Near-Surface Sea Temperature (NSST) and Satellite Data Assimilation

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Background

- GFS (Operational) with external daily SST analysis → GFS with internal 6-hourly NSST analysis
- SST and NWP → NSST and NWP

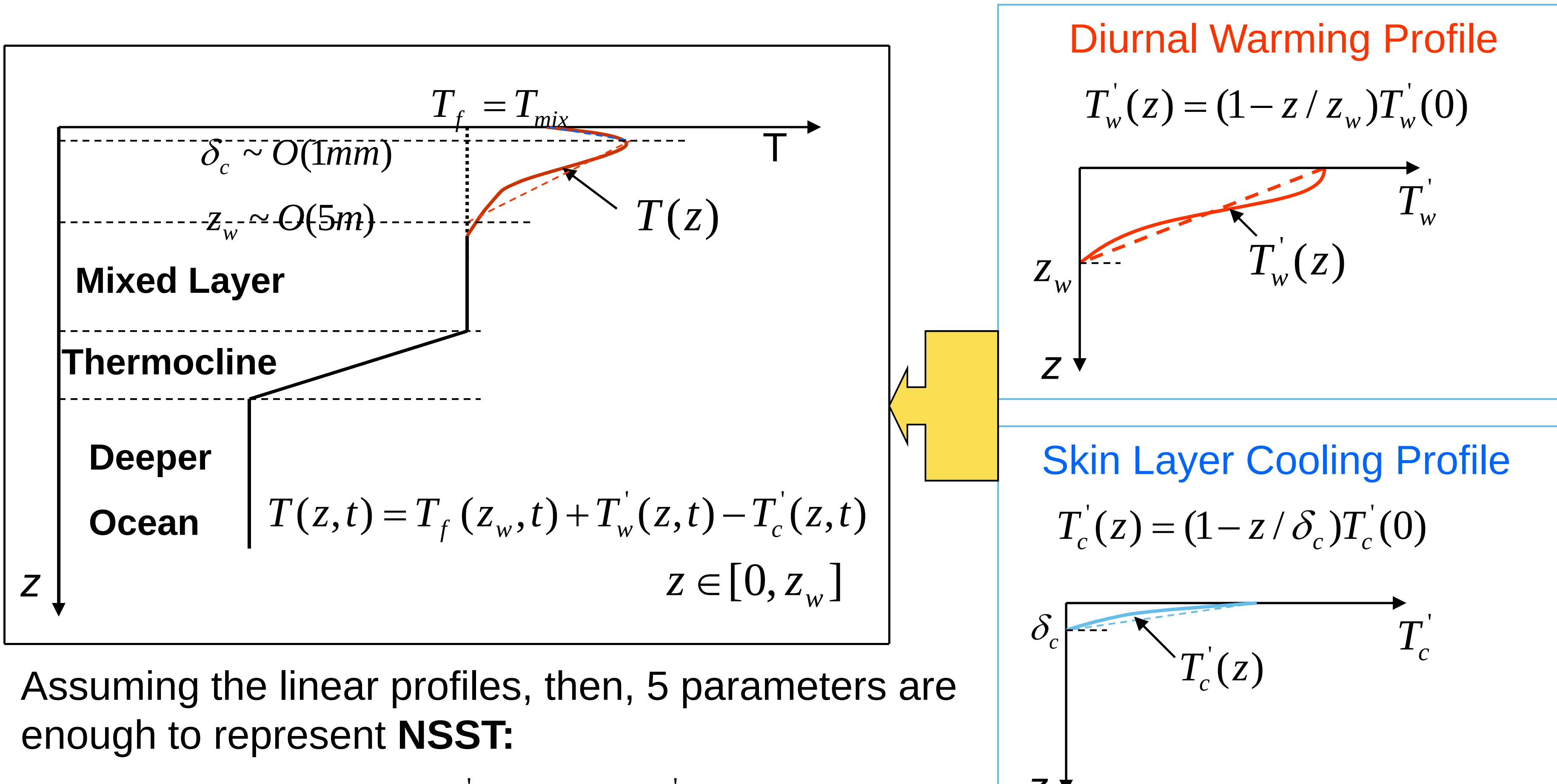
Today's Presentation:

1. The changes from SST to NSST in NWP:
   Analysis, Forecasting and Cycling

2. The impact evaluation with cycling experiments

What is NSST?

NSST is a **T-Profile** just below the sea surface.
Here, only the vertical thermal structure due to **diurnal thermocline layer warming** and **thermal skin layer cooling** is resolved



Assuming the linear profiles, then, 5 parameters are enough to represent **NSST:**

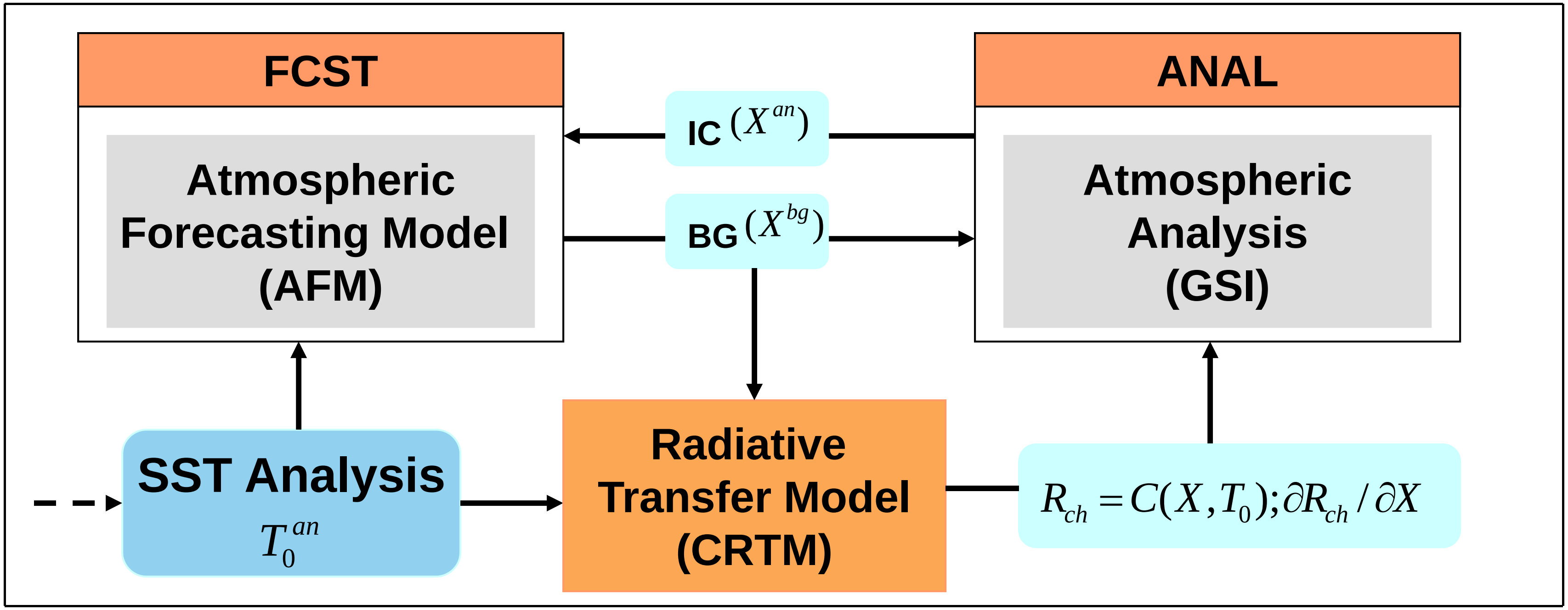
$$T(z) = F[T_f, T_w'(0), z_w, T_c'(0), \delta_c]$$

Why switch SST (T_0) to NSST $T(z)$ in NWP?

- **NSST-Profile is closely related to High Frequency Variability (HFV, minutes to hours time scale) in SST.**
  - The introduction of NSST into the NWP system enables to resolve the HFV in SST analysis and forecasting directly.
  - The resolved HFV of SST helps to resolve the HFV in atmospheric analysis and weather forecasting.
- **NSST-Profile contains additional information essential:**
  - To treat the related sea temperature observations (insitu and satellite) depth dependent
  - To provide wavelength (or depth) dependent lower thermal boundary condition to radiance simulation model such as CRTM

SST (T_0) and NWP

(For example, GFS with external daily SST analysis)



