Assimilation of GPS RO observations at NCEP

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NOAA/NCEP

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Outline

- Introduction
- Recent work on Forward Operators
- Use of GPS RO at Central Weather Bureau (Taiwan)
  - Collaborative Project between NOAA and CWB to support RO work and GSI (NCEP's analysis) implementation in Taiwan, including the RO algorithms
  - CWB transitioned to GSI operationally in 2010072800

Introduction

- **COSMIC became operationally assimilated at NCEP on 1 May 2007** (GFS, Global Forecast System)
- Observations from **Metop/GRAS and GRACE-A** were added to the operational observing system in **February 2010**
- The assimilation of COSMIC (and other GPS RO sensors) into the regional system (NAM) is under pre-operational testing
- Evaluation of SAC-C and TSX is underway
- Expect to evaluate C/NOFS very soon
- Results show that **RO is a very significant component of the observing system and that we have not reached saturation in model skill with the current RO constellation**

Improved algorithms for N

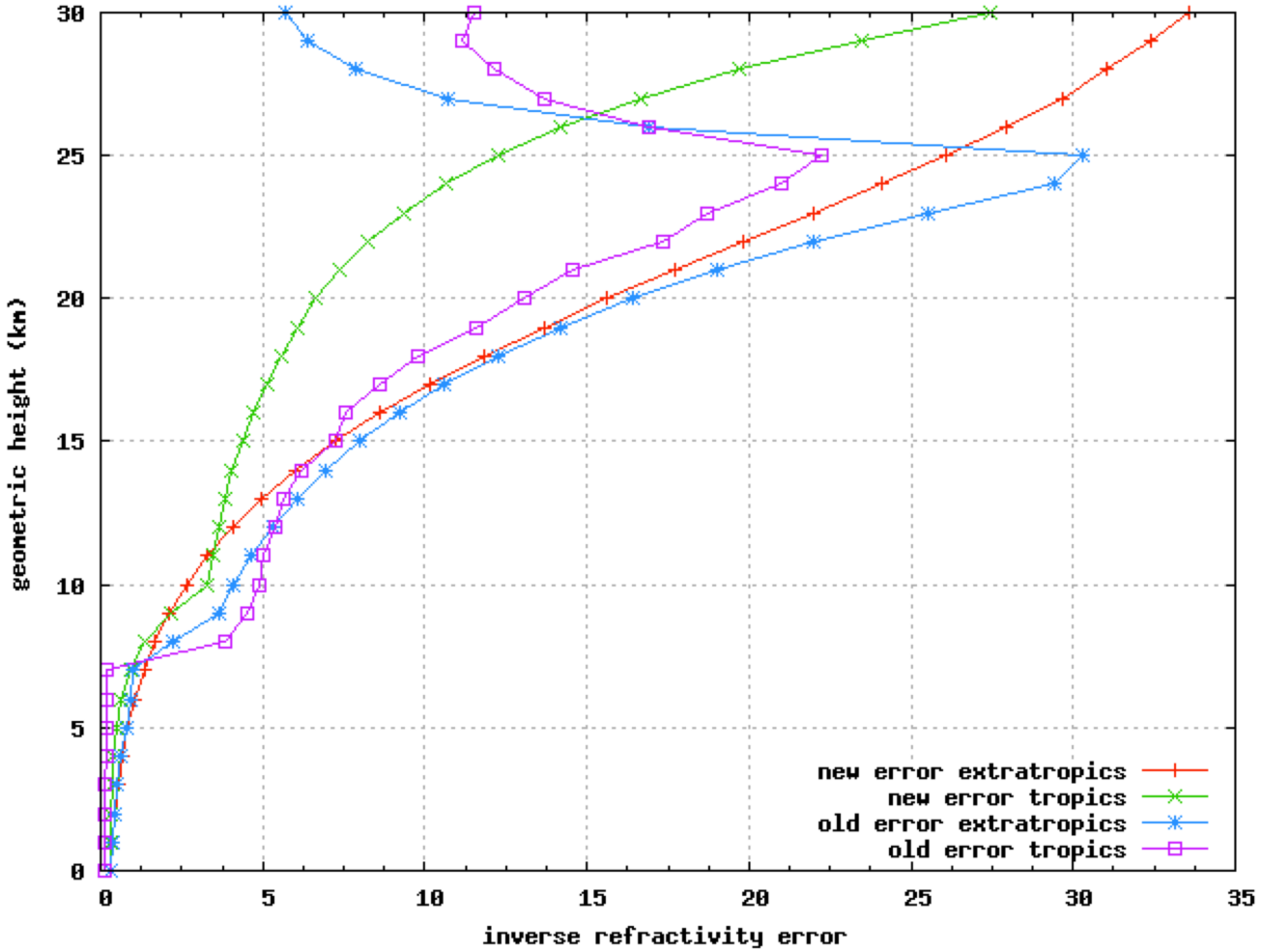
- More accurate forward operator for refractivity
  - Three term expression
  - Analysis of different sets of refractive indexes
- Update of the quality control procedures
  - More observations (in particular in tropical latitudes)
- Optimal observation error characterization (*Desroziers 2005*)
  - Smoother normalized differences
  - No empirical tuning
- Changes resulted in an improvement in model skill in SH (mass fields) and reduction of the low- and high-level tropical wind errors
- **These changes were implemented operationally at NCEP in Dec 2009**
- Detailed description of the changes and results can be found in *Cucurull 2010, WAF,* **25**,2,769-787

3-term Forward Operator for refractivity

$$N = 77.60\frac{P_d}{T} + 70.4\frac{P_w}{T} + 3.739 \times 10^5 \frac{P_w}{T^2}$$

- (1) Geometric height of observation is converted to geopotential height.
- (2) Observation is located between two model levels.
- (3) Model variables of pressure, (virtual) temperature and specific humidity are interpolated to observation location.
- (4) Model refractivity is computed from the interpolated values.
- The assimilation algorithm produces increments of
  - surface pressure
  - water vapor of levels surrounding the observation
  - (virtual) temperature of levels surrounding the observation and all levels below the observation (ie. an observation is allowed to modify its position in the vertical)

- Each observation is treated independently and we account for the drift of the tangent point within a profile

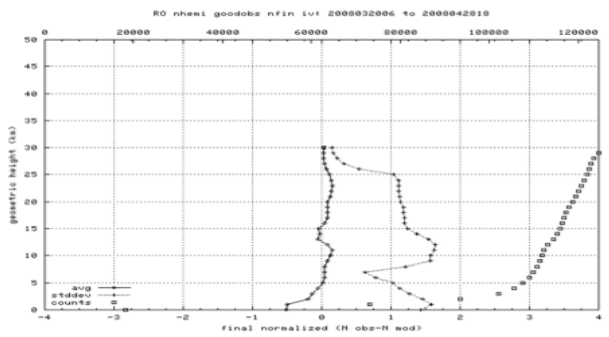

geometric height (km)
inverse refractivity error
0
5
10
15
20
25
30
35
new error extratropics
new error tropics
old error extratropics
old error tropics

