

Adaptation of HIRLAM v7.0 for assimilation of MODIS AMVs

- The system v7.0 is prepared for assimilation of MODIS winds (K.Mogensen).
- However, some important updates have been necessary, and some enhancements have been done too.

AT SCRIPT LEVEL

Env_expdesc, has now two new environment variables used to drive the run:

AMVGEO, which should be set to “yes” for **geo-stationary AMVs** to be included

AMVPOL, which should be set to “yes” for **MODIS AMVs** to be included.

Prepob, when any of the previous variables is “yes”, creates a file named **ob\${DTG}amv holding AMV buffer messages**. The implementation as it is now, will of course **only work when retrieving data from MARS**.

ExtractOBSfromMARS, to handle the **retrieval of AMV data from MARS**.

3DVARan, to handle the blacklisting and bias correction scheme file “**modis_bl_and_bc.dat**”.

VARinput, **new options in namelists** driving the upper-air analysis.

MakeCMA, **new options in namelists** driving the generation of CMA and to handle obs statistical files.

CMAstat, minor modifications in namelists.

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BUFFER messages decoding:

- Modifications in **library bufr36** to resize JTAB parameter
- Modifications in **library bufr** for the same reason (through **DIMMS.inc**)
- Generation of binaries for tables **B0000981101.TXT** and **D0000981101.TXT**

MODIS AMV data pre-processing:

- **Handling the obs codes.** In MARS, Geo and Polar AMVs archived under (5,87) buffer codes.

GEO-AMVs CMA observation codes (3,90) <-> CMA obs sequence numbers (3,4)

MODIS-AMVs CMA observation codes (3,91) <-> CMA obs sequence numbers (3,6)

- **Extracting additional info from buffer messages... (but at the end not all of it used)**

number of actual Qis

originating centre

channel frequency (in microns)

land-sea mask (from AMV provider)

Height assignment method used

Number of alternative height assignments

Value of those alternative height assignments

Info added and accomodated in the optional header of AMV CMA record.

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MODIS AMV data transfer to/from CMA array

MODIS AMV data pre-processing:

obsproc/control/cmoctmap.F90
obsproc/control/defmkcma.F90
obsproc/control/defrun.F90
obsproc/control/sucmaho.F90
obsproc/control/sucmoctp.F90
obsproc/control/sulim.F90

obsproc/make_cma/bufrfot.F90
obsproc/make_cma/cmoctmap.F90
obsproc/make_cma/obscreen.F90
obsproc/make_cma/repset.F90
obsproc/make_cma/satamin.F90
obsproc/make_cma/satamohd.F90
obsproc/make_cma/scanbufr.F90
obsproc/make_cma/sucmaho.F90
obsproc/make_cma/sucmoctp.F90

obsproc/module/yomglp.F90
obsproc/namelist/namglp.h

obsproc/obs_error/suobserr.F90 ← assign MODIS winds observation errors to CMA observation sequence numbers (3,6).

hlcmaio/cmoctmap.F
hlcmaio/setcmform.F
hlcmaio/setcmoctp.F

modules/modiwinddata.F90
modules/satobdata.F90

obsalloc/alloc_modiswind.F
obsalloc/alloc_satob.F
obsalloc/dealloc_modiswind.F
obsalloc/dealloc_satob.F

cmatoobs/cmatomodiswind.F
cmatoobs/cmatoobsmod.F
cmatoobs/modiswindtocma.F
cmatoobs/obsmodtocma.F
cmatoobs/satobtocma.F

obssupport/print_modiswind.F
obssupport/print_satob.F

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MODIS AMV data assimilation (screening)

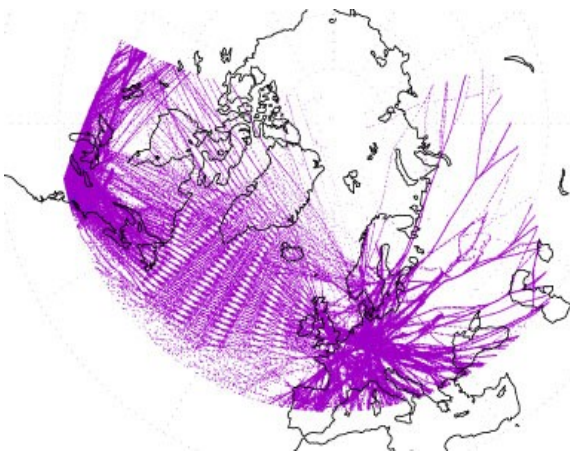
```
scrobs/scrcom_default.F  
scrobs/screen_modiswind.F  
scrobs/bl_and_bc_modis.F  
scrobs/rejectlow_modis.F  
scrobs/chkfirstguess_modis.F  
scrobs/chkwindir_modis.F  
scrobs/thinning_modis.F  
scrobs/collect_modis.F  
scrobs/distrib_modis.F
```

```
include/varpar/obsmodpar.h  
include/varcom/scrcom.h  
include/varcom/scrnam.h
```

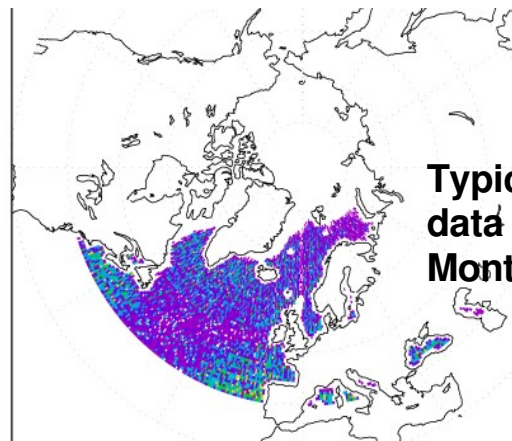
MODIS AMV data assimilation (minimization, monitoring only)

```
obop/jograd_airep.F  
obop/jograd_dribu.F  
obop/jograd_obs.F  
obop/jograd_pilot.F  
obop/jograd_satem.F  
obop/jograd_satob.F  
obop/jograd_ship.F  
obop/jograd_synop.F  
obop/jograd_synop.F  
obop/jograd_temp.F  
obop/jograd_windprof.F
```

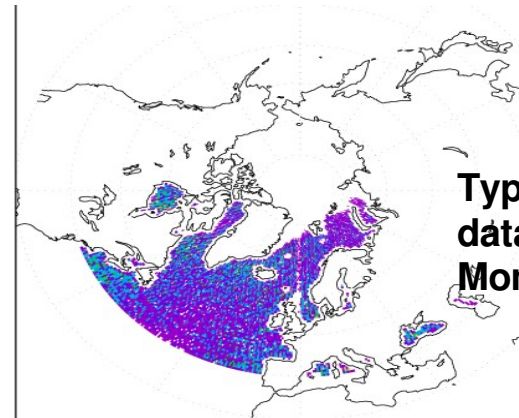
```
include/varcom/costcontrib.h
```



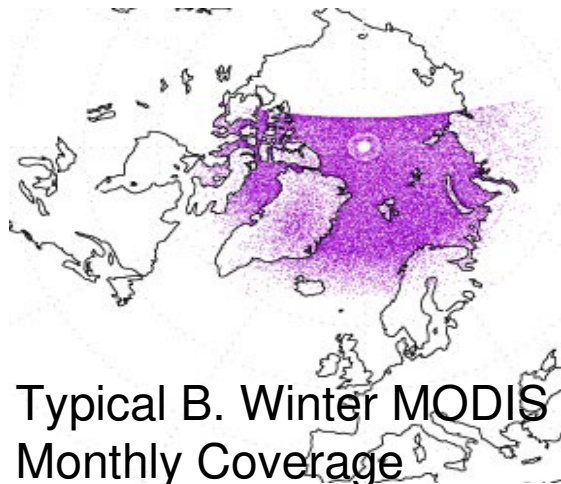
Typical AIRCRAFT wind data
Monthly Coverage



Typical B. Winter AMSU-A T(p)
data
Monthly Coverage

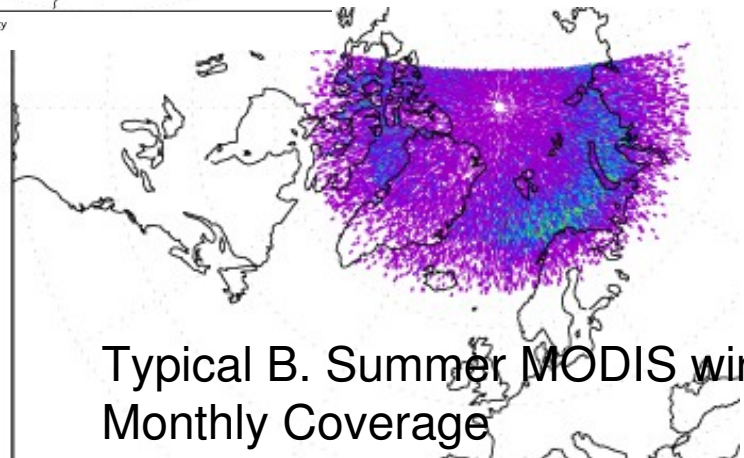


Typical B. Summer AMSU-A T(p)
data
Monthly Coverage



Typical B. Winter MODIS wind data
Monthly Coverage

July06 ATOVs (MOX) Observations Density

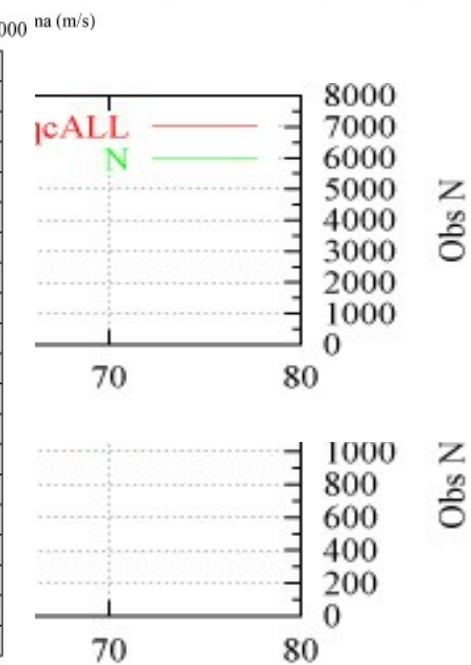
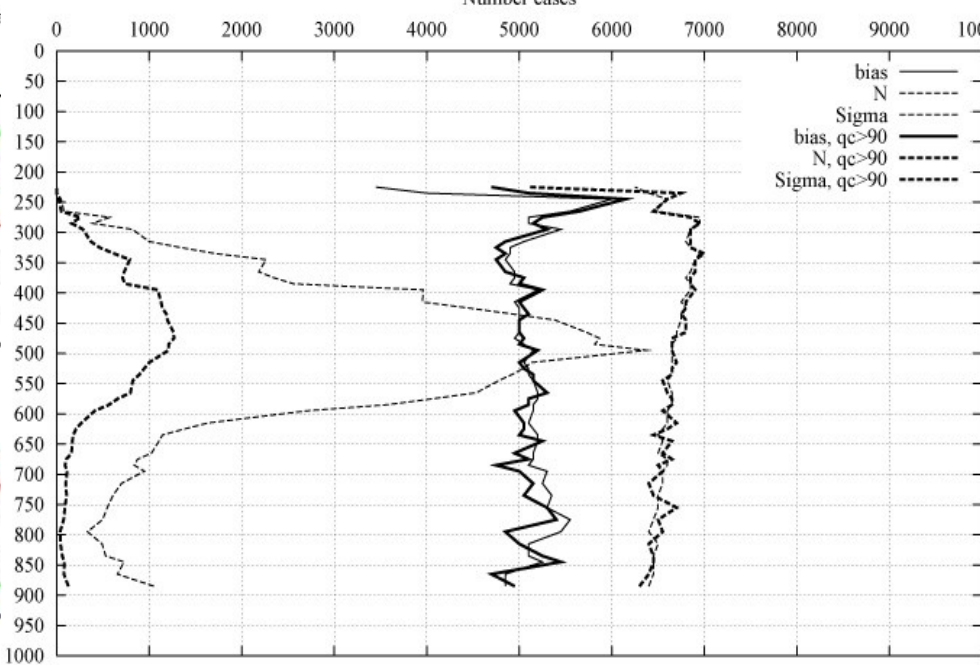
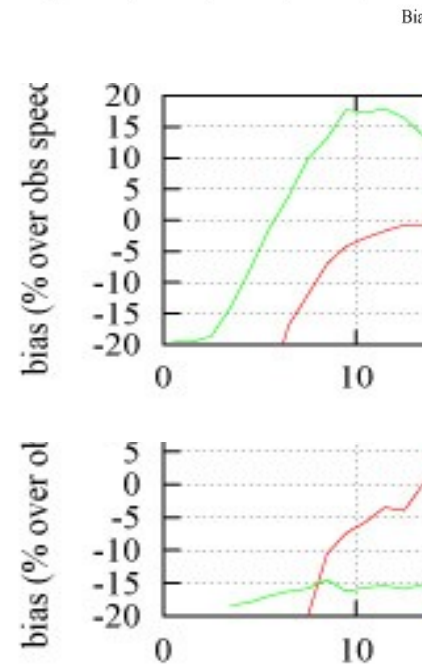
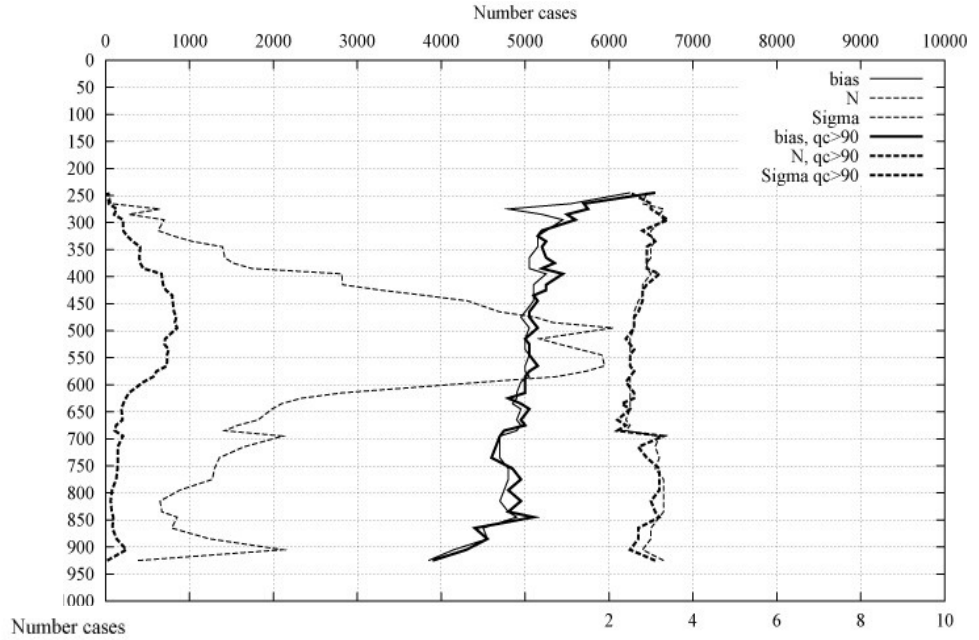
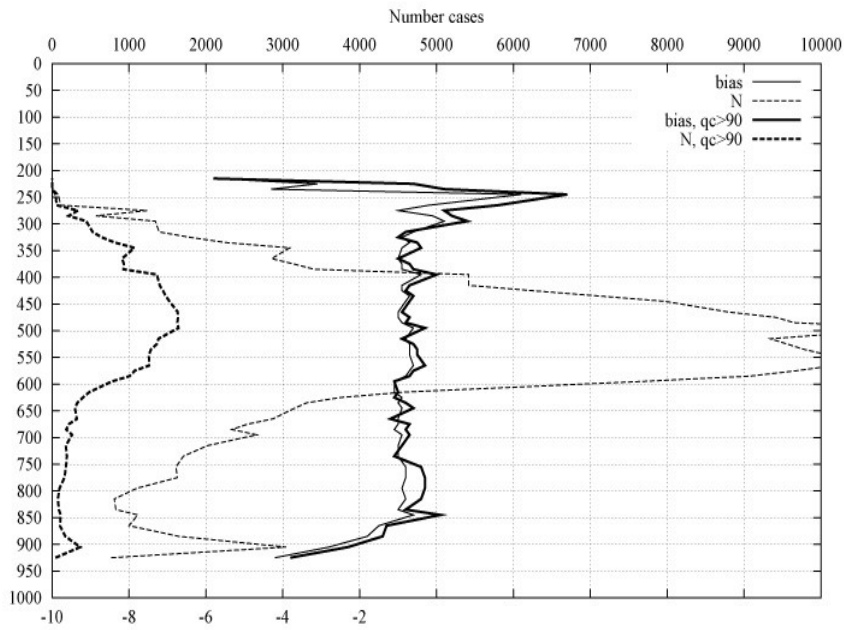


Typical B. Summer MODIS wind data
Monthly Coverage

MODIS AMVs types used in this work (status as of July 2006)

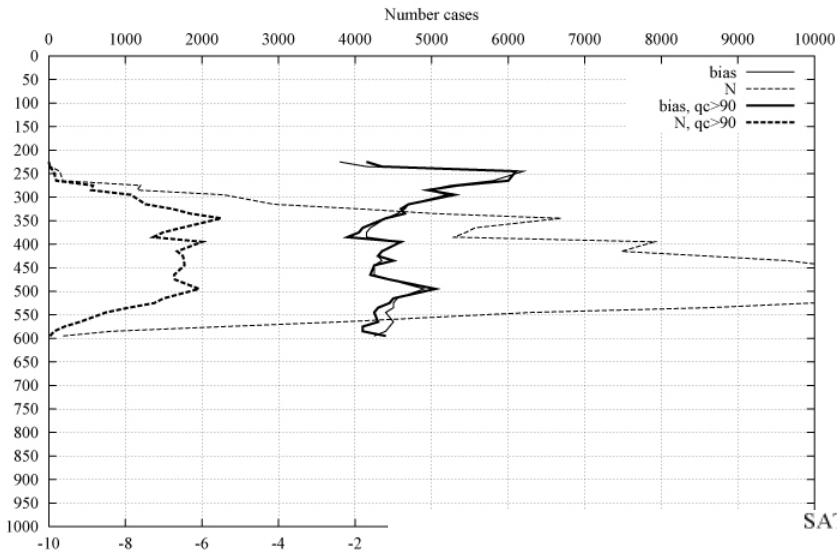
Vector type Key 15 in buffer Message	Channel frequency (in microns) Key 19 in b.m	Height assignment Method Key 22 in b.m	Description
1	10.69	1 or 3	IR winds opaque (EBBT) or semitransparent (CO ₂ slicing)
0	6.8	2 or 3	Water vapour cloudy tracers (H ₂ O intercept or CO ₂ slicing)
5	6.8	2 or 3	Clear Sky with moisture patterns as tracers. (H ₂ O intercept or CO ₂ slicing)

January 2006 vector type (1,1) from "Terra" : i.e. Infra-red EBBT

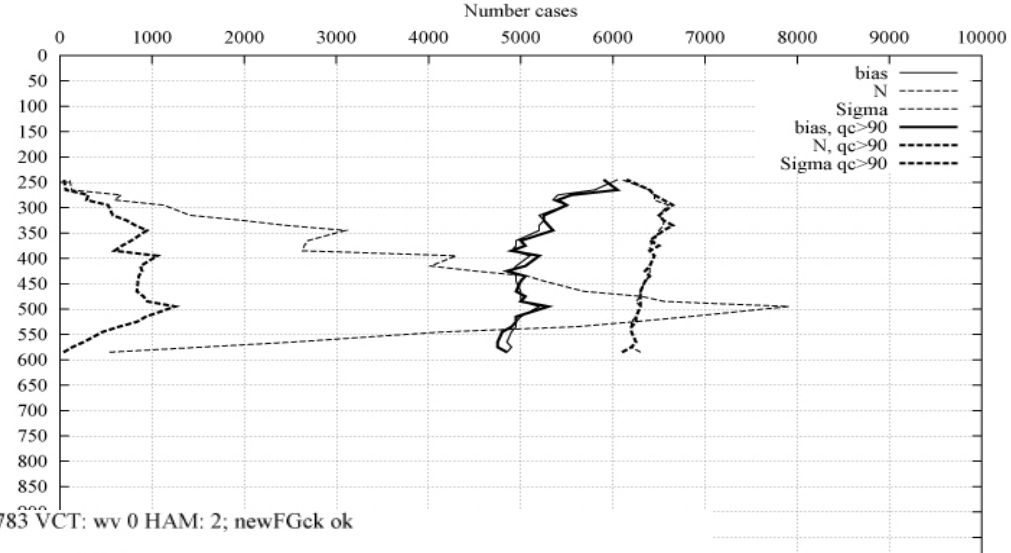


January 2006 vector type (0,2) from "Terra" : i.e. water-vapour cloudy tracers H₂O inter.

