GEOS Atmospheric Data Assimilation System: diagnostics and validation with tropical moorings

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Introduction

The GMAO is developing an Integrated Earth System Analysis (IESA) system which would include a coupled Atmosphere-Ocean (AO) Data Assimilation System (DAS). Central to this AO-DAS is the ability to assimilate for interfacial states: SST, SSS and sea-ice.

Since Jan. 24, 2017, the GMAO near-real time Atmospheric DAS has been assimilating for skin SST.

Skin SST

- serves as the lower boundary condition for the Atmospheric GCM
- used in atmospheric analysis: radiative transfer model
- air-sea fluxes, ocean state and gas exchange critically depend on it

Diurnal Variation

Near-surface diurnal warming and cool-skin variations are well known → unresolved by daily SST datasets.

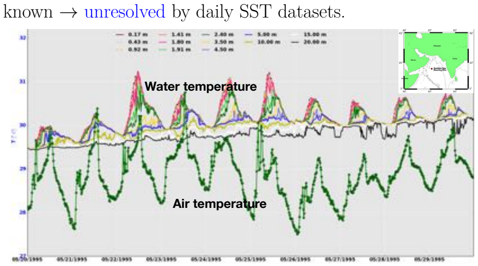

Figure 1: Time-series of observed temperatures (^{o}C) during the Arabian Sea Mooring Experiment

Skin SST (T_s) in GEOS AGCM

1. *Foundation* SST (T_d) and sea-ice fraction are prescribed from OSTIA
2. $T_s = T_d + \Delta T_w - \Delta T_c$; dT_w & dT_c are changes in temperature due to diurnal warming and cool-skin respectively
3. ΔT_w : a prognostic model based on [TAK2010] is used for diurnal warming; with few modifications described in [ATS2017]
4. ΔT_c : cool-skin temperature drop is empirically calculated.

ΔT_w and ΔT_c are shown in Fig. 2(a), (b), respectively

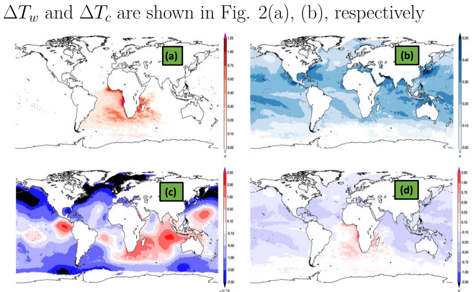

Figure 2: Contributions to the 12UTC, Dec 2017, mean T_s calculated within the GEOS ADAS. (a) diurnal warming (ΔT_w), (b) temperature drop (ΔT_c) due to cool-skin layer, (c) analysis increment in T_s, (d) difference between T_s and OSTIA SST. Note the difference in scales, particularly panel (c).

Shortwave radiation absorbed within the diurnal warm layer depends on climatological chlorophyll concentration. Ratio of absorbed to incident shortwave in the diurnal warm layer.

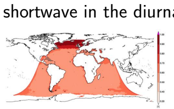

Figure 3: Monthly mean of the ratio of shortwave radiation absorbed within the diurnal warm layer to the net surface shortwave radiation for 12UTC, Dec 2017.

Contrast this spatially varying ratio to a parameterized shortwave absorption profile that has a constant value of 0.61

Analysis of T_s in GEOS-ADAS

Analysis: Hybrid 4D-EnVar using the Grid-point Statistical Interpolation (GSI) and the Ensemble Square-Root Filter (EnSRF).

The T_s analysis is carried out in central analysis using GSI, analysis using EnSRF is being tested.

Background innovation

Background temperature at observation depth (z_{ob}):

$$T(z_{ob}) = T_d + \begin{cases} \Delta T_w - \Delta T_c \left(1 - \frac{z_{ob}}{\delta}\right) & 0 \le z_{ob} \le \delta \ \textbf{Cool} \\ \Delta T_w - \left(\frac{z_{ob}-\delta}{d-\delta}\right)^{\mu_s} \Delta T_w & \delta < z_{ob} \le d \ \textbf{Warm} \end{cases}$$

For satellite radiance observations, penetration depth z_{ob} is set to constant values:

$$z_{ob} = \begin{cases} 15\,\mu\text{m all infrared sensors} \\ 1.25\,\text{mm all microwave sensors} \end{cases}$$

Ideally should be calculated based on instrument/channel specifications (e.g., wavelength or frequency).

