Changes in the Seasonal Cycle of Sea Surface Salinity from 2005-2013

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2. SSS trends
3. SSS variability and its correlation with multiple climate indices
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Data

Analyzed In Situ SSS

- Profile data from World Ocean Database (WOD)
  - Includes data from Argo floats, CTDs, moored buoys (TAO/TRITON, RAMA, PIRATA arrays), gliders, bottles, and ice drifting buoys
  - Only salinity data shallower than 5.25 m was used
  - Out of a total of 2,443,203 salinity profiles between January 2005 and December 2013; 1,460,391 profiles were used in the analyses
    - 31% of Argo floats were eliminated due to depth constraint
    - 33% of all other non-Argo data eliminated due to depth constraint
    - 189,278 eliminated based on QC
- All salinity values are on the PSS-78 Scale.

Satellite SSS

- Aquarius Monthly Level 3 Standard Mapped Image v3.0 (2012/2013)
- Aquarius Monthly Level 3 Standard Mapped Image CAP v3.0 (2012/2013)

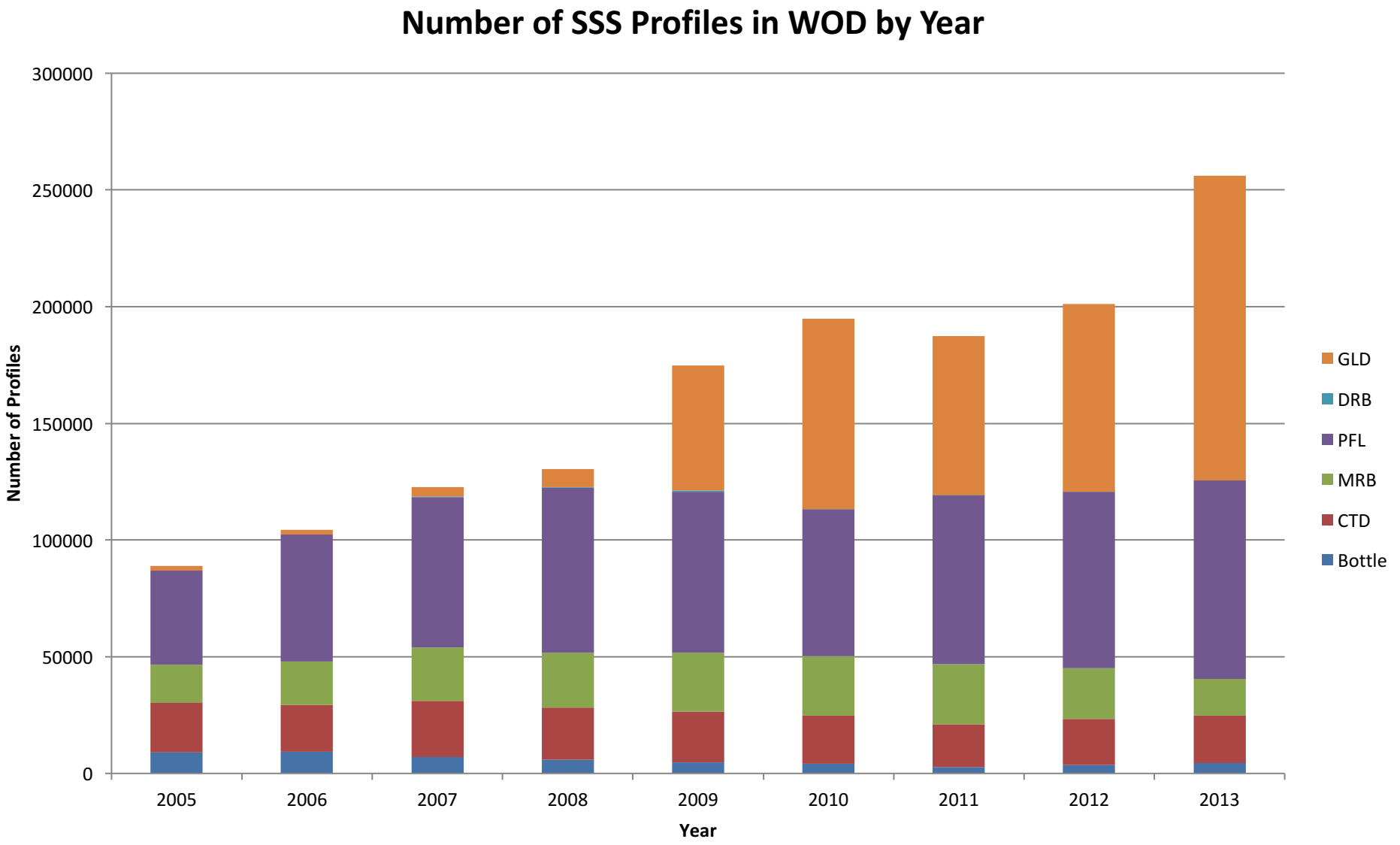
Precipitation and Evaporation

- **Precipitation**
  - Global Precipitation Climatology (GPCP) Version 2.2
    - Monthly fields re-gridded from 2.5°x 2.5° to 1.0°x1.0°
    - Units of mm/dy
- **Evaporation**
  - Woods Hole Oceanographic Institution (WHOI) Objectively Analyzed Air-sea Fluxes (OAFlux)
    - Units converted to mm/dy from cm/yr

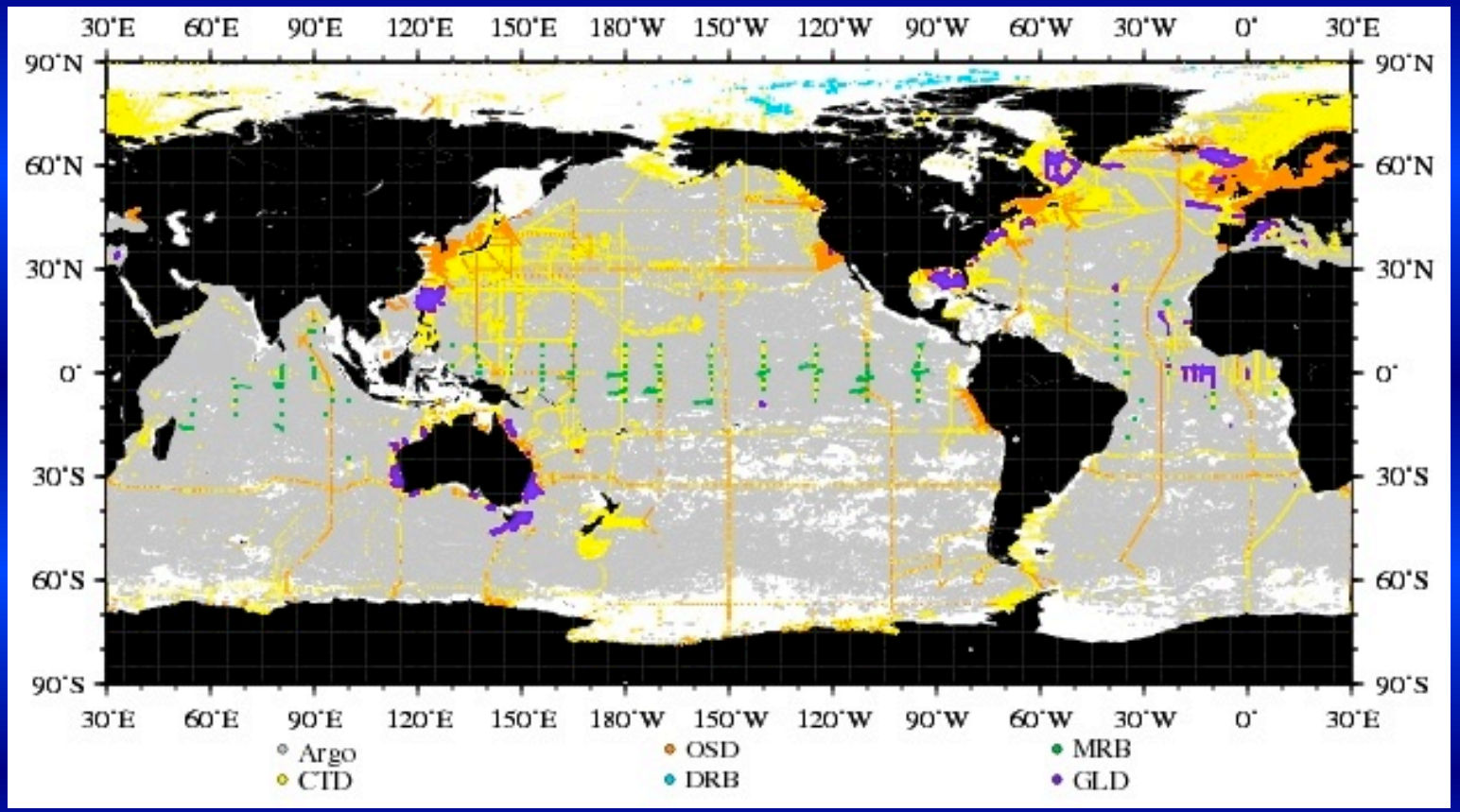
Climate Indices

- Most of the monthly climate indices time series came through NOAA/ESRL
- JAMSTEC provided the Dipole Mode Index.

SSS Profile Distribution



SSS Profile Geographic Distribution



WODSSS Fields

Profile with salinity observation less than 5.25m from surface

↓

Difference between profile and climatological (WOA09) mean value

↓

Average anomaly values into one-degree bins

→

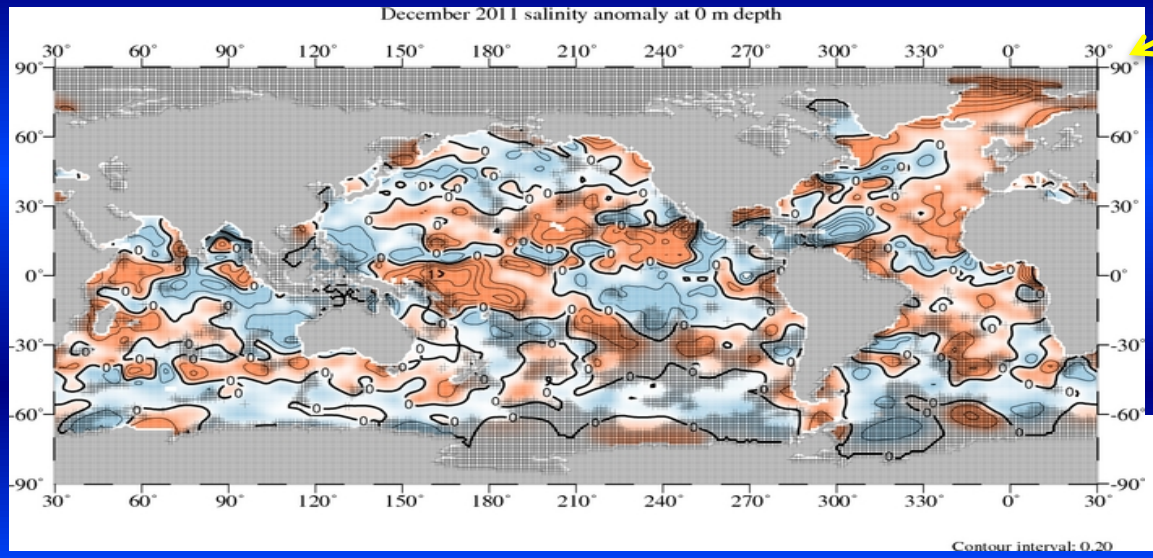
Use first guess field = 0 and objectively analyze the anomaly values

↑

Remove any suspicious profiles that are contributing to bullseyes in the analyzed anomaly fields

↑

Add anomaly field to climatology (WOA09) to create full salinity field



Regions that lack in situ data will be close to monthly climatological mean (WOA09)

*Data Located at NODC's Global Ocean Heat and Salt Content page: http://www.nodc.noaa.gov/OC5/3M_HEAT_CONTENT/