T_0 **: SST**

X **: Atmospheric State Vector**

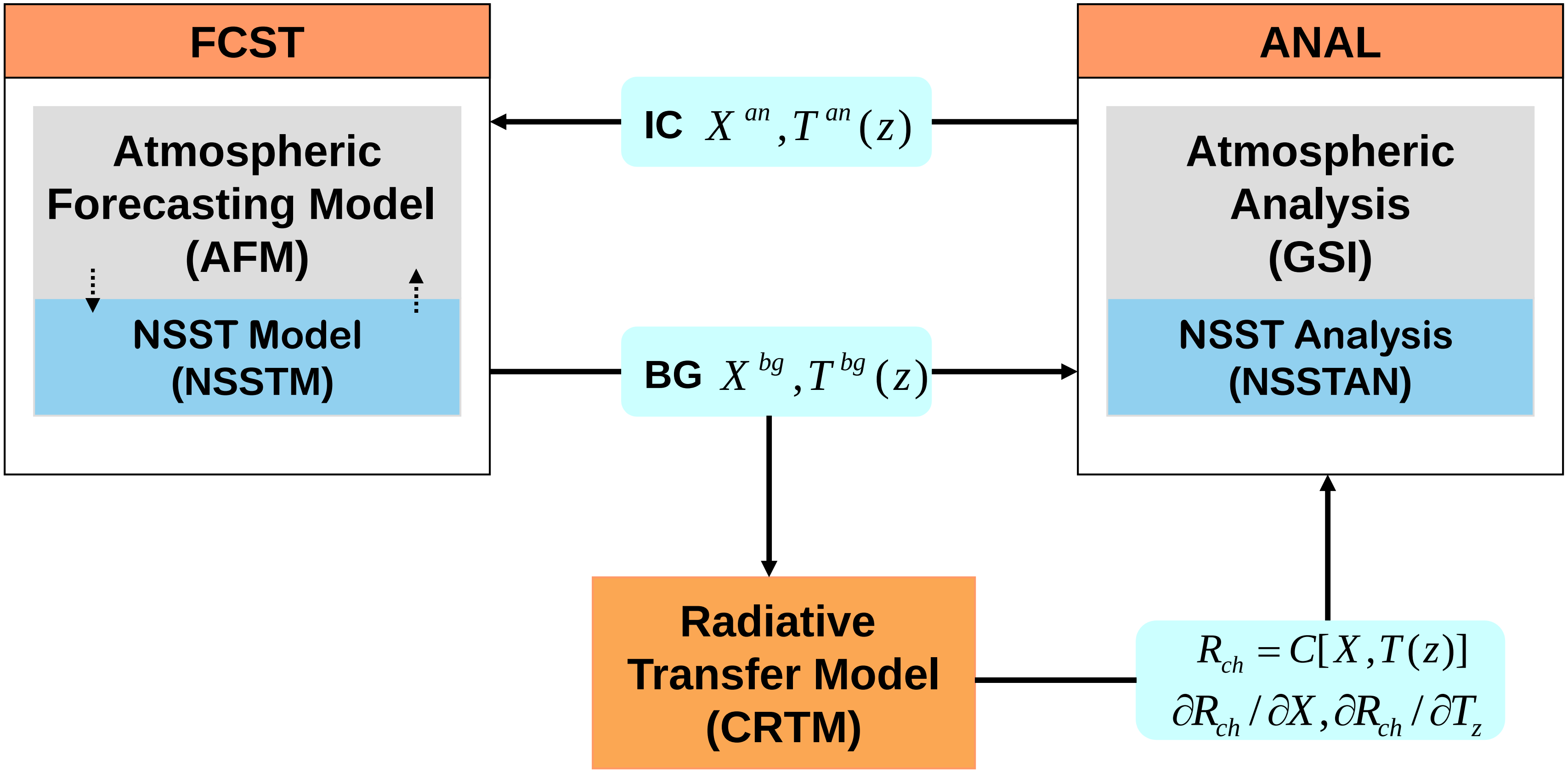
R_{ch} **: Radiance for Channel** ***ch***

C **: Observation operator** (relate control variables to the radiance: e.g. **CRTM**)

$\partial R_{ch} / \partial X$ **: Jacobi** (the sensitivity of the radiance to atmospheric analysis variable)

$\partial R_{ch} / \partial T_0$ **: Jacobi** (the sensitivity of the radiance to SST, not used here)

NSST $T(z)$ and NWP: Interaction



C : Observation operator (relate T-Profile to the radiance)

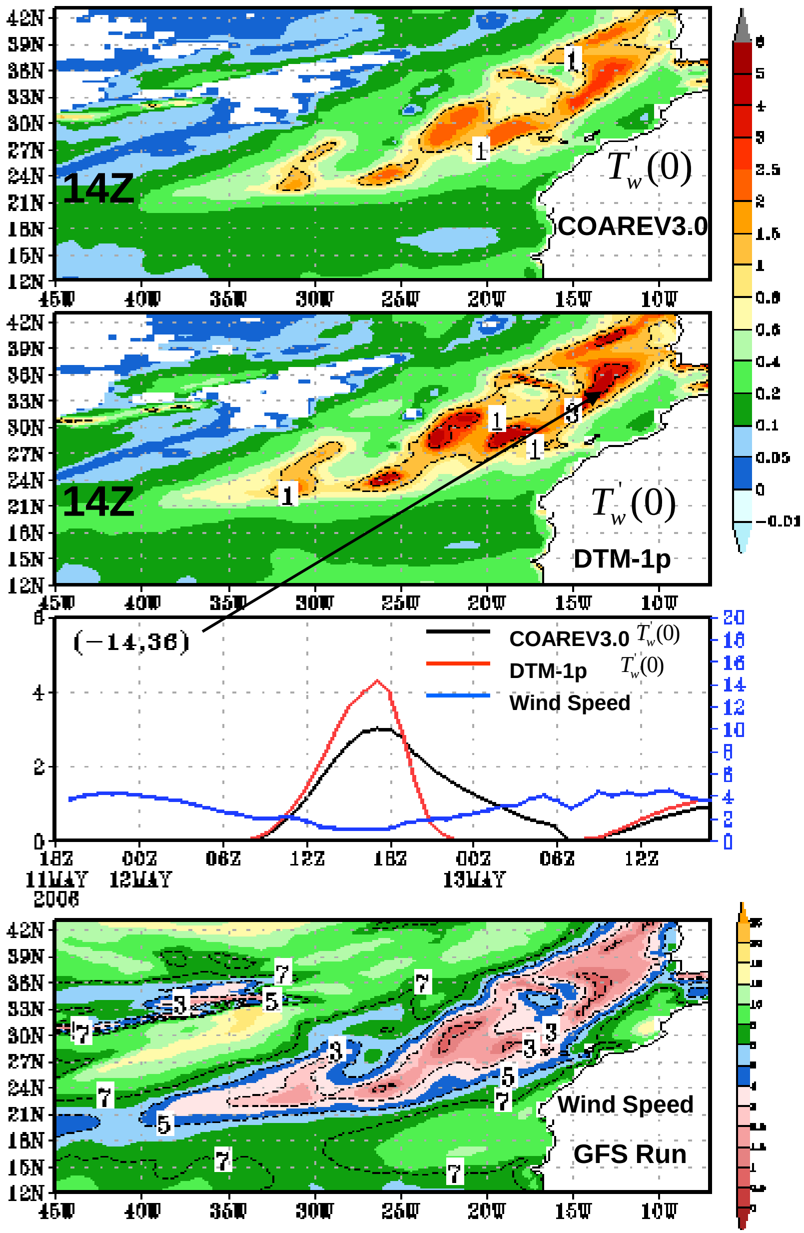
$\partial R_{ch} / \partial T_z$: Jacobi (the sensitivity of the radiance to T-Profile)

NSST model

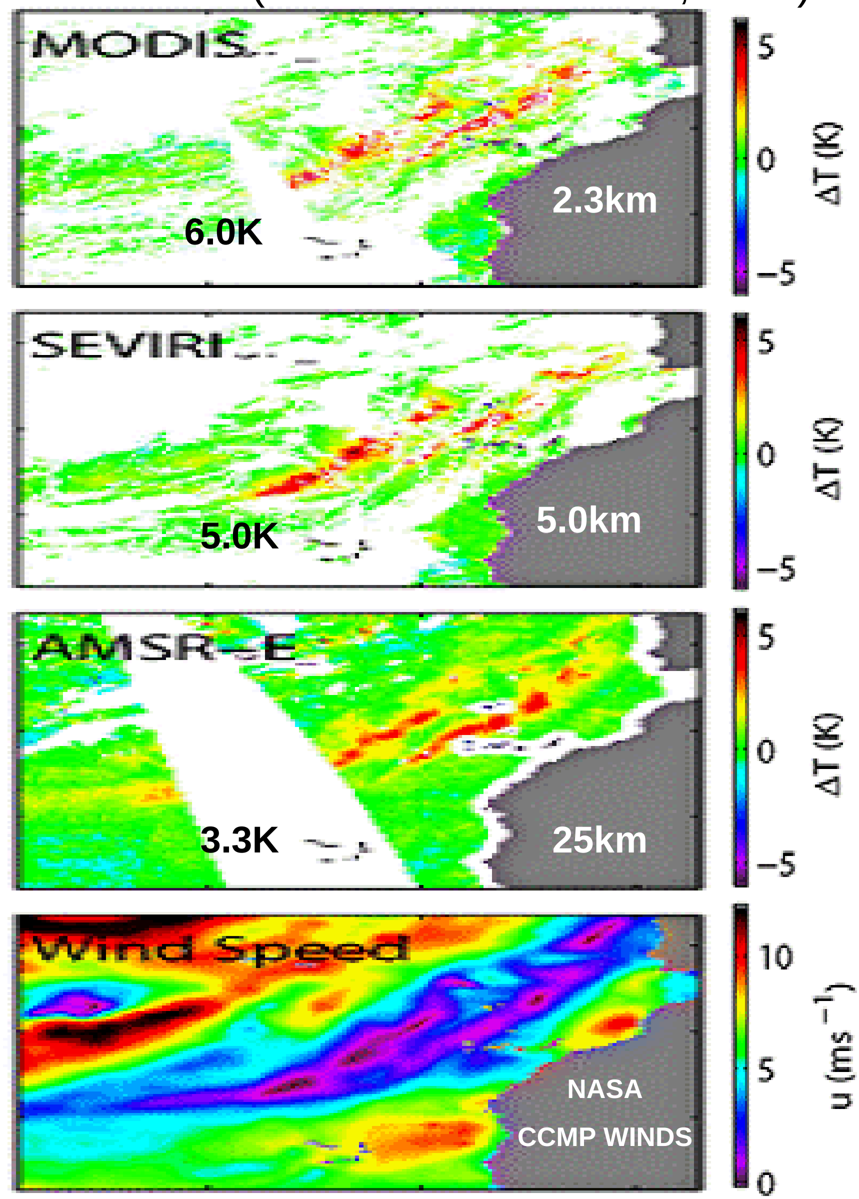
- NSSTM = DTM + TSM
- DTM (Diurnal Thermocline Model)
  - NCEP DTM
    - More physical processes included than COARE V3.0 (Fairall et al, 1996)
- TSM (Thermal Skin-layer Model)
  - COARE V3.0 sub-layer cooling (Fairall et al, 1996)
- Observation operator and its Jacobi
  - Required in direct assimilation

