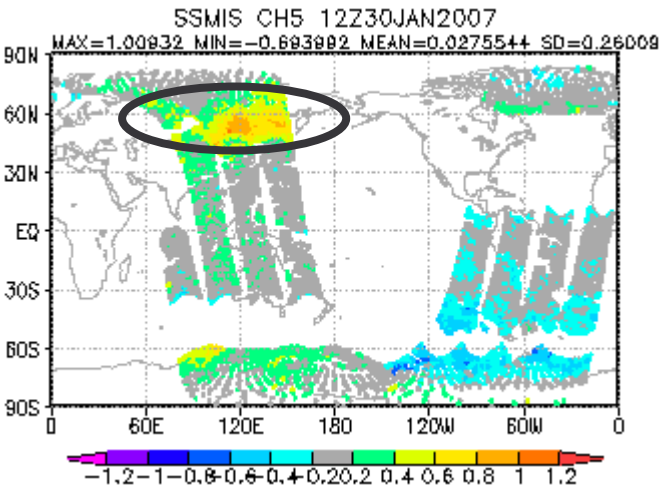
00Z.2/Aug/2006−18Z.4/Aug/2006

(3 days : 12 cases average)

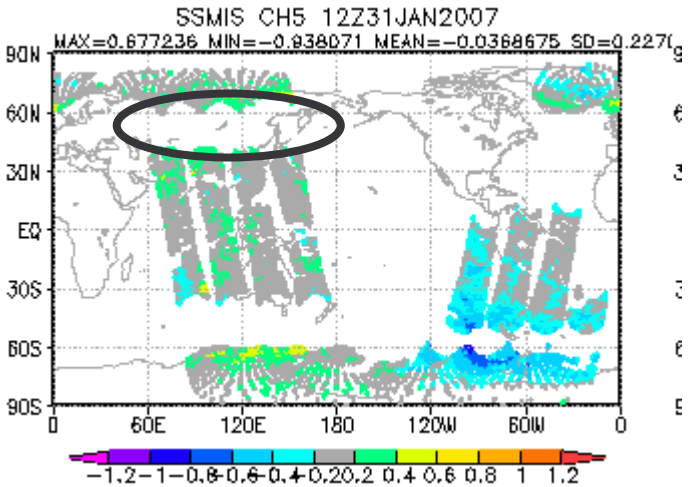
Longitude :: 0−360deg
Latitude :: −90−90deg

Data provider UKMO put additional flag on the data which has remaining bias in ascending orbit since the end of January 2007.

