Progress on Surface Fluxes From Reanalyses

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Summary of the project progress on surface fluxes from reanalyses

Objective:
Provide an assessment of climate reanalyses in representing air-sea heat, freshwater, and momentum fluxes in the context of the global energy and water budgets.

Major activities in 2015 and progress to date:

(1) Surface Freshwater fluxes:
- A manuscript is near-completion on “The ocean water cycle in reanalysis, satellite, and ocean salinity”. It provides an assessment of the ocean-surface freshwater budgets in 9 reanalysis products and 2 combined satellite E-P products.

(3) Surface winds and wind stresses
- An assessment of the surface winds from reanalyses and satellite scatterometers in the tropical Pacific ocean is conducted. A manuscript is in preparation.
- We provided the assessment to the Tropical Pacific Observing System (TPOS) 2020 project planning.

(3) Surface Heat Fluxes:
- A manuscript, entitled “Variations of the Global Net Air-Sea Heat Flux During the Hiatus Period (2001-2010)” by X. Liang (postdoc at MIT) and L.Yu, was submitted to J. Climate.
The spread in the reanalysis products is largest in the tropical ocean.
The tropical wet zone in the reanalyses appears to be broader than that in the satellite-based product.
Width of the tropical wet zone ($\Delta y_{\text{wet}}$) versus Width of the Hadley Cell ($\Delta y_{\text{HC}}$)
The superimposed colored lines denotes the zero E-P location depicted by the 11 products.
Key findings on surface freshwater fluxes from climate reanalyses

• The tropical wet zone in all reanalyses, except for the semi-coupled reanalysis of CFSR, has a broader meridional extent.

• One consequent impact is that the reanalyzed subtropical dry zones are displaced a few degrees of latitude poleward.

• The spread in the width of the tropical wet zone and hence, the magnitude of the tropical precipitation, is largest during June – November, when the southern subtropical dry zone is displaced equatorward and the reanalyses differ considerably in positioning the near-equatorial edge of the dry zone.

From the manuscript on “The ocean water cycle in reanalysis, satellite, and ocean salinity” by L.Yu, X. Jin, S. Josey, T. Lee, ...
(2) Surface Winds from Reanalyses and Scatterometers

Zonal wind stress ($\tau_x$) component

Mean and spread in the mean over the period 11/2007-10/2009
Meridional wind stress ($\tau_y$) component

Mean and spread in the mean over the period 11/2007-10/2009
Wind Stress Curl


Satellite

Curl(\tau) ASCAT−A

Satellite

Curl(\tau) QSCAT JPL

Satellite

Curl(\tau) QSCAT RSS

Satellite

Curl(\tau) QSCAT RSS+rain

Satellite

Curl(\tau) WindSAT

Atmospheric reanalysis

Curl(\tau) CFSR

Atmospheric reanalysis

Curl(\tau) ERAinterim

Atmospheric reanalysis

Curl(\tau) JRA55

Atmospheric reanalysis

Curl(\tau) MERRA

Atmospheric reanalysis

Curl(\tau) NCEP1

Atmospheric reanalysis

Curl(\tau) NCEP2
**Around 10N:**
- The band of positive wind stress curl associated with the ITCZ is broader and more northward displaced in reanalyses compared to scatterometers.

**Around 3N:**
- CFSR is the only reanalysis that is able to depict the narrow band of positive wind stress curl.
- ERAinterm shows the positive curl band in recent years.
Seasonal variability: Wind stress components

Constructed from monthly-mean time series for the period 11/2007-10/2009

**STD $\tau_x$**

Zonal average, 11 $\tau_x$ products

**STD $\tau_y$**

Zonal average, 11 $\tau_y$ products
Spread in mean Curl(τ)


STD Spread in mean curl(τ)

02/2010 – 01/2014

STD Spread in mean curl

Bull’s eyes around TAO buoys
Seasonal Variability: wind stress curl

STD curl ($\tau$)
Zonal average, 11 curl ($\tau$) products

Reanalysis winds have weak variances
Comparison with buoy winds:
- Buoy winds are adjusted to equivalent neutral winds at 10m.
- Reanalysis winds are also adjusted to equivalent neutral winds at 10m.

The Taylor diagram summarizes the statistics of buoy evaluation (2007-2012) at 4 near-equatorial sites: (2N, 170W), (2N, 140W), (EQ, 140W), (2N, 110W).

The Taylor diagram:
- STD represents STD(product)/STD(buoy)
- RMSD represents STD(product-buoy differences)/STD(buoy)
→ The products is better compared to buoy if STD closes to 1 and RMSD closes to 0.

(c) Wind speed
Key findings on winds and wind stresses from climate reanalyses

(1) Winds from the latest reanalyses (CFSR, ERA-interim, MERRA, JRA55) are comparable to each other on both mean and seasonal timescales, but differ considerably from satellite winds. NCEP1 and NCEP2 assimilate TAO observations but no satellites, and have strong bulls-eye features collocating with mooring sites.

(2) Reanalysis wind products differ from satellite products mainly at two latitudes: 3N and 10N.
   - Reanalysis products cannot produce the band of positive curl between 1-3°N, except for CFSR that is a coupled reanalysis and uses SST generated from an ocean model. The problem indicates that, in addition to the need of assimilating satellite winds, there is also the need of improving SST conditions in the reanalysis.
   - Reanalysis products tend to produce a broader meridional extent for the positive curl(τ) associated with the ITCZ, and the effect is most evident at 10N when compared to satellite products.

From the manuscript on “Scatterometer and reanalysis wind stress and stress curl in the tropical Pacific” by L. Yu, X. Jin, ...
(3) Surface heat fluxes from reanalyses and satellite

Global characterization of the uncertainty in Qnet: mean pattern

Spread in 15 Qnet products

STD Qnet (SW–LW–LH–SH)
Uncertainty in $Q_{net}$: association with SST

$Q_{net}$ averaged over the area bounded by SST isotherms $SST \,(^{\circ}C)$

Spread in $Q_{net}$ is 3x larger when $SST > 25^{\circ}C$.

JRA55 is an outlier.
Buoy evaluation: turbulent heat fluxes

LH+SH  Mean Diff (Product – buoy)

SW-LW  Mean Diff (Product – buoy)

Distribution of DIFF (product – buoy) with SST
Key findings on surface heat fluxes from climate reanalyses

• The error characteristics of heat fluxes are highly dependent of SST.
• The spread in Qnet products is 3 times larger when SST > 25C.
• Over the tropical oceans, reanalysis heat fluxes tend to have weaker radiative heat input and stronger turbulent heat loss in the tropical oceans.

• Similar to surface freshwater flux products, surface heat flux products show also a large spread in the tropical ocean.
• A major source of error in reanalysis fluxes arises from the depiction of the ITCZ position and its seasonal movements.

From “The Earth’s Surface Budget: Outcomes, uncertainties, and drawbacks” by L.Yu