SST diurnal warming: May 12, 2006

Simulation



Retrievals (from Gentemann et al, 2008)

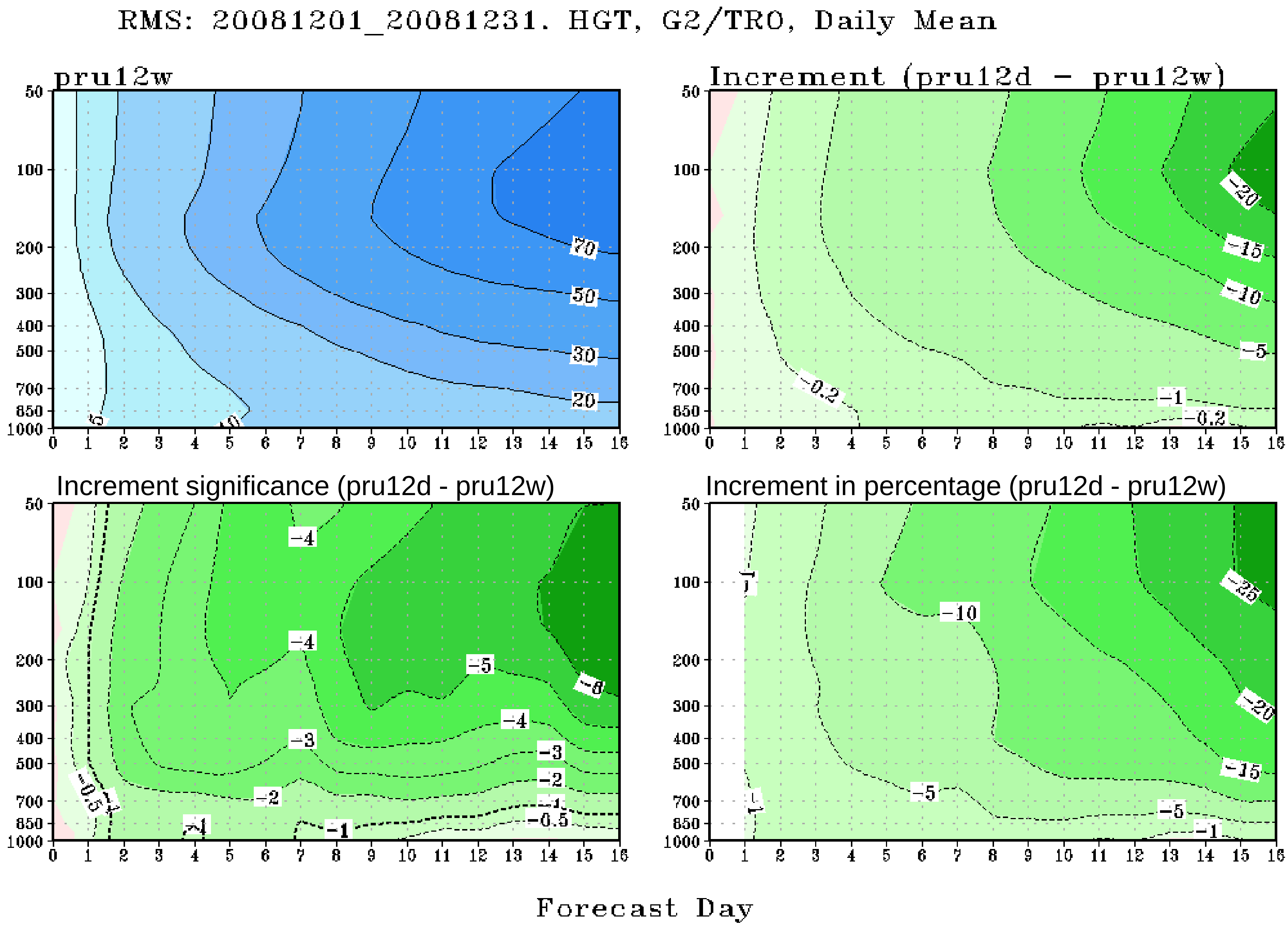


Impacts evaluation: Cycling Runs

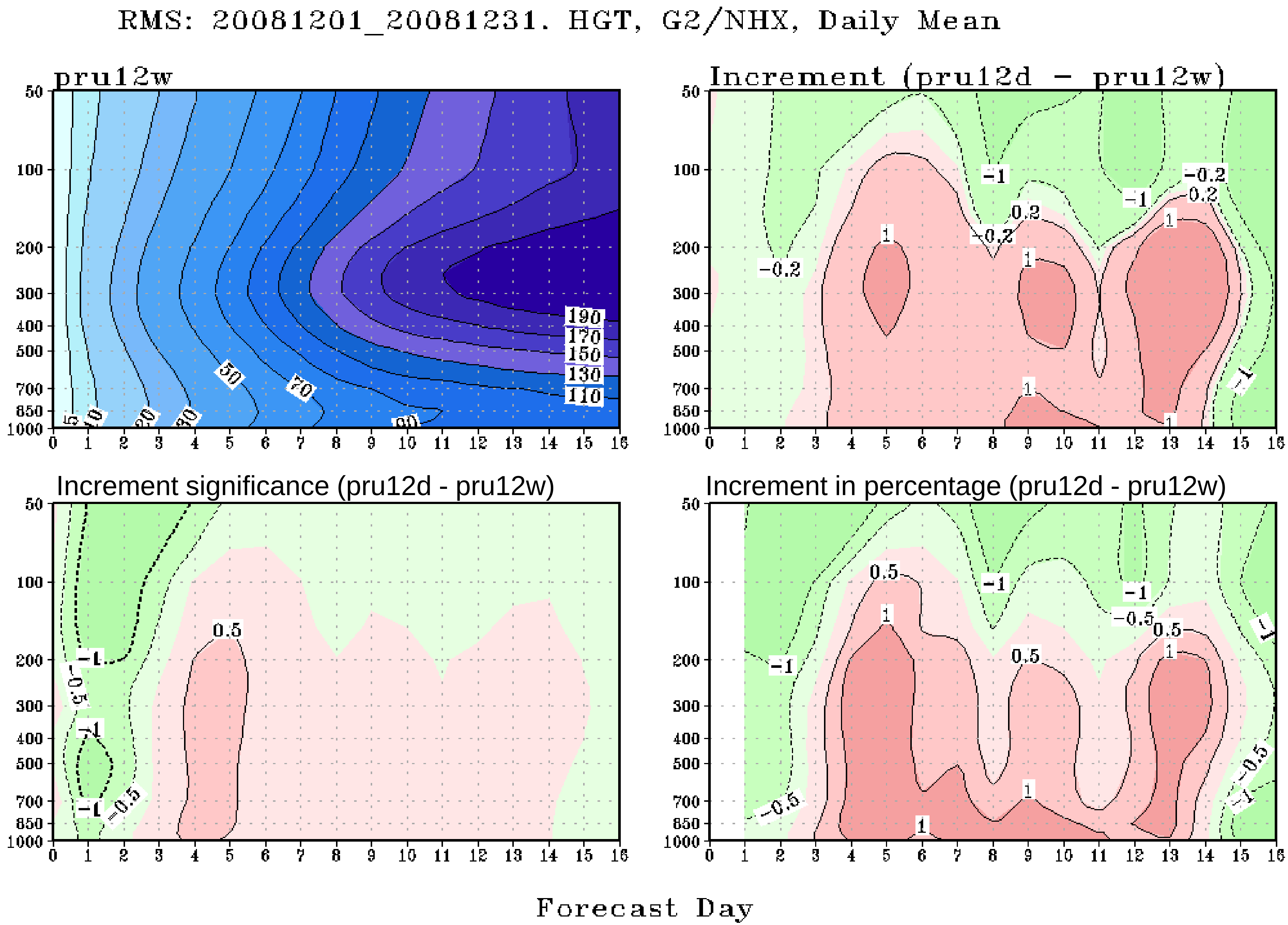
Exps	T_r	SST In FCST	$T(z)$ In ANAL	$\partial T_z / \partial T_r$
pru12w	SST^{op}	SST^{op}	SST^{op}	N/A
pru12d	SST^{op}	$SST^{op} + T_w^{'}(0)$	$SST^{op} + T_w^{'}(z) - T_c^{'}(z)$	N/A
pru12c	SST^{op}	$SST^{op} + T_w^{'}(0)$	SST^{op}	N/A
pru12n	T_r^{an}	$T_r^{an} + T_w^{'}(0)$	$T_r^{an} + T_w^{'}(z) - T_c^{'}(z)$	$\partial T_{ir} / \partial T_r, \ \partial T_{mw} / \partial T_r$

