Comparative Analysis of Upper Ocean Heat Content Variability from an Ensemble of Operational Ocean Reanalyses

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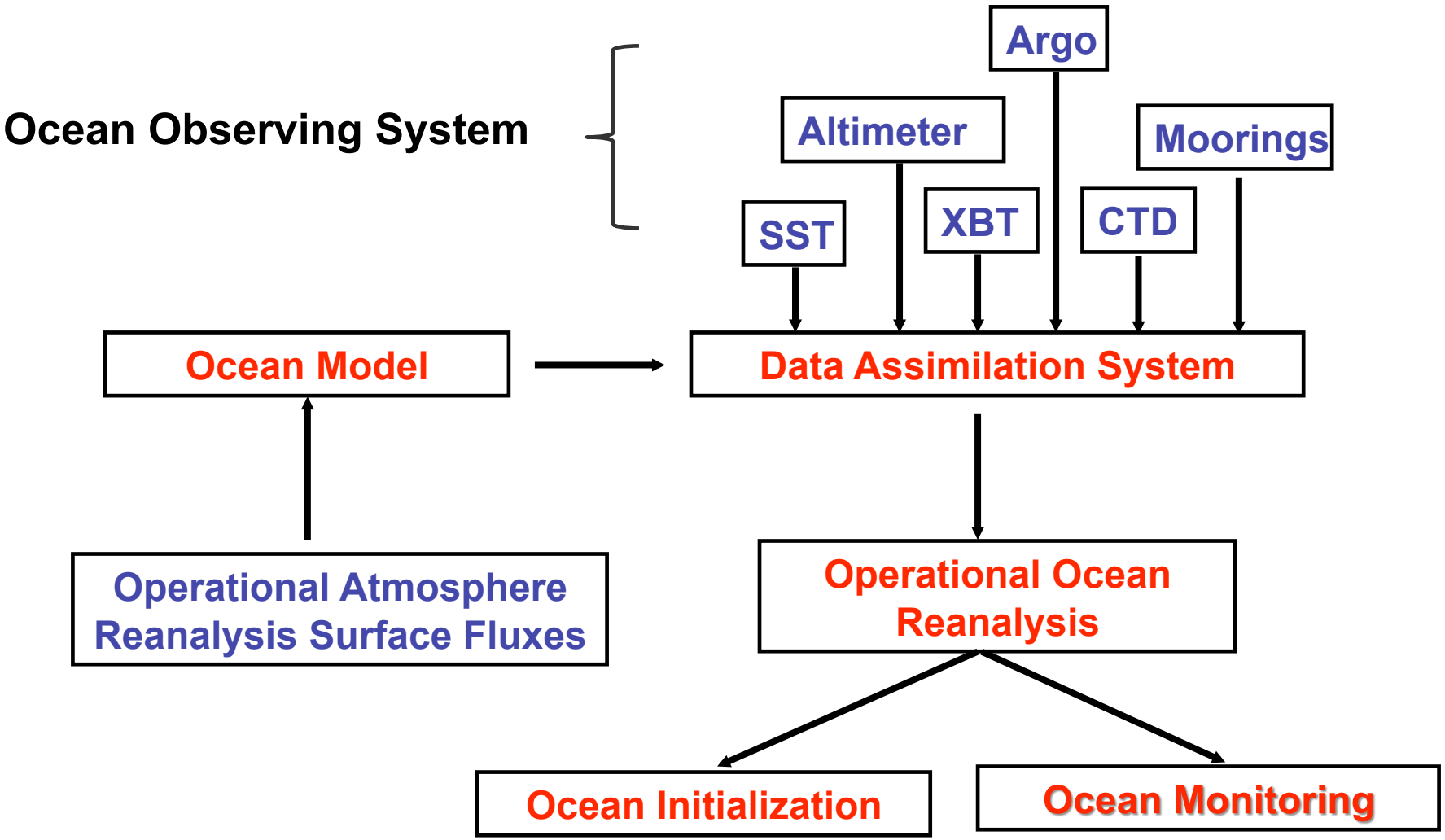
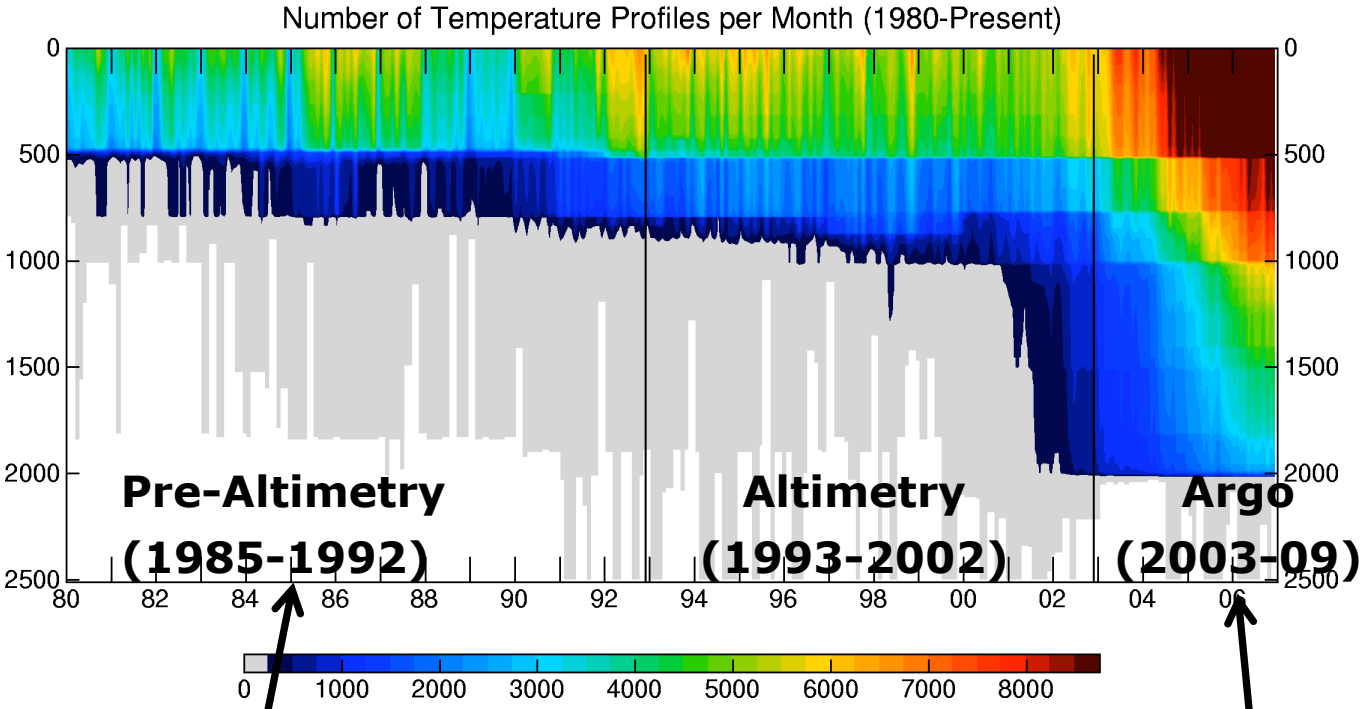
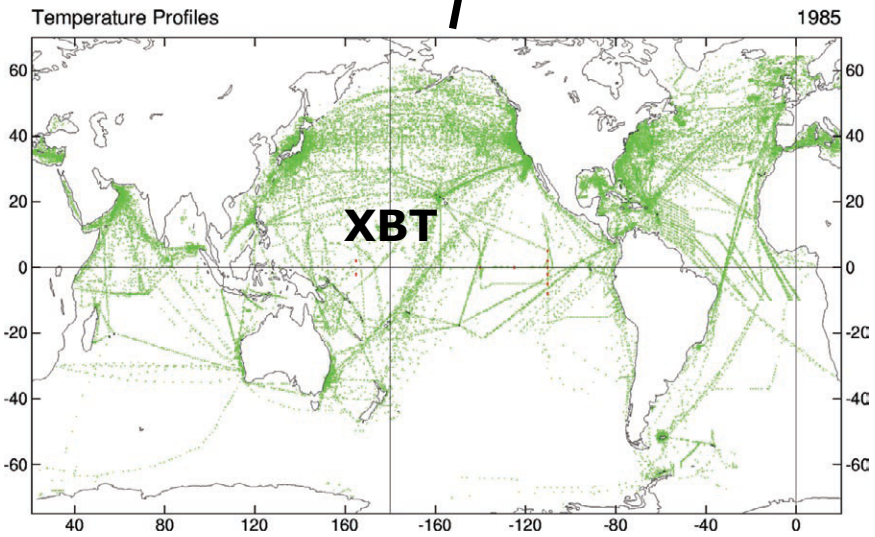
Operational Ocean Reanalysis

