USING AQUARIUS TO QUANTIFY UNCERTAINTY IN MODEL FRESHWATER FLUXES

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Questions

-- Can we use Aquarius Sea Surface Salinity to put constraints on uncertainty in freshwater flux forcing?
-- How is variability in surface salinity related to variability in surface freshwater flux?
-- Can satellite-derived salinity provide limits on runoff?

Global HYCOM Ocean Forecast Model

•The HYbrid Coordinate Ocean Model (HYCOM) is used as the ocean forecast model at NRL
•The model has:
- -- 41 hybrid layers in the vertical
- -- Tri-polar grid north of 47° N
- -- 1/12.5° (~9 km at the Equator) horizontal resolution
- -- K-Profile Parameterization (KPP) mixed layer model
- -- Thermodynamic, energy-loan sea ice model

The system is forced with atmospheric output from the Navy Global Environmental Model (NAVGEM), the operational forecast model of the Navy.

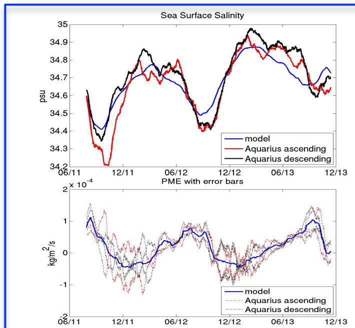
Aquarius Satellite data

-- Aquarius measures sea surface salinity from space
-- Launched in 2011
-- Polar-orbiting satellite provides global coverage every 7 days
-- Expected accuracy of 0.2 psu
-- For this project, along-track data were used (level 2, version 3.0)

The Ocean Rain Gauge at work

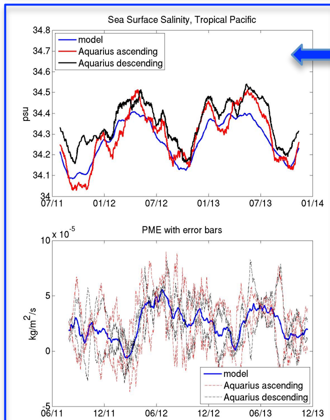
Does the ocean act like a “rain gauge”, with surface salinity responding locally and quickly to surface freshwater fluxes (precipitation and evaporation)?
Can global salinity measurements provided by Aquarius provide “error bars” for estimates of P-E?
We tested this concept in three regions.

ASSUME: Salt is conserved within the mixed layer (mixed layer depth, or MLD, is obtained from the model).
CALCULATE: satellite salinity*(MLD+η) = model salinity*MLD where η is change in depth from excess rain (the “adjustment” to flux necessary for model salinity to match satellite salinity)
FW flux is the change in η with time. Multiply by density of freshwater, so that units are kg/m^2/s. All results smoothed with 30-day running average.



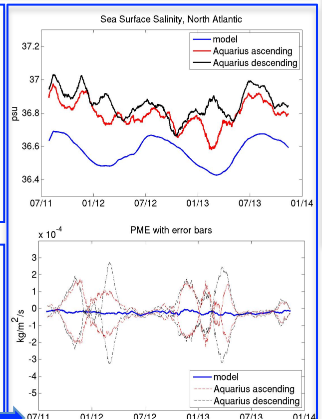
In the western pacific (see maps at right for the location of the box), the estimates of SSS from Aquarius follow the model SSS closely, replicating both the seasonal cycle and the long-term trend. Aquarius results are from daily averages over the region, smoothed over 30 days.

Results:
-- In this region, the satellite measured salinity is well correlated with the measurements.
-- RMS difference in salinity is 0.086 for ascending tracks and 0.074 for descending tracks.
-- Ascending is biased 0.018 psu low, descending is 0.029 psu high.
-- Ascending and descending differences will decreases as model calibration and corrections progress.
-- The envelope is smallest in around July each year, and peaks in January. The lowest PME (most evaporation/least precipitation) is the time of peak uncertainty in this region.
-- Magnitude of PME is very large in this region
-- Peak correlation of 0.72 occurs at 62 days.