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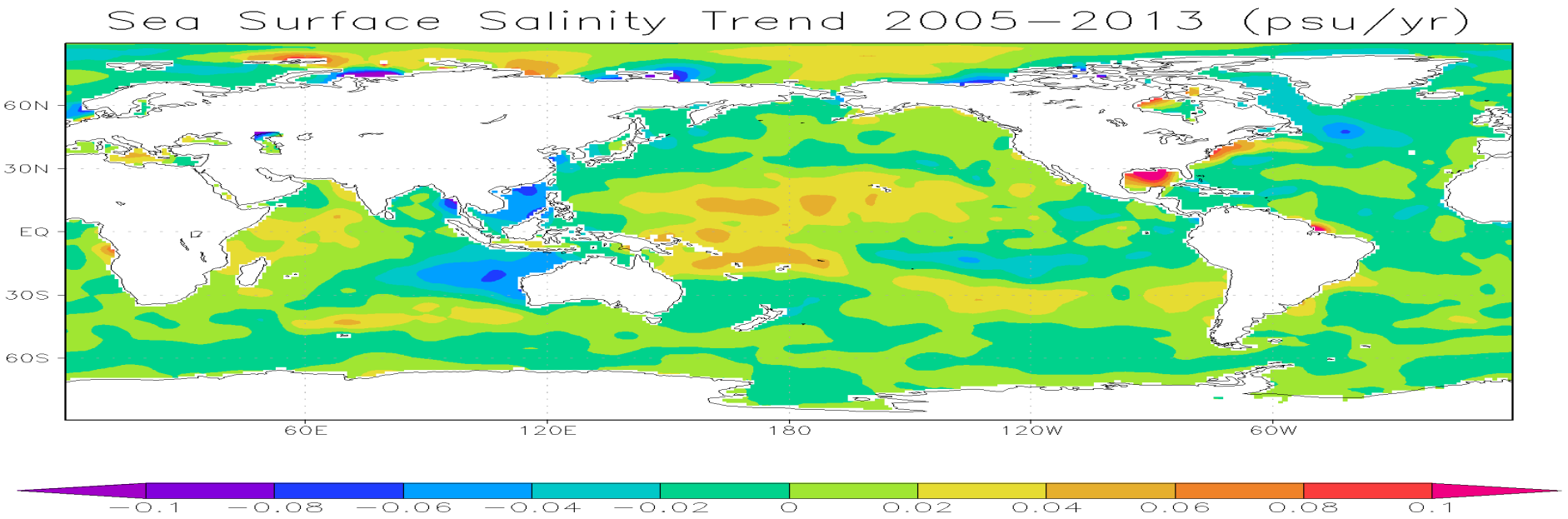
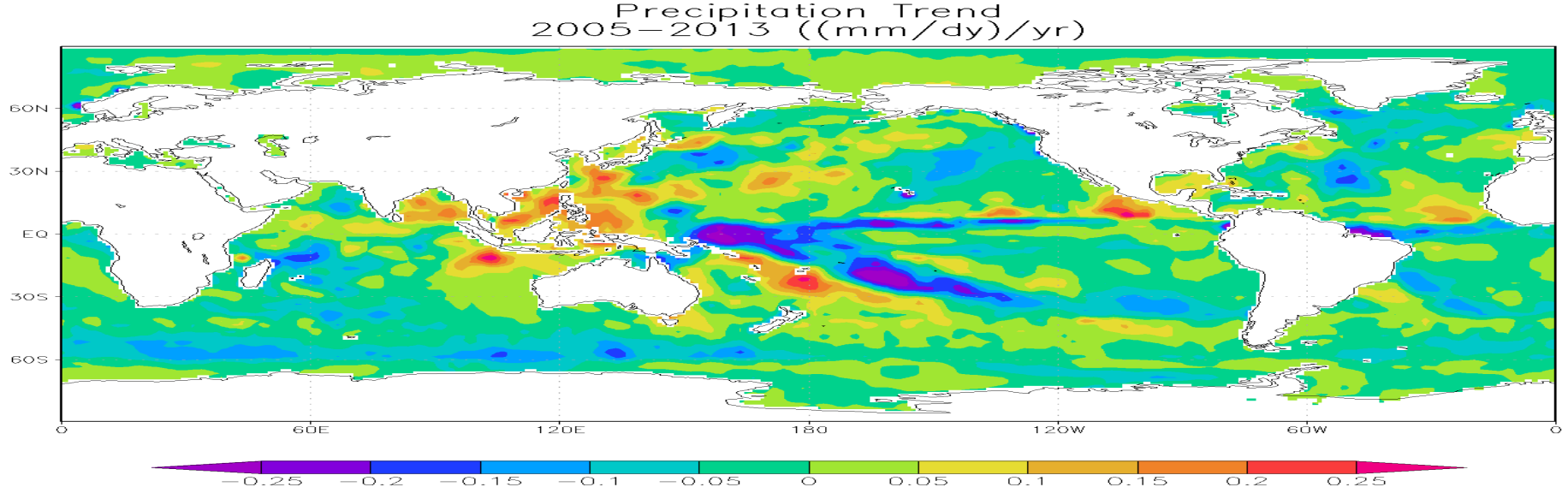
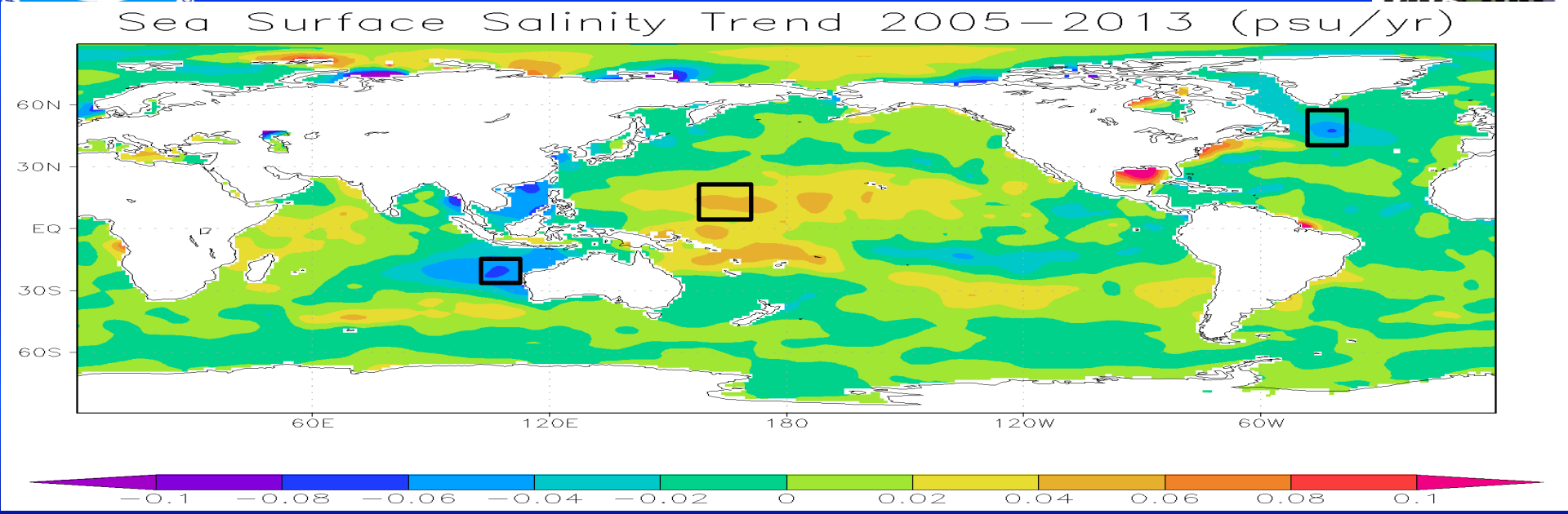
SSS & Precipitation Trend

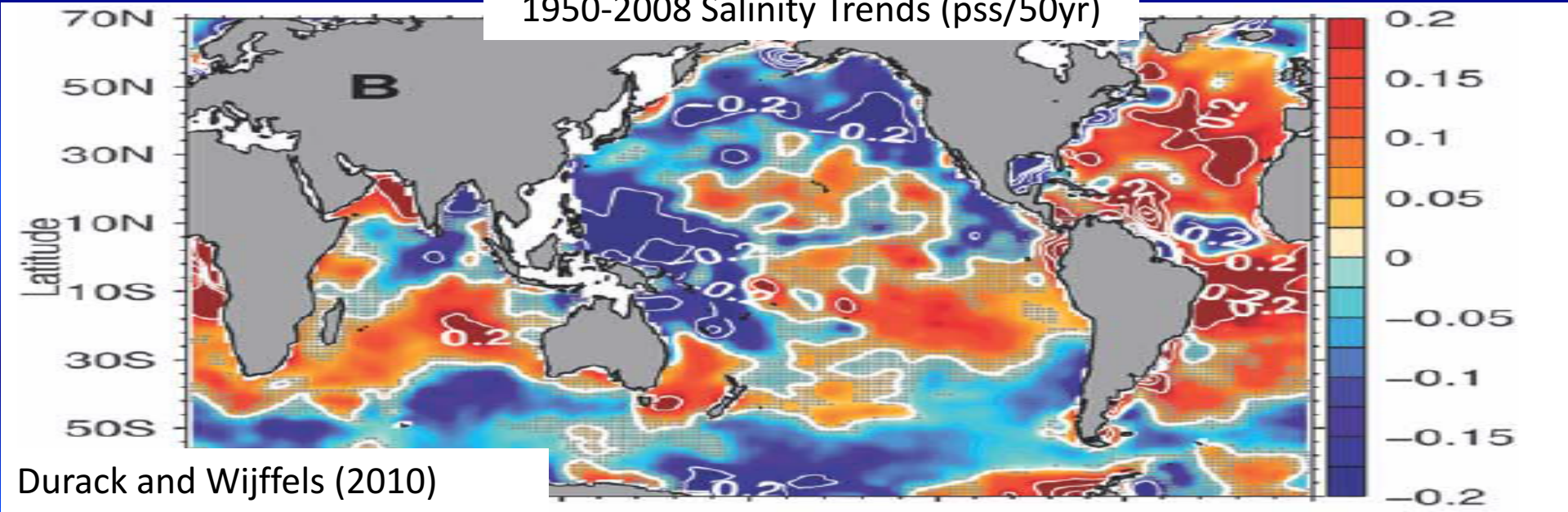




Recent vs Long-term SSS Trends

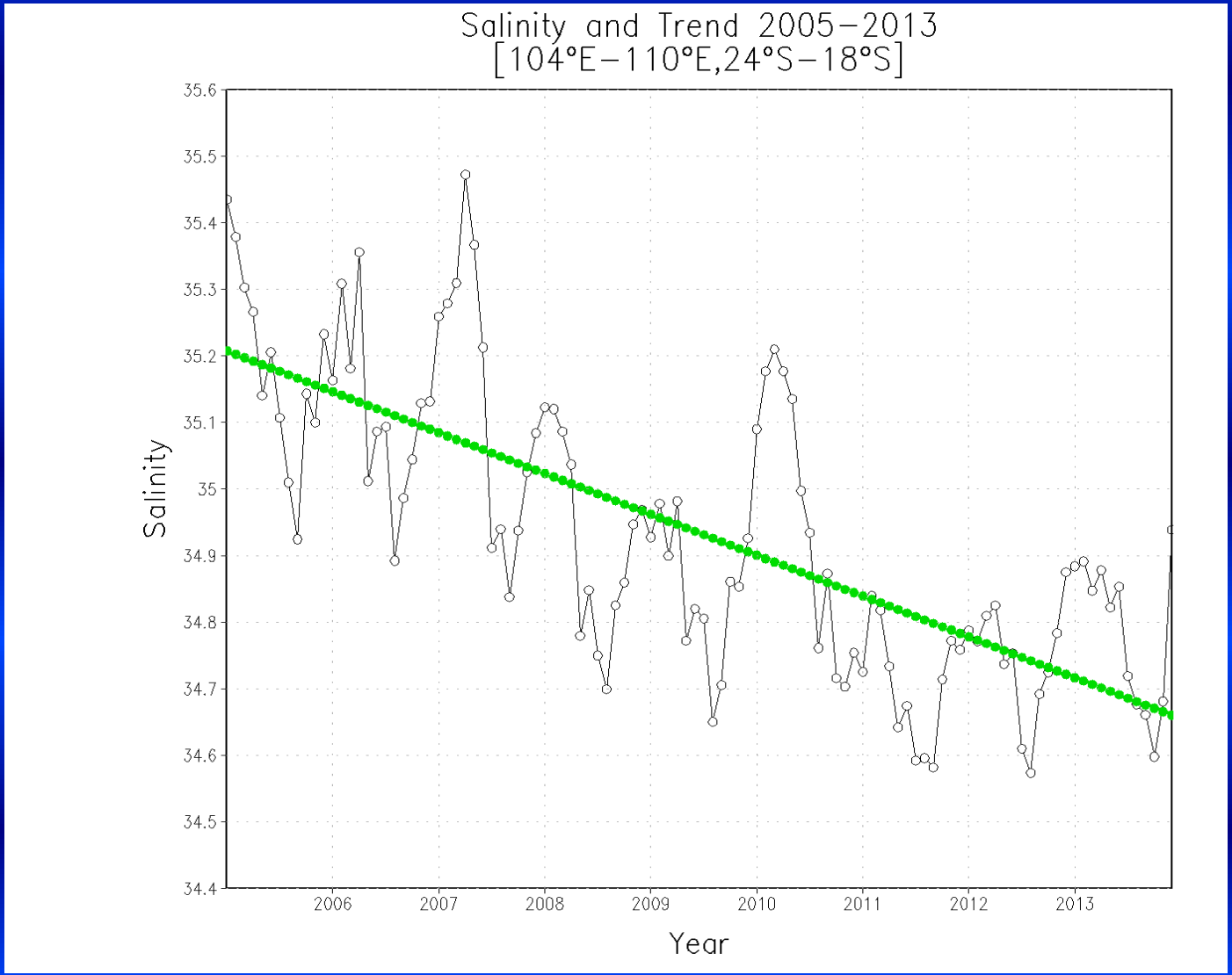


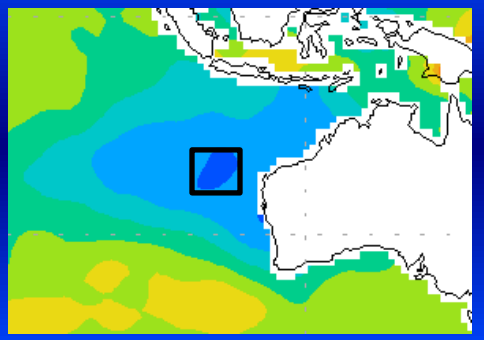
1950-2008 Salinity Trends (pss/50yr)