- The Community Radiative Transfer Model (CRTM) is used to simulate brightness temperatures and Jacobian, $\partial T_b/\partial T_z$. Chain rule: $\partial T_b/\partial T_z = (\partial T_b/\partial T_s)(\partial T_s/\partial T_z)$, *assume* $\partial T_s/\partial T_z \approx 1$
- IR: $10-12\mu m$ AVHRR- NOAA-18 & MetOp-A provide additional relevant observations

T_s is analyzed along with the atmospheric state (u, v, p_s, T, q).

Analysis increment: $T_s^{ANA} - T_s^{BKG}$ is applied to the GEOS-AGCM via Incremental Analysis Update [B1996], see Fig. 2(c), but over *open water* only.

▶ Though small compared to the modeled variables (ΔT_w and ΔT_c), the analysis increment *tries* to *warm* T_s. Therefore information from the observations is *trying* to correct a known diurnal warming model bias which tends to *cool-off* too fast in late-evening to sunset [GA2018, ATS2017, W2017].

Impact on other observations

We obtained small improvements in the assimilation of currently used IR observations and beyond window channels

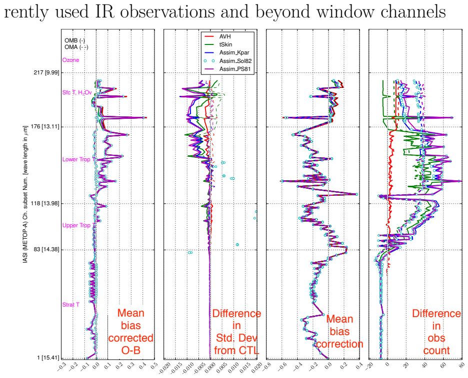

Figure 4: Monthly averaged OBS-BKG statistics for the IASI on Metop-A; statistics computed only over water. CTL used OSTIA SST, did not assimilate for T_s, and AVHRR observations were not used.

Impact on air-sea fluxes

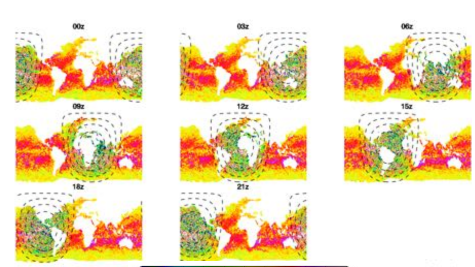

Figure 5: Diurnal variation in the $\Delta Q_{net}(W/m^2)$ for April, 2012, between EXP which assimilated T_s, while CTL used OSTIA SST for T_s; Contours

Impact on forecast skill

- Neutral change to the anomaly correlation and forecast RMSE in northern hemisphere and tropics
- Positive in southern hemisphere, decreased with elevation

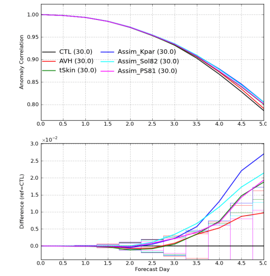

Figure 6: Anomaly correlation for souther hemisphere extratropics at 850-hPa geopotential height for five day forecasts from 00UTC analyses over April 2012.

Current Work

Comparison with an independent data set, such as SEVIRI on Meteosat-10, Fig.7 shows good agreement. With following drawbacks:

- For low wind speeds, the modeled diurnal warming is (too) high
- There is a rapid decay in diurnal warming, right after sunset [GA2018].

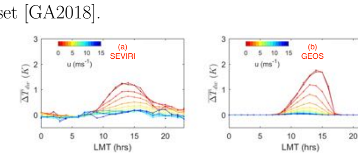

Figure 7: Comparison of monthly mean diurnal warming from (a) SEVIRI retrieved SST, (b) GEOS-ADAS for September, 2015.

A modification of the turbulent diffusivity in the diurnal warming model shows promising results in offline experiments, using *observed* fluxes, over a range of wind speeds, compare panels (c) and (e) in Fig.8.

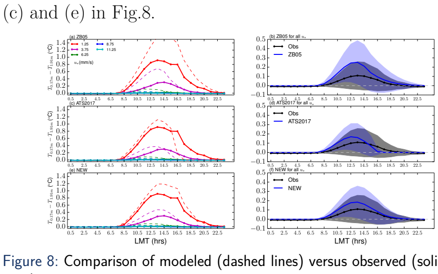

Figure 8: Comparison of modeled (dashed lines) versus observed (solid lines) diurnal warming for the Arabian Sea Mooring Experiment. Top, middle and bottom panels are with the Zeng & Beljaars, 2005, GEOS [ATS2017] and modified scheme, respectively.

References

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