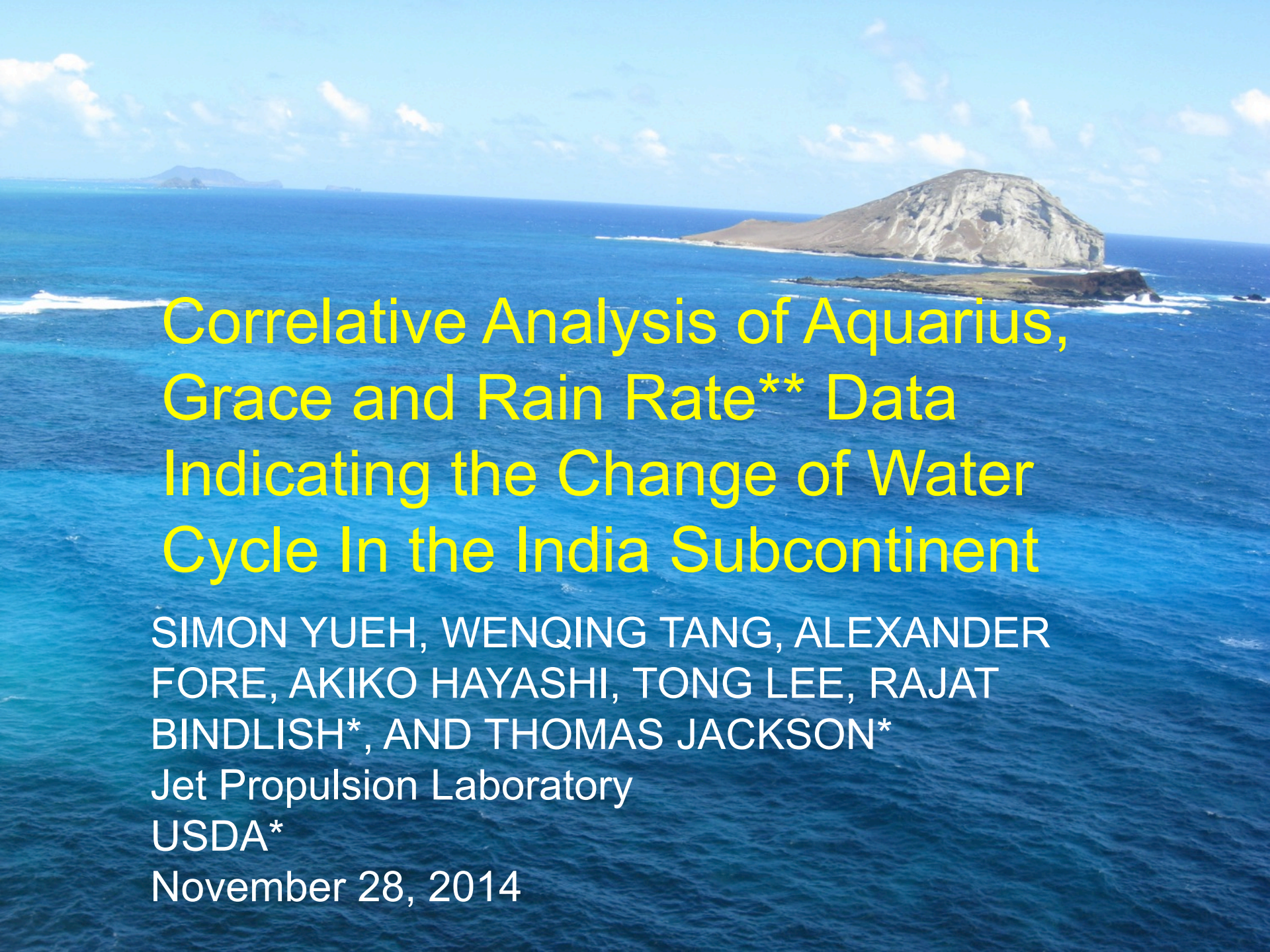

Correlative Analysis of Aquarius, Grace and Rain Rate** Data Indicating the Change of Water Cycle In the India Subcontinent

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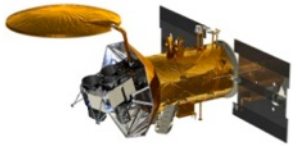
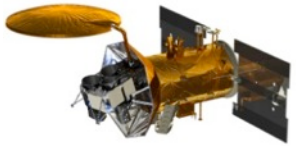
Jet Propulsion Laboratory
USDA*
November 28, 2014

Outline



- Introduction
- CAP Retrieval Algorithm Update
- GRACE and Aquarius soil moisture over land (precipitation)
- Aquarius CAP_RC Salinity and Soil Moisture
- Aquarius CAP_RC Salinity and OSCAR Current
- Summary

Drivers Affecting the Change of Salinity



- What is the impact of the following processes?
  - River discharge (precipitation over land)
  - Rain over ocean (CMORPH rain rate)
  - Advection (current)

AQUARIUS/SAC-D

Aquarius Combined Active-Passive (CAP) Retrieval

- Combined Active-Passive (CAP) Algorithm – minimization of a quadratic cost function
  - Retrieve SSS, Wind Speed and Direction Using Combined Passive and Active Data
  - Account for diffused scattering of galactic reflection
  - Don't need monthly SSS climatology constraint

$$F_{ap}(SSS,w,\phi)=\frac{(T_{BV}-T_{BVm})^2}{\Delta T^2}+\frac{(T_{BH}-T_{BHm})^2}{\Delta T^2}+\frac{(\sigma_{VV}-\sigma_{VVm})^2}{k_p{}^2\sigma_{VV}{}^2}+\frac{(\sigma_{HH}-\sigma_{HHm})^2}{k_p{}^2\sigma_{HH}{}^2}+\frac{(w-w_{NCEP})^2}{\Delta w^2}+\frac{\sin^2((\phi-\phi_{NCEP})/2)}{\delta^2}$$

- Model function for wind, wave and rain-induced roughness

$$\sigma_p(w,R,SWH,\phi)=[A_{0p}(w,R,SWH)+\Delta A_{0p}(w,R)][1+A_{1p}(w)\cos\phi+A_{2p}(w)\cos 2\phi]$$

$$e_p(w,R,SWH,\phi)=e_{0p}(w,SWH)+\Delta e_{0p}(w,R)+e_{1p}(w)\cos\phi+e_{2p}(w)\cos 2\phi$$

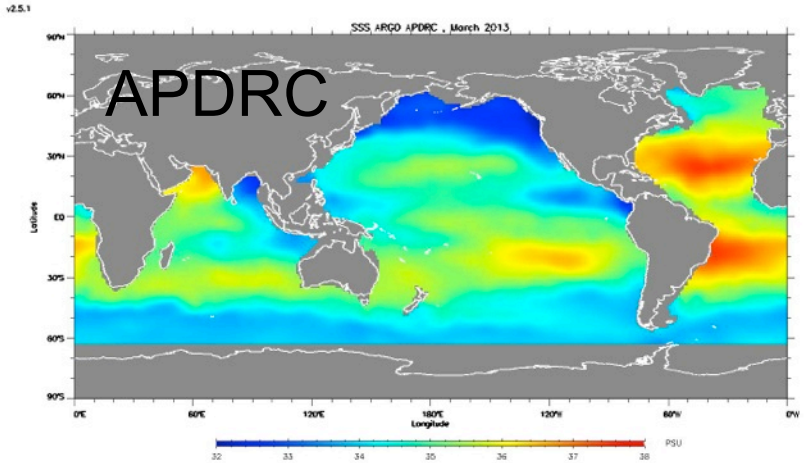
- CAP V3.x includes two SSS outputs
  - SSS with no rain correction
  - SSS_rc with rain correction

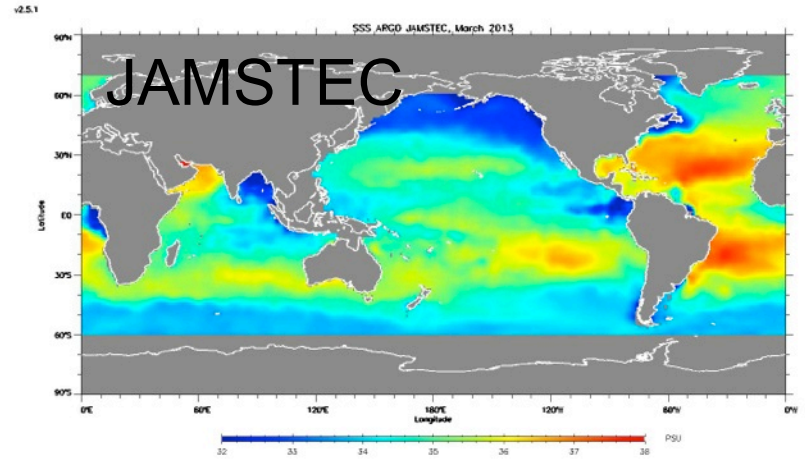
Yueh and Chaubell, IEEE TGRS, April 2012
Yueh et l., IEEE TGRS, 2013
Yueh et al. JGR 2014
Tang et al., RSE 2013

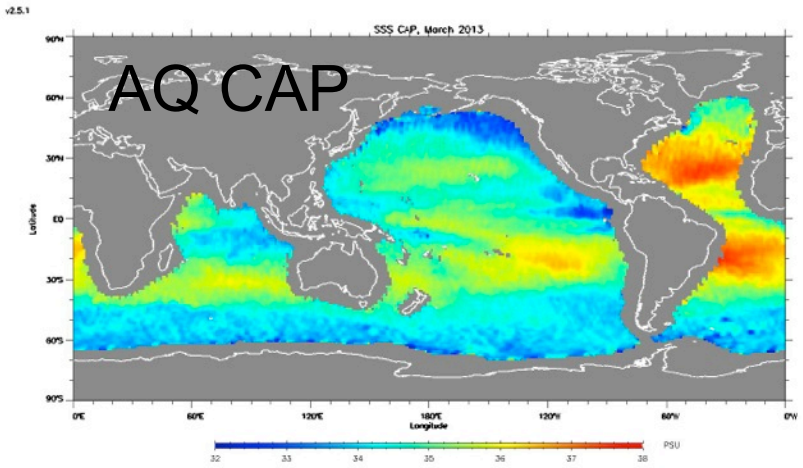
CAP SSS has good Agreement with ARGO Monthly Maps

- Aquarius CAP and JAMSTEC show the split of salinity of tongues in the eastern Pacific
- APDRC seems to be smoother

March 2013





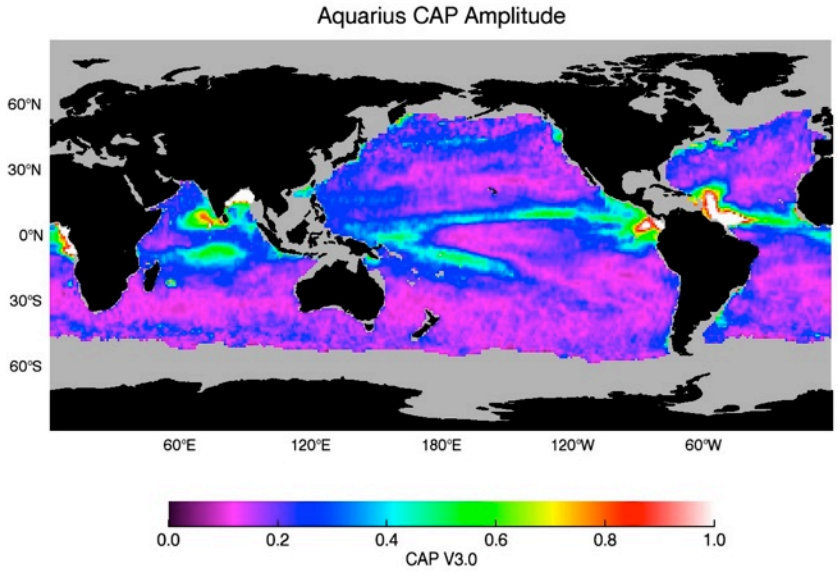


Amplitude of Aq CAP vs APDRC Anomaly

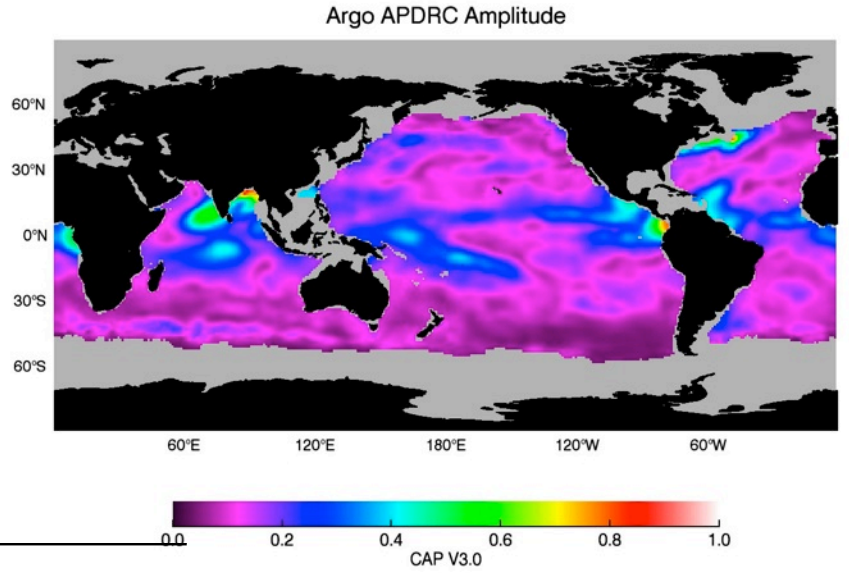
- The spatial patterns of Aquarius CAP and ARGO anomalies are strikingly similar.
- CAP in general has larger anomalies. Surface stratification effects?