Durack and Wijffels (2010)

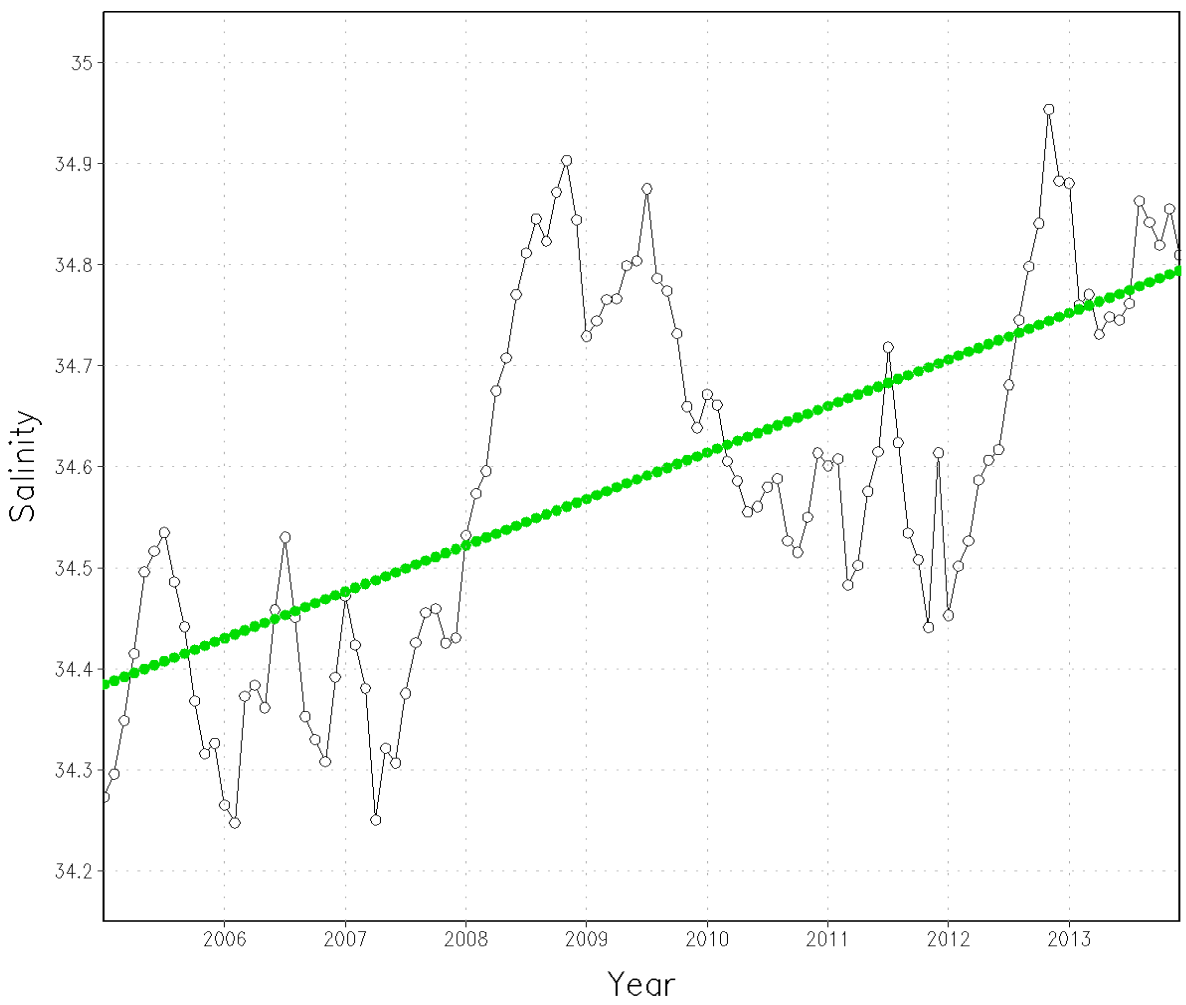
Eastern Indian Ocean Salinity Trend

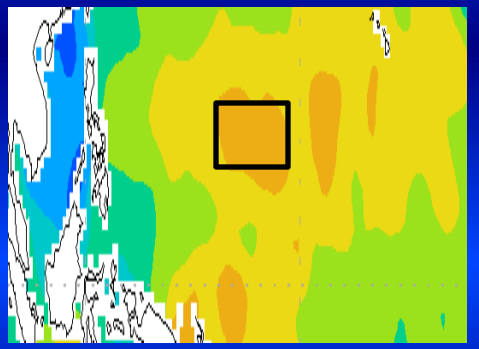




- ~134 SSS observations per year
- Strong seasonal cycle (esp. 2007 & 2010)
- Freshening of 0.55 over the last 9 years
- Perhaps a bucking of the trend towards the end of the time period

Western Tropical Pacific Salinity Trend

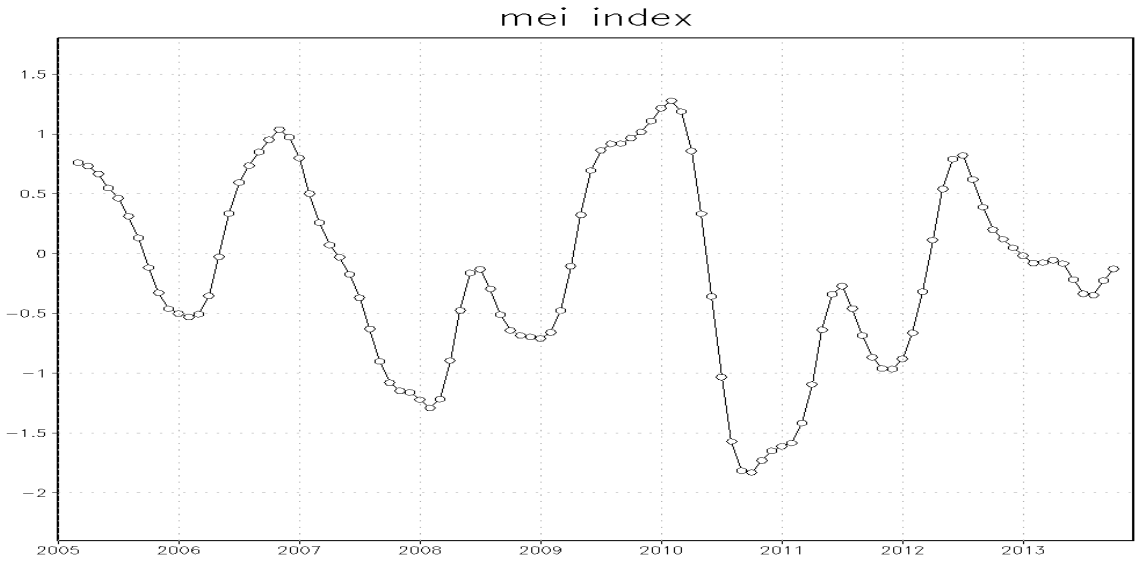




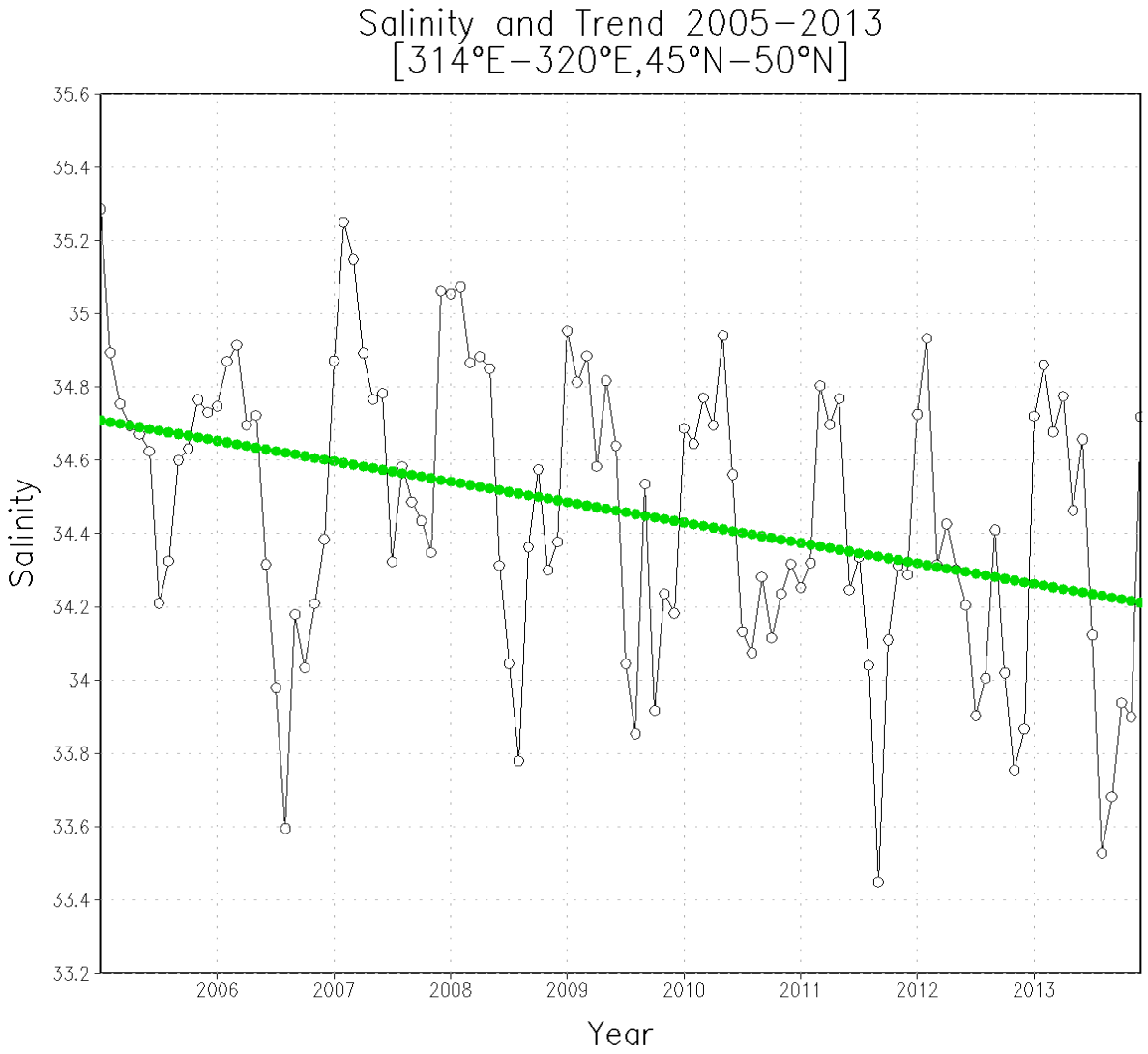
- ~119 SSS observations per year
- Salinification of 0.40 over the last 9 years
- Low-frequency oscillation

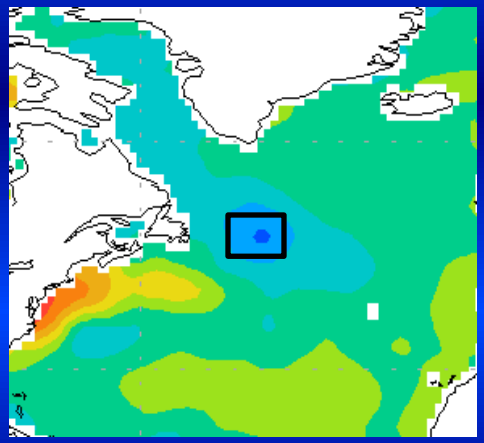
ENSO Related?

