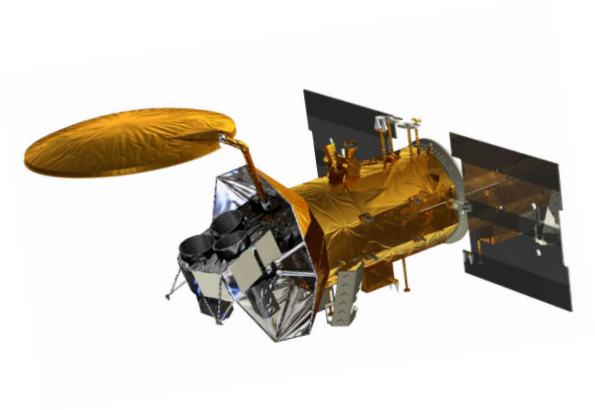


Assimilation of Satellite Sea-surface Salinity Fields: Validating Ocean Analyses and Identifying Errors in Surface Buoyancy Fluxes

Eric Bayler	NOAA/NESDIS/STAR
Sudhir Nadiga	IMSG at NOAA/NWS/NCEP/EMC
Avichal Mehra	NOAA/NWS/NCEP/EMC
David Behringer	NOAA/NWS/NCEP/EMC

Sea-Surface Salinity (SSS) Data

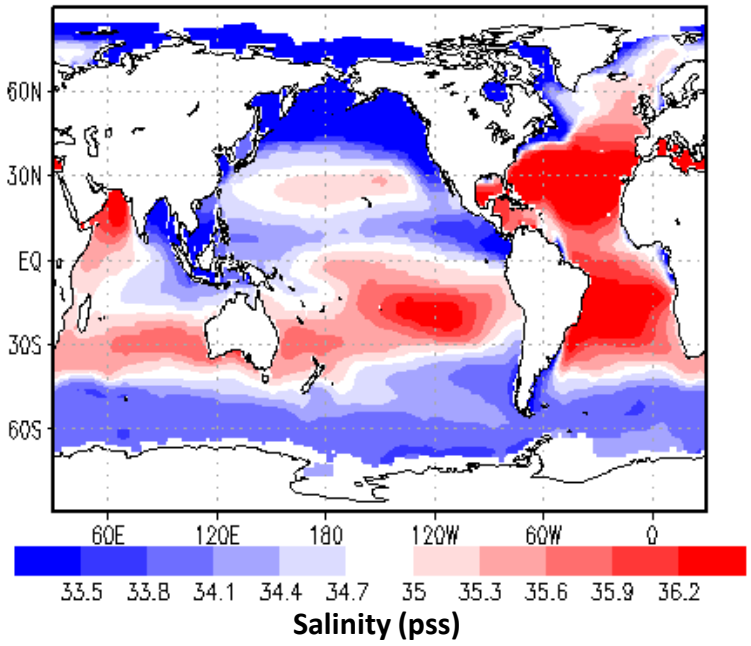
- **NOAA World Ocean Atlas 2009** (WOA09**)**
  - Gridded, 1° × 1° resolution
    - Antonov, J. I., D. Seidov, T. P. Boyer, R. A. Locarnini, A. V. Mishonov, H. E. Garcia, O. K. Baranova, M. M. Zweng, and D. R. Johnson (2010), World Ocean Atlas 2009, Volume 2: Salinity. S. Levitus, Ed. NOAA Atlas NESDIS 69, U.S. Government Printing Office, Washington, D.C., 184 pp., 2010.
  - Monthly-mean climatology used in NOAA's operational seasonal-interannual and near-real-time ocean models

- **Argo float monthly temperature and salinity profiles**; Sep 2011 – Aug 2014
  - Gridded, 1° × 1° resolution
  - International Pacific Research Center, Hawaii
    - Lebedev, K. V., S. DeCarlo, P. W. Hacker, N. A. Maximenko, J. T. Potemra, and Y. Shen (2010), Argo Products at the Asia-Pacific Data-Research Center, Eos Trans. AGU, 91(26), Ocean Sci. Meet. Suppl., Abstract IT25A-01.

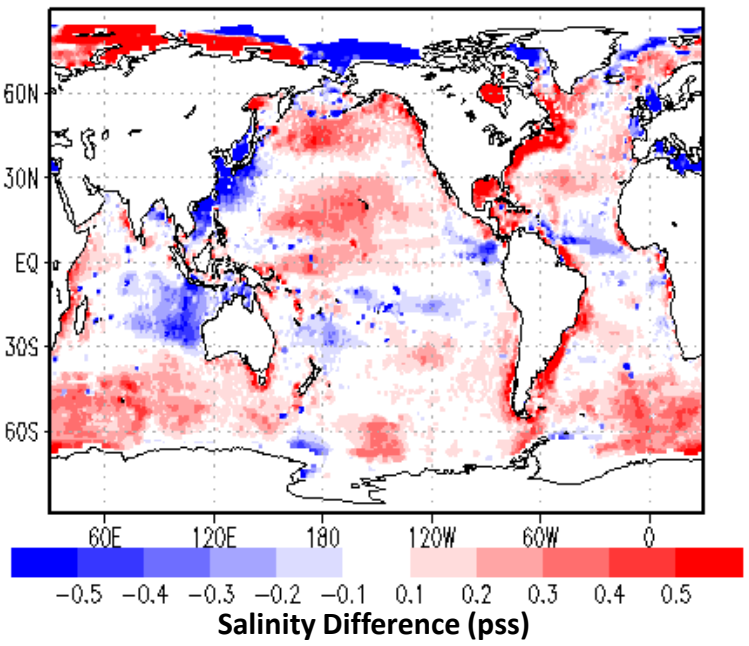
- **Aquarius Official Release Level-3 Sea Surface Salinity Bias-Adjusted Standard Mapped Image Daily Data V3.0** (AQ); 1 Sep 2011 – 31 Aug 2014
  - Gridded, 1° × 1° resolution, aggregate of ascending and descending node data
  - The empirical SST bias adjustment to retrieved salinity values is designed to reduce biases which are observed in the standard SSS product and which correlate with SST. The likely cause of these biases are small errors in the geophysical model that is used in the SSS retrievals.
  - NASA JPL PODAAC

Salinity Observations: Climatology and Variability

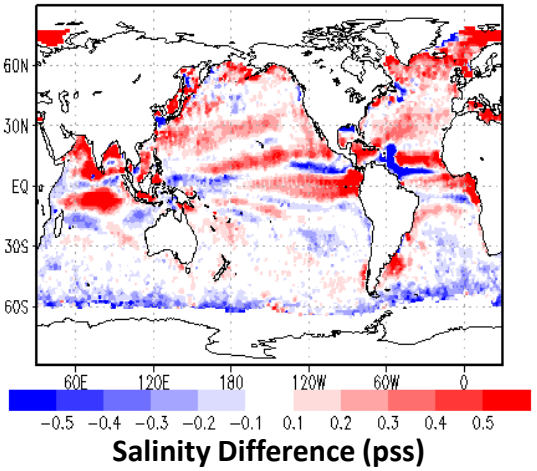
WOA 2009 Annual Mean SSS



Annual Mean SSS Difference (WOA – Aquarius)

