Near Sea Surface Temperatures (NSST) Analysis in NCEP GFS

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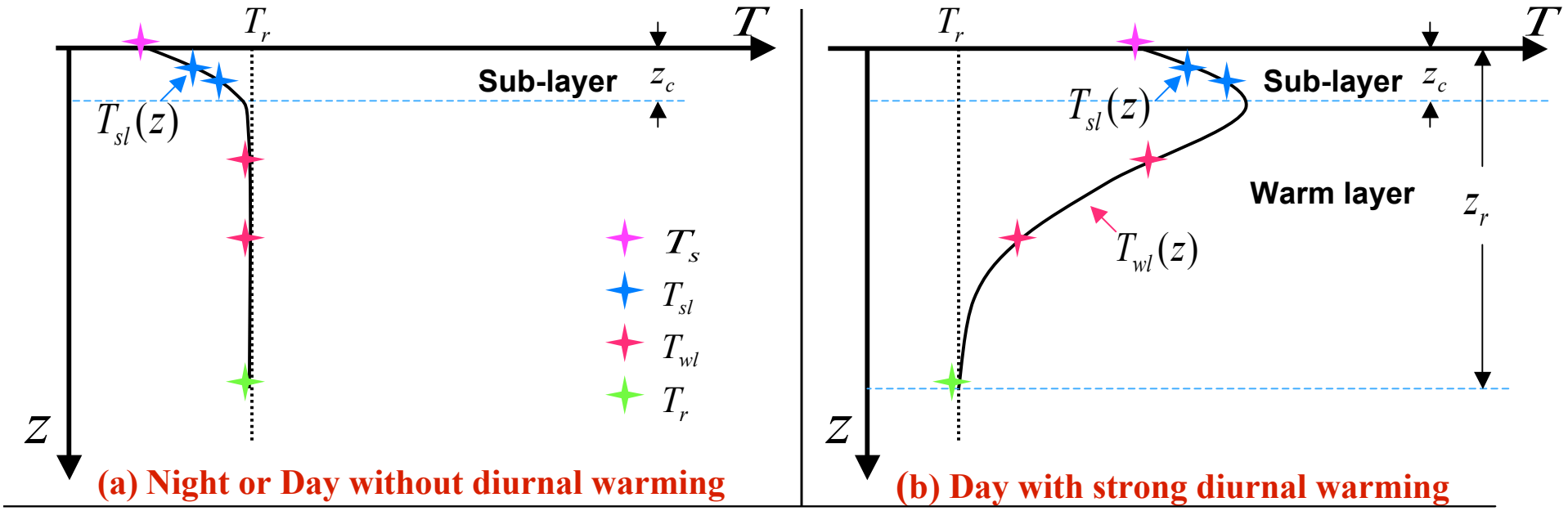
Outline

- What is NSST and why NSST analysis?
- How does NSST analysis in NCEP GFS work?
- Main characteristics of the new scheme
- Progress
- Experiments & Results
- Plan

Near Sea Surface Temperatures (NSST)



$T_s = T(z=0)$: **cannot be observed directly (SST)**

$T_{sl}(z) = T(0 < z \le z_c)$: **can be observed directly by satellites: IR & MW (sub-layer T-profile)**

$T_{wl}(z) = T(0 < z \le z_r)$: **can be observed directly by buoys & ships (warm layer T-profile)**

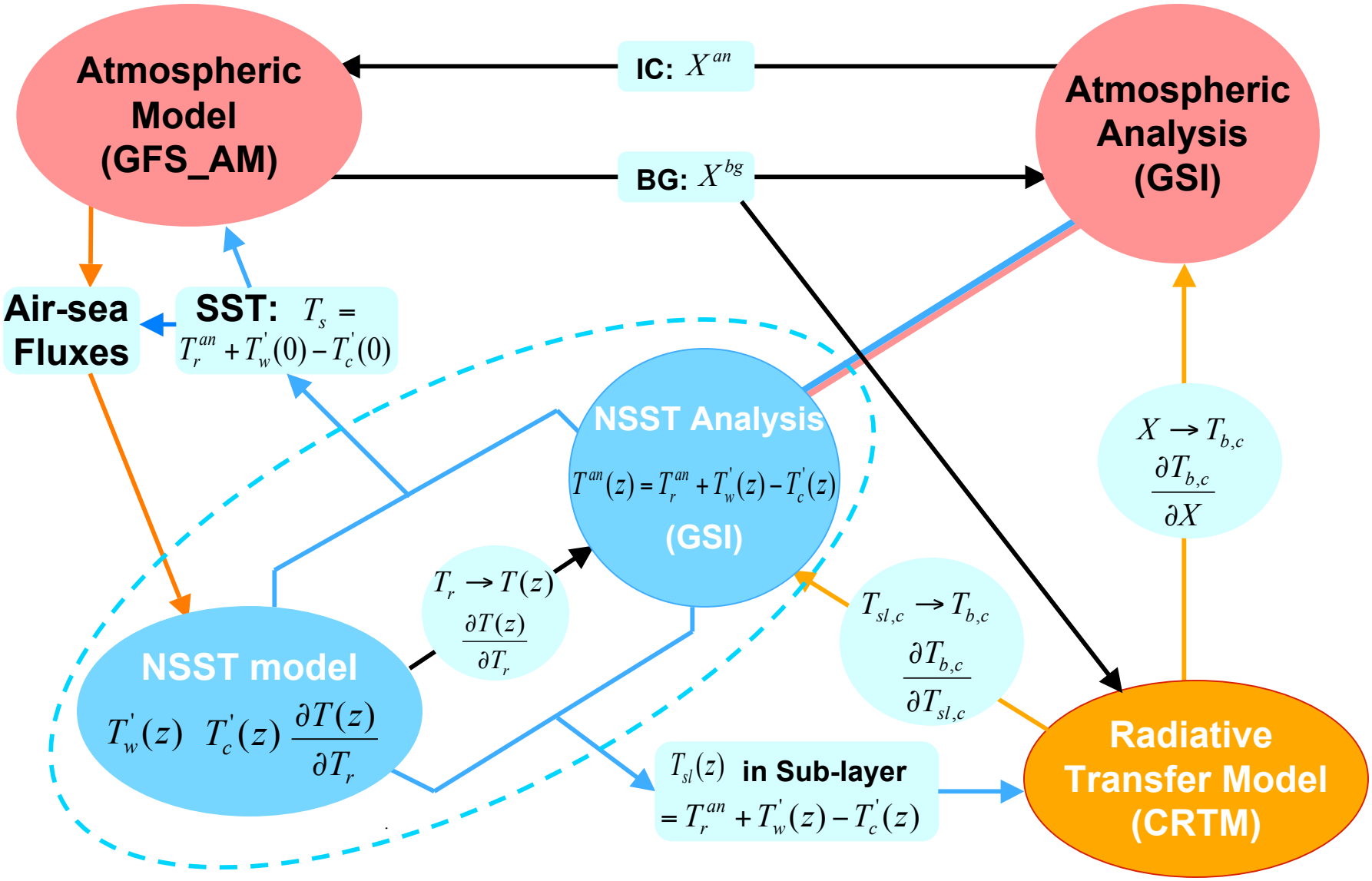
$T_r = T(z = z_r)$: **can be observed directly by buoys & ships (reference T)**