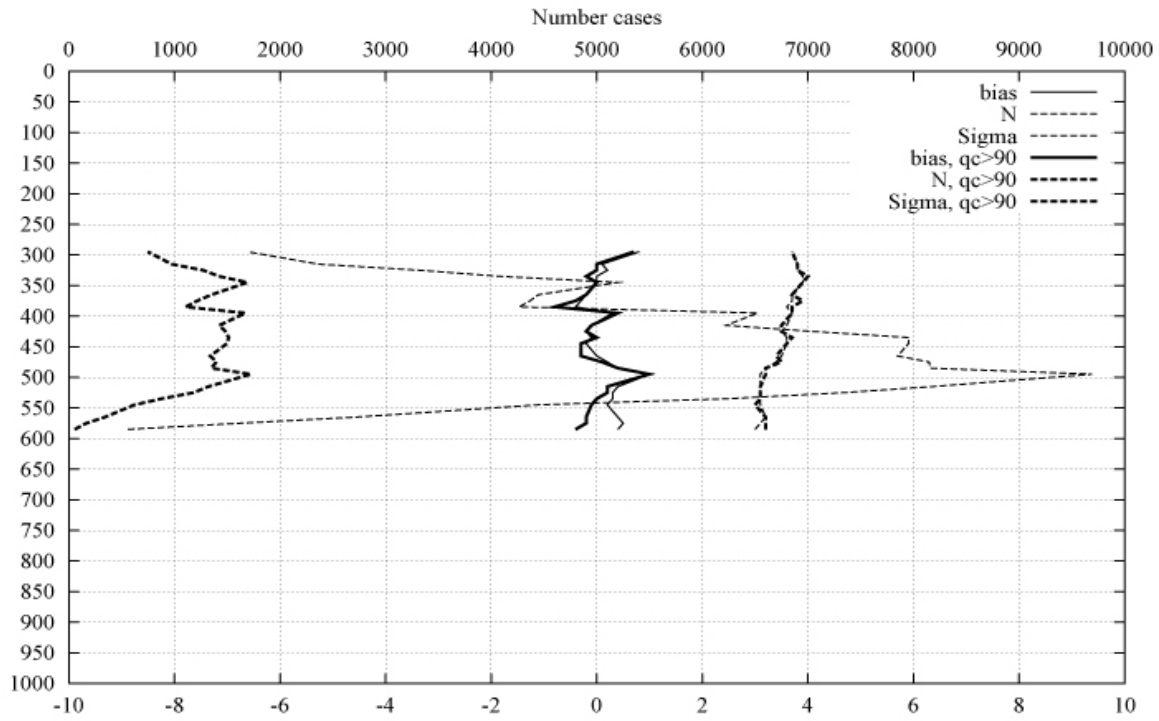
SAT: 783 VCT: wv 0 HAM: 2



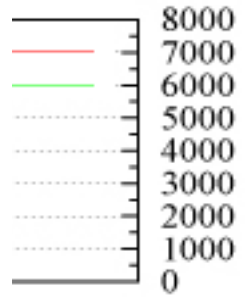
SAT: 783 VCT: wv 0 HAM: 2 oldFGck ok



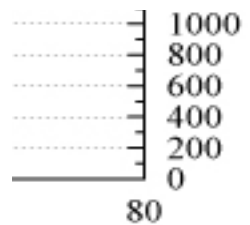
SAT: 783 VCT: wv 0 HAM: 2; newFGck ok



6 8 10

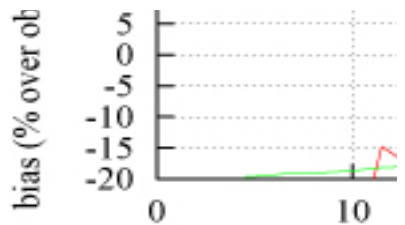
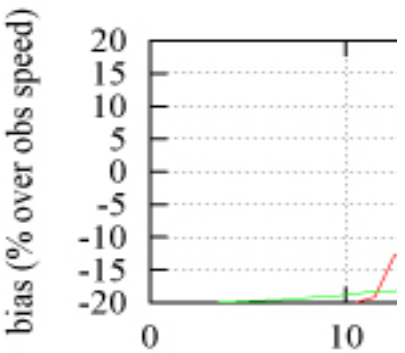


Obs N



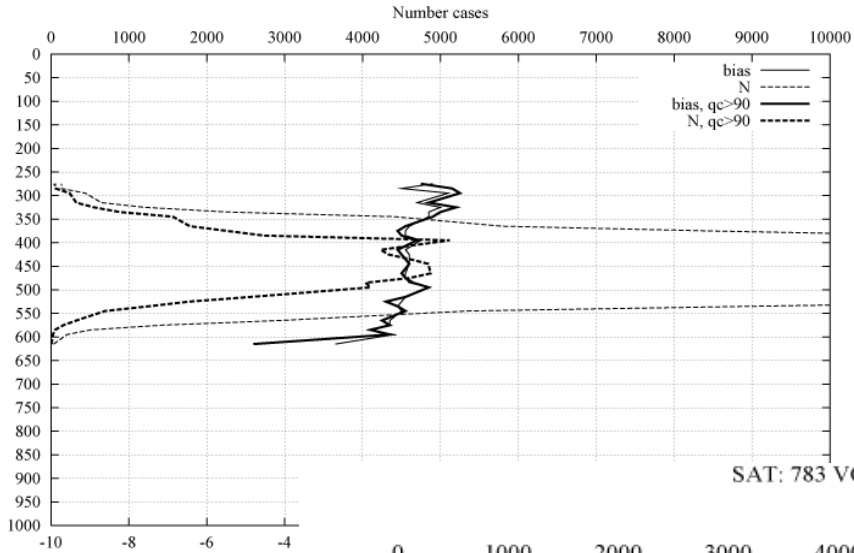
Obs N

80

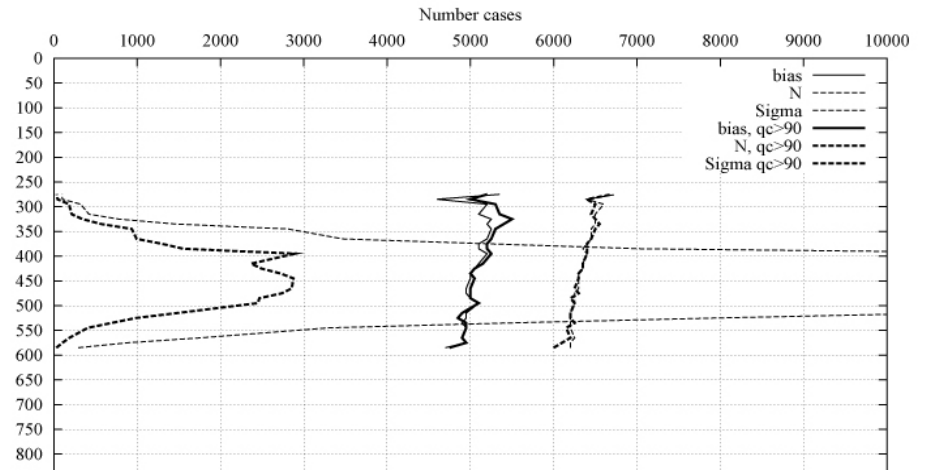


January 2006 vector type (5,2) from "Terra" : i.e. water-vapour CSK tracers H₂O inter.

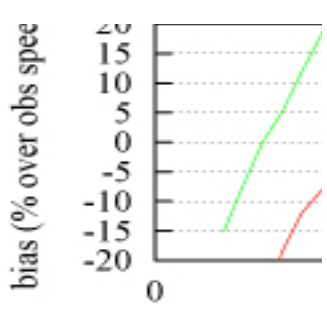
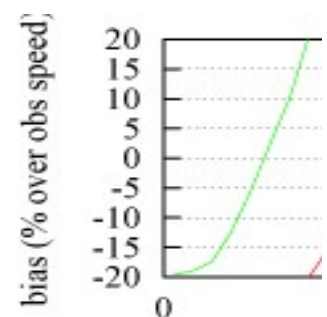
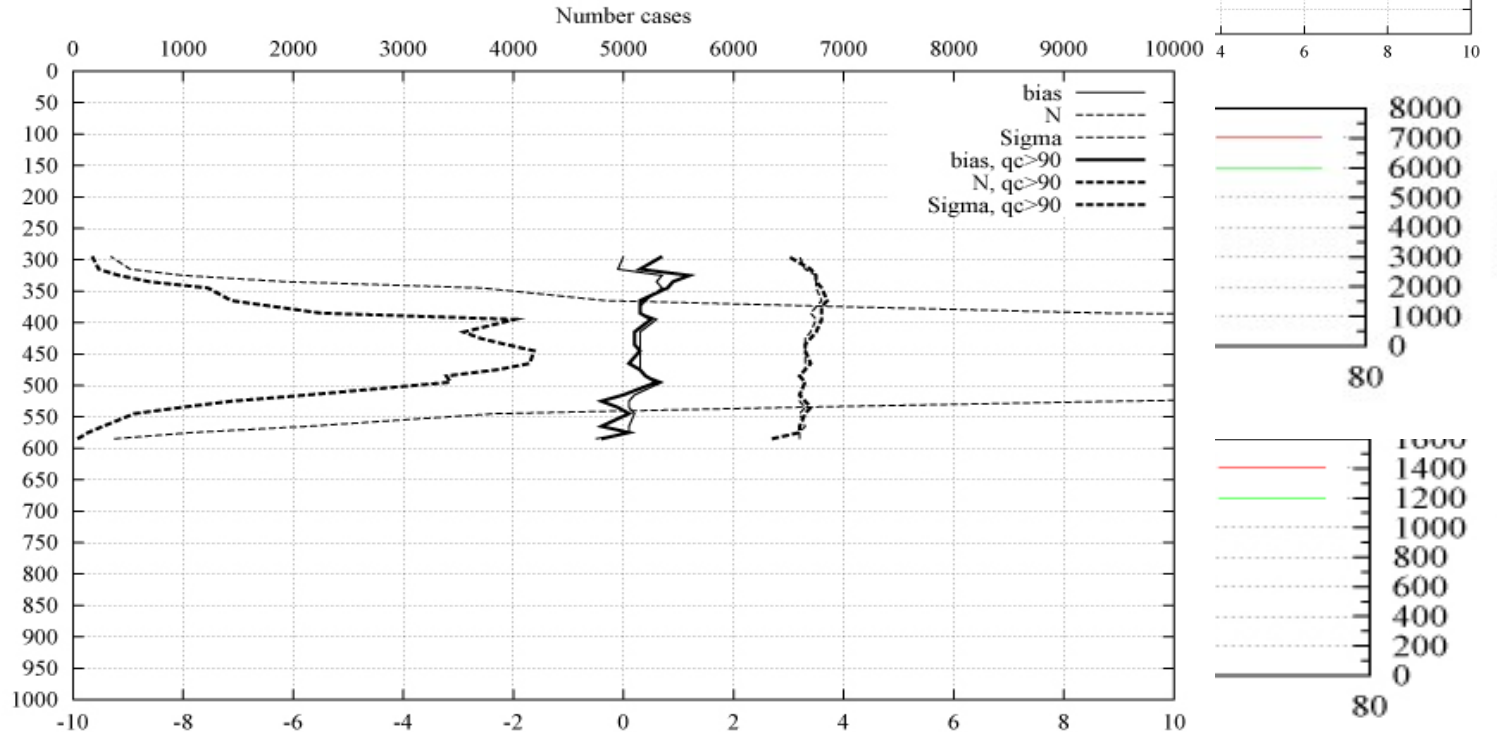
SAT: 783 VCT: wv 5 HAM: 2



SAT: 783 VCT: wv 5 HAM: 2 oldFGck ok



SAT: 783 VCT: wv 5 HAM: 2; newFGck ok



The Blacklisting & Bias Correction decisions drawn from analyses like the previous ones, can be translated into instructions contained in a “modis_bl_and_bc.dat” file like this:

```

16
783 1 1 0. 0. 850000. 30000. 10 60 -3. 0.
784 1 1 0. 0. 850000. 30000. 10 60 -3. 0.
783 1 3 0. 0. 600000. 30000. 20 60 -3. 0.
784 1 3 0. 0. 600000. 30000. 20 60 -3. 0.
783 0 2 0. 0. 400000. 30000. 20 60 -5. 0.25
784 0 2 0. 0. 400000. 30000. 20 60 -5. 0.25
783 0 3 0. 0. 500000. 30000. 15 55 -5. 0.
784 0 3 0. 0. 500000. 30000. 15 55 -5. 0.
783 5 2 0. 0. 500000. 30000. 15 55 -5. 0.
784 5 2 0. 0. 500000. 30000. 15 55 -5. 0.
783 5 3 0. 0. 600000. 30000. 20 40 0. 0.
784 5 3 0. 0. 600000. 30000. 20 40 0. 0.
783 1 1 1. 0. 700000. 30000. 15 40 0. 0.
784 1 1 1. 0. 700000. 30000. 15 40 0. 0.
783 5 2 1. 0. 400000. 30000. 15 60 -5. 0.
784 5 2 1. 0. 400000. 30000. 15 60 -5. 0.

```

```

Bc_coefficient = a0 + a1*(speed - s0)
du=du + Bc_coefficient * u_obs ;
dv=dv + Bc_coefficient * v_obs;
u_obs=(1 - Bc_coefficient) * u_obs ;
v_obs=(1 - Bc_coefficient) * v_obs ;

```

Meaning:

Number of lines in the file

2nd and 3rd lines: vector type (1,1) from both platforms over sea surface, irrespectively of qc. Index value, between 850 and 300 hPa apply a bias correction of +3% for wind speeds between 10 and 60 m/s.

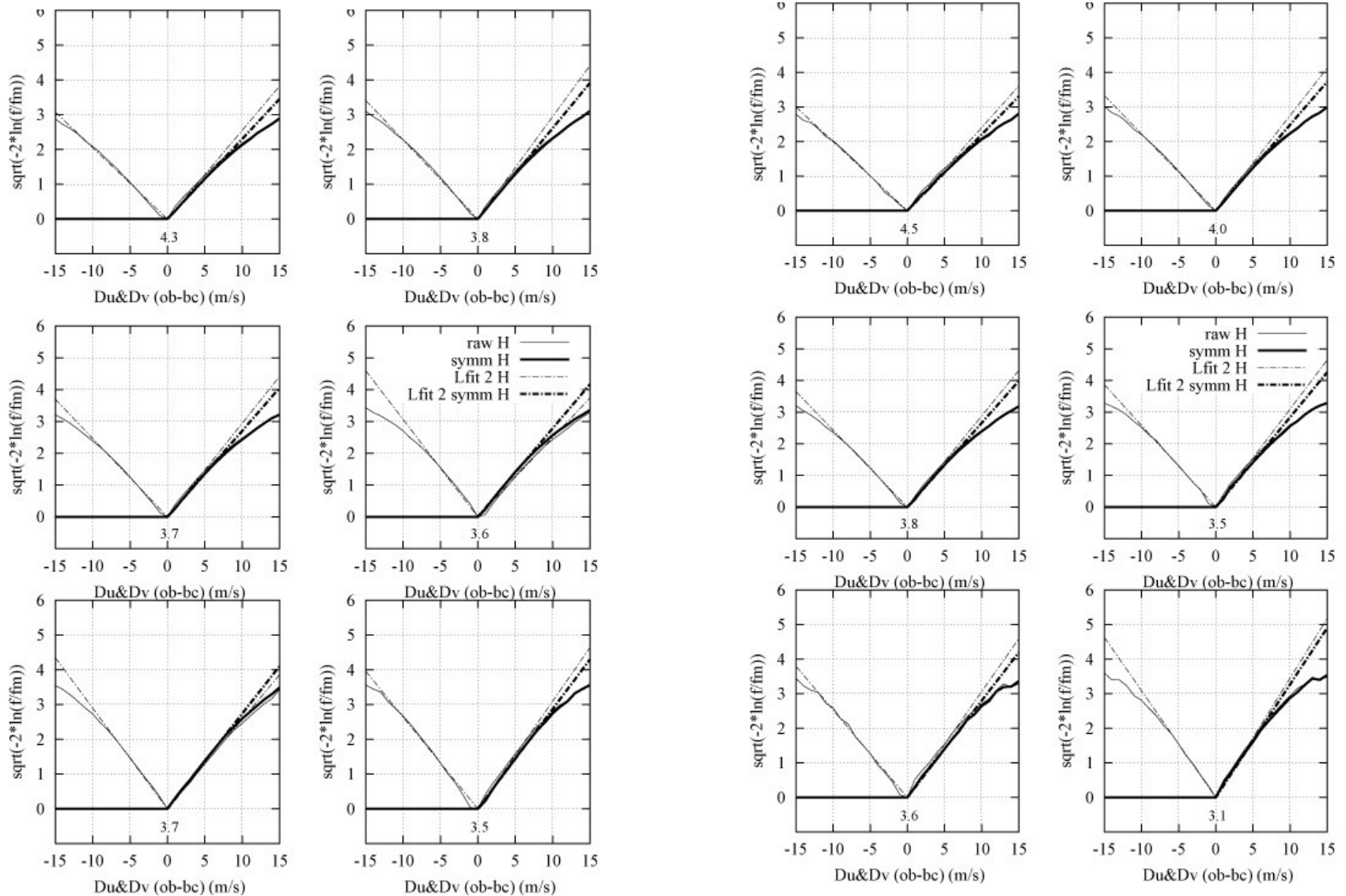
4th and 5th lines: vector type (1,3) from both platforms over sea surface, disregard qc value, between 600 and 300 hPa apply a bias correction of +3% for wind speeds between 20 and 60 m/s.

....

Last two lines: vector type (5,2) from both platforms over land surface, disregard qc value. Between 400 and 300 hPa apply a bias correction of +5% for speeds between 15 and 60 m/s.

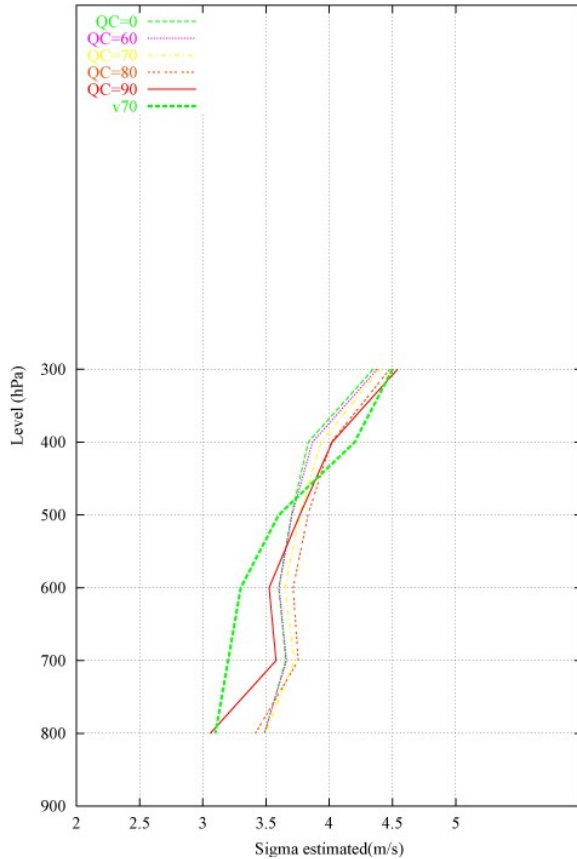
- Bias-corrected obs flagged as (1,1)
- Back-Obs increments and obs rotated values contain the correction.
- Obs in the standard grid contain original Values.
- Need to enlarge the statistical output to be able to recover all the info
- Bias correction calculated as Obs-Back !!

One important parameter σ_{total} . ML estimates (Andersson and Järvinen)



All vectors (after BL and BC)

Only those with QC > 90

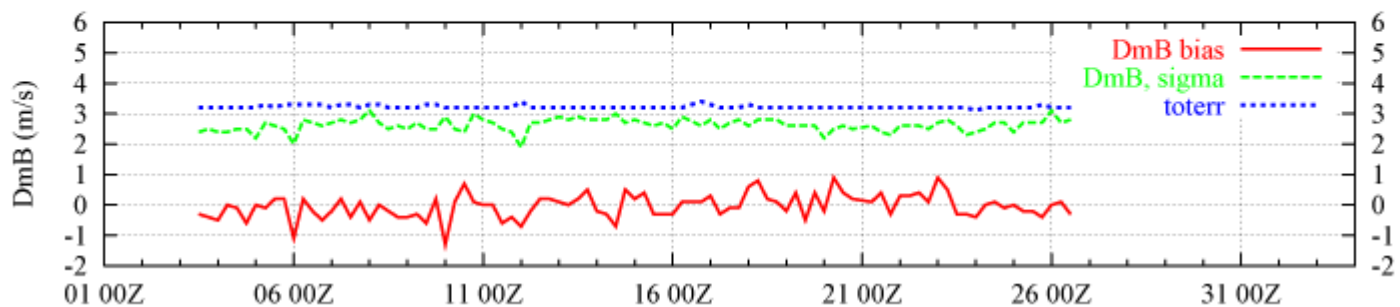
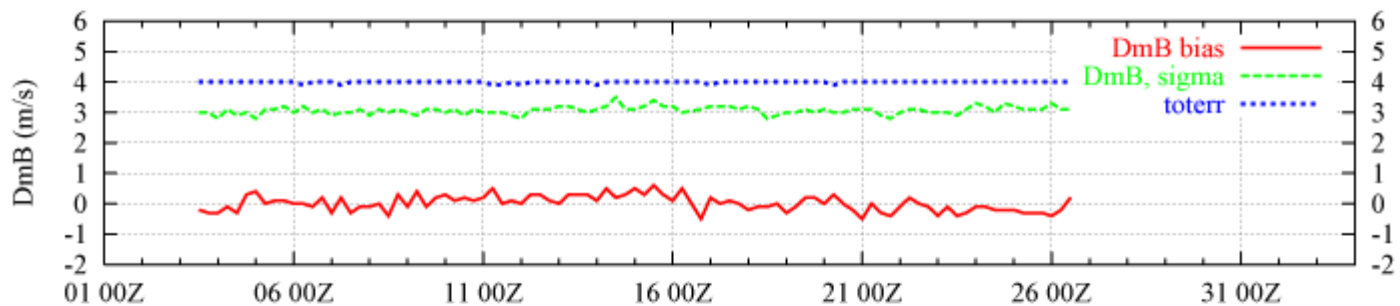
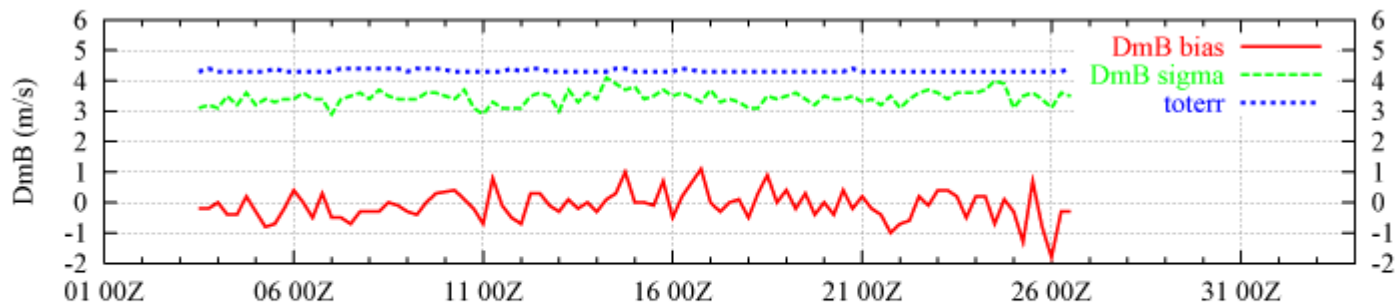


These ML estimates do not indicate clear smaller values than those specified in v7.0 (green line).

However, “a posteriori” diagnostics give consistent overestimation in all v7.0 specified “sigmas”... Why?

	$\tilde{\sigma}_o u / v$	$\sigma_o u / v$	$\tilde{\sigma}_b u / v$	$\sigma_b u / v$	$\tilde{\sigma}_{tot} u / v$	$\sigma_{tot} u / v$
250/350hPa	2.9 / 2.8	3.2	2.1 / 2.1	3.2 / 3.4	3.6 / 3.5	4.5 / 4.6
350/450hPa	2.6 / 2.5	2.9	1.9 / 1.9	3.0 / 3.1	3.2 / 3.2	4.2 / 4.3
450/550hPa	2.4 / 2.4	2.8	1.7 / 1.8	2.3 / 2.5	3.0 / 3.0	3.6 / 3.7
550/650hPa	2.5 / 2.5	2.9	1.5 / 1.5	1.6 / 1.6	3.0 / 2.9	3.4 / 3.4
650/750hPa	2.5 / 2.4	3.0	1.3 / 1.3	1.1 / 1.2	2.8 / 2.8	3.2 / 3.2
750/850hPa	2.3 / 2.3	3.0	1.1 / 1.2	1.0 / 1.0	2.5 / 2.6	3.1 / 3.1

The rejection threshold ($1.8 \sigma_{total}$) is not optimal because it passes to the analysis a set of innovations with actually less variance than σ_{total} .



