Decadal changes in the tropical upper ocean surface salinity: evidence for an anthropogenic fingerprint

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AMA 2006, 18-20 Janvier, Toulouse
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Recent (1988-2008) precipitation trends
GPCP 2.1 and CMAP

Average tropical ocean trend ~ 0 (compensation between wet and dry regions)
Allan et al. 2010
1. **Surface Salinity**: gridded, 1°x1°, objective analysis, error estimates
   - **Atlantic**: 30S-50N, 1970-2002  *Reverdin et al. (2007)*
   - **Pacific**: 30S-30N, 1950-2008  *Cravatte et al. (2009), Delcroix et al. (2010)*

2. **Temperature**: **EN3** analysis (Met. Office)
   - 1960-2005, global product  *Ingleby and Huddleston 2007*
   - Versions with different XBT bias correction
Delcroix et al. (2010)

Pacific SSS dataset
1950-2008

Nb of SSS observations from 1/1950 to 12/2008 per grid 1x1x5 days

Number of observations

- CTD
- bucket
- TSG
- mooring
- Argo
- unknown
- Total
Recent SSS low frequency changes

Tropical SSS linear trend (1970-2002)

Stippling: 95% significance
Recent SSS changes
ARGO period 2003-2008

Increased Atl-Pac Salinity gradient

Hosoda et al. 2009

Von Schuckmann et al. 2009
Future changes CMIP3


- a) observations
- b) multimodel
- c) gfdl_cm2.0
- d) mpi_echam5
- e) cocma_cgcm3.1.2
- f) mri_gcm2.3.2a

psu/century
Increased SSS basin contrast

$H_0$: basin SSS variations only due to internal variability

OBS versus distribution of unforced 33-yr trends from CMIP3 PICNTRL

- **Atl**: $P = 0.28$

- **Pac**: $P = 0.01$
Detection of an anthropogenic fingerprint

D&A: choice of a detection model

- $X_{\text{obs}} \sim X_M + \sum X_i + \varepsilon$ ($\varepsilon$ noise)

- One signal ANT: $X_{\text{obs}} \sim X_M + X_{\text{ANT}} + \varepsilon$

**Hypothesis 1:** $X_{\text{ANT}}(s,t) \sim T(t) S(s)$
unchanged spatial structure, homothetic in time

1. Spatial detection: S known
2. Temporal detection: T known *(Ribes et al. 2010)*
Separability hypothesis

CMIP3 multimodel

Base period 1901-1950

1951-2000

2001-2050

2051-2099

X mean SSS basin change
Temporal detection

- Model: $X_{\text{obs}}(s,t) \sim X_M(s) + T(t)S(s) + \epsilon(s,t)$

*Hypothesis 2: $\epsilon \sim \text{AR}(1)$

Coefficient $\alpha$ from CMIP3 PICNTRL simulations
How to choose $T(t)$?

Upper ocean mean temperature (down to 14°C isotherm)

Temporal detection

*How to choose $T(t)$?* Annual mean Tiso14 from 20C3M simulations with ANTHRO forcing only

- Constrain the response to be smooth (Minimization spline)
Temporal detection

\[ X_{\text{obs}}(s,t) \sim X_M(s) + T(t)S(s) + \varepsilon(s,t) \]

- Simple multivariate regression (after prewhitening)
- \( H_0 : S = 0 \) versus \( H_a : S \neq 0 \) (Hotelling test)

Note that:
- Noise covariance matrix not needed
- Separability hypothesis used only on 20th C
- Gives estimate of spatial pattern S related to T
- \( N_T > N_S + 2 \) and test applied to \( t = N_S + 2, \ldots, N_T \)
Spatial regions for detection test
Summary

- Detection of an anthropogenic fingerprint on recent tropical ocean SSS (1990’s)
- Rich gets richer: enhanced Atlantic/Pacific contrast, warm/fresh pool gets fresher, subtropical Atlantic saltier
- Spatial SSS forced patterns distinct from interannual-to-decadal internal modes
- Atlantic SSS changes mixed with decadal internal variability (Equatorial and midlatitudes)
- Density changes in the west Pacific: influence on barrier layer, ENSO ?
- Enhanced water vapor transport ? Salt transport ?
Caveats

- Short observation period, spatial sampling, data homogeneity (ARGO, XBT bias, SMOS, AQUARIUS), need for extended ocean reanalysis
- Internal variability: model biases, long range persistence (internal ocean modes), validity of the AR(1) assumption
- Other forcings (Solar, Volcanic) and attribution

THANK YOU
Pacific SSS dataset

Data error bar

Delcroix et al. (2010)
SSS PDO-related signal

Regression of detrended SSS on PDO index

Cravatte et al. 2009
ENSO, PDO and SSS fronts

Cor = -0.58
Sign. 99%
Detection test SSS

![Graph showing regression coefficient vs. truncation with labels: No detection, RC test passed, RC test failed.](image-url)
Detection test SSS

Pac. 2006, 18-20 Janvier, Toulouse

Detection test SSS

Pac. centered

95%

Pac. + Atl.

Atl.
Ocean heat content changes using isotherms

OHC changes: Air-sea fluxes and adiabatic vertical displacements

*Palmer et al. 2007, Palmer and Haines 2009*

Tiso14: Mean temperature between surface and 14°C depth

Tiso14 to represent the rate of tropical ocean warming
Heat content changes

- Filters variability due to vertical displacements
- More immune to XBT Bias than fixed depth

![Graph showing temperature anomaly over time](image-url)

Corre et al. 2010
Observed OHC changes: 1965-2005
OHC IPO/PDO signal

EN3-OA

SODA

CERFACS

Tiso14

T250m
Tiso14 AR(1) and detection test
Observed SSS Variability

SSS monthly means StdDev

PSU