Scaling and/or Bias?

Amplitude of CAP 3.0 Anomaly

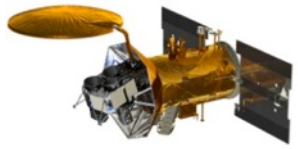


ARGO

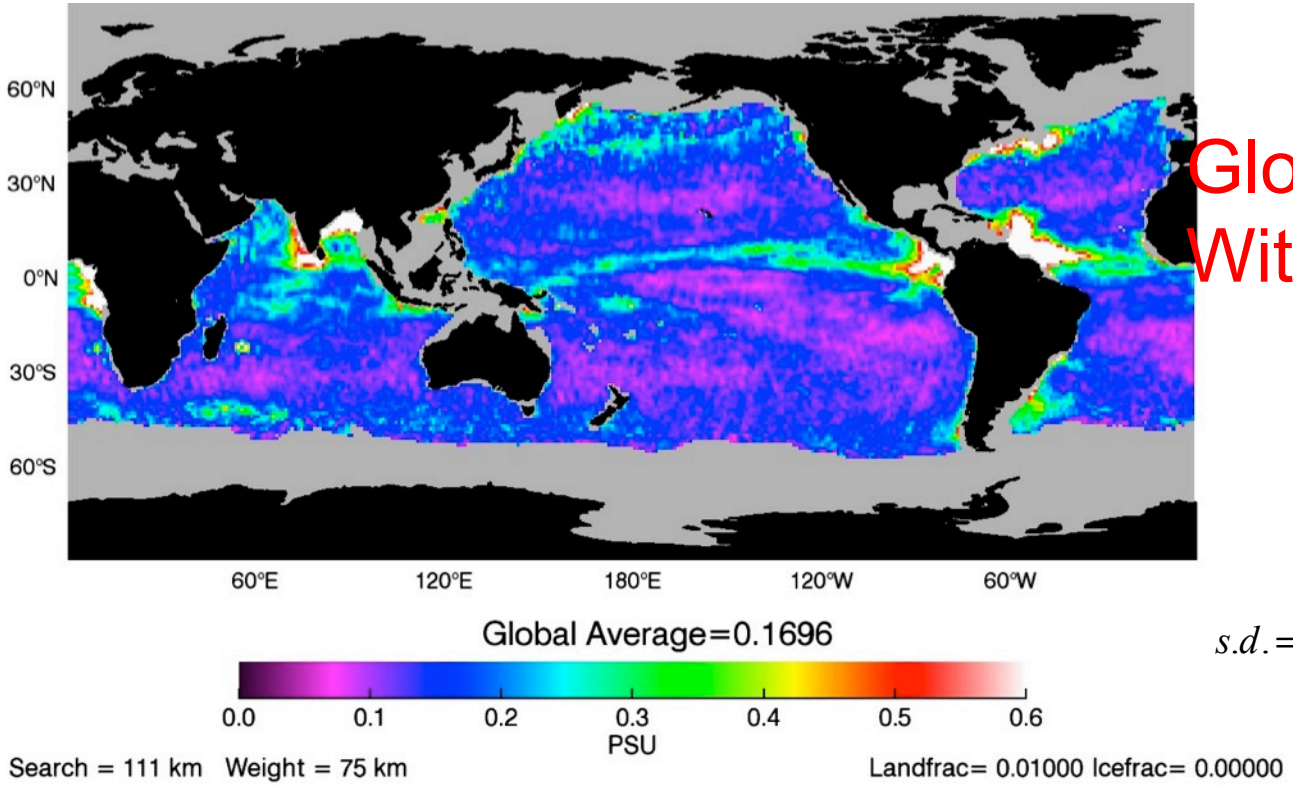


$$A = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - < x_m >)^2}$$

Validation with Argo floats



Standard Deviation of Monthly Averaged Differences of Anomalies (AQ-APDRC)



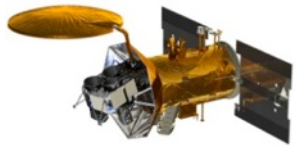
Global average=0.17
Within 40S-40N

$$s.d. = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - < x_m > - y_i + < y_m >)^2}$$

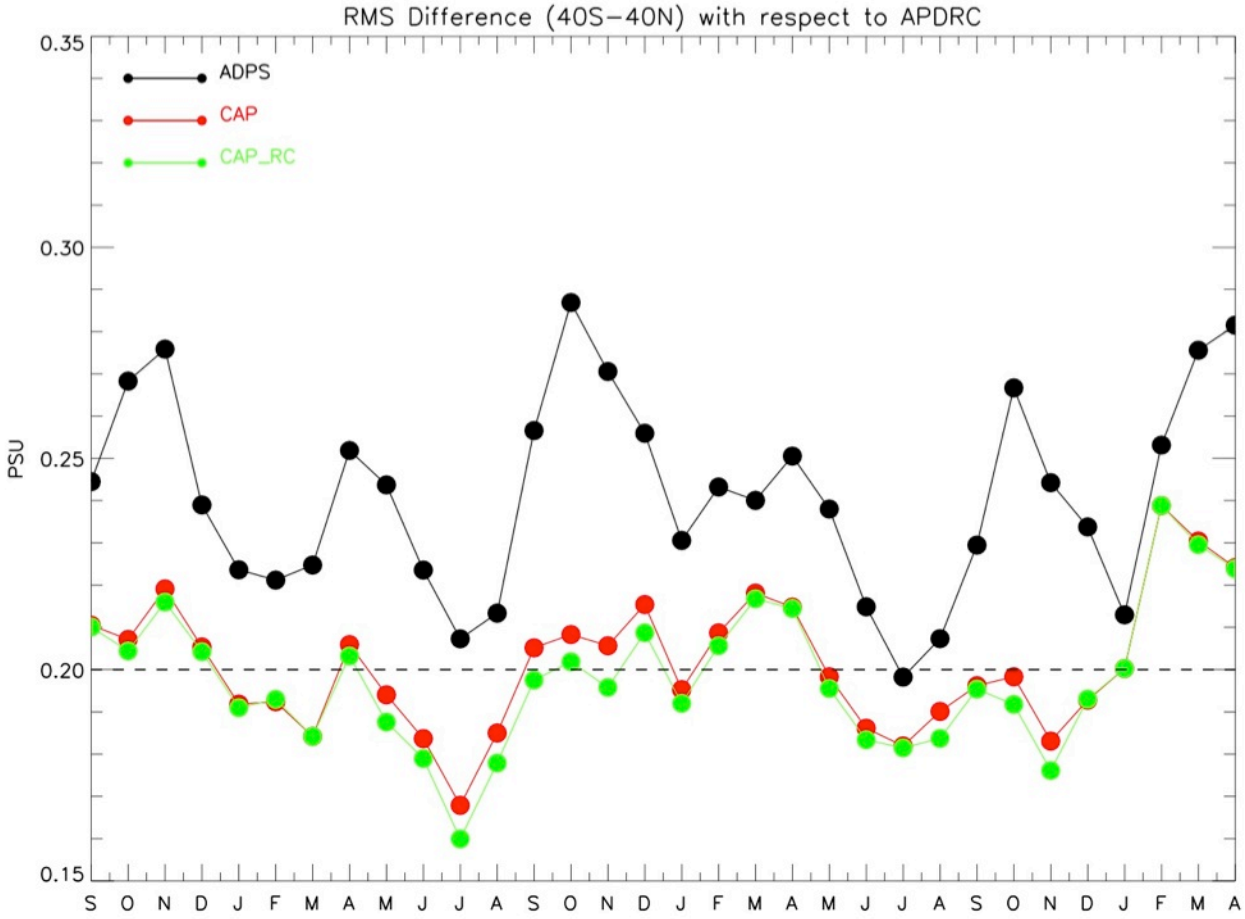
- **Excellent agreement for most locations - between 0.1 to 0.2 psu**
- **Reaching 0.3 to 0.4 psu for regions with high precipitation and evaporation, cold waters (high latitudes) and Amazon outflow**

Yueh et al., JGR, in press 2014

Error assessment



RMSD between CAP and ARGO Monthly Gridded Products
- The Amazon River outflow and Easter Pacific fresh pool excluded.

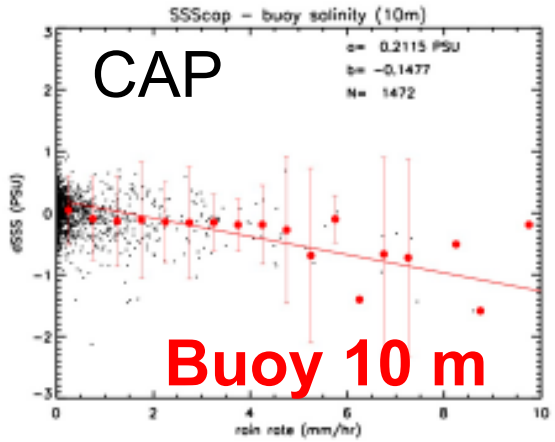


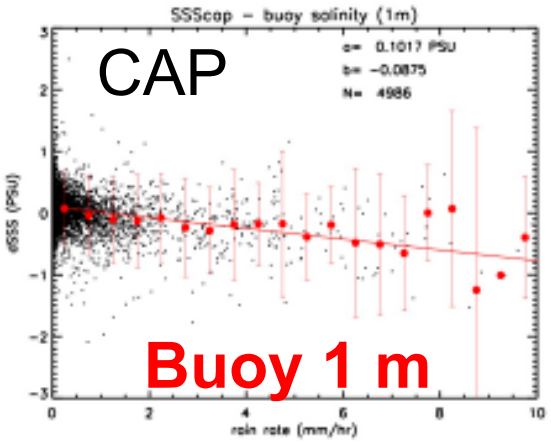
The monthly RMSD between CAP and APDRC between 40° S and 40° N is mostly <0.2 psu

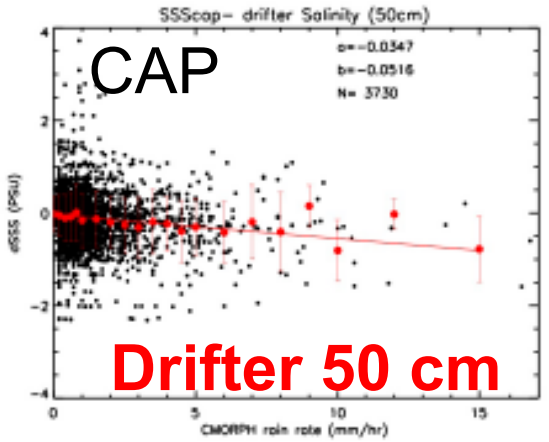
Tang et al., JGR, in press 2014

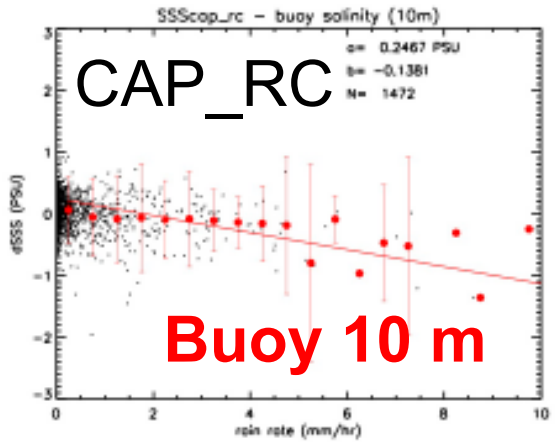
JPL CAP SSS Close to meeting Aquarius requirement?