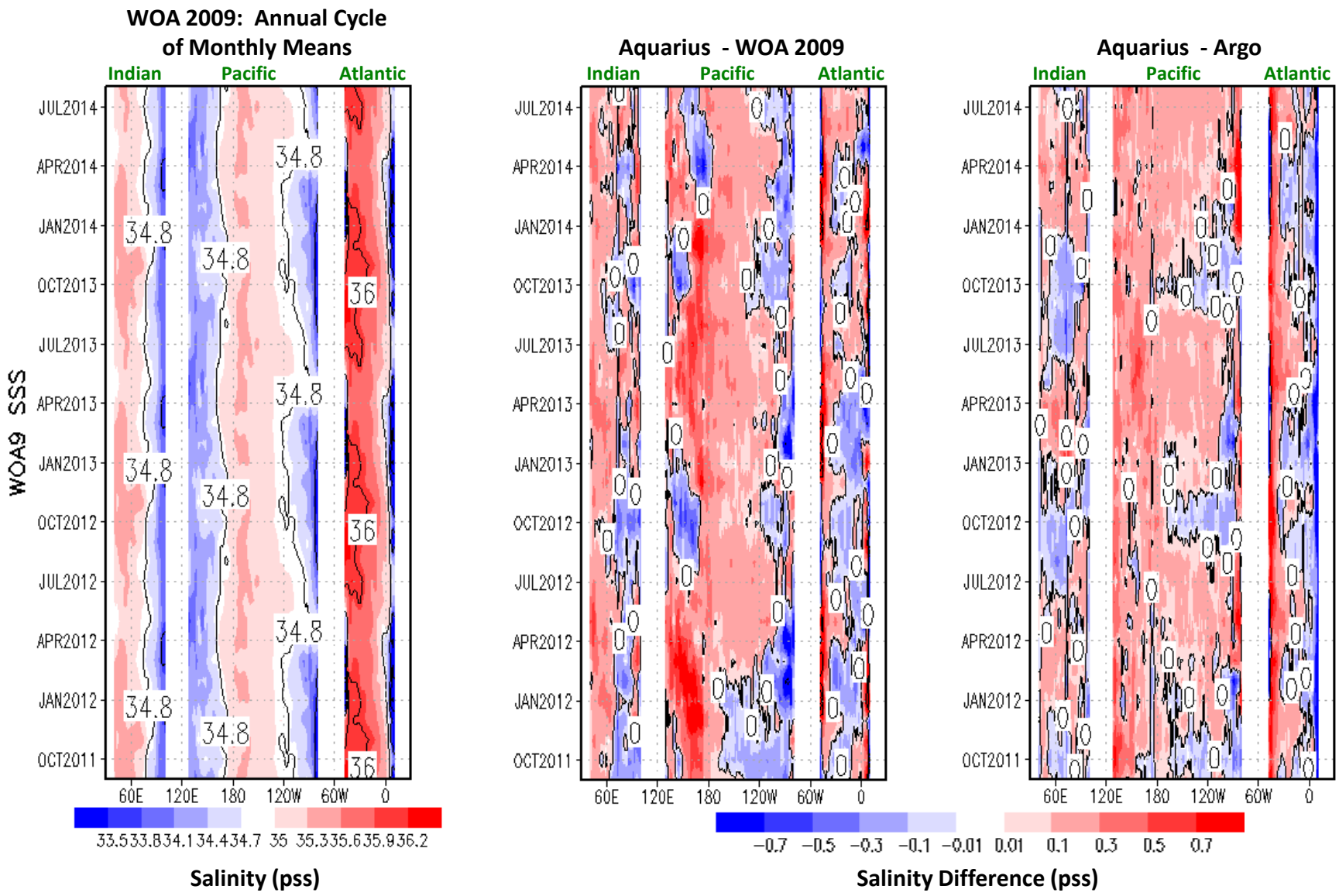


Aquarius SSS Variability (JJA – DJF):
Range of seasonal mean



Aquarius data: 1 Sep 2011 – 31 Aug 2014

SSS Observations (2°S-2°N): Climatology and Variability



Modeling

Model:

- **Modular Ocean Model version 4 (MOM4)**; resolution = 0.5 ° latitude/longitude
  - Computational core for NOAA's National Weather Service's (National Center for Environmental Prediction (NCEP)) operational seasonal-interannual Global Ocean Data Assimilation System (GODAS), the ocean component of NOAA's operational coupled Climate Forecast System (CFS).

Forcing:

- Daily-averaged NCEP/DOE Reanalysis 2 (Kanamitsu, et al., 2002, Bull. Amer. Meteor. Soc.)
- Relaxed to daily satellite sea-surface temperature (SST) fields and the climatological monthly-mean sea-surface salinity (SSS) field.
  - 30-day relaxation for SST
- AQRS SSS were bias-corrected before assimilation such that at each grid-point the AQRS SSS 3-year mean of the simulations was equal to the corresponding WOA9 mean for that grid-point.

Cases:

a) **CTRL30** relaxed to WOA9 monthly climatological SSS with 30-day relaxation time period for SSS
  - NOAA operational configuration

b) **CTRL10** relaxed to WOA9 monthly climatological SSS with 10-day relaxation time period for SSS
  - Examines the impact of more tightly constraining SSS to climatology

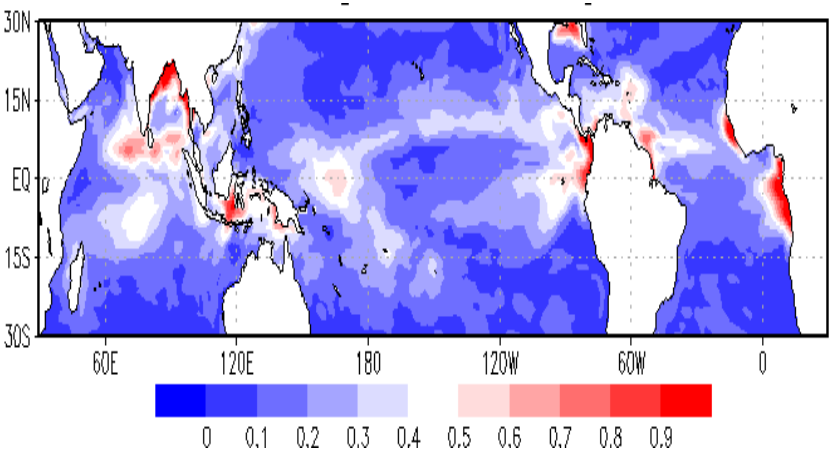
c) **AQ30** relaxed to daily bias-corrected AQRS with 30-day relaxation time period for SSS;
  - Examines the impact of global Aquarius data coverage and its variability

d) **AQ10** relaxed to daily bias-corrected AQRS with 10-day relaxation time period for SSS
  - Examines the impact of more tightly constraining SSS to observations