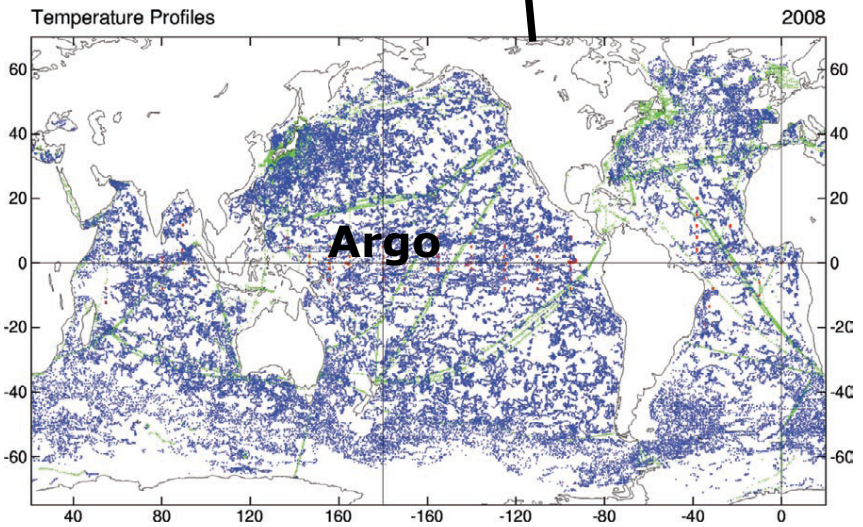


Ocean Observations

from Saha et al. (2010)