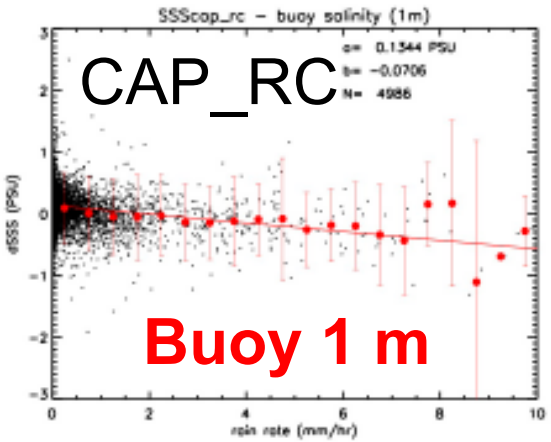
Comparison with salinities from moorings (PMEL) and drifters (Locean)

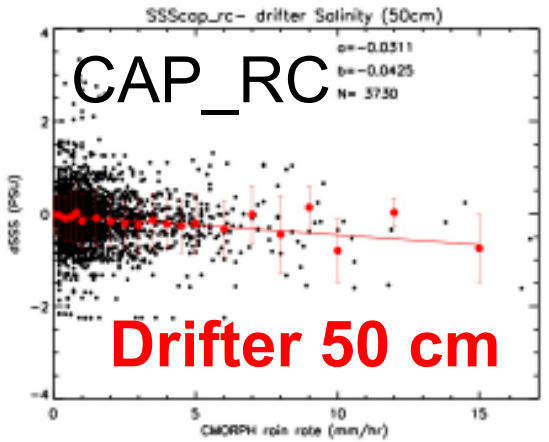








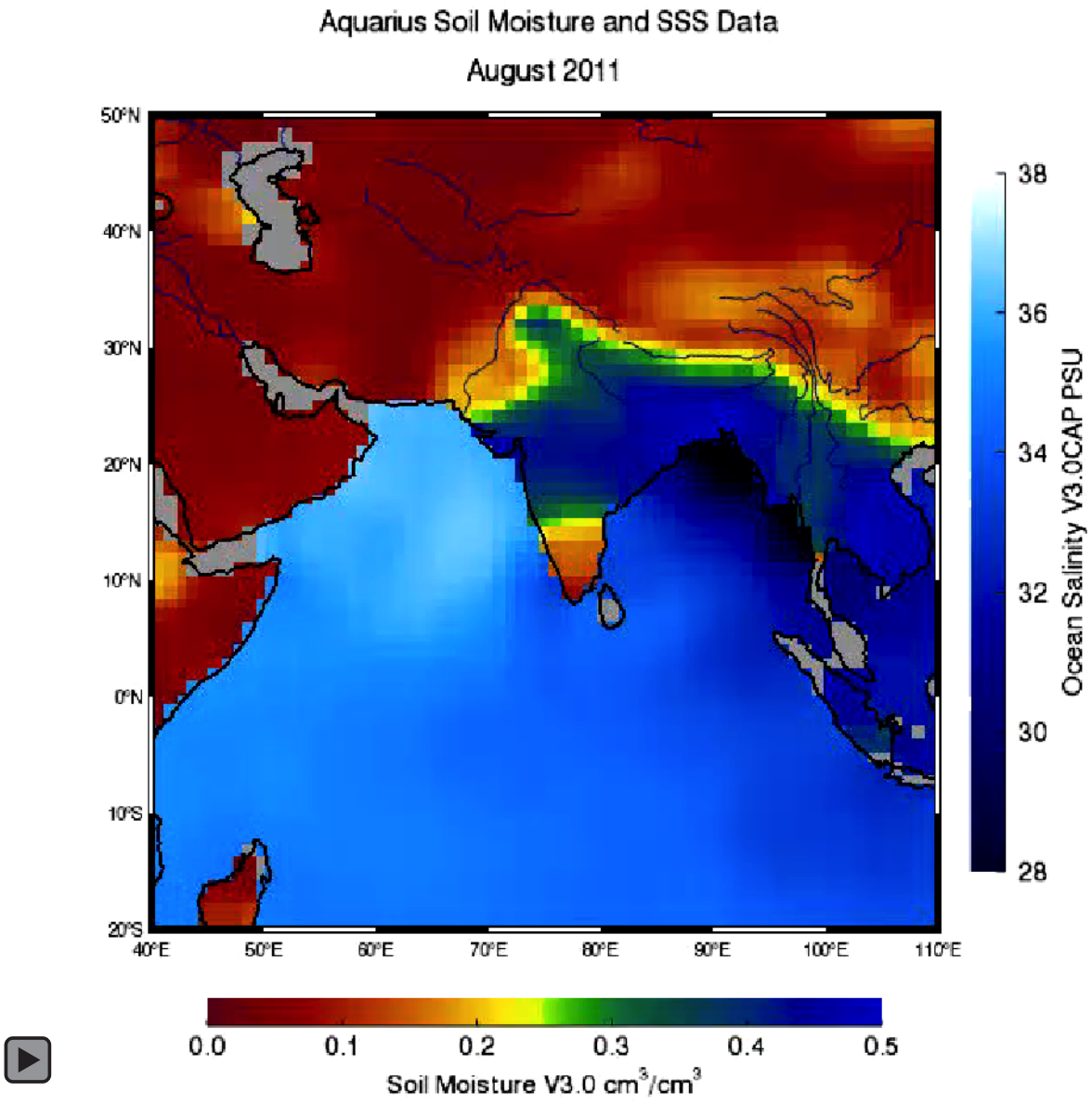




- CAP_RC SSS has the better agreement with the SSS at 50 cm depth

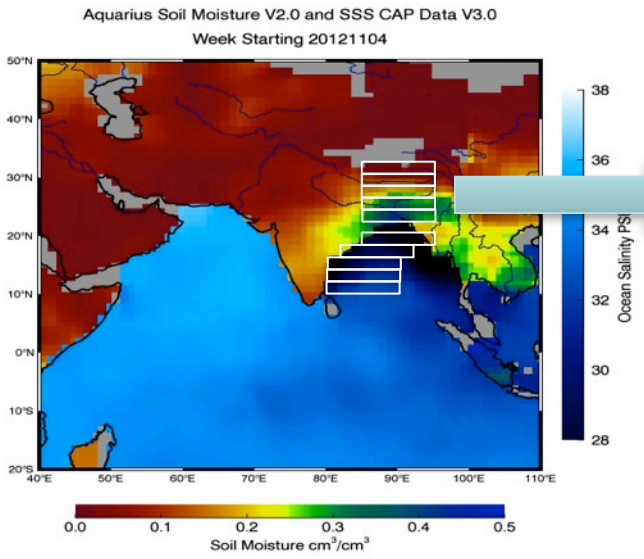
Slope	SSSAq-S10m	SSSAq-S1m	SSSAq-S50cm
CAP	-0.1477	-0.0875	-0.0516
CAP_RC	-0.1381	-0.0706	**-0.0425**

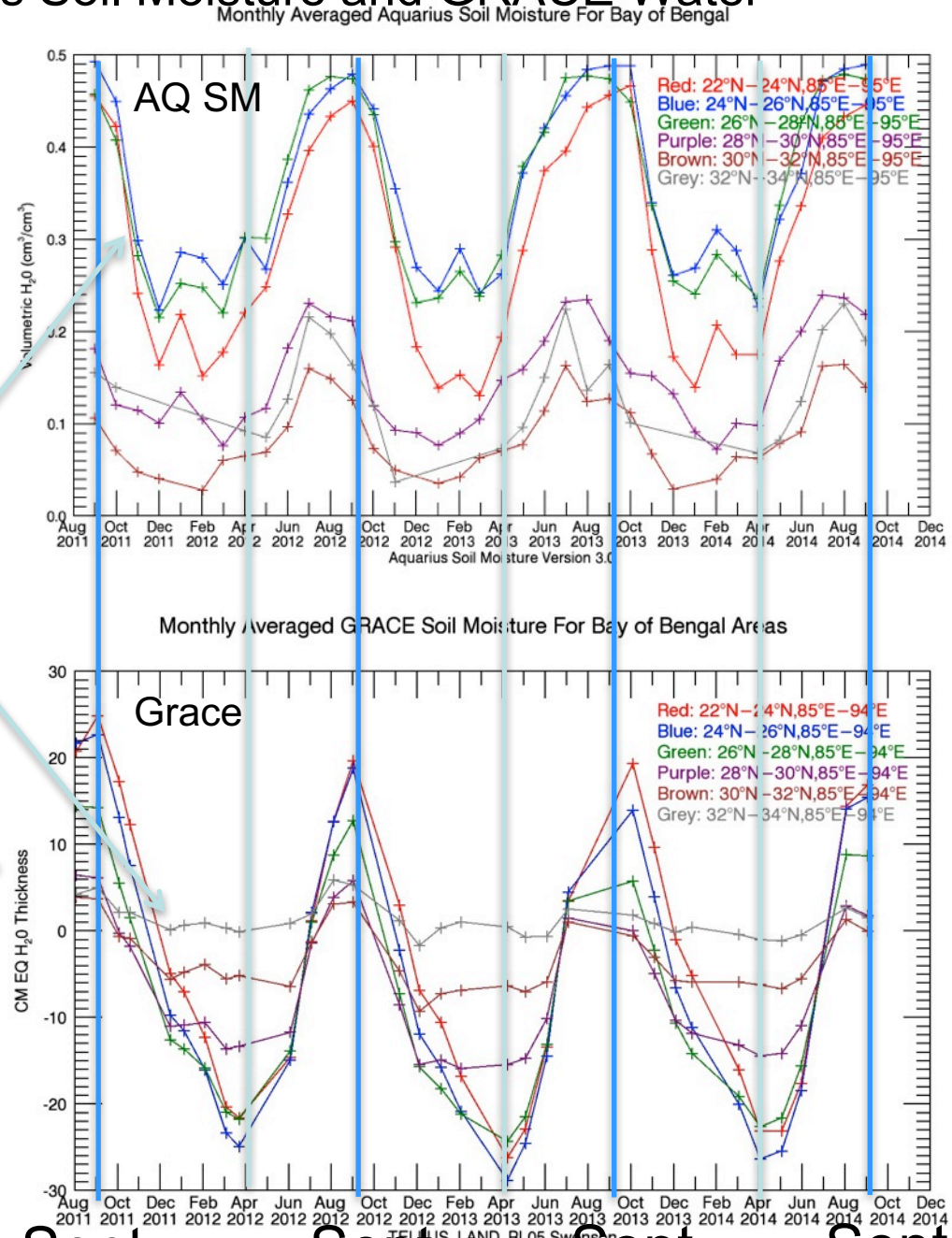
Aquarius CAP_RC SSS and Soil Moisture Animation (Sept 2011-Sept 2014)



Aquarius Soil Moisture and GRACE Water

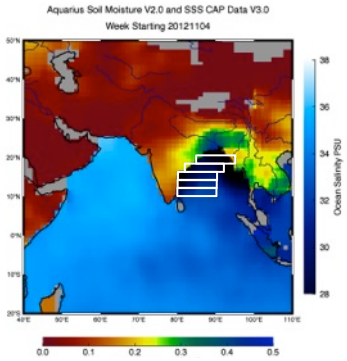
- Rain starts approximately in April
- More rain closer to the coast over land
- Dry down starts in September except 2013