The overestimation observed in the other “sigmas” (σ_o and σ_b) can be understood from the linear relation between innovation vector and “Data-minus-Analysis” vector. It is “exactly equivalent to perform Statistics on either two of these vectors” (Talagrand, 2003).

$$E[\mathbf{d}_a^0 \mathbf{d}_b^{0T}] = \mathbf{R} (\mathbf{HBH}^T + \mathbf{R})^{-1} E[\mathbf{d}_b^0 \mathbf{d}_b^{0T}]$$

$$E[\mathbf{d}_b^a \mathbf{d}_b^{aT}] = \mathbf{HBH}^T (\mathbf{HBH}^T + \mathbf{R})^{-1} E[\mathbf{d}_b^0 \mathbf{d}_b^{0T}]$$

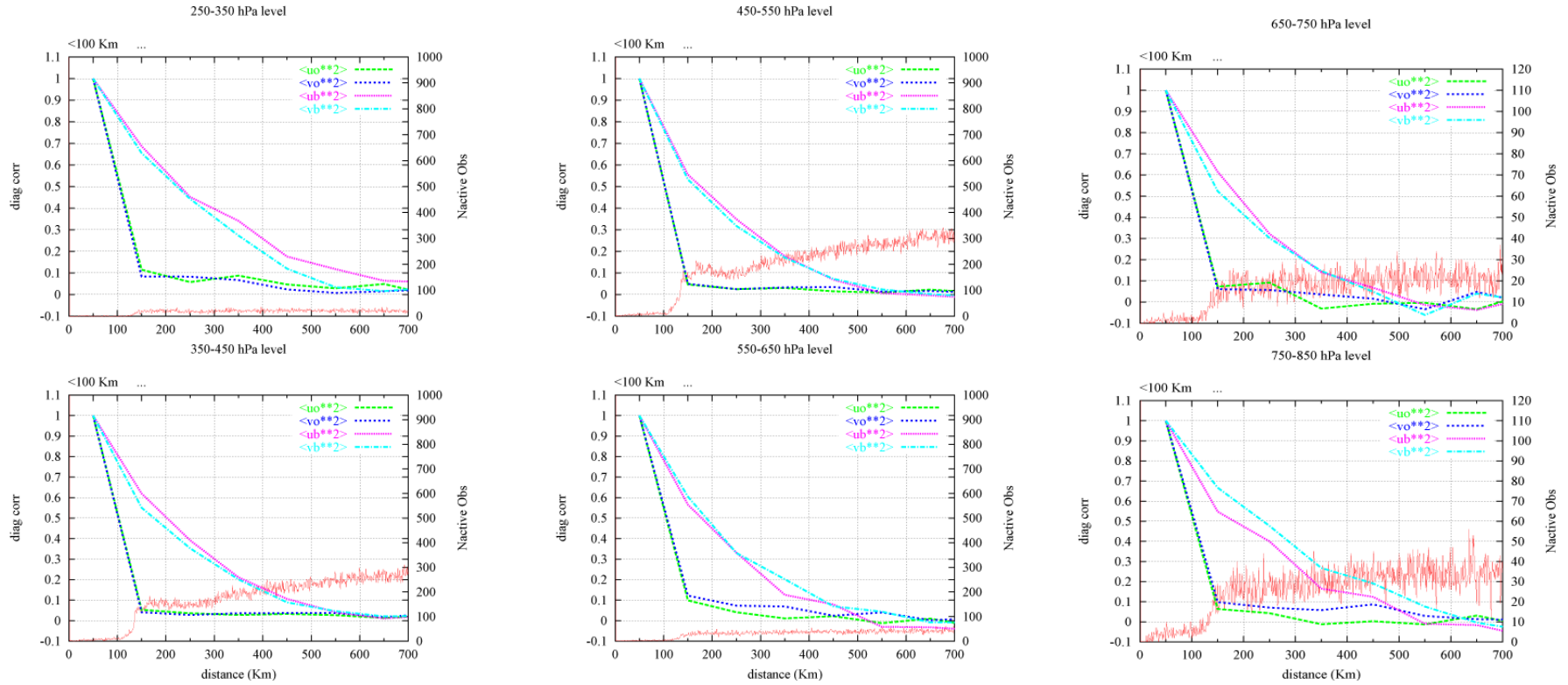
$$E[\mathbf{d}_b^0 \mathbf{d}_b^{0T}] = (\mathbf{HBH}^T + \mathbf{R}) \quad \Leftrightarrow \quad E[\mathbf{d}_a^0 \mathbf{d}_b^{0T}] = \mathbf{R} \quad ; \quad E[\mathbf{d}_b^a \mathbf{d}_b^{aT}] = \mathbf{HBH}^T$$

$$\text{Tr}(E[\mathbf{d}_a^0 \mathbf{d}_b^{0T}]) < \text{Tr}(\mathbf{R}) \quad \text{and} \quad \text{Tr}(E[\mathbf{d}_b^a \mathbf{d}_b^{aT}]) < \text{Tr}(\mathbf{HBH}^T) \quad \Rightarrow \quad \text{Tr}(E[\mathbf{d}_b^0 \mathbf{d}_b^{0T}]) < \text{Tr}(\mathbf{HBH}^T + \mathbf{R})$$

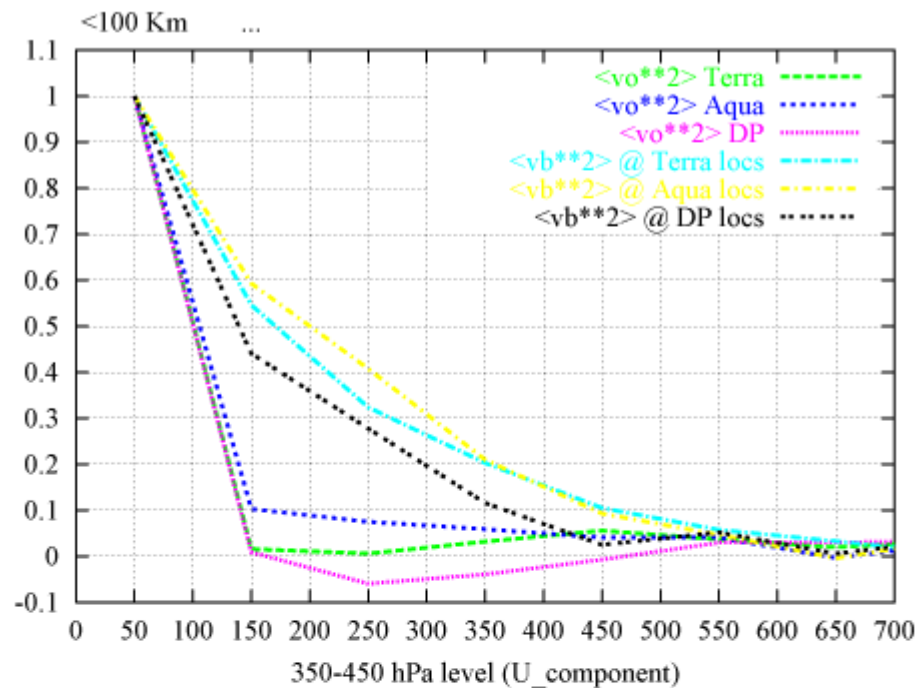
$$E[(x_a - x_b)(x_b - x_0)] = \sigma_b^2 / (\sigma_o^2 + \sigma_b^2) E[(x_b - x_0)^2]$$

$$E[(x_a - x_0)(x_b - x_0)] = \sigma_o^2 / (\sigma_o^2 + \sigma_b^2) E[(x_b - x_0)^2]$$

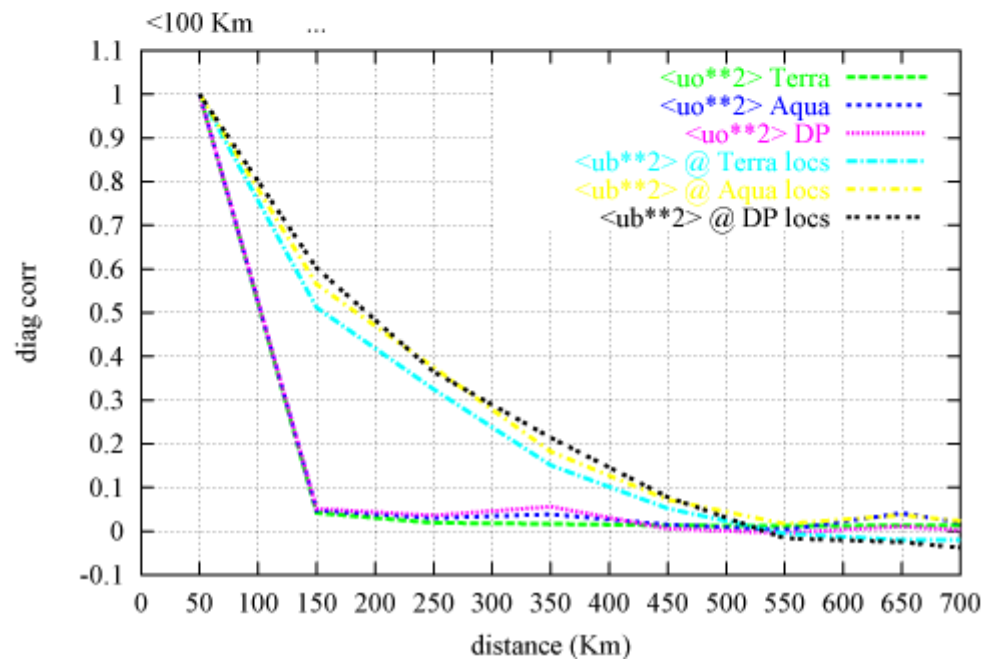
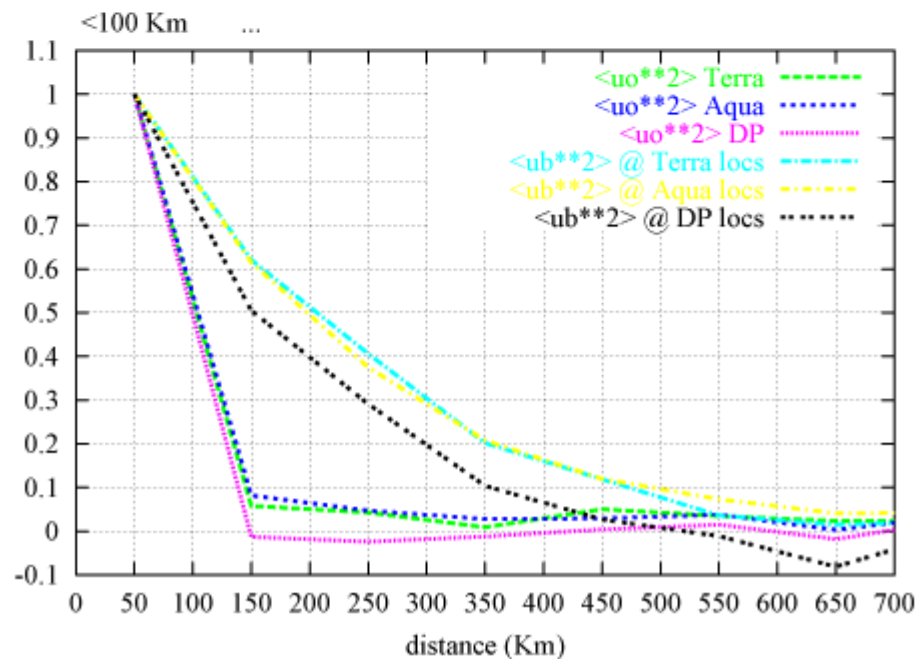
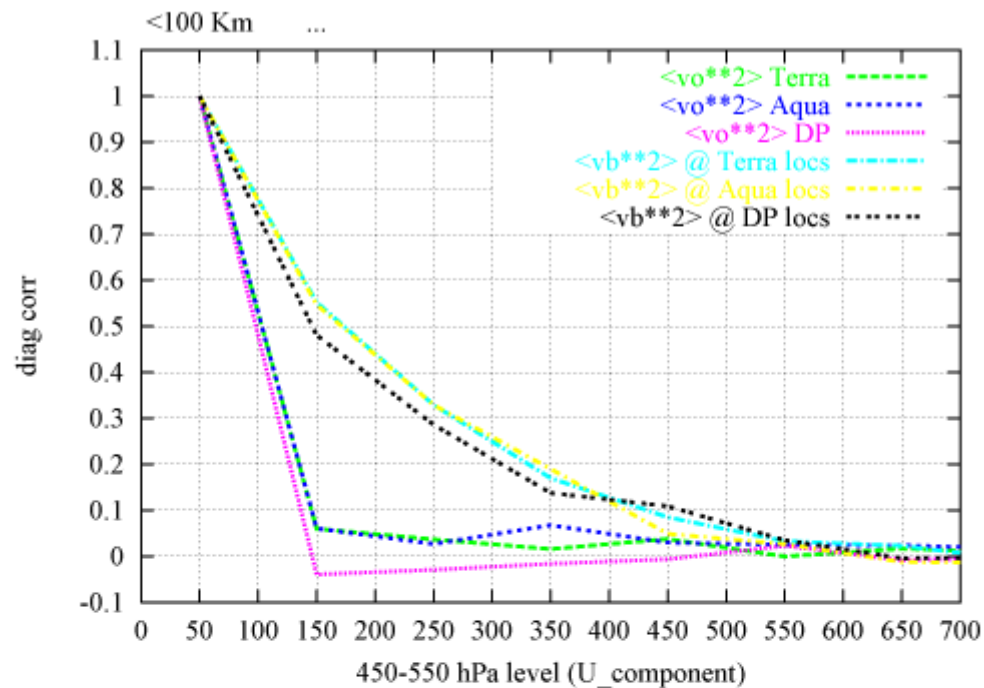
Use if the diagnosed R matrix to tune the amount of thinning



350-450 hPa level (V_component)

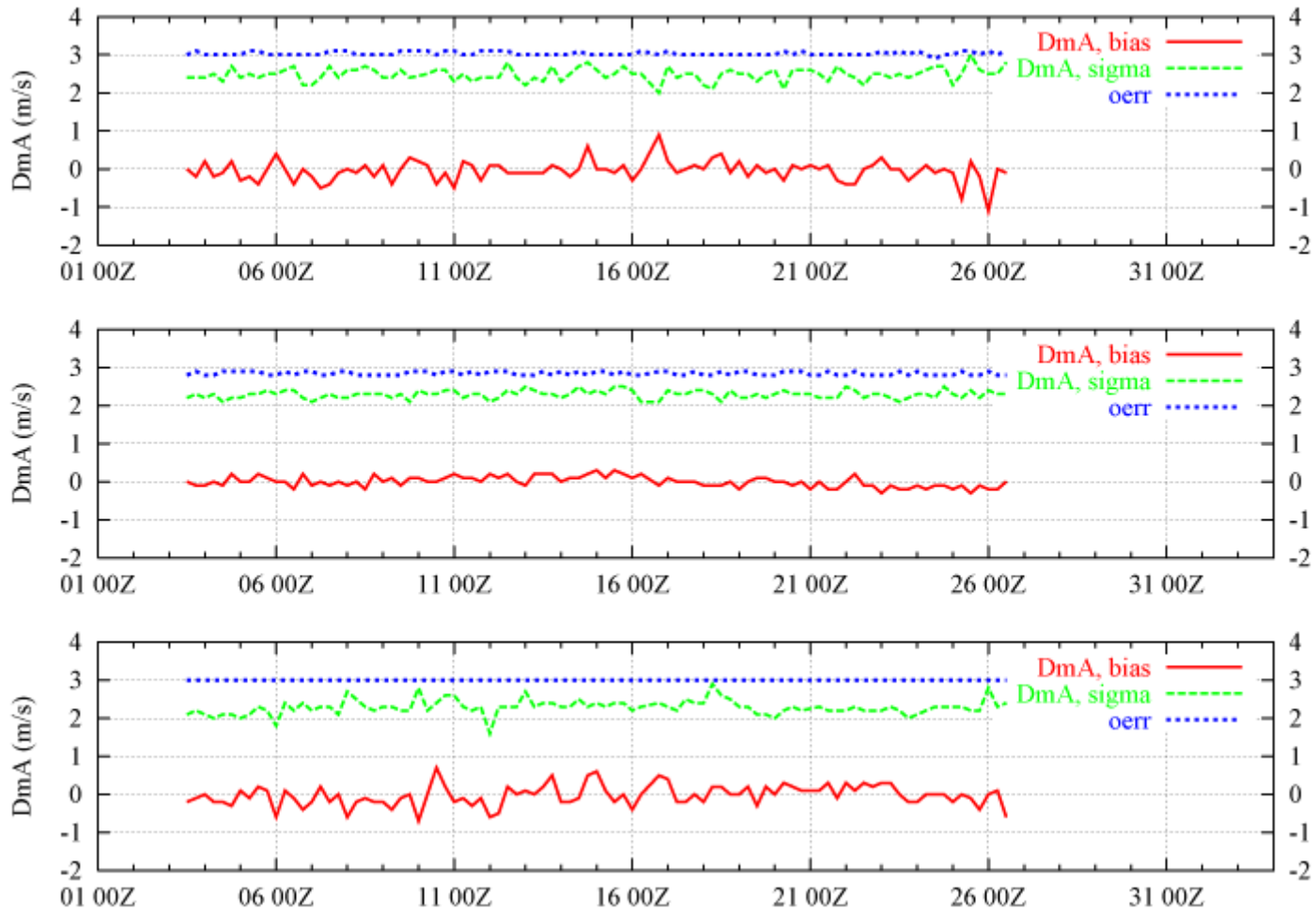


450-550 hPa level (V_component)

