Operational Sea Surface Temperature Analysis within the NCEP GFS

Xu Li[1], John Derber[2], Andrew Collard[1], Shrinivas Moorthi[2],
[1]IMSG at Environment Modeling Center, National Center for Environmental Prediction, NOAA, USA
[2]Environment Modeling Center, National Center for Environmental Prediction, NOAA, USA

Abstract

- A brief introduction to NSST, the SST analysis within the NCEP GFS (Global Forecast System)
- Status, issues and future of NSST
- An evaluation of 6 SST analyses through the platform dependent fit to in situ observations
- An evaluation on how well the observations with diurnal warming signal are used in NSST
- A possible NSST improvement related to an issue of Infra-Red emissivity in CRTM

Status

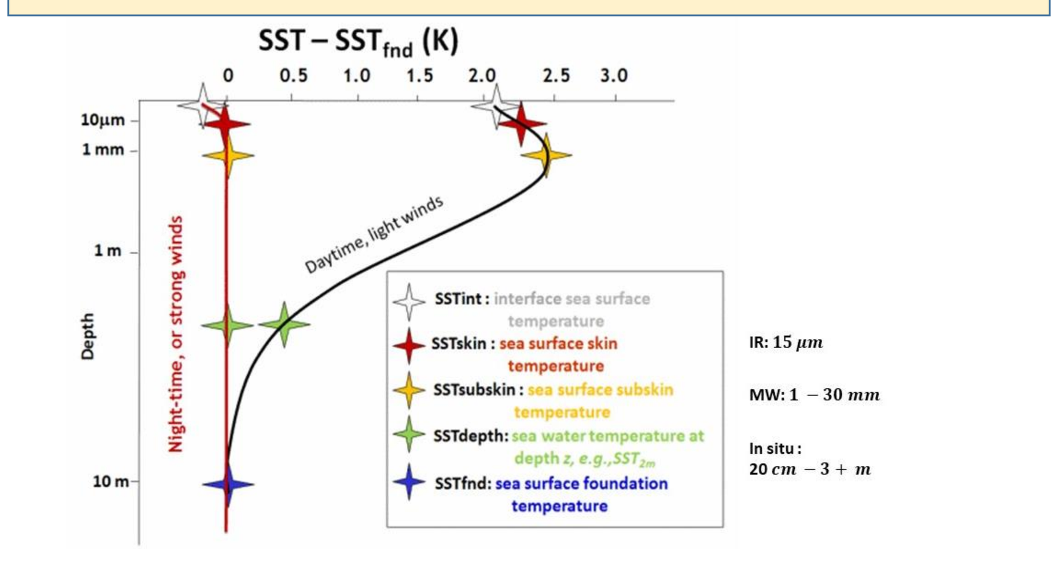
- Operational in NCEP GFS since July 2017
- Two updates (operational soon in FV3GFS):
  - Background error correlation length
  - The use of SST climatology to improve the background
- The evaluation has been done with O – B and O – A against in situ and satellite observations and comparisons with other SST analyses.
- Some problems have been found out in some circumstances and the improvements are underway

Issues

- In some areas and time periods, the NSST analysis is problematic due to
  - Too coarse Observations
    - Microwave radiances are not used yet
    - Newer AVHRR and VIIRS are not used yet
    - Most of the buoy observations are lost in the NCEP GFS system
  - No forward model to predict the analysis variable
    - The use of the SST climatology
  - Cloud contaminated radiances

NSST within the NCEP GFS

SST definition



Hypothetical vertical profiles of temperature for the upper 10m of the ocean surface in high wind speed conditions or during the **night** (red) and for low wind speed during the **day** (black).