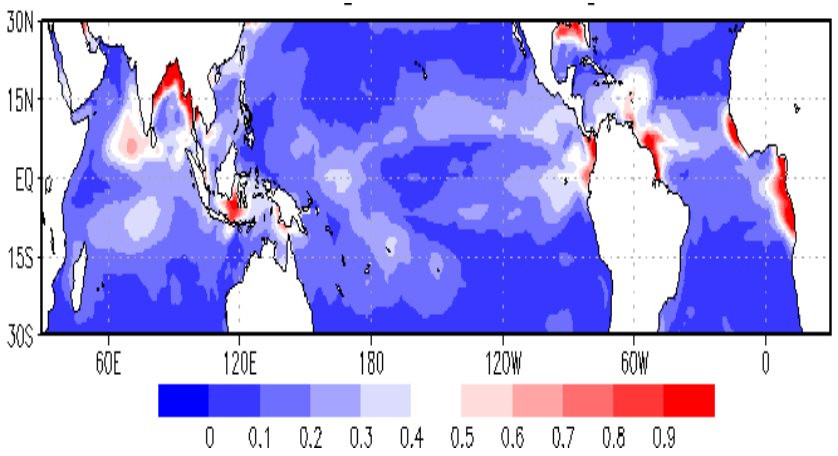
- All runs initiated from the same ocean initial condition and run for 09/2011 – 08/2014