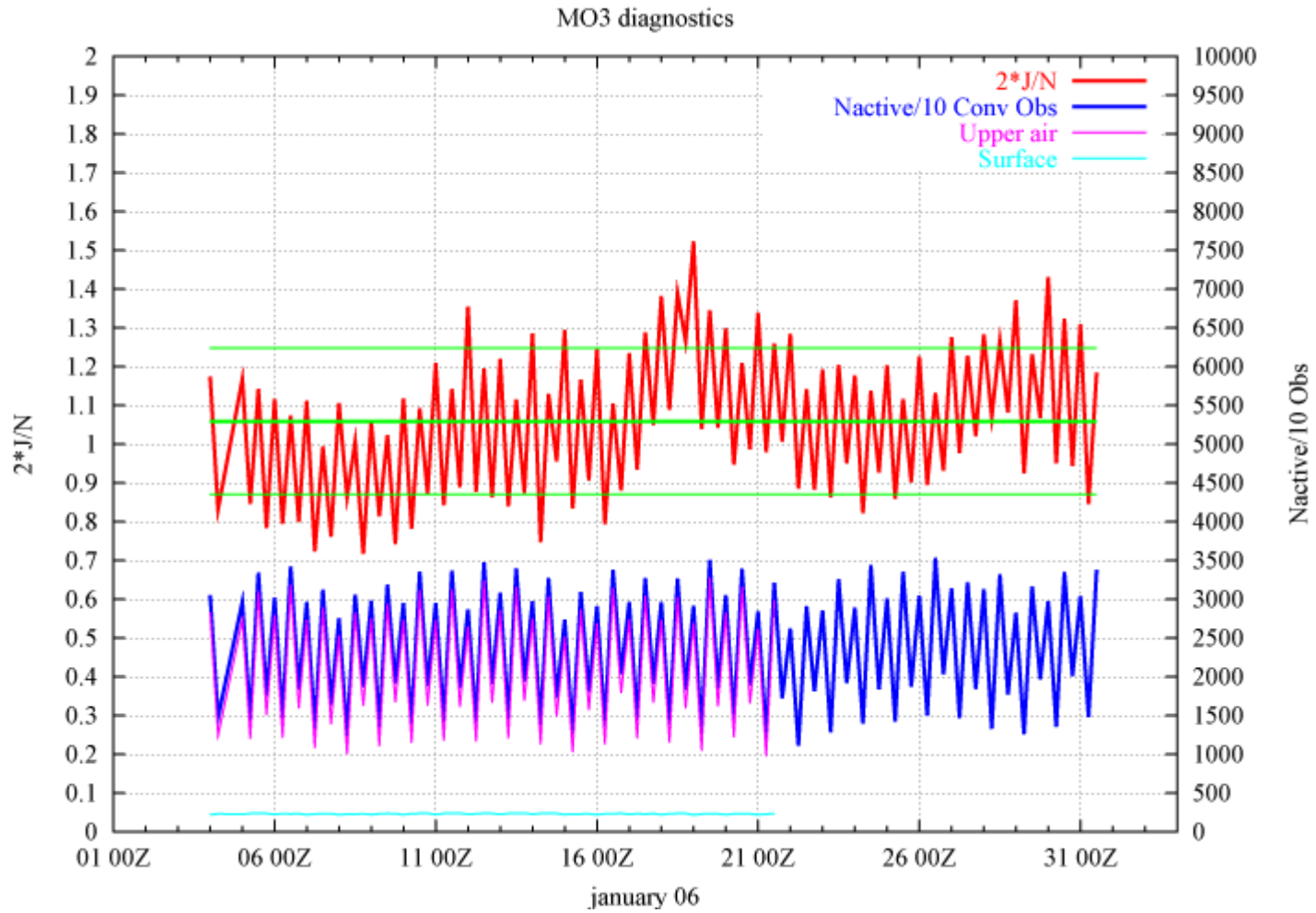


The analysis fits the MODIS observations well

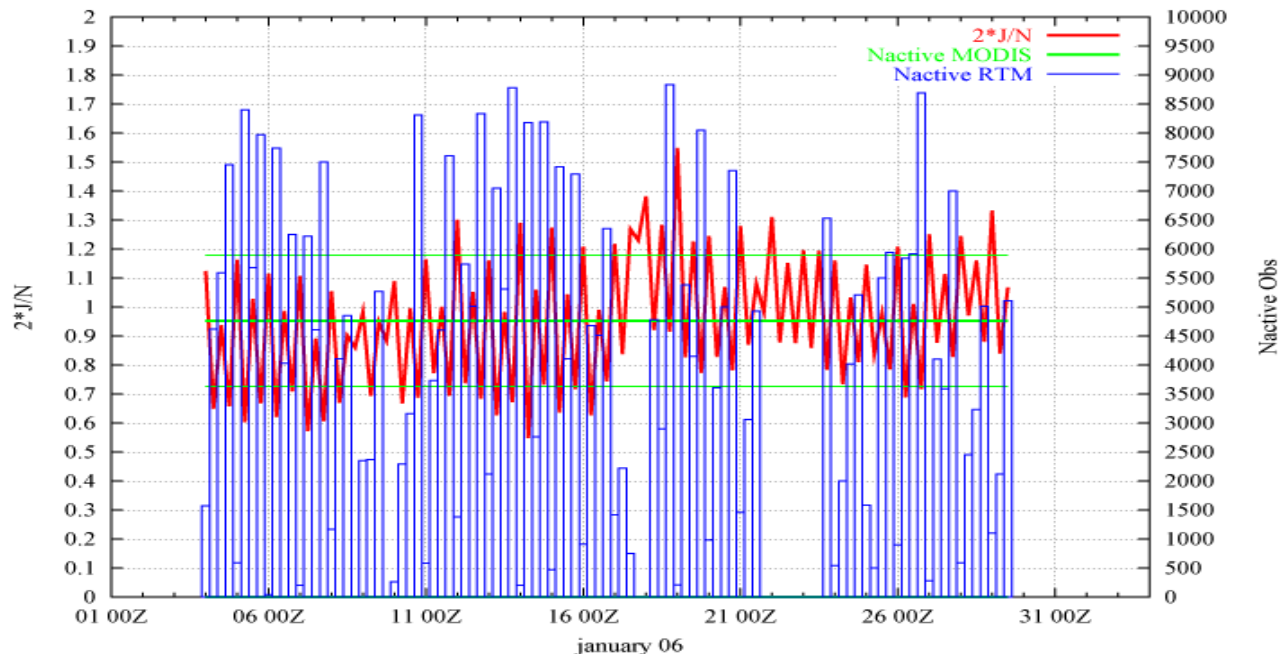
DmA = Analysis residues



Diurnal cycle in the residue of J

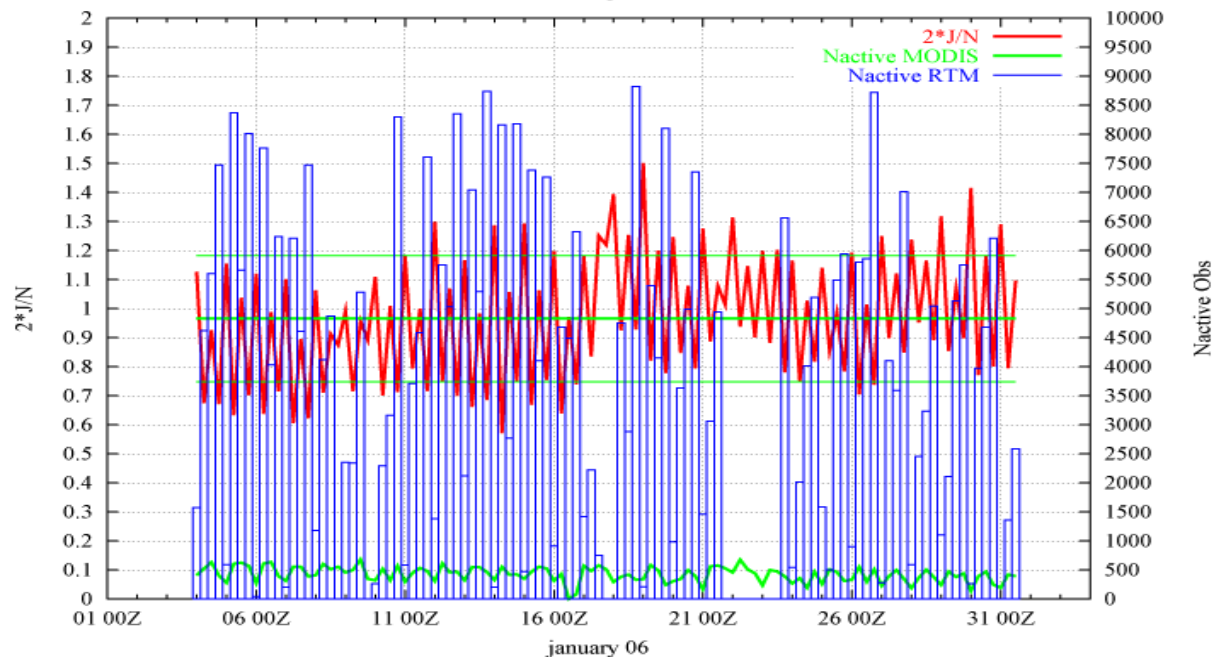


MO2 diagnostics



AMSU-A
January 2006

MOX diagnostics



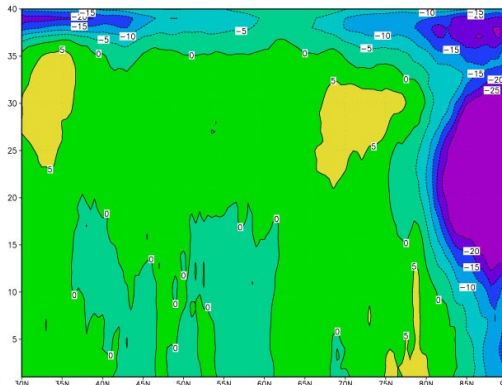
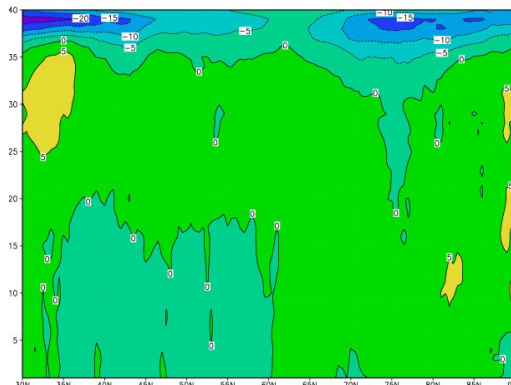
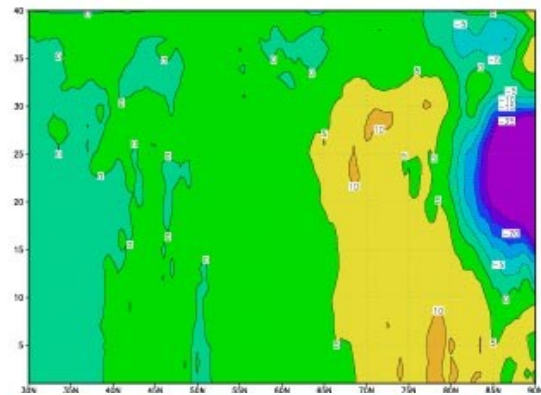
AMSU-A + MODIS
January 2006

July 2006, zonal means for *Wind Impact*: $\langle || \vec{V}_{fc} - \vec{V}_{an} || \rangle_{cnt} - \langle || \vec{V}_{fc} - \vec{V}_{an} || \rangle_{exp}$
 (in % over $\langle || V_{fc} - V_{an} || \rangle_{cnt}$)

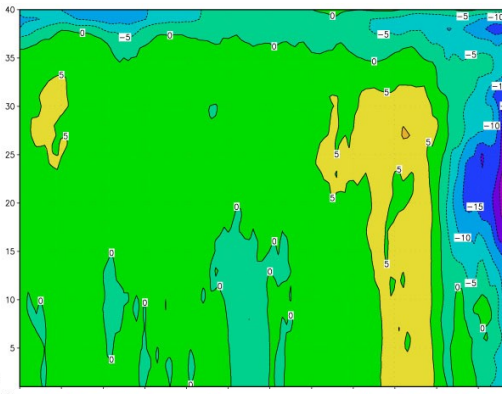
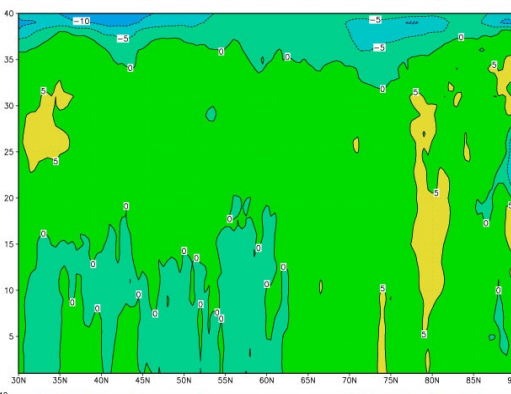
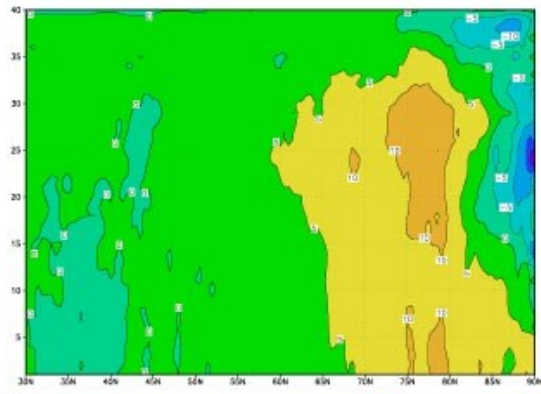
MODIS AMVs

AMSU-A

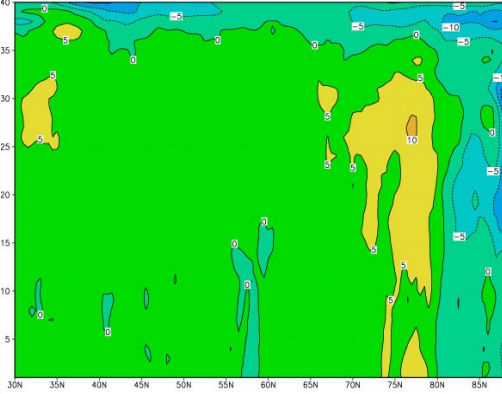
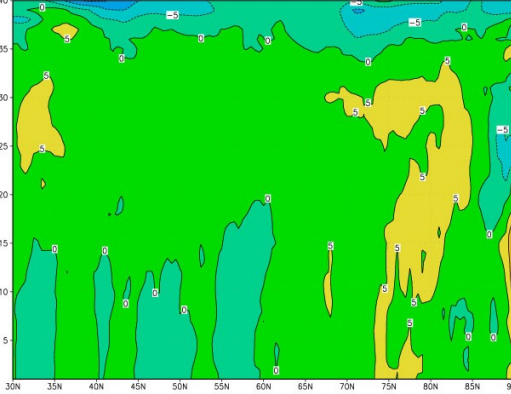
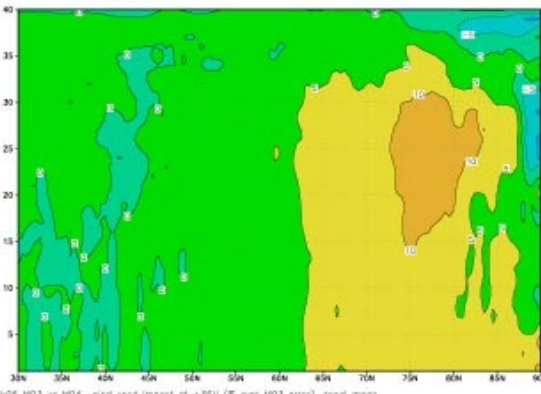
MODIS AMVs + AMSU-A



+ 12 H



+ 24 H

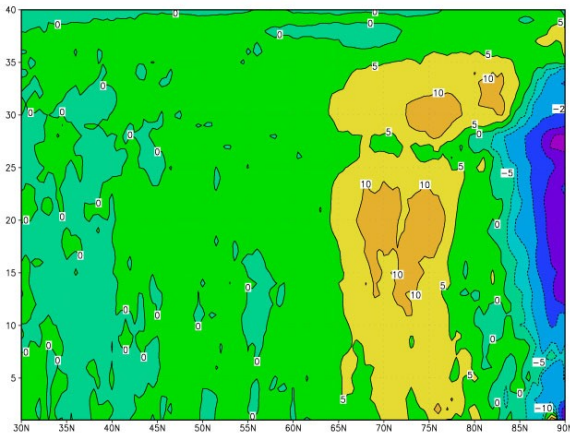


+ 36 H

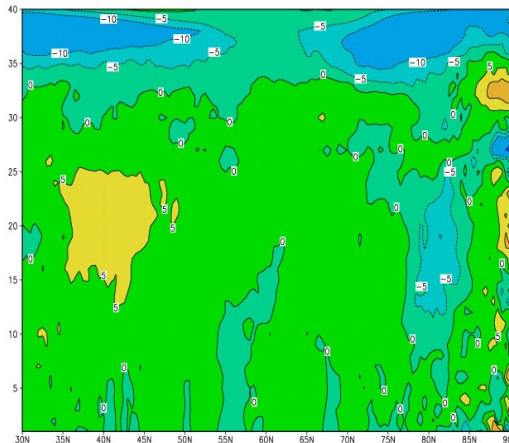
July 2006, zonal means for *Temperature Impact*
(in % over $\sigma_{\text{cnt}}(T_{\text{fc}}-T_{\text{an}})$)

$$\sigma_{\text{cnt}}(T_{\text{fc}}-T_{\text{an}}) - \sigma_{\text{exp}}(T_{\text{fc}}-T_{\text{an}})$$

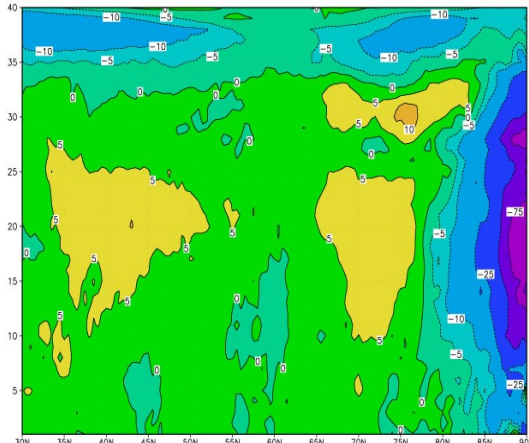
MODIS AMVs



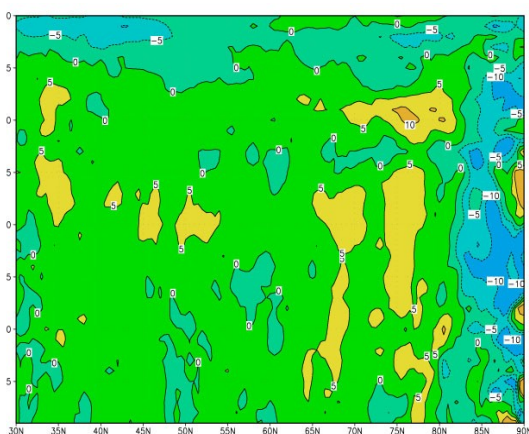
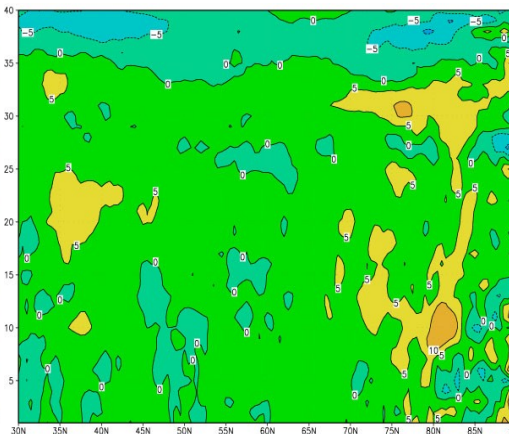
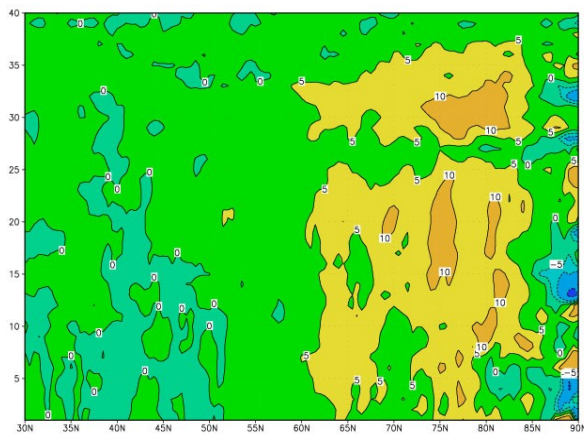
AMSU-A



MODIS AMVs + AMSU-A



+12H

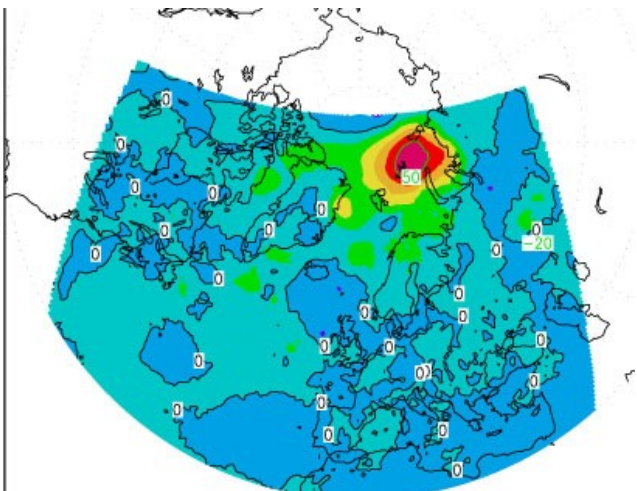


+ 36 H

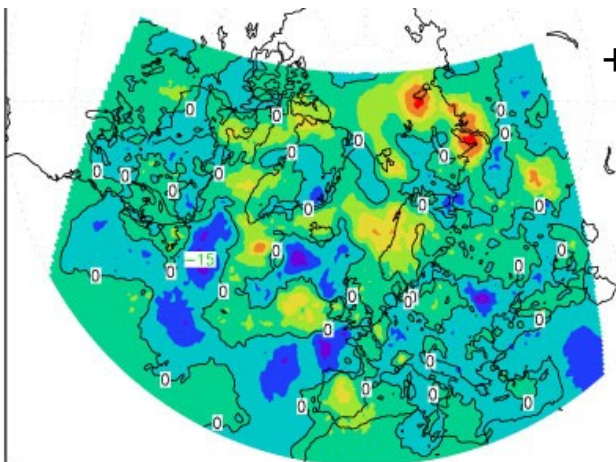
July 2006, *Surface Pressure Impact*
In Pascals

$$\sigma_{\text{cnt}} (P_{s_{\text{fc}}} - P_{s_{\text{an}}}) - \sigma_{\text{exp}} (P_{s_{\text{fc}}} - P_{s_{\text{an}}})$$

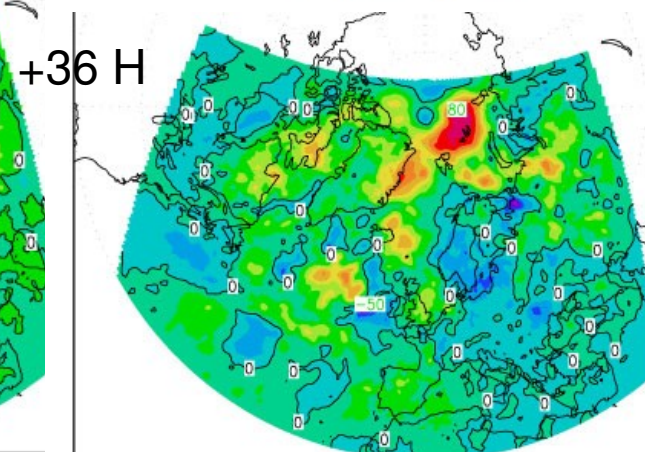
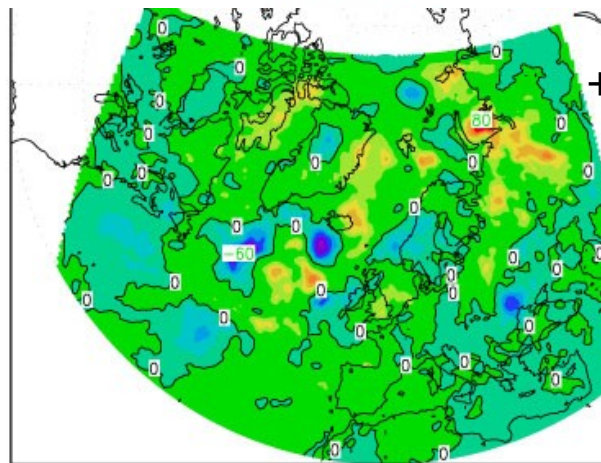
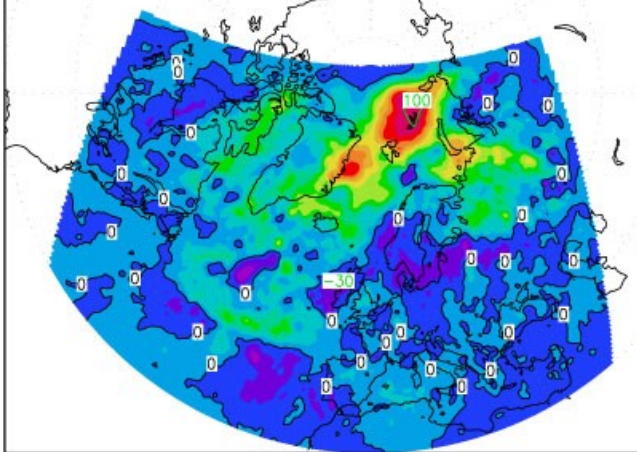
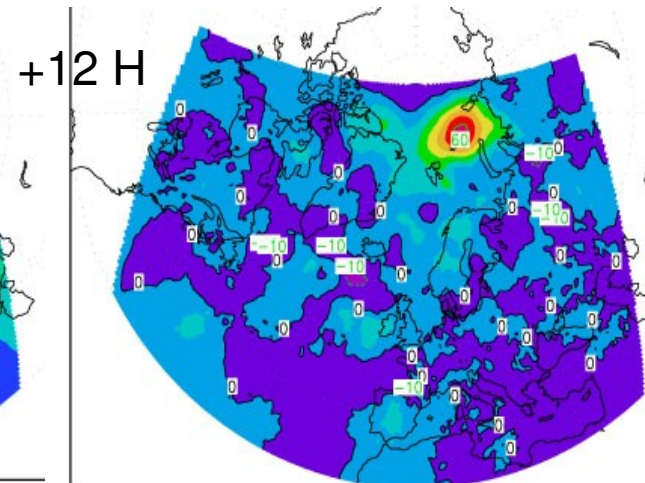
MODIS AMVs



AMSU-A



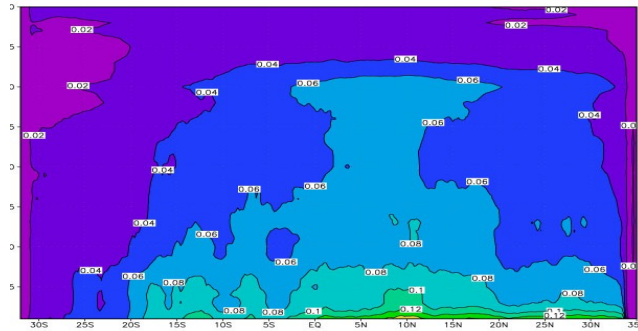
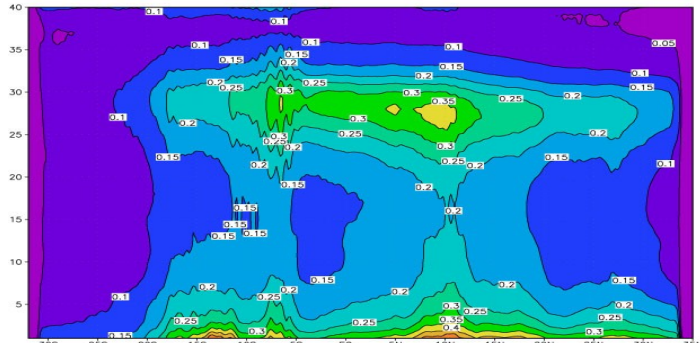
MODIS AMVs + AMSU-A



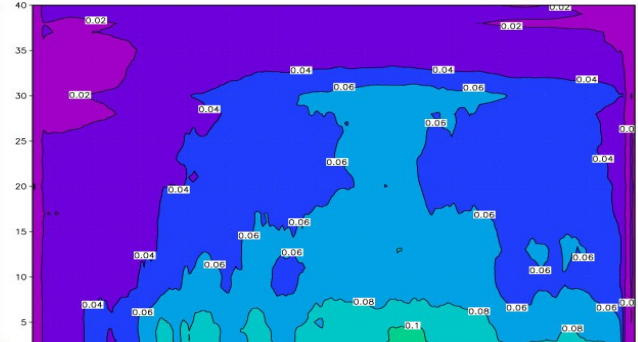
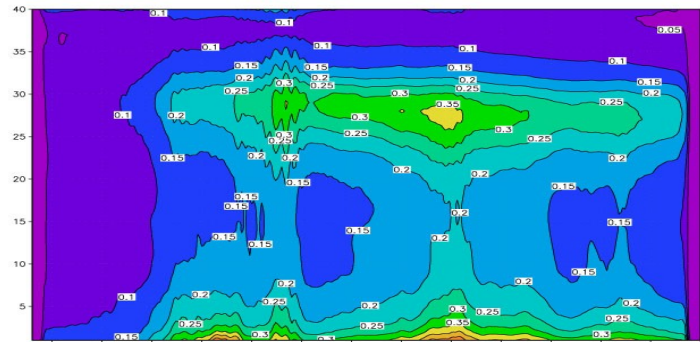
July 2006, “zonal” means for *Initialization Increments: MODIS experiment*