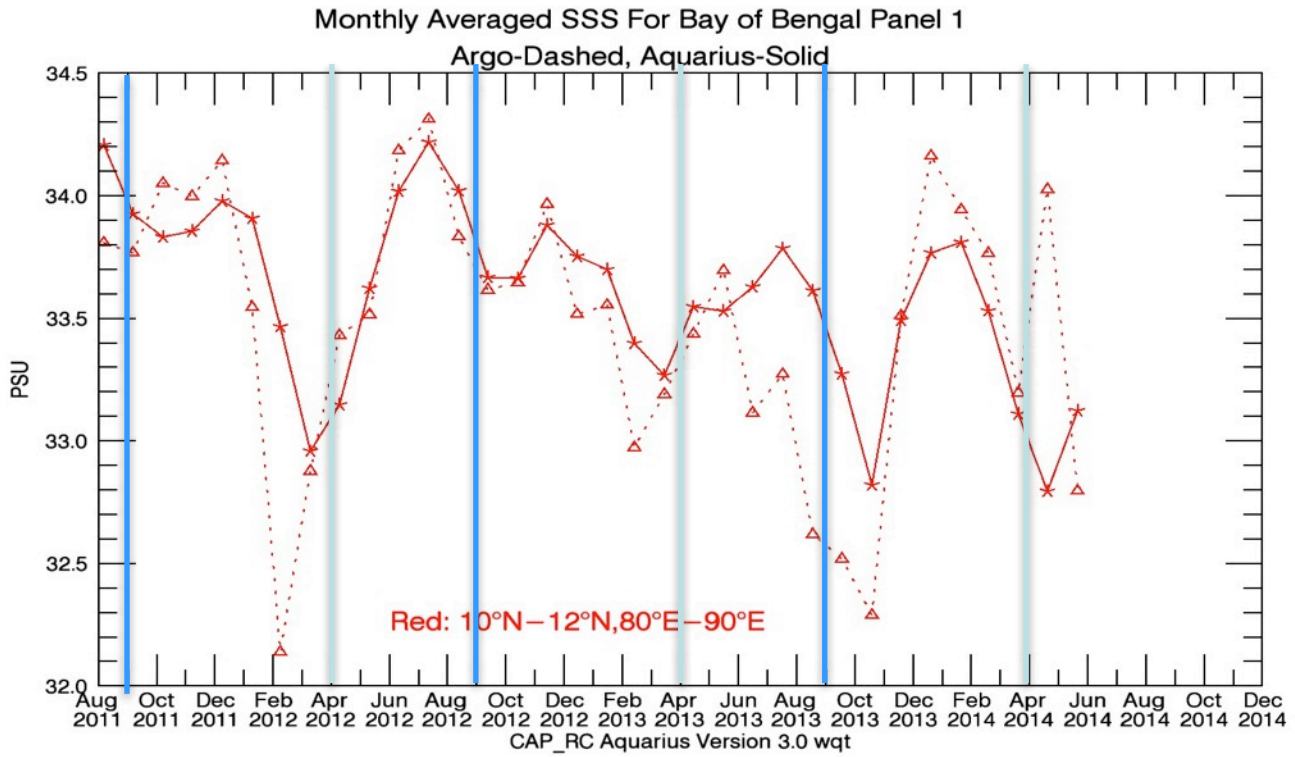




Aquarius CAP_RC and ARGO Salinity

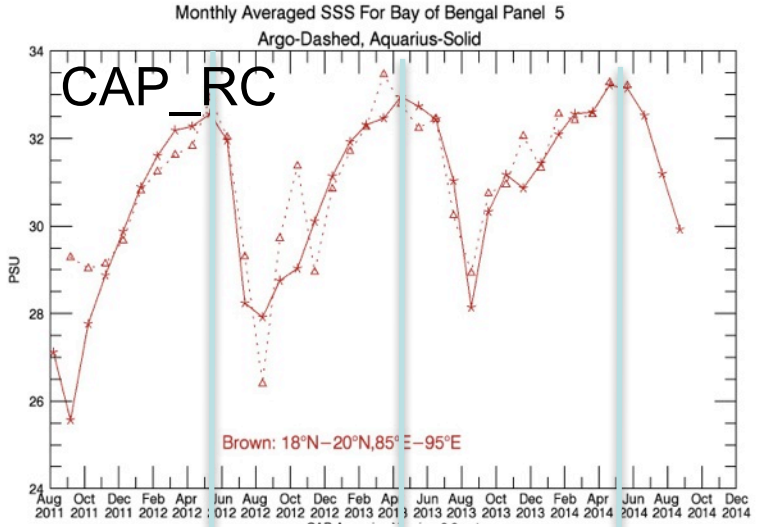
- Salinity change near the coast corresponds well with the change of soil moisture
- Salinity change further away from the coast affected by other processes

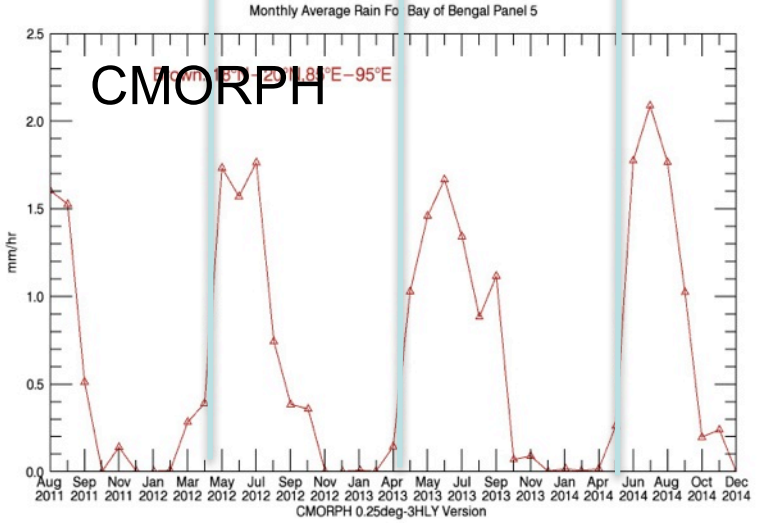




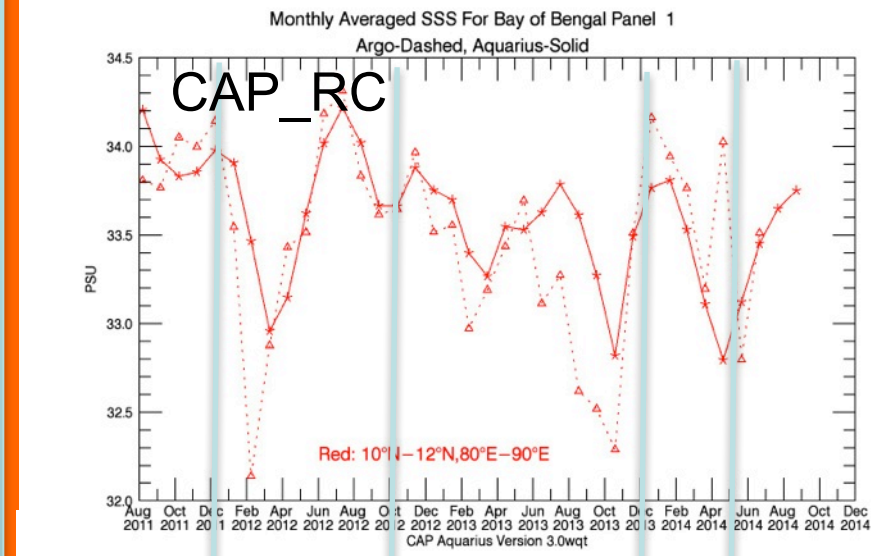
Comparison of CAP_RC and CMORPH Rain Rate for Boxes 1 and 5

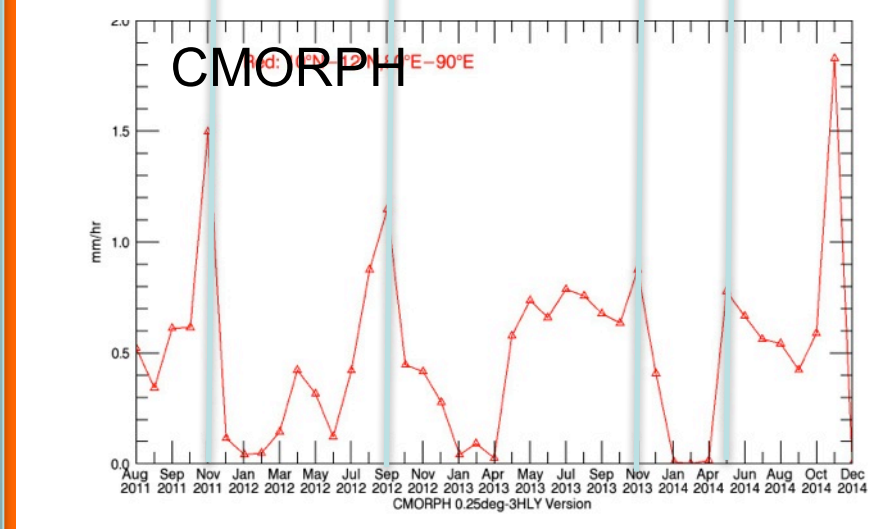
Good anti-correlation near coast





Weak correlation far off coast

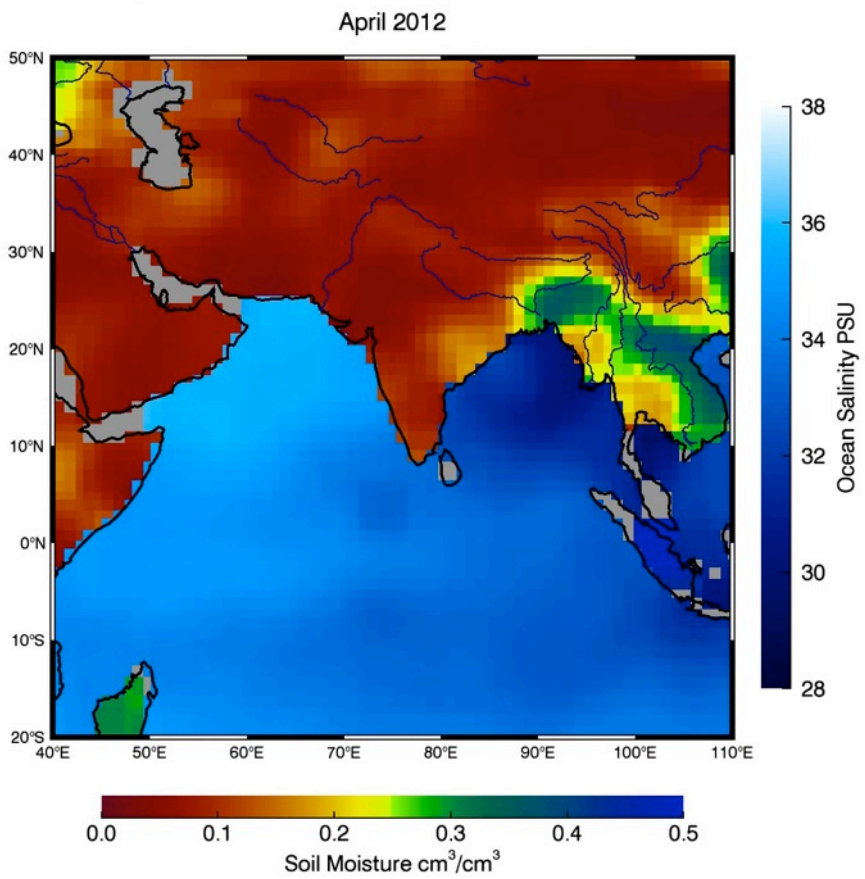


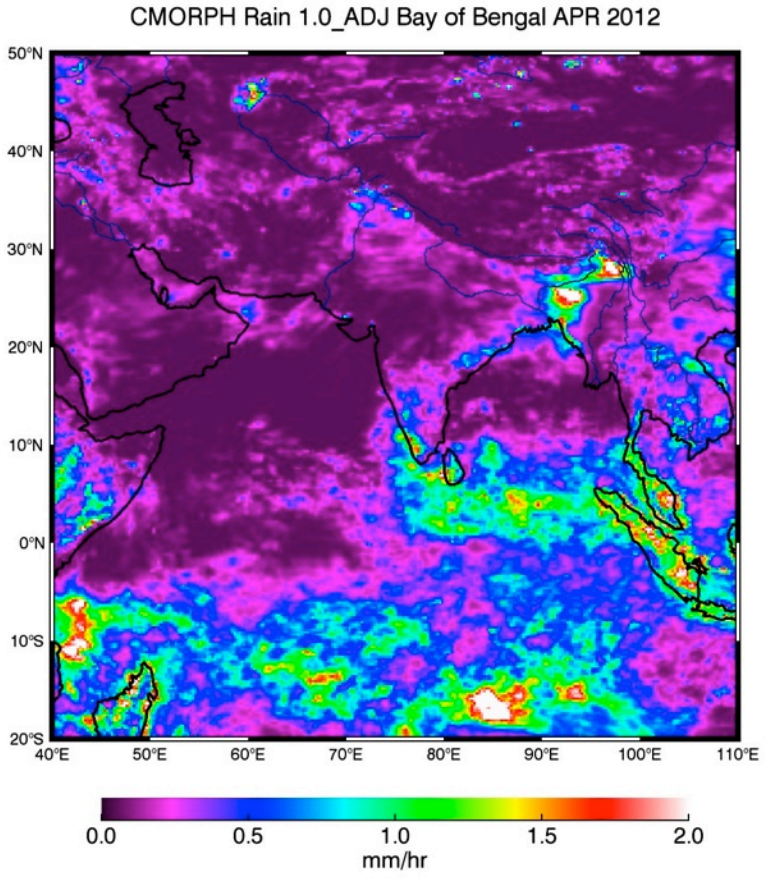


Change of SSS and Rain in the Bay of Bengal in April 2012

- Fresher water in the Bay
- Higher precipitation does not correspond to fresher water