Diurnal warming profile : $T_w'(z)$ **(0 ~ 4.0K at z=0),** $z_r \sim O(5m)$

Sub-layer cooling profile : $T_c'(z)$ **(0 ~ 0.8K at z=0),** $z_c \sim O(1mm)$

NSST Profile : $T(z) = T_r + T_w'(z) - T_c'(z)$

NSST Analysis in NCEP GFS: Components and Interaction



NSST Analysis in NCEP GFS: Main Characteristics

- **NSST is treated as depth dependent**
  - **Advantages**
    - More realistic thermal boundary condition to atmospheric model and radiative transfer model
    - Short time scale (hours) air-sea interaction included in weather forecasting
    - Diurnal variation in NSST resolved
  - **Work**
    - NSST model and its coupling with GFS_AM
    - Observation operator and its Jacobi for the new analysis variable and NSST data
    - Determination of the observation depth for NSST data (satellite, buoys & ships)

- **NSST is analyzed within GSI**
  - **Advantages**
    - 6-hourly analysis
    - Use more types of data easily
      - Better data coverage
    - Assimilate the raw observations directly
      - Simpler observation error
    - NSST analyzed with atmospheric analysis variables in a single cost function
      - Better consistency
  - **Work**
    - Incorporation of NSST analysis in GSI
    - The use of more data: AVHRR, insitu NSST and more

Progress

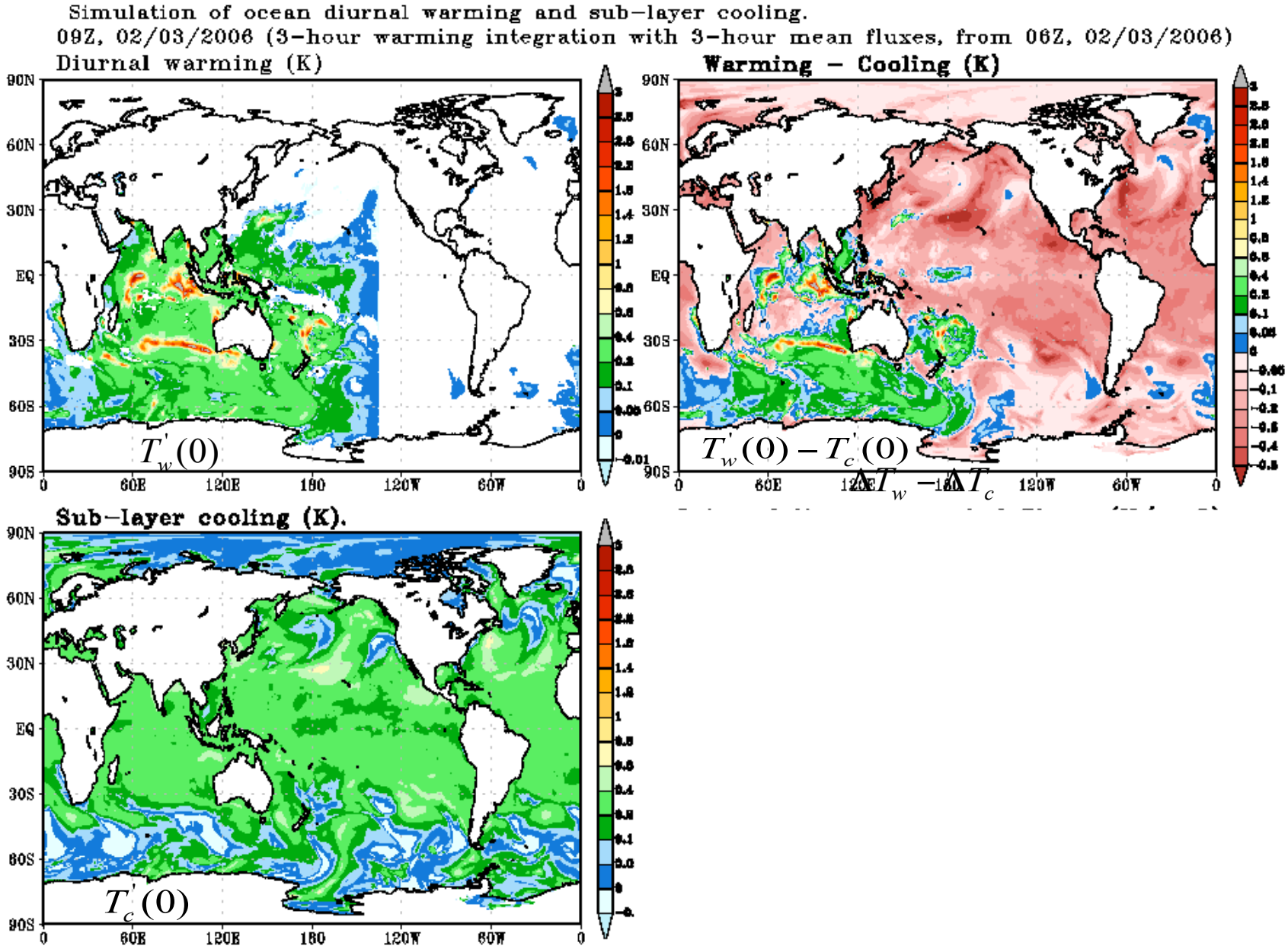
- A 6-hourly NSST analysis scheme in NCEP GFS has been developed
  - Boundary condition (SST) for GFS_AM
  - Boundary condition (sub-layer T-profile) for CRTM
- A series of experiments on this new scheme have been done and the results are encouraging
  - Impact of NSST model on CRTM and therefore atmospheric analysis (reported last year)
  - Tr analysis with GSI
  - Impact of NSST model on GFS_AM (7-day forecasting)
  - Coupled assimilation (parallel run) in preparation

Experiments of Tr analysis in GSI

	Observation Data	Analysis variable	Lower thermal boundary condition to CRTM
CTL	Used in operation + AVHRR GAC + NSST of buoys &ships	SST	SST^{bg}
OCN	Used in operation + AVHRR GAC + NSST of buoys &ships	T_r	IR: $T_r^{bg} + T_w^{'}(z_{ir}) - T_c^{'}(z_{ir})$ MW: $T_r^{bg} + T_w^{'}(z_{mw})$

$T_w^{'}(z), T_c^{'}(z)$ **: Provided by uncoupled NSST model (forced by available NCEP 3-hourly operational fluxes)**

Experiment period: 09/01/2007 ~ 09/07/2007


Simulation of ocean diurnal warming and sub-layer cooling.
09Z, 02/03/2006 (3-hour warming integration with 3-hour mean fluxes, from 06Z, 02/03/2006)
Diurnal warming (K)
$T_w'(0)$
Warming – Cooling (K)
$T_w'(0) - T_c'(0)$
$\Delta T_w - \Delta T_c$
Sub-layer cooling (K).
$T_c'(0)$
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W

Sensitivities of $T(z)$ to T_r

$$\frac{\partial T_z}{\partial T_r} = \frac{1}{1 - W_0 + C_0} + \frac{W_d - C_d}{1 - W_0 + C_0} z \qquad 0 \le z \le z_c$$

$$\frac{\partial T_z}{\partial T_r} = \frac{1 + C_0}{1 - W_0 + C_0} + \frac{W_d}{1 - W_0 + C_0} z \qquad z_c \le z \le z_r$$

