



# Interaction of GPS Radio Occultation with Hyperspectral Infrared and Microwave Sounder Assimilation

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# Outline



## What is new?

EUMETSAT GRAS-SAF Software Deliverable ROPP\* version 4

*\*Radio Occultation Processing Package*

GPS sensors added to the NAVDAS-AR system

COSMIC FM1-6; GRAS MetOp-A; GRACE-A

## Experiment:

**Base** -- 39 IASI, 34 AIRS, AMSU-A ch3-10, SSMIS ch2-7

**GPS** -- add bending angle (BA) assimilation

**GPS+** -- add BA and AMSU-A ch11-12, SSMIS ch23-24

## Questions:

How is GPS data performing?

How does it effect IASI, AIRS, AMSU-A and SSMIS radiance RMS?

How does it effect forecast of Jan20-24, 2009 Stratospheric Warming?

How does it effect forecast scores?



# Jan20-24, 2009 SSW



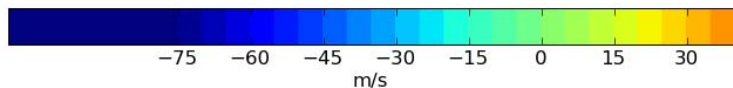
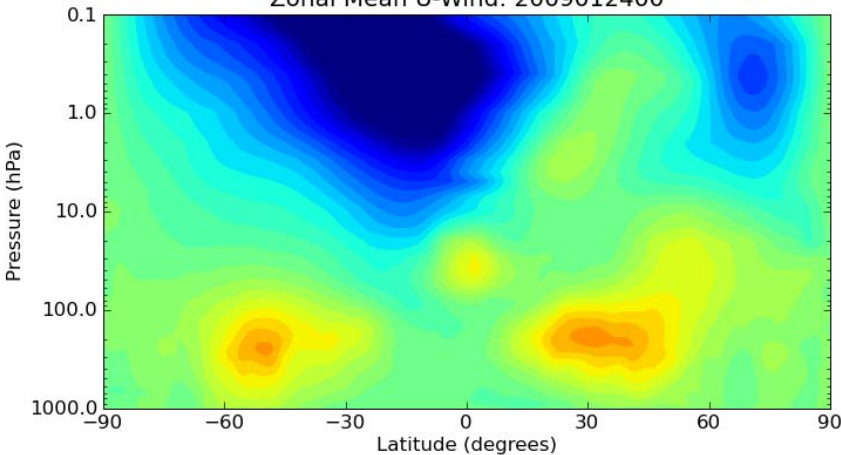
## At that time:

The operational model was t239I30 NOGAPS and 3D-Var NAVDAS

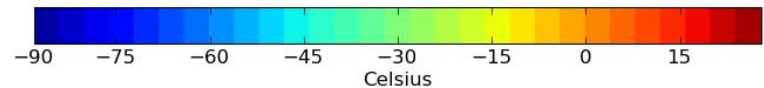
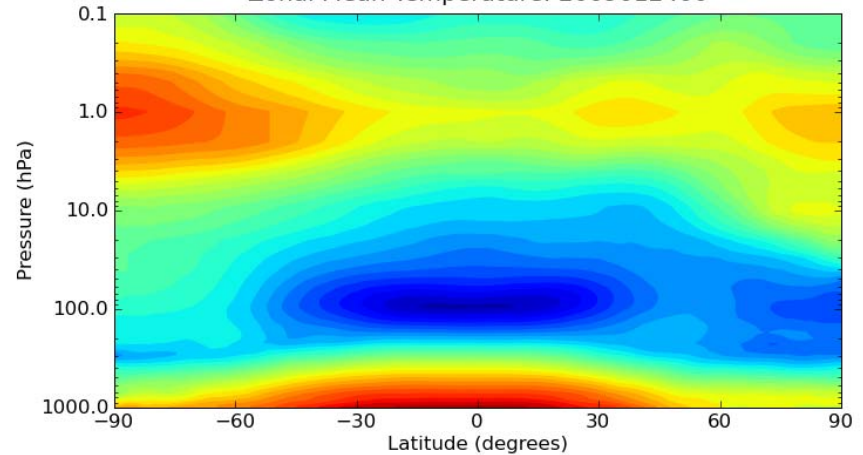
**The Apr 2010 operational version is t239I42 NOGAPS and 4D-Var NAVDAS-AR which can capture this event better – however, the Polar jet core winds are spread too broadly and the dissipation after the warming event is too weak**