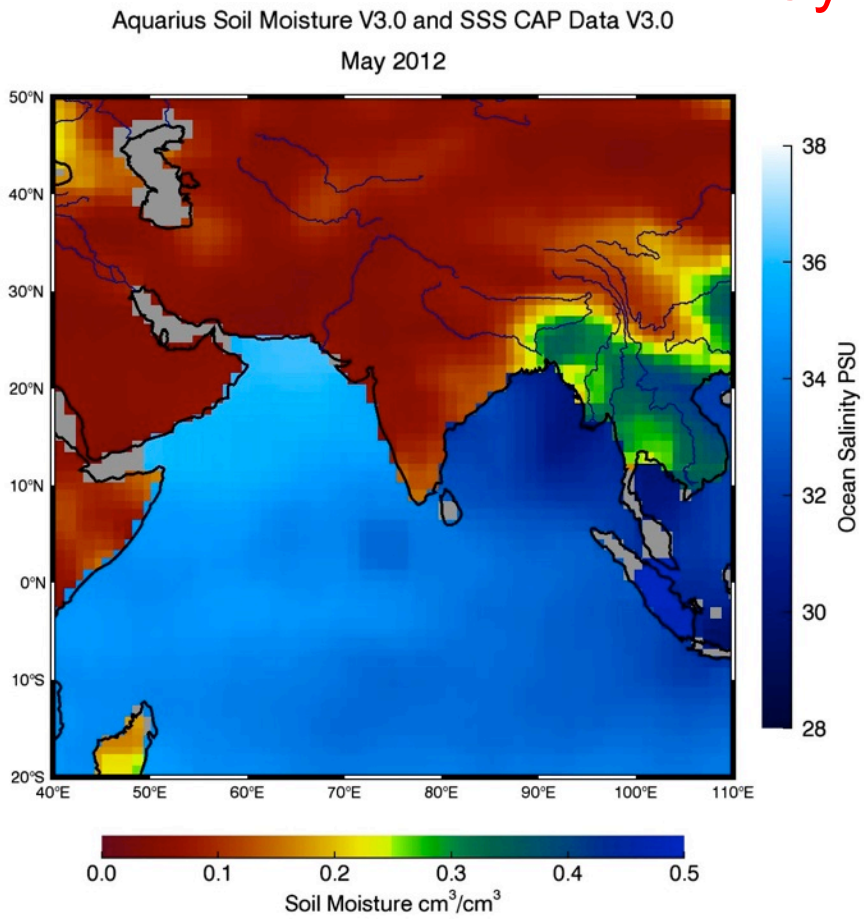
CAP_RC SSS April 2012 CMORPH Rain

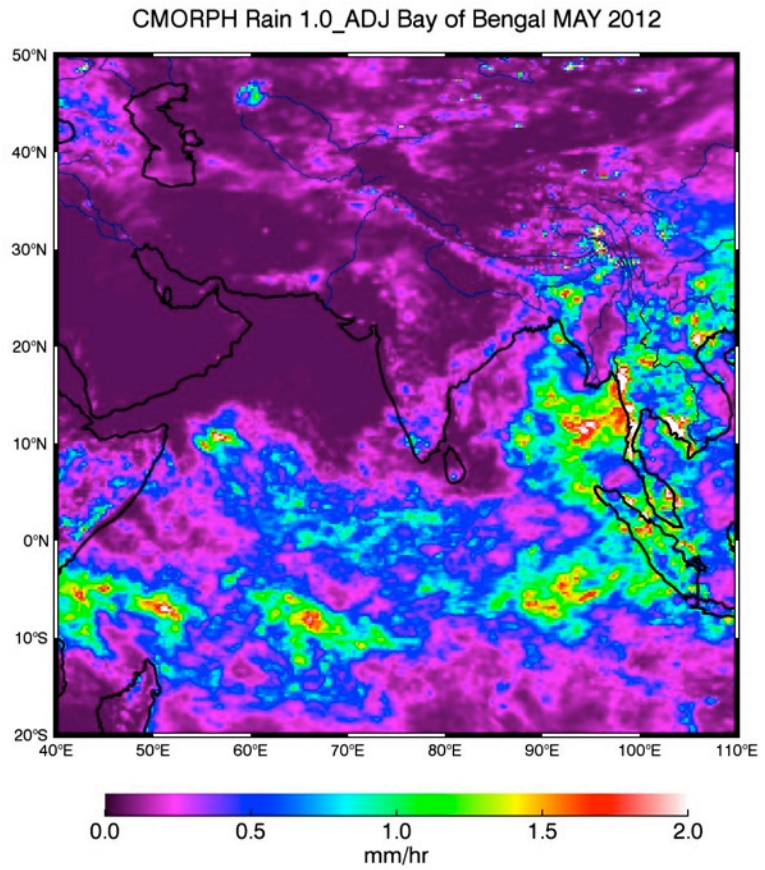




Change of SSS and Rain in the Bay of Bengal in May 2012

May 2012

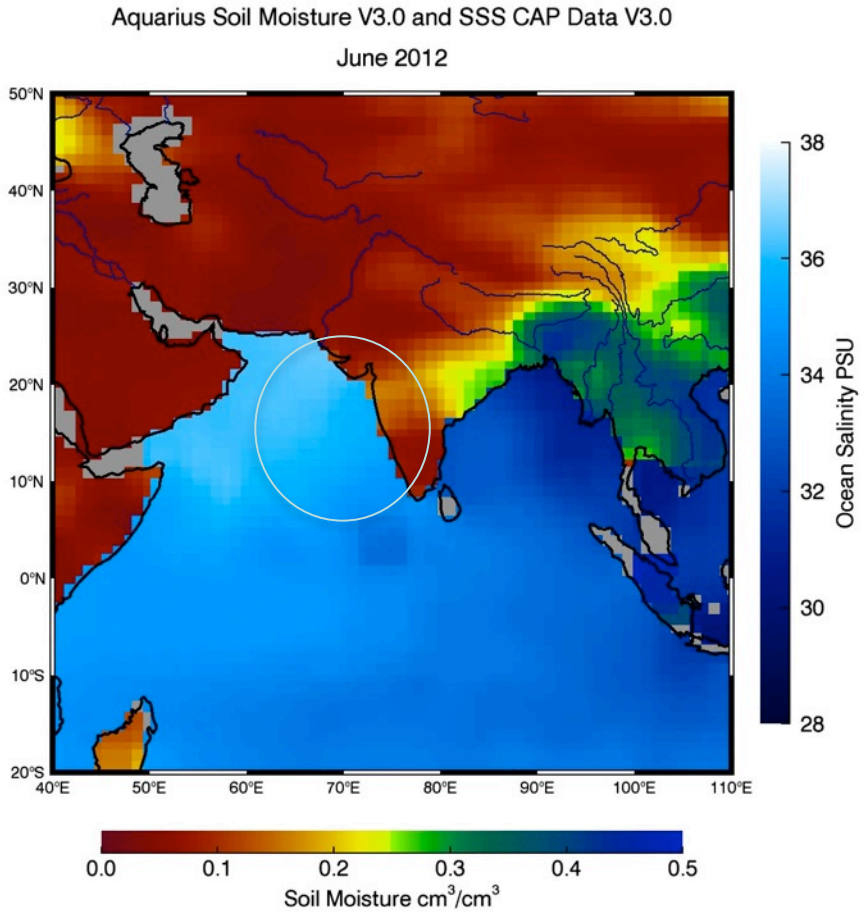


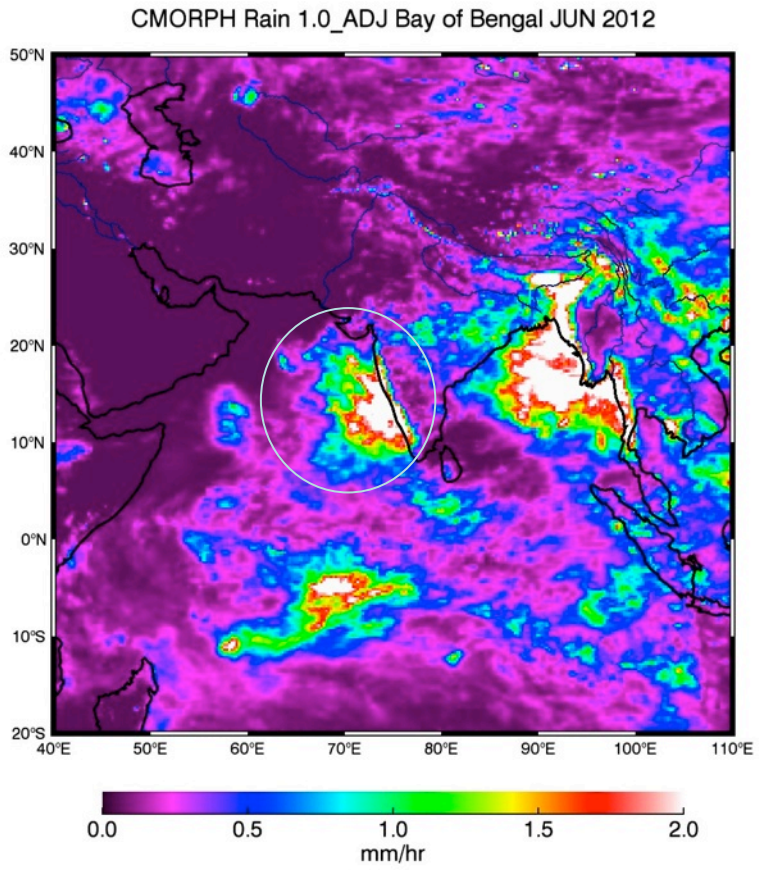


Change of SSS and Rain in the Bay of Bengal in June 2012

- Higher precipitation does not correspond to fresher water in Arabian Sea
  - **No obvious freshwater lensing**

June 2012

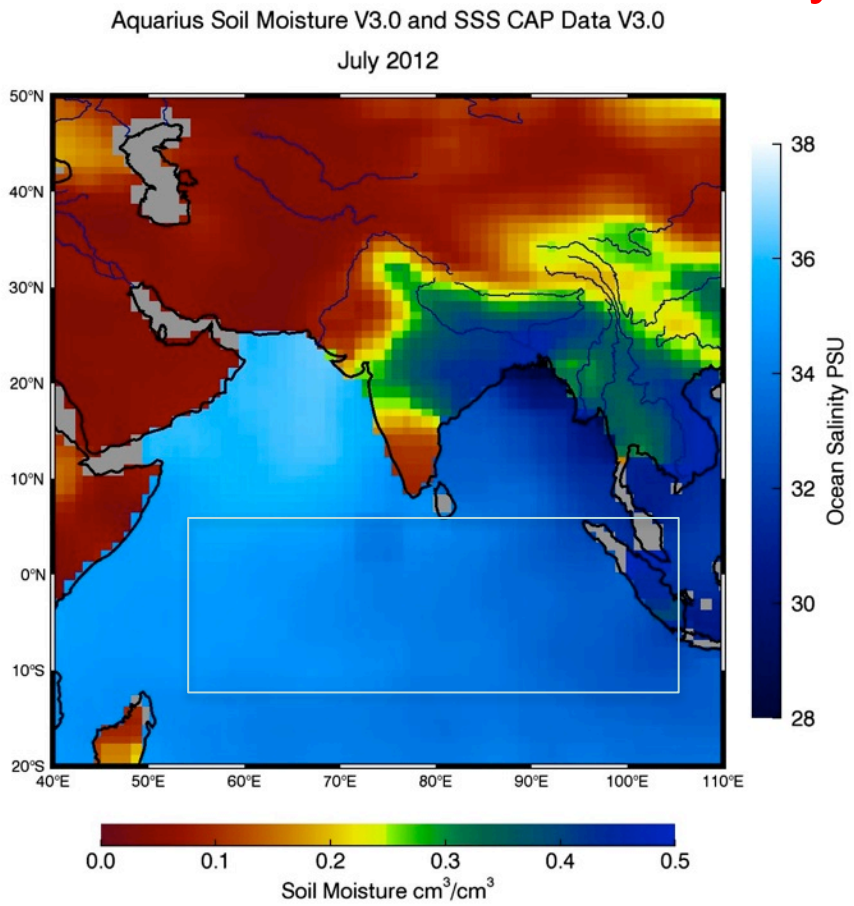


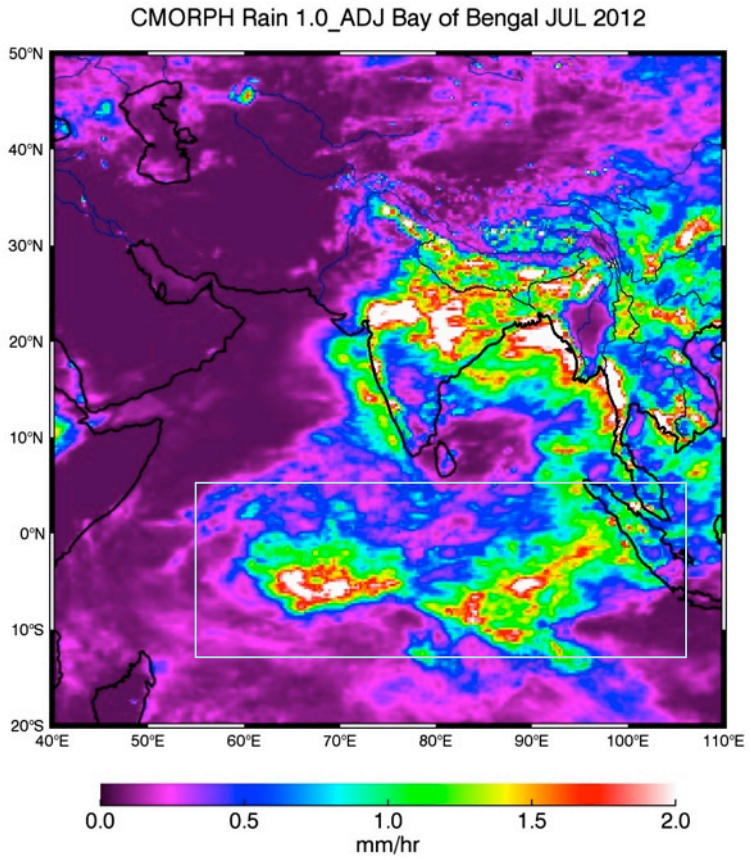


Change of SSS and Rain in the Bay of Bengal in July 2012

- Higher precipitation does not correspond to fresher water in Arabian Sea and Indian Ocean
  - **No obvious freshwater lensing**