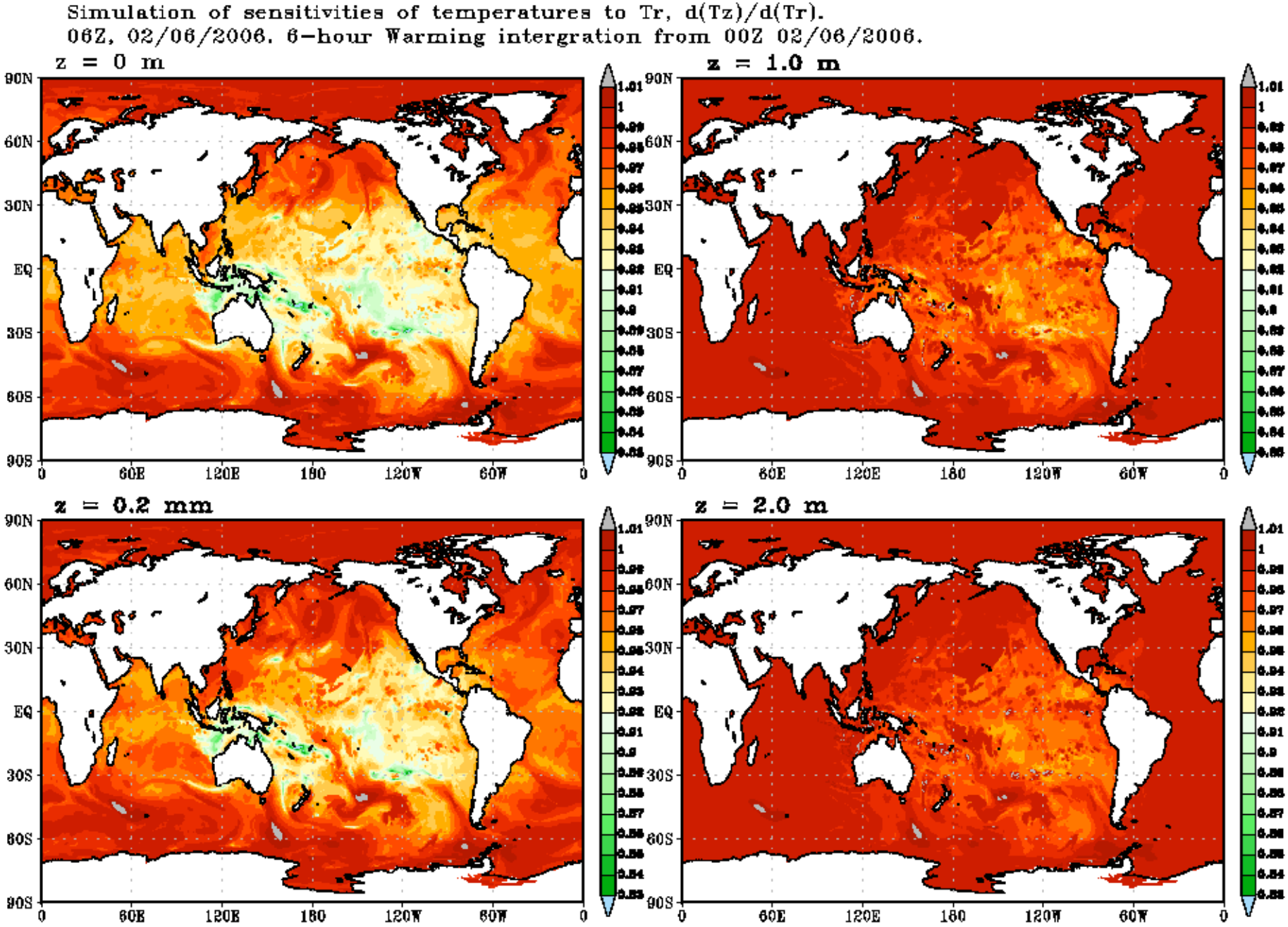
$$W_0 = \frac{2}{\rho_o c_p z_r}\left[\left(\frac{\partial I_{sw}}{\partial z_r} - \frac{I_h}{z_r}\right)\frac{\partial z_r}{\partial T_s} - \frac{\partial I_Q}{\partial T_s}\right]$$

$$W_d = \frac{2}{\rho_o c_p z_r^2}\left[\left(\frac{2I_h}{z_r} - \frac{\partial I_{sw}}{\partial z_r}\right)\frac{\partial z_r}{\partial T_s} + \frac{\partial I_Q}{\partial T_s}\right]$$

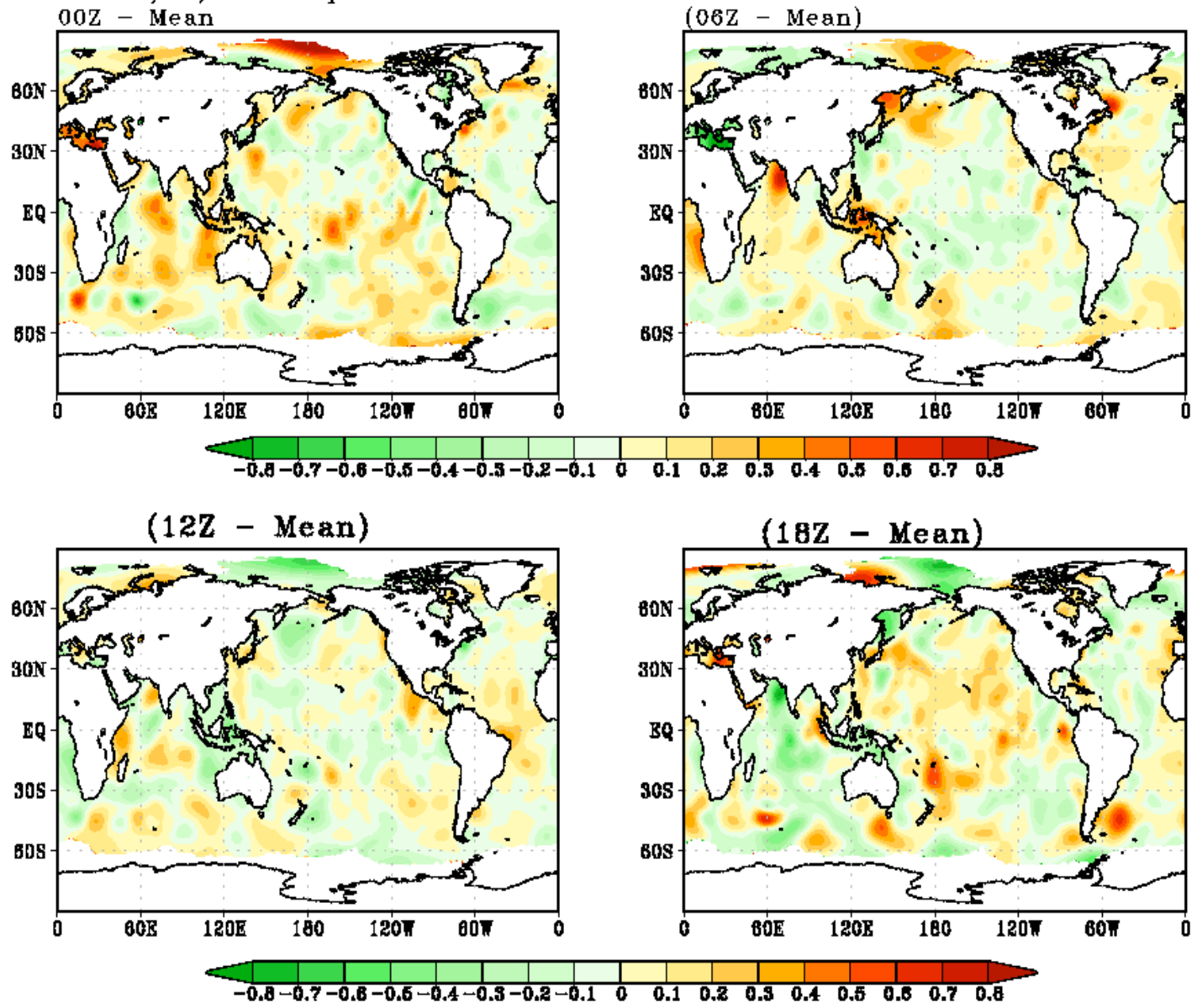
$$C_0 = \frac{1}{\kappa}\left[z_c \frac{\partial Q}{\partial T_s} + (Q - S_c - \omega_c R_{ns} A_c z_c)\frac{\partial z_c}{\partial T_s}\right]$$

$$C_d = \frac{1}{\kappa}\left(\omega_c R_{ns} A_c \frac{\partial z_c}{\partial T_s} - \frac{\partial Q}{\partial T_s}\right)$$