R=0.02



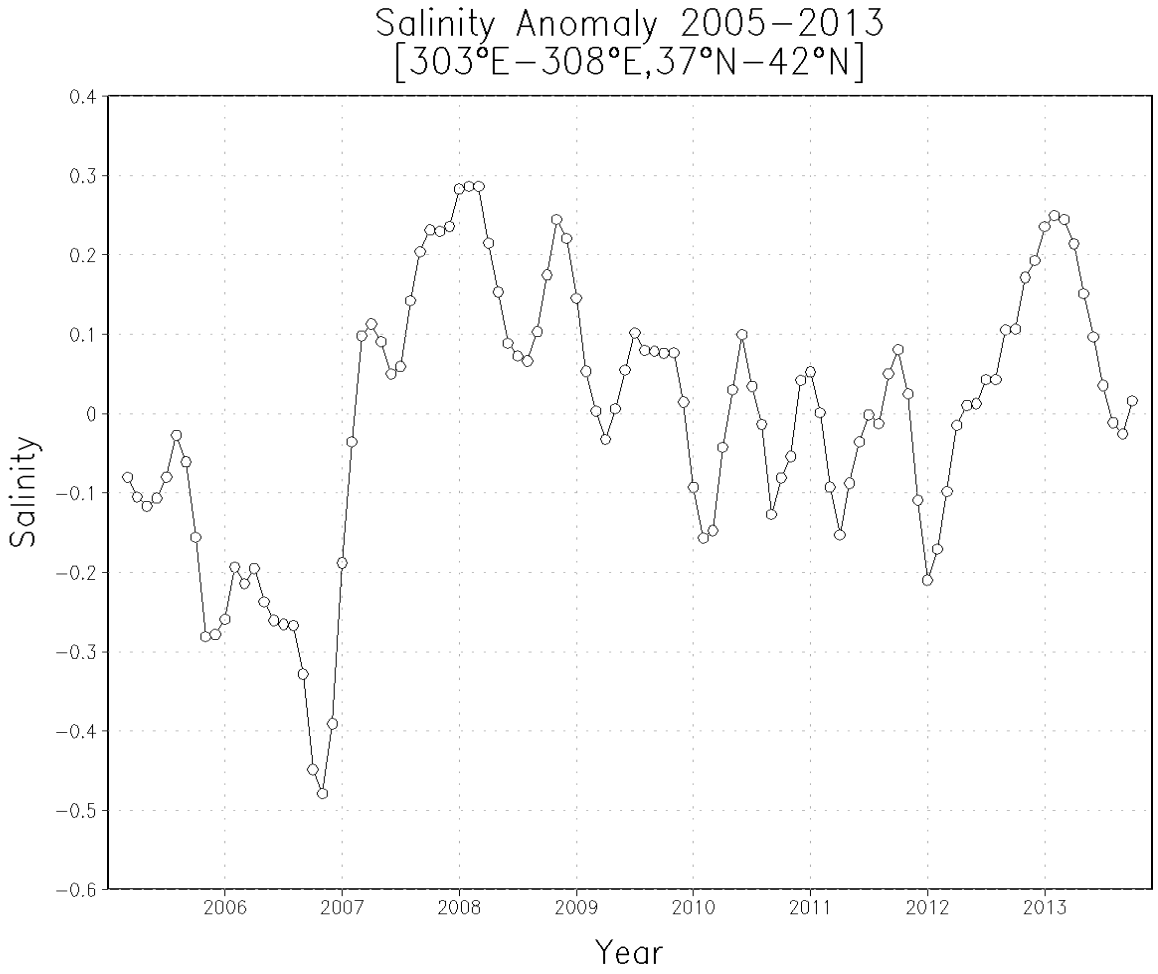
North Atlantic Salinity Trend

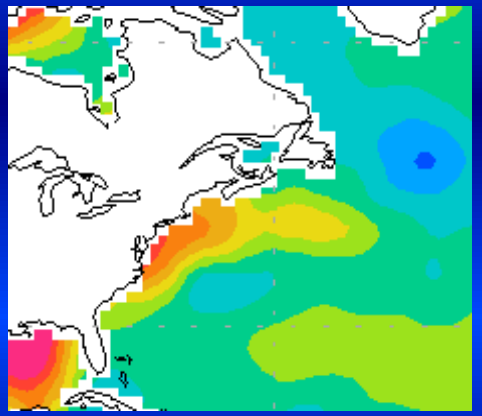




- ~126 SSS observations per year
- Freshening of 0.50 over the last 9 years
- Southwest of this freshening region is a region of increasing salinity…

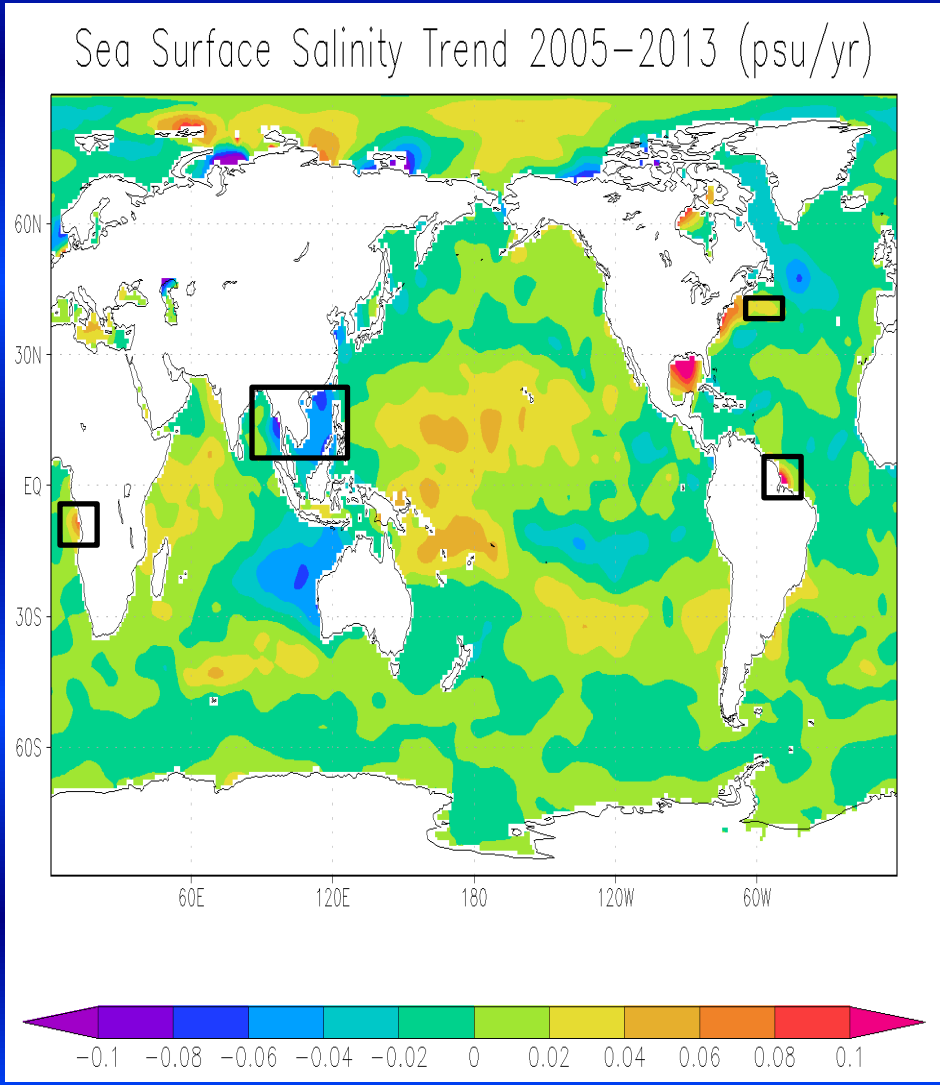
Gulf Stream Salinity Anomaly

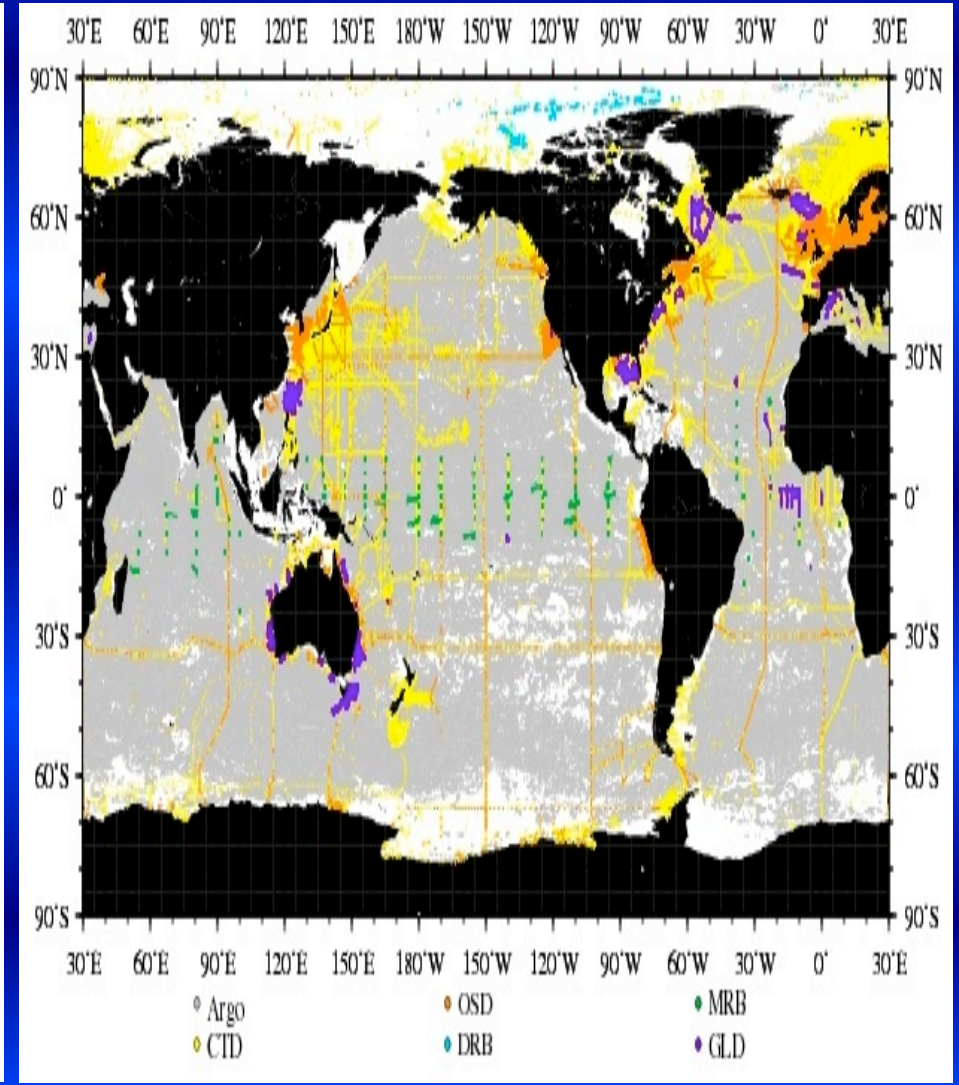




- ~67 SSS observations per year
- First two years have little data (21 total SSS profiles).
- Possible low-frequency oscillation (~5 years)?

Real Trends?


Sea Surface Salinity Trend 2005–2013 (psu/yr)
60N
30N
EQ
30S
60S
60E
120E
180
120W
60W
−0.1
−0.08
−0.06
−0.04
−0.02
0
0.02
0.04
0.06
0.08
0.1


30°E
60°E
90°E
120°E
150°E
180°W
150°W
120°W
90°W
60°W
30°W
0°
30°E
90°N
60°N
30°N
0°
30°S
60°S
90°S
Argo
CTD
OSD
DRB
MRB
GLD