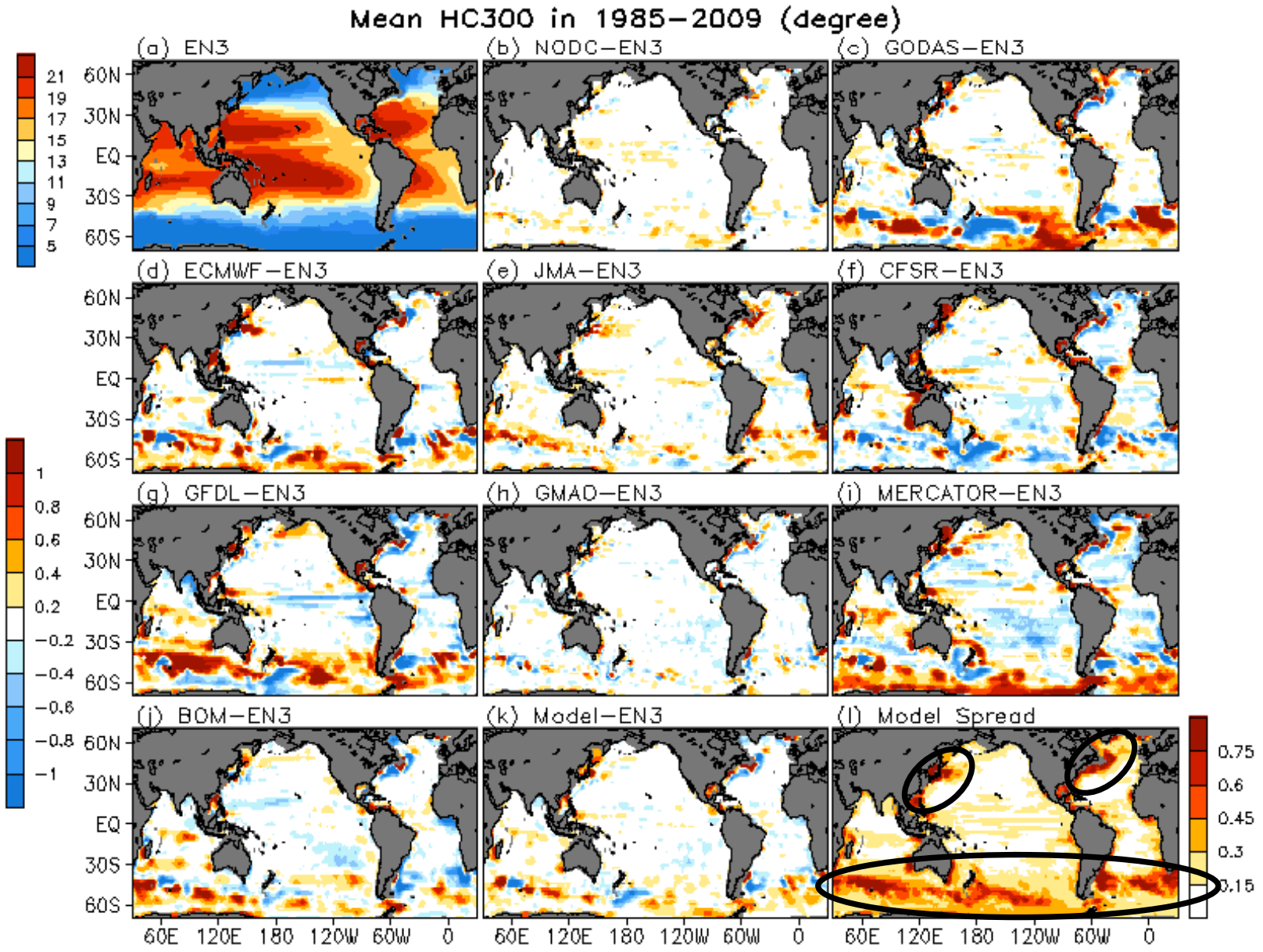
Operational Ocean Reanalyses

Name	Method & Forcings	In Situ Data	Altimetry Data	Resolution	Period	Vintage	Reference
EN3.v2a	Analysis Correction Scheme	No XBT corrections	No	1°x 1°, 42 Levels Monthly Temp.	1950-present	2009	Ingleby and Huddleston (2007)
NODC	Objective Analysis	No XBT corrections	No	1°x 1°, 16 Levels, 0 to 700m Seasonal Temp.	1955-present	2010	Levitus et al. (2009)
GODAS	3D-VAR	No XBT corrections	NO (Yes in real time)	1°x 1° (1/3° near Eq), 40 Levels Pentad, Monthly	1979-present	2003	Behringer and Xue (2004
ECMWF (S3)	OI	No XBT corrections	Yes	1°x1° (1/3° near Eq), 29 Levels Daily, Monthly	1959-present	2007	Balmaseda et al. (2008)
JMA	3D-VAR	No XBT corrections	Yes	1°x1° (1/3° near Eq), 50 Levels Pentad, Monthly	1979-present	2009	Usui et al. (2006)
CFSR	3D-VAR Partially coupled	No XBT corrections	No (Yes in real time)	1/2°x 1/2° (1/4° near Eq), 40 Levels Daily, Pentad, Monthly	1979-present	2010	Xue et al. (2010)
GFDL	EnKF Fully coupled	XBT corrections	Yes	1°x 1° (1/3° near Eq), 50 Levels Daily, Pentad, Monthly	1970-present	2010	Zhang et al. (2009)
GMAO	EnOI Fully coupled	XBT corrections	No	1/2°x 1/2° (1/4° near Eq), 40 Levels Daily, Monthly	1980-present	2011	Rienecker at al. (2011)
MERCATOR (PSY2G2)	KF-SEEK	No XBT corrections	Yes	2°x 2° (1/2° near Eq), 31 Levels Daily, Pentad, Monthly	1979-present	2007	Drévillon et al. (2008)
BOM (PEODAS)	EnKF	No XBT corretions	No	2°x 1.5 ° (1/2° near Eq.), 25 Levels Daily, Monthly	1980-present	2009	Yin et al. (2010)

Heat Content Analysis

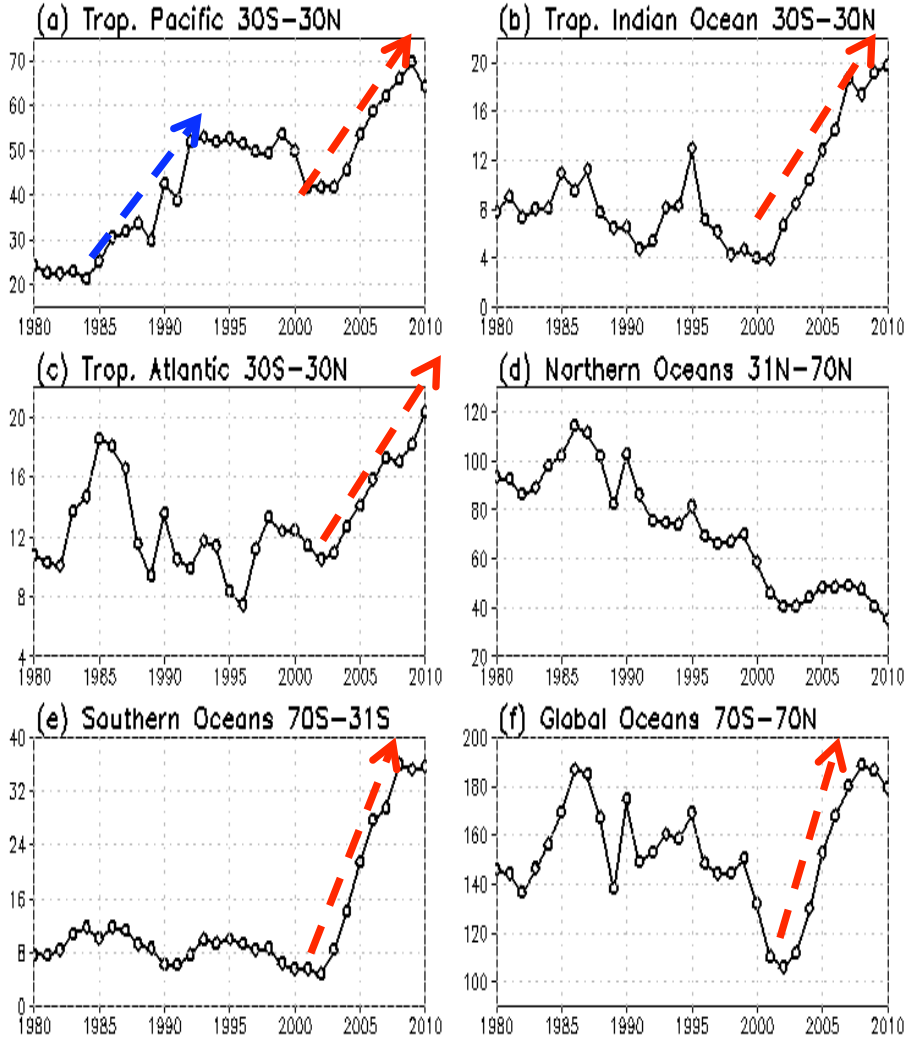
- **How well is the mean upper 300m ocean heat content (HC300) analyzed by operational ocean reanalysis (ORA)?**
- **How well is the interannual variability, multi-decadal and long term variability of HC300 analyzed by ORAs?**
- **What are the impacts of changes of ocean observing systems on the quality of HC300 analysis?**
- **What are the prospects for operational HC300 climate indices derived from an ensemble of operational ORAs?**
- **What is the role of HC300 on potential predictability of ENSO, Indian Ocean Dipole and Atlantic Nino?**

