Narrowing Ocean Latent Heat Flux Uncertainties: Perspectives from Reanalysis and Satellite Estimates

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Issues & Challenge:

Latent heat flux (LHF) is a major component of the net surface energy exchange governing ocean heat content and storage rate. Reanalyses using reduced observational input: NOAA 20th Century Reanalysis (P_s); CERA-20C (Marine wspd, P_s) and JRA-55C (conventional data only), avoid discontinuities induced by assimilating broader satellite record. But how useful are they? LHF retrievals using passive microwave satellite data (e.g. SeaFlux, JOFURO-3, IFREMER4 and HOAPS4) are maturing but still suffer from inadequate validation data, lack of direct sensitivity to near-surface moisture, and ambiguities in surface wind stress / wind speed relationships. *Can the complementary aspects of these data sets help quantify and reduce ocean LHF / Evaporation uncertainties?*

Summary Points:

(1) Regime dependent biases associated with large-scale dynamics and SST distributions control vertical moisture stratification and uncertainty in satellite qa retrievals; however, the effect on global mean LHF variations is small.
(2) SST trend differences between OISST-AVHRR (used by HOAPS4, SeaFlux2 and IFREMER4) and reanalyses whose SST record includes cooler passive microwave-derived SSTs post-1992 are a significant source of larger satellite qs-qa trends compared to those of reanalyses.
(3) Global mean LHF / E estimated independently from GPCP P and ocean → land moisture transport inferred from LSM P-ET suggests further improvement to satellite derived near-surface meteorology will reduce decadal scale global LHF trends.

Data Sets

SeaFlux 2, https://cclayson.whoi.edu/seaflux/
J-OFURO3, https://j-ofuro.scc.u-tokai.ac.jp/en/
IFREMER4, https://wwz.ifremer.fr/oceanheatflux/
HOAPS4,https://wui.cmsaf.eu/safira/action/viewDoiDetails?acronym=HOAPS_V002
JRA55C, http://jra.kishou.go.jp/JRA-55/index_en.html
NOAA/ESRL 20CRv2c,https://www.esrl.noaa.gov/psd/data/20thC_Rean/
CERA-20C, https://www.ecmwf.int
ERA5,https://www.ecmwf.int

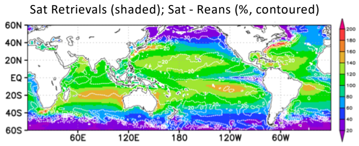
Ancillary passive / active microwave wind speed retrievals from Remote Sensing Systems (RSS) http://www.remss.com/.

P-ET from GPCP, https://precip.gsfc.nasa.gov/ and seven LSM systems, see Robertson et al, (2014 J. Climate)

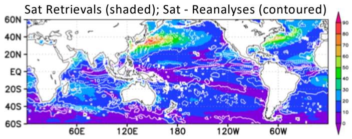
All data are monthly mean quantities and have been interpolated to a 1.0 x 1.0 latitude / longitude grid.

Climatologies and State / Time Dependent qa Biases

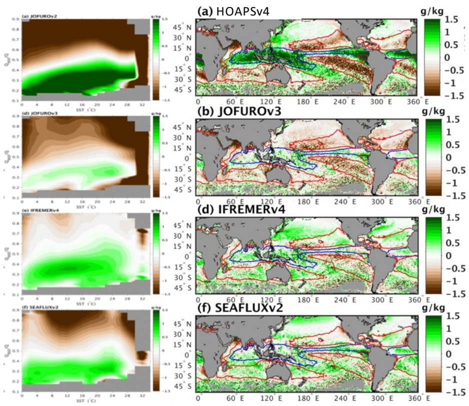
Ensemble Mean LHF Climatologies (Wm^{-2})
Sat Retrievals (shaded); Sat - Reans (%, contoured)



Ensemble Annual Cycle RMS (Wm^{-2})
Sat Retrievals (shaded); Sat - Reanalyses (contoured)

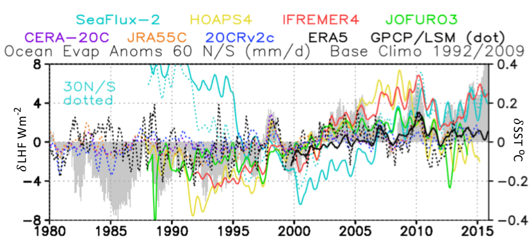


- Though pattern-wise similar, reanalyses are typically up to 20% larger than satellite retrievals, with the latter averaging ~ 81 Wm^{-2}.
- Mean annual cycle amplitudes are smaller in reanalyses, particularly off east coasts of NH continents.



