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Diurnal Variation in Latent and Sensible Heat Fluxes using MERRA

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Introduction

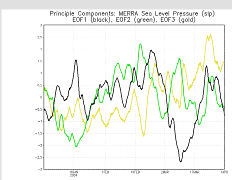
Short-term variability exists in the input surface parameters over the oceans impacting the values of the latent heat flux (LHF) and the sensible heat flux (SHF). These fluxes demonstrate a diurnal signal, which has not been well-quantified. Biases in the heat fluxes on the order of 10 Wm^{-2} have significance for the tropics on an annual scale. Additionally, errors of this magnitude are significant on a seasonal scale for the mid-latitudes where the mixed-layer is relatively thin. Establishing an accurate, representative value for the diurnal variation in the surface moisture flux is key to improving latent and sensible heat flux products, an important consideration for coupled climate models.

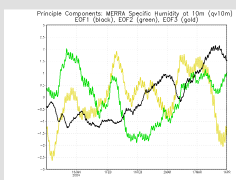
Data

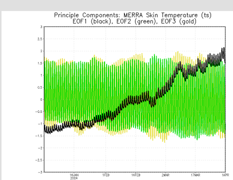
In order to compute the latent and sensible heat fluxes, hourly time-averaged data was used from the Modern Era Retrospective-Analysis for Research and Applications (MERRA) project.

MERRA quantities used:
- Sea-level pressure (SLP)
- Surface skin temperature (TS)
- Temperature at ten meters (T10M)
- Specific humidity at ten meters (QV10M)
- Eastward wind component at ten meters (U10M)
- Northward wind component at ten meters (V10M)

These quantities demonstrate variability on appropriate time scales for resolving the diurnal signal of the heat flux products. Processing was done using the Grid Analysis and Display System (GrADS) scripting language.







Figures: Time series plots of the principal components (PCs) of the first three empirical orthogonal functions (EOFs) for SLP, QV10M, and TS. Illustrating the scales of variability that are present in the MERRA data.

Methods

The latent and sensible heat fluxes were computed using a bulk-aerodynamic approach for oceanic regions, specifically the Bourassa-Vincent-Wood (BVW) model was implemented. The formulae used are as follows:

$$LHF = \rho L_v C_E (q_{sfc} - q_{air}) w$$
$$SHF = \rho c_p C_H (T_{sfc} - T_{air}) w$$

Most of the variables were directly input from the MERRA data, but air density, surface specific humidity, and wind speed required dedicated computation from MERRA data. The ideal gas law was used in the computation of the air density, and a relative humidity of 98% was assumed for obtaining the surface specific humidity from the specific humidity at ten meters. The transfer coefficients, C_e and C_H, were obtained via the BVW look-up table. For this analysis, MERRA data from 2000 to 2005 was processed using this algorithm, creating hourly latent and sensible heat flux products.

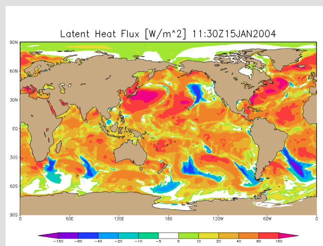


Figure (left): Global plot of the hourly Latent Heat Flux for the 11:30 UTC hour of 15 January 2004, computed using the BVW algorithm.

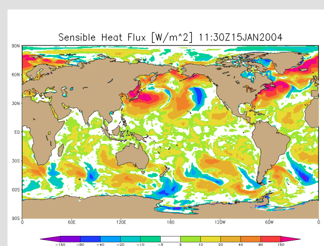


Figure (right): Global plot of the hourly Sensible Heat Flux for the 11:30 UTC hour of 15 January 2004, computed using the BVW algorithm.

Acknowledgements

We thank Paul Hughes and Ryan Maue for their contributions.
This project was supported by grants from NASA NEWS and NOAA COD.

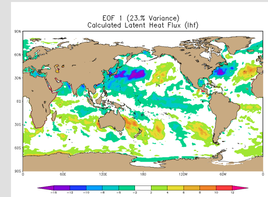


Figure (above): First EOF of the LHF showing the regions of variability.

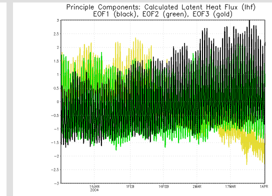


Figure (above): Principle components for the first three EOFs of the LHF, showing a strong diurnal signal.

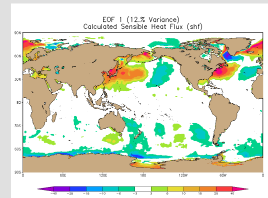


Figure (above): First EOF of the SHF showing the regions of variability.

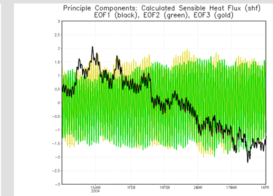


Figure (above): Principle components for the first three EOFs of the SHF, showing a synoptic and diurnal signal.

Discussion

From the Principal Components, a diurnal signal can be seen in both the latent and sensible heat fluxes. Using the EOFs and Principal Components, animations of the anomalies were produced to determine the magnitude of the signals, which does vary regionally. For the latent heat flux, a synoptic signal is present but small in magnitude compared to the diurnal signal. The magnitude of the diurnal signal of the LHF for the Western Boundary Current regions is ~60 Wm^{-2}, for the Mediterranean Sea: ~30 Wm^{-2}, and for the tropics: ~ 25 Wm^{-2}. The synoptic signal in the sensible heat flux, however, has a comparatively larger magnitude than the diurnal signal. The diurnal signal of the SHF for the Western Boundary Current regions is ~10 Wm^{-2}, for the Mediterranean Sea: ~6 Wm^{-2}, and for the tropics: ~3 Wm^{-2}. These values of the diurnal variation of the latent and sensible heat fluxes approximate a lower bound to the diurnal signal as a result of the variability within the initial MERRA data.

References

Bourassa, M. A., D. G. Vincent, and W. L. Wood, “A Flux Parameterization Including the Effects of Capillary Waves and Sea State,” J. Atmos. Sci., 56, 1999
Smith, S. R., P. J. Hughes, and M. A. Bourassa, “A Comparison of Nine Monthly Air-Sea Flux Products,” I. J. Clim., (submitted), 2009