WIND : $\langle || V_{fc00} - V_{an} || \rangle$ (m/s)

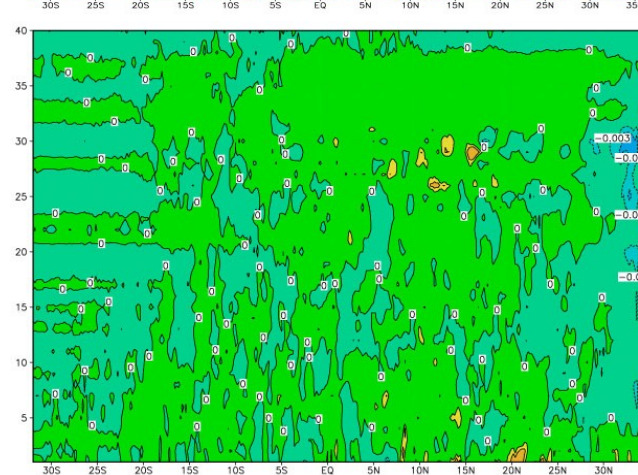
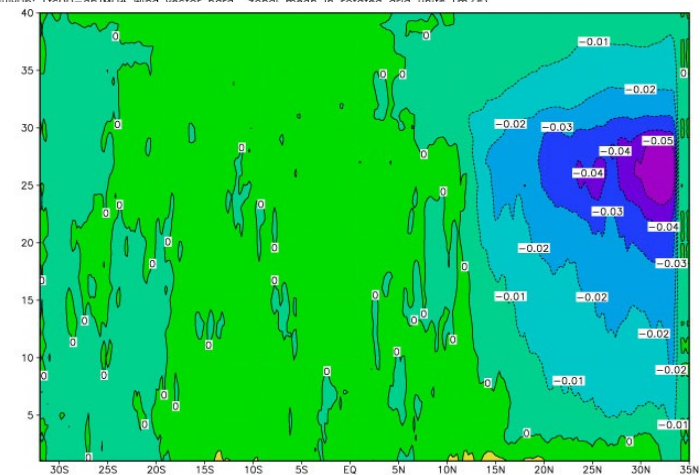
TEMPERATURE : σ (T_{fc00}-T_{an}) (K)



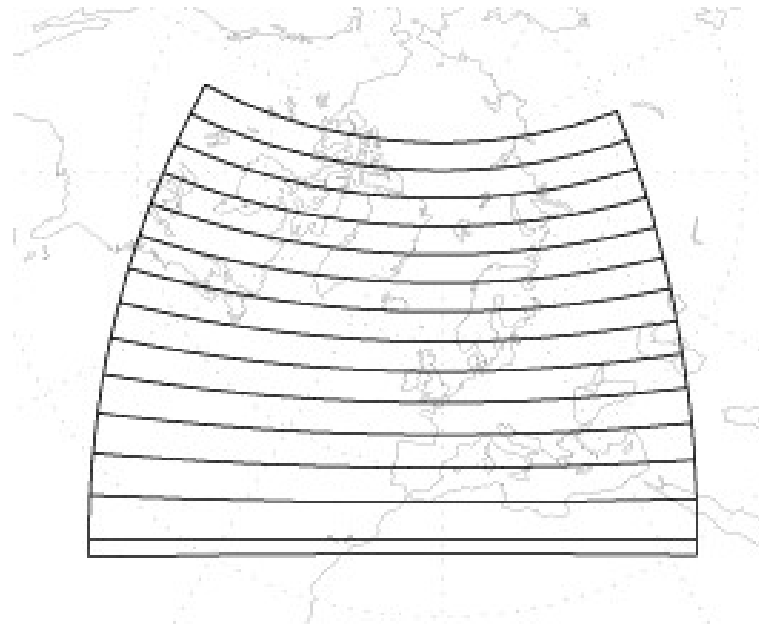
CNTL



EXP



CNTL- EXP

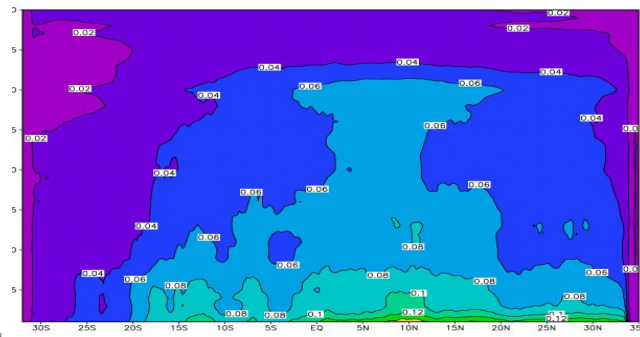
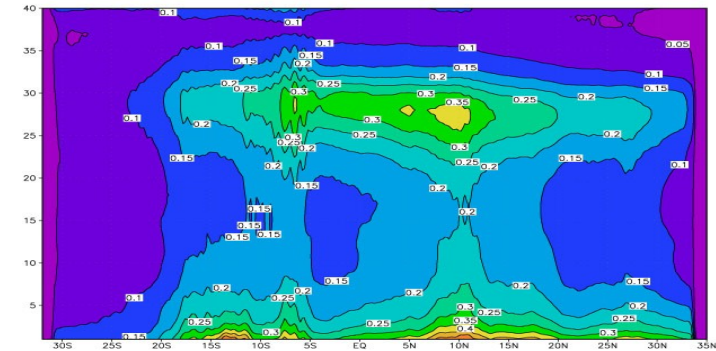


Averaging over
Equal distance to Boundary Bands

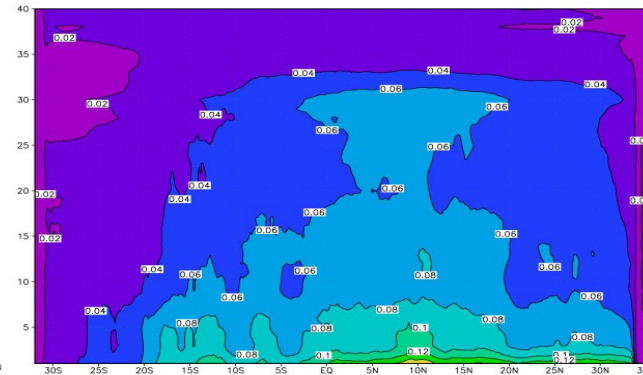
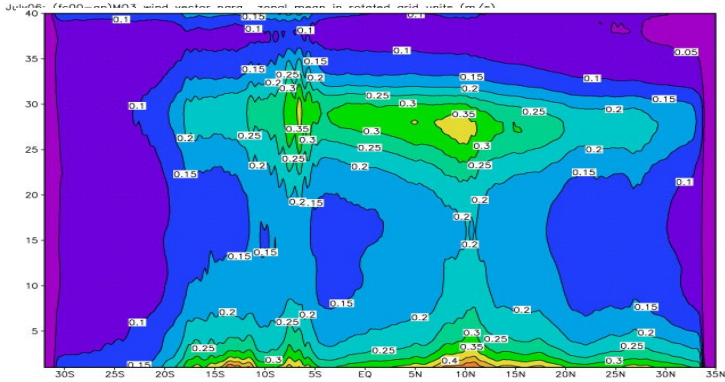
July 2006, “zonal” means for *Initialization Increments: AMSU-A experiment*

WIND : $\langle || V_{fc00} - V_{an} || \rangle$ (m/s)

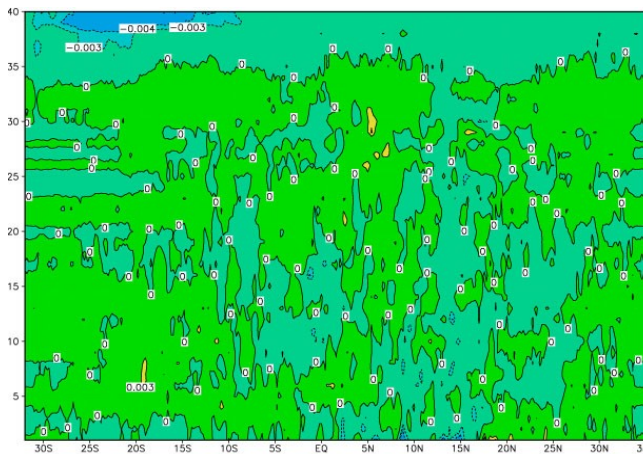
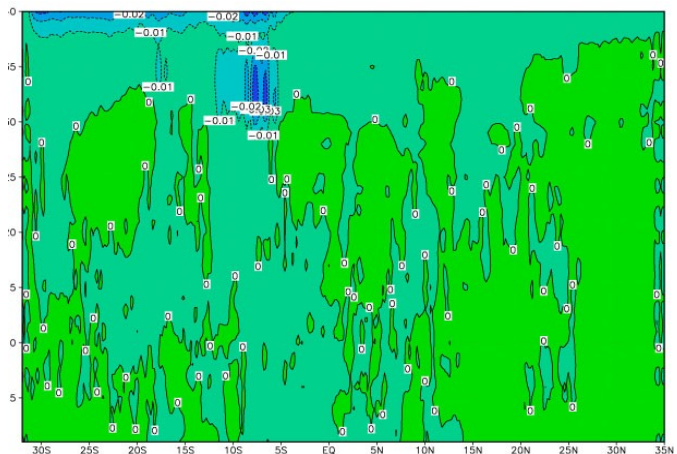
TEMPERATURE : σ (T_{fc00}-T_{an}) (K)



CNTL



EXP

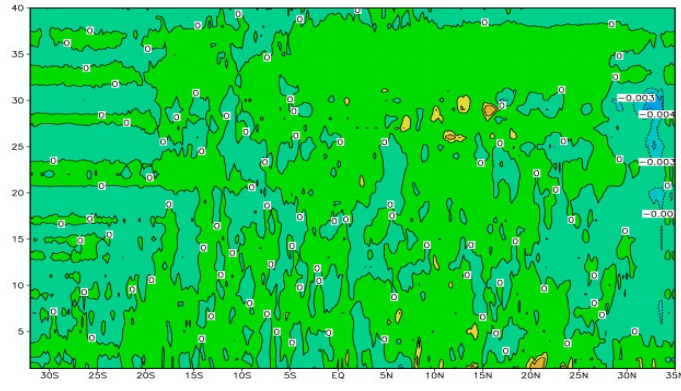
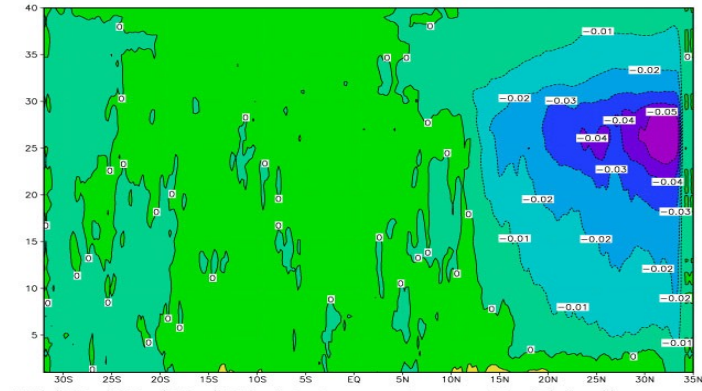


CNTL- EXP

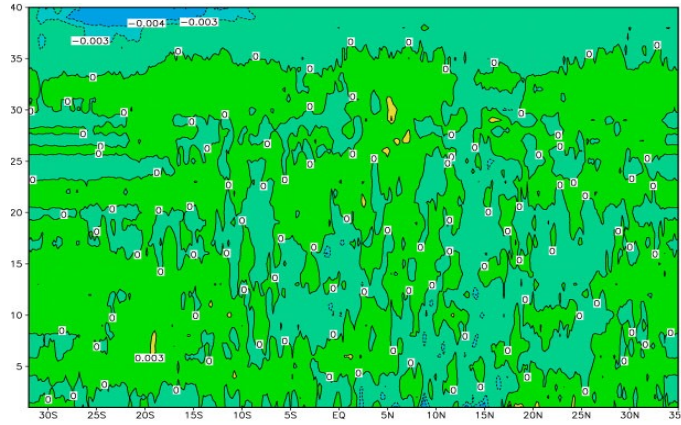
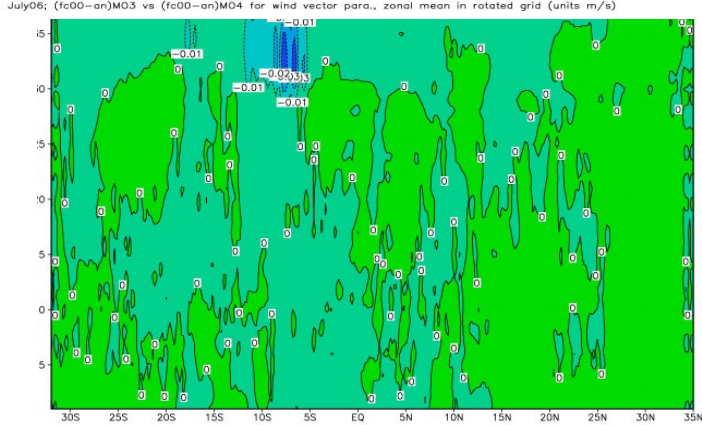
July 2006, “zonal” means for *Initialization Increments*

WIND : $\langle || V_{fc00} - V_{an} || \rangle$ (m/s)

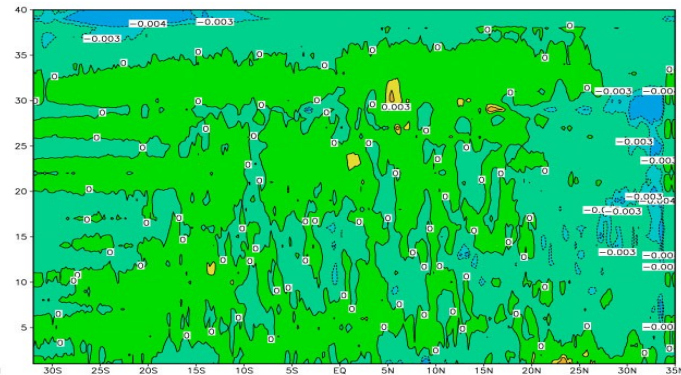
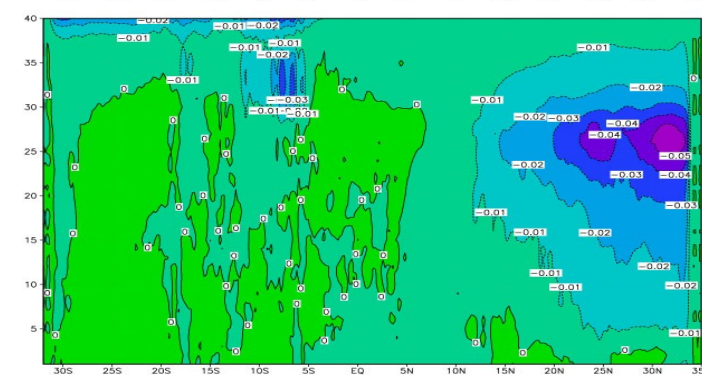
TEMPERATURE : σ (T_{fc00}-T_{an}) (K)



MODIS



AMSU-A



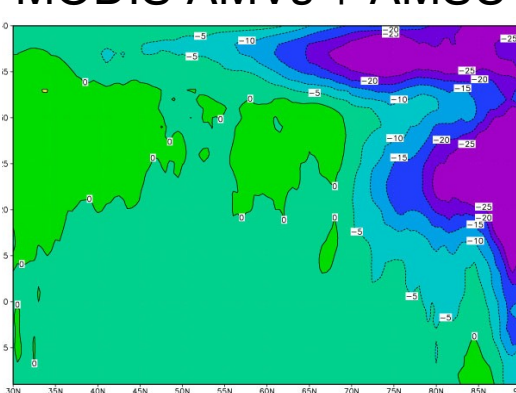
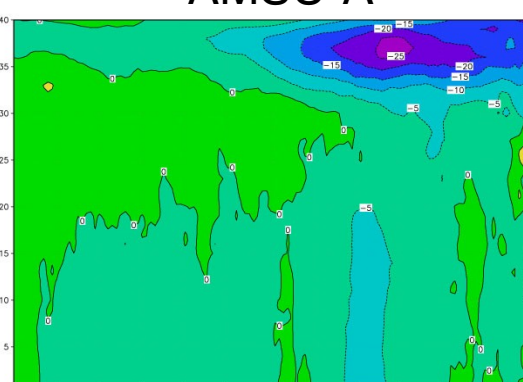
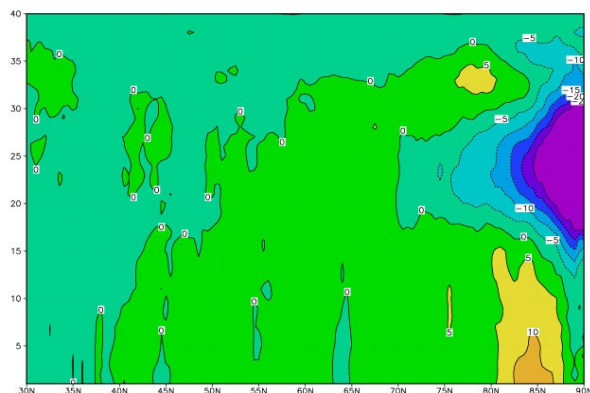
BOTH

January 2006, zonal means for *Wind Impact* : $\langle || \vec{V}_{fc} - \vec{V}_{an} || \rangle_{cnt} - \langle || \vec{V}_{fc} - \vec{V}_{an} || \rangle_{exp}$
 (in % over $\langle || V_{fc} - V_{an} || \rangle_{cnt}$)

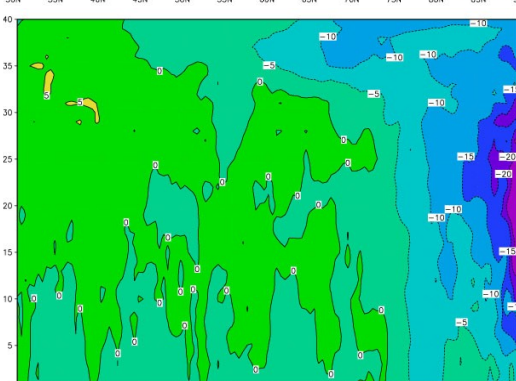
MODIS AMVs

AMSU-A

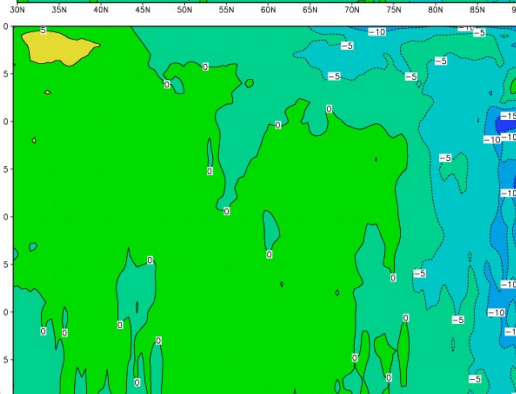
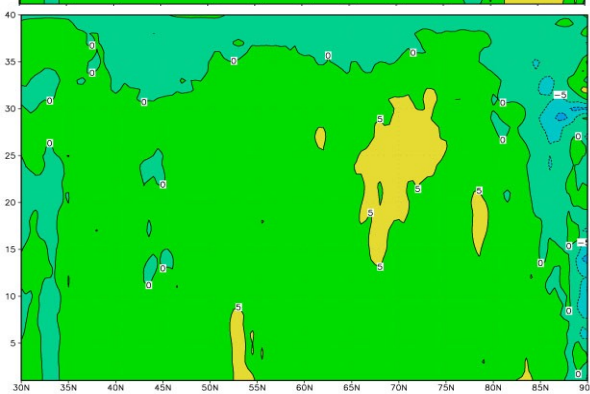
MODIS AMVs + AMSU-A



+ 12 H



+ 24 H



+ 36 H

January 2006, zonal means for *Temperature Impact*
in % over σ_{cnt} ($T_{\text{fc}} - T_{\text{an}}$)

$$\sigma_{\text{cnt}} (T_{\text{fc}} - T_{\text{an}}) - \sigma_{\text{exp}} (T_{\text{fc}} - T_{\text{an}})$$