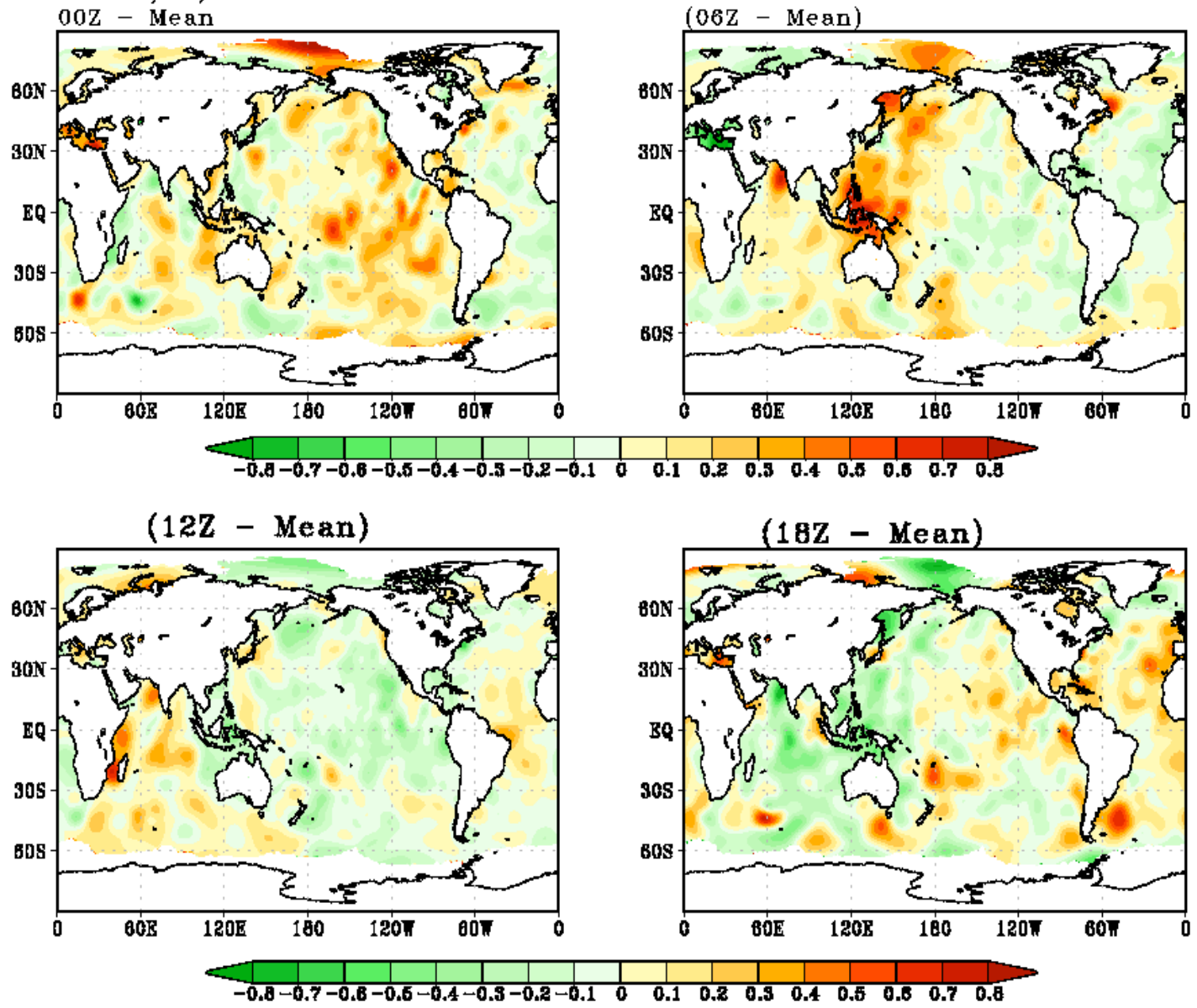
Sensitivities of *T(z)* to *Tr*



Diurnal variability of analysis variable (*Tr*)



Diurnal variability of analysis variable (*SST*)



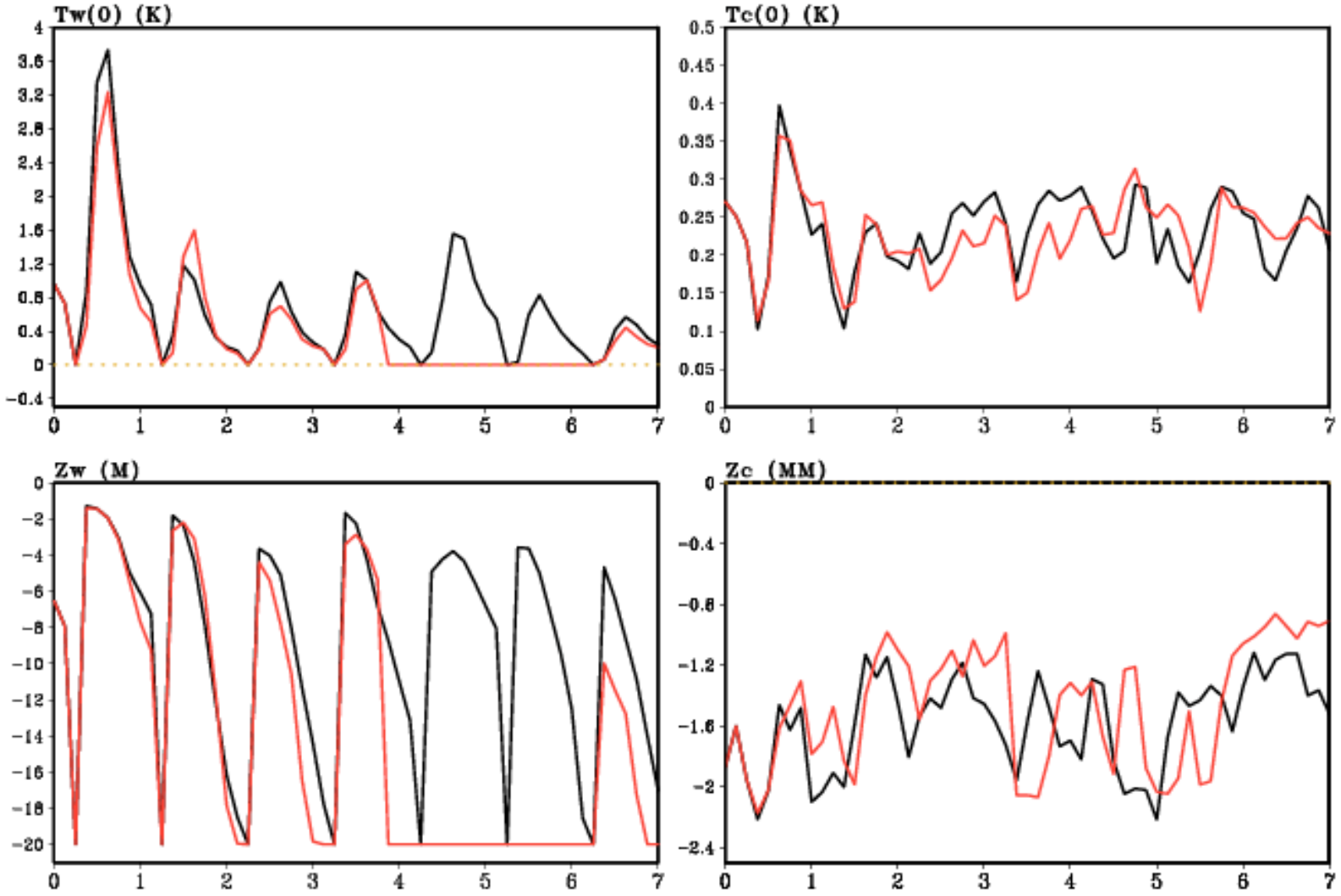
Experiments of NSST model on GFS 7-day forecasting.