(O-B)/O_err

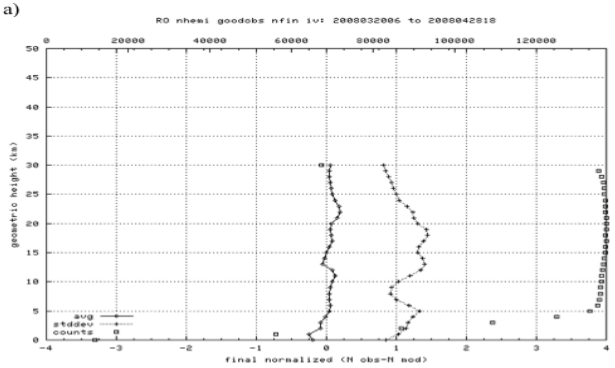
Original QC & error

modified QC & error

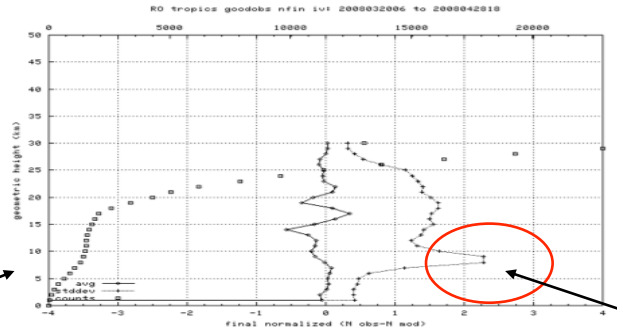
a)



NH



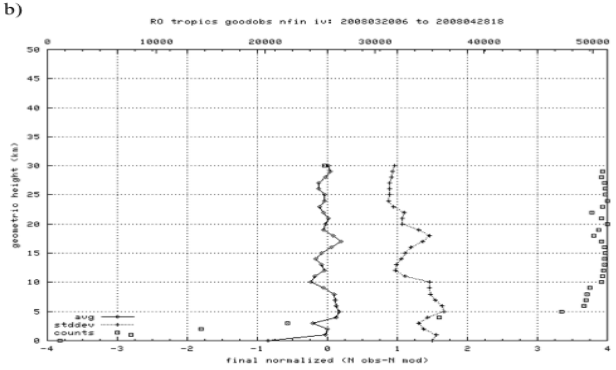
b)



TR

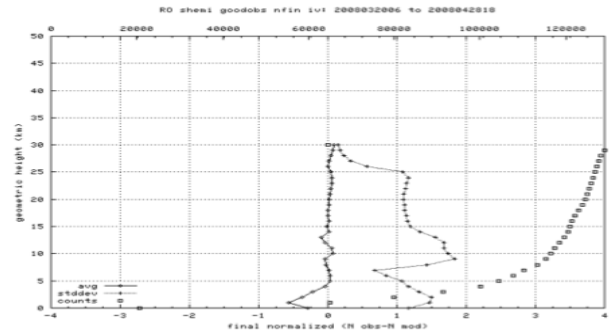
Very few observations

Errors too small

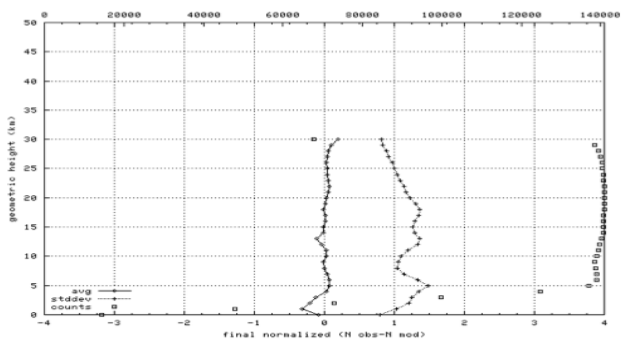


Many more Observations !!

c)