Mean Heat Content Analysis

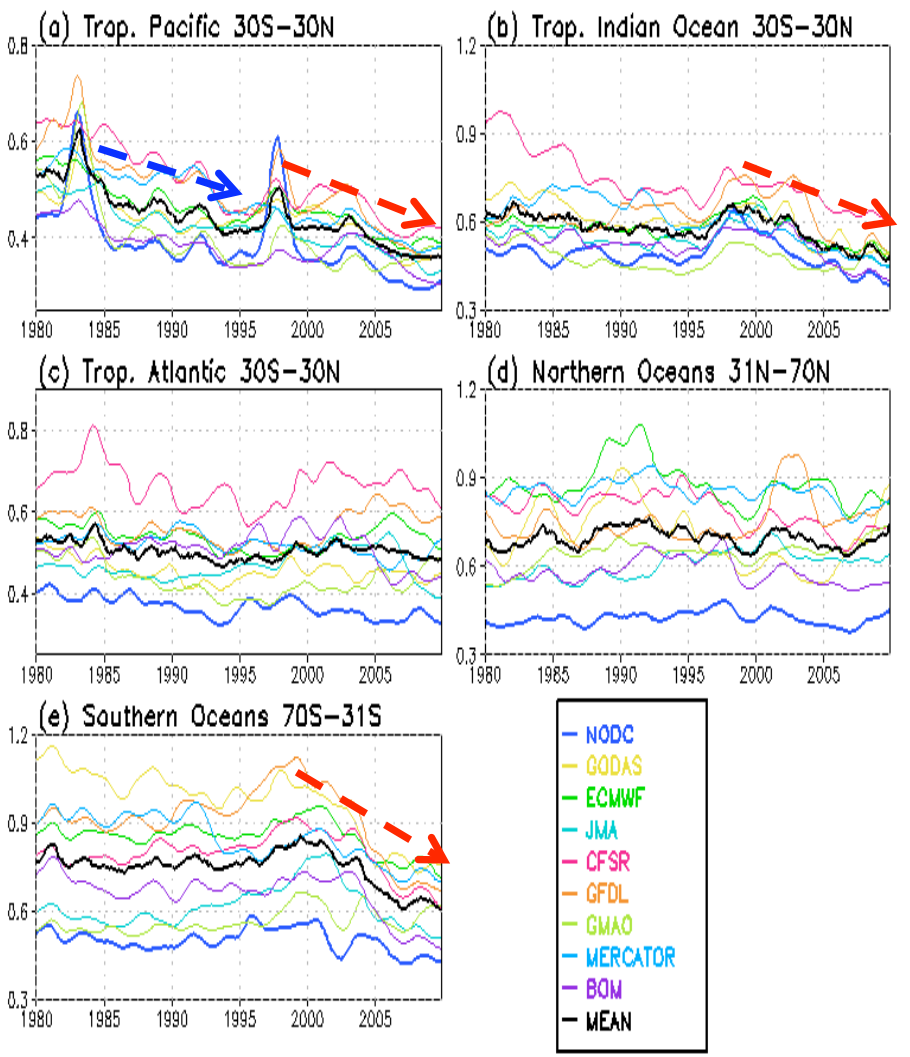


Impacts of Changes of Ocean Observing Systems

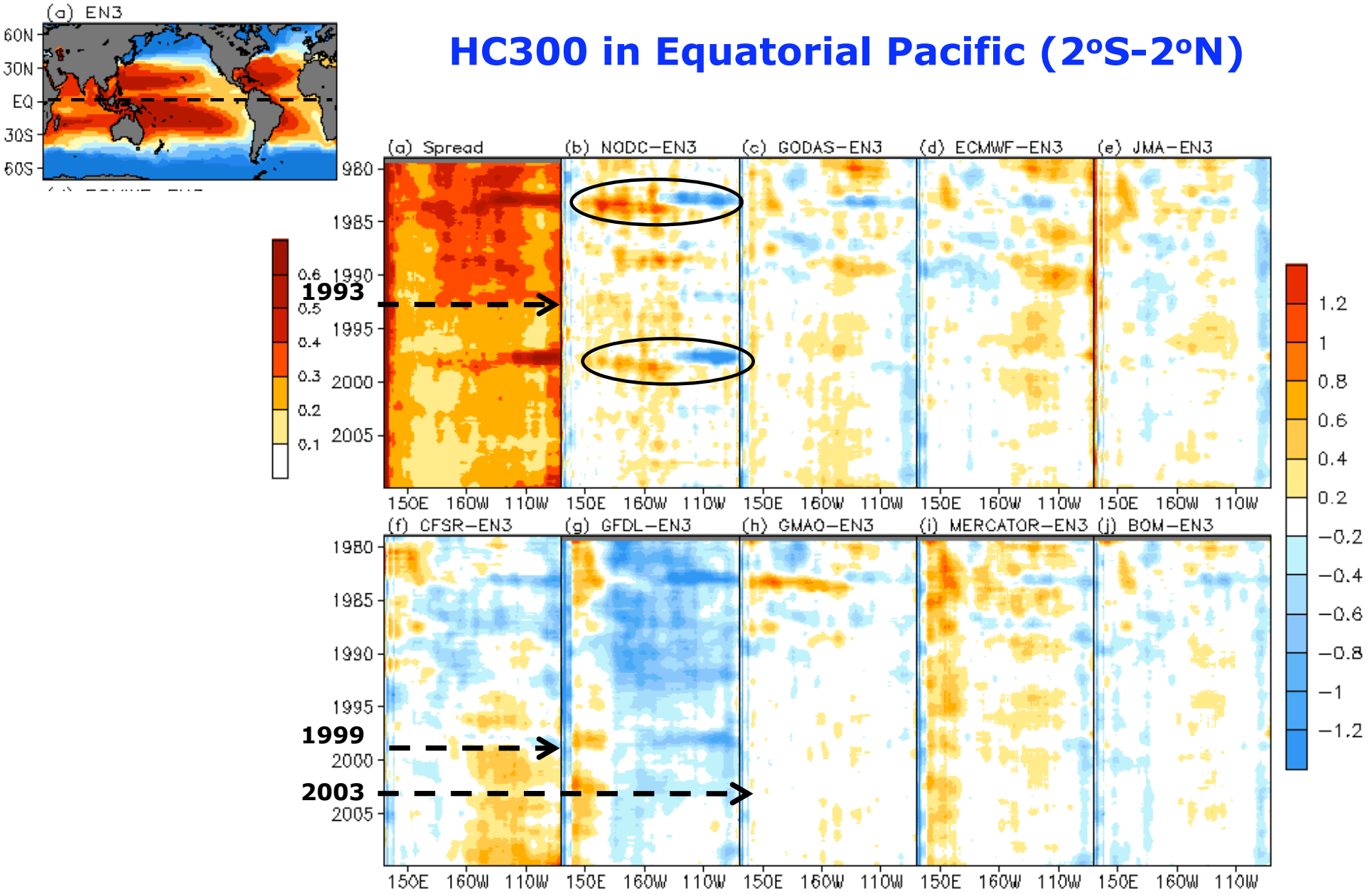
Data Count



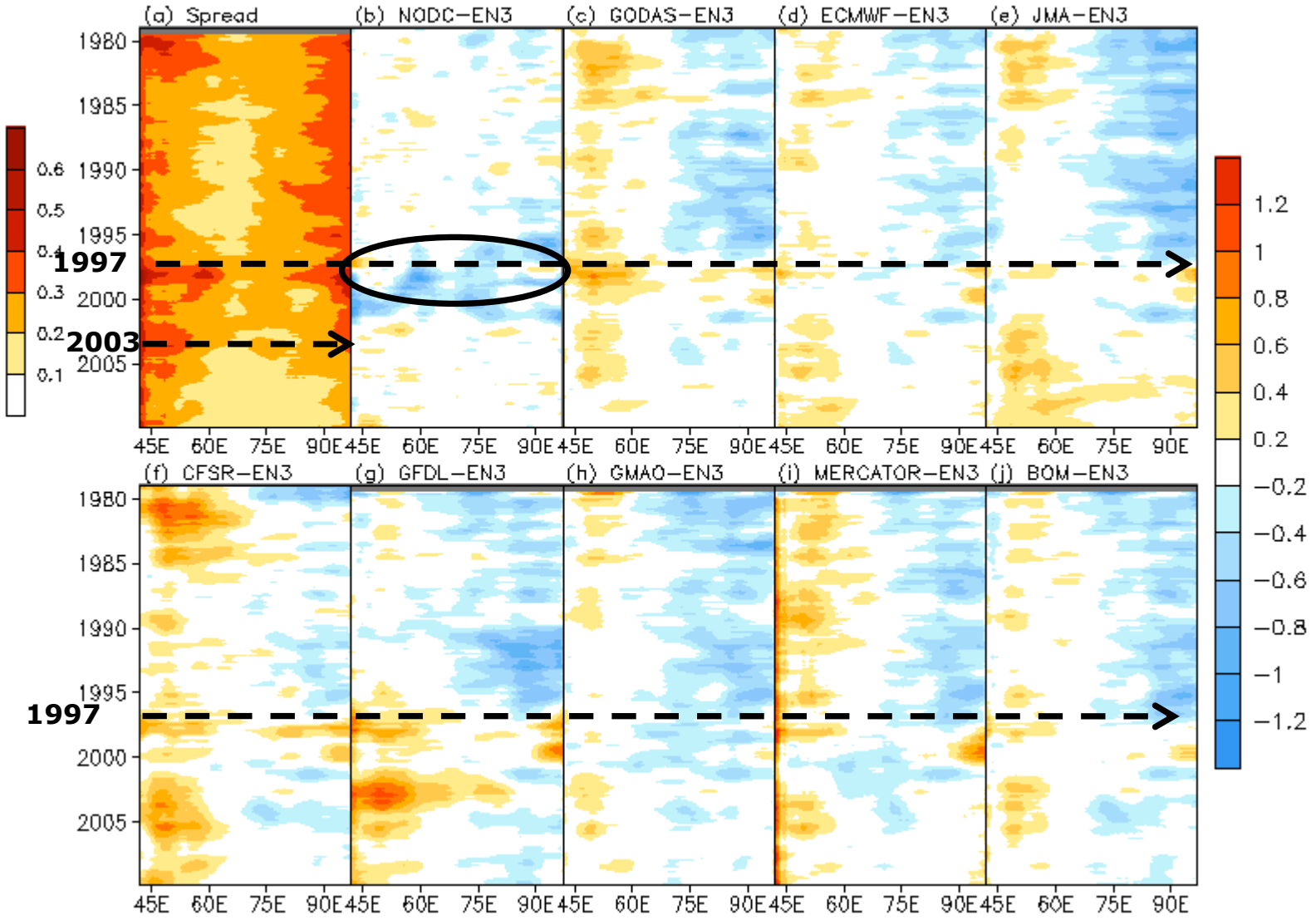
RMSD from EN3



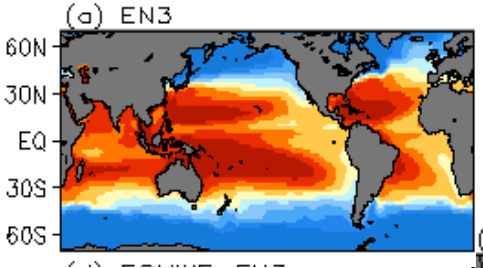
HC300 in Equatorial Pacific (2ºS-2ºN)