Model Salinity Annual RMS Variability

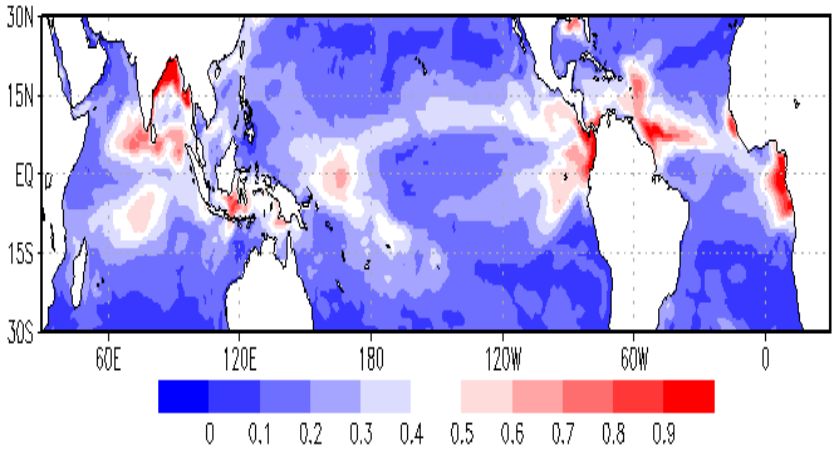
CTRL30



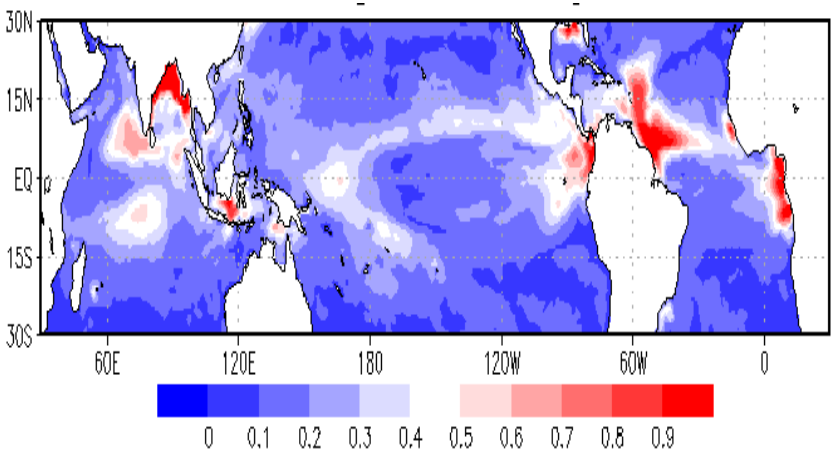
CTRL10



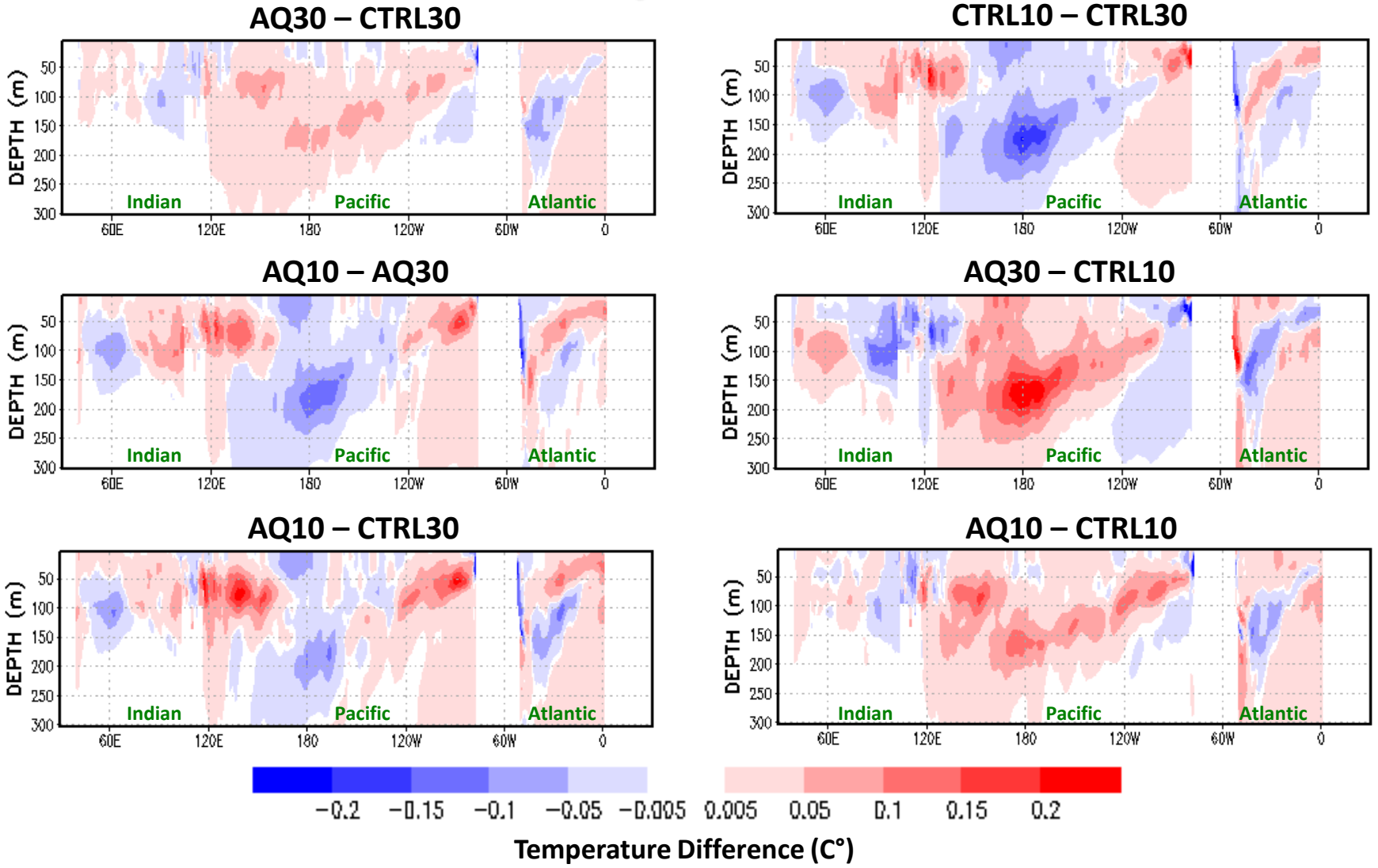
AQRS30



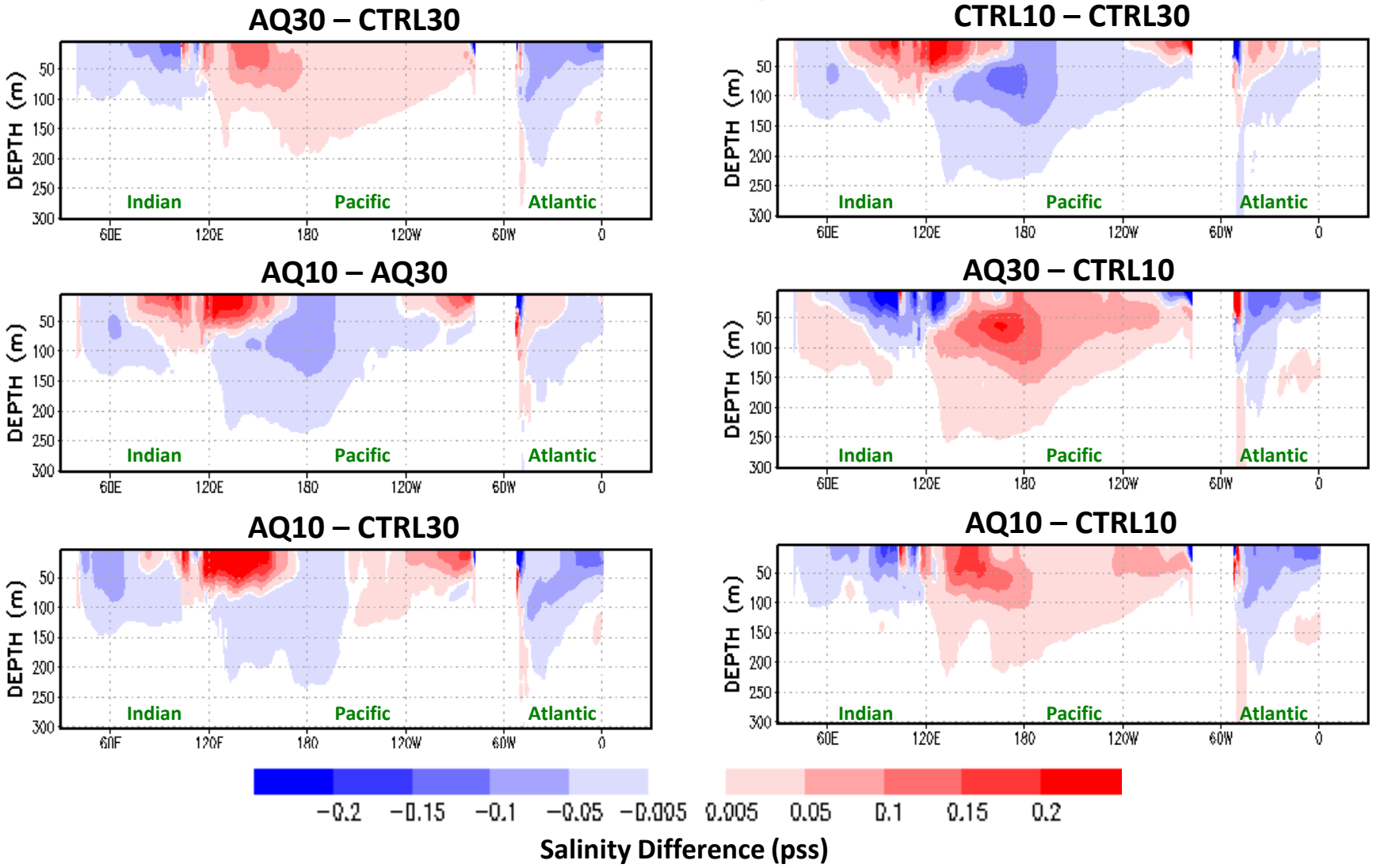
AQRS10



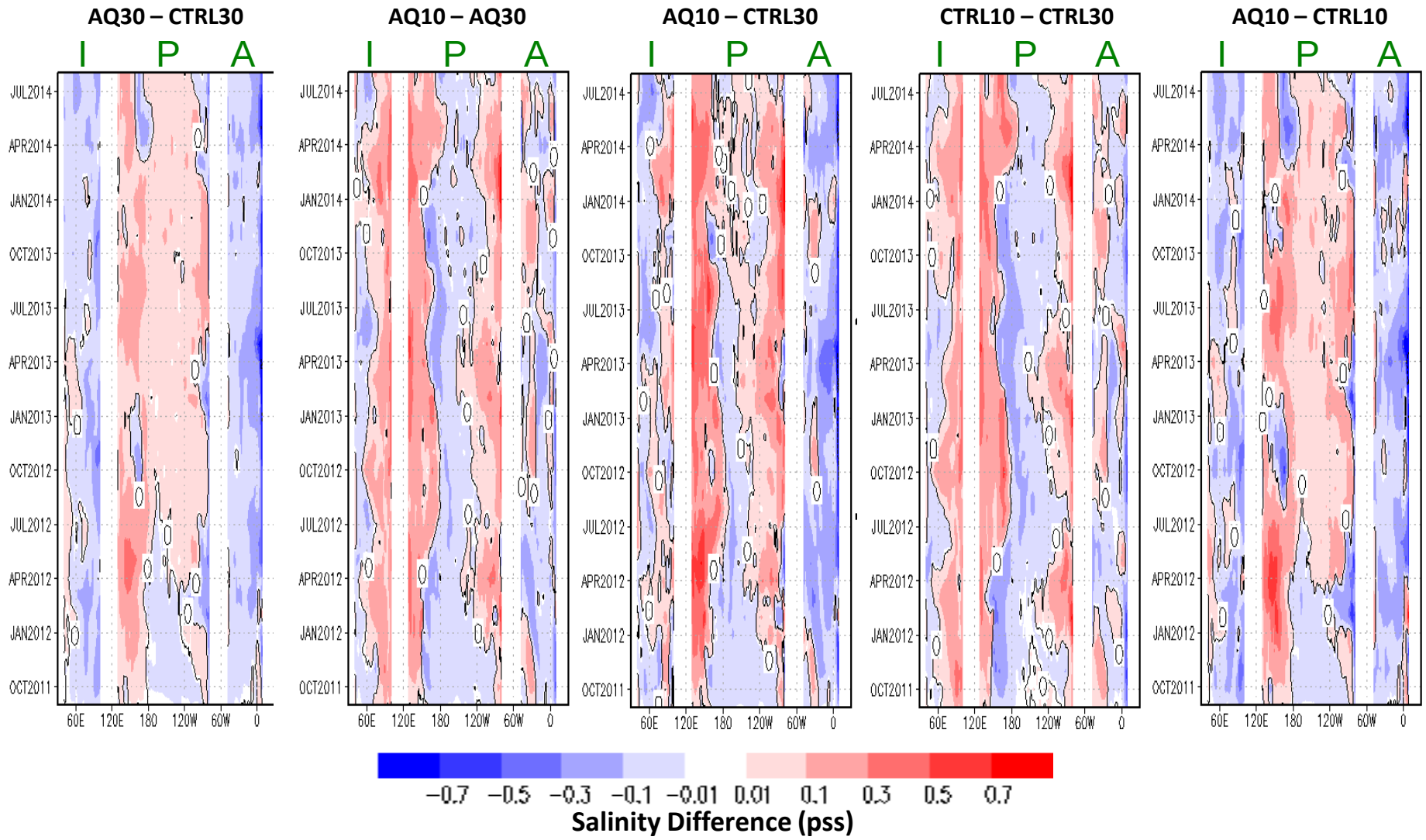
Annual-mean Upper-ocean (0-300m) Impact (5°S - 5°N): Temperature