## Event as analyzed by GPS+ configuration

Zonal Mean U-Wind: 2009012400



Zonal Mean Temperature: 2009012400





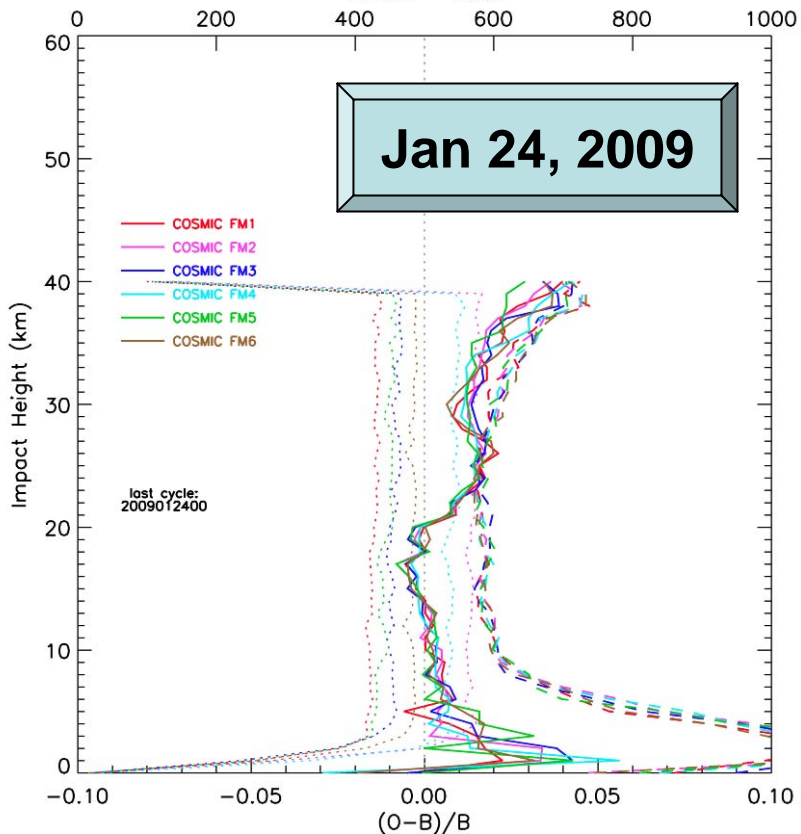
# GPS Bending Angle Monitoring



**Bending Angle innovation normalized by the background bending angle**  
\*statistics from a single update cycle

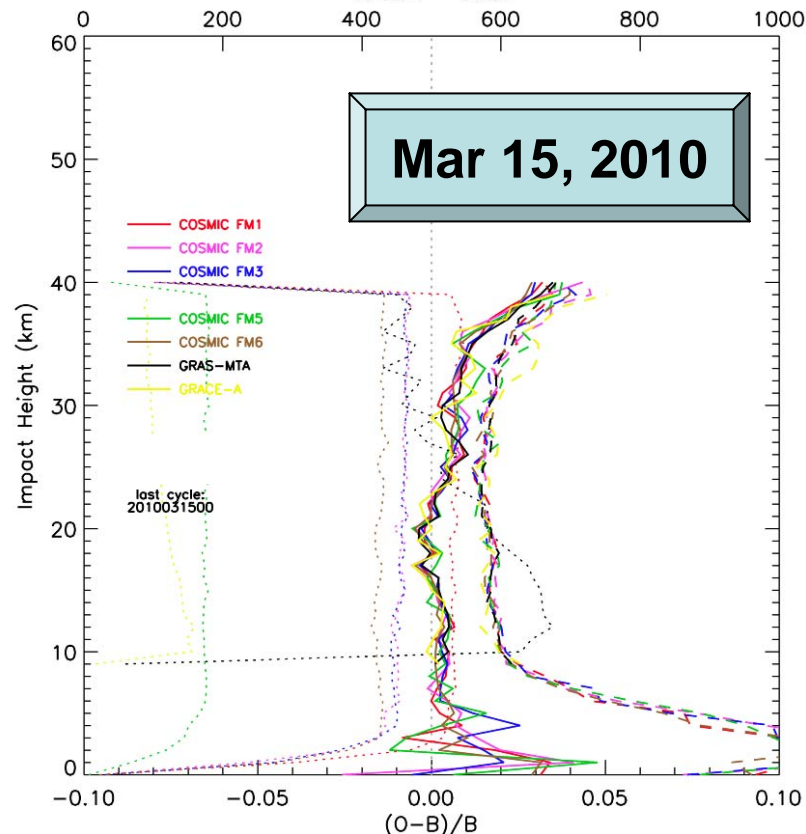
Global BA Innovation Statistics

Mean  $(O-B)/B$  -- Solid  
STDV  $(O-B)/B$  -- Dashed  
Ob Count -- Dotted



Global BA Innovation Statistics

Mean  $(O-B)/B$  -- Solid  
STDV  $(O-B)/B$  -- Dashed  
Ob Count -- Dotted







# GPS Bending Angle Monitoring

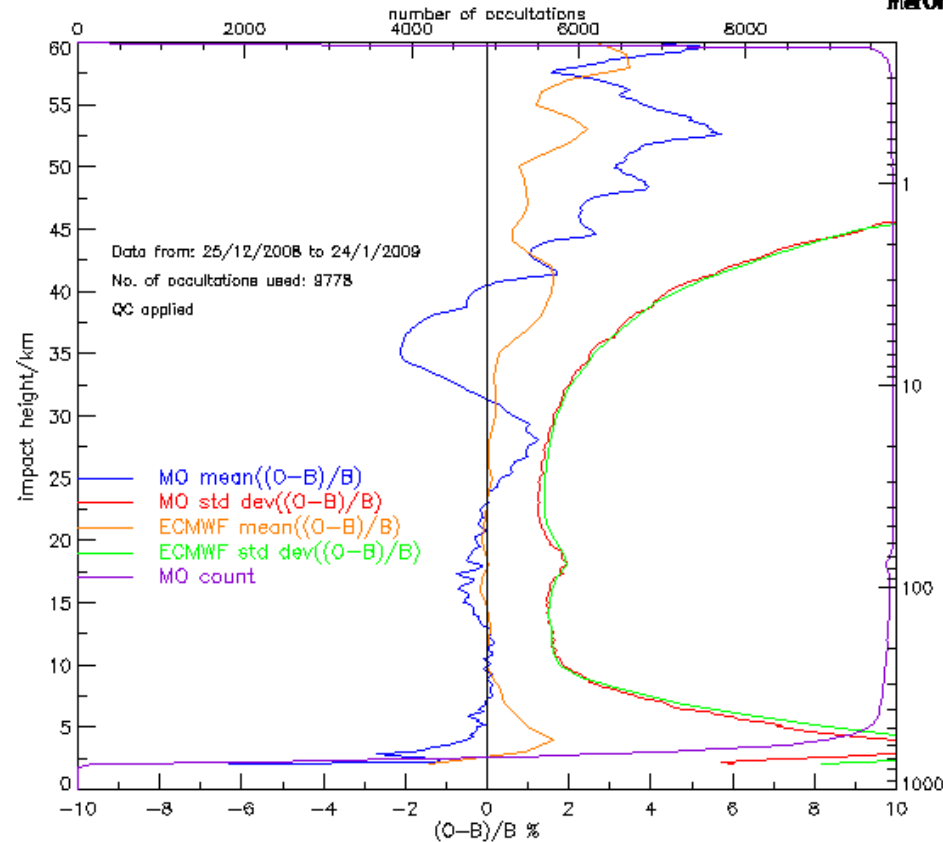


## Bending Angle innovation normalized by the background bending angle

statistics averaged  
over one month

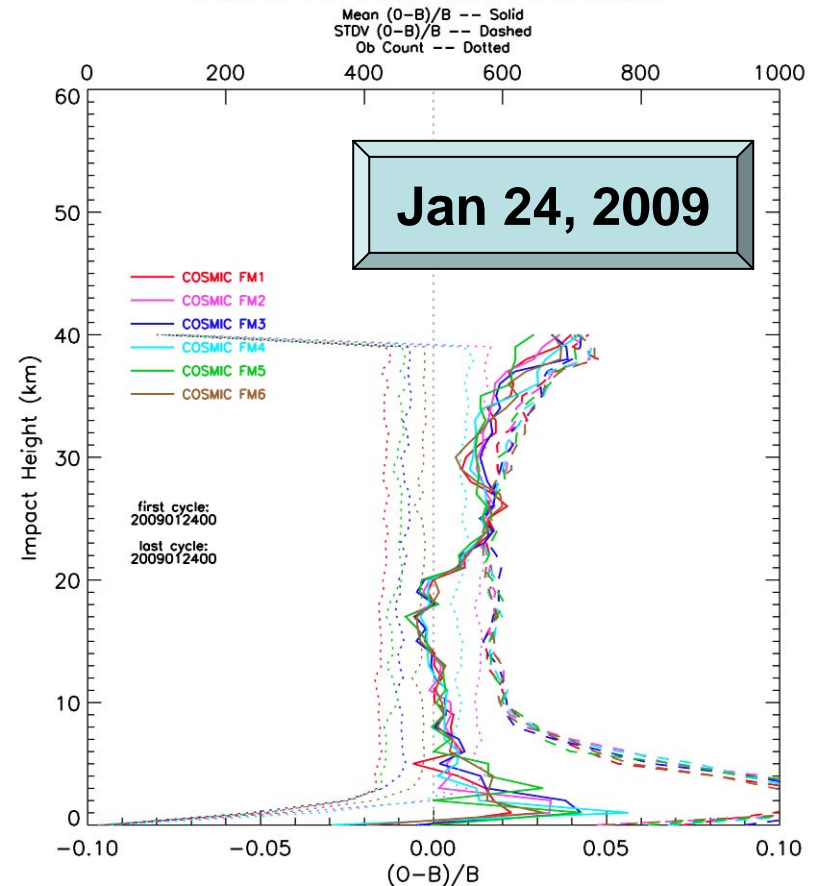
UCAR processed Cosmic1 data, global

Bending angle bias and standard deviation plots



Plotted at: 13:51 24-Jan-2009

statistics averaged  
over one update cycle  
Global BA Innovation Statistics





# GPS Bending Angle Monitoring

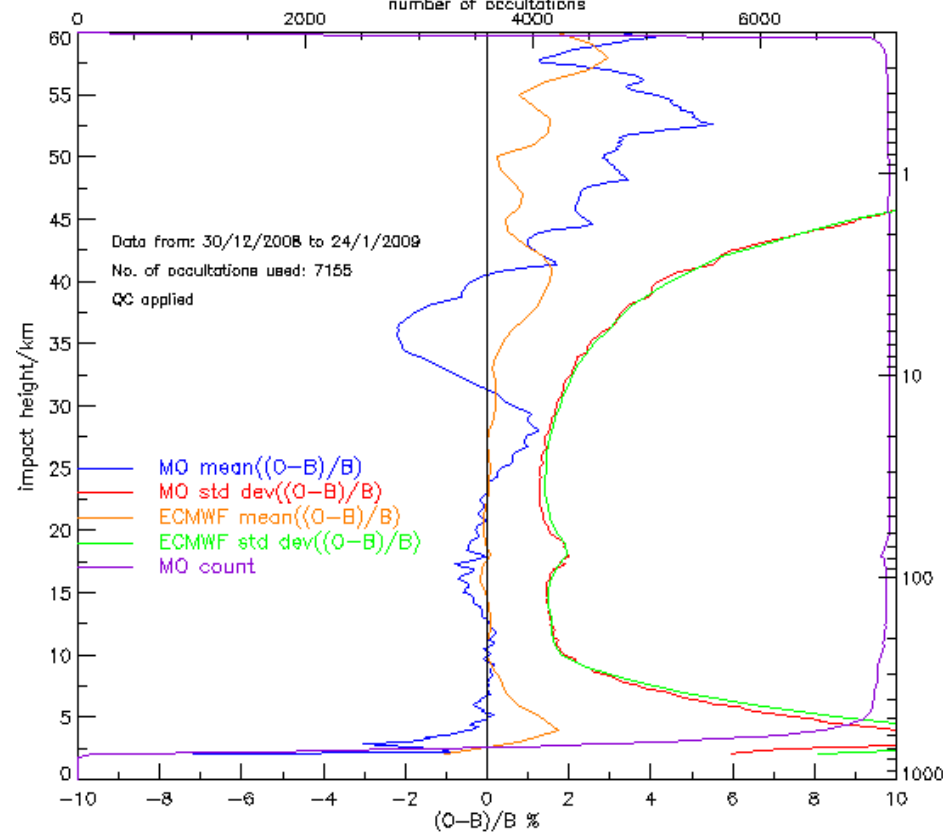


## Bending Angle innovation normalized by the background bending angle

statistics averaged  
