Langley Research Center

Evaluation of the Tropical TOA Flux Diurnal Cycle in Reanalysis Models

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1. Introduction and Motivation

•The diurnal cycle is an oscillation in a geophysical variable with a 24-hour period in response to the daily solar cycle.

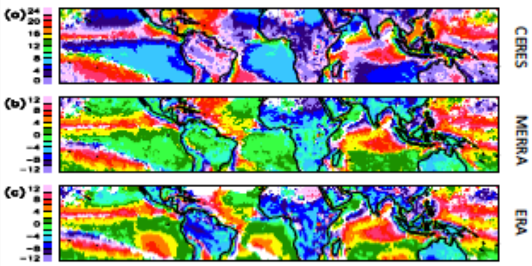


Figure above shows the differences between the CERES observed and reanalysis model climatological-annual P_{lwcf}: (a) $P_{lwcf,clim}$ CERES, (b) $P_{lwcf,clim}$ MERRA minus $P_{lwcf,clim}$ CERES, (c) $P_{lwcf,clim}$ ERA minus $P_{lwcf,clim}$ CERES.

Numerical models have difficulty reproducing the timing of the observed climatological diurnal cycles.

2. Errors in Reanalysis TOA flux diurnal cycle

- The variability in the TOA flux diurnal cycle is quantified using a RMSE metric, Eq. (1) normalized by Eq. (2)

$$RMSE_{Var,model} = \sqrt{\frac{1}{N}\sum_{h=1}^{N}\left(Var_{model}(h) - Var_{CERES}(h)\right)^2} \quad (1) \qquad \sigma_{Var,DC} = \sqrt{\frac{1}{N}\sum_{h=1}^{N}\left(Var_{CERES}(h)\right)^2} \quad (2)$$

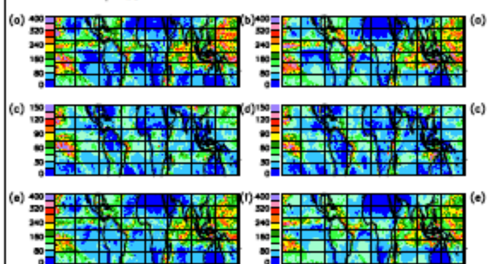


Figure above shows the longwave climatological-annual diurnal cycle Normalized RMSE (units: %) for (left column) MERRA and (right column) ERA against CERES SYN Ed3a: (a) $NRMSE_{MERRA,OLR}$, (b) $NRMSE_{ERA,OLR}$, (c) $NRMSE_{MERRA,OLRCLR}$, (d) $NRMSE_{ERA,OLRCLR}$, (e) $NRMSE_{MERRA,LWCF}$, and (f) $NRMSE_{ERA,LWCF}$.

The largest errors in LW TOA flux 3-hourly composites occur over land and ocean in regions of frequent convection. $NRMSE_{LWCF}$ is the dominant contributor to $NRMSE_{OLR}$ in land and ocean convective regions. $NRMSE_{OLRCLR}$ is the dominant contributor to $NRMSE_{OLR}$ in land nonconvective regions.

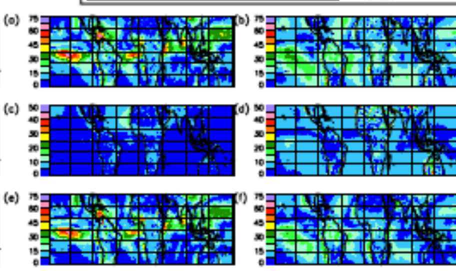


Figure above shows the shortwave climatological-annual diurnal cycle Normalized RMSE (units: %) for (left column) MERRA and (right column) ERA against CERES SYN Ed3a: (a) $NRMSE_{MERRA,RSW}$, (b) $NRMSE_{ERA,RSW}$, (c) $NRMSE_{MERRA,RSWCLR}$, (d) $NRMSE_{ERA,RSWCLR}$, (e) $NRMSE_{MERRA,SWCF}$, and (f) $NRMSE_{ERA,SWCF}$.

The largest errors in SW TOA flux 3-hourly composites occur over land convective and ocean nonconvective regions. $NRMSE_{SWCF}$ is the dominant contributor to $NRMSE_{RSW}$ in nearly all regions. $NRMSE_{RSWCLR}$ values are small over the land and ocean.

6. Conclusions

•MERRA and ERA reanalysis models are able to reproduce large-scale features of the TOA flux diurnal cycle climatology.

•The OLR and RSW diurnal cycle errors convective regions are 5-10 times larger than in non-convective regions.

•Both reanalysis models are unable to capture the diurnal cycle of propagating convection.