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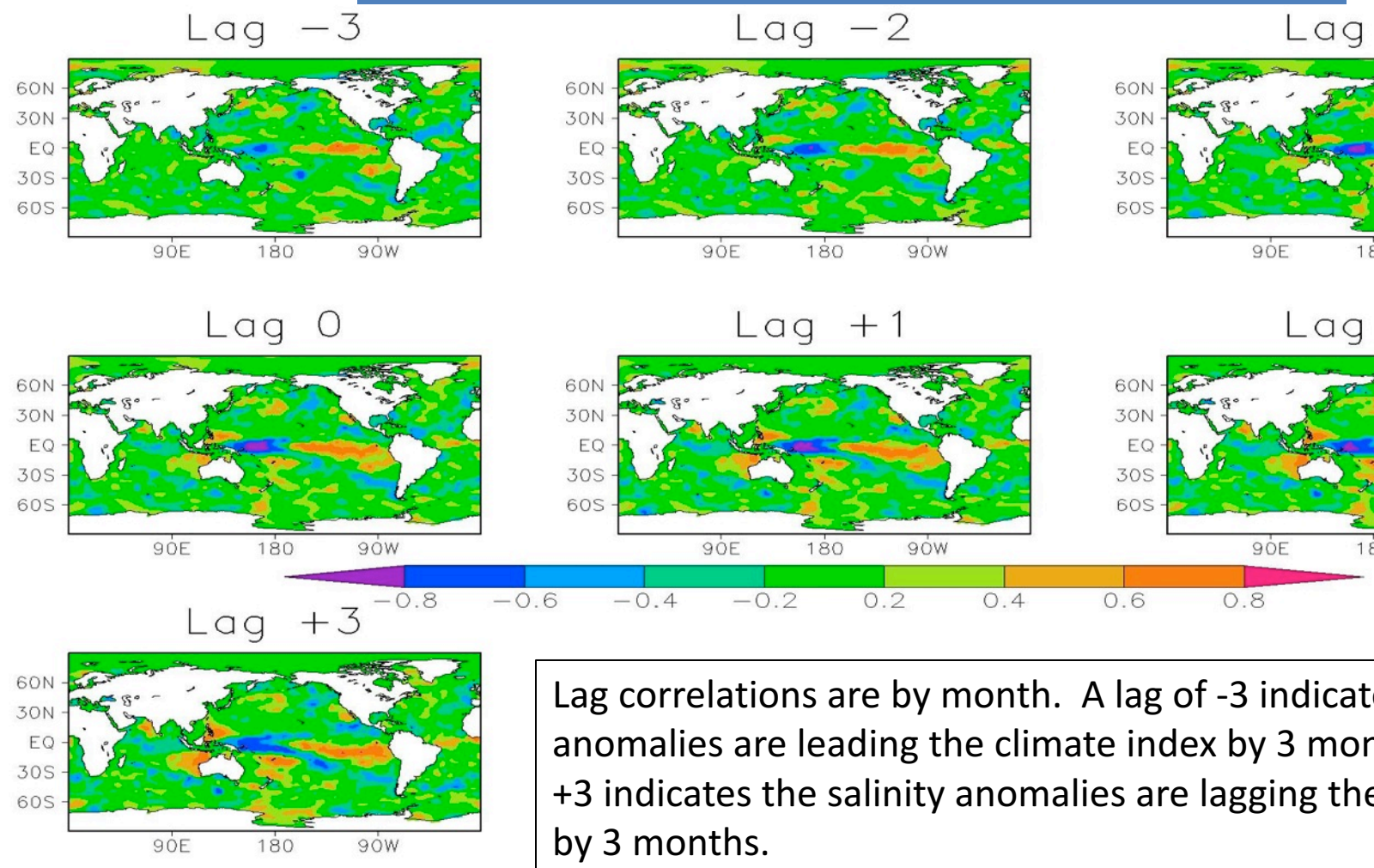
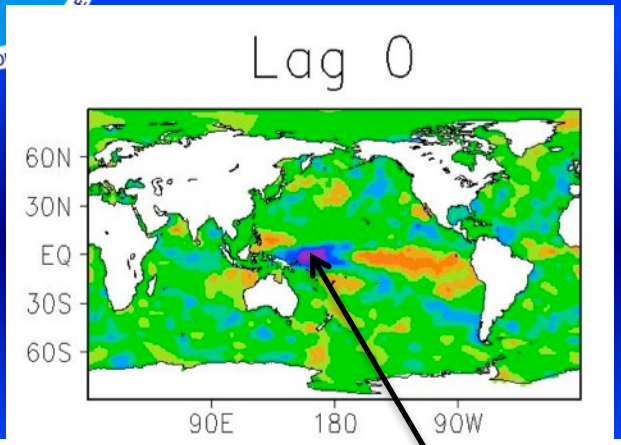
ENSO

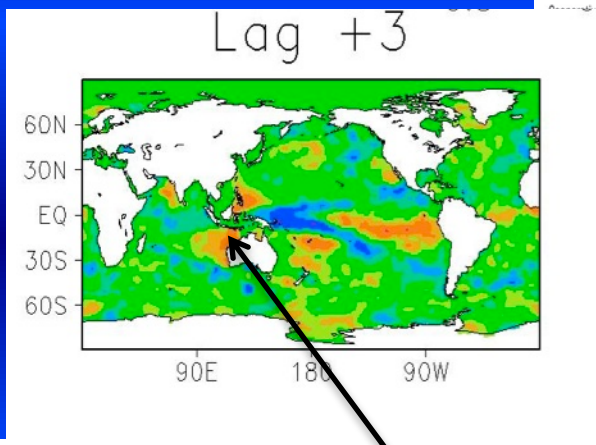
Lag Correlation Map between the Multivariate ENSO Index (MEI) and SSS Anomalies



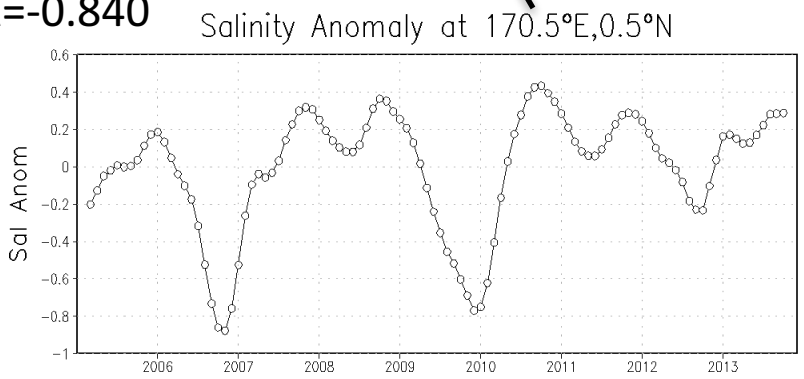
Lag correlations are by month. A lag of -3 indicates the salinity anomalies are leading the climate index by 3 months. A lag of +3 indicates the salinity anomalies are lagging the climate index by 3 months.

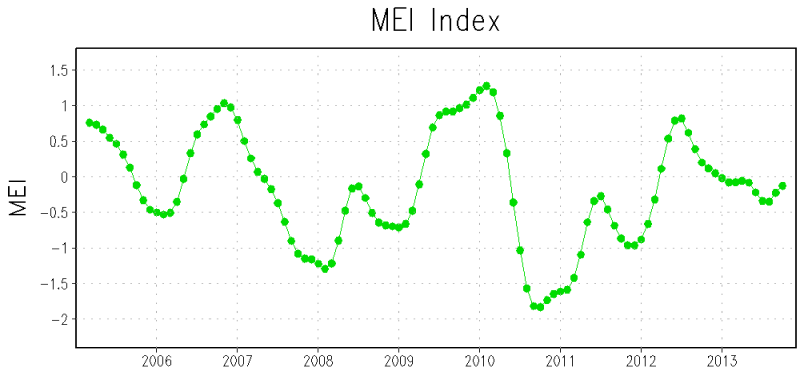
ENSO cont...