over one month

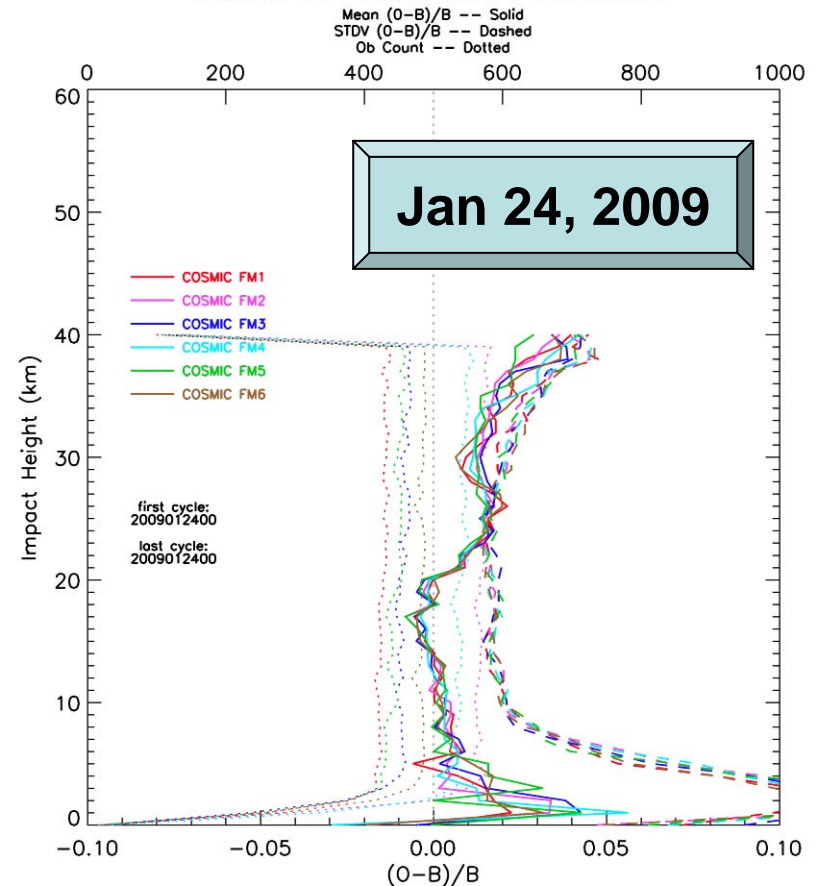
UCAR processed Cosmic3 data, global

Bending angle bias and standard deviation plots



Plotted at: 14:26 24-Jan-2009

statistics averaged  
over one update cycle  
Global BA Innovation Statistics





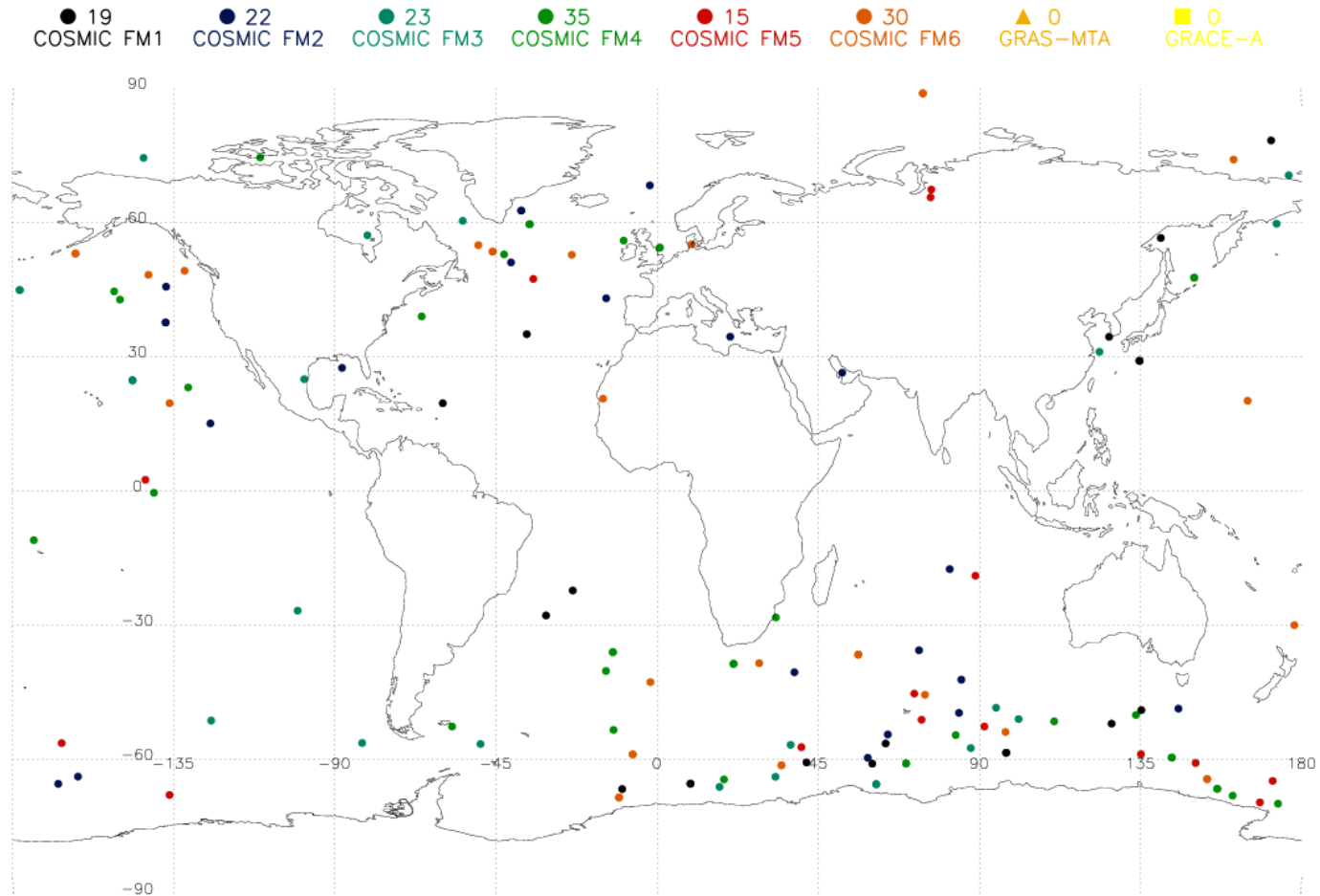
# GPS Bending Angle Monitoring

*observation vertical distribution*



## Location of assimilated occultations for Jan 24, 2009 (gif animation)

1km observation density





# IASI Innovation Monitoring

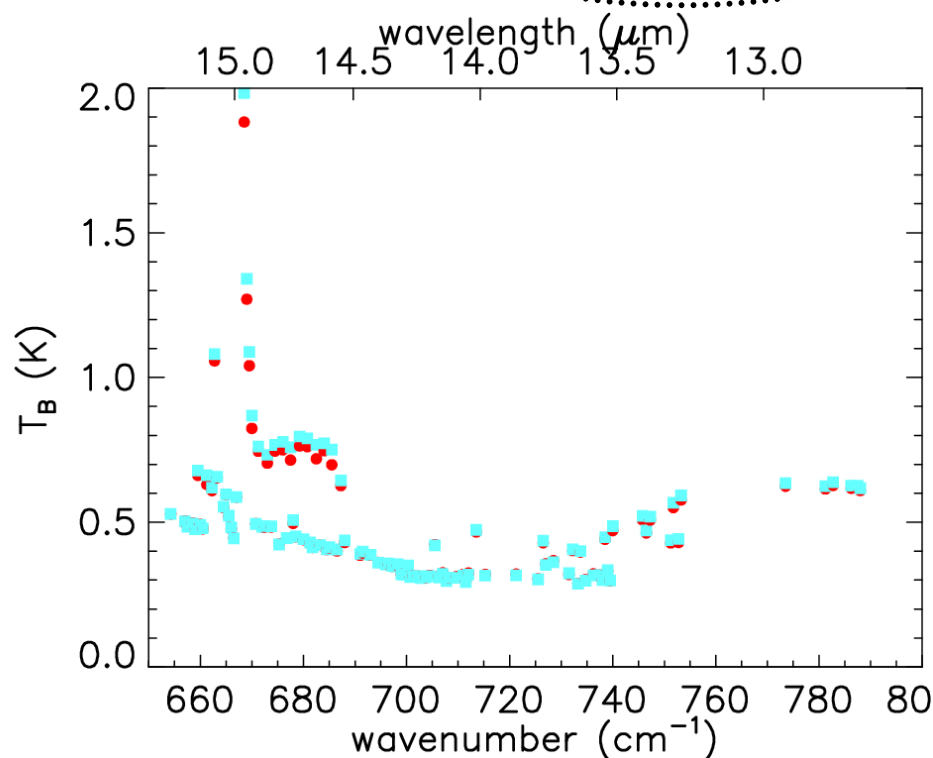
*BASE and GPS configurations*



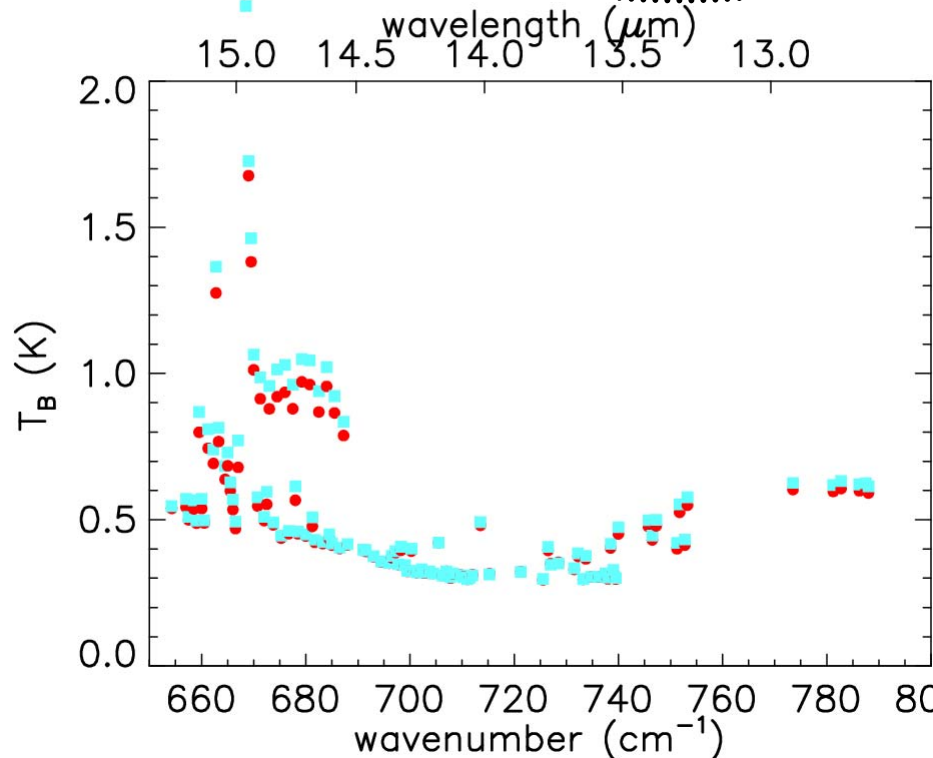
**STDV of the bias corrected (ob-bk) from IASI  
for January and September of 2009**

**BASE run in blue**  
**GPS configuration in red**

IASI STDV (Ob-Bk) dtg: 2009012400



IASI STDV (Ob-Bk) dtg: 2009091500







# IASI Innovation Monitoring

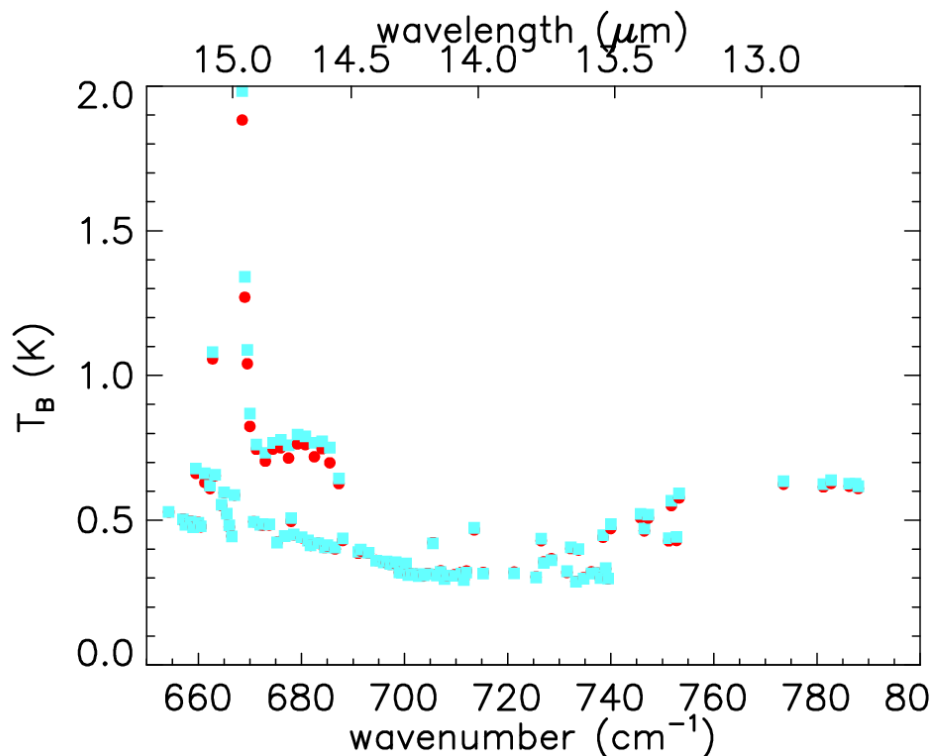
BASE, GPS and GPS+ configurations



STDV of the bias corrected (ob-bk) from IASI  
for Jan 2009, comparing GPS and GPS+ difference from BASE

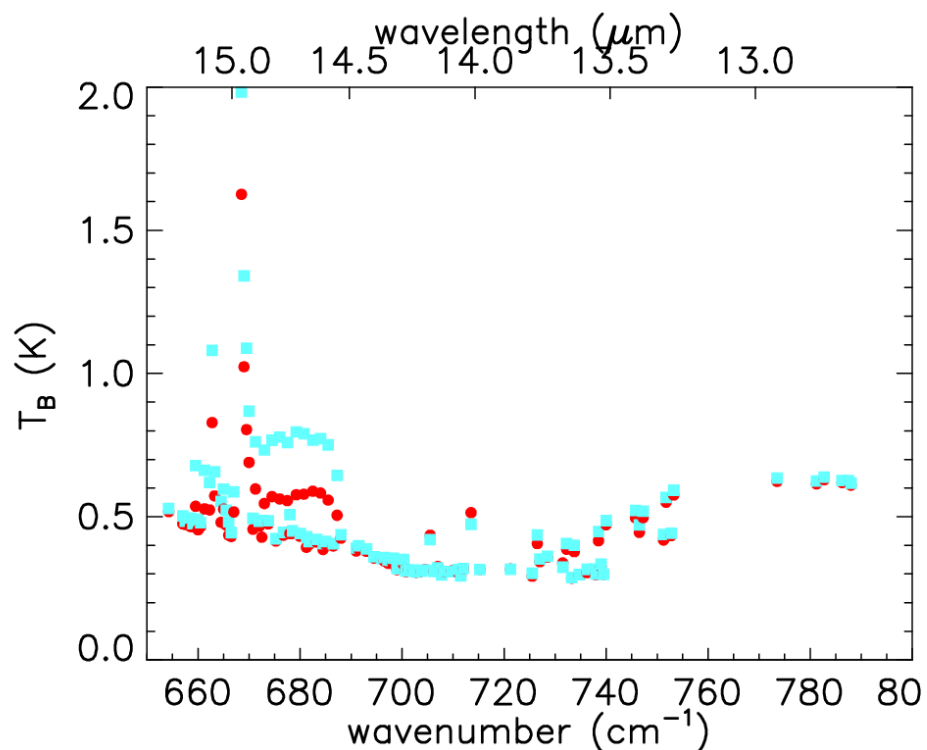
BASE run in blue  
GPS configuration in red