July 2012

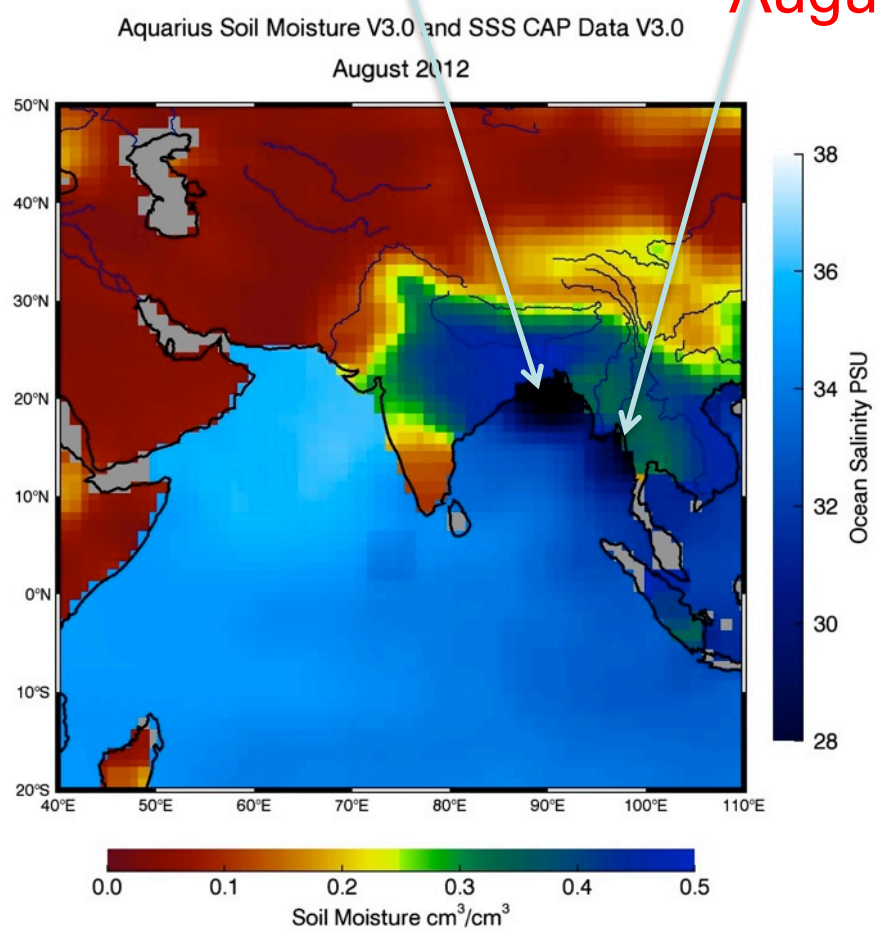


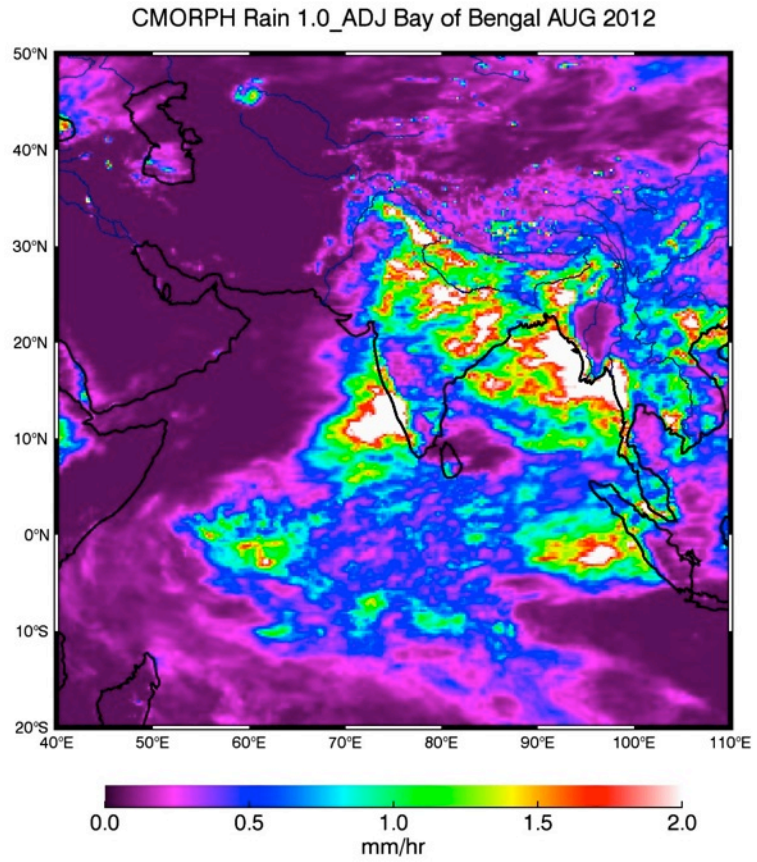


Change of SSS and Rain in the Bay of Bengal in August 2012

- **Salinity change due to river discharge**
  - **The Ganges, Irrawaddy and Salween**

August 2012

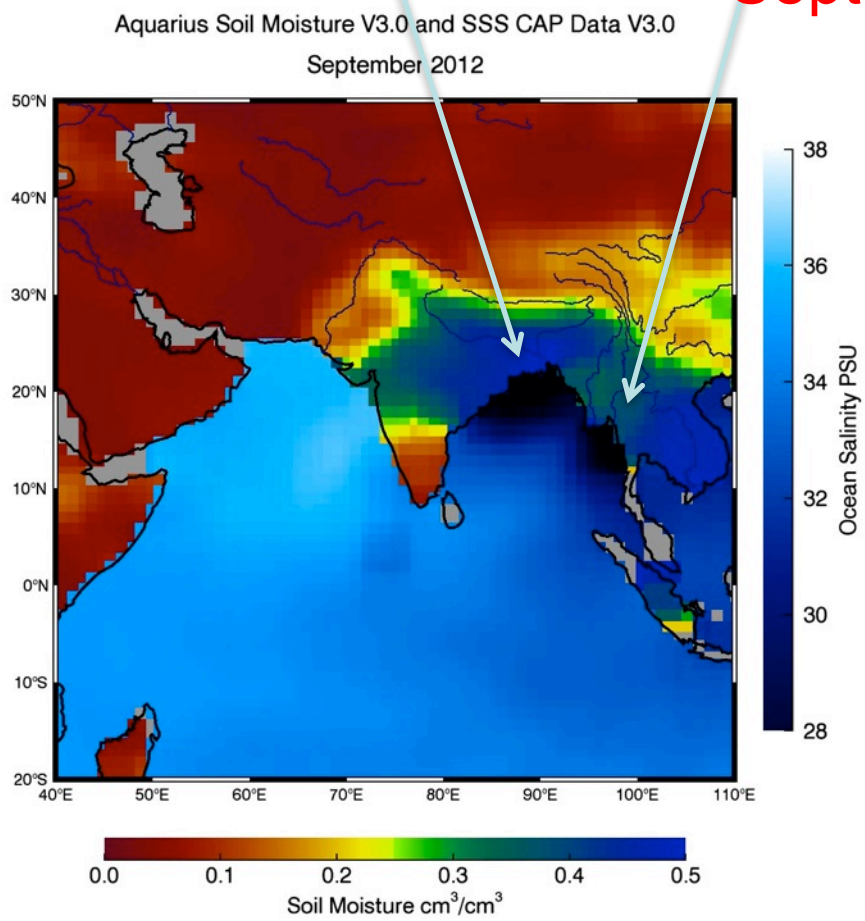


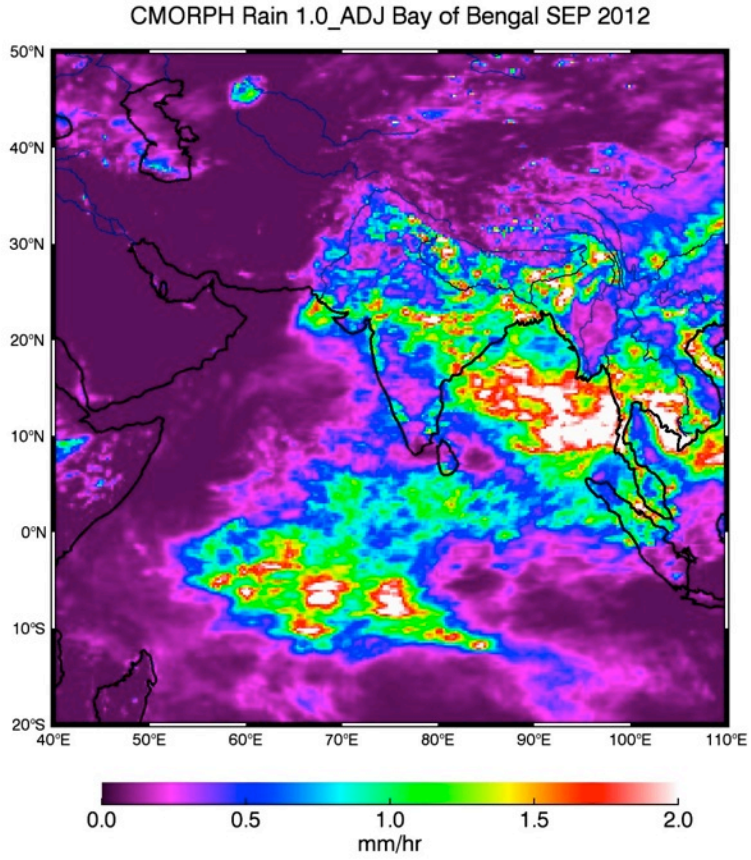


Change of SSS and Rain in the Bay of Bengal in September 2012

- **Salinity change due to river discharge**
  - **The Ganges, Irrawaddy and Salween**