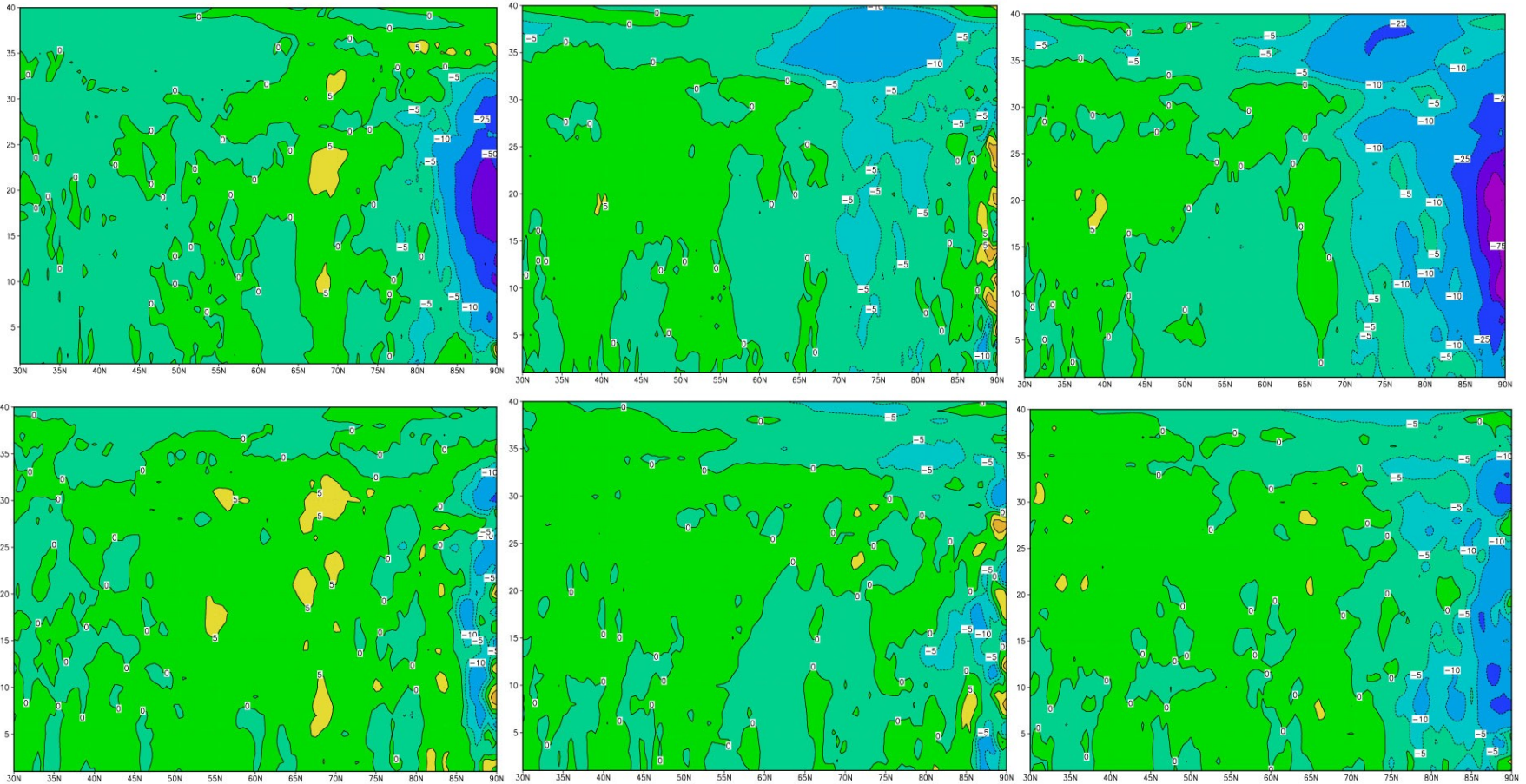
MODIS AMVs

AMSU-A

MODIS AMVs + AMSU-A

+12H

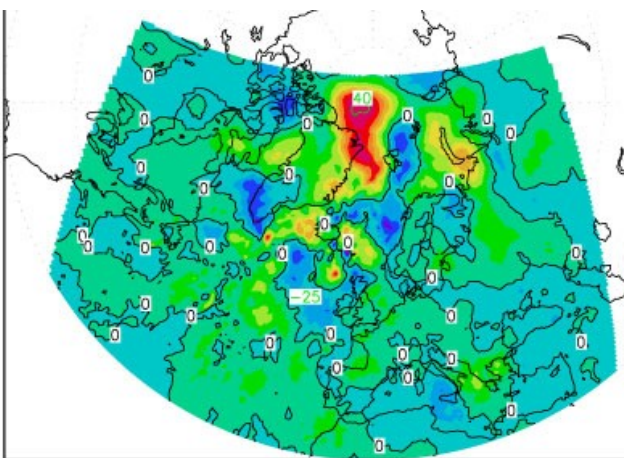
+ 36 H



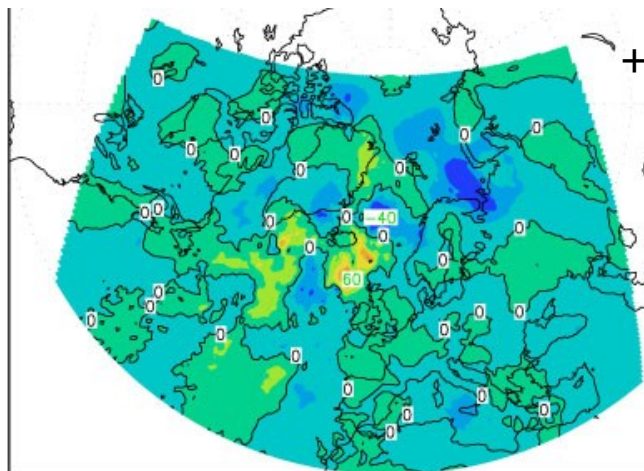
January 2006, *Surface Pressure Impact*
In Pascals

$$\sigma_{\text{cnt}} (P_{\text{fc}} - P_{\text{an}}) - \sigma_{\text{exp}} (P_{\text{fc}} - P_{\text{an}})$$

MODIS AMVs

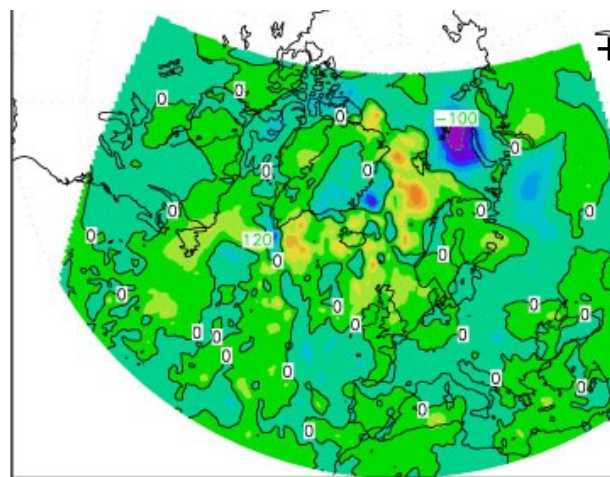
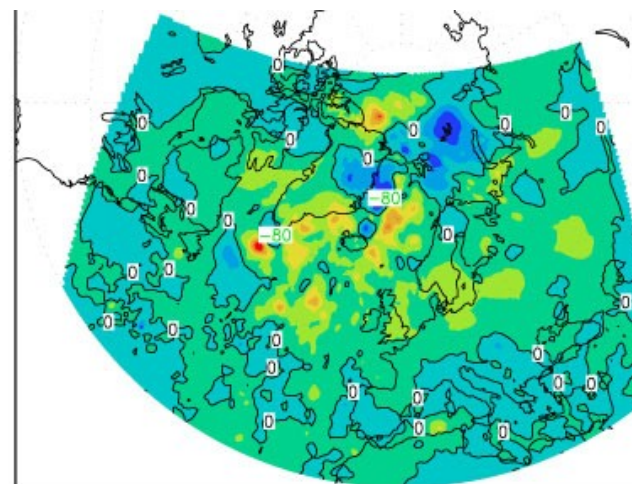
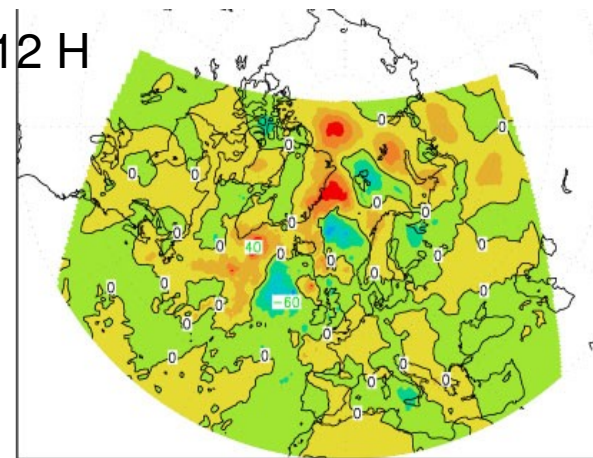


AMSU-A

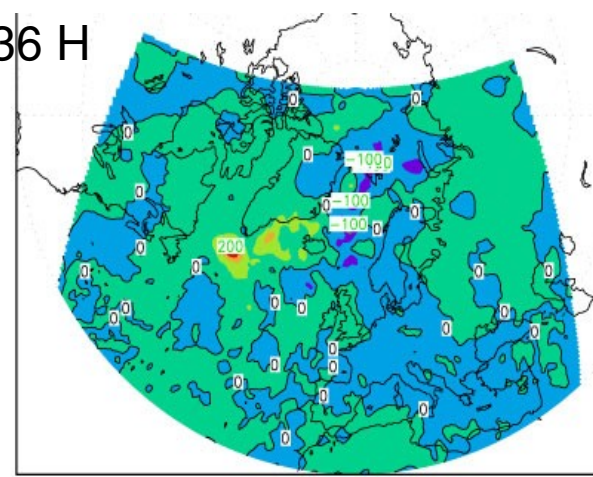


MODIS AMVs + AMSU-A

+12 H



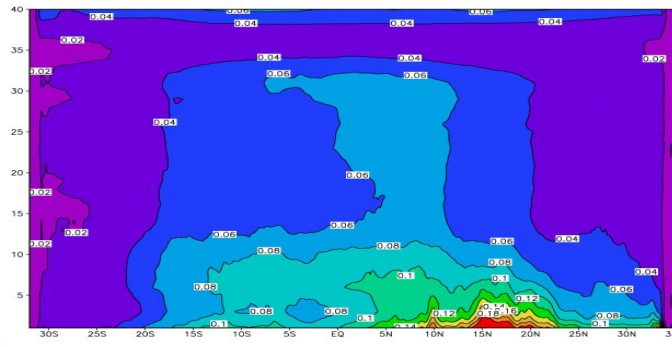
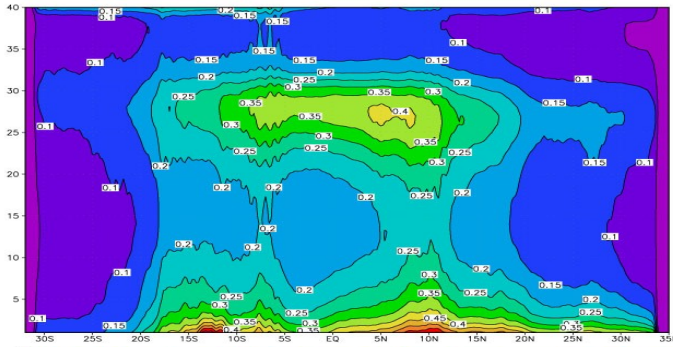
+36 H



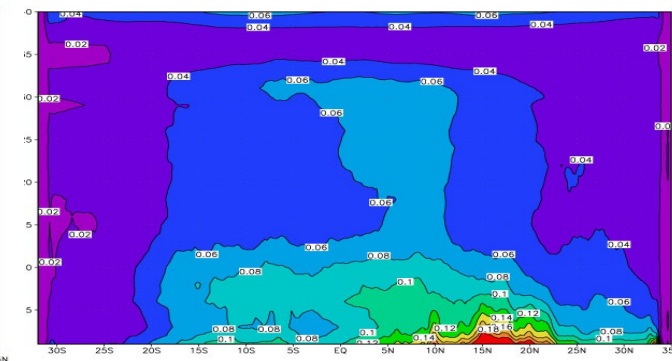
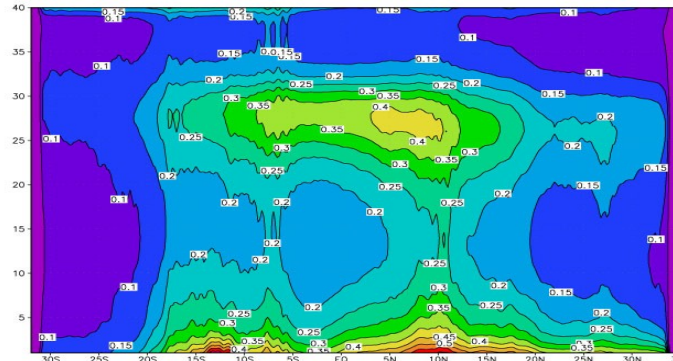
January 2006, “zonal” means for *Initialization Increments: MODIS experiment*

WIND : $\langle || V_{fc00} - V_{an} || \rangle$ (m/s)

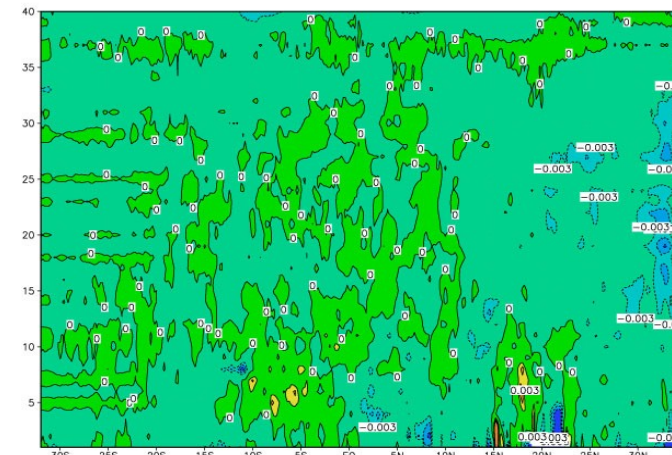
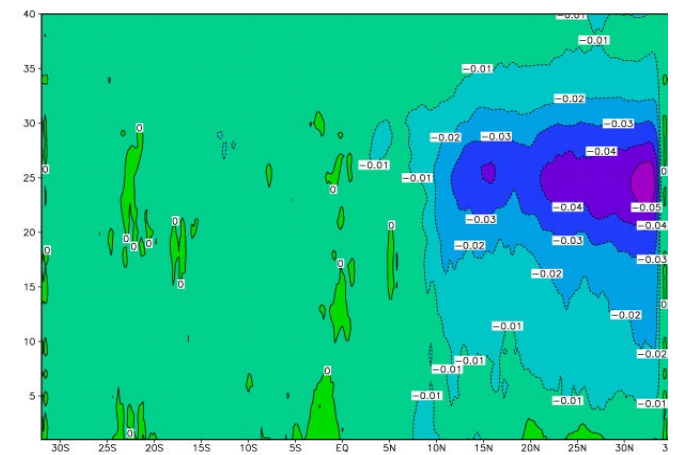
TEMPERATURE : σ (T_{fc00}-T_{an}) (K)



CNTL



EXP

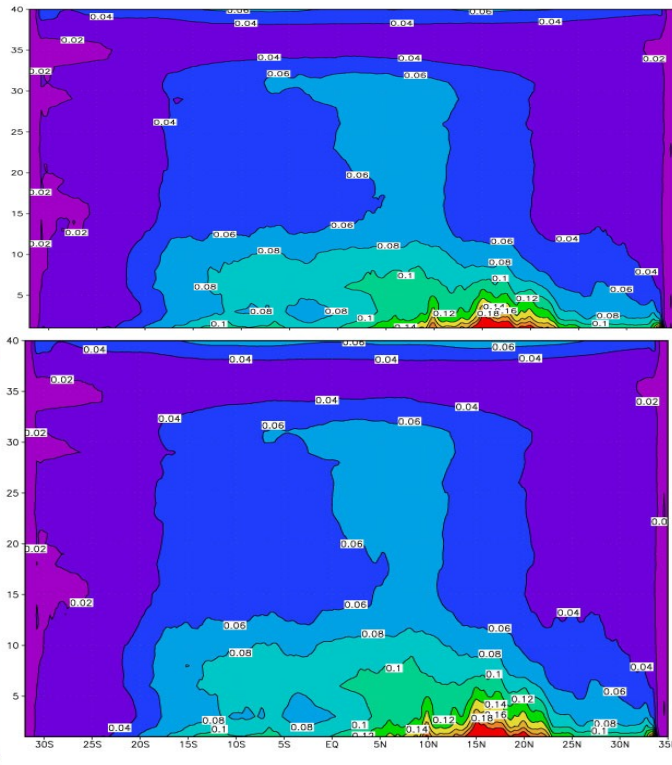
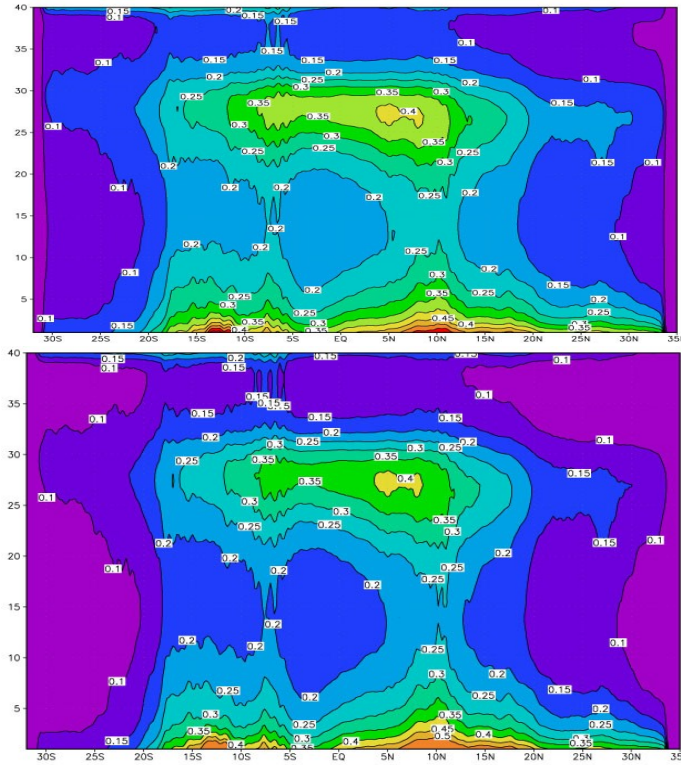


CNTL- EXP

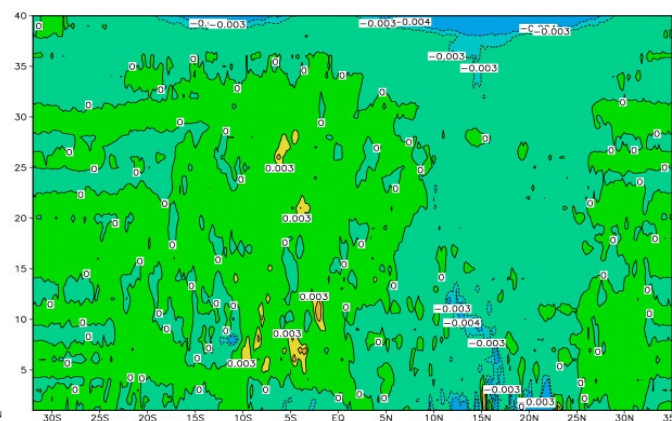
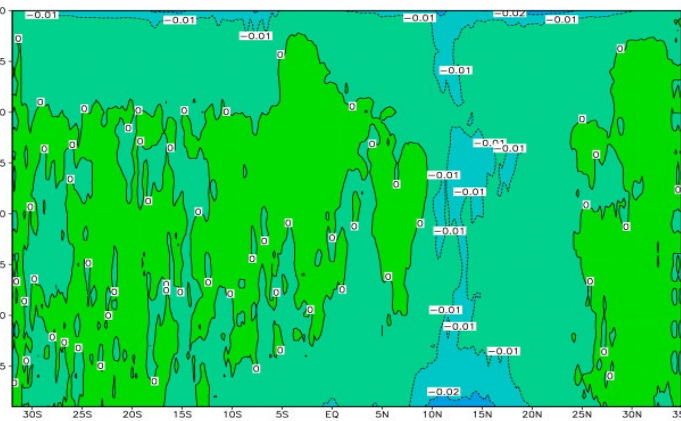
January 2006, “zonal” means for *Initialization Increments: AMSU-A experiment*

WIND : $\langle || V_{fc00} - V_{an} || \rangle$ (m/s)

TEMPERATURE : σ (T_{fc00}-T_{an}) (K)



CNTL



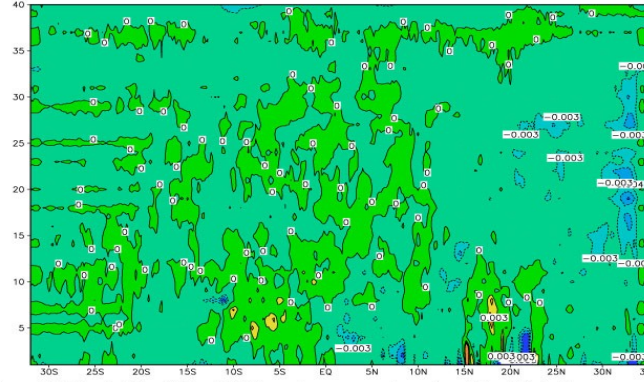
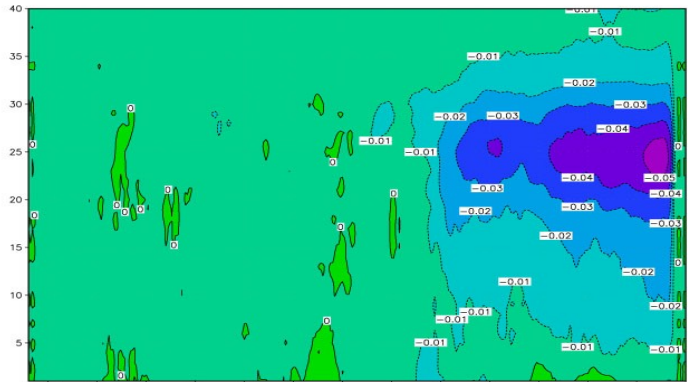
EXP

CNTL- EXP

January 2006, “zonal” means for *Initialization Increments*

WIND : $\langle || V_{fc00} - V_{an} || \rangle$ (m/s)

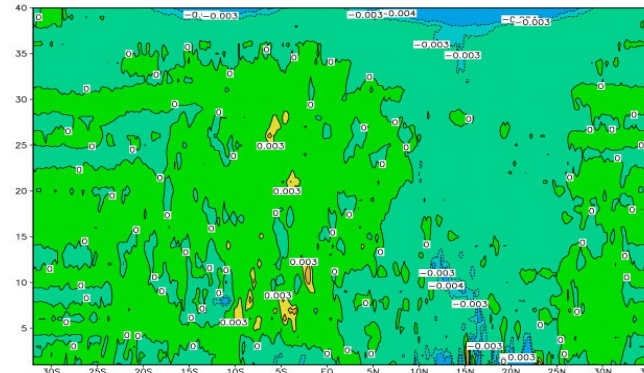
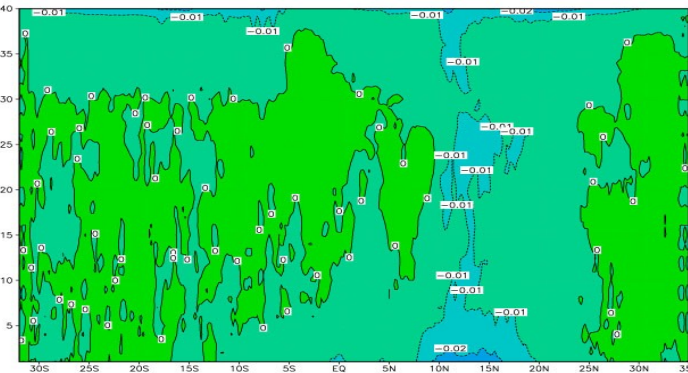
TEMPERATURE : σ (T_{fc00}-T_{an}) (K)



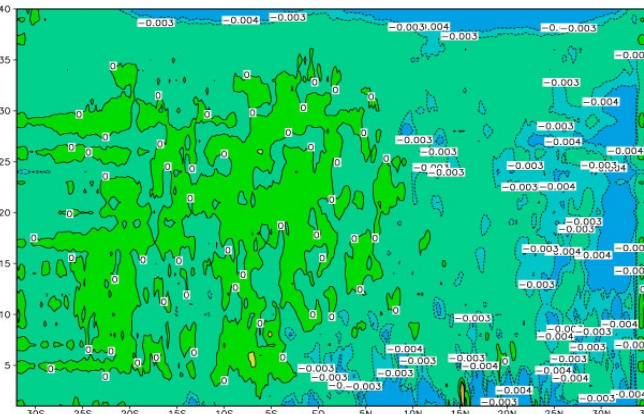
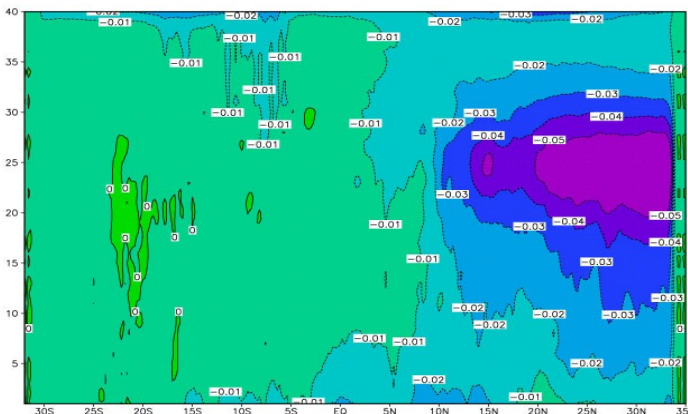
MODIS