	Atmospheric Initial Conditions	SST
GFS	GFS analysis (00Z, 06Z, 12Z, 18Z)	SST^{op}
CTL	GDAS analysis (00Z, 06Z, 12Z, 18Z)	$SST^{op} + T_w^{'}(0) - T_c^{'}(0)$
OCN	GDAS analysis (00Z, 06Z, 12Z, 18Z)	$SST^{op} + T_w^{'}(0) - T_c^{'}(0)$

SST^{op} **: NCEP operational SST analysis**

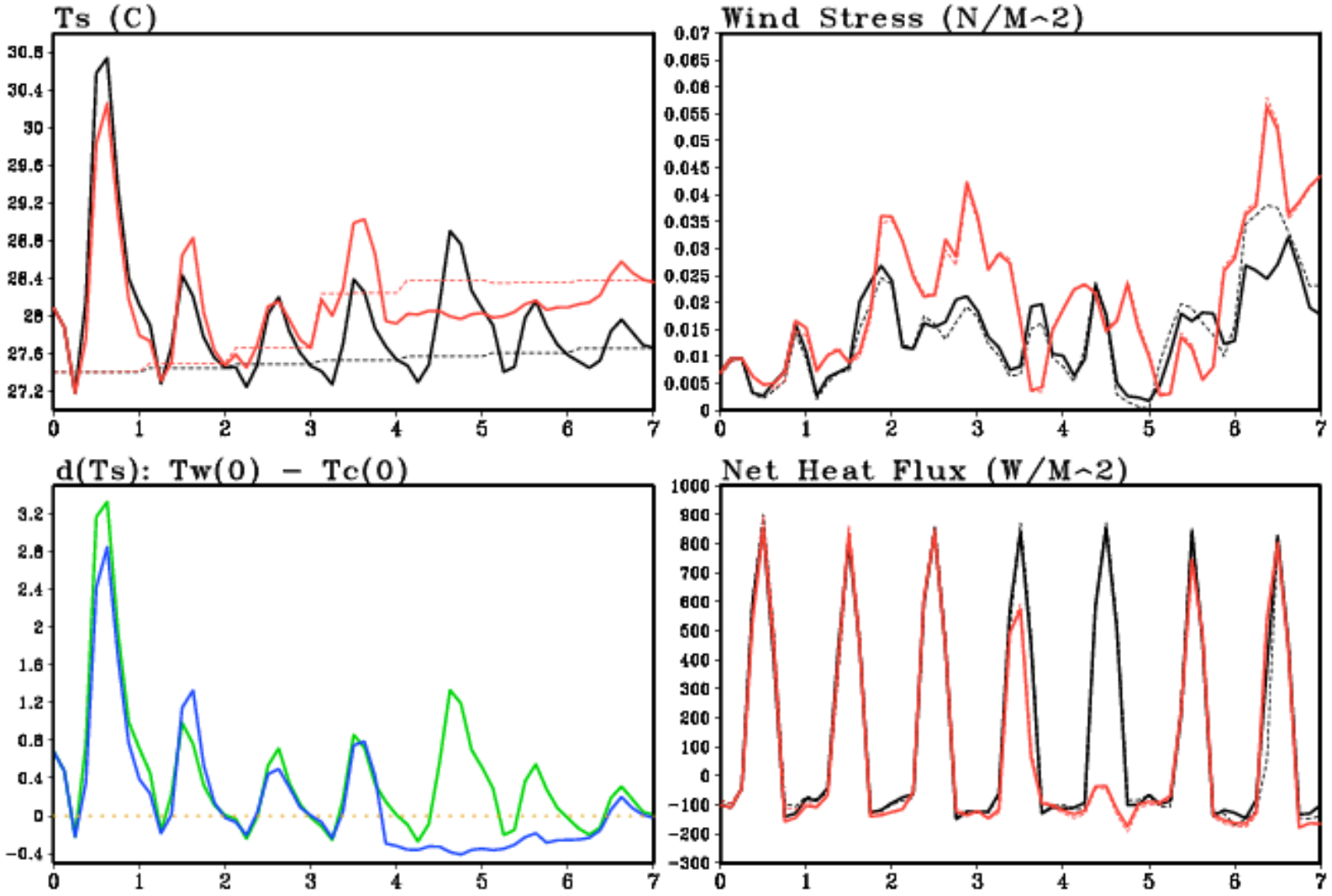
$T_w^{'}, T_c^{'}$ **: Provided by coupled model (GFS_AM + NSST model)**

The experiments (CTL and OCN) have been done for 3 months: July 2007. January 2008 and September 2007.