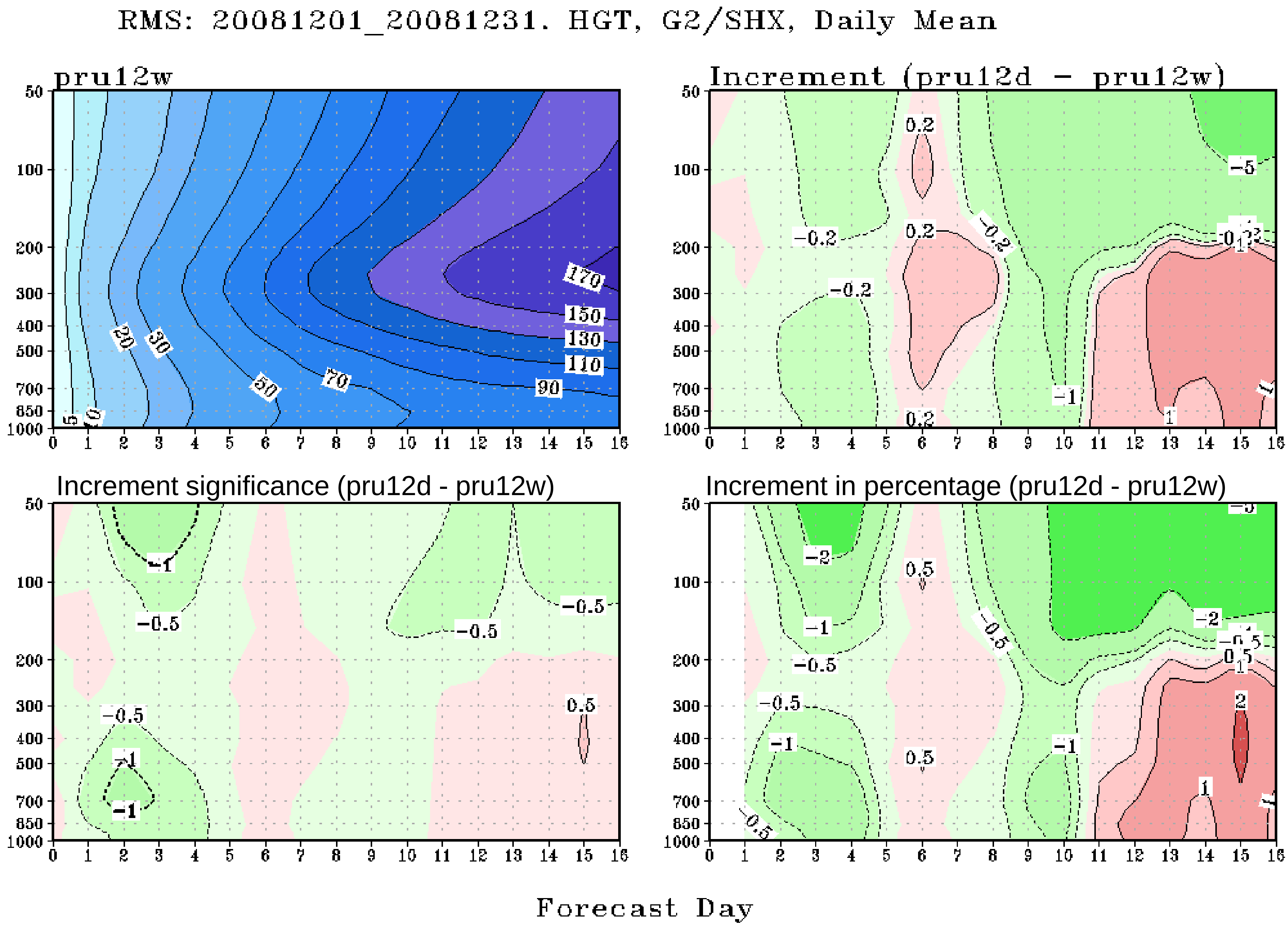
$$T(z) = T_r \ (z_w) + T_w^{'}(z) - T_c^{'}(z)$$

The operational version of NCEP GFS (T382) is used to do the experiments for the period of November 12, 2008 to December 31, 2008. The analysis and 16-day forecasting are performed 4 times a day.



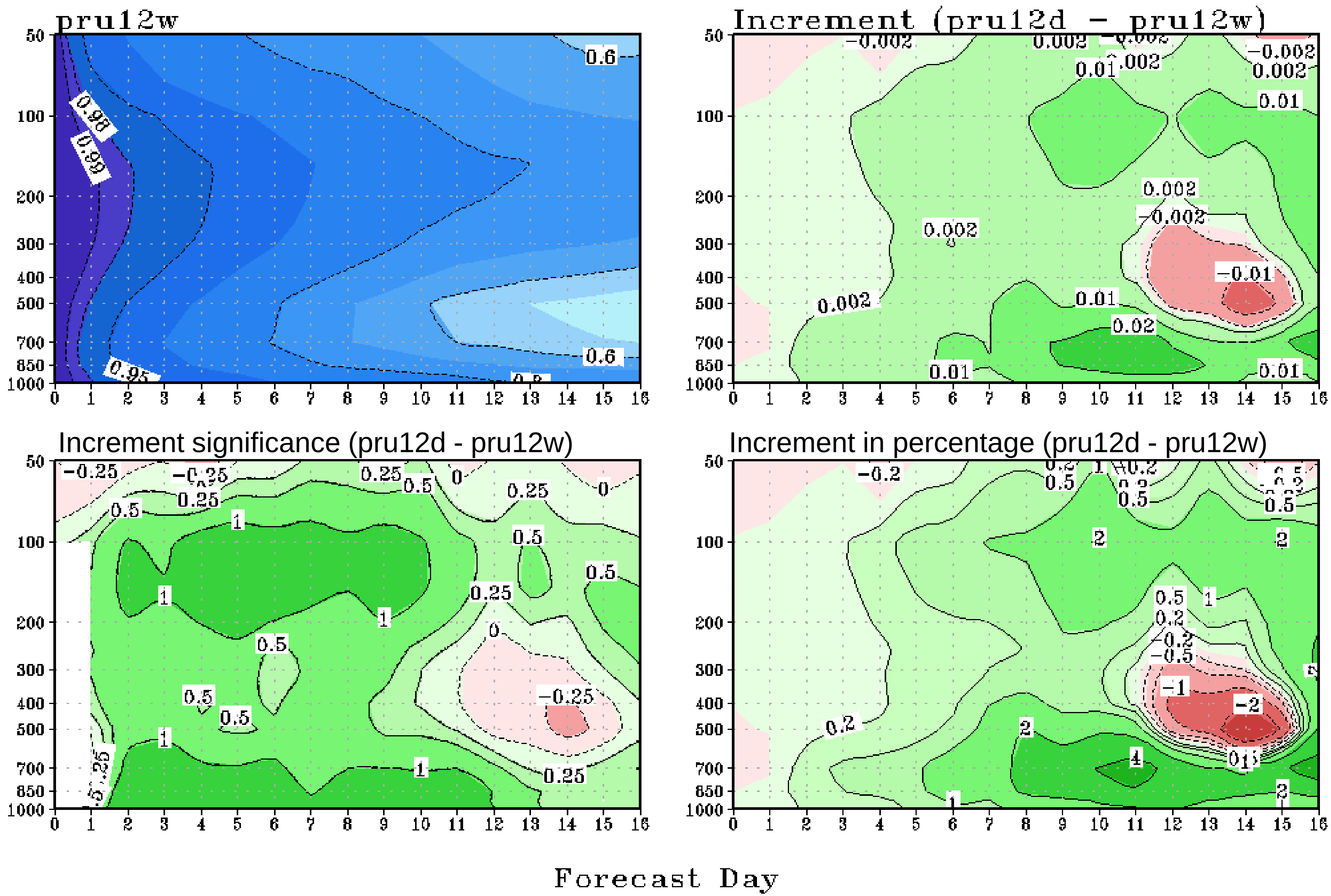
RMS: 20081201_20081231. HGT, G2/TRO, Daily Mean
pru12w
Increment (pru12d - pru12w)
Increment significance (pru12d - pru12w)
Increment in percentage (pru12d - pru12w)
50
100
200
300
400
500
700
850
1000
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
70
50
30
20
-20
-15
-10
-5
-1
-0.2
-4
-5
-8
-3
-2
-1
-0.5
-25
-10
Forecast Day


RMS: 20081201_20081231. HGT, G2/NHX, Daily Mean
pru12w
Increment (pru12d - pru12w)
Increment significance (pru12d - pru12w)
Increment in percentage (pru12d - pru12w)
Forecast Day



