

NSST Analysis in NCEP GFS

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Abstract

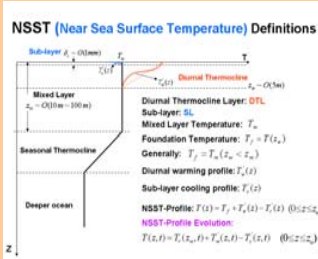
An Near Sea Surface Temperature (NSST) analysis scheme has been developed to provide a better lower thermal boundary conditions over water surface to the analysis and forecasting in NCEP GFS System.

An NSST model, including Diurnal Thermocline Model (DTM) and Sub-Layer Model (SLM) in COARE V3.0, is introduced to resolve the Diurnal Thermocline Layer (DTL). All the observations, including satellite and in situ data, are assimilated directly with GSI variational assimilation technique.

The significant positive impacts can be seen in the tests on the developed components, in non-cycling mode, and the integrated system, in cycling mode.

A new DTM is in development at NCEP to resolve the DTL more effectively.

Some elements and major characteristics in the scheme



NSST Analysis

Analysis variable: a defined reference temperature, currently the foundation temperature. Therefore, $T_s = T_r$.

Observation operators and their Jacobi: Relate the depth dependent data, Satellite, T_s, z (channel) dependent with skin depth of 0.5 ~ 1.0 mm in sub-layer. In $\text{Rho}(T_s, z)$ with depth of 0.2 ~ 15.0 m, to z with CRTM and NSSTM.

Analysis increments:

$$\text{Tr}: \Delta T_s^k = T_s^k - T_s^{k-1} = \Delta T_s^k - \Delta T_s^{k-1}$$

$$\text{SST}: \Delta T_s^k = T_s^k - T_s^{k-1} = \Delta T_s^k + \Delta T_s^{k-1}$$

Products:

The boundary condition for GFS_AM: $T_r = T_s + T_w(0) - T_c(0)$

The boundary condition for CRTM: $T_m(z) = T_r + T_w(z) - T_c(z)$ ($0 \leq z \leq \delta$)

$T_c(z)$ ($0 \leq z \leq z_m$) will be used to combine NSSTM and OGSIM

Simulation/Parameterization of $T_r(z,t)$ and $T_c(z,t)$

- Fairall et al (1996) COARE V3.0 NSSTM

- DTL onset criterion: Interface net heat flux > Q_{min}

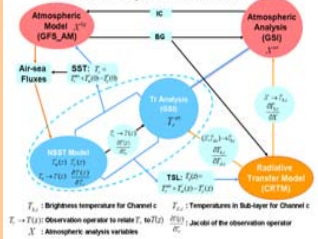
- DTL evolution:

- Scale analysis version of 1-dimensional control equations
- Assumed linear warming profile
- Bulk Richardson number (Mixed layer stability)

- DTL reset

- Artificially: reset forcefully at midnight

NSST Analysis in NCEP GFS



- Analysis is done within GSI

- Take the advantages of the on-going GSI development
- Produce higher time resolution product (6-hourly analysis)
- Add more data easily
- Assimilate the raw observations directly
- Oceanic variable analyzed with atmospheric analysis variables in a single cost function

- Introduction of the NSST Model

- Resolve diurnal variation
 - Better background for analysis in GSI
 - Hourly air-sea interaction in weather forecasting
- Select an analysis variable, T_r (T_s , T_m , T_{10m_av} ...), derive others in DTL with the analysis and NSSTM
- Together with CRTM, relate all types of observations to T_r
 - Observation operators and their Jacobi to assimilate the raw observation directly
- Provide appropriate products
 - SST for GFS_AM
 - Sea Temperature in sub-layer for CRTM

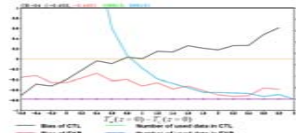
Scheme performance tests

Experiments of NSST model on radiance simulation

Lower Thermal Boundary Condition for CRTM	
CTL	$T_r = T_m = SST$
EXP	$T_r = SST^* + T_w(0) - T_c(0)$
	$T_m = SST^* + T_w(z)$

SST^* : NCEP operational SST analysis (regarded as Tr)

T_w, T_c : Provided by NSST model (Stand alone with 3-hour forcings)



The inclusion of the diurnal warming and sub-layer cooling effects indeed reduce the bias of the simulated radiance.

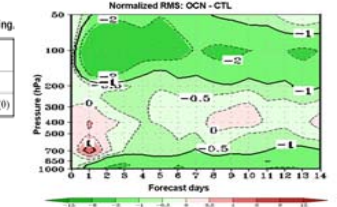
Experiments of NSST model on GFS 14-day forecasting.

Atmospheric Initial Conditions		SST	
CTL	GDAS analysis (00Z, 06Z, 12Z, 18Z)	SST^*	
OCN	GDAS analysis (00Z, 06Z, 12Z, 18Z)	$SST^* + T_w(0) - T_c(0)$	

SST^* : NCEP operational SST analysis (regarded as Tr)

T_w, T_c : Provided by NSST model (embedded in GFS_AM)

The experiments (CTL and OCN) have been done for 2 months: July 2007, January 2008 with T382, operational version of GFS.

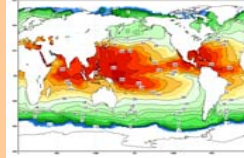


The significant positive impact on tropics wind forecasting over the 14-day period. The negative value (in green) means less RMS verified against the operational analysis. The areas with amplitude greater than 1 represent significance confidence more than 95%.

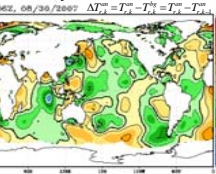
NSST Analysis Experiment with Cycling GFS

- 10 days (08/22/2007 - 08/31/2007), 6-hour cycling analysis.
- Operational version of T382 GFS_AM and QAFY08 version of GSI.
- NSST model coupled into GFS_AM (every time step)
- Data used:
 - Satellite:
 - IR: AQUA (NOAA-17), IRS, AIRS (AQUA), HIRS, GOES
 - Sounder:
 - AMSU-A, AMSU-B
 - In Situ:
 - Ships, Ships in MOCSBUFR

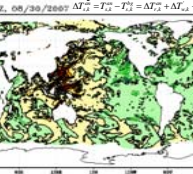
Operational SST analysis (Wesley, Reynolds) 08/20/2007



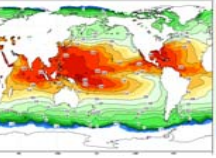
Tr analysis increment with GSI:



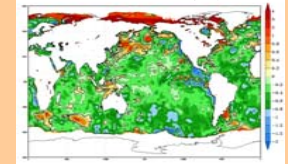
SST Analysis increment:



Tr analysis by GSI: 7-day mean (08/20/2007 - 08/26/2007)

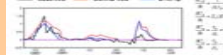


The difference between two SST analysis (GSI - OPR)



DTM development at NCEP: DTM-1p

Time - Time: Based on Jason-2 Ships Cruise



The end of the diurnal warming event becomes natural in DTM-1p.

- Based on the 1-D control equations
- Nonzero fresh water flux
- Rotation effect added
- Free convection effect included
- The evolution of DTL is controlled by a system with 5 ordinary differential equations after the control equation for T_r is derived.
- DTM-1p is in development where the diurnal warming profile is generated: a line (mixed layer) in an exponential curve (stratification layer).

Plan

Performance test of NSST analysis in NCEP GFS, with longer cycling run for operational application

At the same time, develop DTM-2p and replace COARE V3.0 with when ready