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

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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?
**At that time:**
The operational model was t239l30 NOGAPS and 3D-Var NAVDAS

The Apr 2010 operational version is t239l42 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**
Bending Angle innovation normalized by the background bending angle
*statistics from a single update cycle

Global BA Innovation Statistics

Jan 24, 2009

Mar 15, 2010
Bending Angle innovation normalized by the background bending angle

statistics averaged over one month

UCAR processed COSMIC data, global
Bending angle bias and standard deviation plots
number of occultations

Jan 24, 2009

statistics averaged over one update cycle

Global BA Innovation Statistics

Jan 24, 2009
Bending Angle innovation normalized by the background bending angle

statistics averaged over one month
UCAR processed COSMIC data, global
Bending angle bias and standard deviation plots
number of observations

statistics averaged over one update cycle
Global BA Innovation Statistics

Data from: 30/12/2008 to 24/1/2009
No. of occultations used: 7125
QC applied

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

Plotter: ug 24-Jan-2009

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

1km observation density
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
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**

**BASE run in blue**

**GPS+ configuration in red**
Difference of the STDV for the bias corrected (ob-bk) from IASI

**GPS – BASE**

\[
\text{IASI} \quad \text{GPS}_{STDV(Ob-Bk)} - \text{NOGPS}_{STDV(Ob-Bk)} \\
\text{dtg: 2009012400} \\
\text{wavelength (\(\mu\text{m}\))}
\]

**GPS+ – BASE**

\[
\text{IASI} \quad \text{GPS}_{STDV(Ob-Bk)}^+ - \text{NOGPS}_{STDV(Ob-Bk)} \\
\text{dtg: 2009012400} \\
\text{wavelength (\(\mu\text{m}\))}
\]
Difference of the STDV for the bias corrected (ob-bk) from AMSU-A

**GPS – BASE**

NOAA15 AMSUA

\[ \text{GPS}_{\text{STDV(ob-Bk)}} - \text{NOGPS}_{\text{STDV(ob-Bk)}} \]

dtg: 2009012400

**GPS+ – BASE**

NOAA15 AMSUA

\[ \text{GPS}_{\text{STDV(ob-Bk)}} - \text{NOGPS}_{\text{STDV(ob-Bk)}} \]

dtg: 2009012400
Difference of the STDV for the bias corrected (ob-bk) from AMSU-A

**GPS – BASE**

NOAA16 AMSUA

\[
\text{GPS}_{\text{STDV(ob-Bk)}} - \text{NOGPS}_{\text{STDV(ob-Bk)}}
\]

dtg: 2009012400

**GPS+ – BASE**

NOAA16 AMSUA

\[
\text{GPS}_{\text{STDV(ob-Bk)}} - \text{NOGPS}_{\text{STDV(ob-Bk)}}
\]

dtg: 2009012400
Difference of the STDV for the bias corrected (ob-bk) from AMSU-A

**GPS – BASE**

NOAA18 AMSUA

\[ \text{GPS}_{\text{STDV(Ob–Bk)}} - \text{NOGPS}_{\text{STDV(Ob–Bk)}} \]

dtg: 2009012400

**GPS+ – BASE**

NOAA18 AMSUA

\[ \text{GPS}_{\text{STDV(Ob–Bk)}} - \text{NOGPS}_{\text{STDV(Ob–Bk)}} \]

dtg: 2009012400
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
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.
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](image1) ![GPS+](image2)
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.
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.
The GPS+ configuration compares well with the analysis of the UK Met Office on the dissipation of the stratospheric warming in the NH.
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.
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.
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.