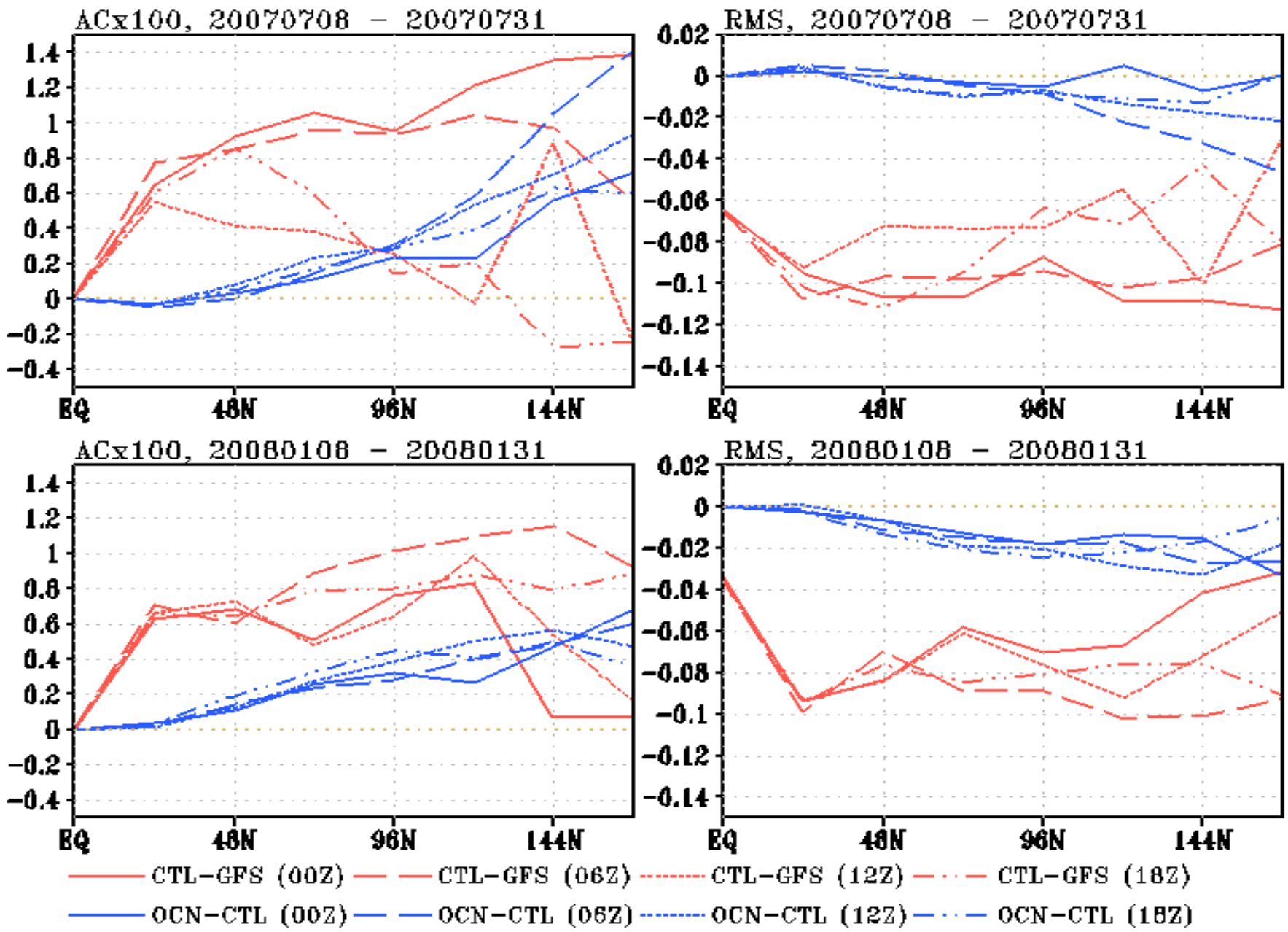

Diurnal warming & sub-layer cooling in coupled GFS(GFS_AM + NSST) forecasting.
LON: 9.0 ~ 10.0; LAT: -5.0 ~ -4.0 OCN:—— OCN3h6h:—
Starting from 00Z, 01/25/2008.
Tw(0) (K)
Tc(0) (K)
Zw (M)
Zc (MM)

Ts & Fluxes in GFS forcasting: Control and Coupled (GFS + NSST). From 00Z, 01/25/2008.
LON: 9.0 ~ 10.0; LAT: -5.0 ~ -4.0. Sampled 3-hourly.

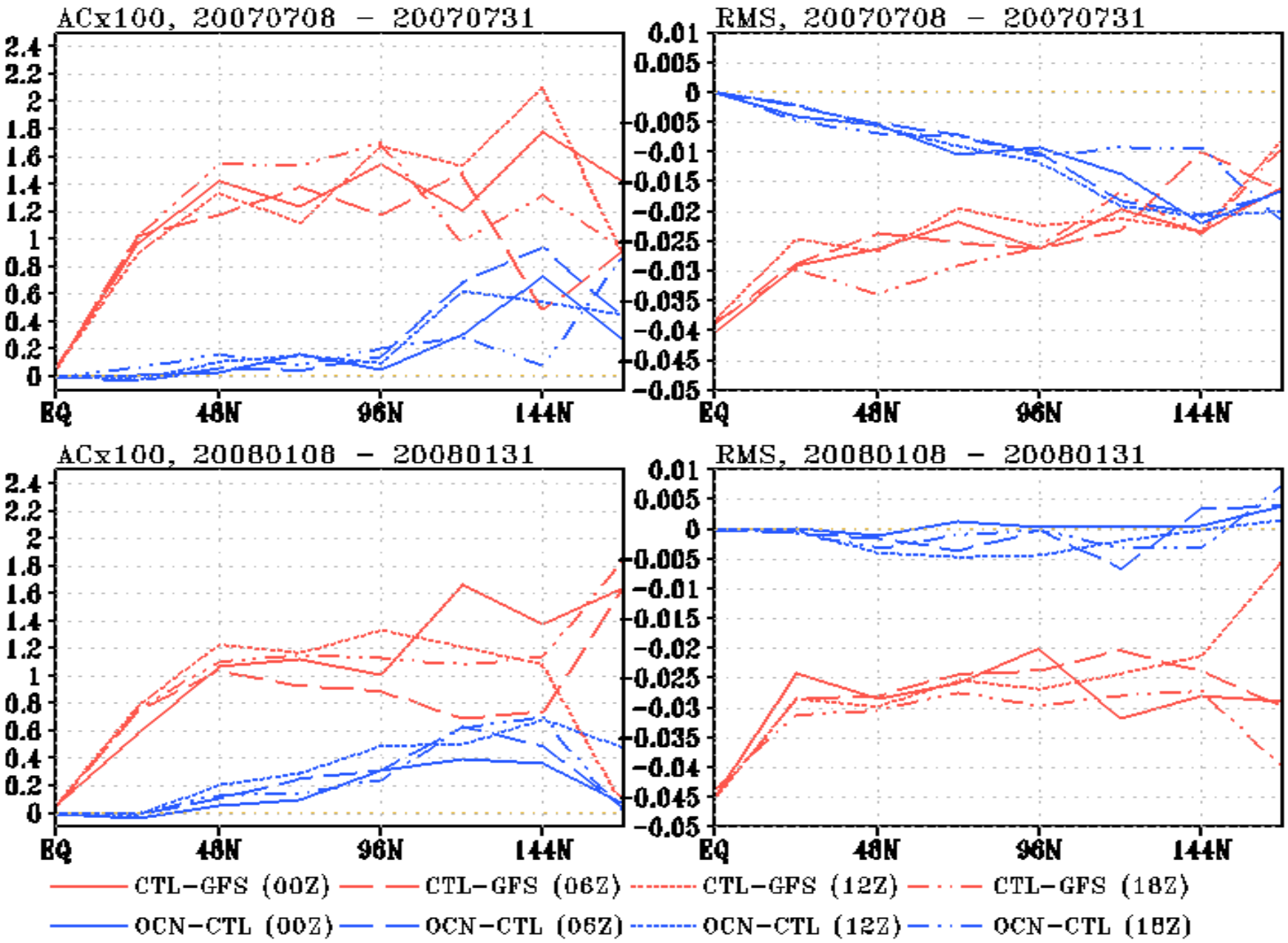
CTL: ----- CTL3h6h: ----- OCN: —— OCN3h6h: —— OCN - CTL: —— OCN3h6h - CTL3h6h: ——