January06 (fc00-an) M03 vs (fc00-an) M04 wind vec para., zonal mean in rotated grid (units m/s)

January06 (fc00-an) M03 vs (fc00-an) M04 Temperature para., zonal mean in rotated grid (units K)

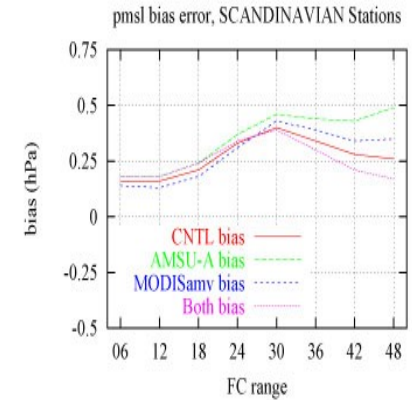
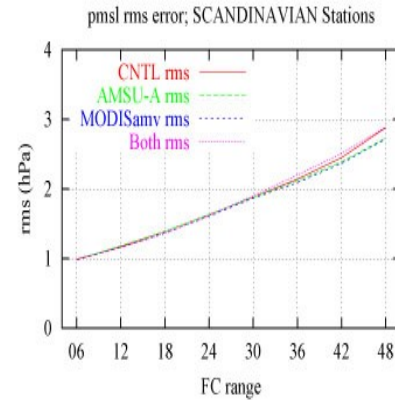
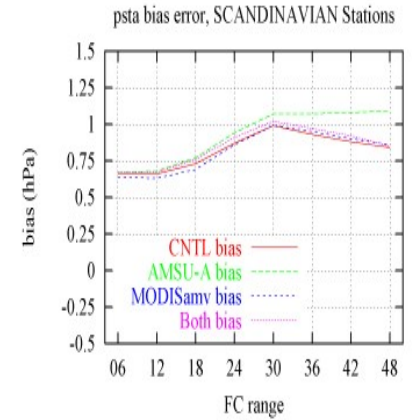
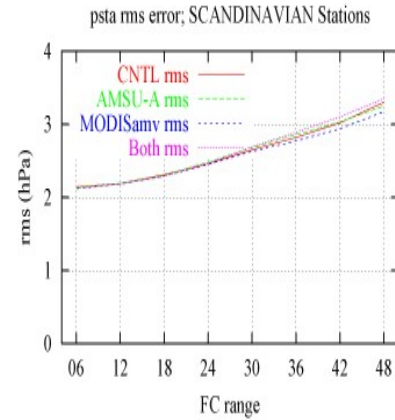
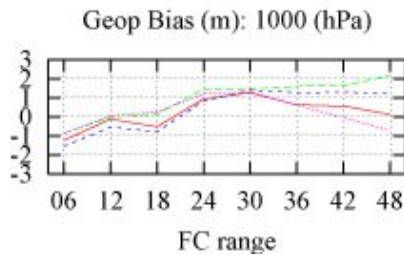
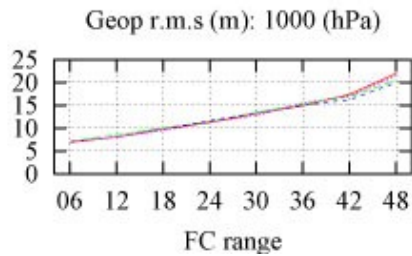
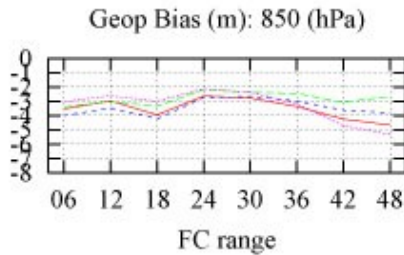
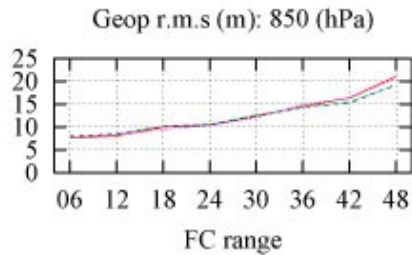
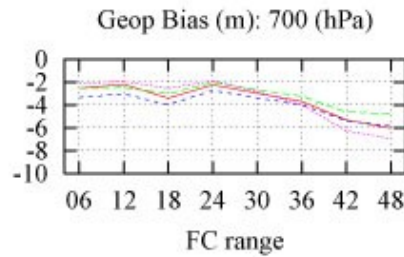
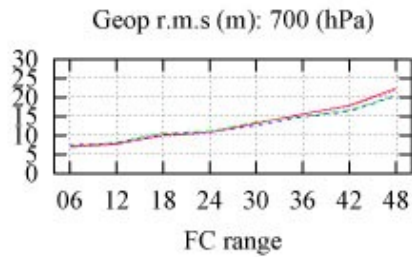
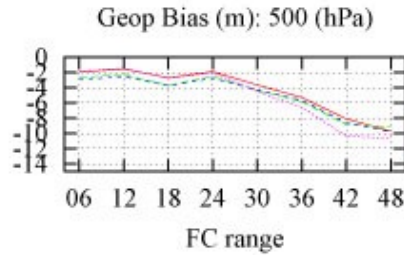
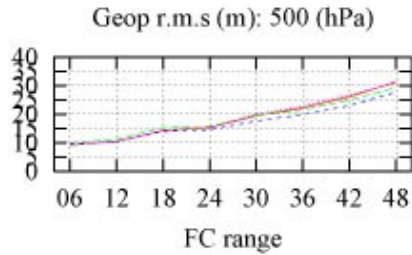
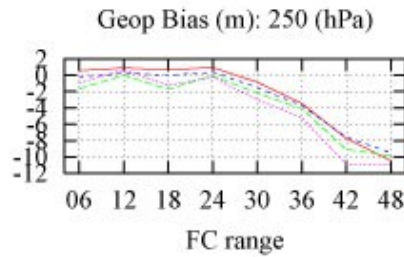
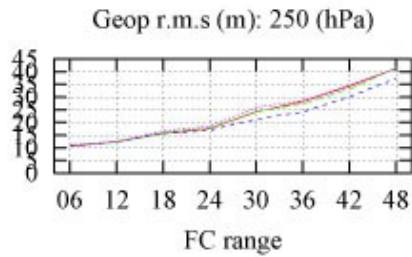


AMSU-A



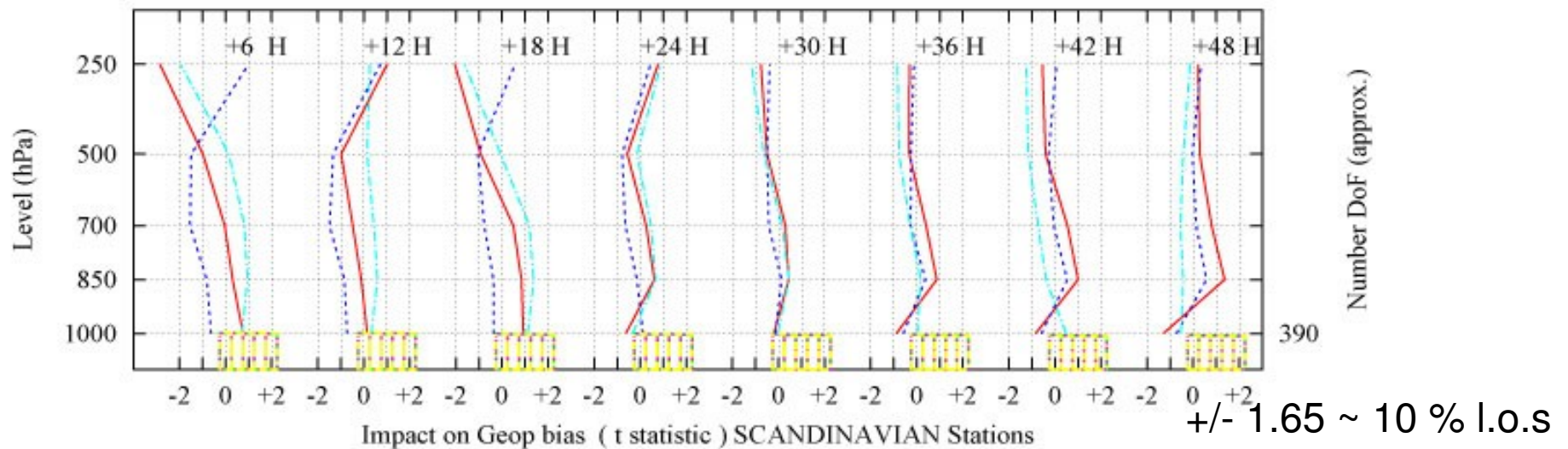
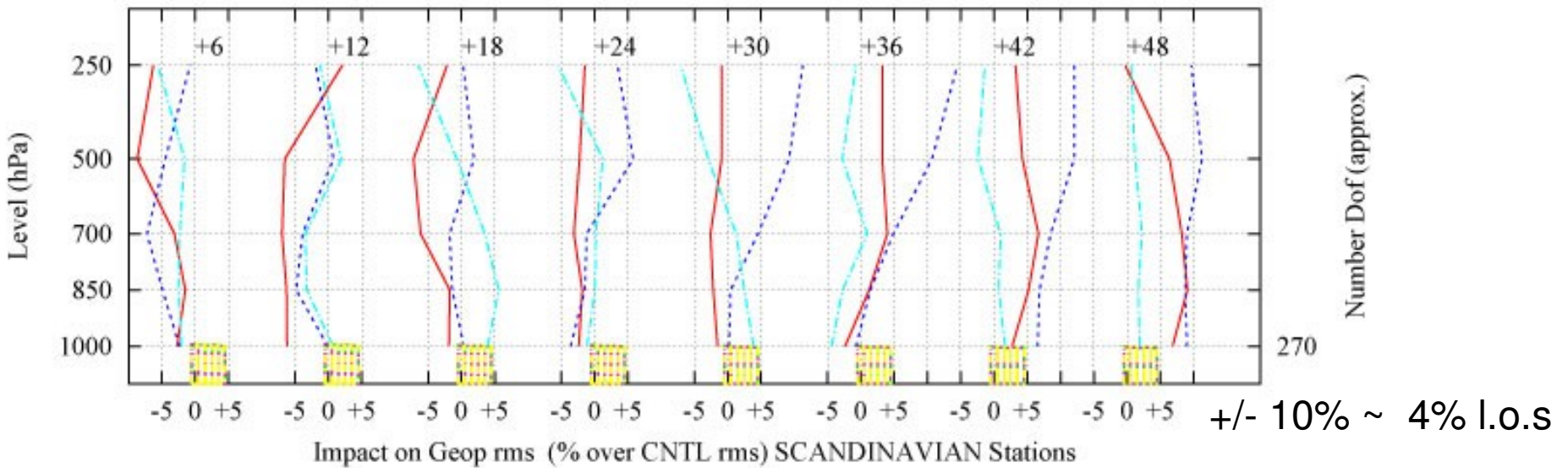
BOTH

SCA stations January06 MASS FIELD



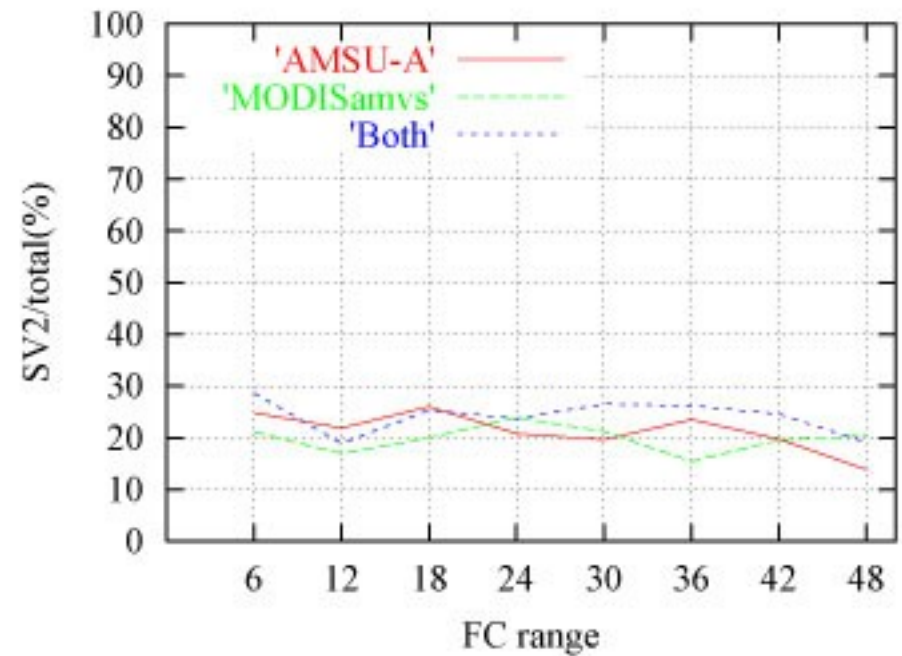
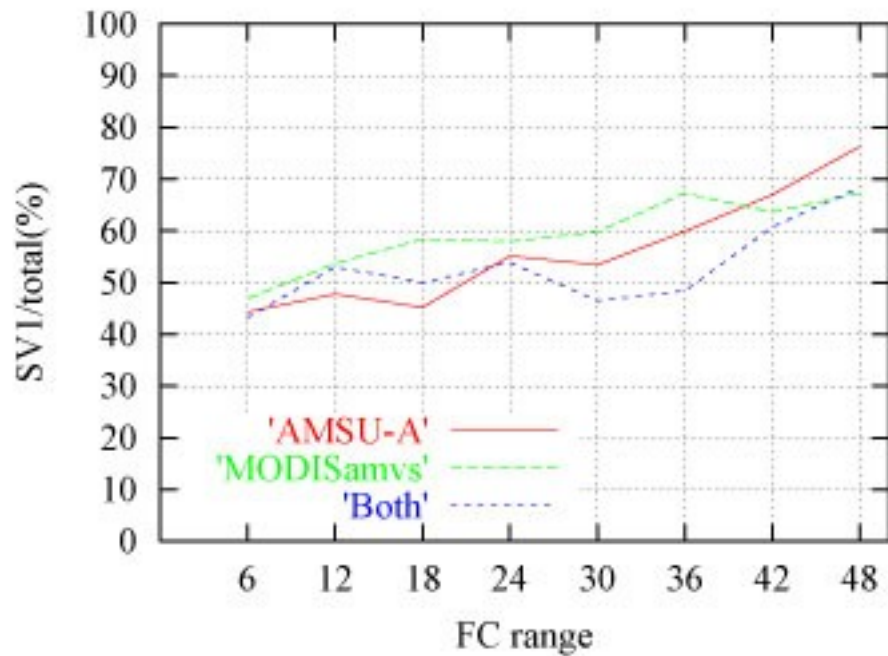
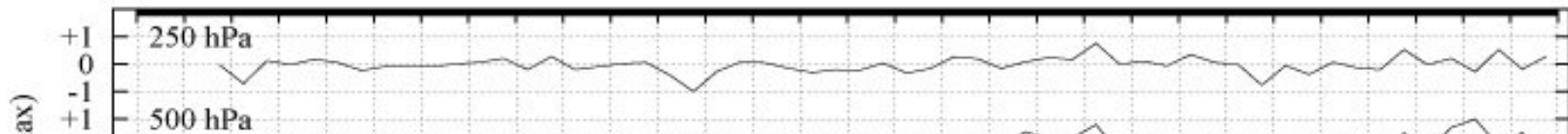
$$\text{BIAS} = \text{FCST} - \text{OBS}$$

SCA stations January06 MASS FIELD



SCA stations January06 VERTICAL STRUCTURE of the IMPACT on MASS FIELD

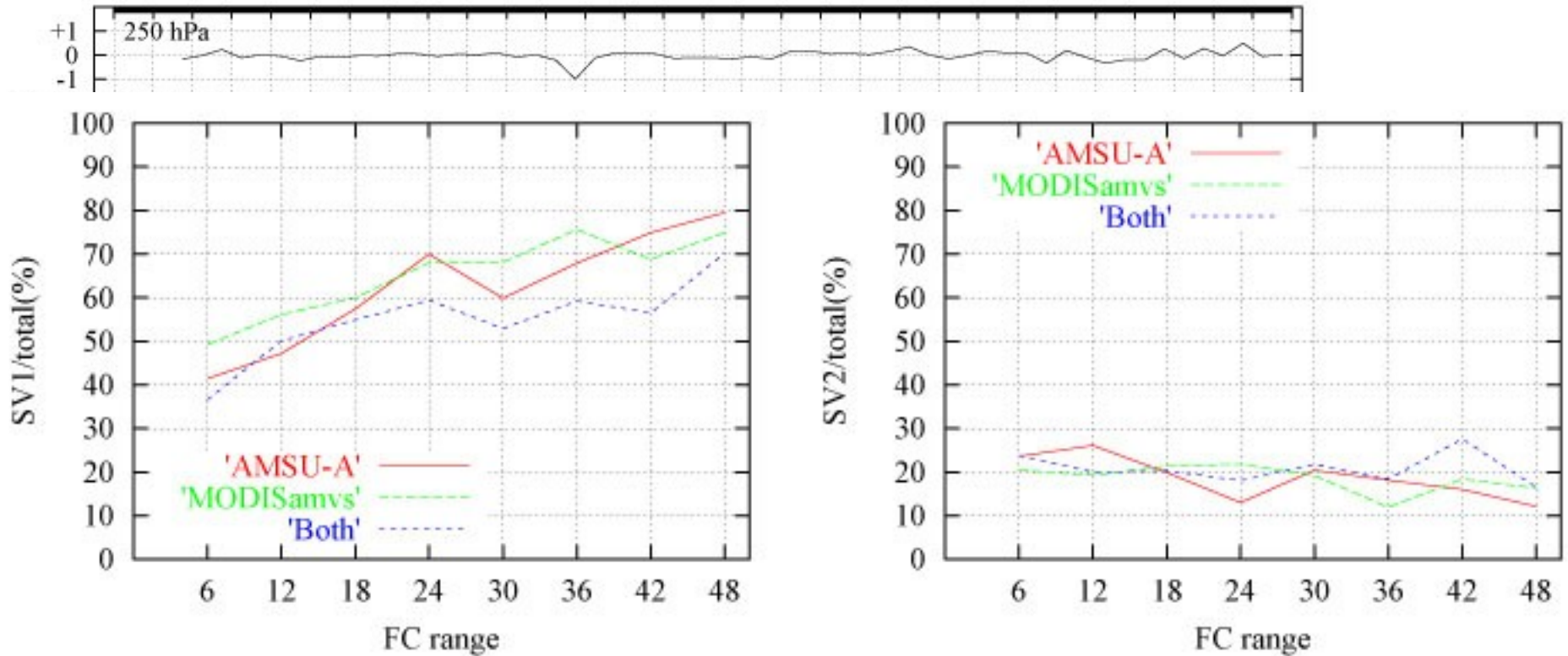
SCA FC: +06



diff / max(diff) ; where diff = abs (BIASctl) – abs (BIASexp)

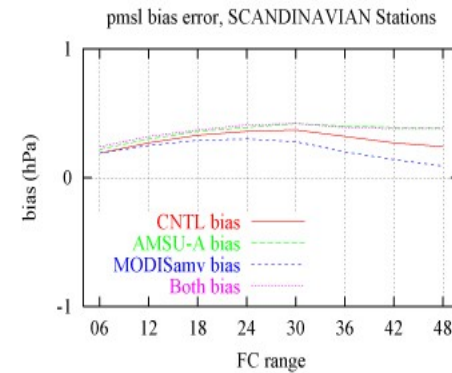
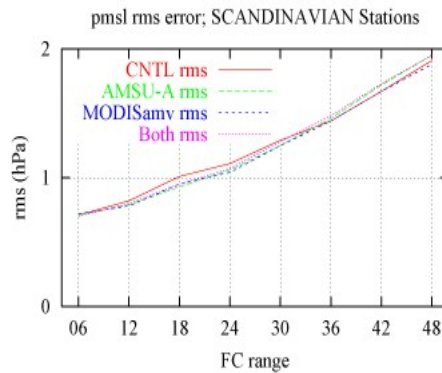
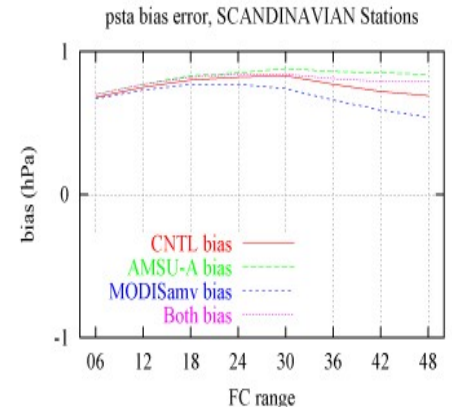
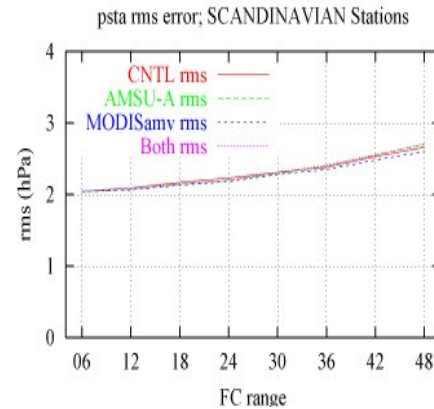
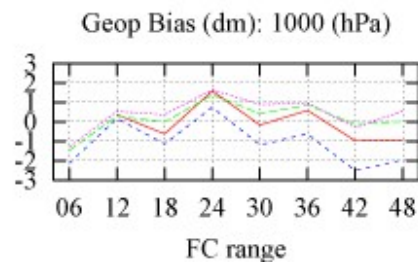
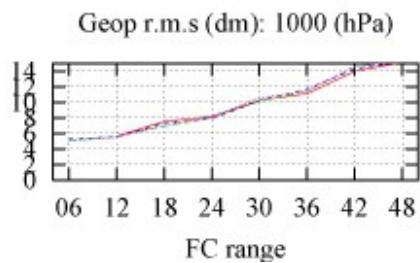
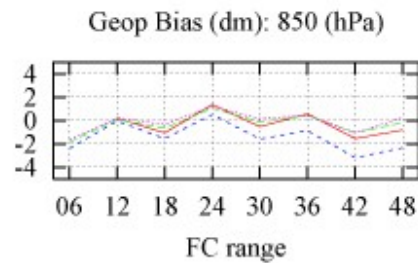
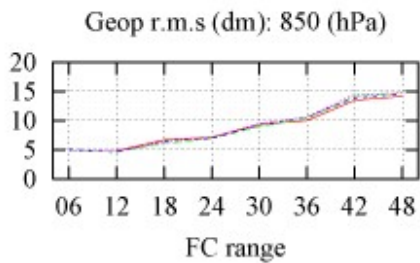
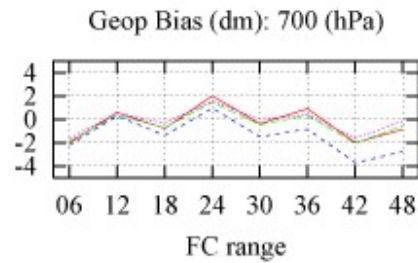
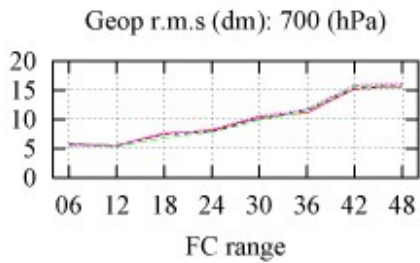
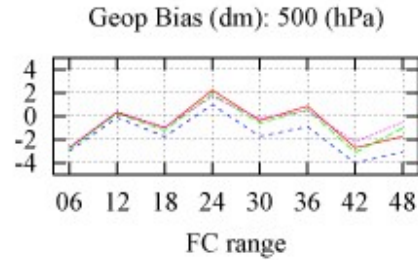
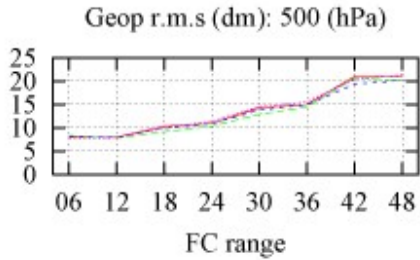
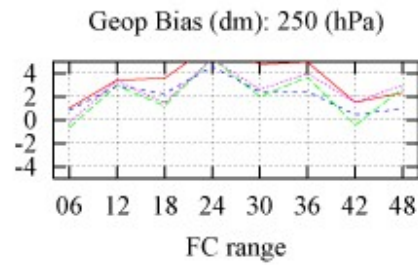
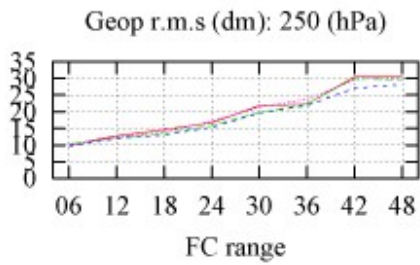
SCA stations January06 VERTICAL STRUCTURE of the IMPACT on MASS FIELD