NSST definition

- Near-Surface Sea Temperature (**NSST**) is a temperature profile with the vertical thermal structure due to the diurnal warming and sub-layer cooling physics

$$T(z,t) = T_f(z_w,t) + T'_w(z,t) - T'_c(z,t)$$

T_f : foundation temperature

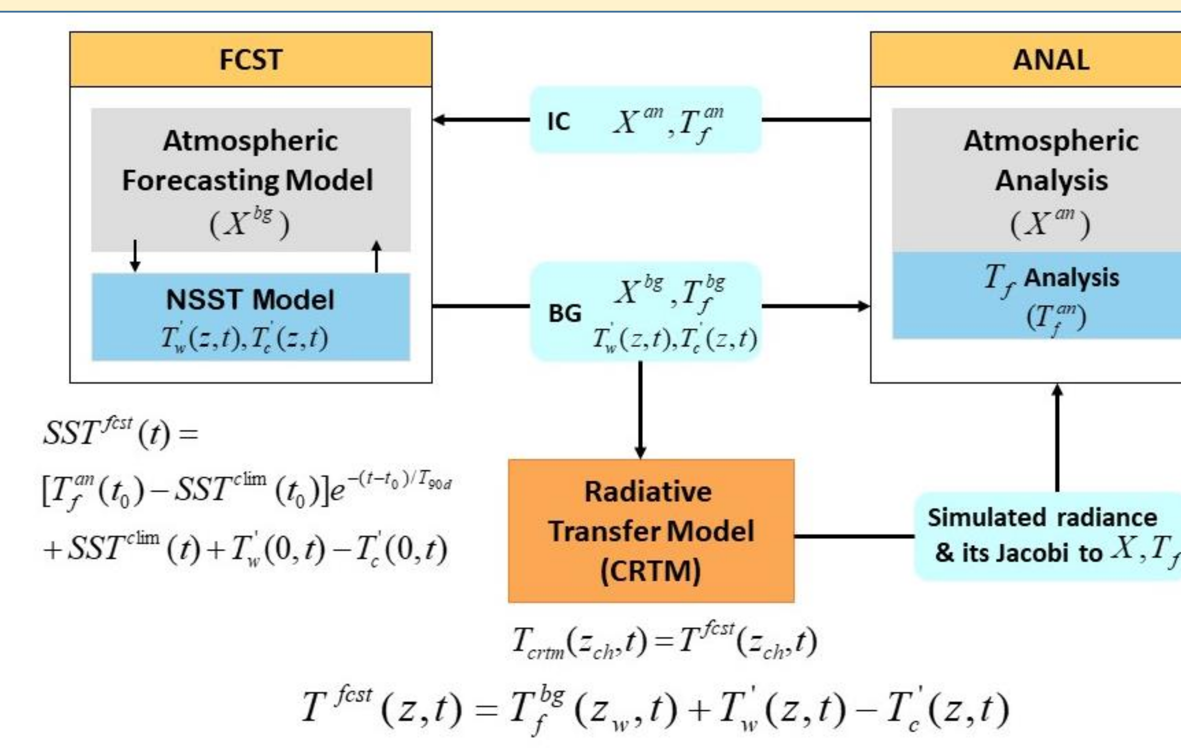
$z_w = z_w(t)$: diurnal warming layer thickness

T'_w : diurnal warming profile

T'_c : sub-layer cooling profile

- The temperatures at any depth, including SSTint, SSTskin, SSTsubskin, SSTdepth and SSTfnd, can be handled in the frame of NSST T-Profile
- The capability to merge the observations from the different platform is available in NWP data assimilation system, particularly with the direct assimilation