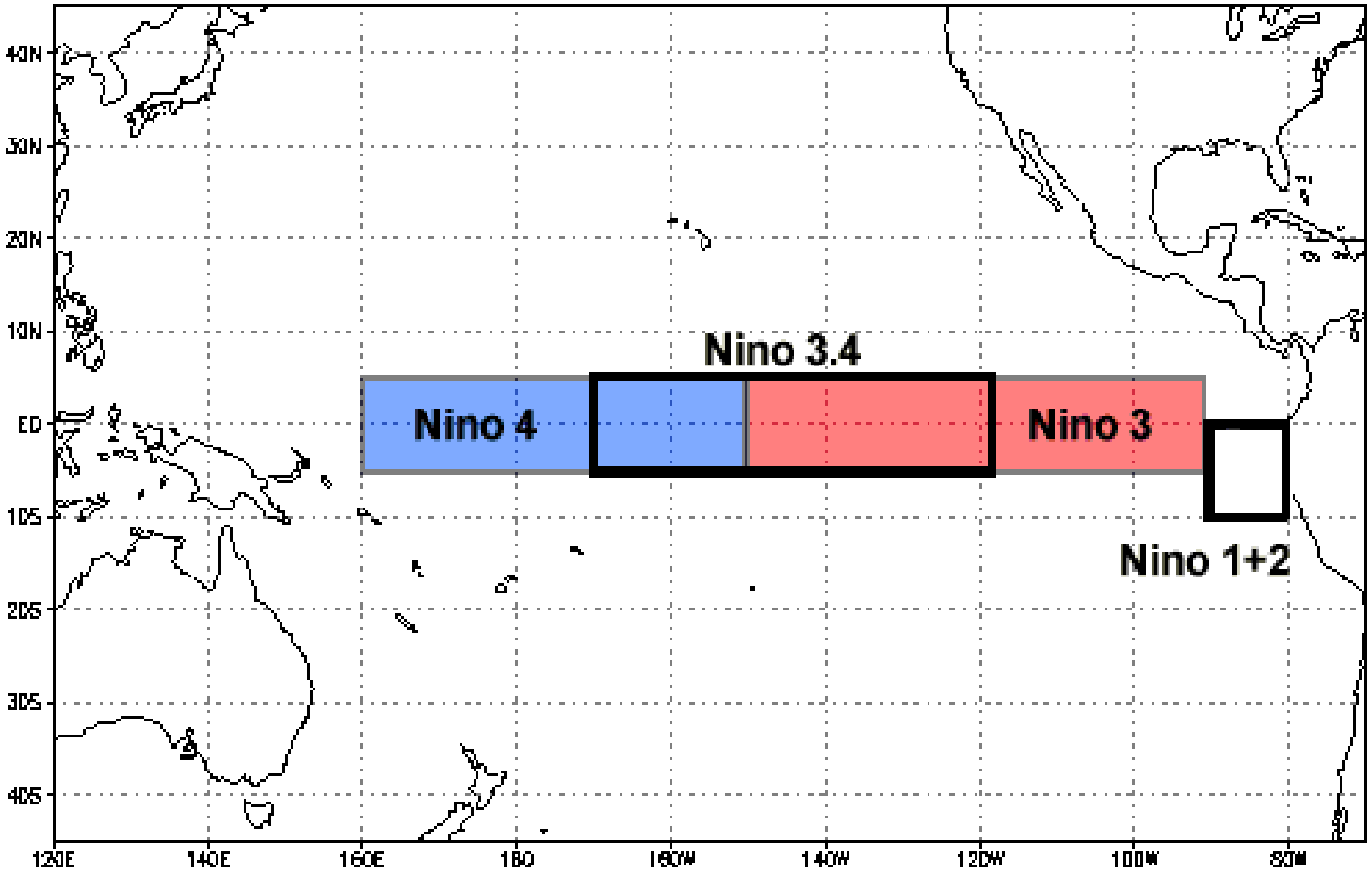
Annual-mean Upper-ocean (0-300m) Impact (5°S - 5°N): Salinity



Temporal Impact: Equatorial Salinity (2°S – 2°N)