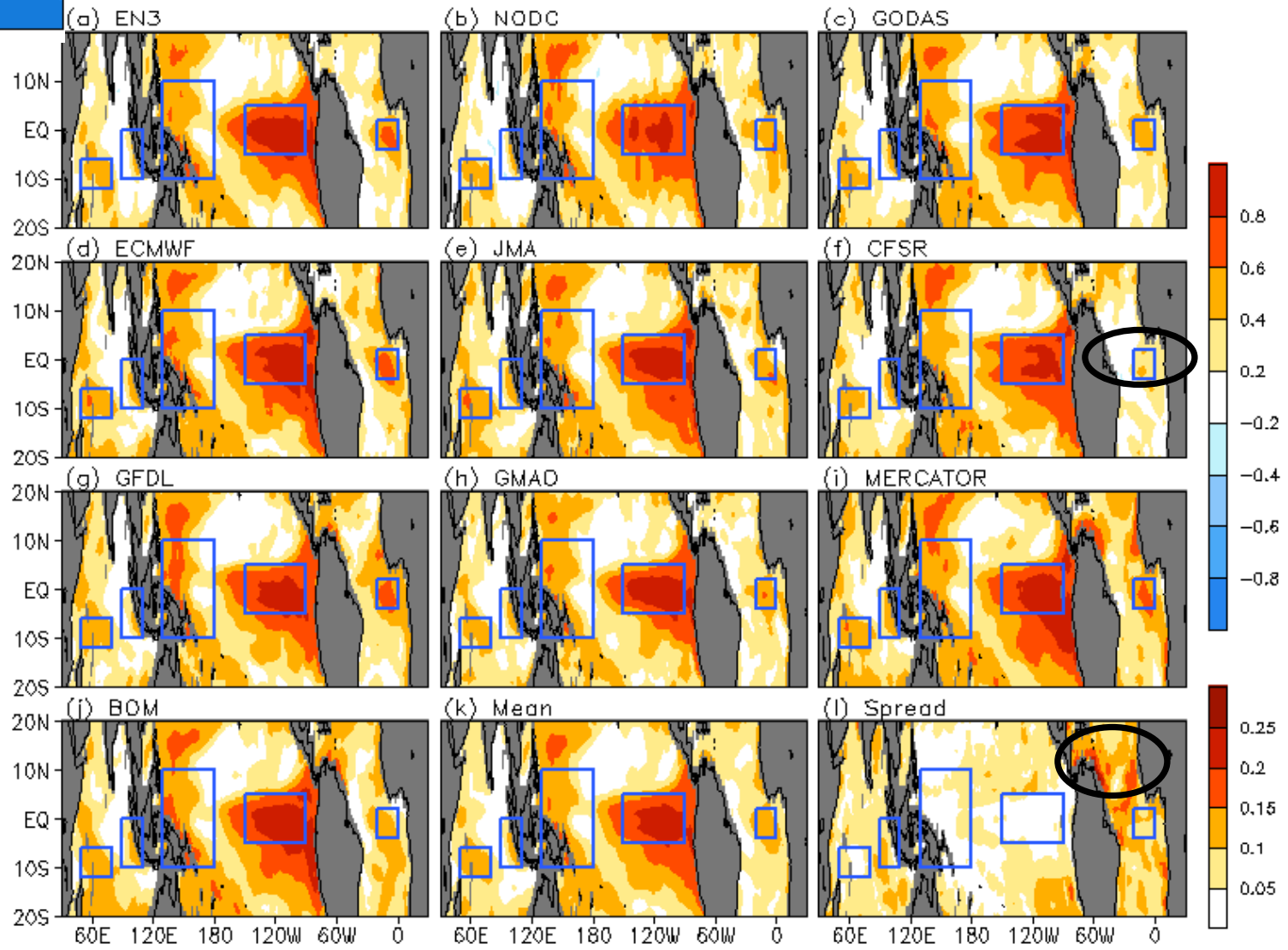


HC300 in Equatorial Indian Ocean (2°S-2°N)