Diagram of NSST within the NCEP GFS



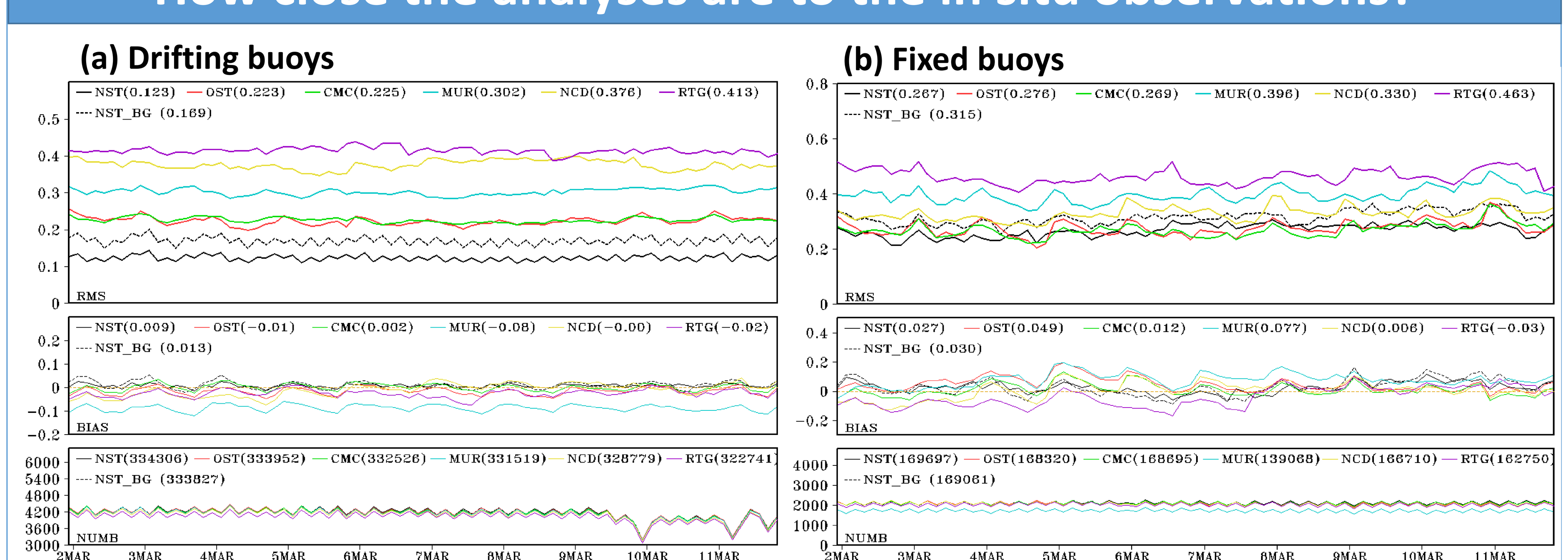
NSST Model within the NCEP GFS

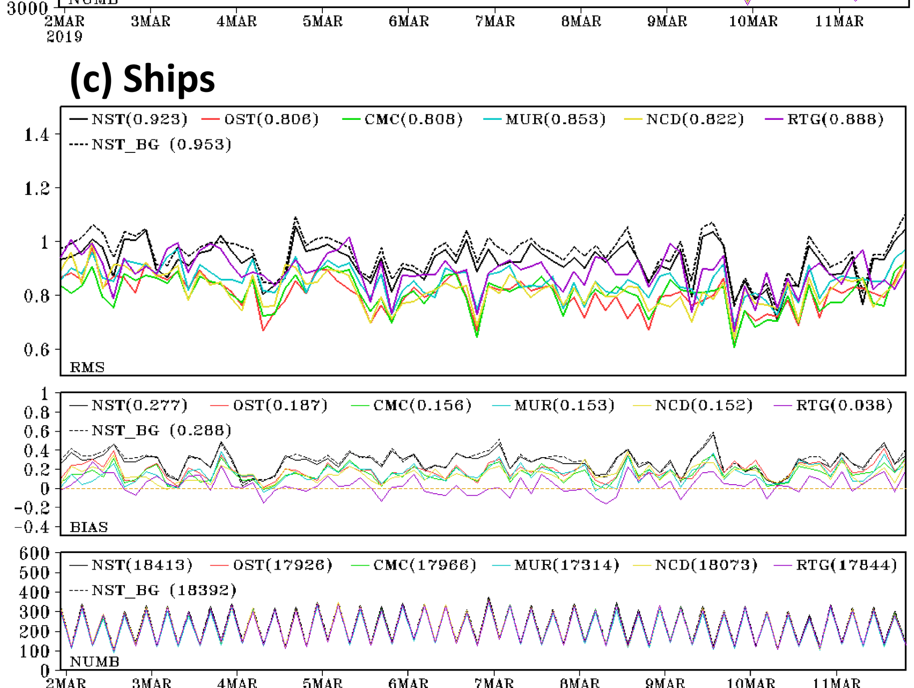
- Resolve the high frequency SST variability in prediction mode
  - NSSTM is built in GFS atmospheric model (GSM, FV3) with the same time step
    - Diurnal warming profile: $T'_w(z,t)$
    - Sub-layer cooling profile: $T'_c(z,t)$
    - $SST = T(0,t) = T_f(z_w,t) + T'_w(0,t) - T'_c(0,t)$, used in fluxes calculation
- Provide a skin-depth (wavelength) dependent thermal lower boundary condition to CRTM
- Relate the analysis variable to the temperature at the observation depth