IASI STDV (Ob-Bk) dtg: 2009012400



BASE run in blue  
GPS+ configuration in red

IASI STDV (Ob-Bk) dtg: 2009012400





# IASI Innovation Monitoring



Difference of the STDV for the bias corrected (ob-bk) from IASI

GPS – BASE

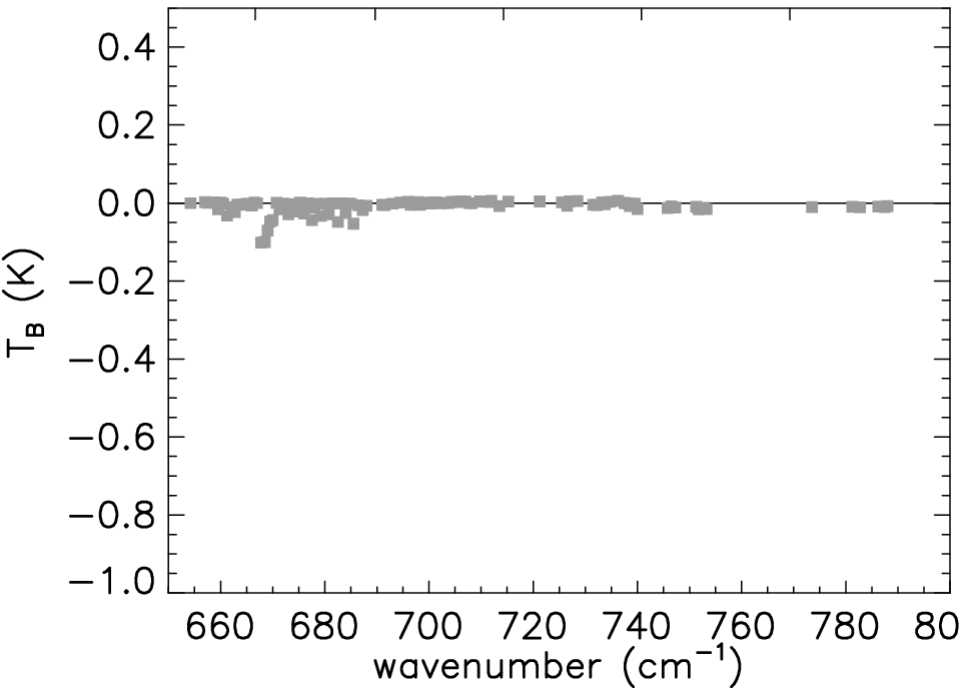
GPS+ – BASE

IASI  $GPS_{STDV(Ob-Bk)} - NOGPS_{STDV(Ob-Bk)}$

dtg: 2009012400

wavelength ( $\mu m$ )

15.0 14.5 14.0 13.5 13.0

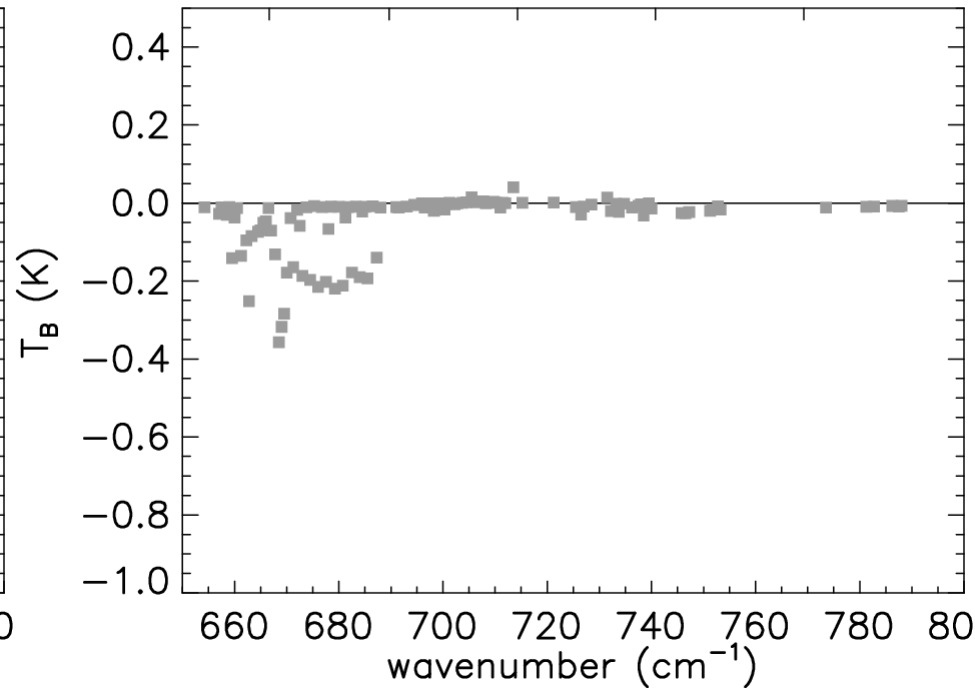


IASI  $GPS^+_{STDV(Ob-Bk)} - NOGPS_{STDV(Ob-Bk)}$

dtg: 2009012400

wavelength ( $\mu m$ )

15.0 14.5 14.0 13.5 13.0





# AMSU-A Innovation Monitoring

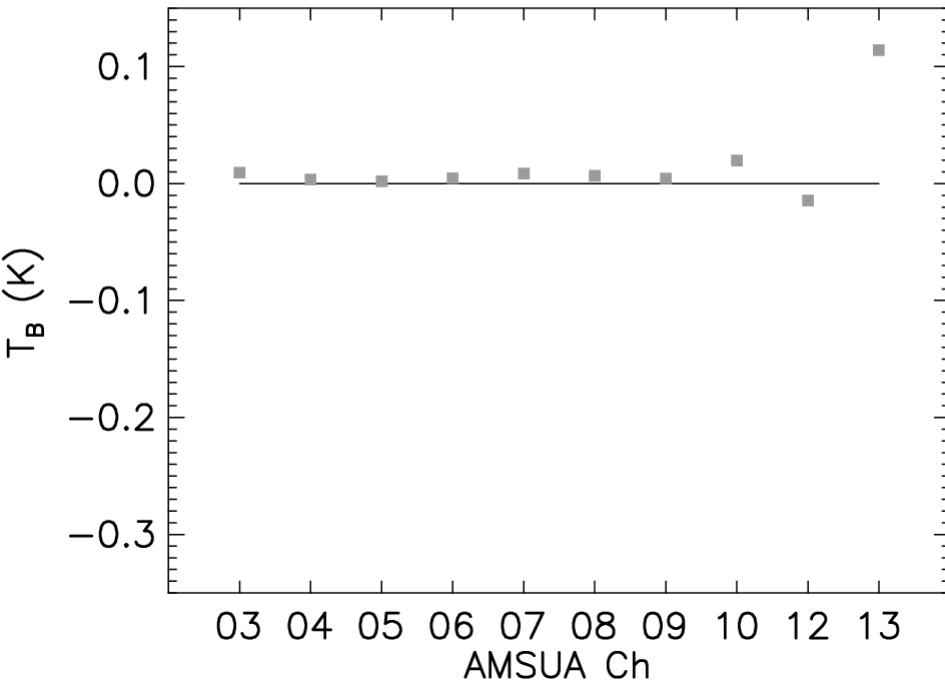


Difference of the STDV for the bias corrected (ob-bk) from AMSU-A

**GPS – BASE**

NOAA15 AMSUA

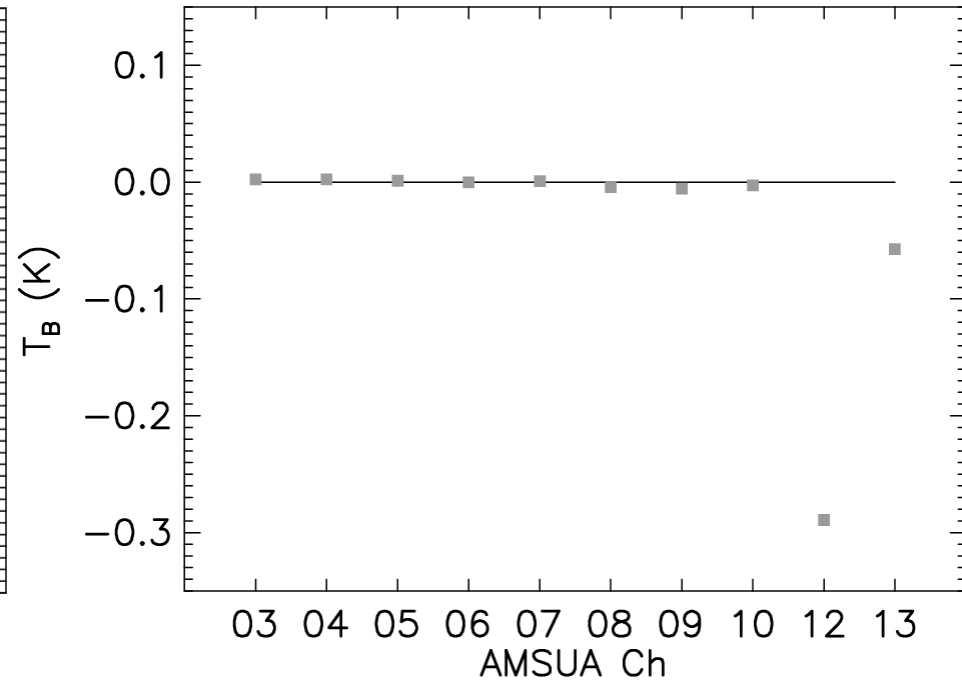
$GPS_{STDV(Ob-Bk)} - NOGPS_{STDV(Ob-Bk)}$   
dtg: 2009012400



**GPS+ – BASE**

NOAA15 AMSUA

$GPS_{STDV(Ob-Bk)} - NOGPS_{STDV(Ob-Bk)}$   
dtg: 2009012400





# AMSU-A Innovation Monitoring



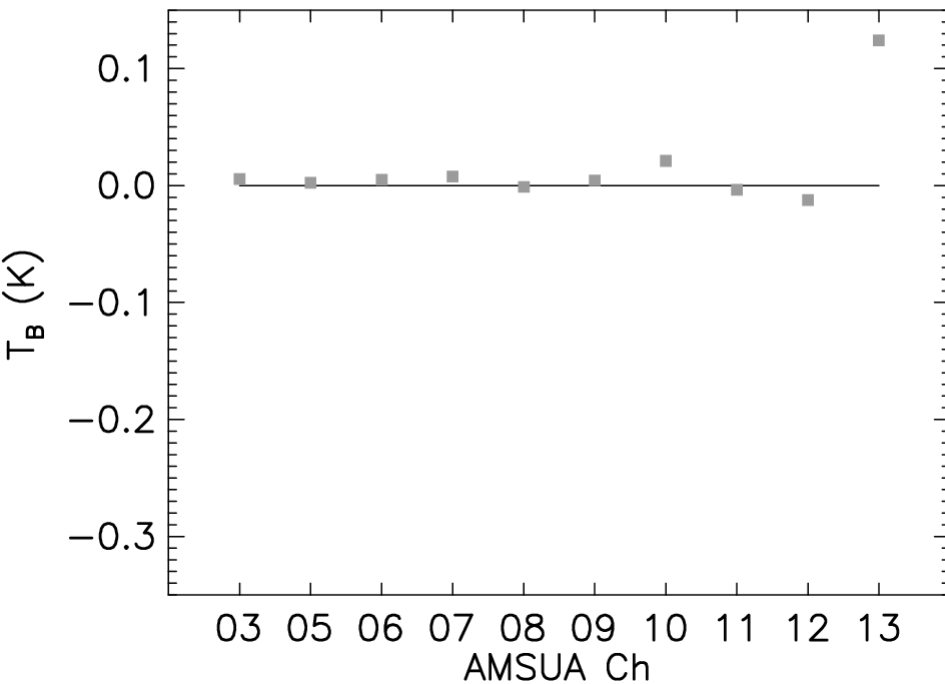
Difference of the STDV for the bias corrected (ob-bk) from AMSU-A