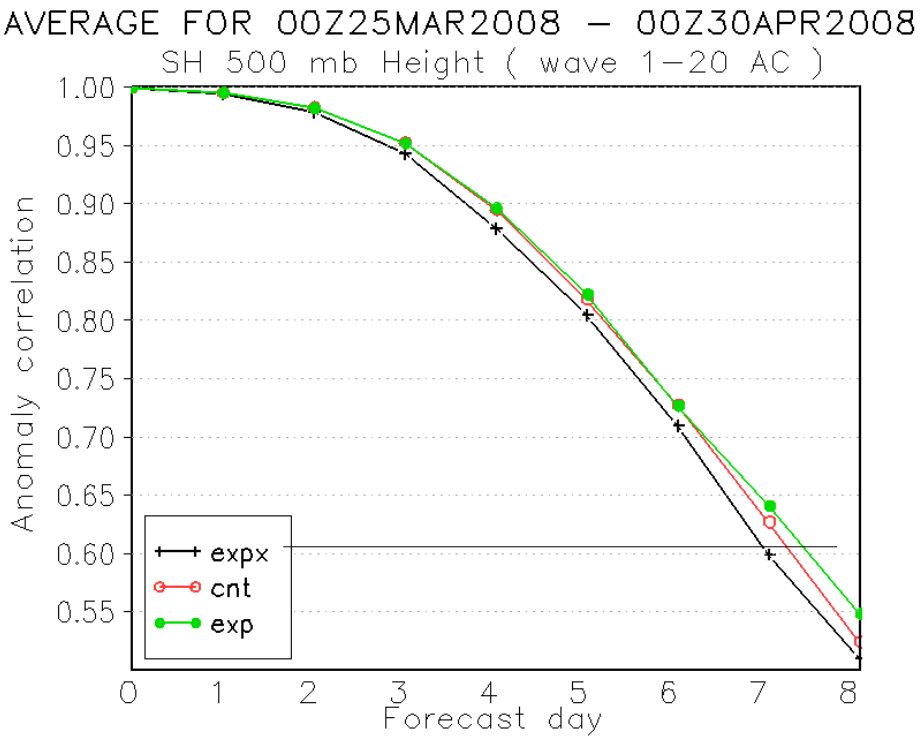


SH



Impact with COSMIC

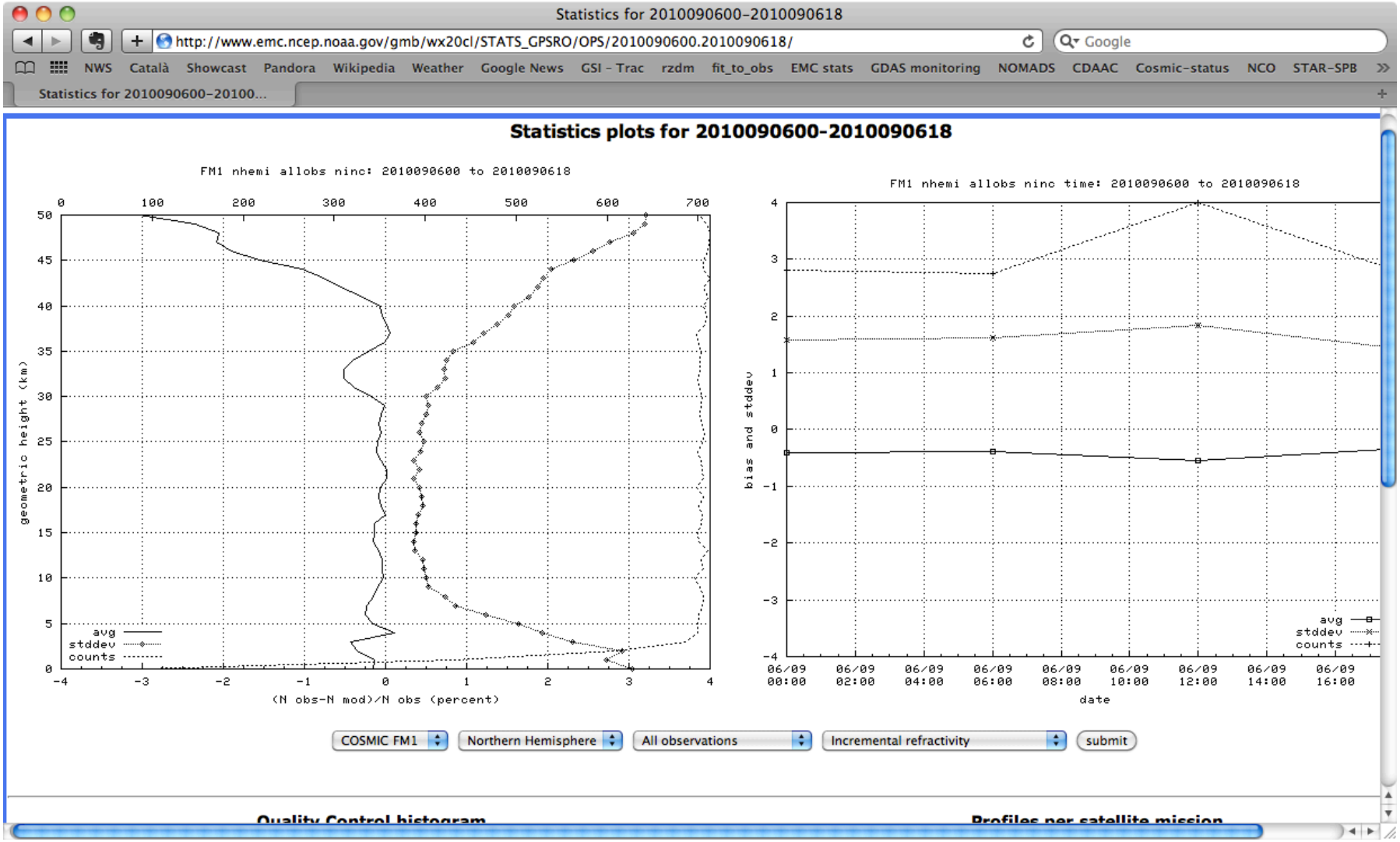
- AC scores (the higher the better) as a function of the forecast day for the 500 mb gph in Southern Hemisphere
- 40-day experiments:
  - **expx (NO COSMIC)**
  - **cnt (old RO assimilation code - with COSMIC)**
  - **exp (ops**
  - **- with COSMIC)**



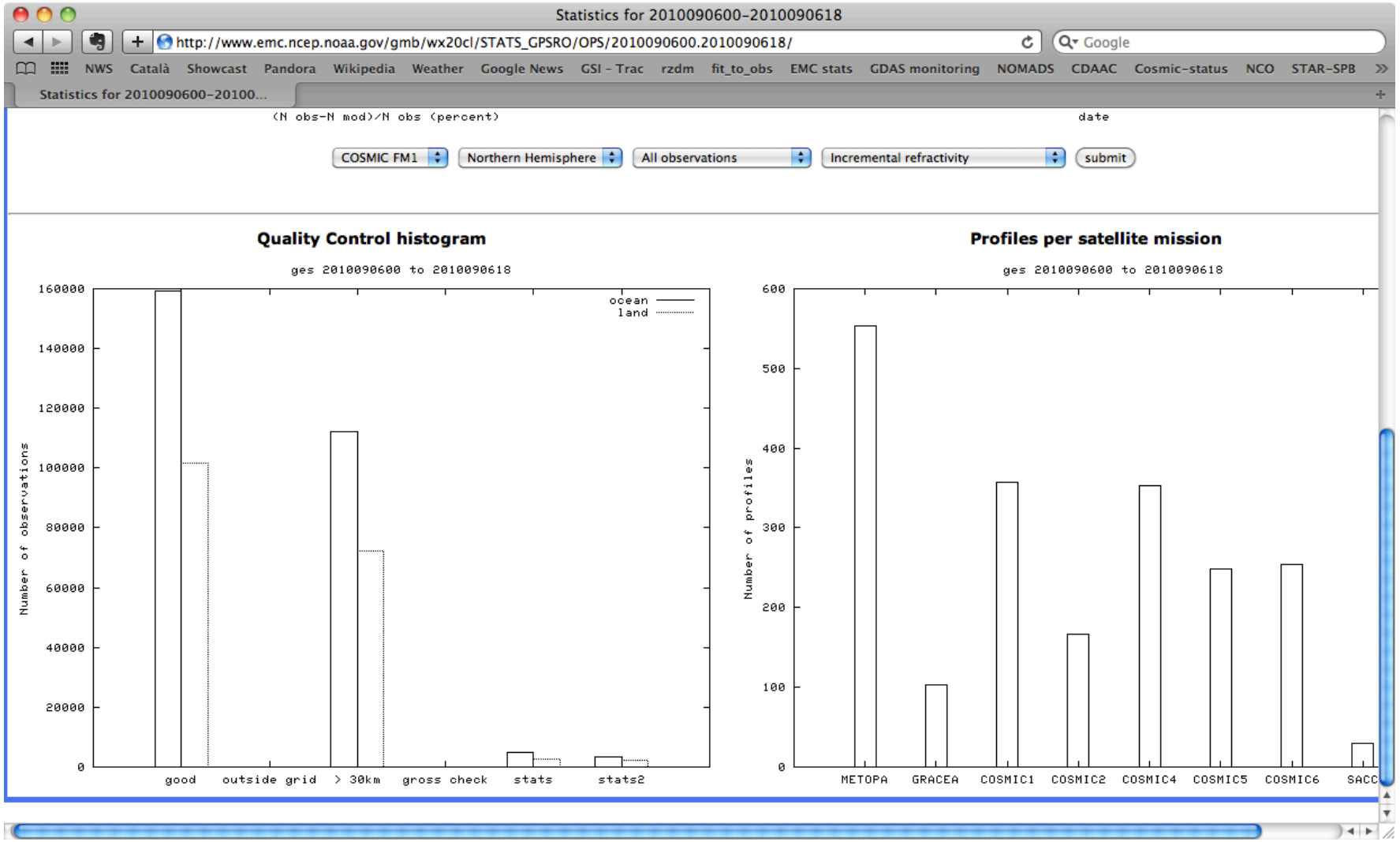
COSMIC provides 8 hours of gain in model forecast skill starting at day 4 !!!