SCA FC: +06



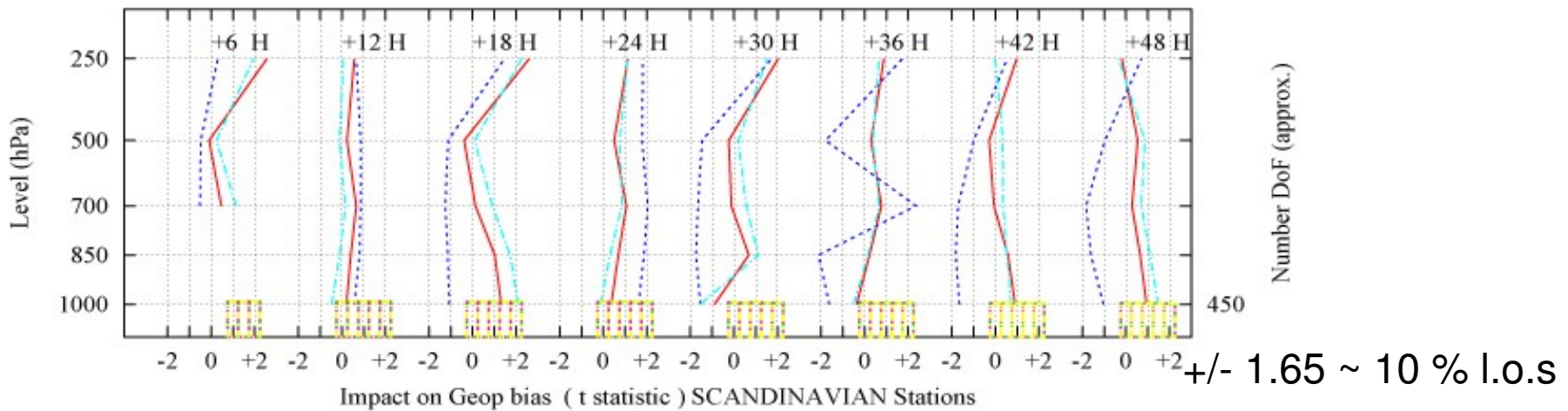
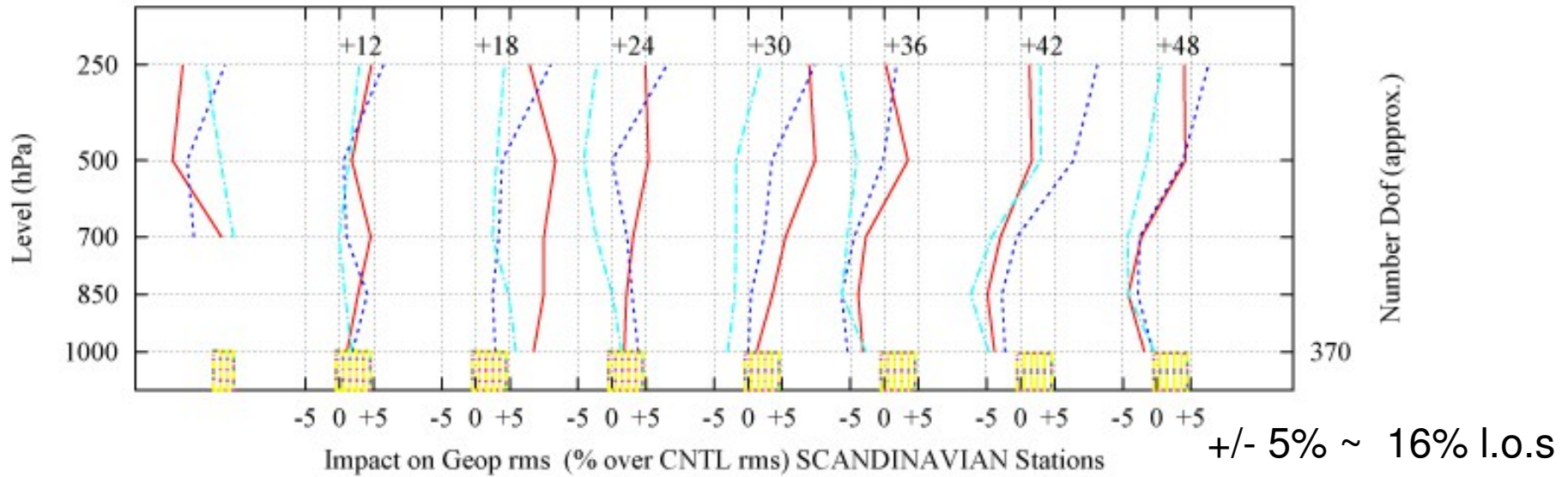
diff / max(diff) ; where diff = RMScntl – RMSexp

SCA stations July06 MASS FIELD

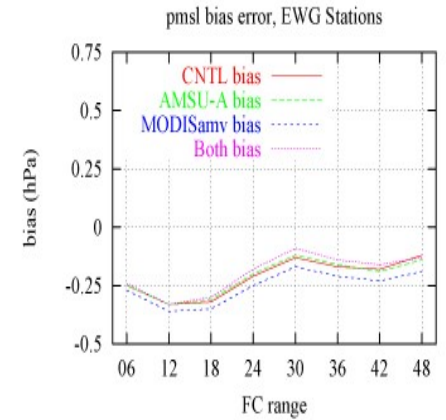
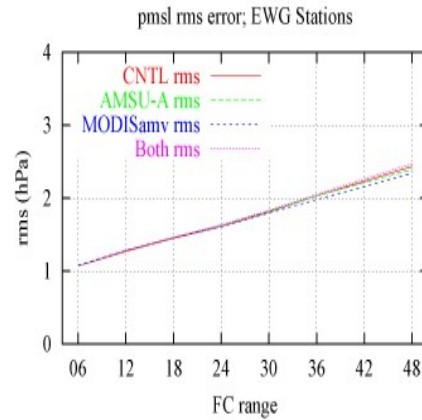
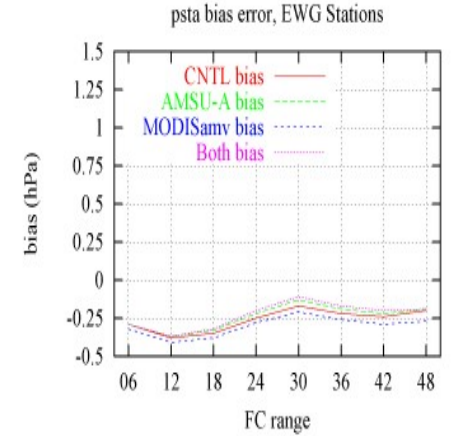
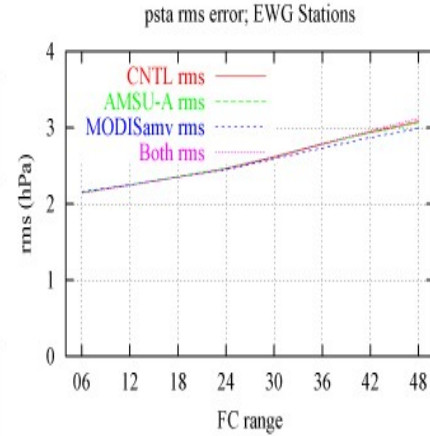
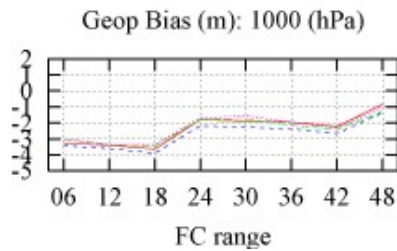
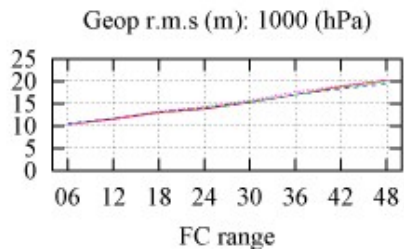
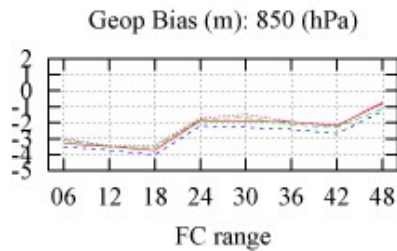
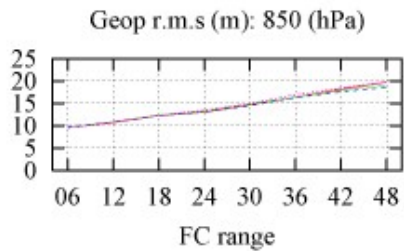
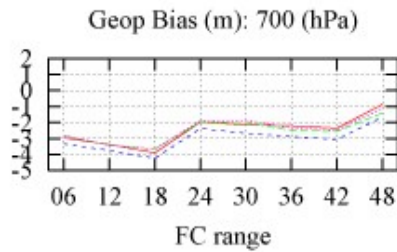
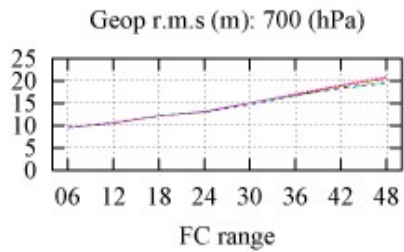
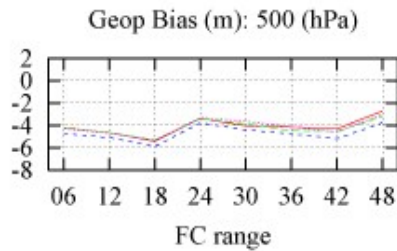
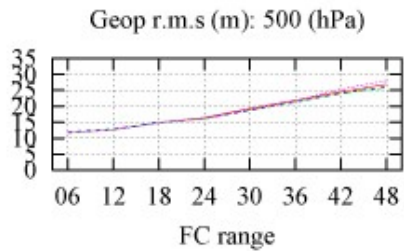
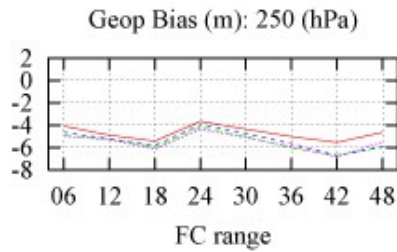
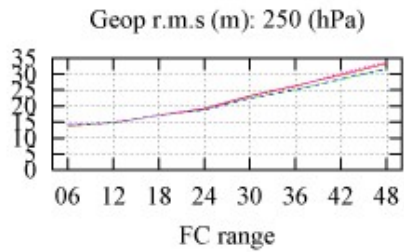


$$\text{BIAS} = \text{FCST} - \text{OBS}$$

SCA stations July06 MASS FIELD

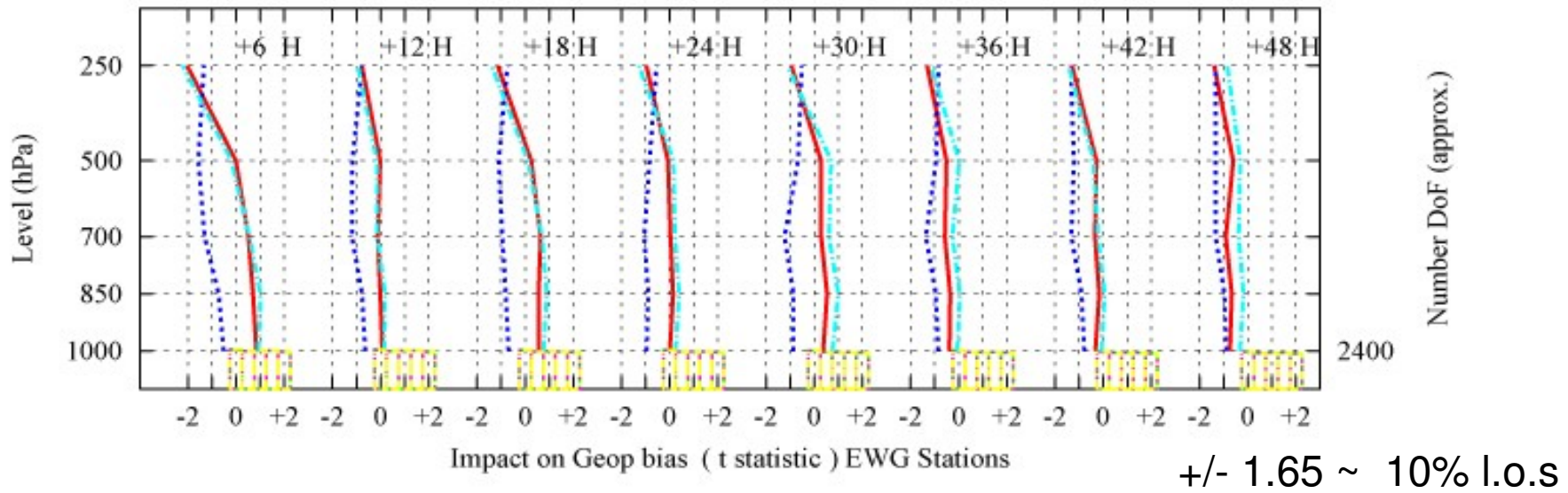
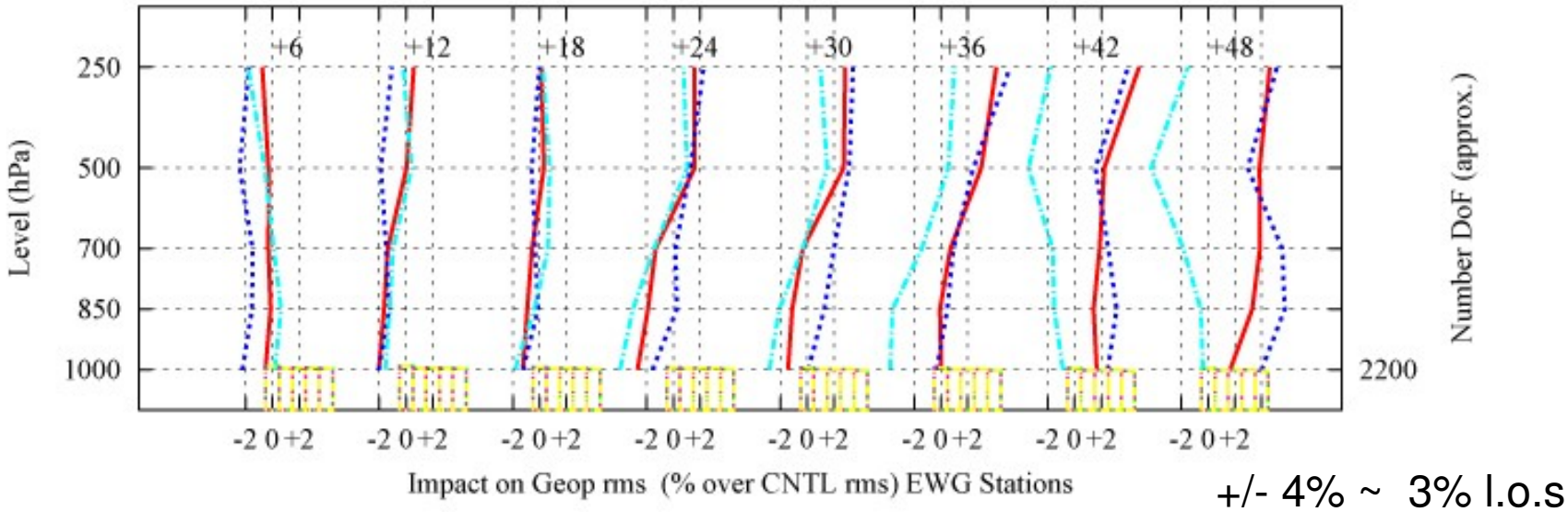


EWG stations January 06 MASS FIELD

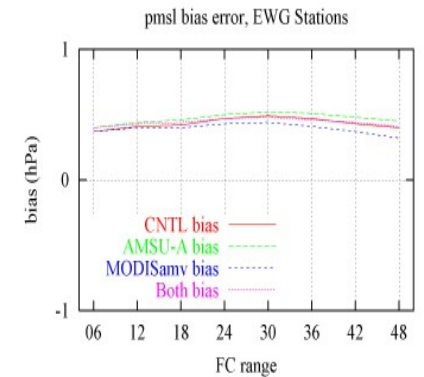
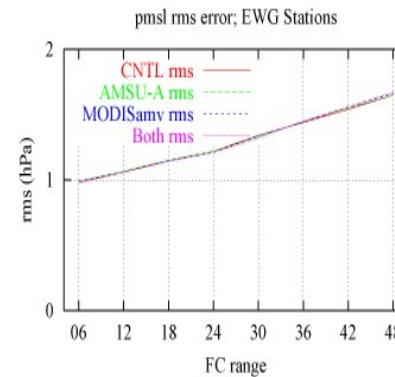
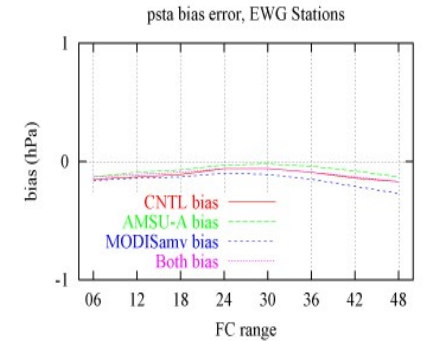
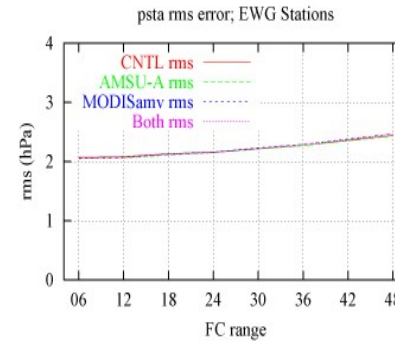
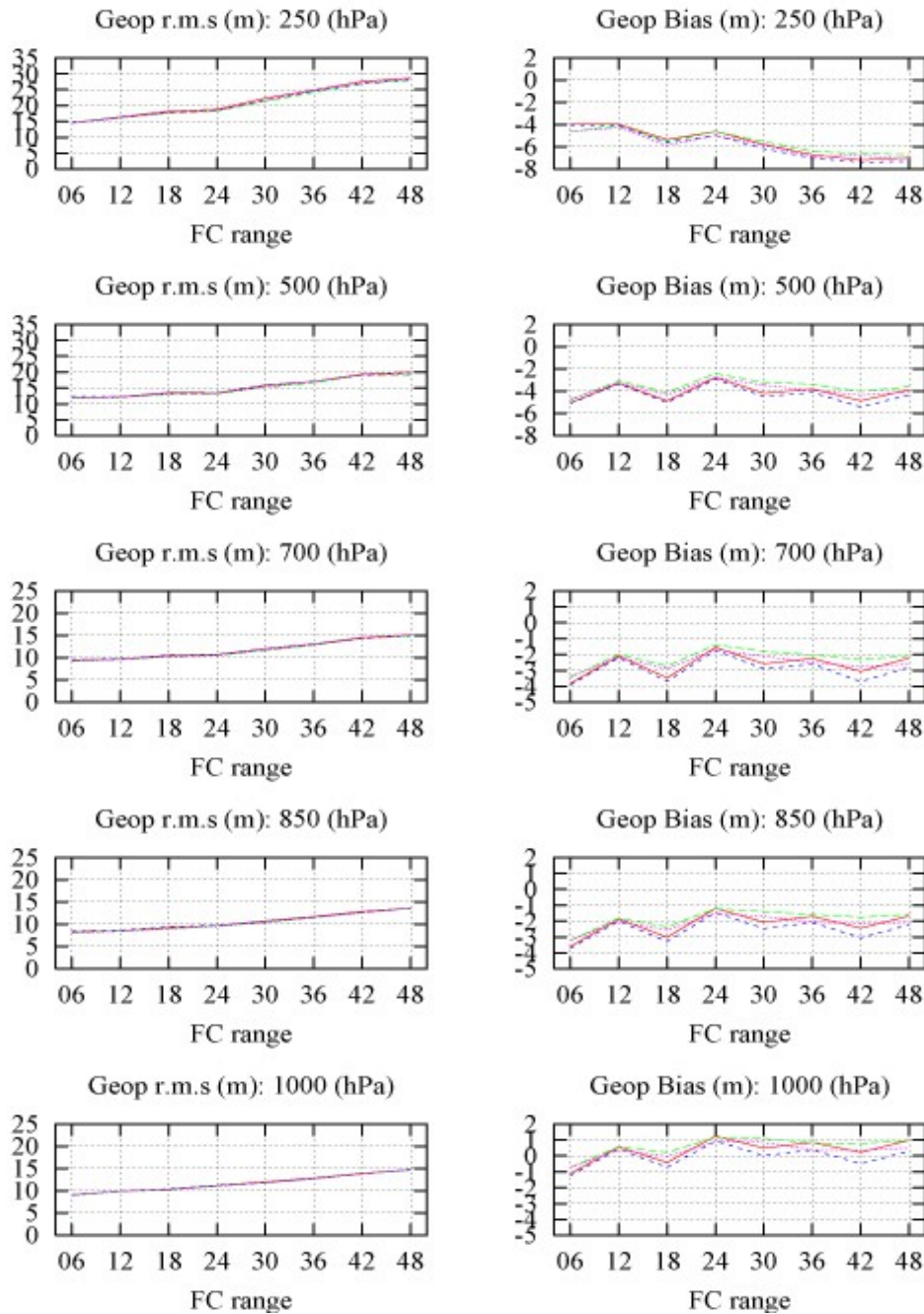


$$\text{BIAS} = \text{FCST} - \text{OBS}$$

EWG stations January 06 MASS FIELD



EWG stations July06 MASS FIELD



$$\text{BIAS} = \text{FCST} - \text{OBS}$$

EWG stations July 06 MASS FIELD