NSST analysis within the NCEP GFS

- T_f, an oceanic variable, is added to GSI, the NCEP atmospheric data assimilation system, as a new analysis variable and then analyzed together with other atmospheric analysis variables.
- Direct assimilation
- A step towards coupled assimilation

How close the analyses are to the in situ observations?





$$O - A: T^{ob}(z_{ob}) - \{T_f^{an}(z_w) + [T_w^{\prime bg}(z_{ob}) - T_c^{\prime bg}(z_{ob})]\}$$

Figure 1. Observation minus Analysis (O – A) time series of RMS, BIAS and the number of used data, Global, 10-day period in March, 2019 for 6 SST analyses: NSST, OSTIA, CMC, MUR, NCDC and RTG. (a), (b) and (c) is for drifting buoys, fixed buoys and ships respectively.

- Generally, the fit of the analysis to the observation depends on the analysis scheme, specifically, the weights given to background and observation
- The comparisons help find the way to improve
- For NSST, based on Figure 1c, we should toss more ships data and reduce the observation error

How well the observations with diurnal warming signal are assimilated in NSST?

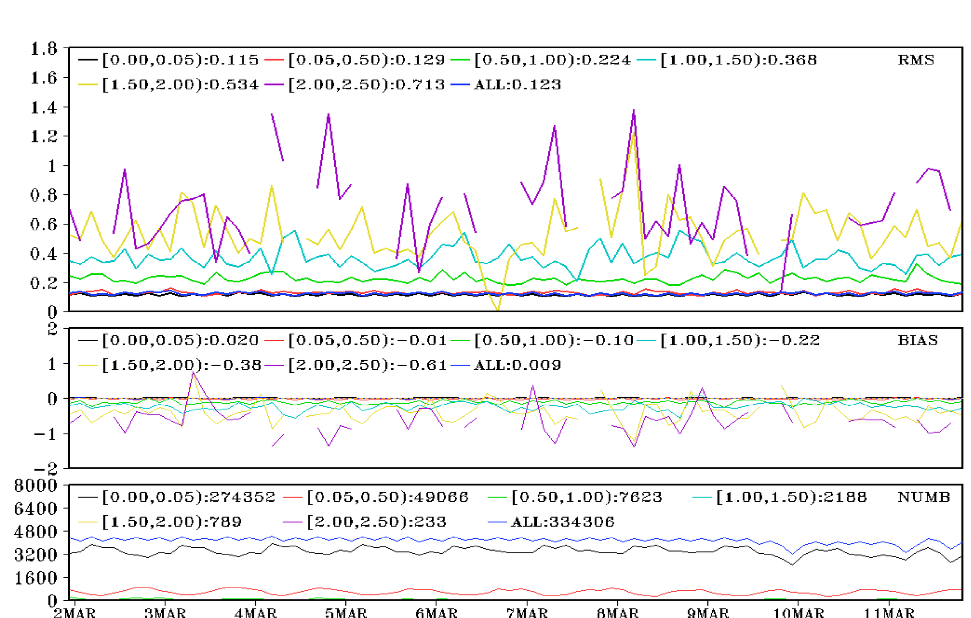


Figure 2. Observation minus Analysis (O – A) time series of RMS, BIAS and the number of used data, Global, 10-day period in March, 2019, depends on the interval of the diurnal warming amount.