Cucurull 2010 (WAF)

Statistics web-tool



Statistics web-tool (cont'd)



Forward Model for bending angle

$$\alpha(a) = -2a\int_a^\infty \frac{d\ln n / dx}{(x^2 - a^2)^{1/2}}\,dx$$

$$(x = nr)$$

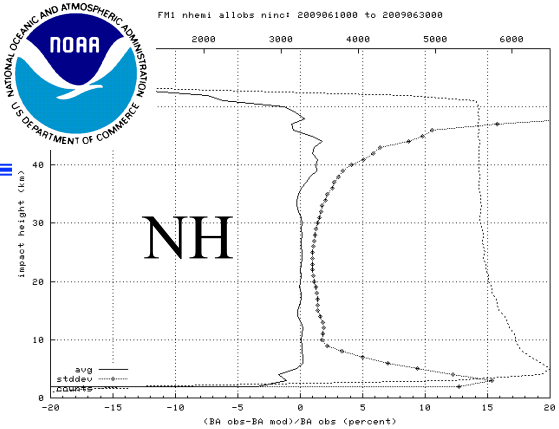
- Make-up of the integral:
  - Change of variable to avoid the singularity

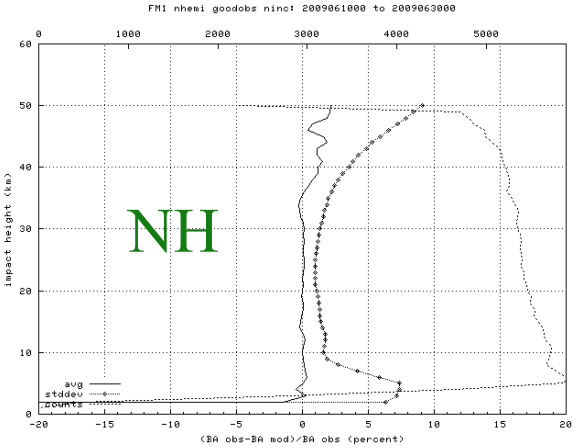
$$x = \sqrt{a^2 + s^2}$$

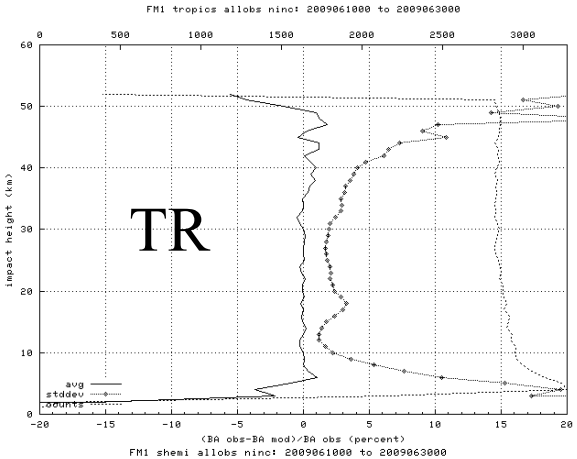
  - Choose an equally spaced grid to evaluate the integral by applying the trapezoid rule

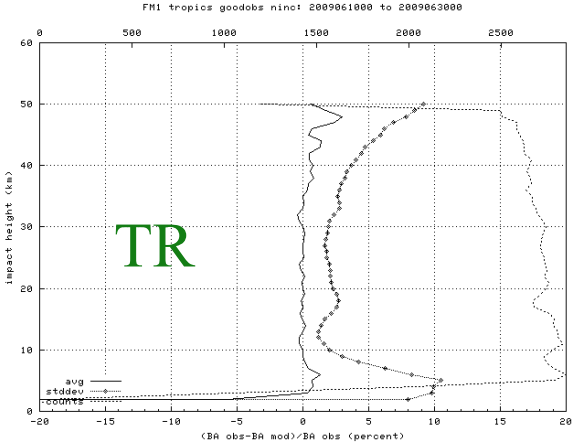
<u>Each observation is treated independently and we account for the drift of the tangent point within a profile</u>

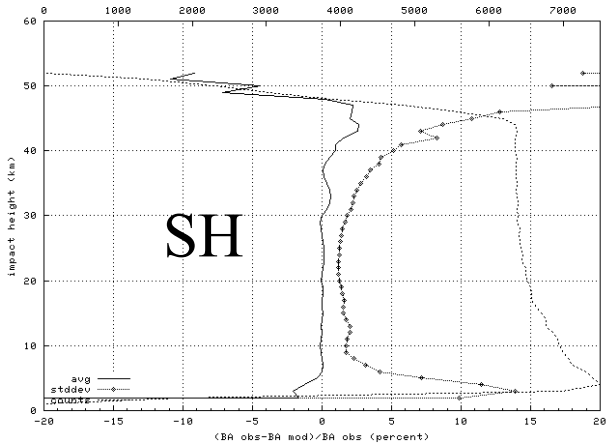
QC

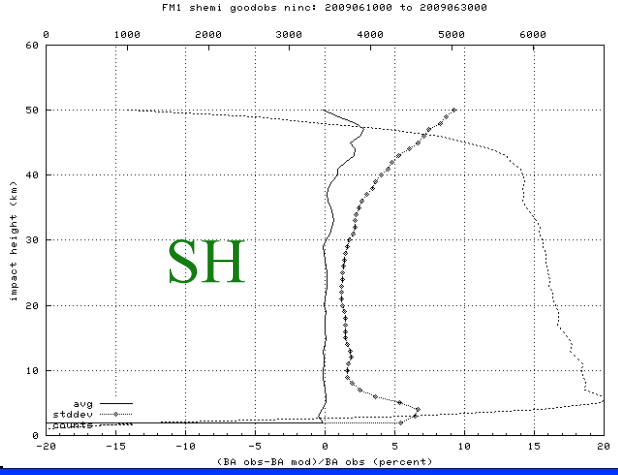

FM1 nhemi allobs ninc: 2009061000 to 2009063000
impact height (km)
(BA obs-BA mod)/BA obs (percent)
avg
stddev
counts
NH


FM1 nhemi goodobs ninc: 2009061000 to 2009063000
impact height (km)
(BA obs-BA mod)/BA obs (percent)
avg
stddev
counts
NH

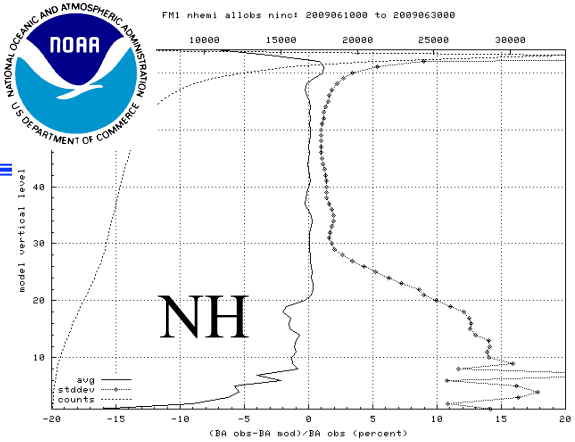

FM1 tropics allobs ninc: 2009061000 to 2009063000
impact height (km)
(BA obs-BA mod)/BA obs (percent)
avg
stddev
counts
TR

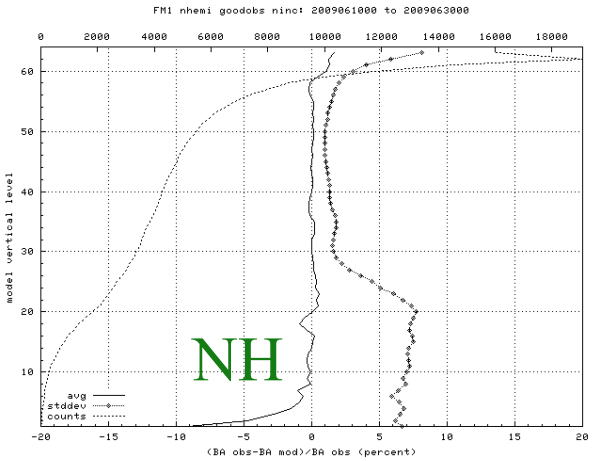

FM1 tropics goodobs ninc: 2009061000 to 2009063000
impact height (km)
(BA obs-BA mod)/BA obs (percent)
avg
stddev
counts
TR