September 2012

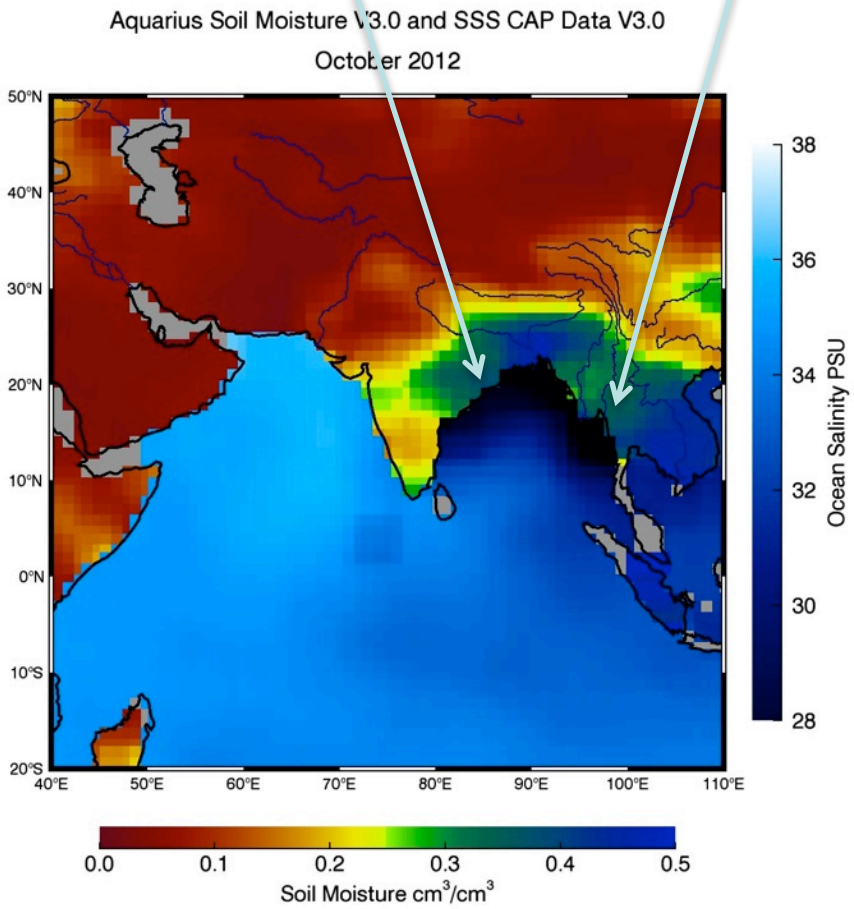


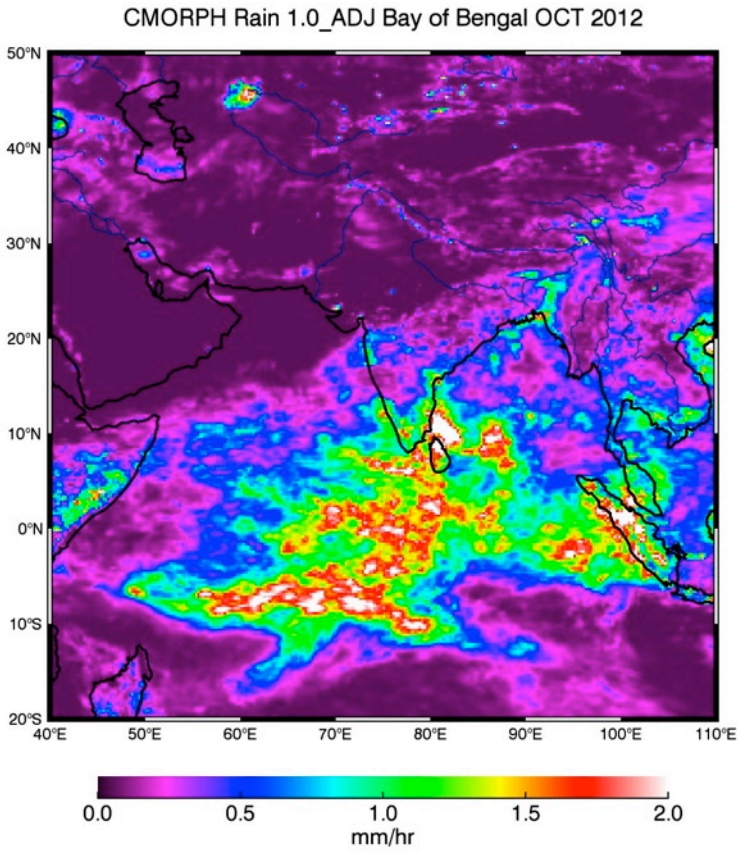


Change of SSS and Rain in the Bay of Bengal in October 2012

- **Salinity change due to river discharge**
  - **The Ganges, Irrawaddy and Salween**
- **Advection**