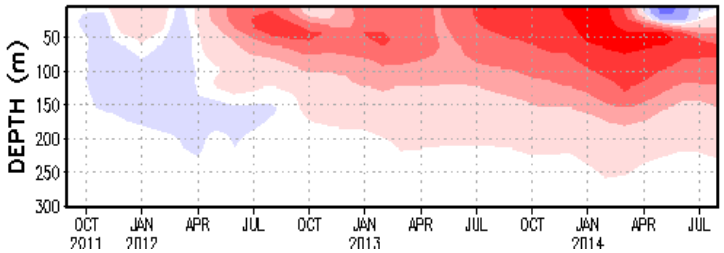
Pacific Ocean Impact



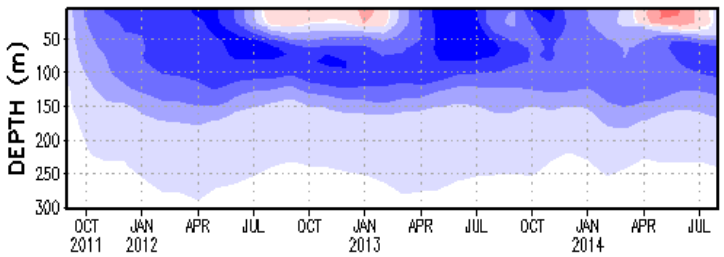
Temporal Salinity Differences

Niño 4

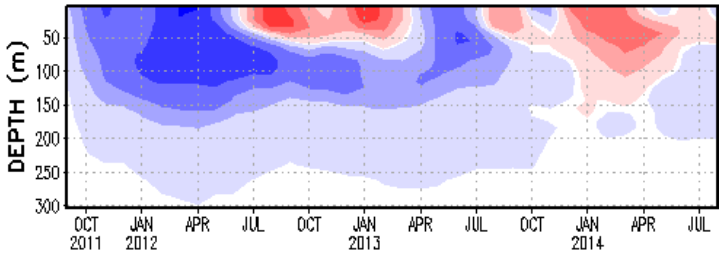
AQ30 – CTRL30



AQ10 – AQ30

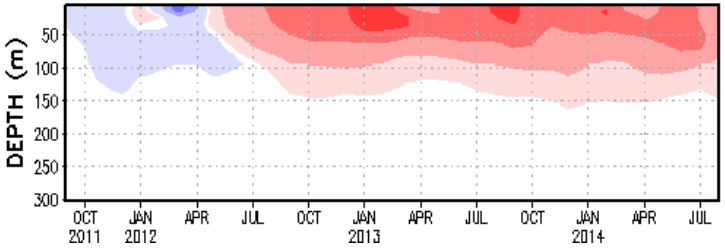


AQ10 – CTRL30

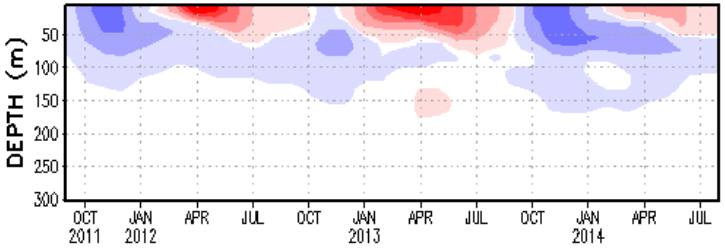


Niño 3

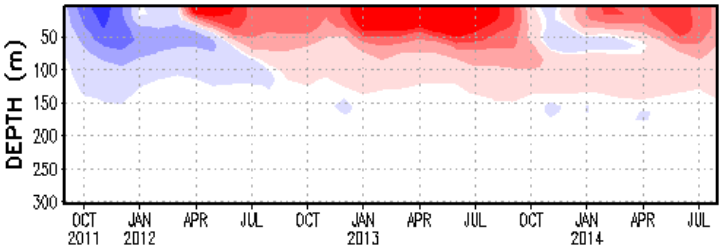
AQ30 – CTRL30

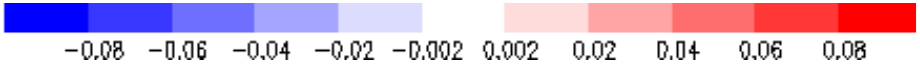


AQ10 – AQ30



AQ10 – CTRL30



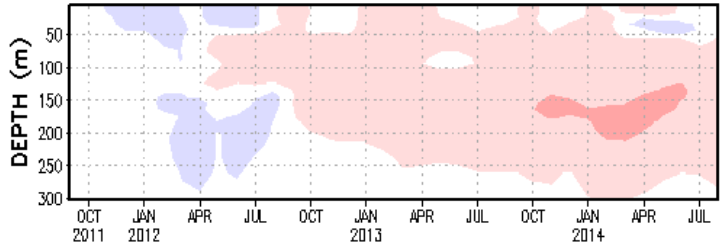


Salinity Difference (pss)

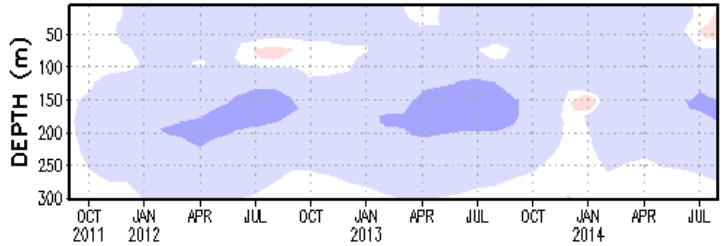
Temporal Temperature Differences

Niño 4

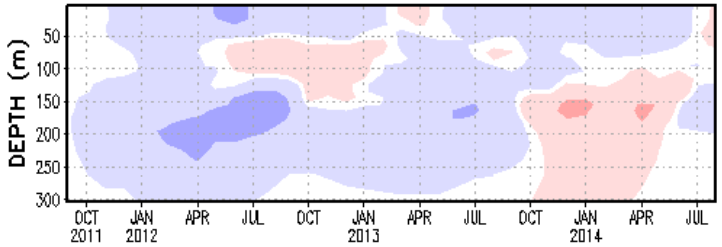
AQ30 – CTRL30



AQ10 – AQ30

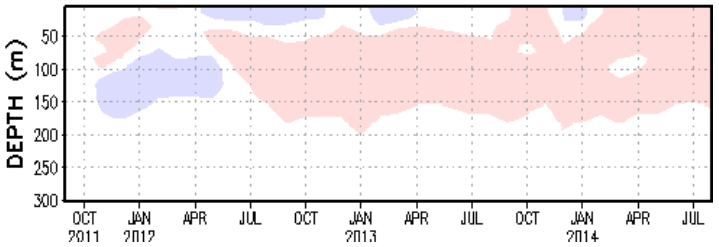


AQ10 – CTRL30

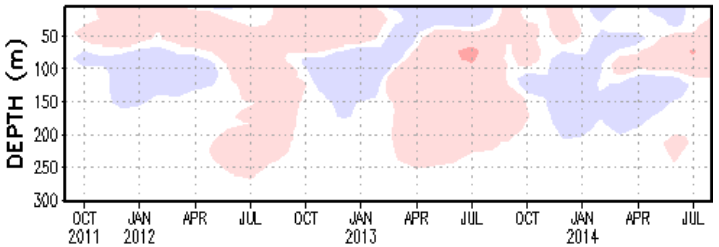


Niño 3

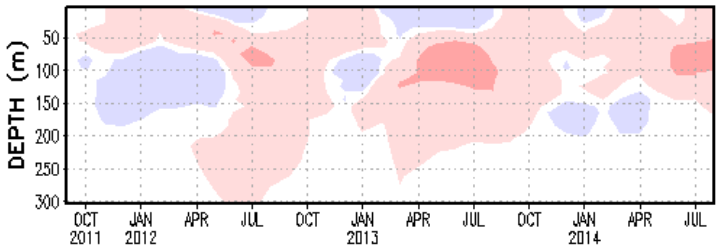
AQ30 – CTRL30

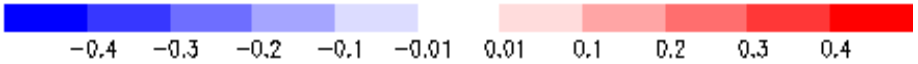


AQ10 – AQ30



AQ10 – CTRL30





Temperature Difference (°C)