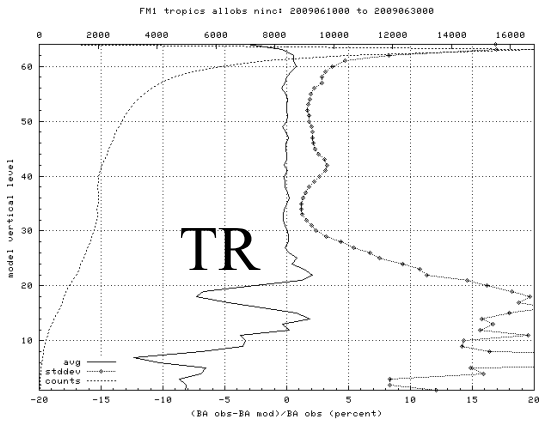

FM1 shemi allobs ninc: 2009061000 to 2009063000
impact height (km)
(BA obs-BA mod)/BA obs (percent)
avg
stddev
counts
SH

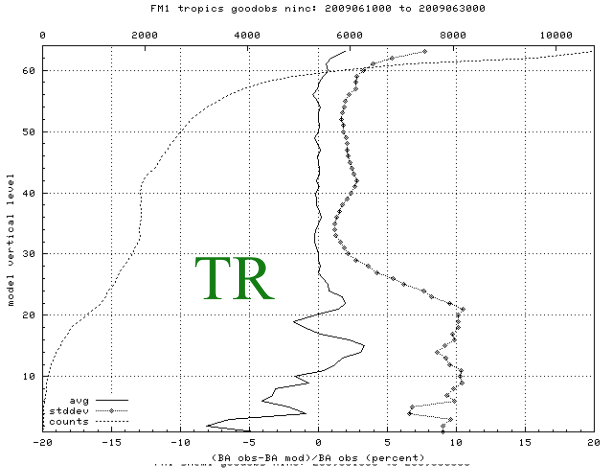

FM1 shemi goodobs ninc: 2009061000 to 2009063000
impact height (km)
(BA obs-BA mod)/BA obs (percent)
avg
stddev
counts
SH

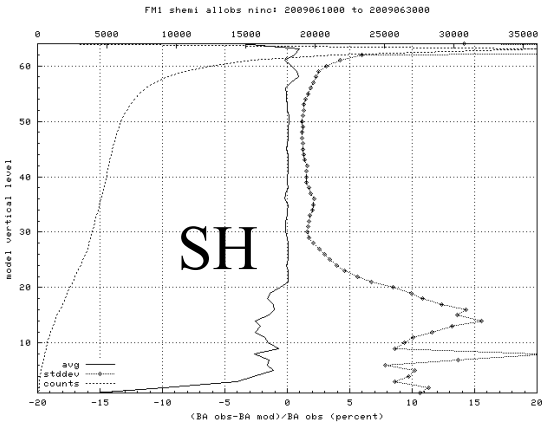
QC (model level)