- The data with diurnal warming signal are tossed in the available foundation temperature analyses except for NSST
- They are used well in NSST, but the RMS and BIAS increase with the diurnal warming amount, and it maybe too large in some cases while it is warmer than 1.50 K, however, which is only about 0.1 % of the total data counts
- One more quality control can be added to reject the data with large diurnal warming amount

Future

- The use of more observations
- The better use of the SST climatology with seasonal variability
- Upgraded background error correlation length
- Smaller or correlation length dependent thinning box size
- New or modified cloud detection to avoid cloud contaminated radiances
- Inclusion of NSST in EnKF part of 4D-EnVAR GSI
- The combination of NSST into a coupled system

A possible NSST improvement - an Infra-Red emissivity issue in CRTM

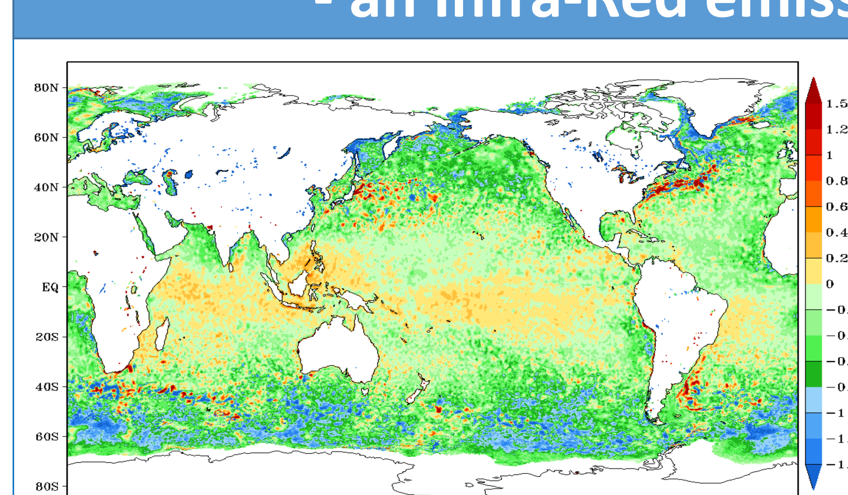


Figure 3. The difference between NSST and CMC monthly mean foundation temperature analysis. May, 2019.

- **In higher latitudes areas, NSST is too cool as shown in Figure 3, and the simulated radiance is warmer in CRTM than in RTTOV as shown in Figure 4**
- **SST is one of the predictor in RTTOV Infra-Red emissivity model but not in CRTM one**

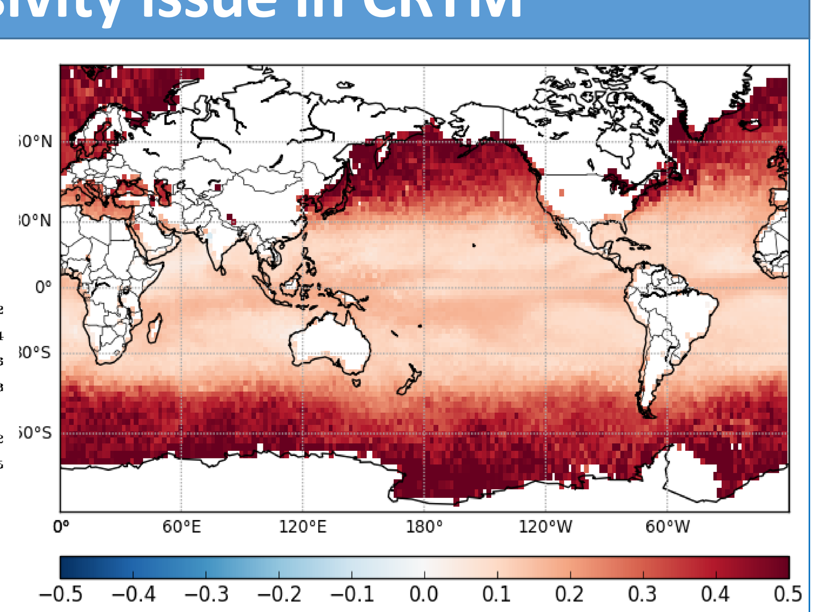


Figure 4. The difference between simulated brightness temperature by CRTM and RTTOV. A monthly mean in 2017, for an IASI window channel. Courtesy from Emily Liu (IMSG, EMC/NOAA).