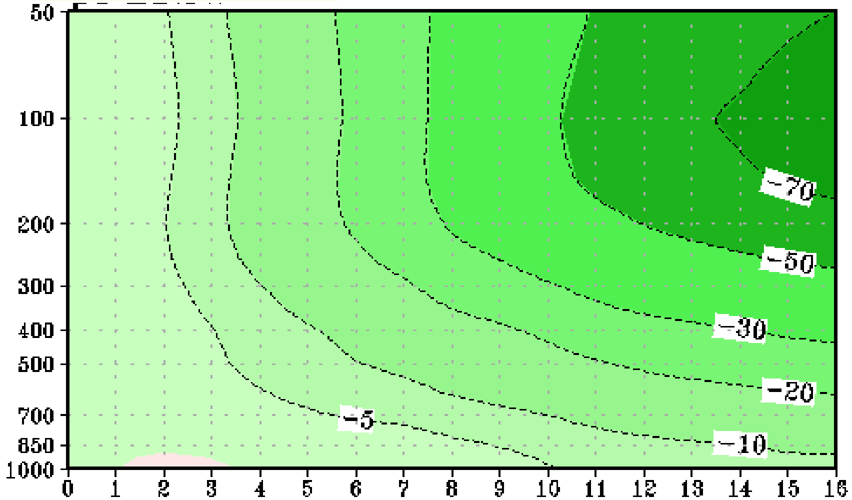
RMS: 20081201_20081231. HGT, G2/SHX, Daily Mean
pru12w
Increment (pru12d - pru12w)
Increment significance (pru12d - pru12w)
Increment in percentage (pru12d - pru12w)
Forecast Day

COR: 20081201_20081231. HGT, G2/TRO, Daily Mean

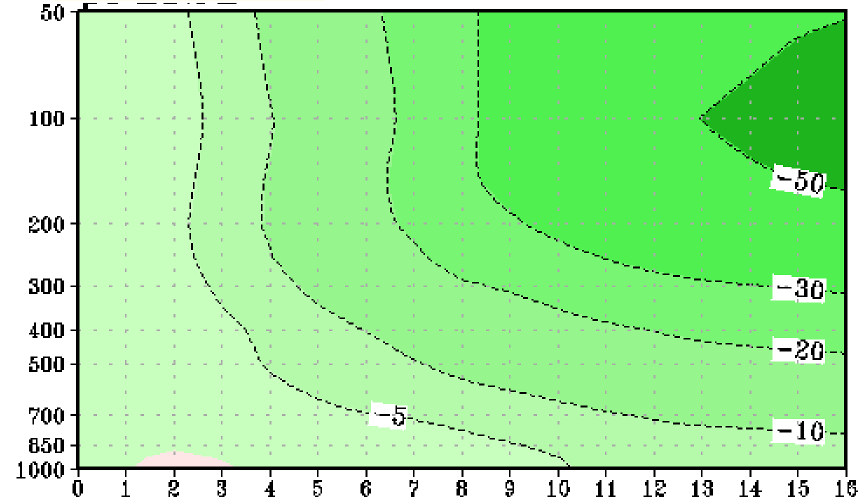


Bias & Bias difference for Dec. 2008 (31 x 4 samples): HGT, Tropics

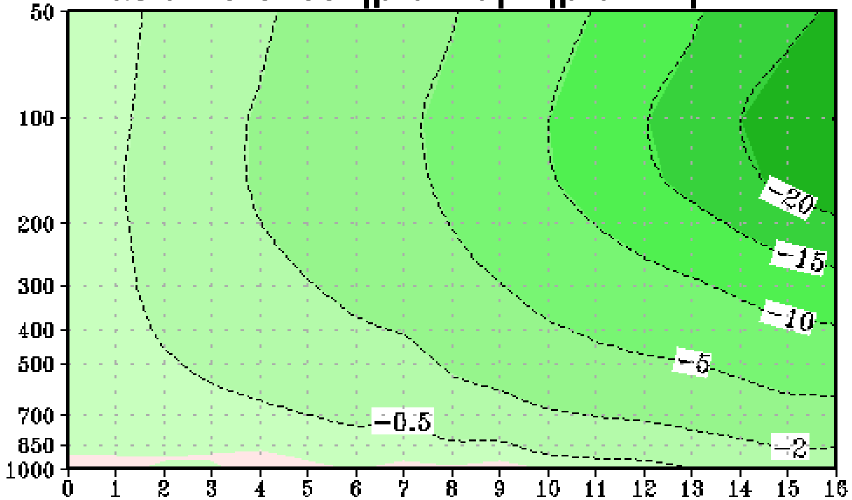
Bias: pru12w



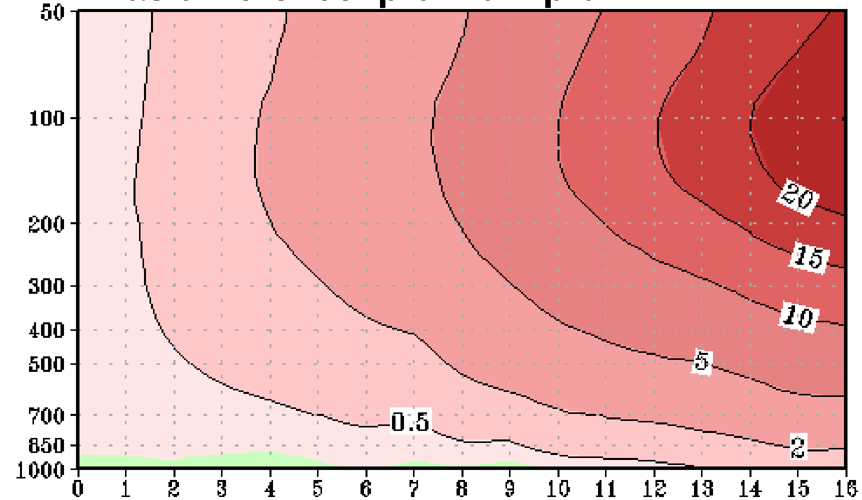
Bias: pru12d



Bias difference: |pru12d| – |pru12w|

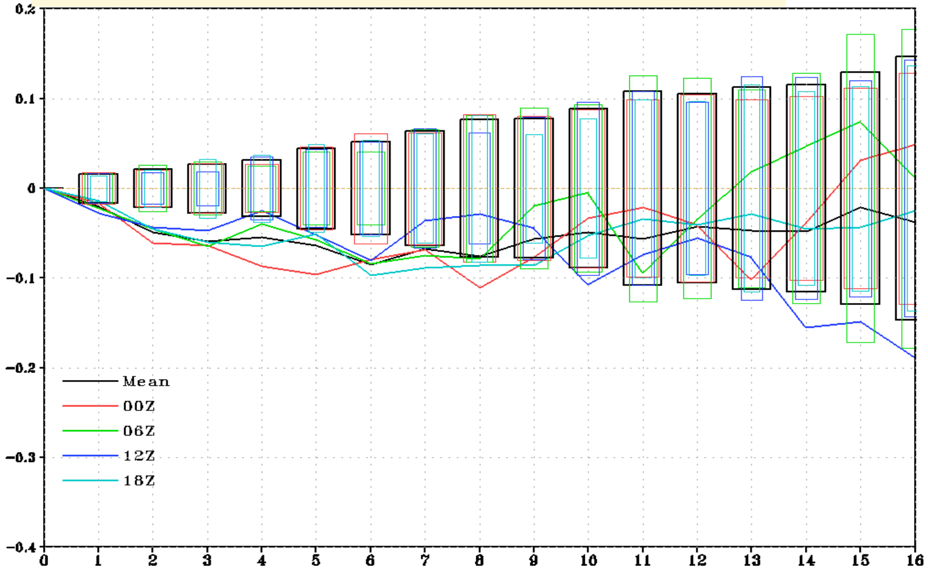


Bias difference: pru12d – pru12w

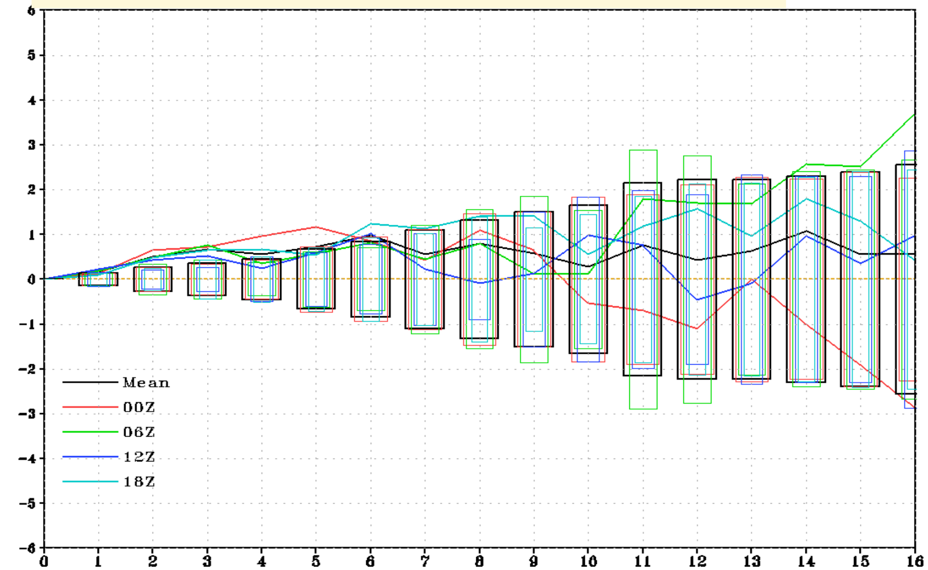


Forecast Day

RMS: (pru12d – pru12w)