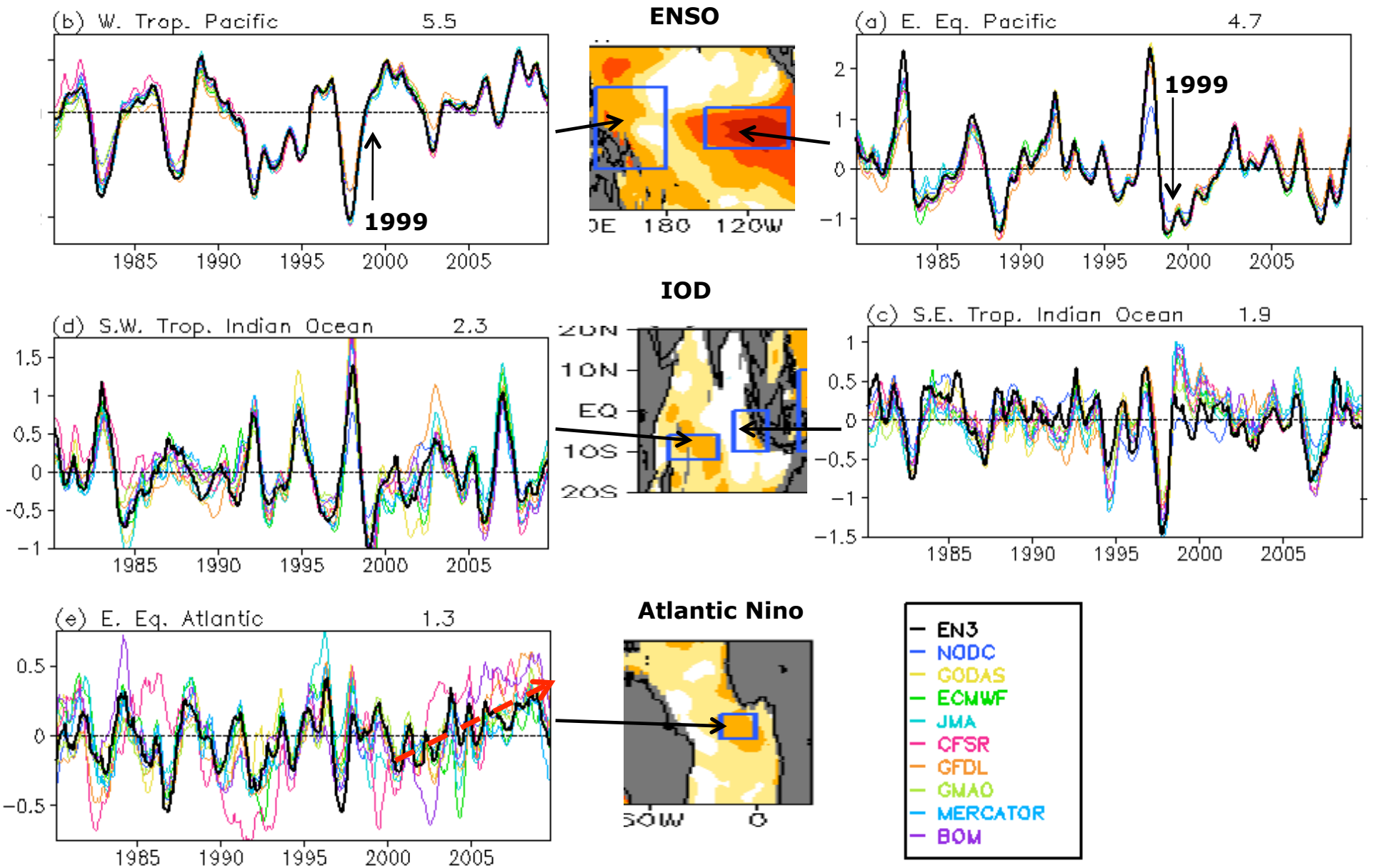


HC300 Anomaly Correlation with OI SST

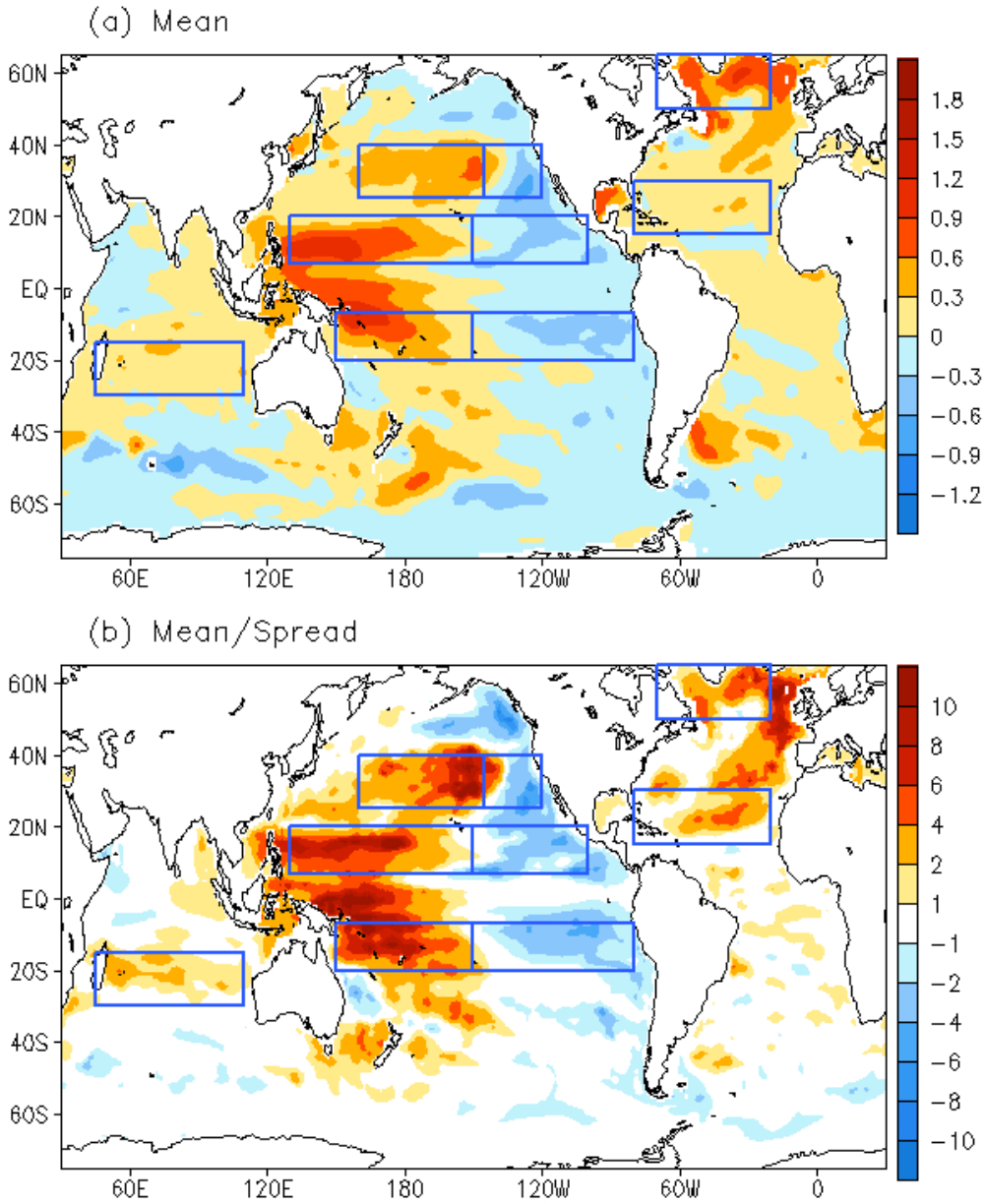