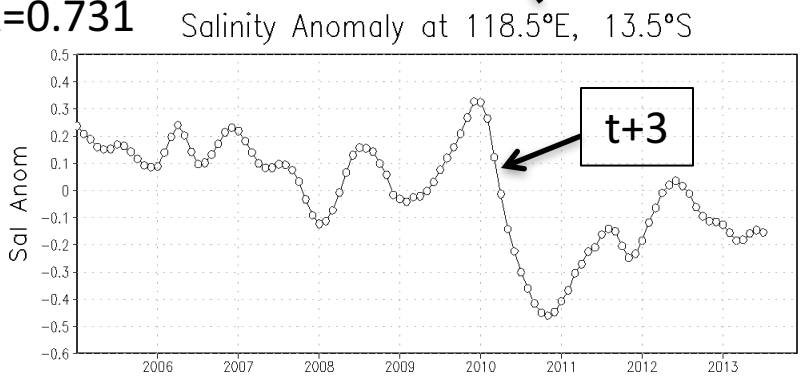


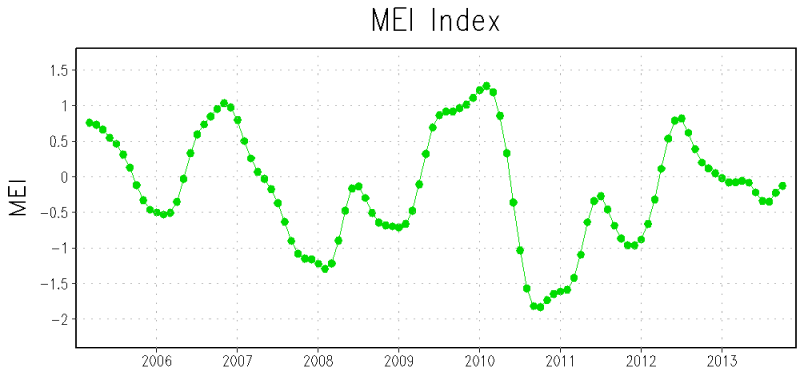
R=-0.840





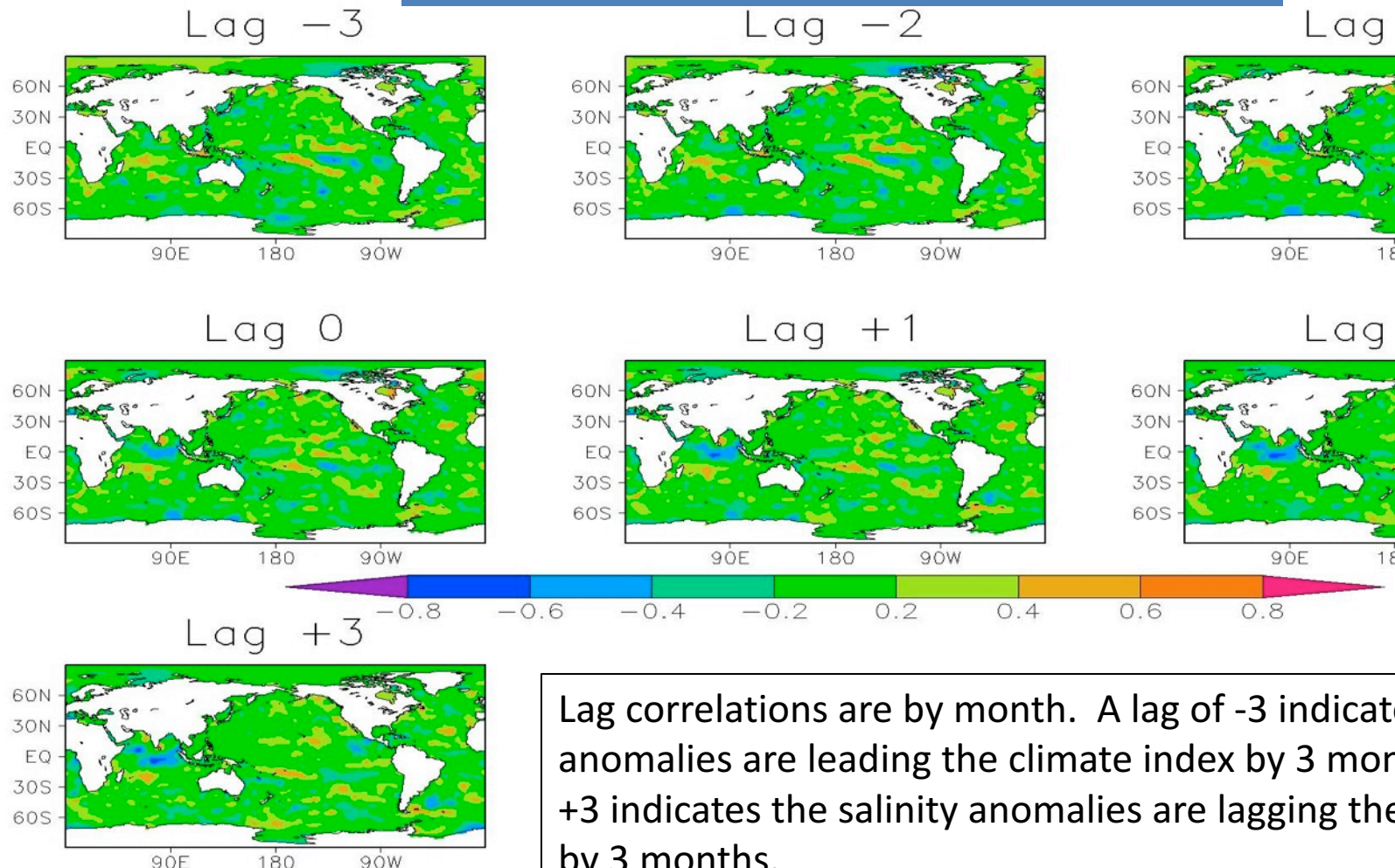
R=0.731





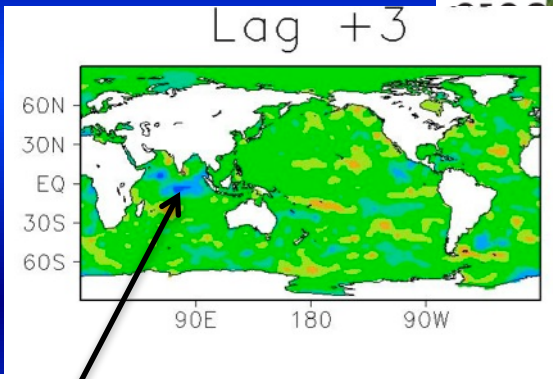
Indian Ocean Dipole

Lag Correlation Map between the Dipole Mode Index and SSS Anomalies

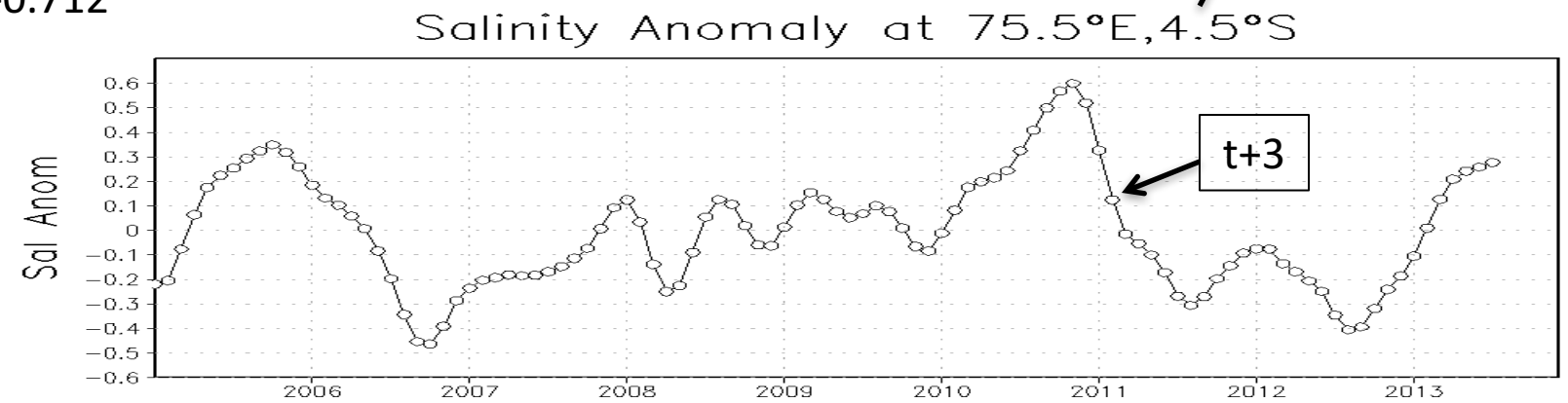


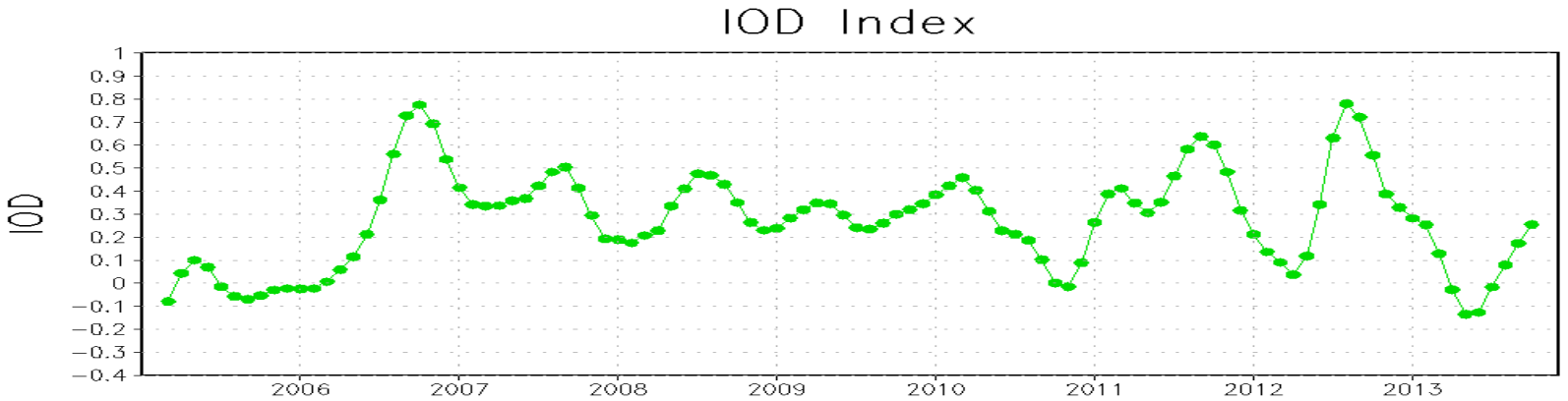
Lag correlations are by month. A lag of -3 indicates the salinity anomalies are leading the climate index by 3 months. A lag of +3 indicates the salinity anomalies are lagging the climate index by 3 months.

IOD cont…



R=-0.712

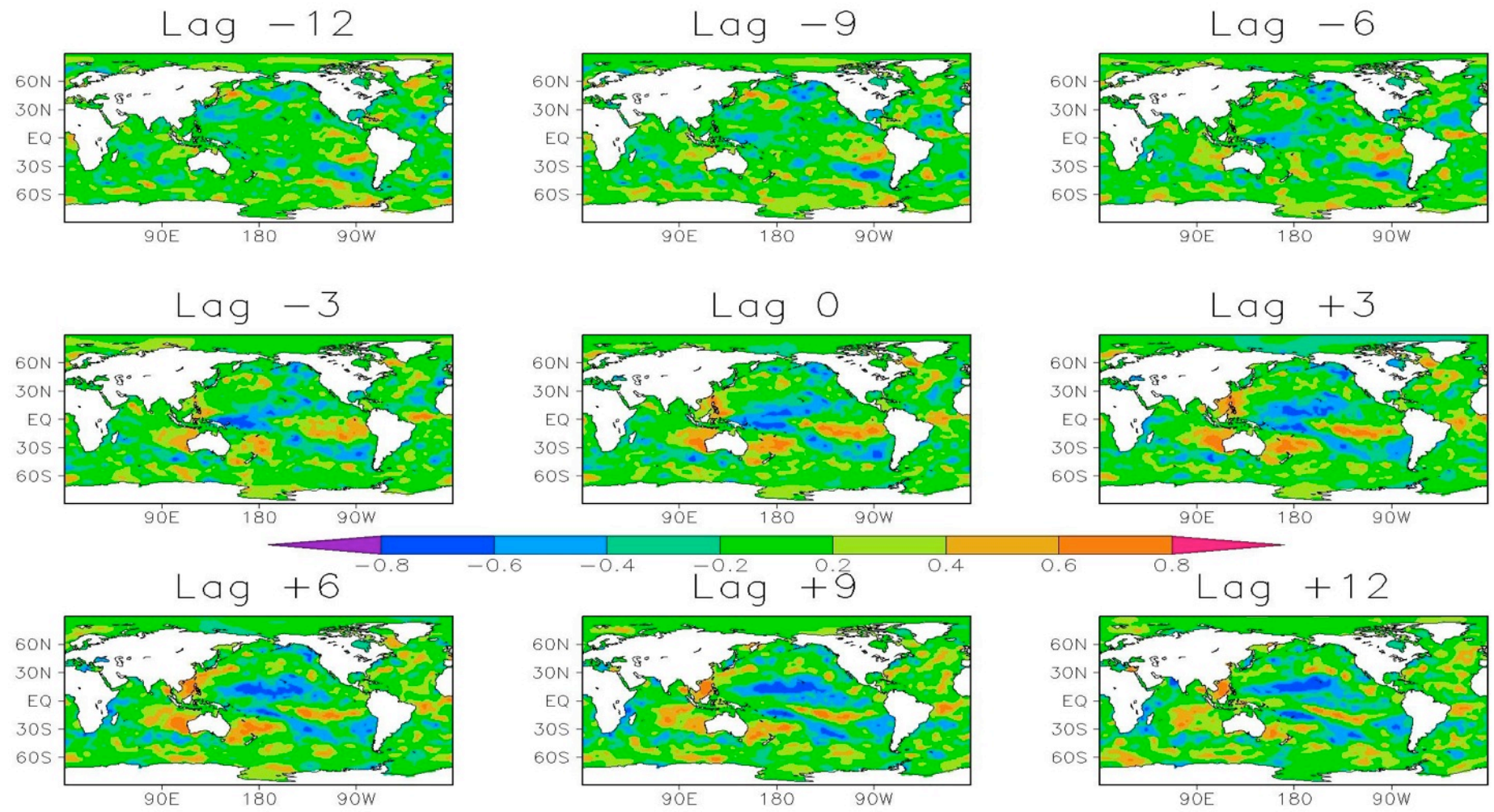




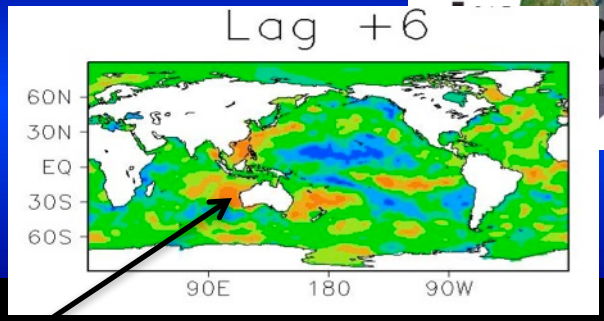
*Grunseich *et al., (*2011) found similar correlations for this region

Pacific Decadal Oscillation Index

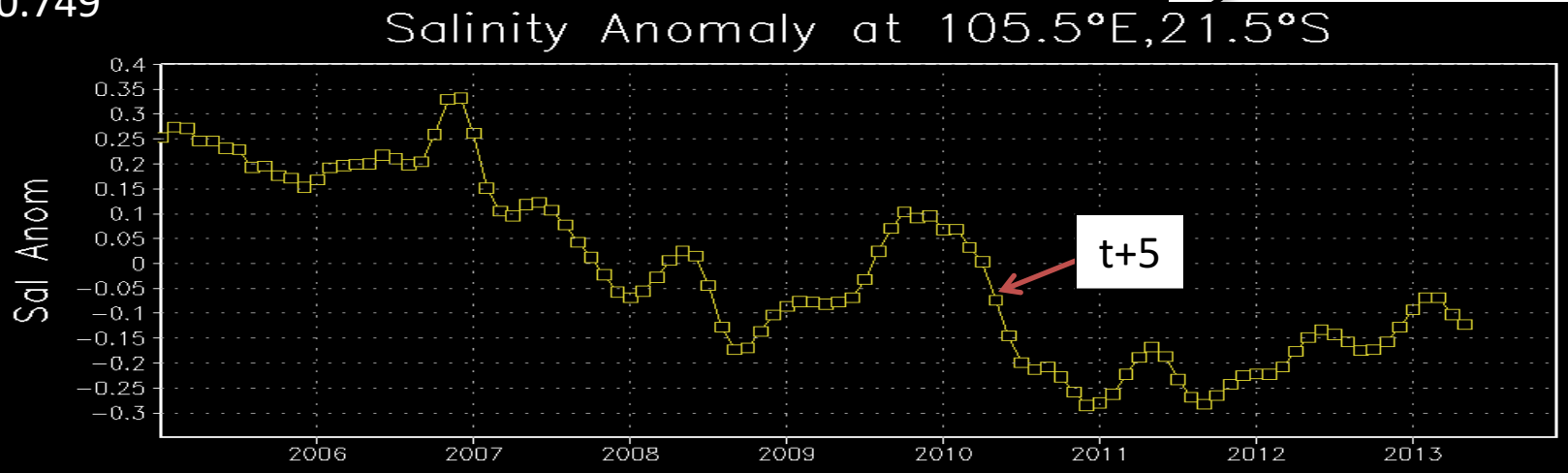
Lag Correlation Map between the Pacific Decadal Oscillation index and SSS Anomalies