**GPS – BASE**

NOAA16 AMSUA

$$\text{GPS}_{\text{STDV}(\text{Ob-Bk})} - \text{NOGPS}_{\text{STDV}(\text{Ob-Bk})}$$

dtg: 2009012400

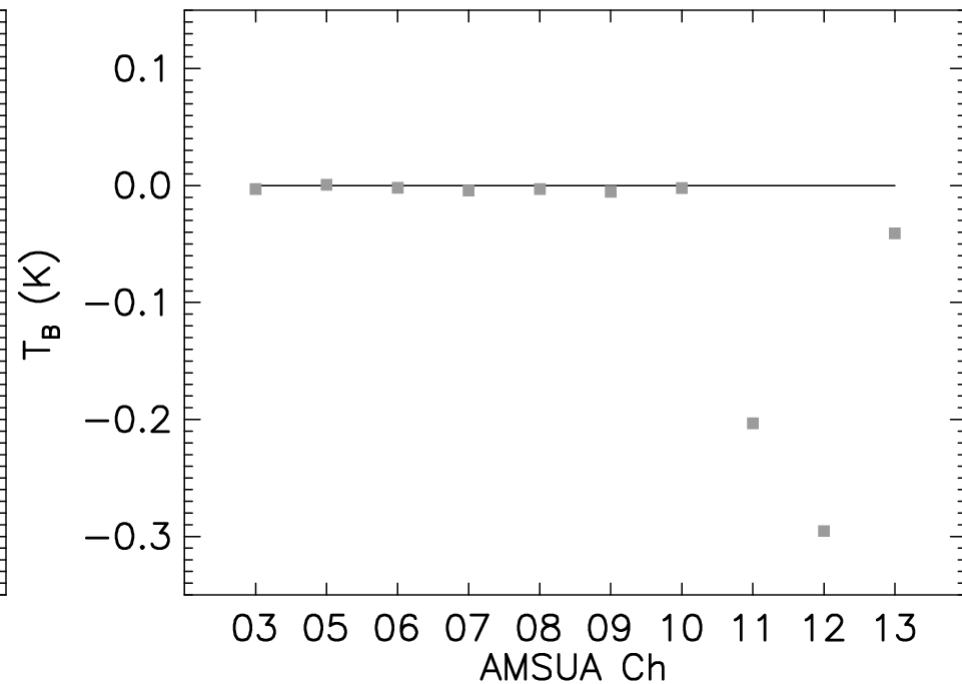


**GPS+ – BASE**

NOAA16 AMSUA

$$\text{GPS}_{\text{STDV}(\text{Ob-Bk})} - \text{NOGPS}_{\text{STDV}(\text{Ob-Bk})}$$

dtg: 2009012400







# AMSU-A Innovation Monitoring

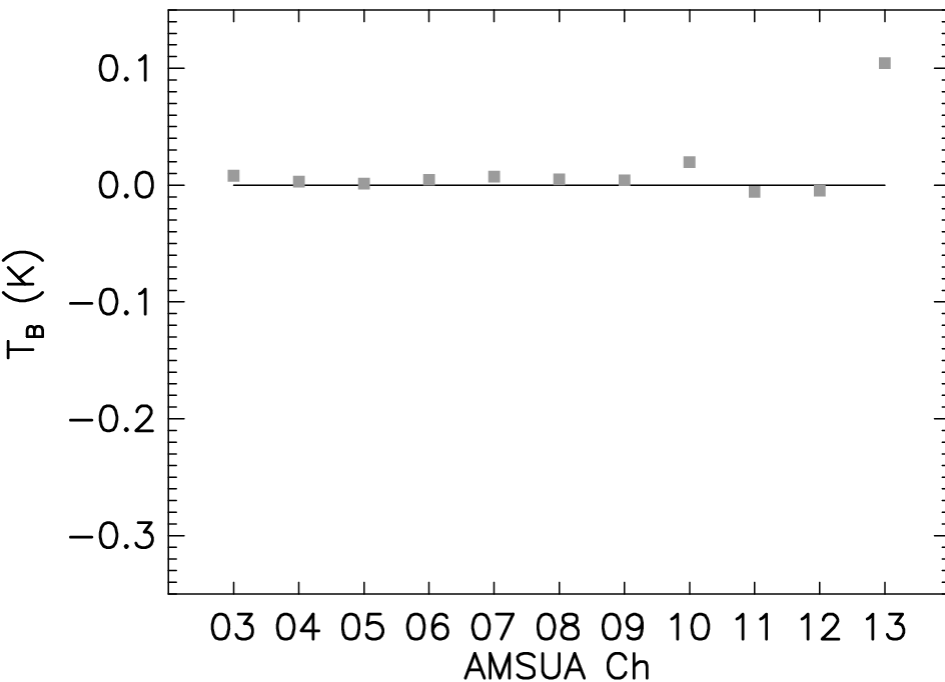


Difference of the STDV for the bias corrected (ob-bk) from AMSU-A

**GPS – BASE**

NOAA18 AMSUA

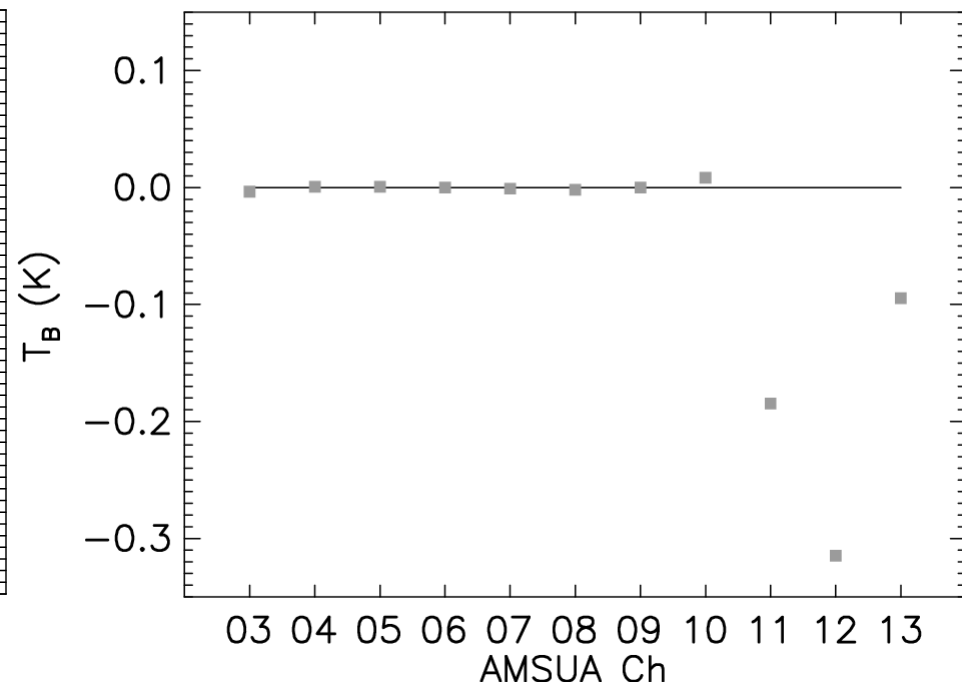
$GPS_{STDV(Ob-Bk)} - NOGPS_{STDV(Ob-Bk)}$   
dtg: 2009012400