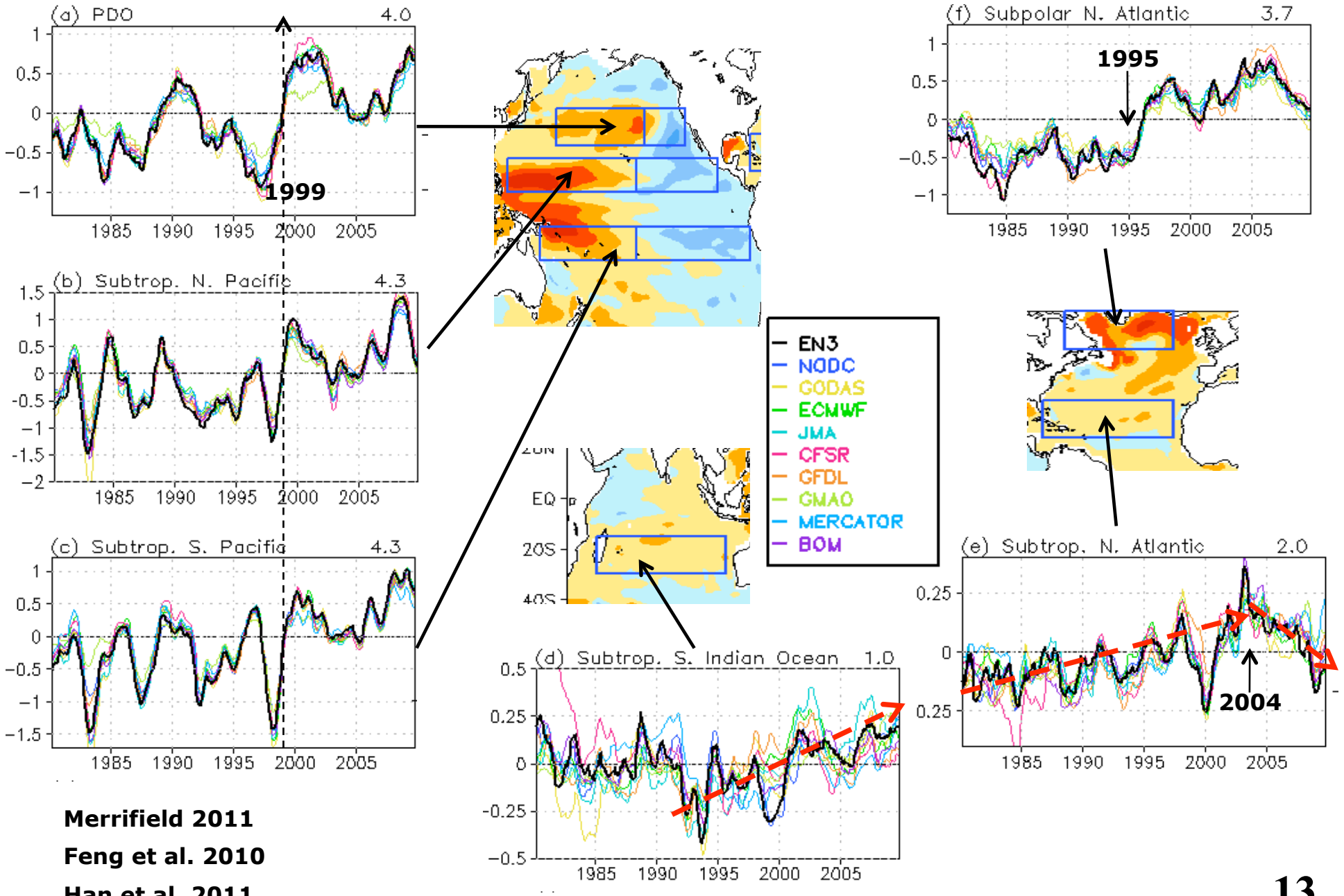
HC300 Anomaly Indices for ENSO, IOD and Atlantic Nino