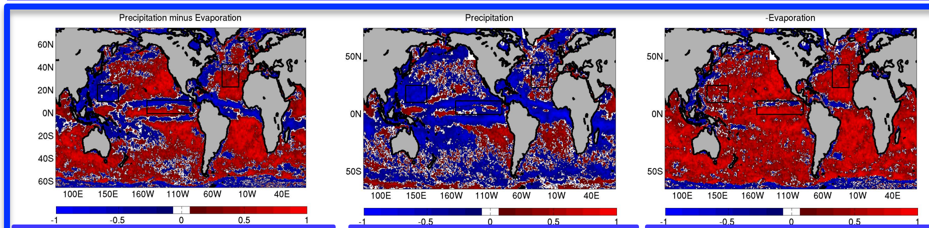


Tropical Pacific
-- Aquarius replicates the model seasonal cycle relatively well.
-- “Error” estimates are of the same magnitude as the signal.
-- RMS difference is 0.0.059 ascending, 0.095 descending
-- Bias is 0.022 high for ascending, 0.086 high for descending.
-- Note the magnitude of PME variability is smaller than in the Western Pacific

North Atlantic
-- SSS variability shown by Aquarius is significantly different from the model variability.
-- RMS difference is 0.23 ascending, 0.29 descending
-- Bias is 0.22 high for ascending, 0.28 high for descending.
-- The PME “error” estimates are overwhelmed by these other effects.



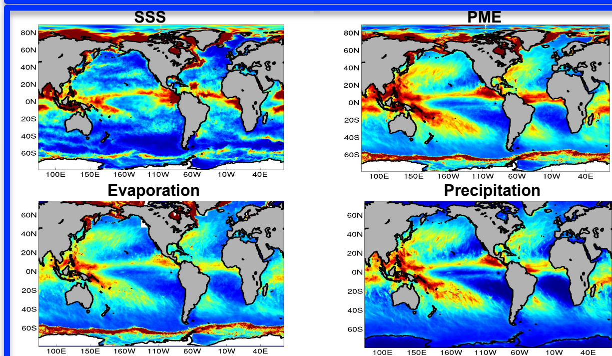
Correlations between SSS and PME



The dominant feature of this map is high, positive correlations. Positively correlated precipitation and salinity indicate non-local forcing. The tropics and the western pacific are exceptions.

In the tropics, high precipitation in the tropics is well-correlated with low salinity.
In the subtropical gyres (especially in the south Pacific) precipitation is positively correlated with salinity.

This map shows correlation between negative evaporation and SSS (for easy comparison with the other two panels). The largest values show high evaporation correlated with low salinity in subtropical gyre regions.



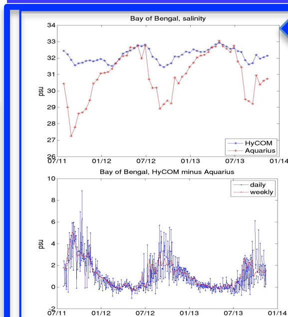
--These maps show standard deviation (variability) of SSS, PME, evaporation and precipitation

-- High PME variability in the tropics and western boundary regions is in regions of high precipitation variability

-- In subtropical gyre regions where variability is lower in all quantities, variability is due more to evaporation than precipitation

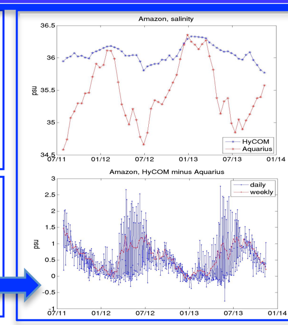
--Together with correlation maps above, this indicates that where evaporation dominates over precipitation, salinity is controlled by non-local processes.

Validating Runoff Estimates with SSS



-- The seasonal monsoon produces very large runoff annually in the Bay of Bengal (85°E-94°E, 16°N-22°N)
-- Large freshwater input leads to a decrease in surface salinity.
--The observed seasonal cycle of surface salinity is considerably stronger than the HYCOM estimate.

-- The Amazon river also adds seasonally varying freshwater to the ocean
-- As in the Bay of Bengal, the seasonal reduction of salinity due to runoff is underestimated in the model
-- This is averaged over 43°W-56°W, 7°N-20°N; north and east of the Amazon.



Conclusions

In some areas, Sea Surface Salinity is well-correlated with Surface Freshwater Flux (Precipitation and Evaporation) and Aquarius data could be used to put error bars onto this quantity.
In MOST regions, the local balance is outweighed by other factors (advection, mixing).
In high runoff regions, the model consistently underestimates the seasonal cycle of salinity. Aquarius can help improve estimates of this effect and its spatial and temporal implications.
Aquarius should be used carefully, but it is a powerful tool for model validation, development, and improvement.