NASA ENERGY AND WATER CYCLE STUDY

Ocean / Land Moisture Transport: Estimates from Reanalyses, Satellites and Land Surface Models

Franklin R. Robertson[1] , Michael G. Bosilovich[2] and Jason B. Roberts[1]

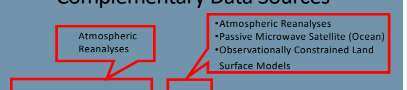
[1]NASA / Marshall Space Flight Center, Earth Science Office, 320 Sparkman Dr., Huntsville, AL 35805, USA [2]NASA / GSFC Global Modeling and Assimilation Office, 880 Greenbelt, Rd, Greenbelt, MD 20771

Issues & Challenge:

Vertically-integrated atmospheric transport of moisture between ocean and land is a fundamental component of the physical climate system linking the hydrologic and energy cycles of the planet as well as determining fresh water availability to the biosphere.

For land / ocean domains and monthly time scales, vertically-integrated moisture convergence $\int_m -\nabla \cdot q\boldsymbol{V}\,dm \sim$ P-E; thus, (i) direct estimates of this transport from reanalysis wind and moisture fields, (ii) E and P from satellite retrievals and, (iii) E and P from observationally constrained land surface models relatively independent information on land /ocean moisture exchange.

Atmospheric Moisture Budget and Complementary Data Sources

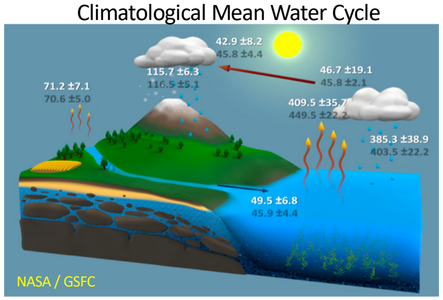


$$\frac{\partial W}{\partial t} = \int_m -\nabla \cdot q\boldsymbol{V}\,dm + E - P$$

$$\int_{oc}\int_m \nabla \cdot q\boldsymbol{V}\,dm\,\delta a_{oc} = \int_{land}\int_m -\nabla \cdot q\boldsymbol{V}\,dm\,\delta a_{land}$$

$$E'_{OC} = P'_{OC} + \int_{area} (P-ET)'_{LAND}\,\delta a$$

Climatological Mean Water Cycle

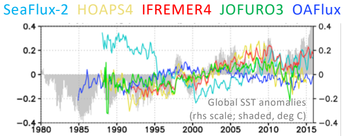


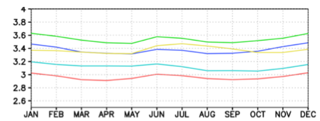
Time–Dependent Flux Variability over Ocean / Land Domains

Quantities area averaged over 60°N/S Land and Ocean Regions
(units: mm/day, fluxes; kgm^{-2}, climatology)

Global Ocean Evaporation

SeaFlux-2 HOAPS4 IFREMER4 JOFURO3 OAFlux

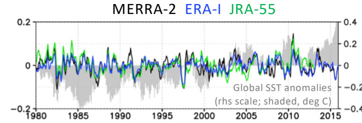




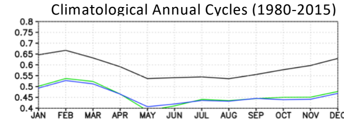
- Low-frequency behavior and trends are much greater in IFREMER4 and HOAPS4 and contrast strongly with OAFlux. JOFURO3 correlates best to reanalyses.
- SeaFlux algorithm extreme sensitivity to: (1) Earth Incidence Angle variability and (2) single sensor algorithm training data coverage.

Reanalysis $\int_m \nabla \cdot q\boldsymbol{V}\,dm$ Global Oceans

MERRA-2 ERA-I JRA-55



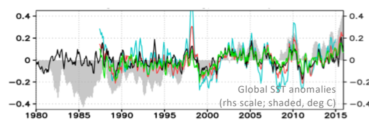
Climatological Annual Cycles (1980-2015)



- Systematic anomalous export of moisture from ocean to land (land to ocean) during transition to ENSO cold (warm) events. Moisture export leads global SST minimum.
- Maximum moisture export to land in late NH Winter.
- MERRA-2 climatological values appear biased high.