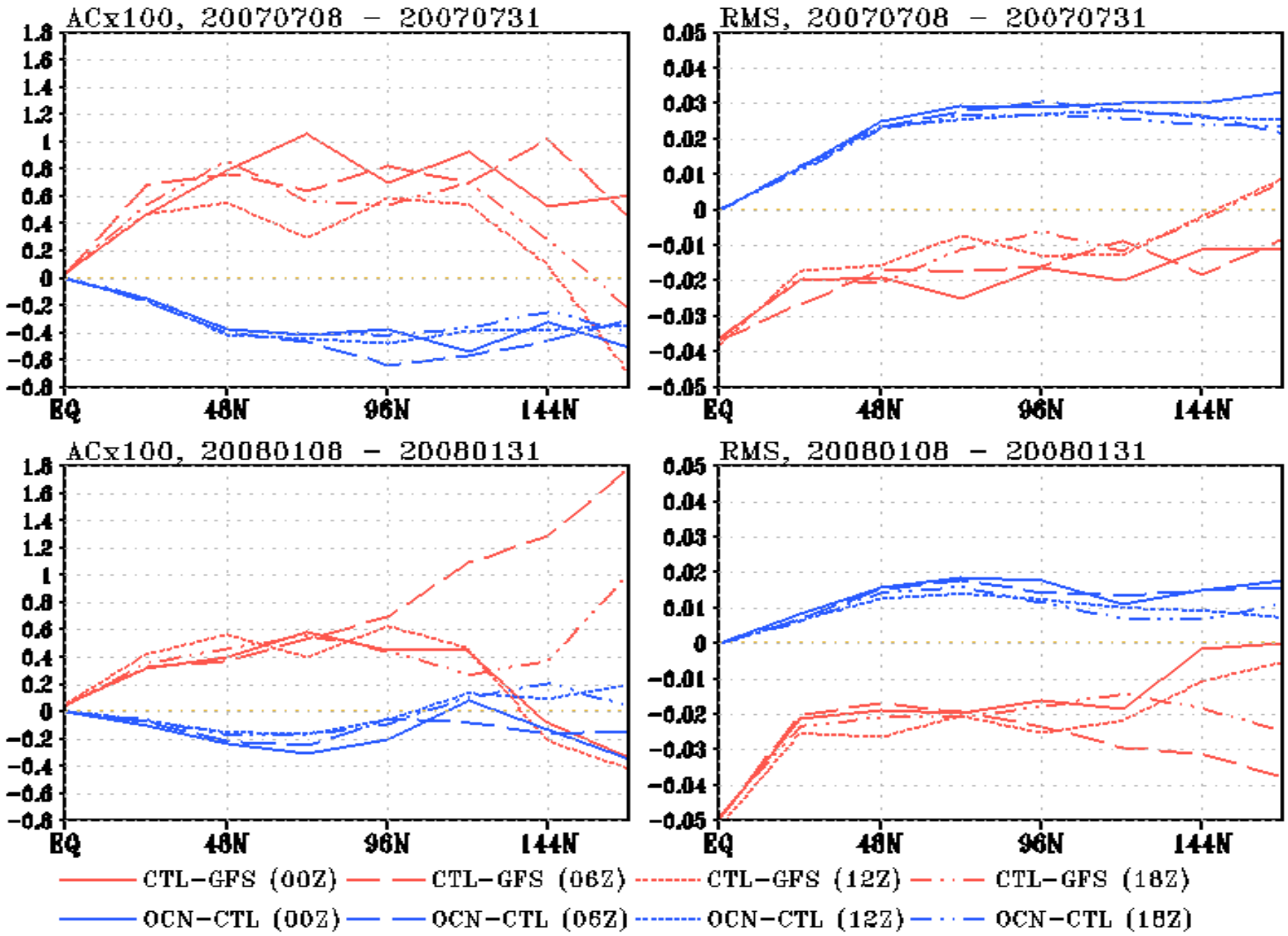
Impacts of NSST model on GFS 7-day forecasting. WIND P850 Tropics



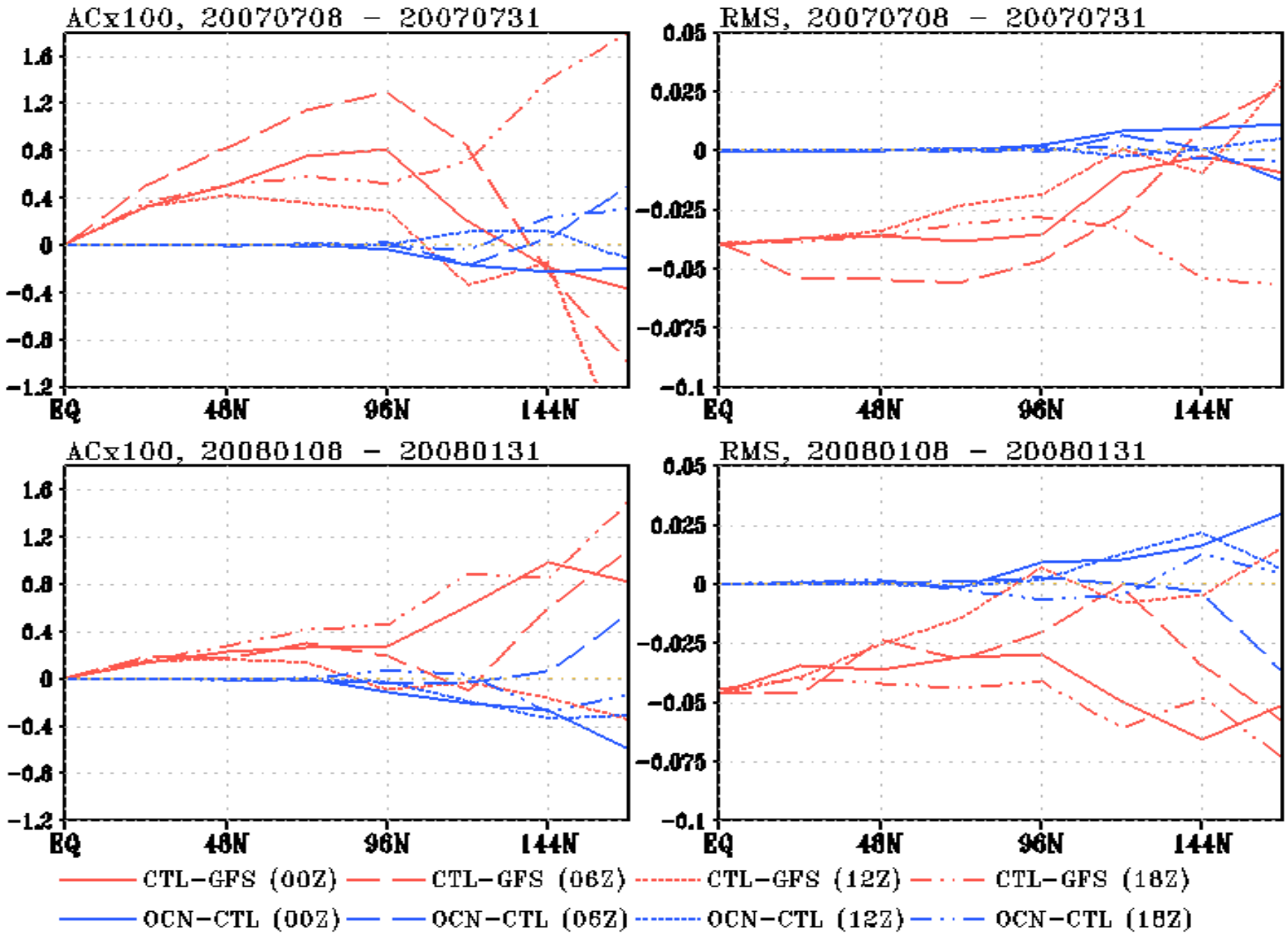
Impacts of NSST model on GFS 7-day forecasting. T P500 TR0