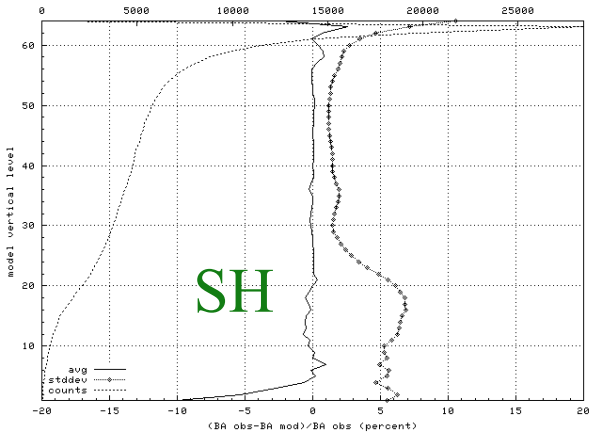




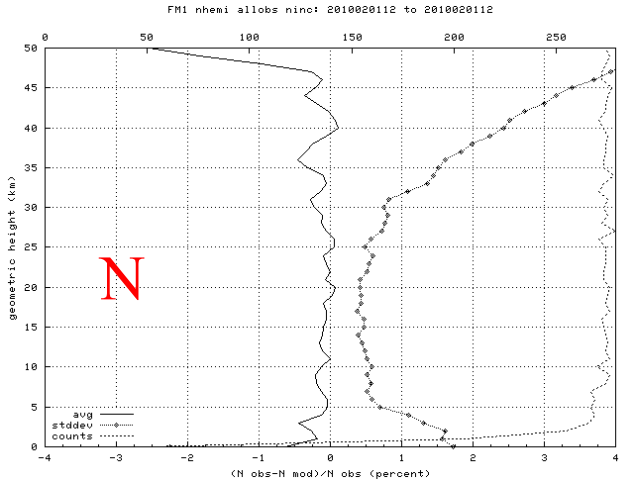


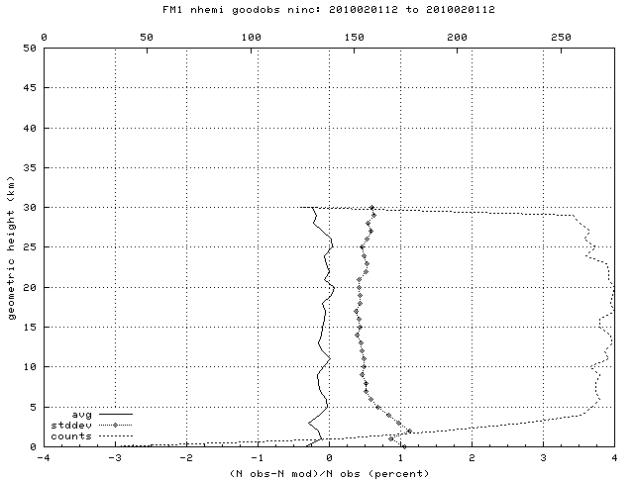


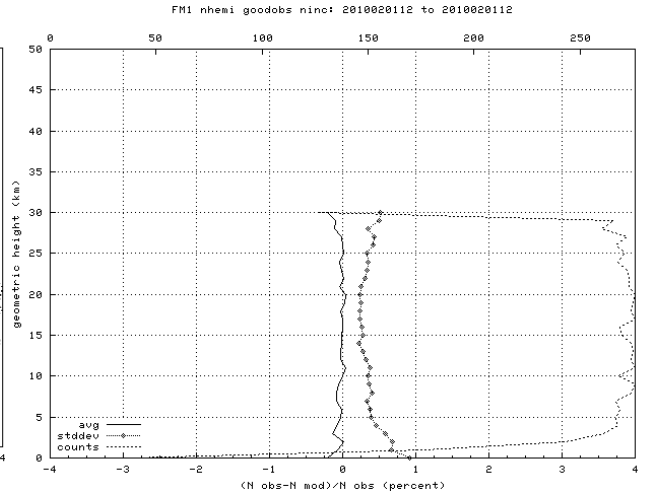


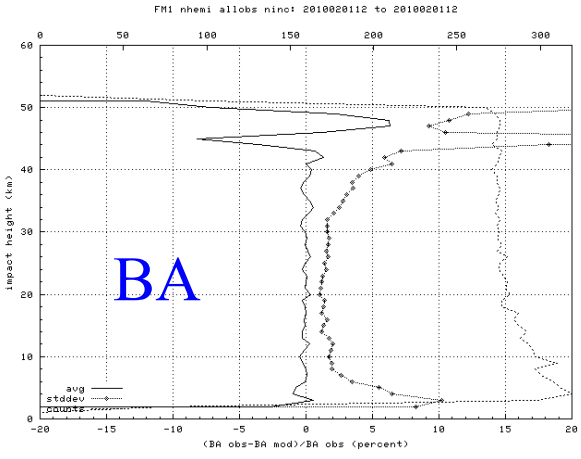


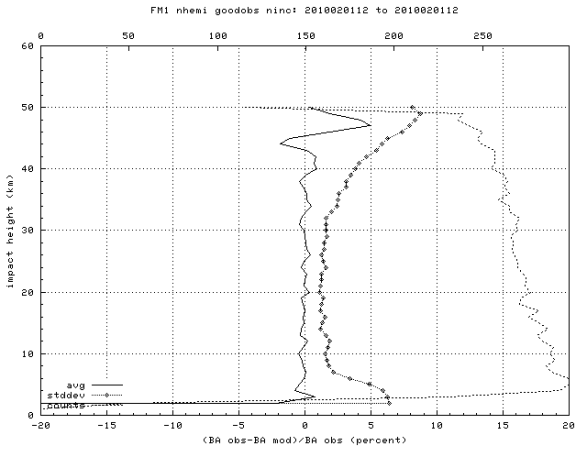
N vs BA (single case, T62L64)