October 2012

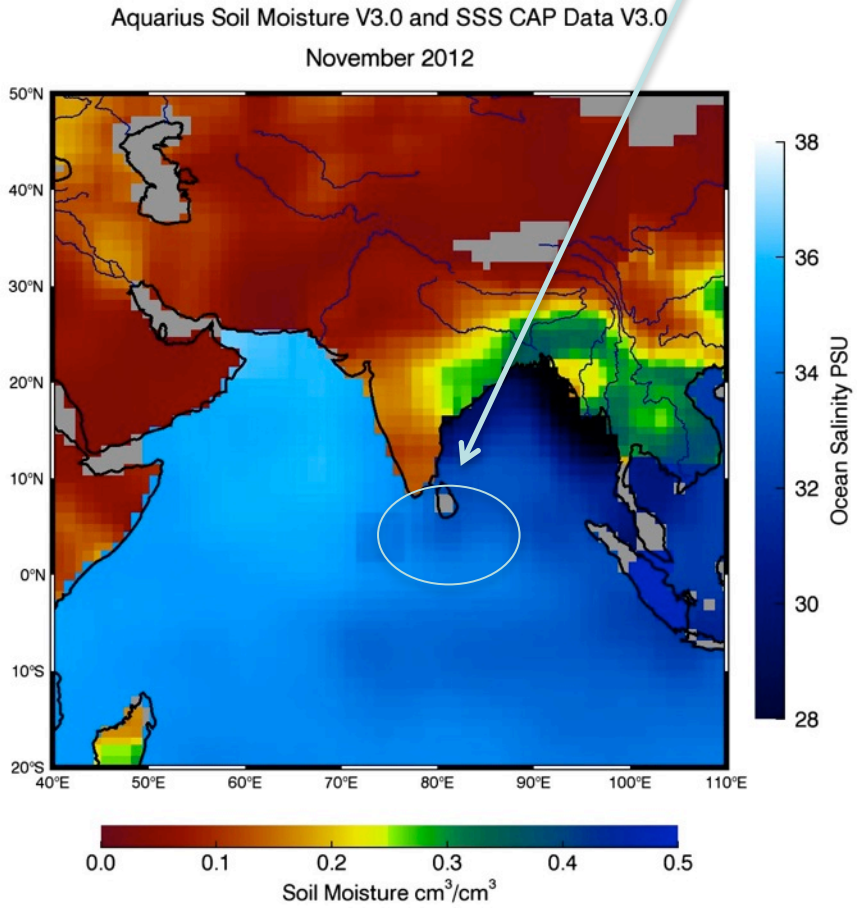


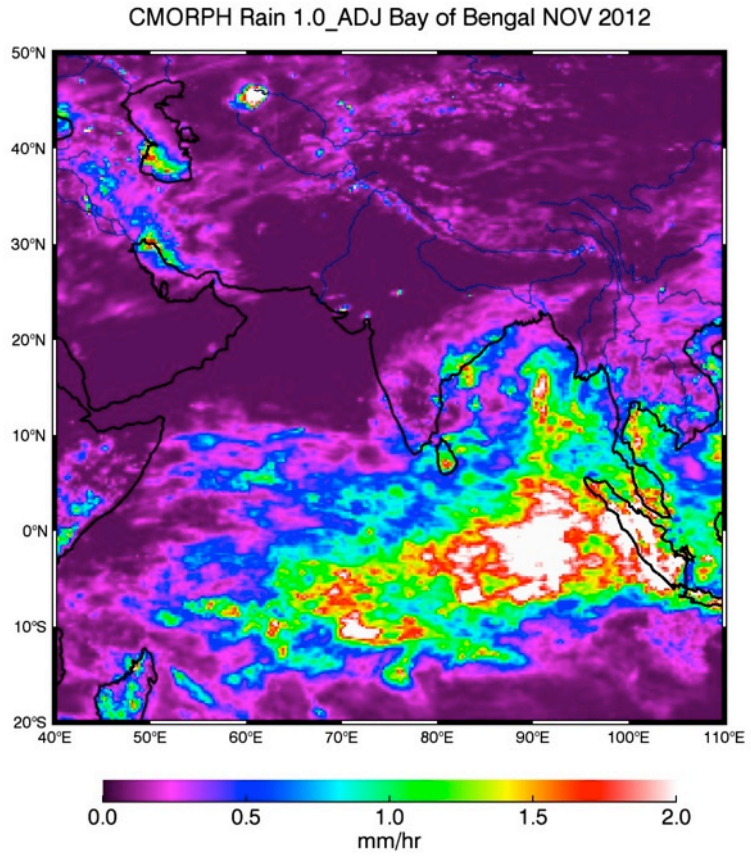


Change of SSS and Rain in the Bay of Bengal in November 2012

- **Fresher water advection into the Indian Ocean**

November 2012

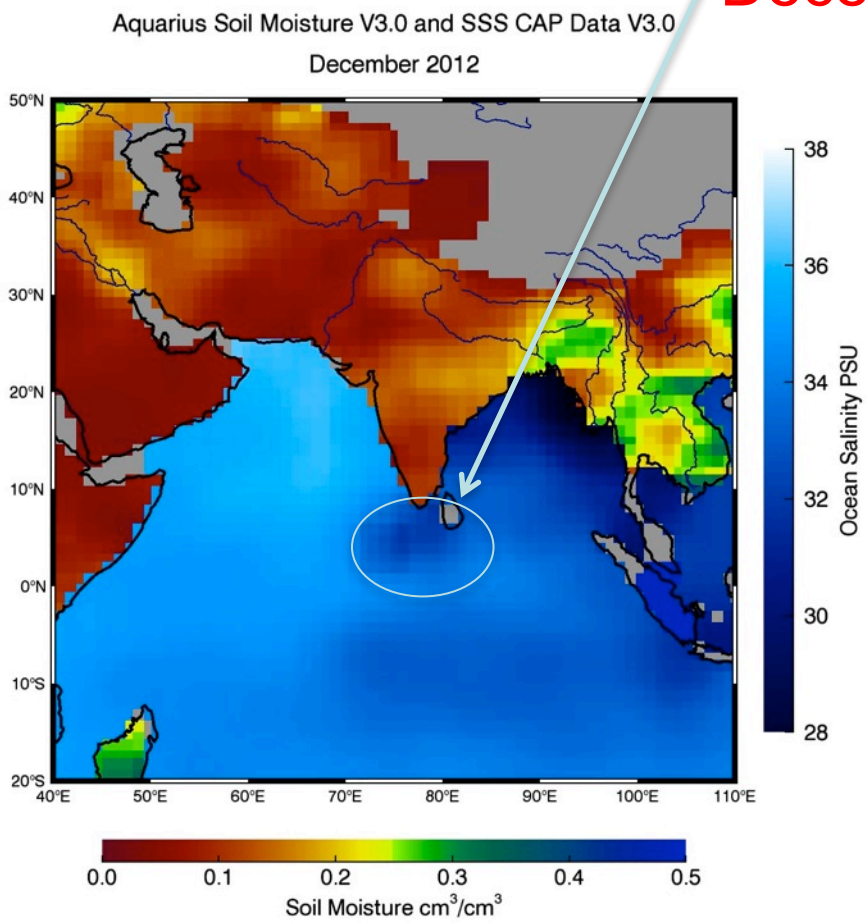


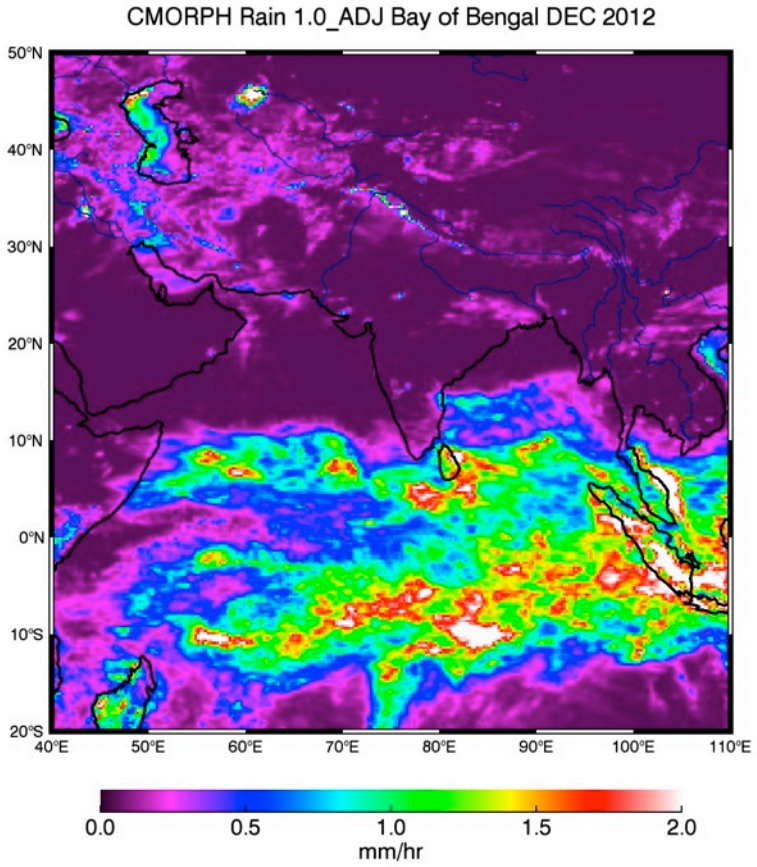


Change of SSS and Rain in the Bay of Bengal in December 2012

- **Fresher water advection into the Indian Ocean**

December 2012

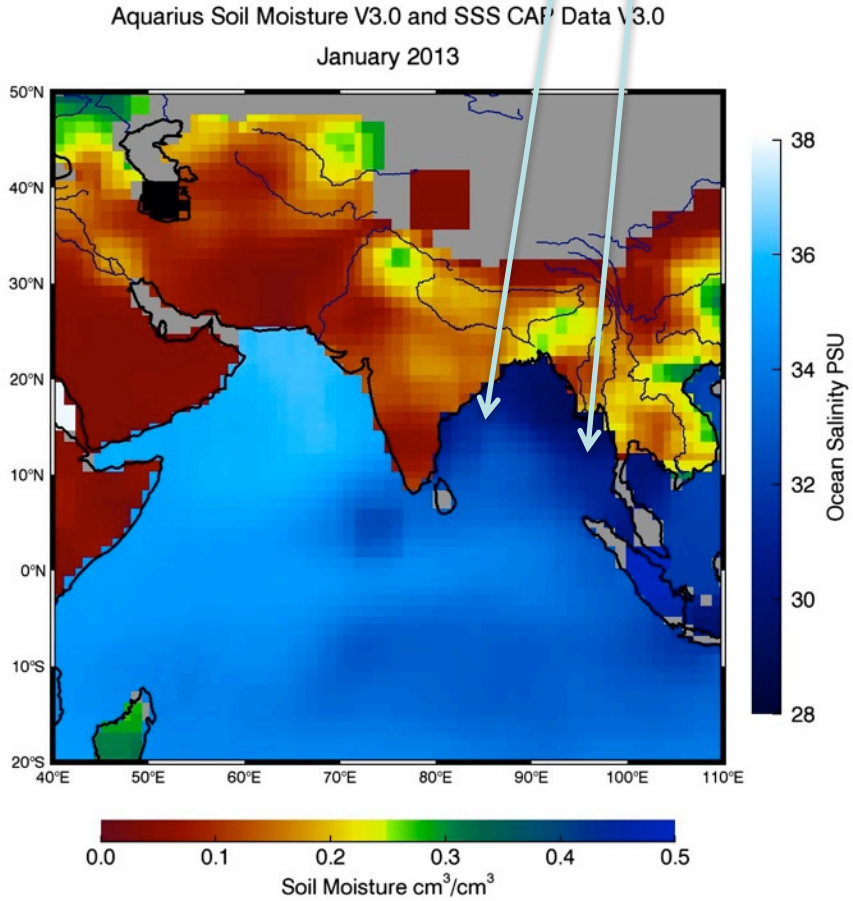


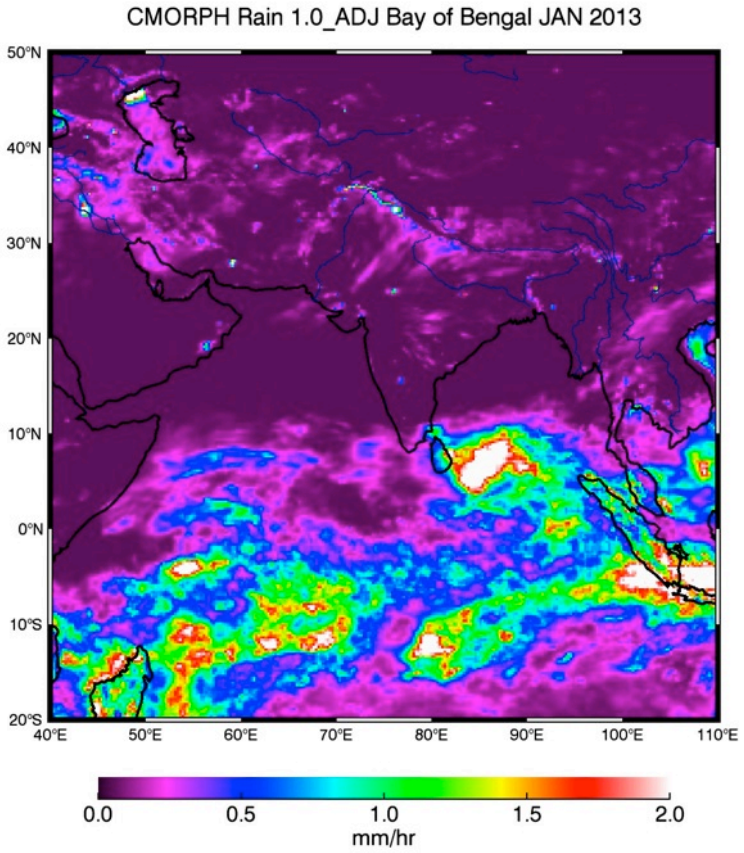


Change of SSS and Rain in the Bay of Bengal in January 2013

- **Fresher water advection in the Bay of Bengal**

January 2013

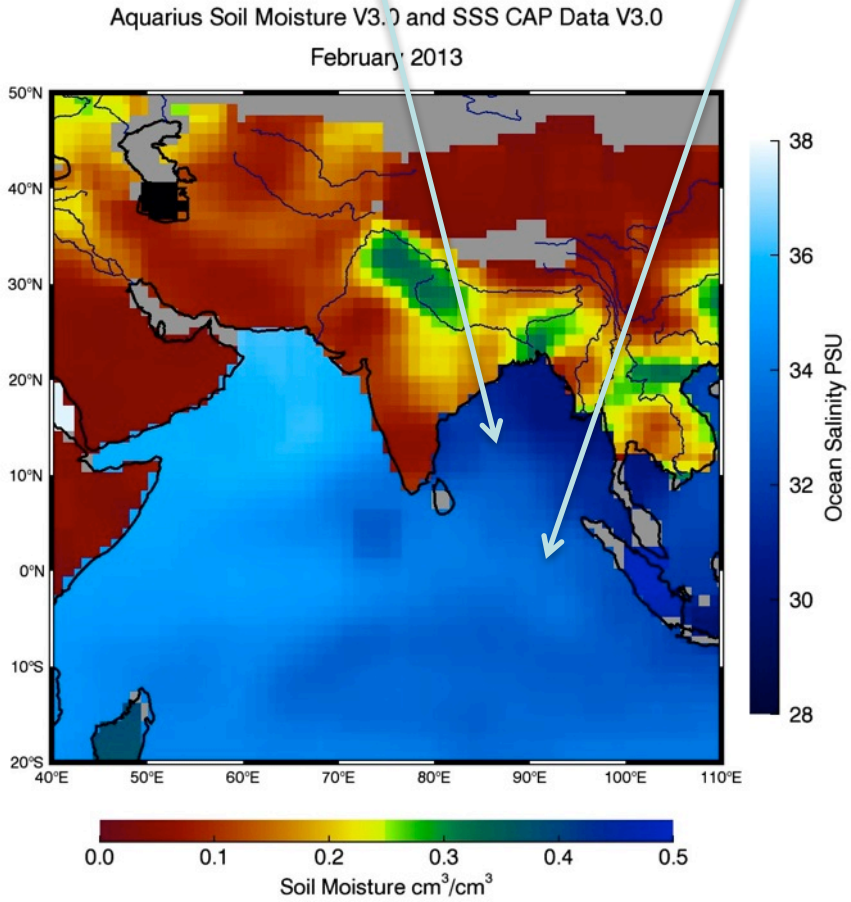


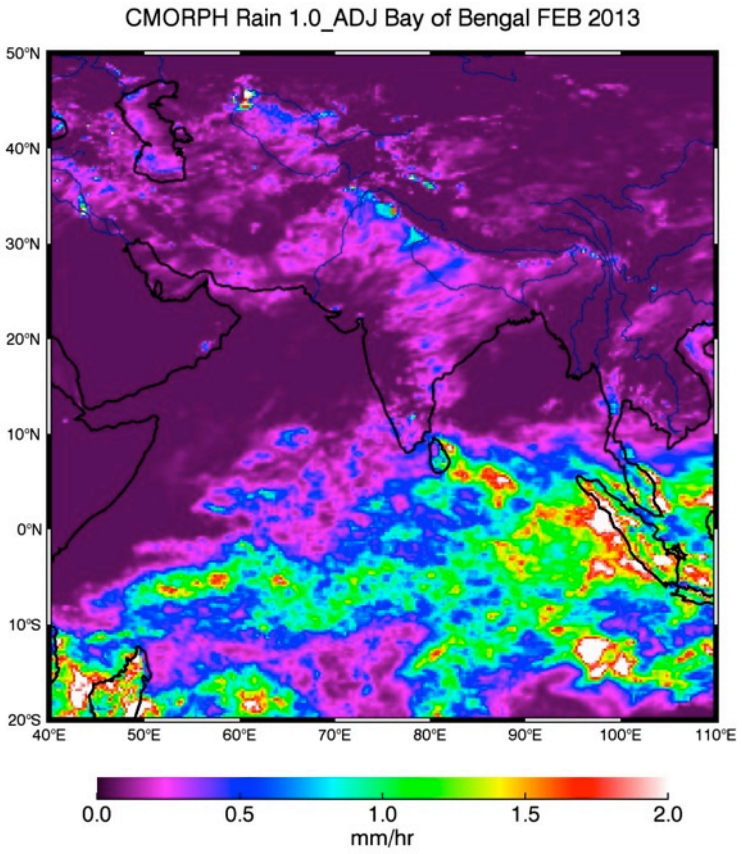


Change of SSS and Rain in the Bay of Bengal in February 2013

- **No obvious freshwater lensing due to precipitation**
- **Advection (Oct-April)**

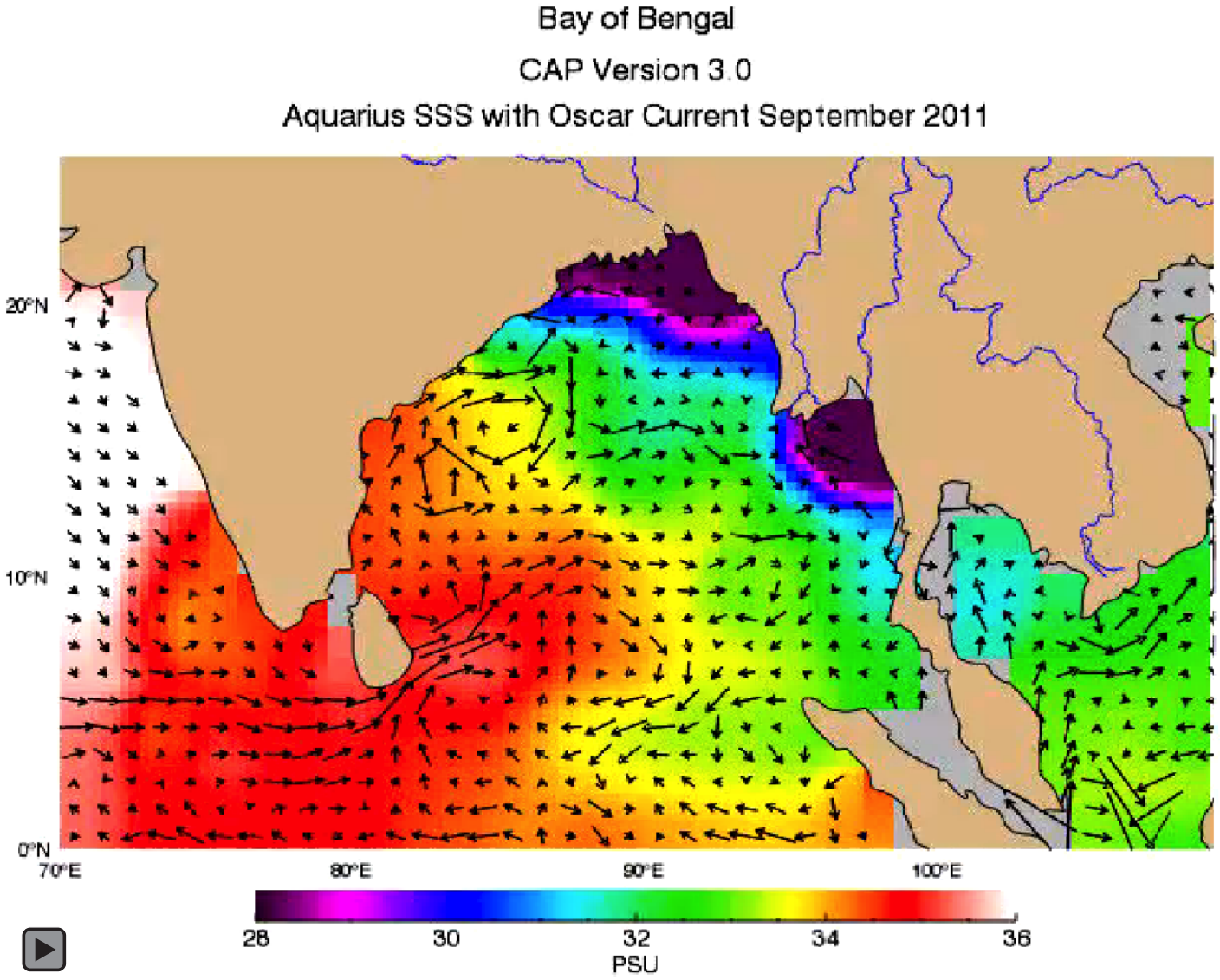
February 2013



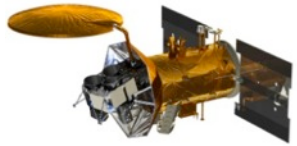


Aquarius CAP_RC and OSCAR Current Effects of Advection

- The advection of salinity seems to correspond to the OSCAR current



Summary



- Geophysical model functions for rain-free and rain-induced roughness impact updated to better account for the surface stratification effects – close to Locean float data
- CAP_RC SSS agrees very well with the ARGO near coast
- River discharge critical for the coastal areas for the salinity change
- River discharge and advection (April-September)
- Advection and maybe evaporation dominates (Oct-March)
- No obvious freshwater lensing effects due to rain in the Bay of Bengal

Salinity, soil moisture and rain products provide a consistent depiction of water cycle