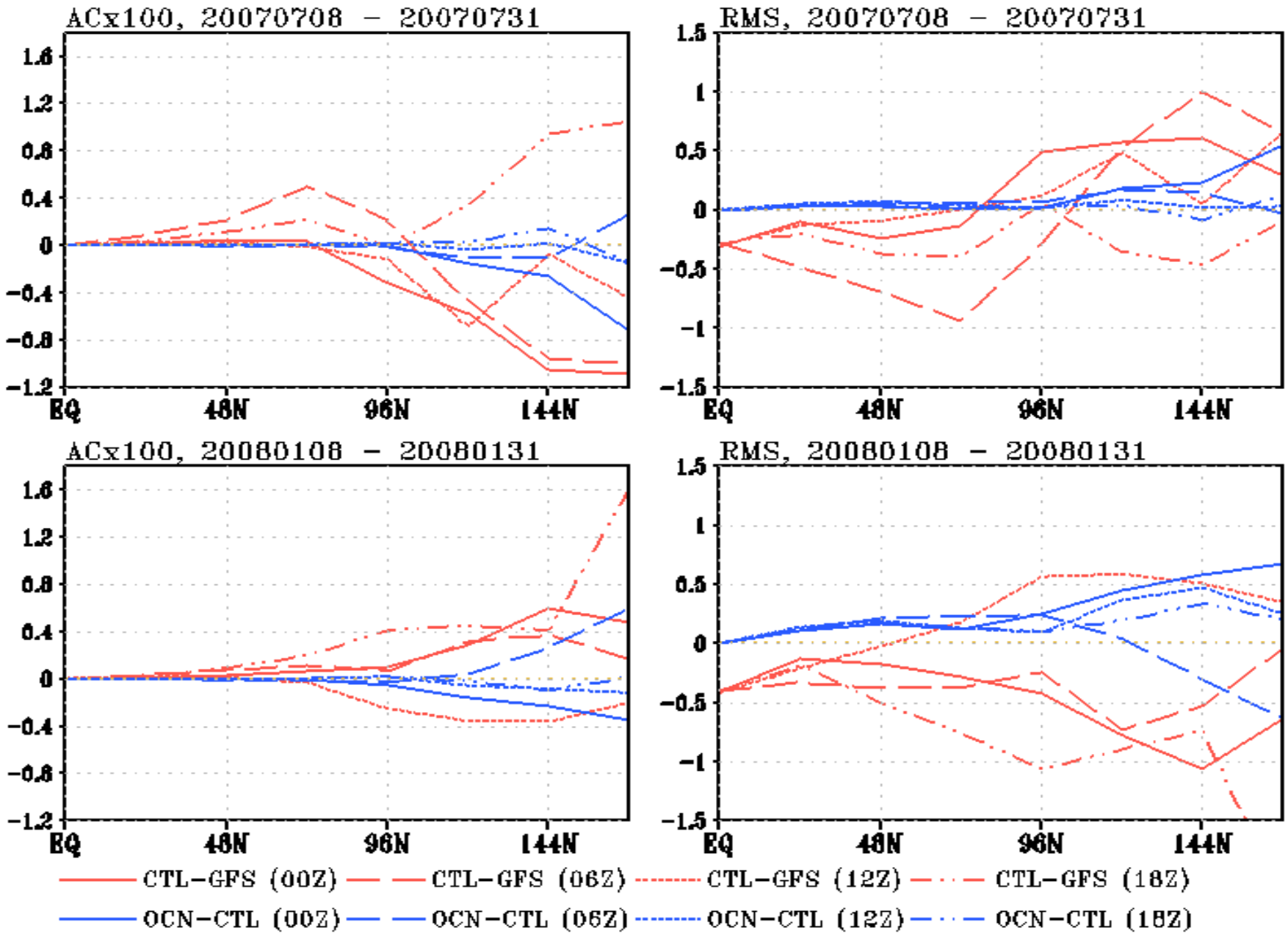
Impacts of NSST model on GFS 7-day forecasting. T P850 TR0



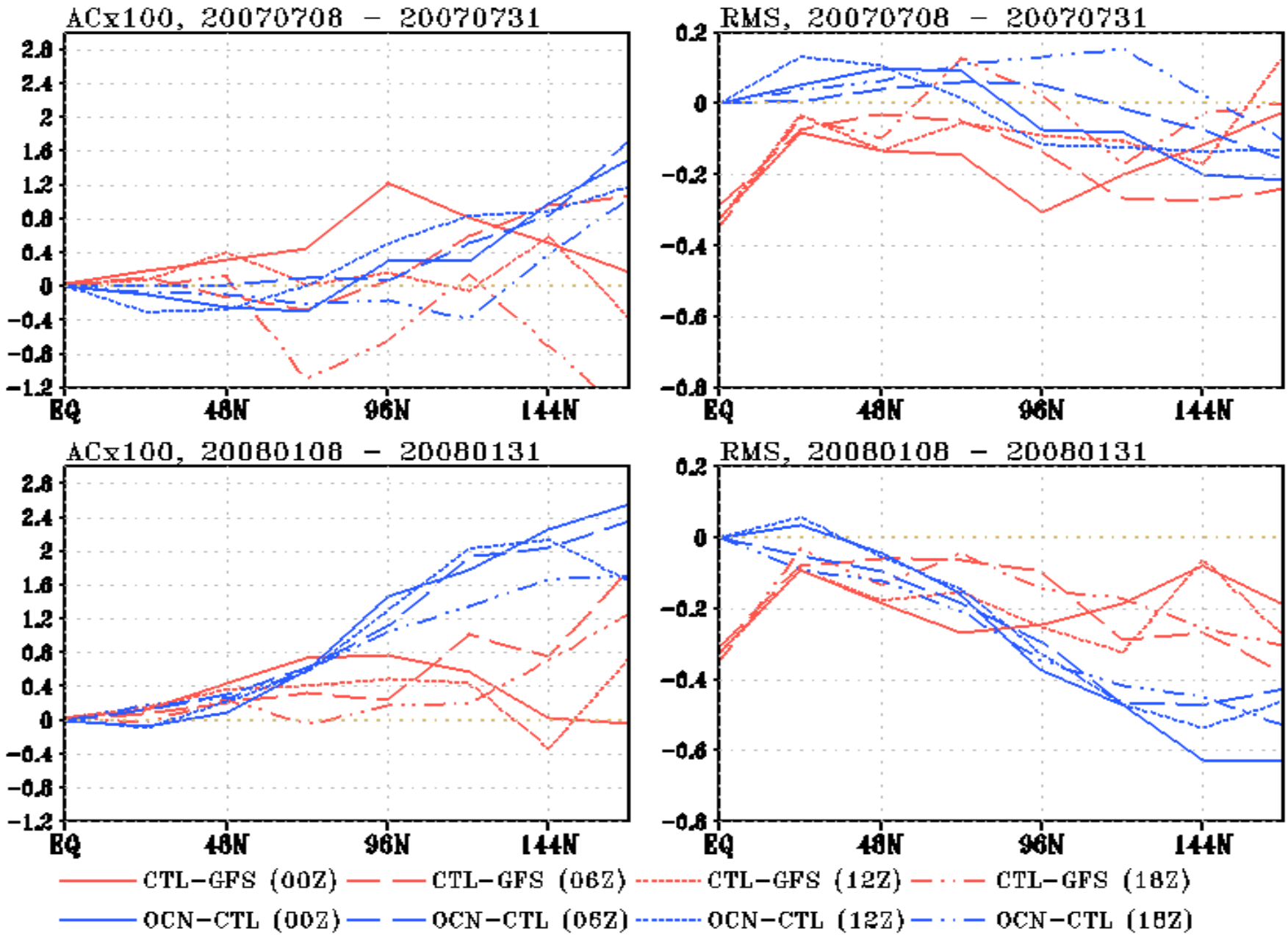
Impacts of NSST model on GFS 7-day forecasting. T P500 NHX



Impacts of NSST model on GFS 7-day forecasting. HGT P500 NHX



Impacts of NSST model on GFS 7-day forecasting. HGT P1000 TRO



Plan

- Extend the 7-day forecasting to 14-day
- Parallel run
  - Feedback between analysis and forecasting
- Operational in 2008
- Coupling of GFS_AM, NSST model and OGCM?