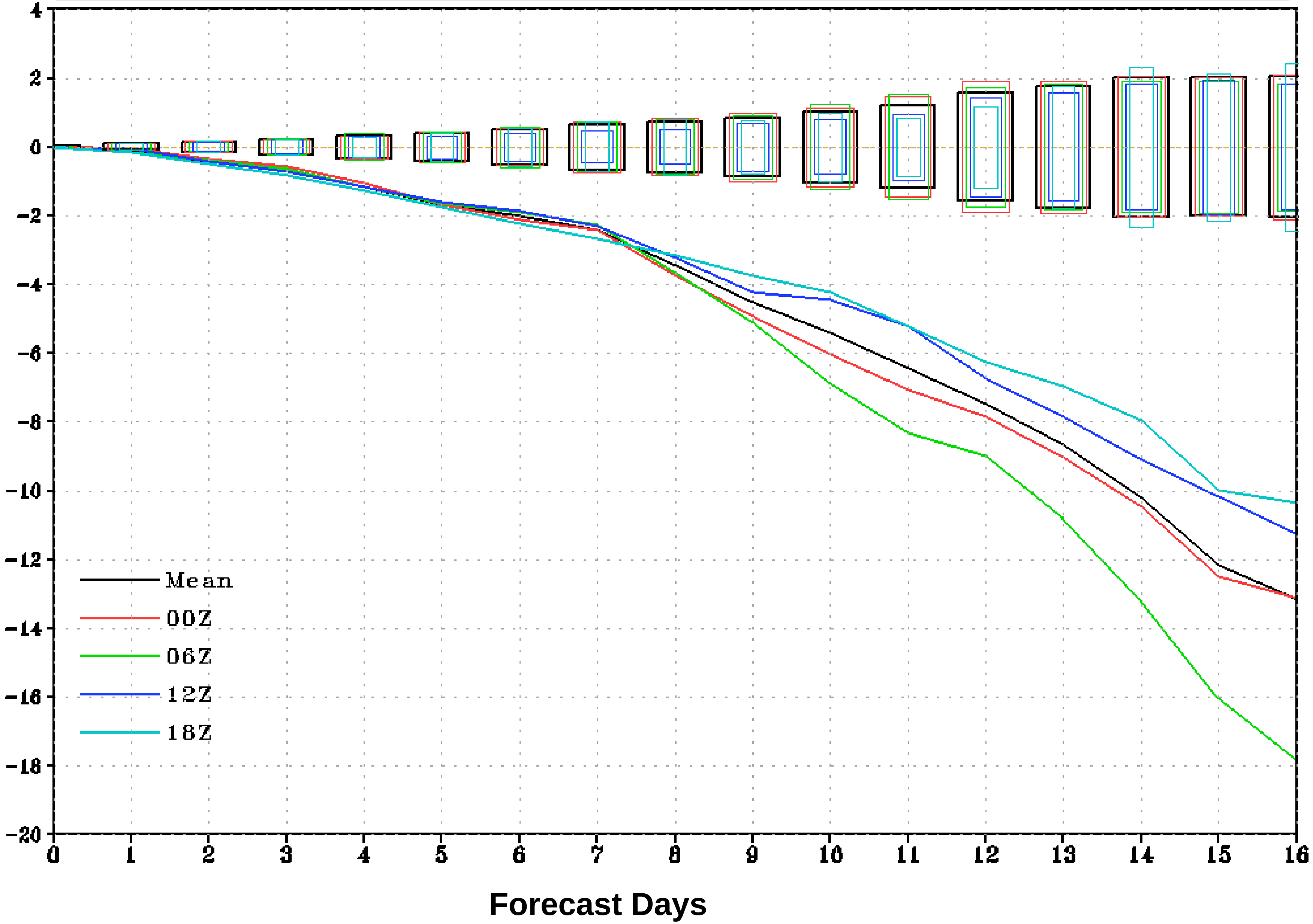
AC: (pru12d – pru12w)