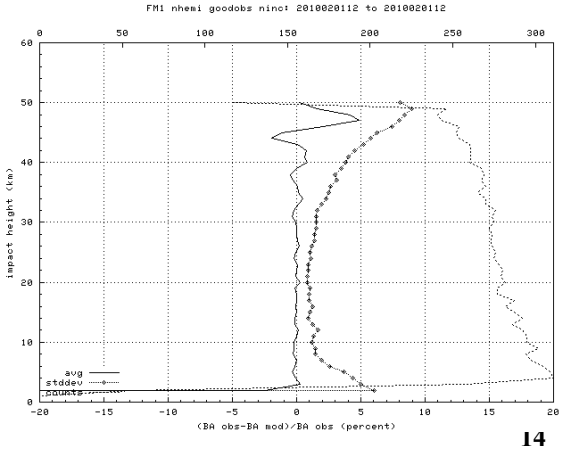


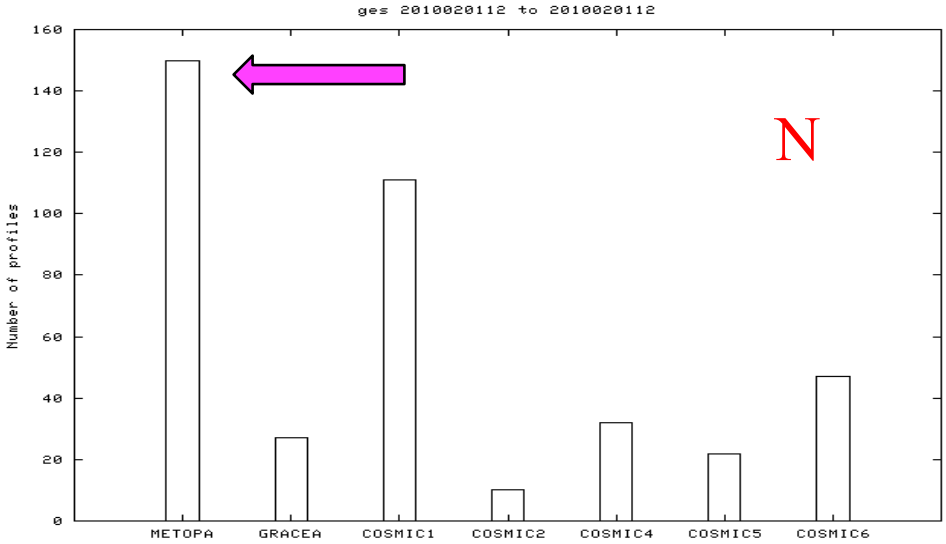


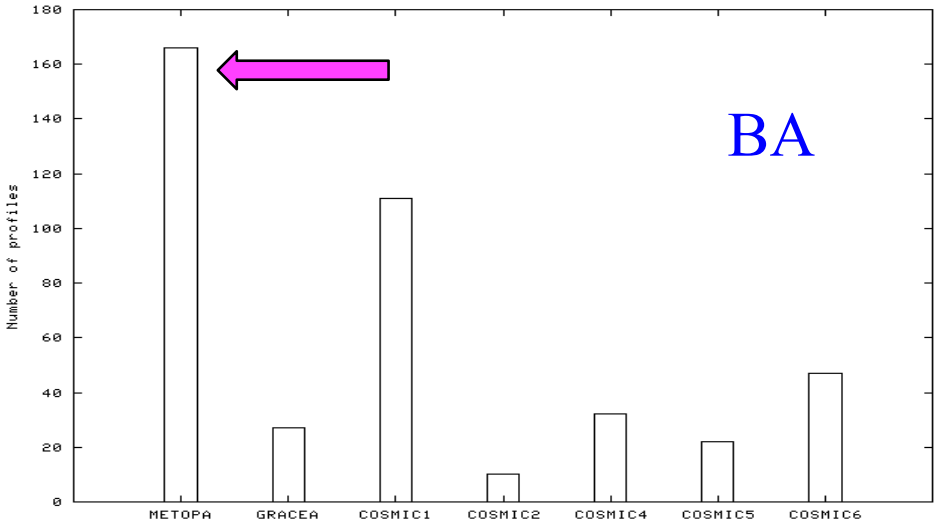


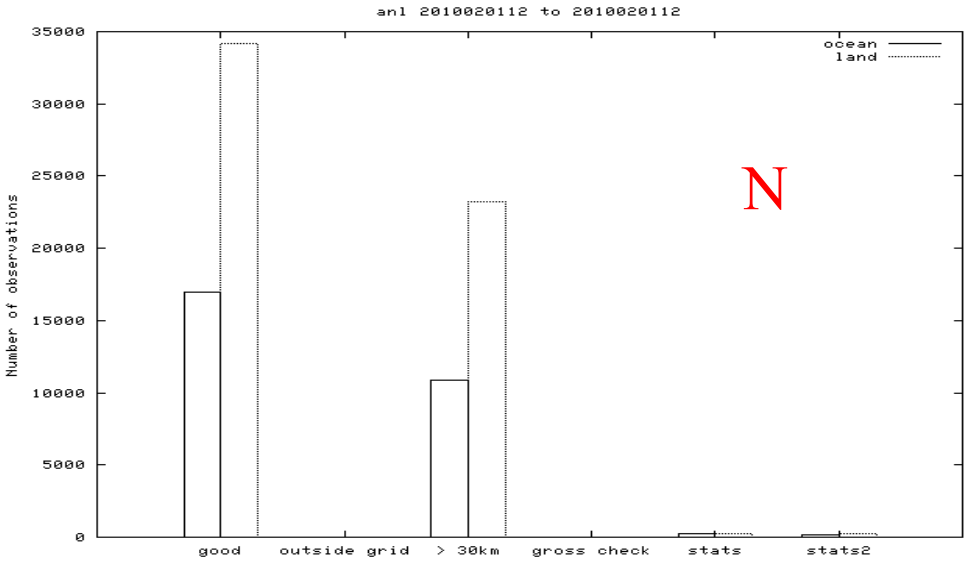


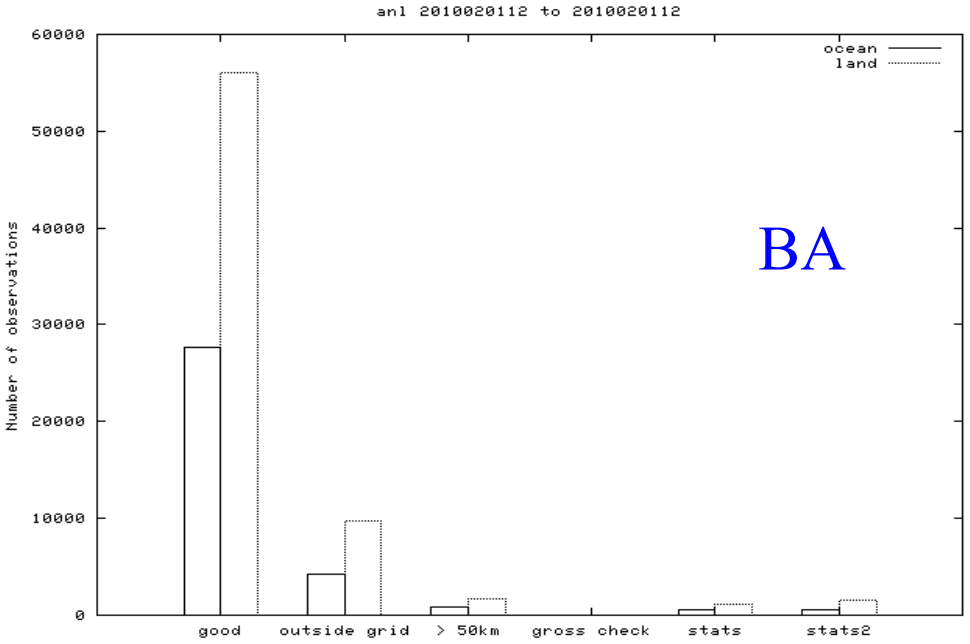





ges 2010020112 to 2010020112
Number of profiles
0
20
40
60
80
100
120
140
160
METOPA
GRACEA
COSMIC1
COSMIC2
COSMIC4
COSMIC5
COSMIC6
N


Number of profiles
0
20
40
60
80
100
120
140
160
180
METOPA
GRACEA
COSMIC1
COSMIC2
COSMIC4
COSMIC5
COSMIC6
BA

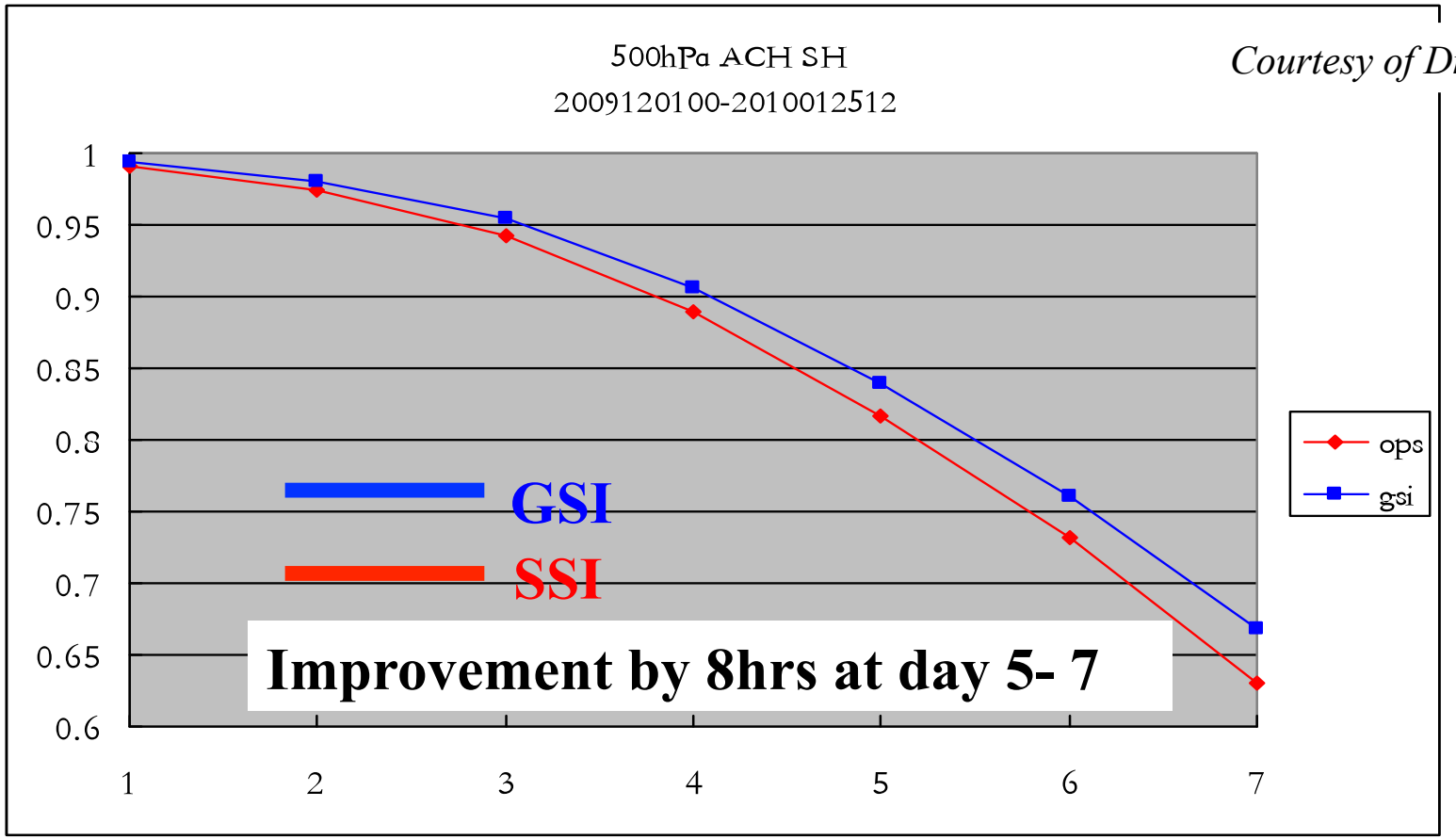

anl 2010020112 to 2010020112
ocean
land
N
Number of observations
35000
30000
25000
20000
15000
10000
5000
0
good
outside grid
> 30km
gross check
stats
stats2


anl 2010020112 to 2010020112
ocean
land
BA
Number of observations
60000
50000
40000
30000
20000
10000
0
good
outside grid
> 50km
gross check
stats
stats2