Before

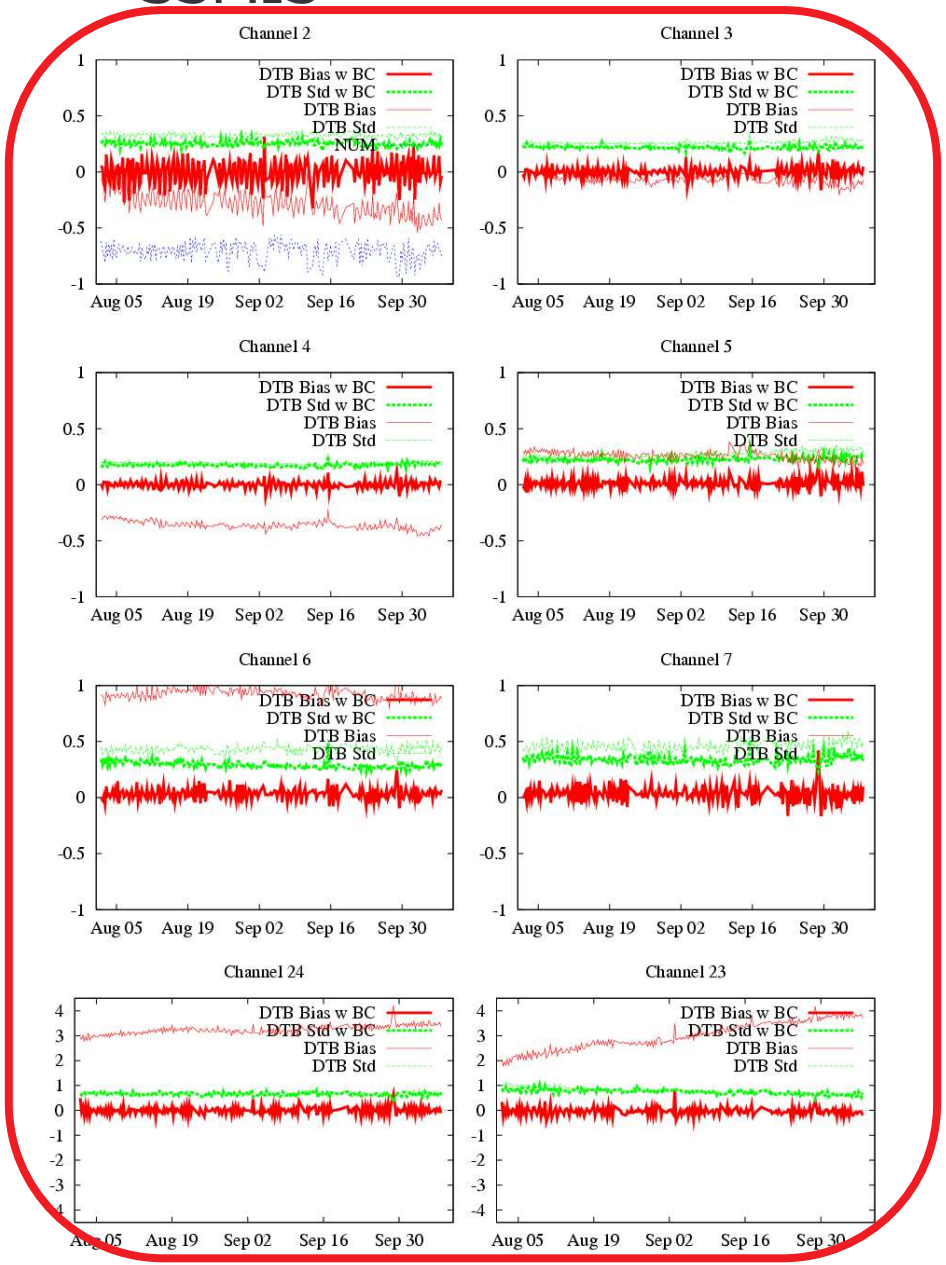


After

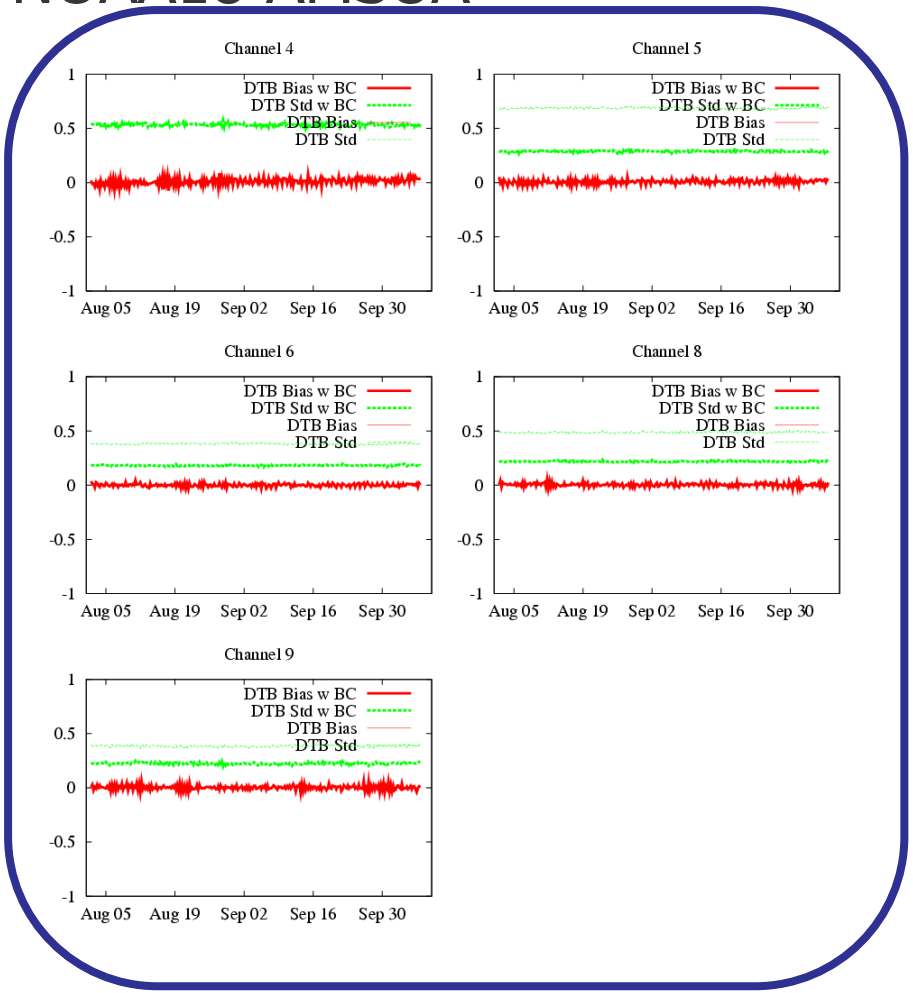


Time sequence of O-B

SSMIS



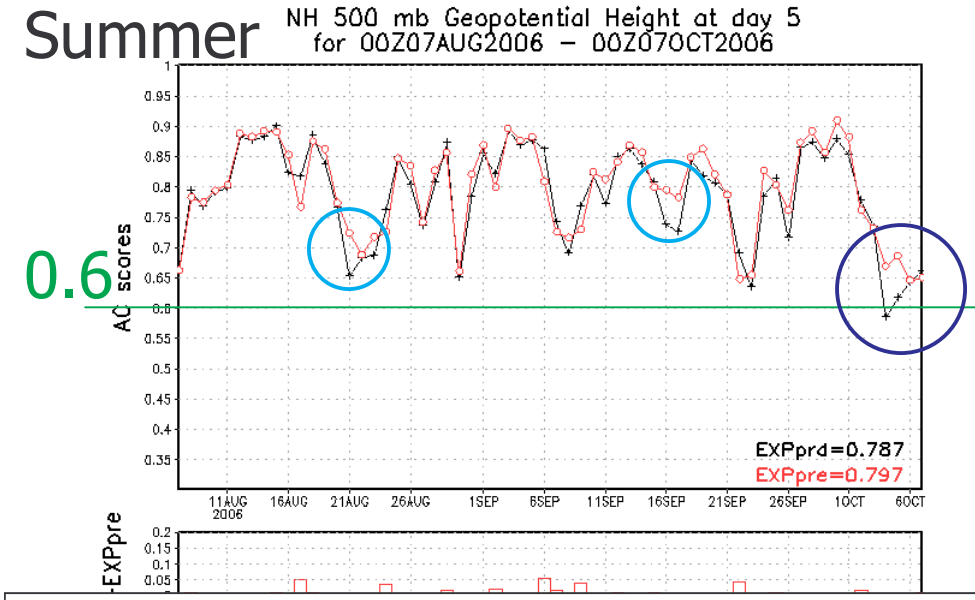
NOAA18 AMSUA

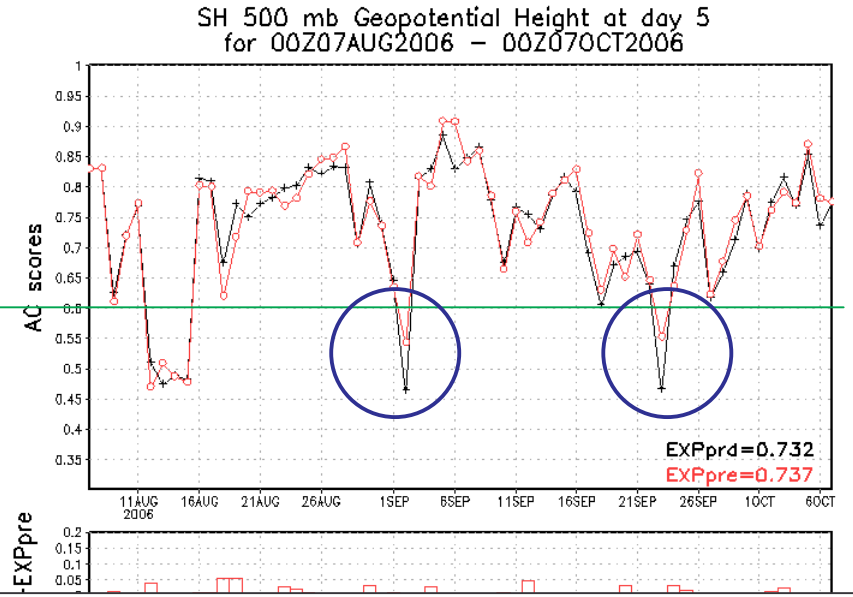


In general, SSMIS bias correction works properly.

An oscillation of mean O-B depending on analysis time was found. Remaining unbalance bias in orbit might make the oscillation.

Summer





Neutral for winter season because there are few forecast bust.

Winter