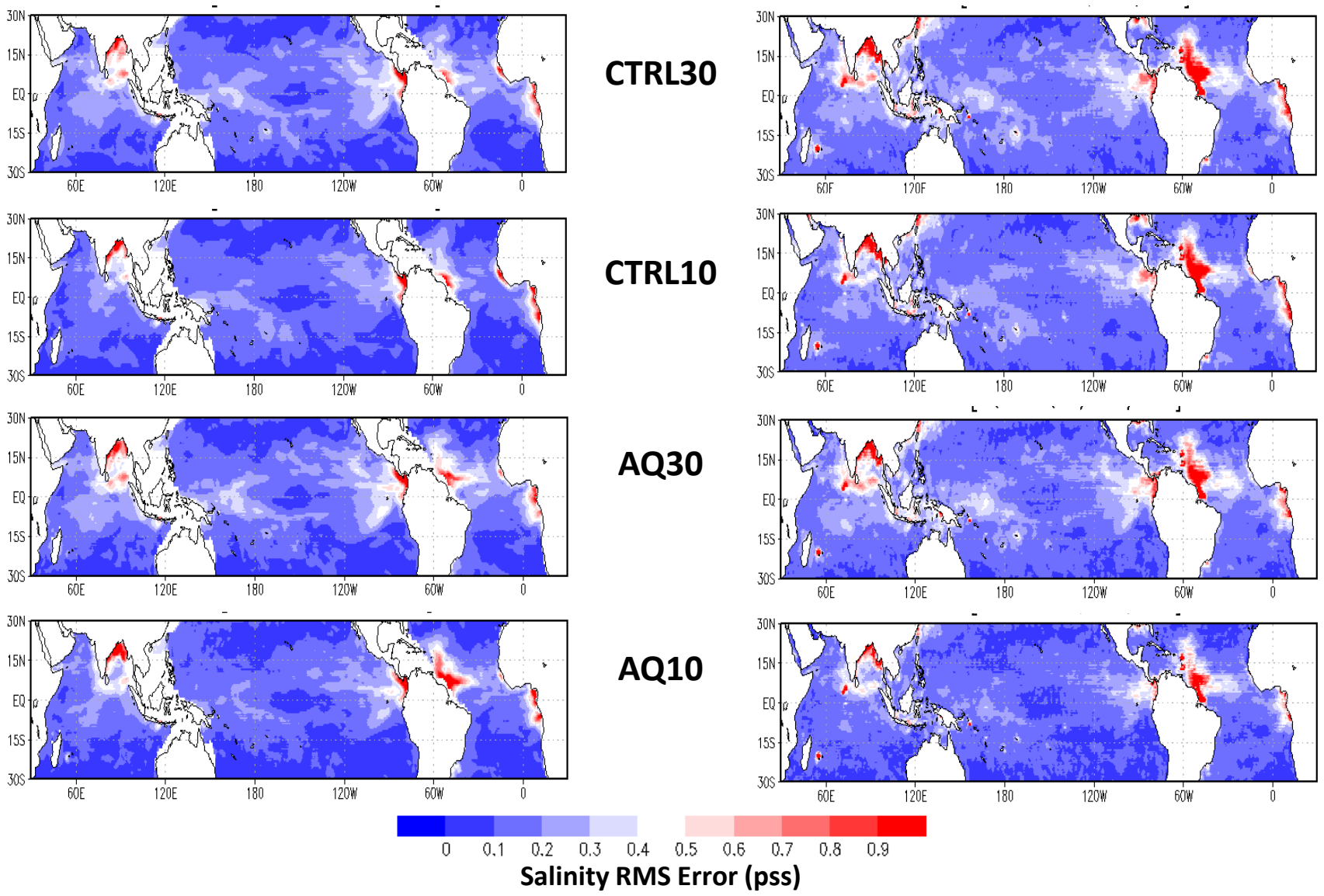
Definition

- **Root Mean Square Error (RMSE) Percent Change:**

$$100 \times \left[\frac{RMSE(Case1_{(obs\_reference)}) - RMSE(Case2_{(obs\_reference)})}{RMSE(CTRL30_{(obs\_reference)})} \right]$$

***** Percent changes referenced to NOAA's operational configuration (CTRL30)***

Model Salinity Error



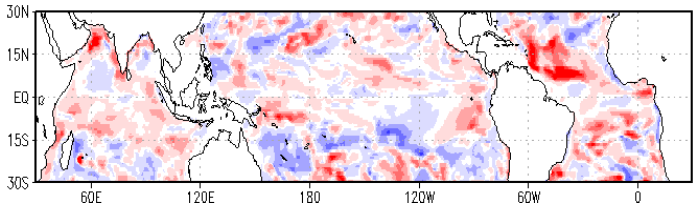
Modeled Salinity: Percent RMS Error Change