Assimilation algorithm

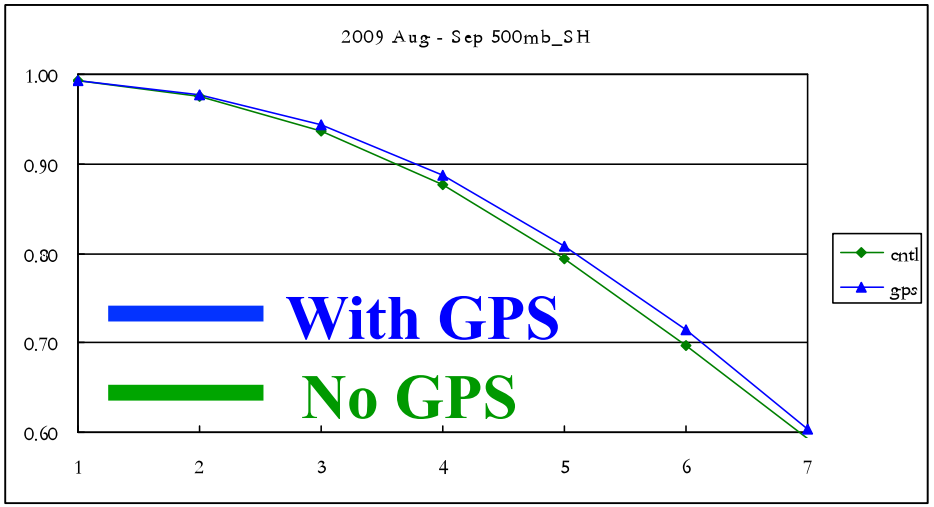
	Counts	J	J/counts
N	0:gps 49970	7.7231250467998078E+04	1.546
	0:gps 50934	2.8707346020729292E+04	0.564
	0:gps 51138	2.7751283896612065E+04	0.543
BA	0:gps 82761	9.1646957113037395E+04	1.107
	0:gps 83635	5.1683558671757288E+04	0.618
	0:gps 83705	5.1001526772670179E+04	0.609

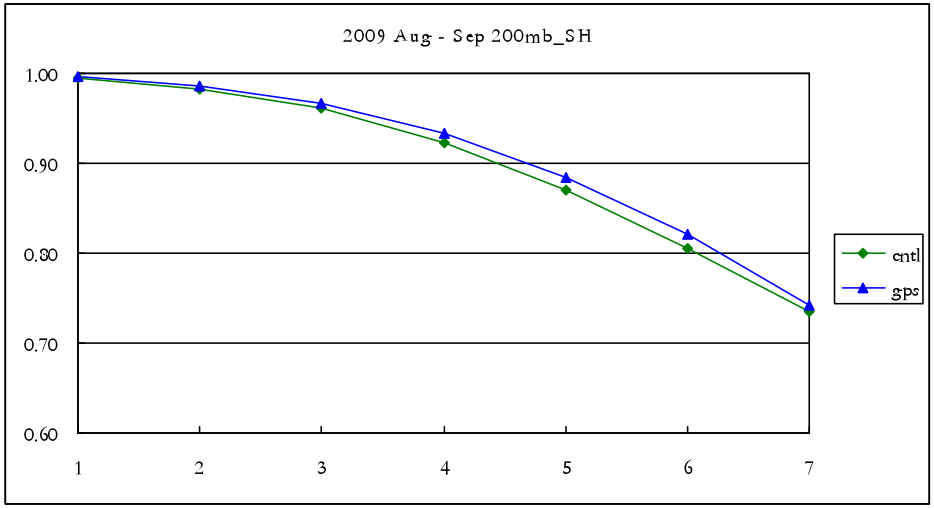
Central Weather Bureau (Taiwan)



The comparison was done with the same observational data use by GFS-T239L30, where satellite data assimilated only involves NOAA 15 AMUA and COSMIC RO data . The significantly positive impact is contributed by the improvement of RO data assimilation between SSI and GSI.

COSMIC RO Data Impact at CWB

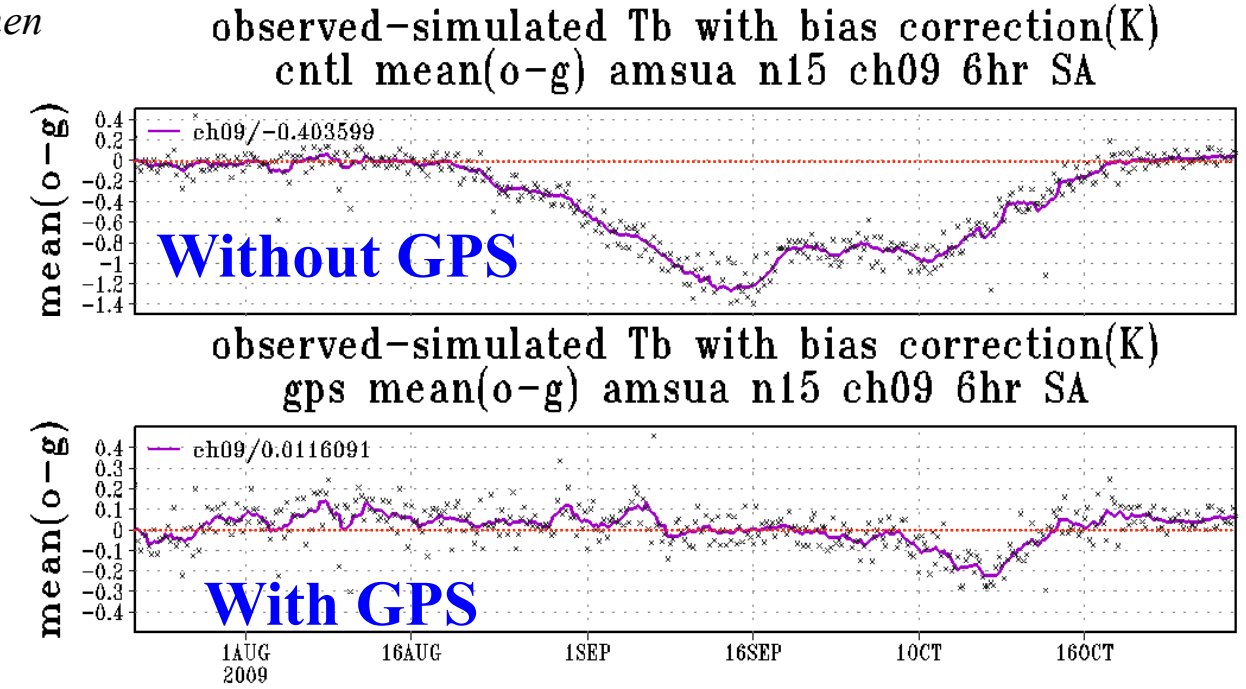




Courtesy of Dr. Fong

COSMIC RO Data Impact on Radiance Data

Courtesy of Y-C Shen



- Figures show Tb differences between the observed and simulated after doing bias correction for channel 9 of NOAA-15 AMSUA from July to November, 2009.
- During the period of mid-Aug to mid-Oct, poor bias correction occurred without RO data assimilated. By contrast, it disappeared with the use of RO data, which produces a positive impact on radiance data assimilation.

Percentage of COSMIC RO Data (CWB)

Courtesy of Y-C Shen

2009072200-2009121400