•Reanalysis models show a complete misrepresentation of the cloud diurnal evolution over tropical convective oceans.

•Seasonally, the largest errors in the TOA flux diurnal cycle occur during the season with the largest solar insolation

•Overall, the intermodel differences in the TOA flux diurnal cycle are smaller than the differences with observations

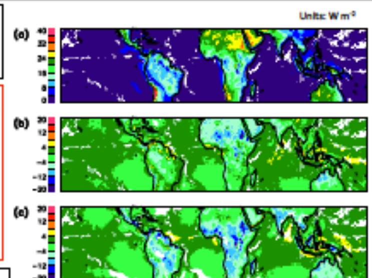
3. How well do the models capture the diurnal cycle amplitude?

MERRA produces smaller LW errors by representing the diurnal cycle amplitude and phase in land convective regions better than ERA. ERA, however, produces smaller errors than MERRA over many land non-convective regions by producing larger OLR diurnal cycle amplitudes.

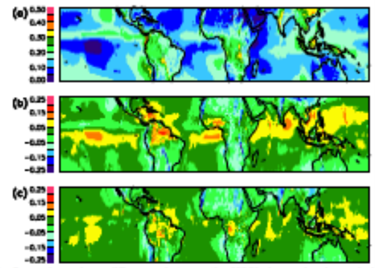
MERRA produce larger SW flux errors over tropical oceans due to an overestimation of cloudy-sky albedo diurnal range.

A: Reanalysis models produce a LW TOA flux diurnal cycle amplitude that is too weak.

Units: W m^{-2}

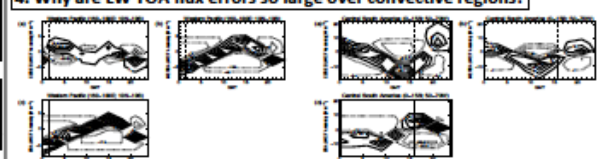


The figure above shows differences between the CERES observed and reanalysis model climatological-annual A_{olr}: (a) $A_{olr,clim}$ CERES, (b) $A_{olr,clim}$ MERRA minus $A_{olr,clim}$ CERES, (c) $A_{olr,clim}$ ERA minus $A_{olr,clim}$ CERES.



The figure above shows differences between the CERES observed and reanalysis model climatological-annual cloudy sky albedo, A_{albedo}: (a) $A_{albedo,clim}$ CERES, (b) $A_{albedo,clim}$ MERRA minus $A_{albedo,clim}$ CERES, (c) $A_{albedo,clim}$ ERA minus $A_{albedo,clim}$ CERES.

4. Why are LW TOA flux errors so large over convective regions?



Figures show climatological-annual LWCF diurnal evolution histograms over the Western Pacific (top-left), Amazon (top-right), and Indian Ocean (bottom-left) for (a) CERES, (b) MERRA, (c) ERA. Contours represent the percent difference between the 3-hourly and daily PDFs of LWCF. The y-axis is LWCF (W m^{-2}) and x-axis is GMT. The black dotted line represents local noon.

In the Western Pacific, CERES observations show a bimodal structure in $LWCF_{DC}$ with maximum values around 1500 Z and 0400 Z. The reanalysis models, however, simulate a single maximum occurring around 1500 Z. In the Indian Ocean, CERES $LWCF_{DC}$ peaks in mid-afternoon around 1000 Z, the models peak between 1800-2200 Z.

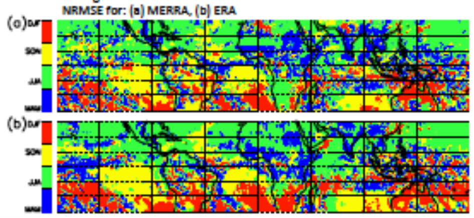
A: The reanalysis models completely misrepresent the timing of clouds in tropical oceans. Over the Amazon, MERRA captures the timing of clouds well, however both models underestimate the LWCF diurnal amplitude.

5. How are reanalysis TOA flux errors influenced by season?

- To analyze the influence of seasons, errors in OLR_{DC} and $LWCF_{DC}$ are sorted into 3-month seasons (Figs. to right). Hemispheric patterns are immediately apparent (i.e. largest errors in hemispheric summer).

A: The largest OLR NRMSE values are found in the season with highest values of solar insolation. Some exceptions include: ocean nonconvective regions and areas where local effects dominate.

The figure below shows the 3-month season with maximum OLR NRMSE for: (a) MERRA, (b) ERA



The figure below shows seasonal LWCF RMSE over the Amazon for: (a) MERRA, (b) ERA