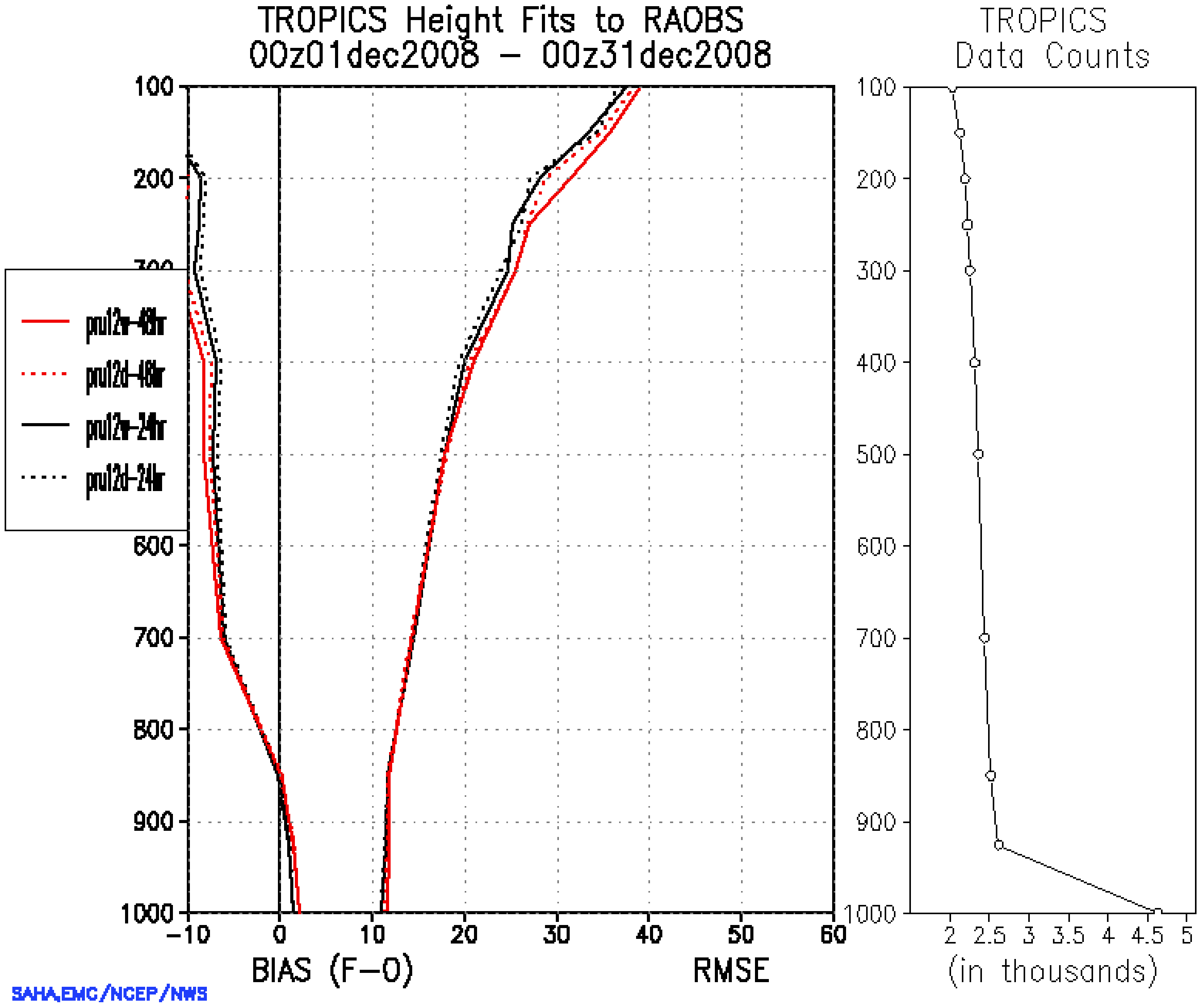


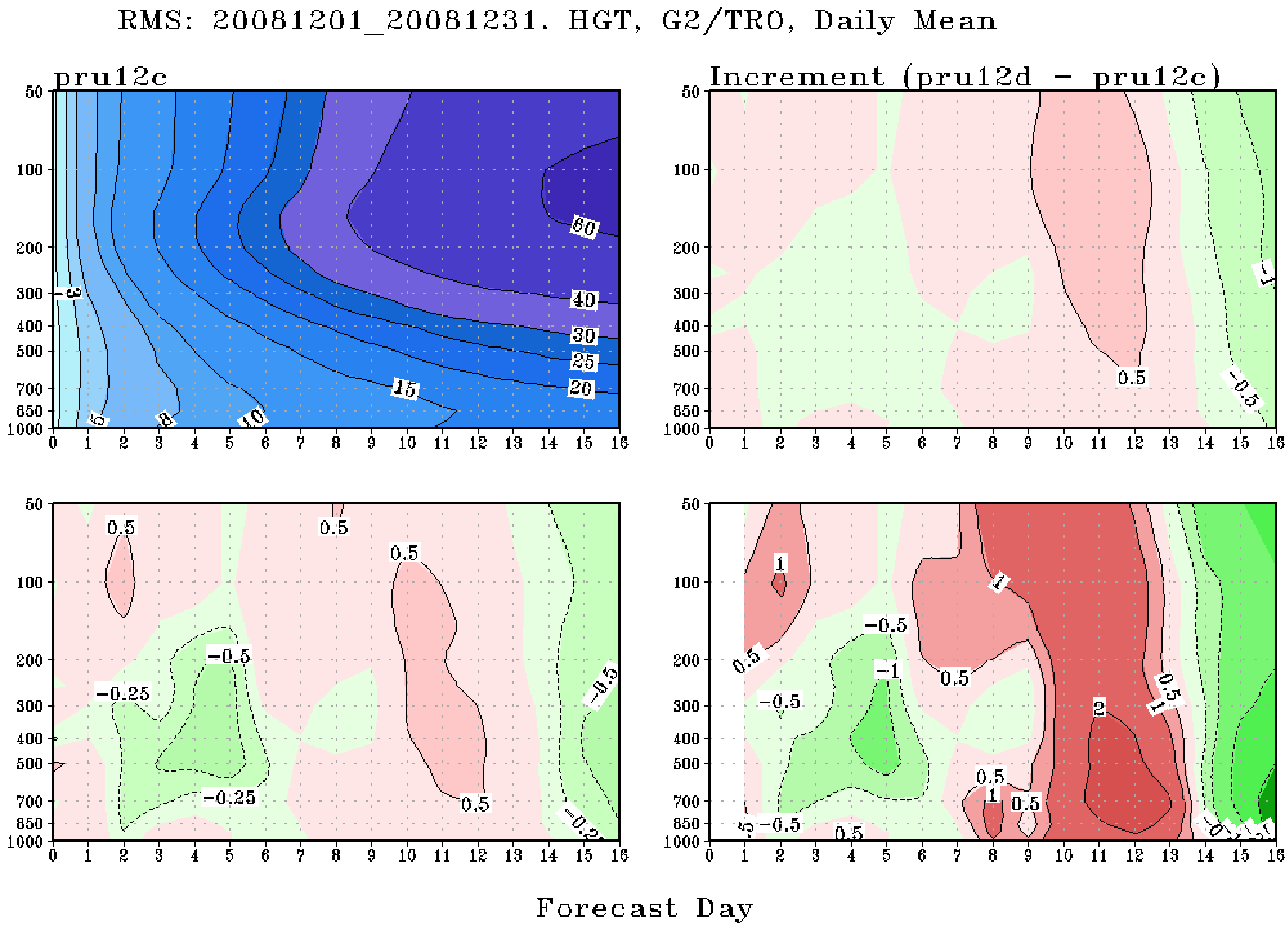
Forecast Days

Verification of 16-day forecasting. Based on 31 x 4 samples in Dec. 2008. 850 hPa Wind, Tropics

Verification of 16-day forecasting. Based on 31 x 4 samples in Dec. 2008.
250 hPa Geopotenial Height, Tropics

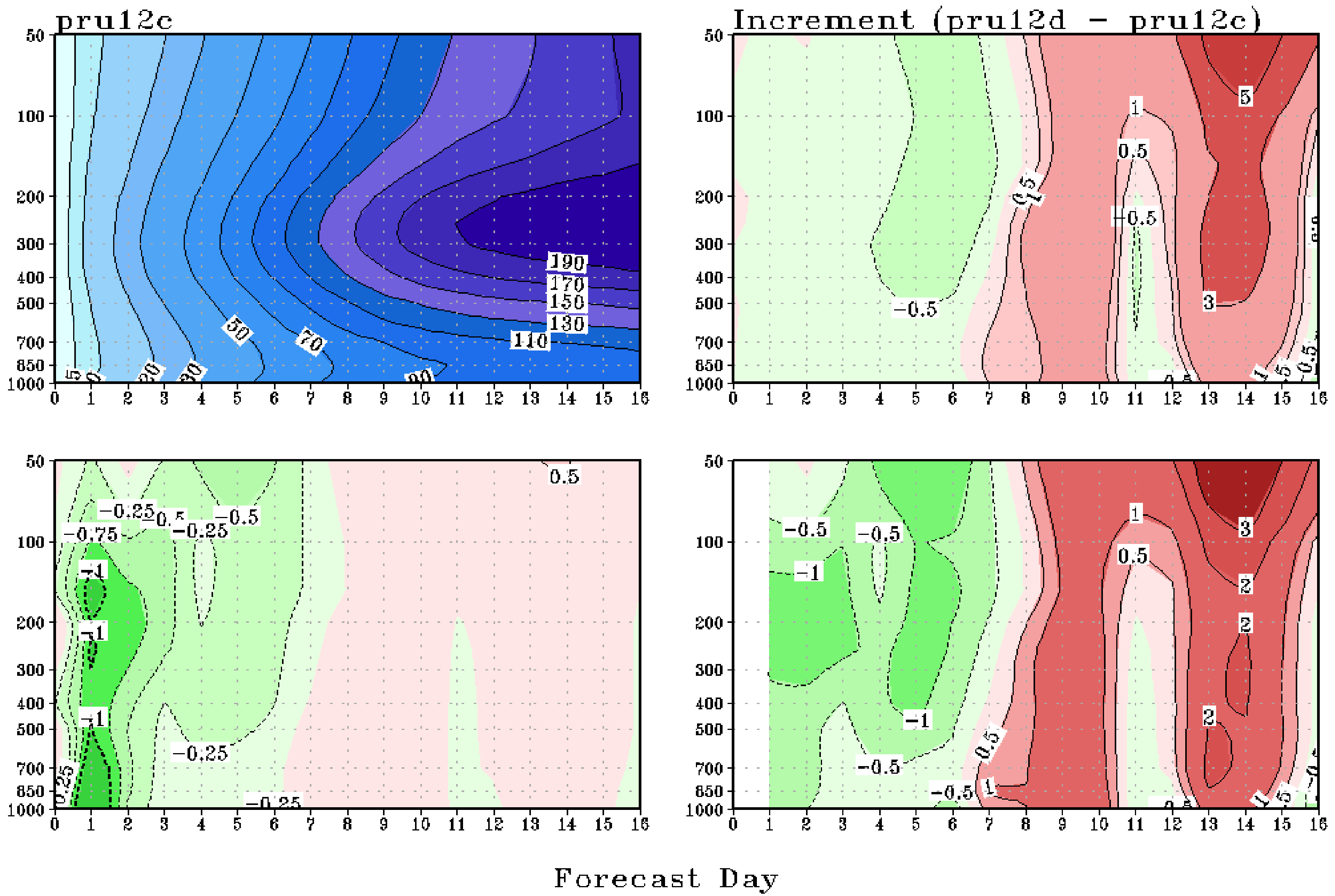


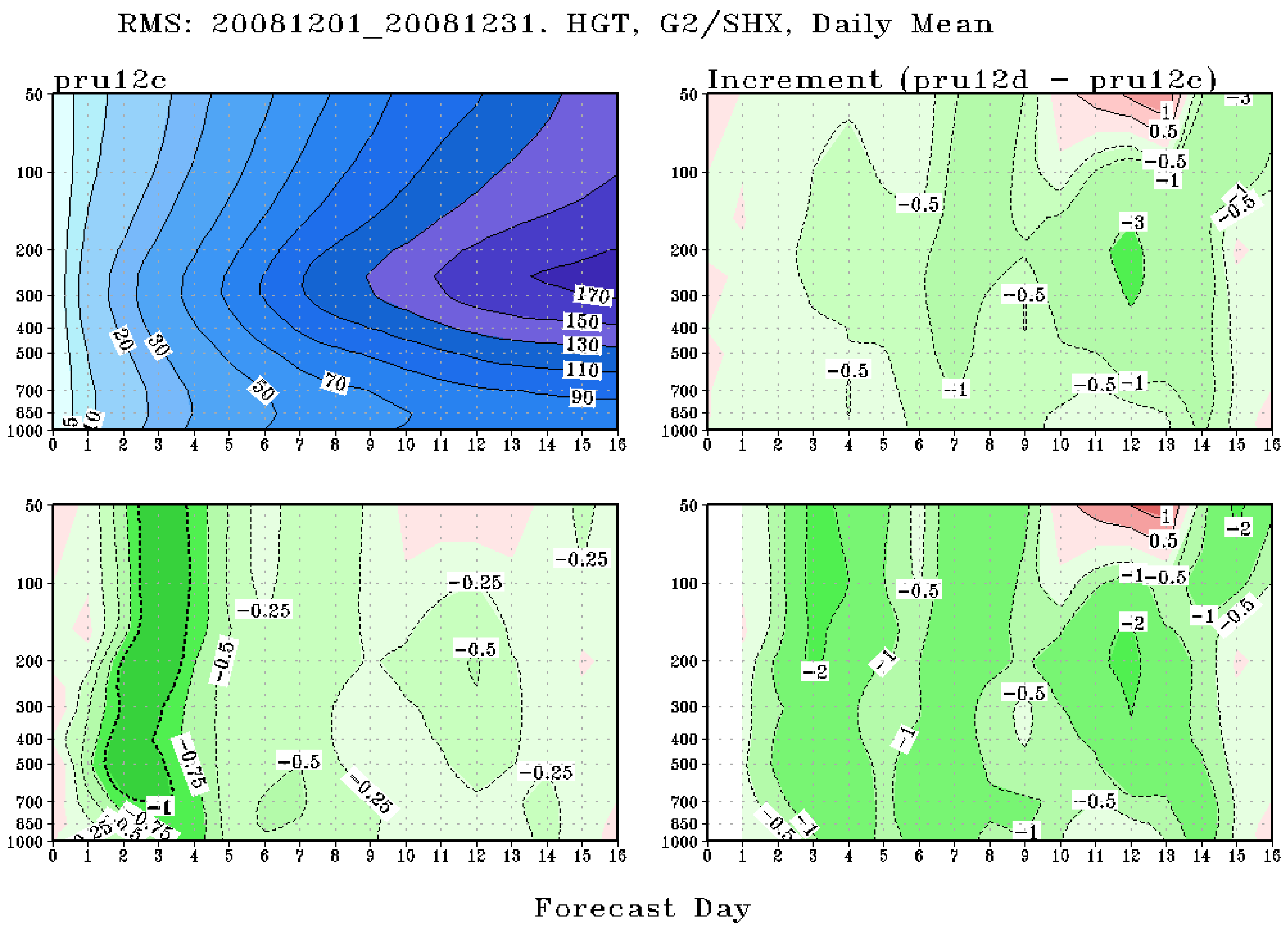

TROPICS Height Fits to RAOBS
00z01dec2008 – 00z31dec2008
TROPICS
Data Counts
100
200
300
400
500
600
700
800
900
1000
−10
0
10
20
30
40
50
60
BIAS (F−O)
RMSE
2
2.5
3
3.5
4
4.5
5
(in thousands)
SAHA,EMC/NCEP/NWS