**GPS+ – BASE**

NOAA18 AMSUA

$GPS_{STDV(Ob-Bk)} - NOGPS_{STDV(Ob-Bk)}$   
dtg: 2009012400





# AMSU-A Innovation Monitoring

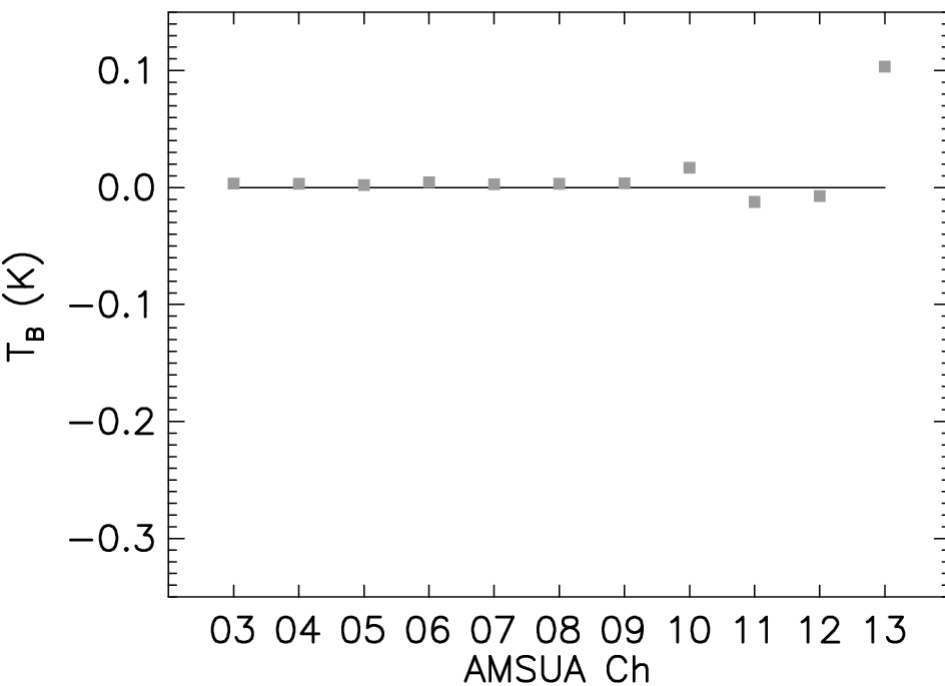


Difference of the STDV for the bias corrected (ob-bk) from AMSU-A

**GPS – BASE**

METOPA AMSUA

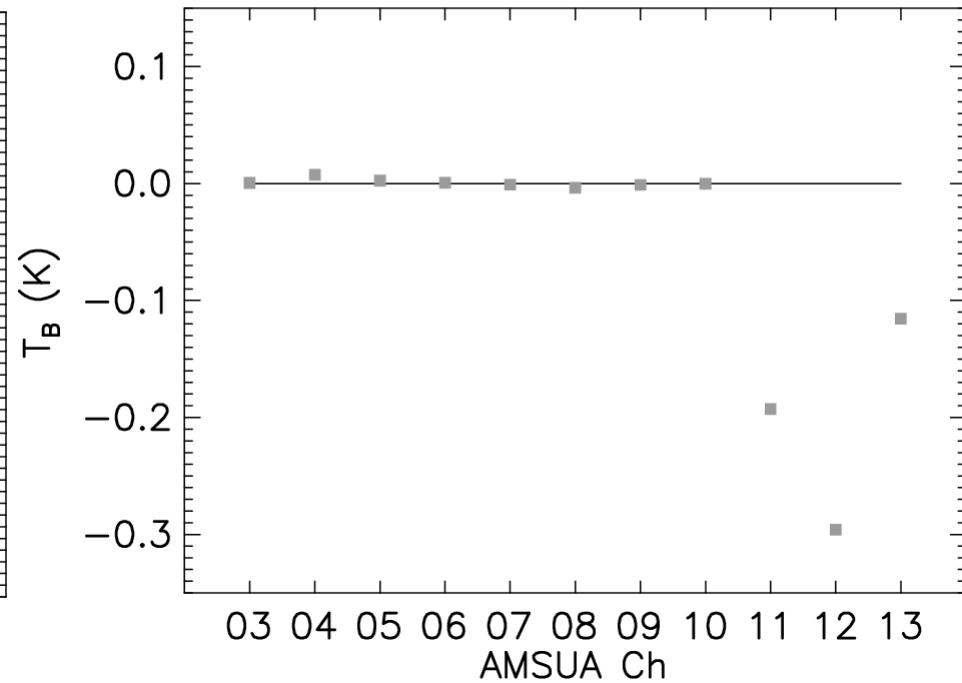
$GPS_{STDV(Ob-Bk)} - NOGPS_{STDV(Ob-Bk)}$   
dtg: 2009012400



**GPS+ – BASE**

METOPA AMSUA

$GPS_{STDV(Ob-Bk)} - NOGPS_{STDV(Ob-Bk)}$   
dtg: 2009012400





# SSMIS Innovation Monitoring



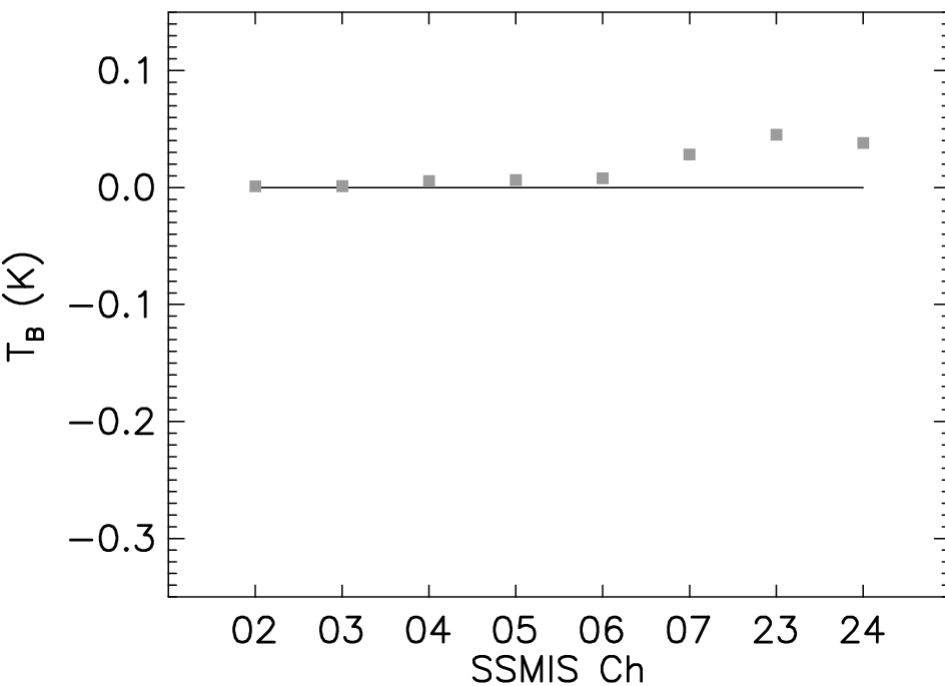
## Difference of the STDV for the bias corrected (ob-bk) from SSMIS

**GPS – BASE**

DMSPF16 SSMIS

$$\text{GPS}_{\text{STDV}(\text{Ob-Bk})} - \text{NOGPS}_{\text{STDV}(\text{Ob-Bk})}$$

dtg: 2009012400

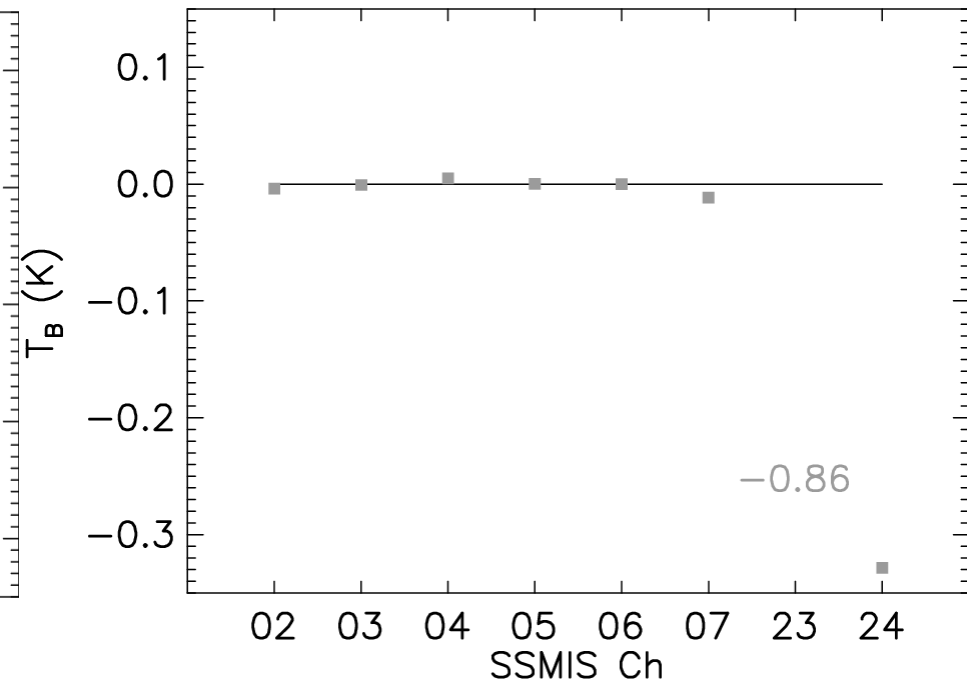


**GPS+ – BASE**

DMSPF16 SSMIS

$$\text{GPS}_{\text{STDV}(\text{Ob-Bk})} - \text{NOGPS}_{\text{STDV}(\text{Ob-Bk})}$$

dtg: 2009012400





# GPS Effect on SSW

Analyses from Jan24 00UTC



The current BASE system captures the reversal of the Polar Winds but the core of the Polar jet remains slightly too broad

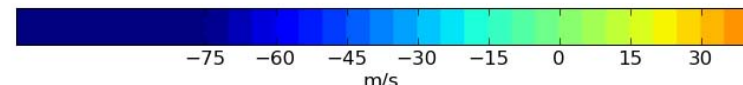
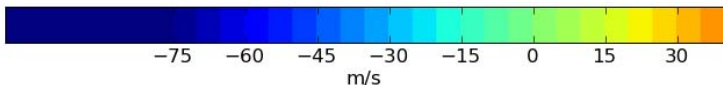
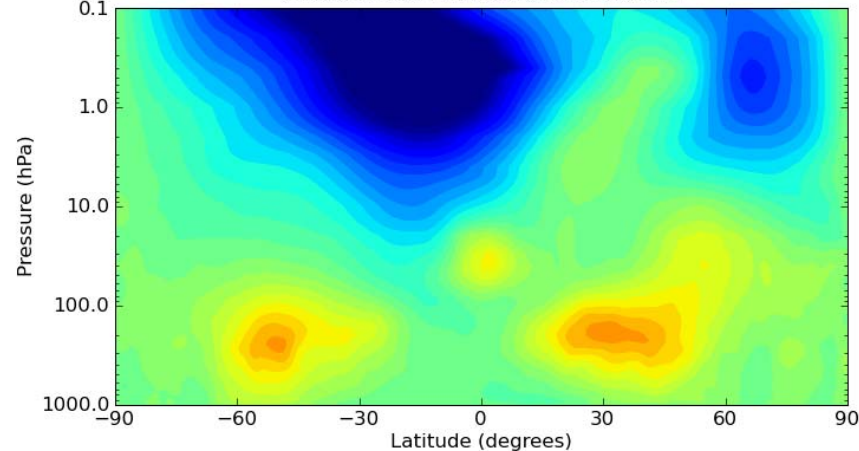
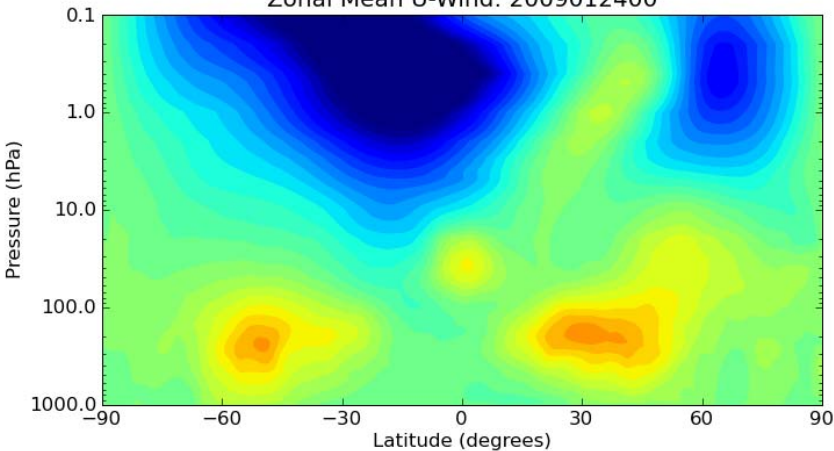
GPS assimilation begins to better resolve this feature

**BASE**

**GPS**

Zonal Mean U-Wind: 2009012400

Zonal Mean U-Wind: 2009012400







# GPS Effect on SSW

Analyses from Jan24 00UTC



The GPS+ configuration allows addition of:  
AMSU-A ch11 & ch12, and SSMIS ch23 & 24