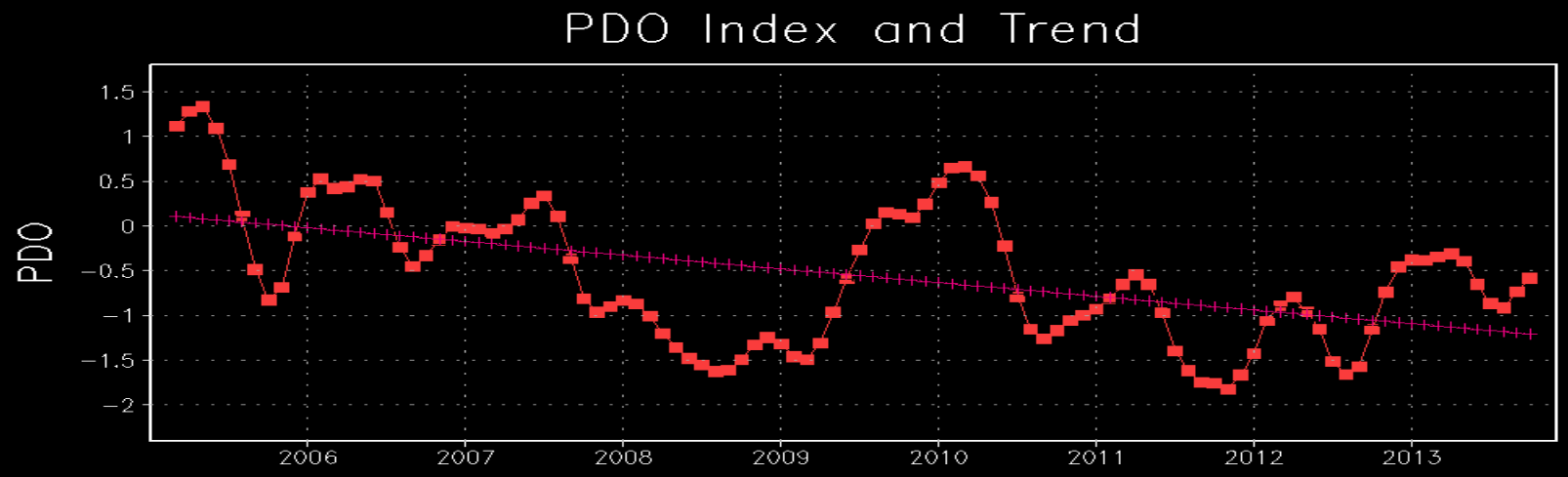


PDO cont…



R=0.749





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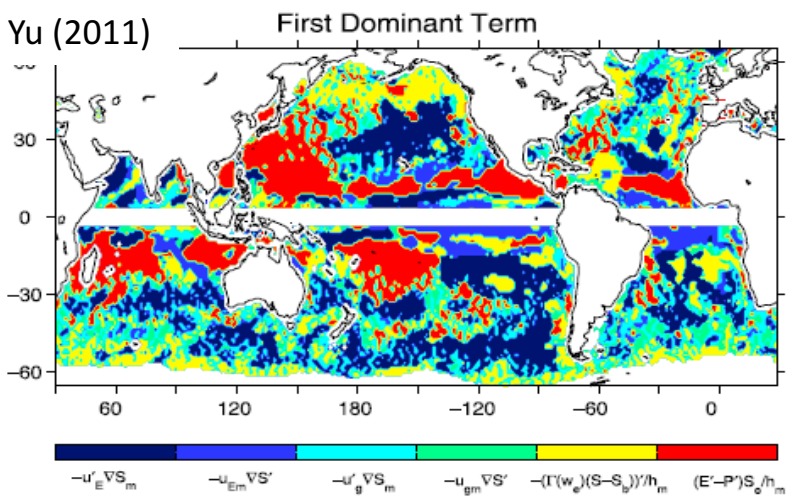
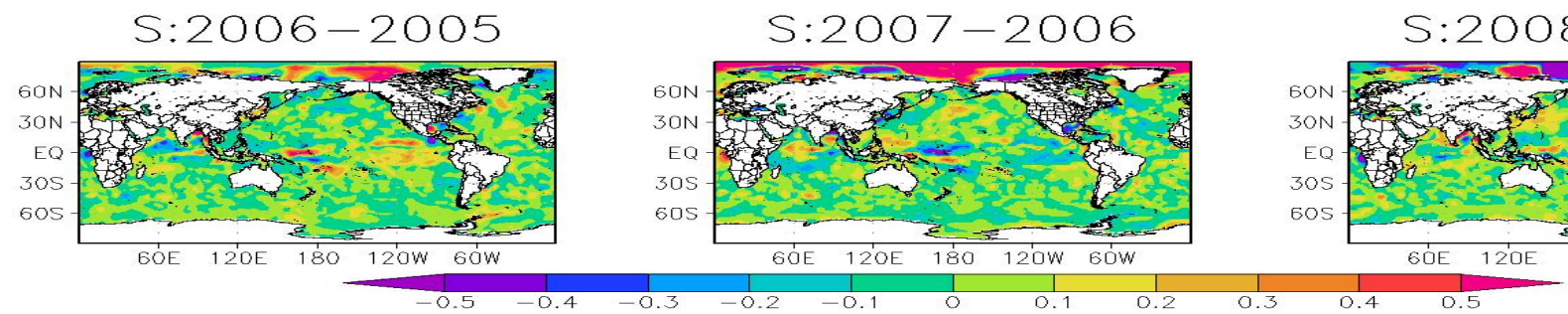
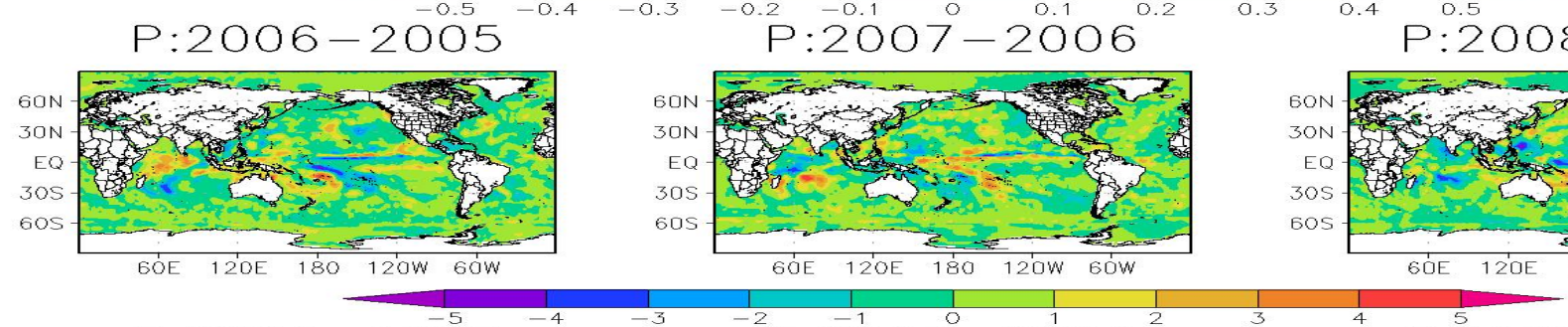
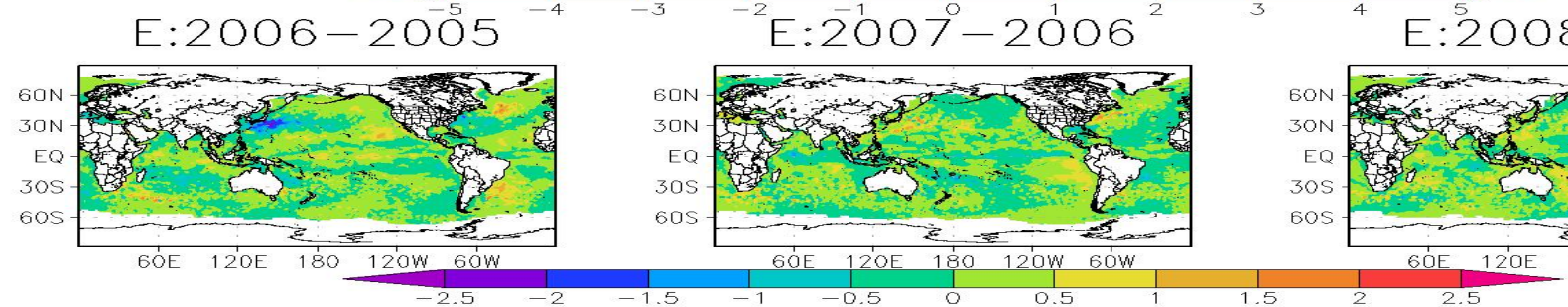
SSS Annual Cycle Changes