Global Ocean Precipitation

GPCP RSS V7 GPROF 10.2 HOAPS4



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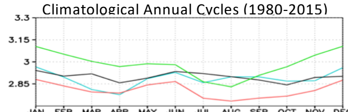
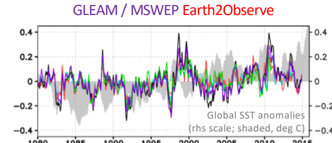


- Strong correlation between oceanic P and SST on ENSO time scales with more (less) P sequestered over oceans during warm (cold) events.
- GPROF10.2 and HOAPS4 likely have regime-dependent sensitivity to frozen precipitation.

Land Surface Model P-ET

WaterGAP (GPCC precip) Princeton MEaSUREs
GLEAM / MSWEP Earth2Observe



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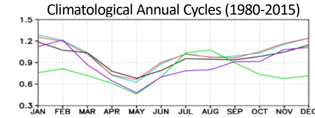


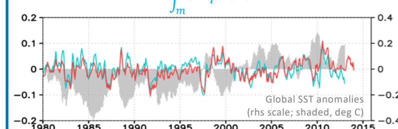
- On ENSO time scales a strong anti-correlation is present (warm SSTs→ P-ET) and implied reduction in transport of moisture to land. P-ET also leads global SST maximum.
- P-ET maximum is in NH winter as ET is at a minimum.

Summary Points:

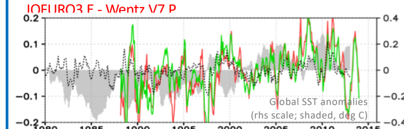
(1) Reanalysis vertically-integrated moisture flux divergence estimates shopw strong consistency with LSM P-ET estimates, (2) ENSO warm and cold SST events provide primary interannual signal modulating land ocean moisture exchange, (3) Satellite P - E estimates over ocean exhibit significantly stronger interannual signals than either reanalyses or LSMs. Known intercalibration issues with satellite evaporation retrievals are a likely driver.

Consistency Checks

Reanalysis Ensemble $\int_m \nabla \cdot q\boldsymbol{V}\,dm$ LSM Ensemble P-ET



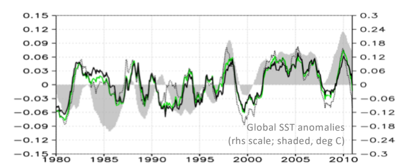
Reanalysis Ensemble $\int_m \nabla \cdot q\boldsymbol{V}\,dm$ JOFURO3 E – GPCP P
IFURO3 E - Wentz V7 P



- Significant agreement exists between reanalysis export of moisture from ocean to land and land P-ET diagnosed from observationally-constrained Land Surface Models.
- Warm (cold) ENSO events retard (enhance) this export.
- Satellite retrievals of E-P over the global oceans, while consistent in terms of interannual signals, exhibit much greater amplitudes. (HOAPS4 and IFREMER E values yield even more extreme results.
- Known systematic biases in satellite Qs-qa signals used in bulk formula retrievals are a major source of the large amplitude E-P signals.

Alternative Global Ocean Global Ocean Mean Calculation

- $E'_{OC} = P'_{OC} + \int_{area} (P-ET)'_{LAND}\,\delta a$ Changes in ocean evaporation anomalies are balanced by precipitation changes and transports to / from land. (Atmospheric storage is small on the scales of interest.)
- Use GPCP v2.3 precipitation (ocean, land and (P-ET)' from observationally constrained Land Surface Models (*Robertson et al. 2016; GLEAM 3.0a ET, Martens et al. [2016, GMDD]*).



Diagnosed Ocean Evaporation Anomalies
60 N/S (12-mo smooth; mm/d)

E: GPCP Ocn Precip + LSM P-ET
GPCP Ocn Precip only (dotted)
E: GPCP Ocn, Land Precip + GLEAM 3.0a P-ET