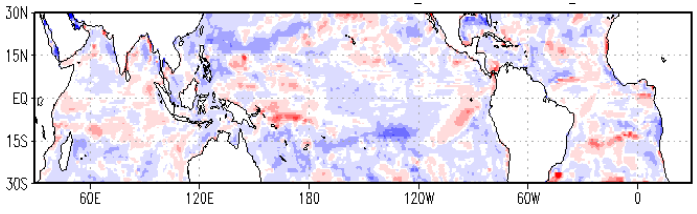
Reference = ARGO

Reference = Aquarius

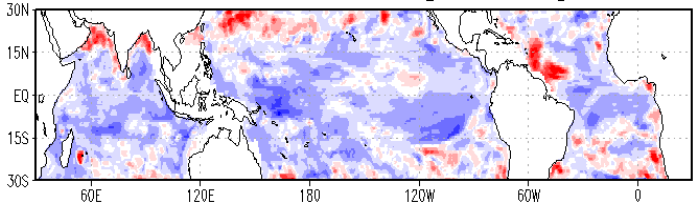
Case Difference

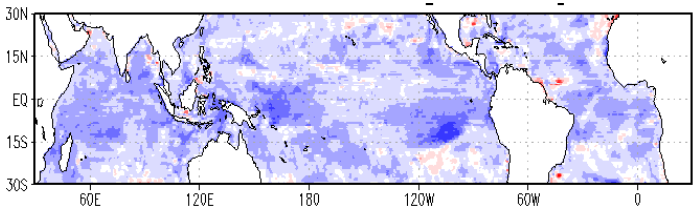
AQ30 - CTRL30



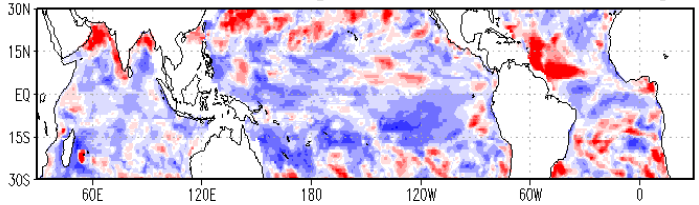


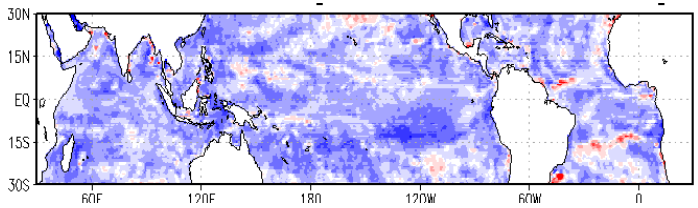
AQ10 – AQ30



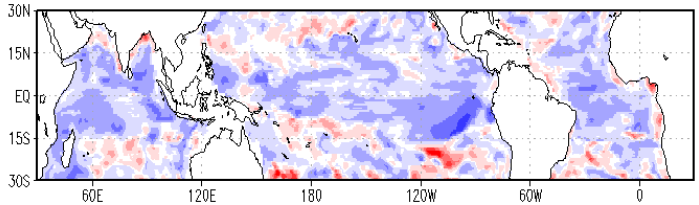


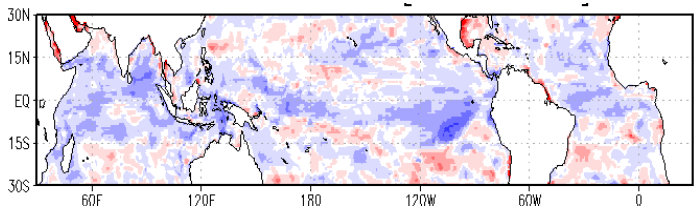
AQ10 – CTRL30



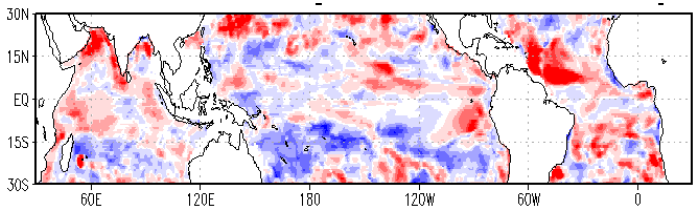


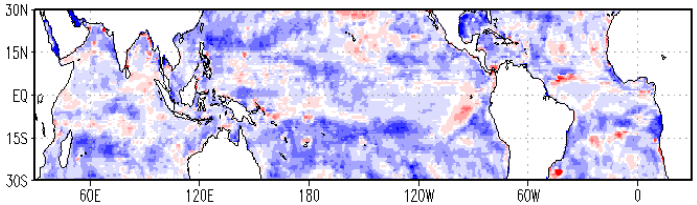
CTRL10 – CTRL30

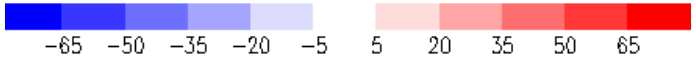




AQ10 – CTRL10







Percent RMS Error Change (%)

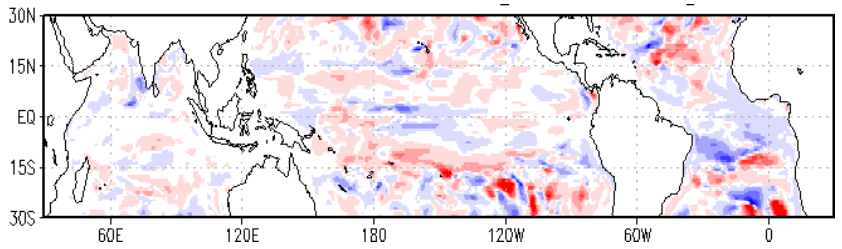
Upper-ocean (0-300m) Heat Content: Percent RMS Error Change

Reference = Argo

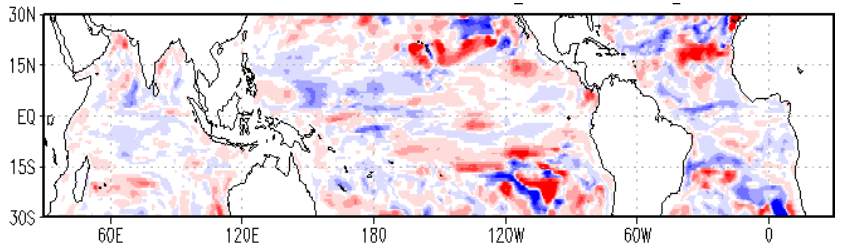
Percent RMS Error Change (%)

Case Difference

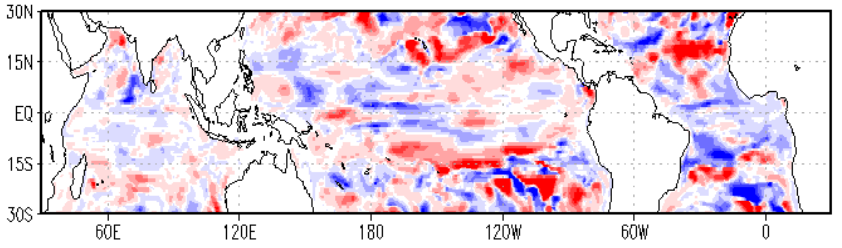
AQ30 - CTRL30



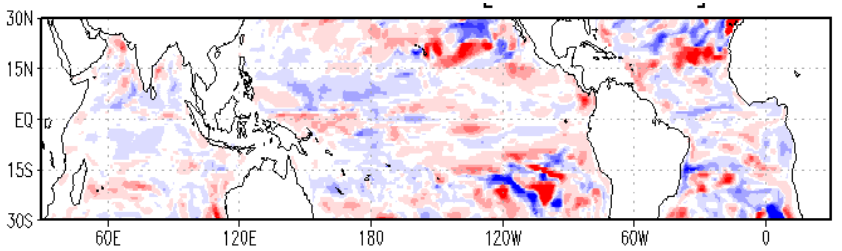
AQ10 – AQ30



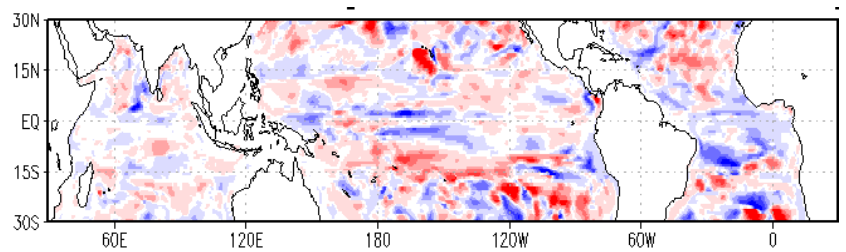
AQ10 – CTRL30



CTRL10 – CTRL30



AQ10 – CTRL10



Conclusions

- Satellite SSS data introduces mean differences and variability with respect to the current sparsely populated climatology used operationally

- Upper-ocean (0-300m) equatorial (5°S – 5°N) impacts:
  - Temperature
    - Employing satellite SSS tends to create general heating throughout
    - More tightly constraining the model to reflect near-real-time salinity tends to intensify heating while creating significant cooling in the central Pacific
  - Salinity
    - Employing satellite SSS generally freshens the Atlantic and Indian Oceans while increasing the salinity in the Pacific
    - More tightly constraining the model to reflect near-real-time salinity values increases the salinity in the eastern Indian, western and eastern Pacific and western Atlantic, while freshening the western Indian, central Pacific, and eastern Atlantic Oceans

- Net effect within the Pacific: Niño-3 is generally warmer and saltier while Niño-4 is generally cooler and fresher

- Using satellite SSS data improves the model's representativeness for salinity; however, with respect to upper-ocean heat content, the results are less conclusive.