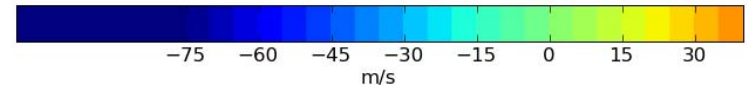
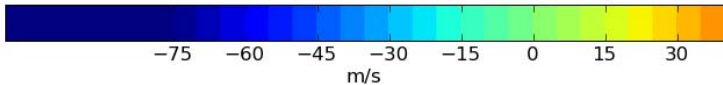
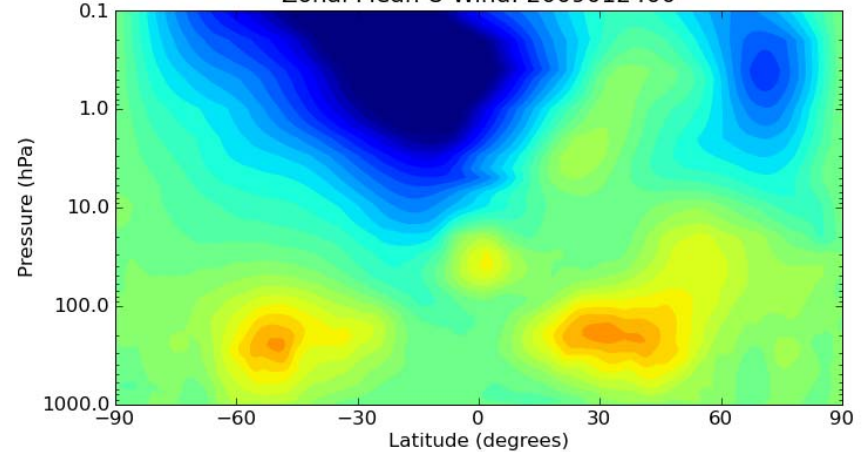
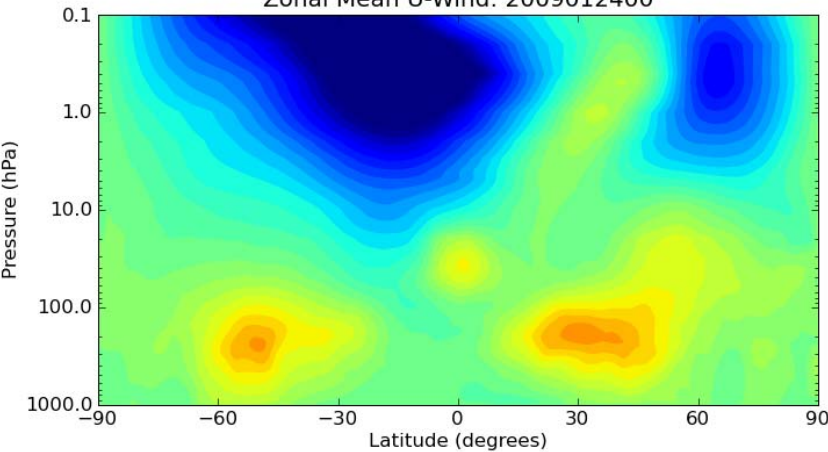
These channels along with GPS data give the  
best resolution of the Polar jet core

**BASE**

**GPS+**

Zonal Mean U-Wind: 2009012400

Zonal Mean U-Wind: 2009012400





# GPS Effect on SSW

Analyses from Jan24 00UTC



The peak of the Sudden Stratospheric Warming occurs when the Polar vortex has broken down on Jan 22; while by Jan 24 the warming should be rapidly dissipating

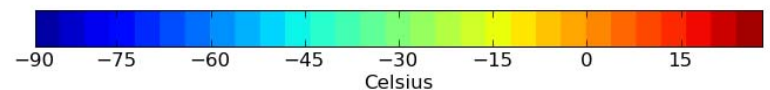
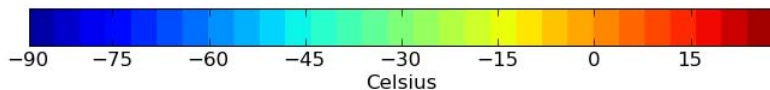
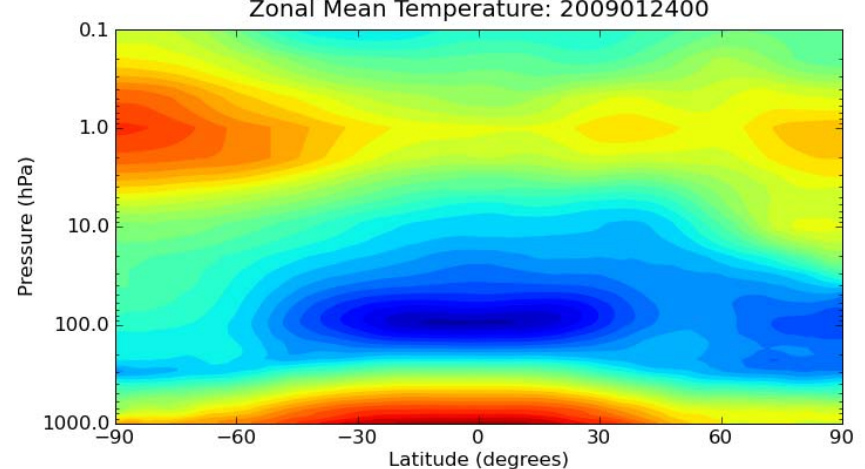
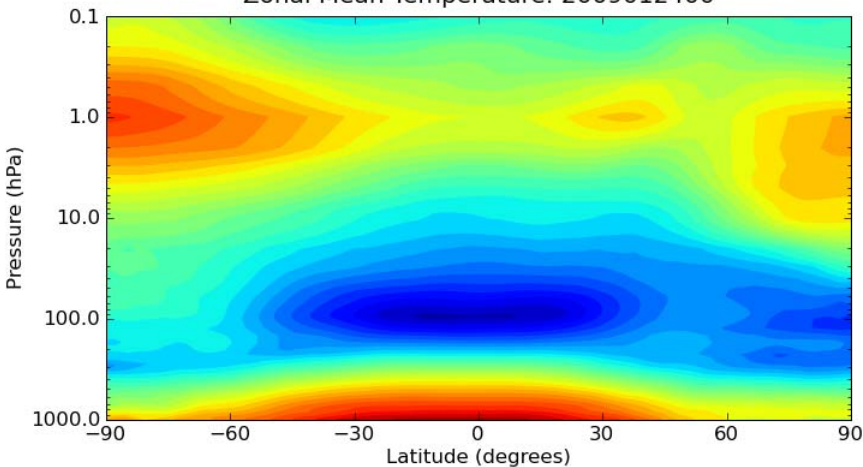
The GPS+ configuration does the most accurate job capturing both the warming and the following dissipation

BASE

GPS+

Zonal Mean Temperature: 2009012400

Zonal Mean Temperature: 2009012400





# Vicarious Validation

Analyses from Jan24 00UTC

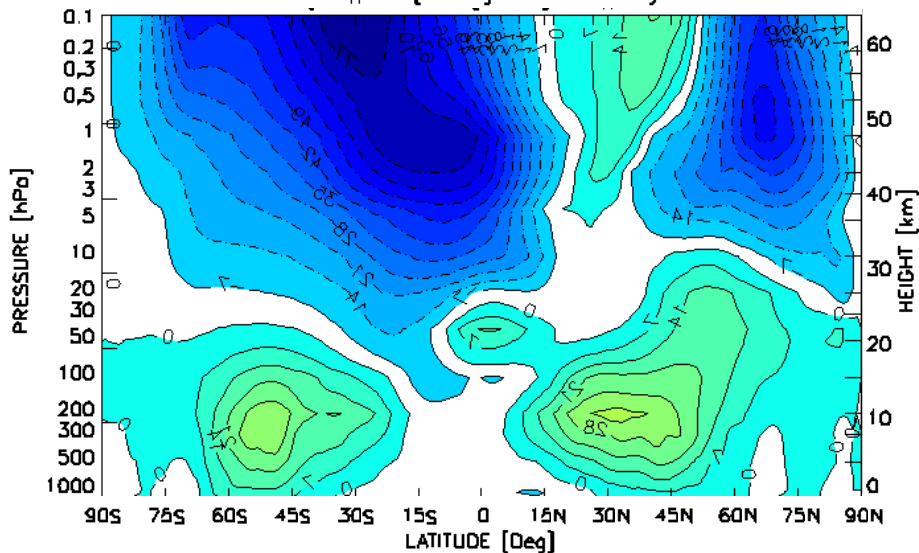


The GPS+ configuration compares well with the analysis of the UK Met Office on the strength and location of the Polar jet core in the NH

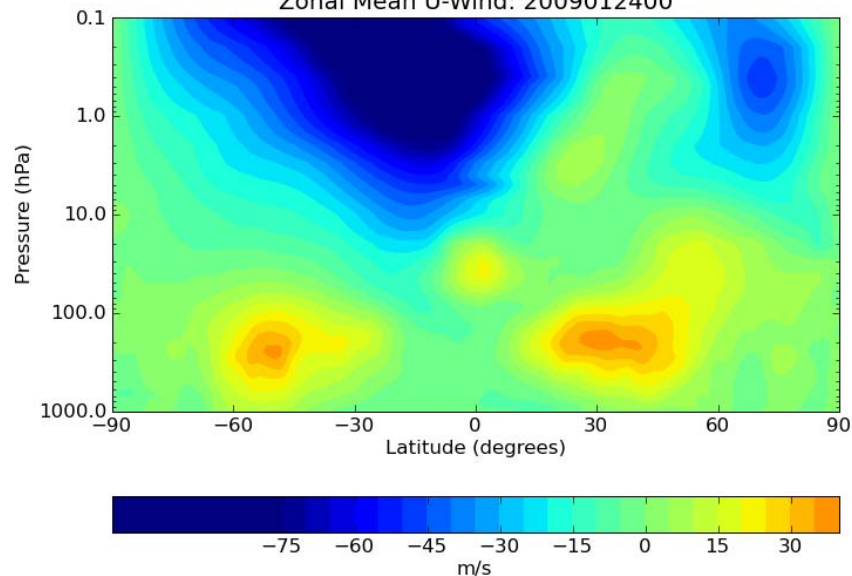
Met Office

GPS+

Zonal Wind [ $\text{ms}^{-1}$ ] 0Hr Analysis



Zonal Mean U-Wind: 2009012400



NOGAPS 2009-01-24-00Z MetOffice Max:38, Min:-86, Ave:-9







# Vicarious Validation

Analyses from Jan24 00UTC

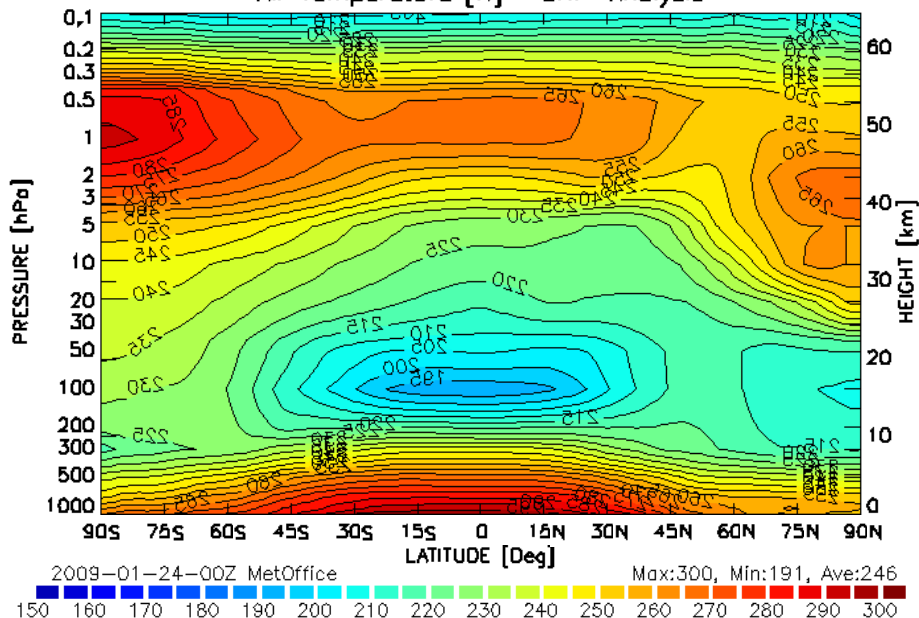


The GPS+ configuration compares well with the analysis of the UK Met Office on the dissipation of the stratospheric warming in the NH

