Research Objectives

The recently produced Modern Era Retrospective-Analysis for Research and Applications (MERRA; Rienecker et al. 2011) provides a high-resolution dataset that can be used to examine components of the Earth’s surface energy and water balance. Latent and sensible heat exchanges between the ocean and atmosphere are fundamental components of these balances and are the focus of this study. The primary objectives are to characterize the MERRA surface energy fluxes with respect to their:

1. Accuracy against direct measurements;
2. Large scale spatio-temporal variability and representation of extremes;
3. Connection to forcing by the data assimilation system.

Observational Database

High-quality, direct in situ measurements of the turbulent latent and sensible heat fluxes and near-surface variables serve as a standard against which the veracity of turbulent flux products are compared. The SEAFLUX (Curry et al. 2004) program has compiled a large dataset of these measurements and are utilized in this study for validation purposes. The spatial and temporal distribution of these observations are characterized below (Fig. 1).

Evaluating Large Scale Variability

Validating surface heat flux estimates at large spatial and temporal scales relies on intercomparisons between multiple estimates and the use of physically based constraints. Further support is provided through the use of local or regional comparisons to direct observations. This study makes use of three additional products to characterize the large scale variability of the MERRA surface turbulent fluxes. These products and their primary data sources are:

1. OAFlux 3.0 (Yu et al. 2008) / Satellite, Buoy, VOS, Reanalyses
2. GSIIFS (She et al. 2008) / Satellites
3. NOCS 2.0 (Berry and Kent, 2009) / VOS

The ensemble mean of these products is used to characterize the annual mean (Fig. 3, right) estimate from MERRA. The differences between MERRA and observational estimates show that MERRA captures the major patterns; however, MERRA tends to underestimate the latent and sensible heat flux over the western boundary currents by 50Wm\(^{-2}\) and 10Wm\(^{-2}\), respectively. There are outside the range (hatching) of any of the available observations based estimates. Within the tropics, MERRA LHF and SHF are less than 10Wm\(^{-2}\) from the ensemble estimates. For an annual mean, WSPD estimates from MERRA are larger, the QSQA is too large in the tropics, and TSTA appears too large poleward of 15°.

Seasonal Covariability

The results of Fig. 3 appear inconsistent given the nature of the bulk heat flux relationships. It is expected that the annual mean LHF should be overestimated in the tropics and underestimated in middle and high latitudes. MERRA is consistently too strong. However, too small LHF implies a weaker surface moisture increment in the Southern Ocean and another important component of the surface heat flux distribution and are captured in the extremes of the distribution.

Representation of Extremes

Climatological-mean values of different datasets provide important information on one component of the surface heat flux distribution. Infrequent, yet strong episodic events are another important component of the surface heat flux distribution. The SHF estimate is fairly consistent with the OE at all latitudes for both the 5th and 95th percentiles. While QSQA and TSTA are in the OE range over the midlatitudes, the WSPD is too strong. However, too small LHF implies a weaker covariance between extremes in WSPD and the near-surface temperature and moisture gradients.

Impact of Data Assimilation

MERRA is a unique analysis in that the analysis increment – the forcing tendency driven by the assimilation system – are readily available to help interpret the impact of data assimilation (DA). The DA tends to moisten the near-surface layers, adding roughly 5%-10% of the daily average moisture per day in many regions. The temperature increments generally covary with moisture (i.e. moist and warm, dry and cool) except over cloud topped boundary layers to the west of South America and Africa. These adjustments tend to bring MERRA closer to the observational ensemble.

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Summary Points

1. MERRA produces estimates of the turbulent fluxes that agree very well with observational estimates for average conditions; however, it is distinct in amplitude with a particularly weak representation of the surface heat fluxes over the western boundary currents and in conditions of very weak and very strong near-surface stratification. A weaker covariability in wind speed and temperature/moisture stratification than observed exists.

2. MERRA has slightly weaker seasonal variability of the latent and sensible heat fluxes compared to observational ensemble estimate. It tends to under-represents the occurrence of strong, episodic events compared with observations in the Northern Hemisphere mid-latitudes.

3. Data assimilation, as expected, tends to drive the analysis closer to the observational ensemble; the impact on near-surface variables contains a systematic response to the changing observing system and could introduce artificial trends into the analysis.