2005-2008



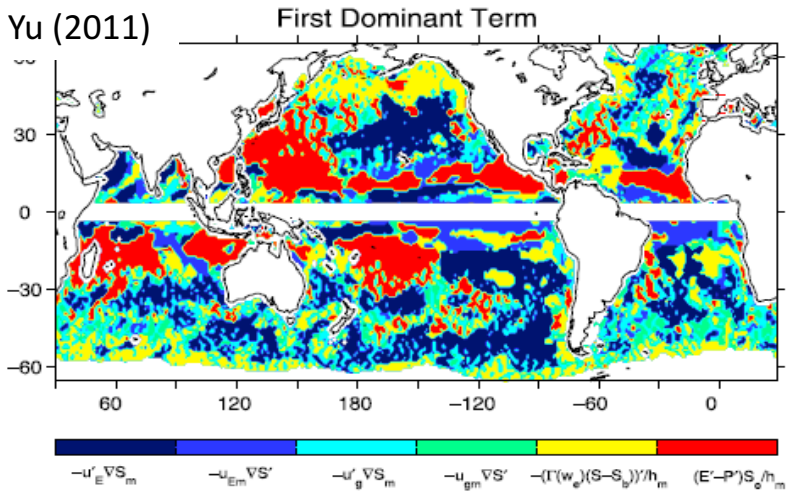


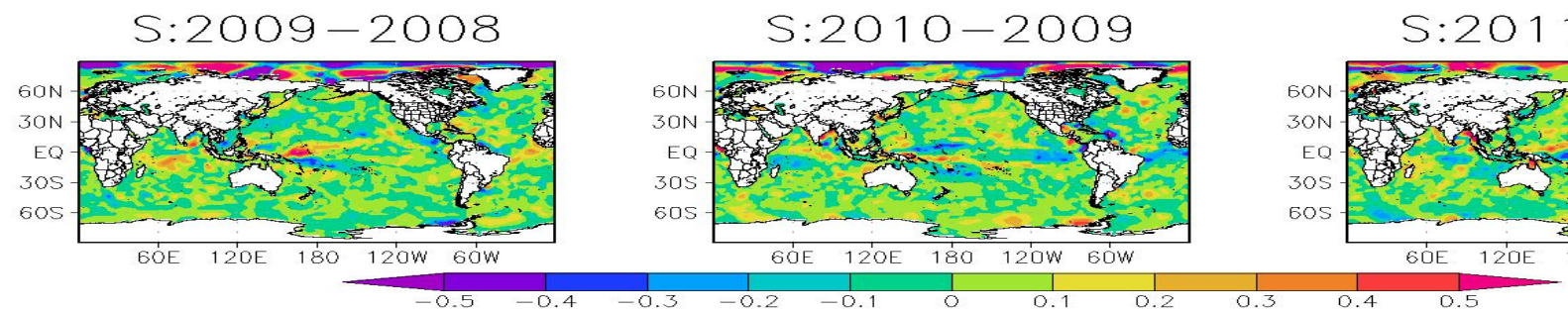


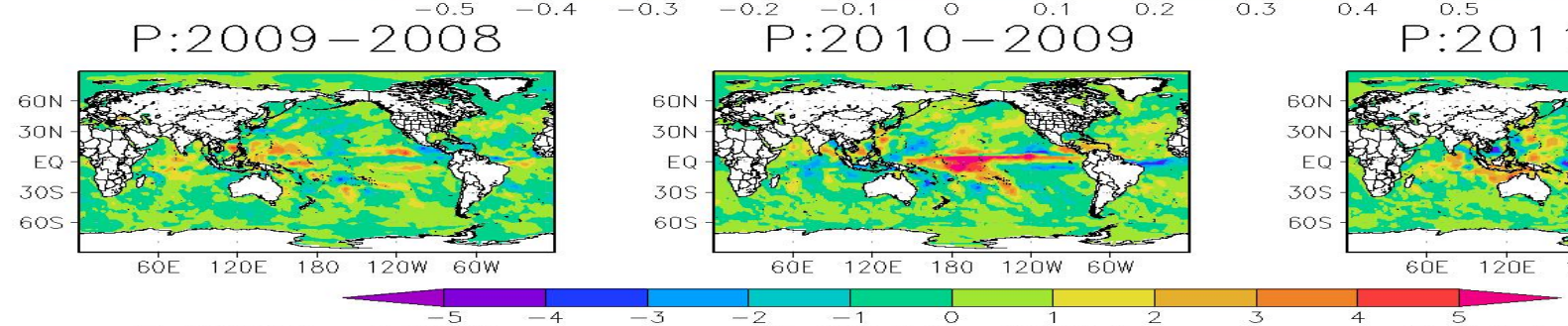


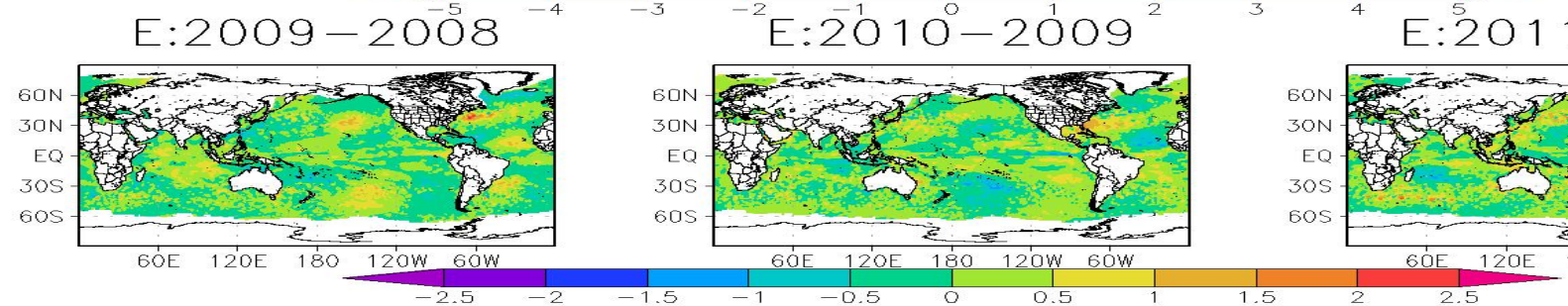
SSS Annual Cycle Changes

2008-2011



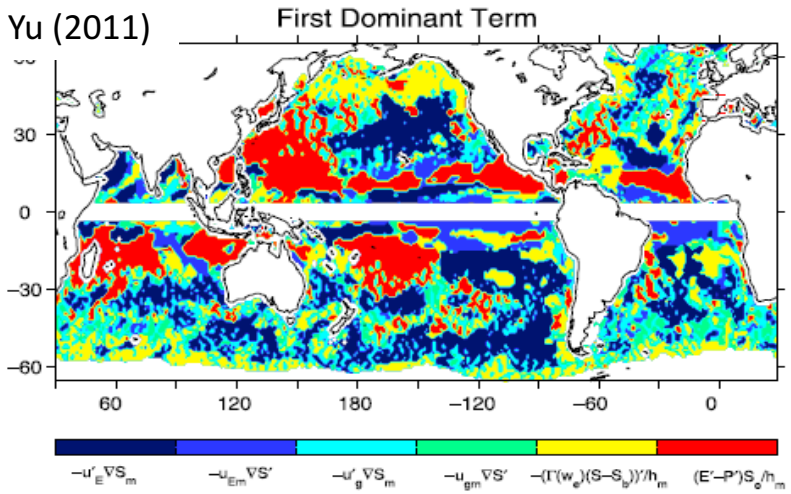


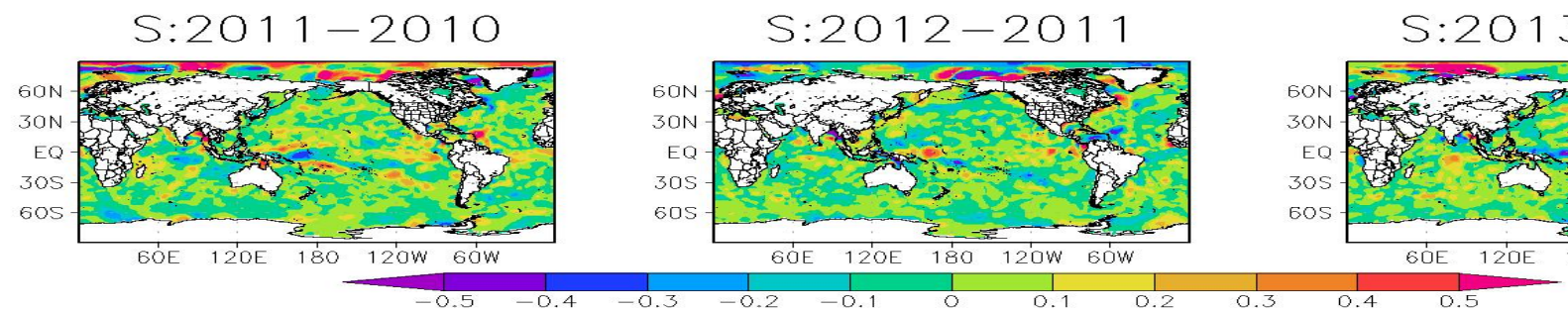


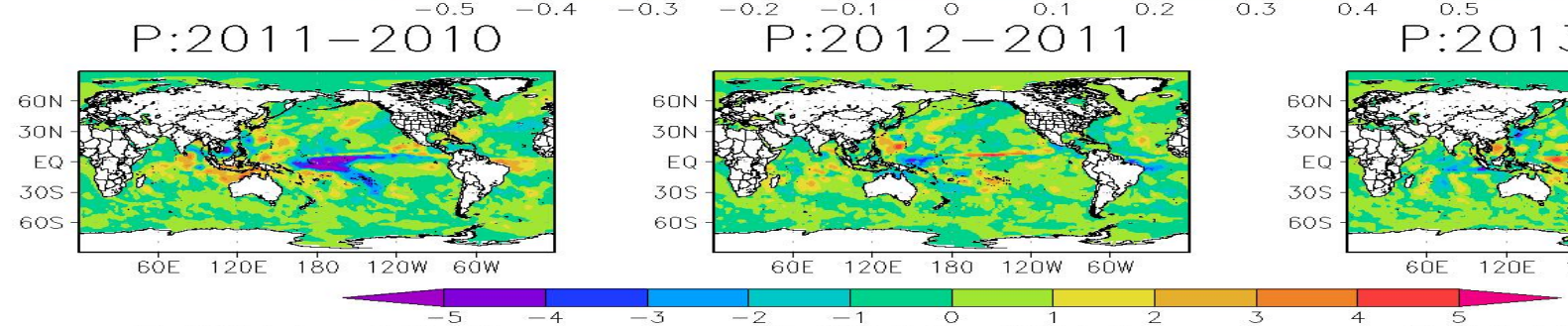


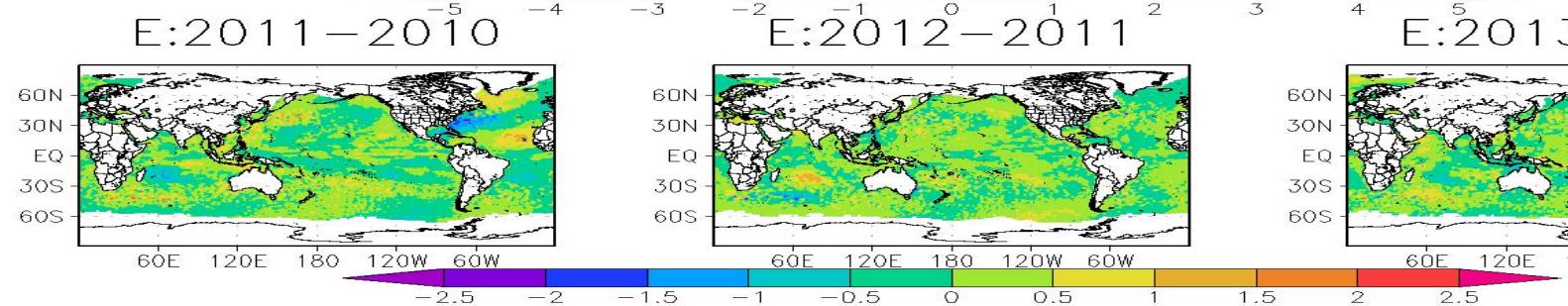
SSS Annual Cycle Changes

2010-2013

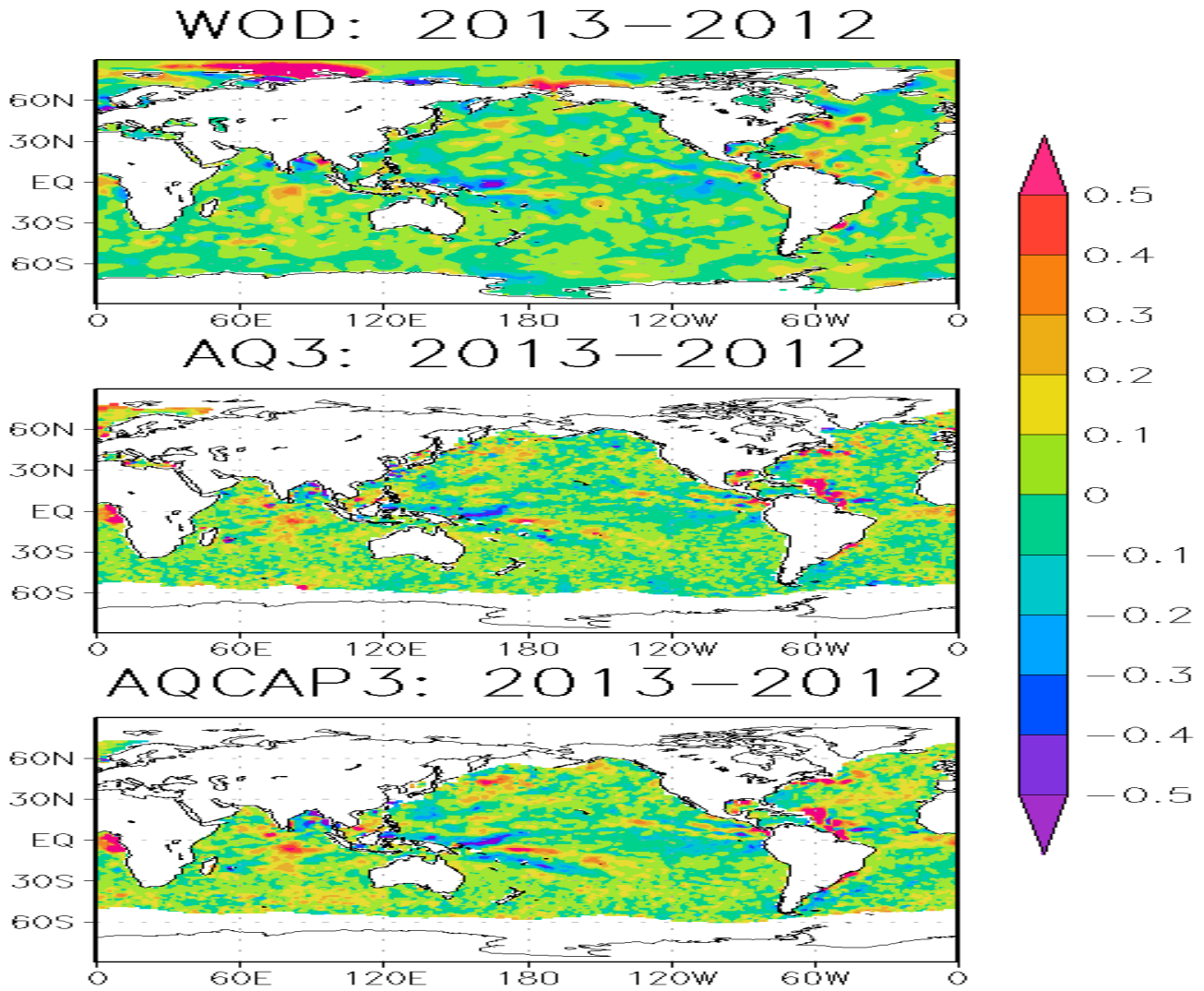








SSS Annual Cycle Changes: WOD and Aquarius



Conclusions

- Evidence of strong linear trends in SSS across multiple regions of the global ocean from 2005-2013
  - Many recent trends are trending opposite of the long-term trend
  - Use caution in drawing conclusions in data sparse regions
- Regional SSS variability is strongly correlated with multiple climate indices
- Interannual changes in the SSS annual cycle tend to not follow the changes seen in the precipitation and evaporation annual cycles in regions E and P dominate the MLS budget.

Future Work

- Incorporate Aquarius and SMOS
- In addition to correlating SSS variability with various climate indices, also begin analyzing changes when related climate indices are in (out) of phase.
- Look at longer lag times
- Begin looking at subsurface changes
- Relate SSS trends and fisheries

References

1. Yu, L. (2011), A global relationship between the ocean water cycle and near-surface salinity, *J. Geophys. Res.*, **116**, C10025, doi:10.1029/2010JC006937.
2. Grunseich, G., B. Subrahmanyam, V. S. N. Murty, and B. S. Giese (2011), Sea surface salinity variability during the Indian Ocean Dipole and ENSO events in the tropical Indian Ocean, *J. Geophys. Res.*, **116**, C11013, doi:10.1029/2011JC007456.
3. Durack, P. J., and S. E. Wijffels, 2010: Fifty-Year Trends in Global Ocean Salinities and Their Relationship to Broad-Scale Warming. *J. Climate*,**23**, 4342–4362. doi: http://dx.doi.org/10.1175/2010JCLI3377.1

Data Sites

- WOD Salinity Anomaly Fields - https://www.nodc.noaa.gov/OC5/3M_HEAT_CONTENT/
- Climate Indices - http://www.esrl.noaa.gov/psd/data/climateindices/list/
- Indian Ocean Dipole index - http://www.jamstec.go.jp/frsgc/research/d1/iod/iod/dipole_mode_index.html
- Aquarius - ftp://podaac-ftp.jpl.nasa.gov/allData/aquarius/
- Precipitation - ftp://precip.gsfc.nasa.gov/pub/gpcp-v2.2/psg
- Evaporation - http://oaflux.whoi.edu/evap.html

Thank You!