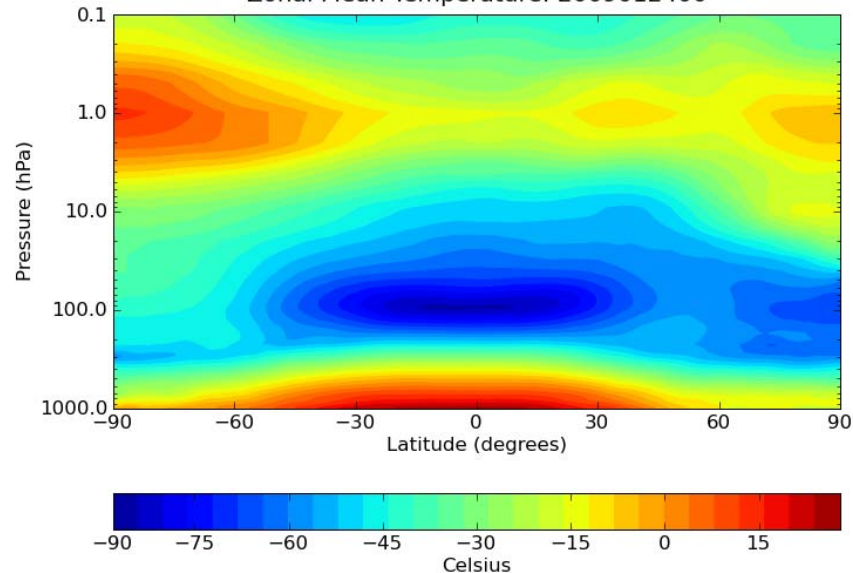
Met Office

GPS+

Air Temperature [K] 0Hr Analysis



Zonal Mean Temperature: 2009012400







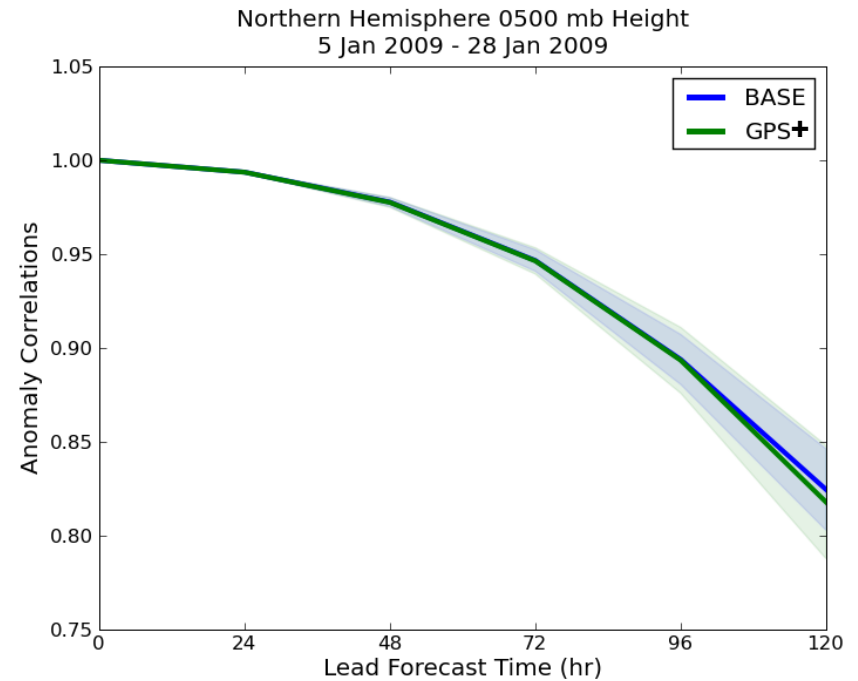
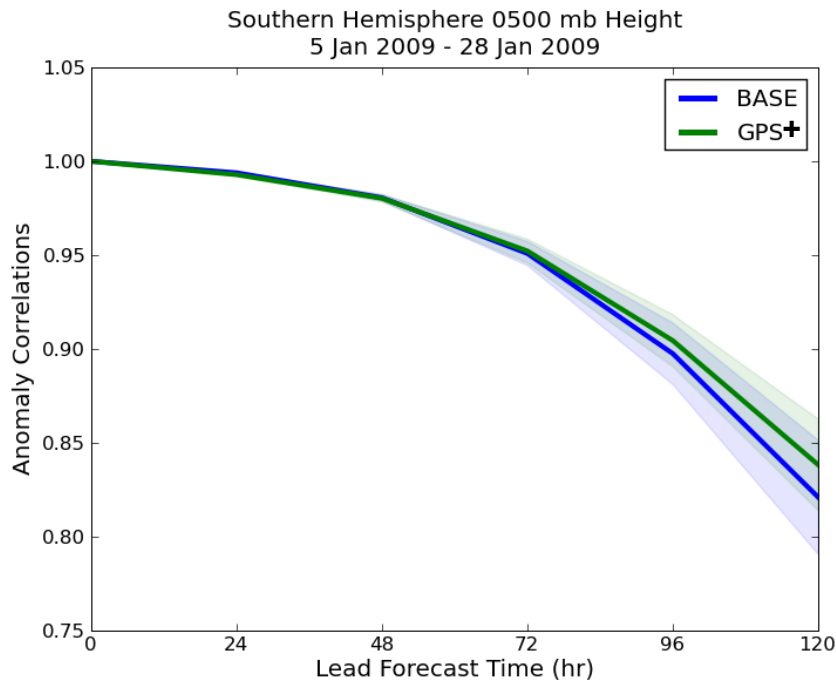
# Forecast Sensitivities

## 500hPa Anomaly Correlation



The GPS+ configuration is showing positive impact in the SH and negative in the NH; however, these are not yet statistically significant

These trials are still maturing, 3 test of 2-months each at a minimum will be required for a more robust result





# Forecast Sensitivities

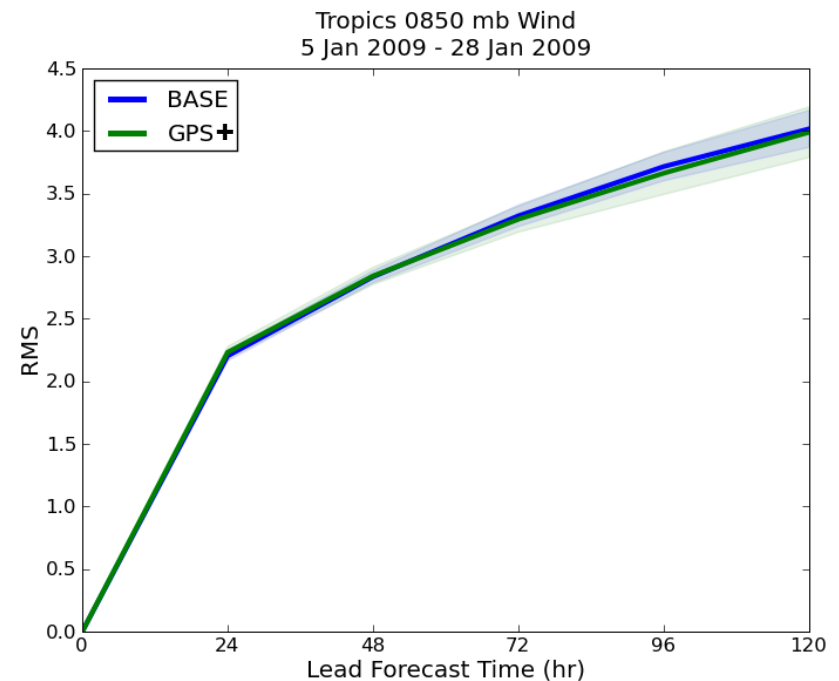
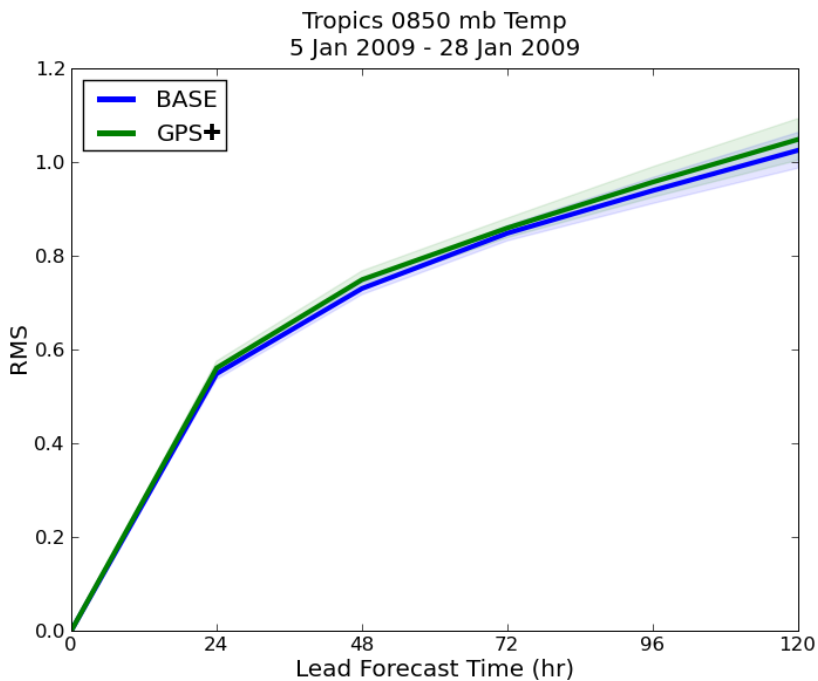
## 850hPa Vector Temperature and Wind



**The GPS+ configuration is showing neutral impact in the tropical wind verification**

**A dramatic impact is not expected, but a negative impact would greatly hinder efforts to include GPS assimilation in operations**

**Similarly, a longer time period is required for a full assessment**





# Conclusions



## **Is GPS BA working?**

Yes, the monitoring statistics show innovations consistent with ECMWF and the MetOffice, with slightly higher innovations approaching the models upper boundary

## **Can the impact be seen on IR and MW radiances?**

For the current selection of radiances used it has a small impact. However, by better constraining the model at it's upper boundary it allows the addition of MW channels; this in turn will allow the addition of further hyperspectral IR channels into NAVDAS-AR.

## **Does it effect the forecast of SSW?**

Certainly, with the effect growing by the ability to add MW radiances, and in the future additional IR radiances.

## **Does it effect the forecast scores?**

The results are preliminary, but promising with positive impact in 500hPa anomaly correlation and neutral impact on tropical winds.