- *(Left)* Climatological biases relative to ICOADS ship data portrayed in q_{900}/TPW; SST space. *(Right)* Mean differences (product minus in situ observations) over the common period 1999-2008.
- All qa retrievals tend to be too moist in well-mixed convecting regions and too dry in stable , descending regions.
- HOAPS4, which uses an older Bentamy (2006) qa algorithm, is most extreme.
- Red (blue) contours outline the 15% relative frequency of occurrence regions for the subtropical descent and deep convective dynamical regimes.

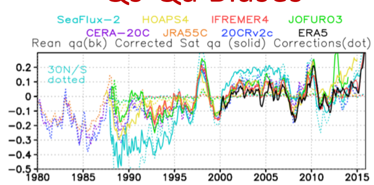
Time–Dependent Global Mean LHF Variability

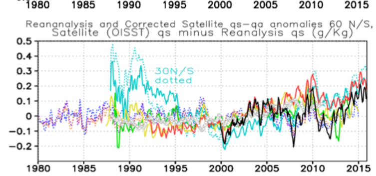


Sensitivities δLHF / δSST (1990-2010)	
SeaFlux 2	-8.0 (5.0 30°N/S)
HOAPS4	20.0
IFREMER4	18.7
JOFURO3	9.7
CERA-20C	4.5
JRA-55C	6.8
NOAA/C20cr	2.3
ERA5	6.8 (2000-2010)
GPCP/LSM	6.0

- Interannual variability (strongly influenced by ENSO events) is similar among all data sets, especially post 1992 when passive microwave satellite coverage is more robust.
- Low-frequency behavior and trends are much greater in IFREMER4 and HOAPS4 but JOFURO3 is generally closer to reanalyses (including the partial record of the emerging ERA5 reanalysis.
- SeaFlux algorithm extreme sensitivity to: (1) Earth Incidence Angle variability and (2) single sensor algorithm training data coverage is currently being corrected.
- An independent global ocean evaporation estimate (···) made by combining GPCP ocean precipitation estimates and land / ocean moisture transport, P-ET, from observationally-driven land surface models: $E'_{OC} = P'_{OC} + \int_{area} (P-ET)'_{LAND} \delta a$. supports much smaller reanalysis LHF/E trends and suggests that larger satellite trends are due to algorithm / data issues.

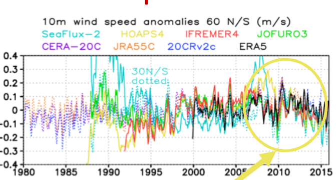
Qs-Qa Biases

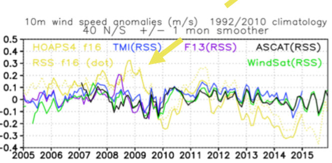




- Differences in qs(SST) used in satellite retrievals (HOAPS4 and IFREMER) vs reanalysis values (○○○) is a significant contribution to qs-qa trend differences.
- IFREMER qs(OISST) is 0.5 gKg^{-1} larger than that of SeaFlux or HOAPS qs(OISST) for Jan2007-Oct2011.

Wind Speed Biases



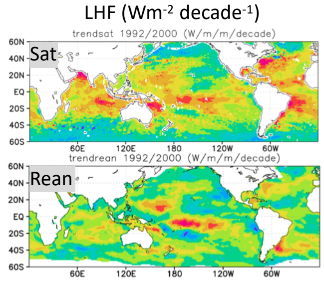


- HOAPS4, JOFURO3 and IFREMER4 winds speeds track reanalyses after robust SSMI coverage in mid-1990s.
- Independent single sensor 10m wind speed retrievals confirm F16 time dependent biases (likely due to sensor antenna degradation).

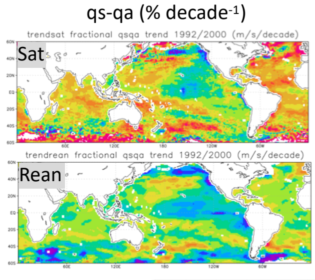
LHF Trends 1992/2010

- Satellite-derived LHF trends (SeaFlux omitted) are systematically higher than reanalyses equatorward of 40°, especially over the Atlantic and Indian Oceans. Reanalysis reductions in eastern Tropical Pacific LHF is consistent with negative trend of Pacific Decadal Variability index during this period.
- Satellite qs-qa trends (expressed as % of climatological values) are substantially larger than in reanalyses and correlate strongly with the LHF trend outside the E Pacifc.
- Reanalysis fractional wind speed trend patterns agree reasonably over the Pacific basin, consistent with changes in PDV, but they differ in the western Indian Ocean.

LHF (Wm^{-2} decade^{-1})



Fractional trend qs-qa (% decade^{-1})



Fractional trend 10m wspd (% decade^{-1})