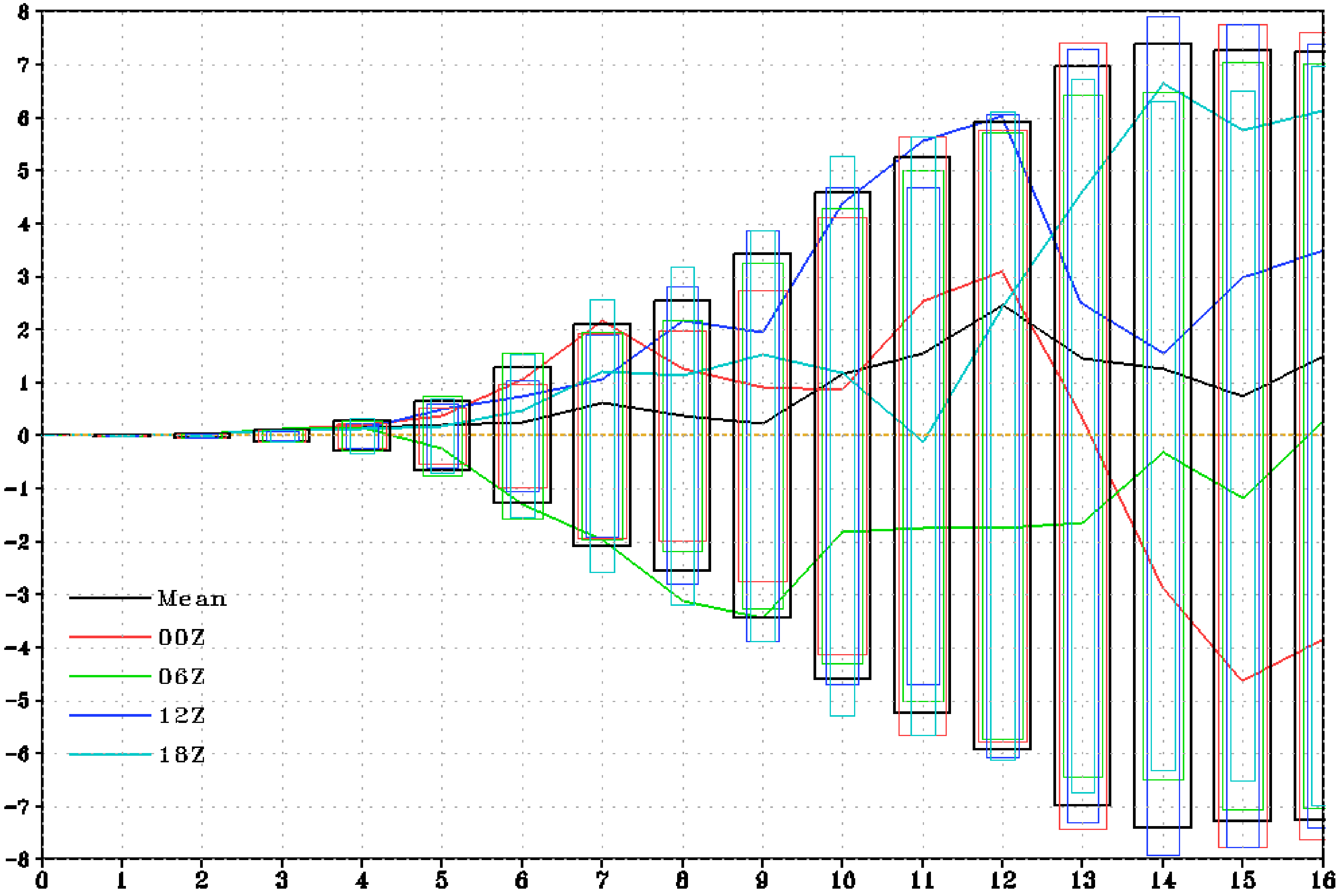
RMS: 20081201_20081231. HGT, G2/TRO, Daily Mean
pru12c
Increment (pru12d − pru12c)
Forecast Day

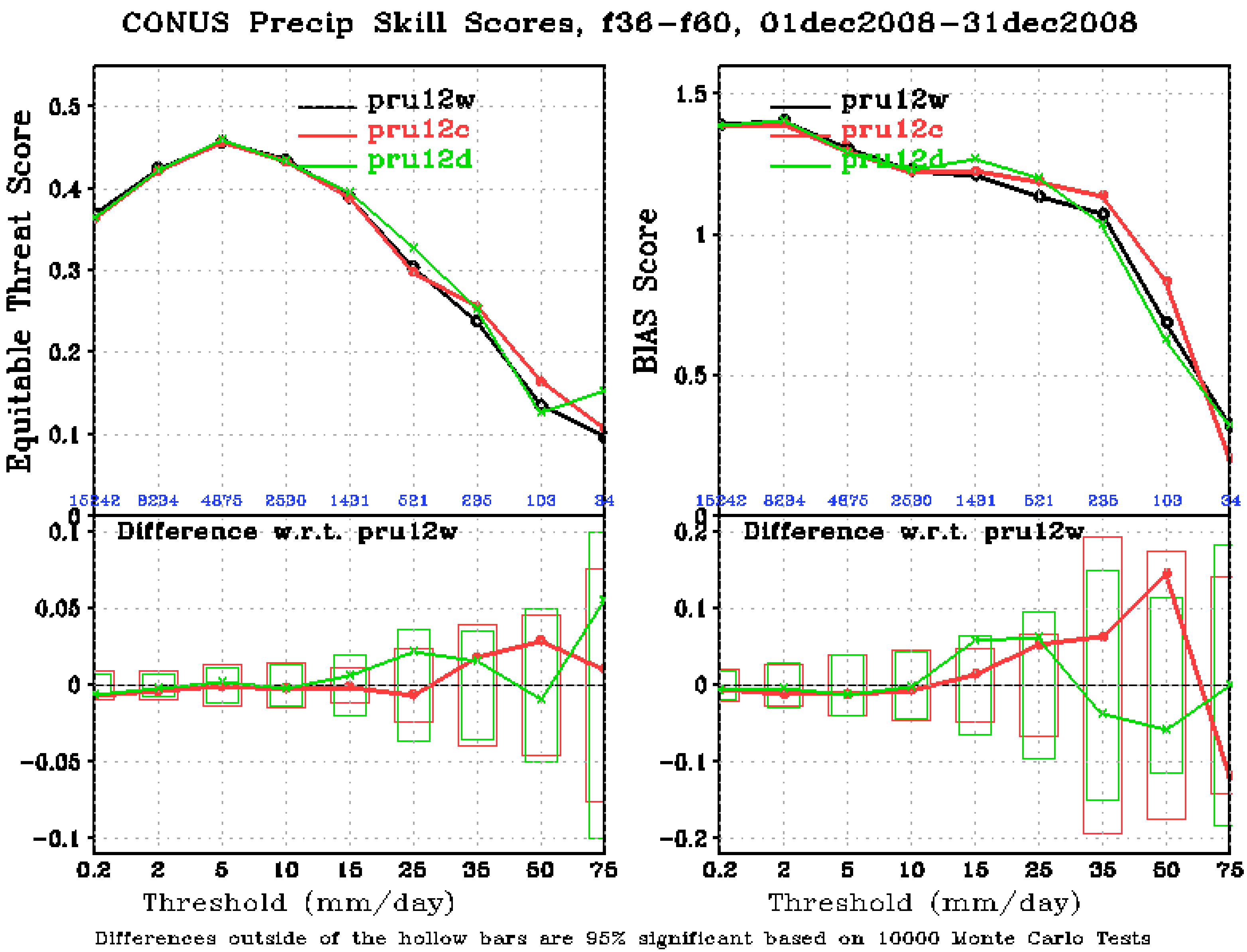
RMS: 20081201_20081231. HGT, G2/NHX, Daily Mean




RMS: 20081201_20081231. HGT, G2/SHX, Daily Mean
pru12c
Increment (pru12d − pru12c)
Forecast Day

AC*100 (pru12d - pru12c) : 200812 (31 x 4). HGT, P250, G2/SHX.




CONUS Precip Skill Scores, f36-f60, 01dec2008-31dec2008
pru12w
pru12c
pru12d
Equitable Threat Score
BIAS Score
15242 8234 4875 2590 1491 521 235 103 34
Difference w.r.t. pru12w
Threshold (mm/day)
0.2 2 5 10 15 25 35 50 75
Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests

Conclusions

- The impact of the NSSTM on NCEP GFS predictive skill is significant in tropics. Neutral to positive for extratropics
- The inclusion of the NSSTM in atmospheric analysis does improve the GFS performance, the relatively significant signal can be seen in Southern Hemisphere.
- NSSTM should improve longer period prediction.
- Detail analysis is necessary with the diagnostic file of GSI in Tr analysis experiment (pru12n) to find out which satellite instruments leads to colder SST analysis product.
- A channel dependent radiance simulation and the corresponding Jacobi calculation in CRTM