Linear Trend of HC300 Anomaly in 1993-2009



HC300 Anomaly Indices for Multi-decadal Variability

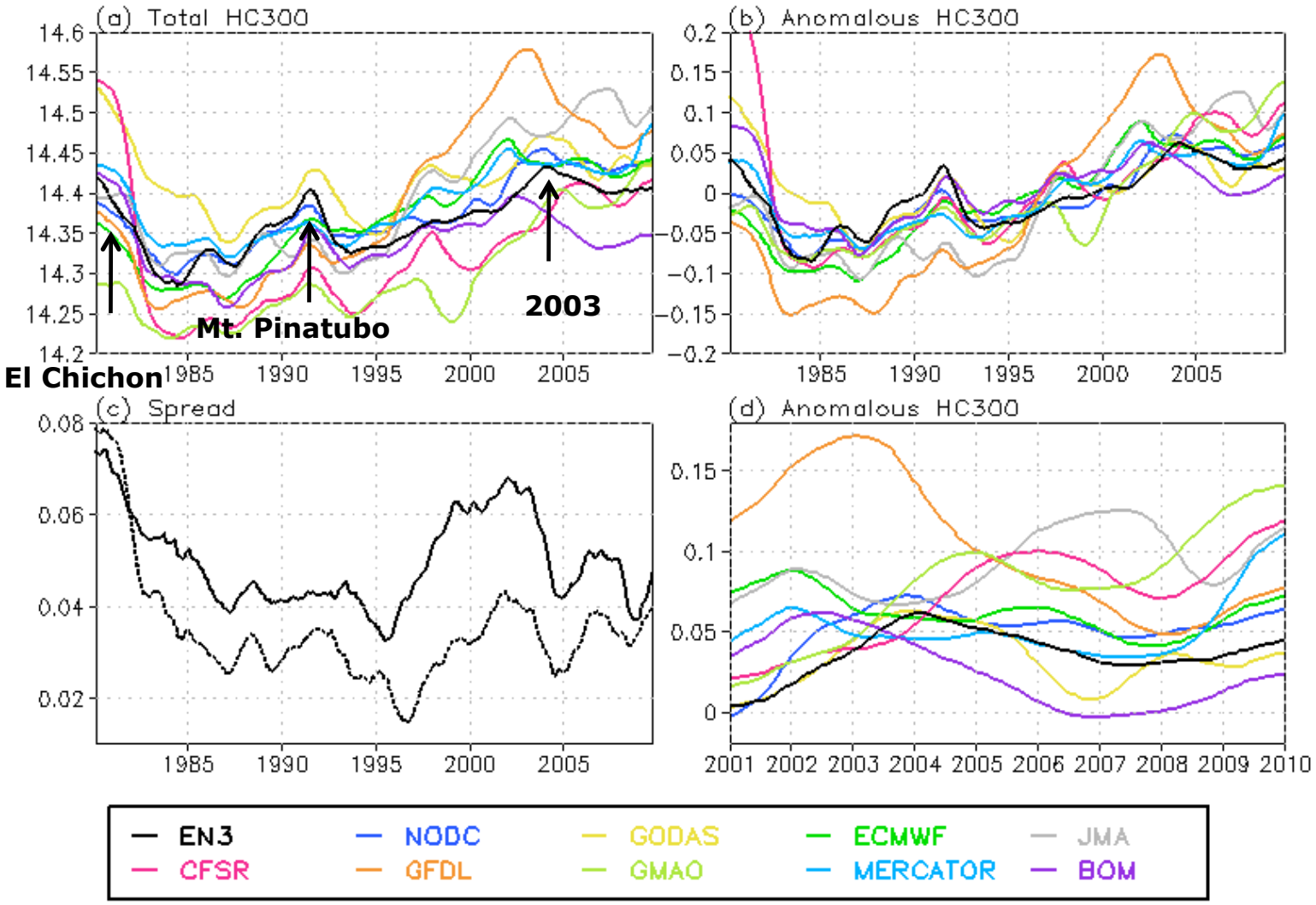


Merrifield 2011

Feng et al. 2010

Han et al. 2011

Mean HC300 and HC300 Anomaly in 70°S-70°N



Summary

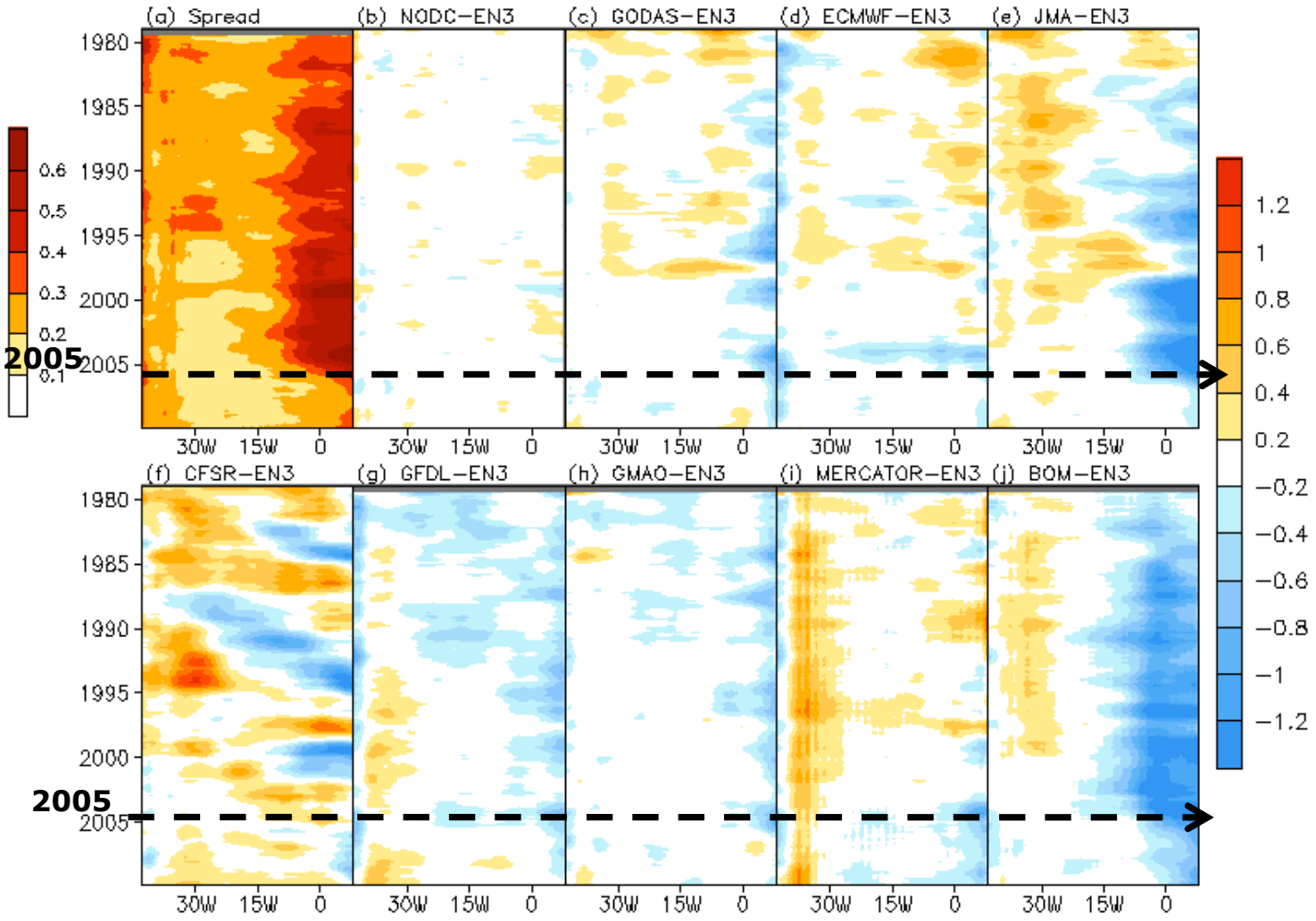
- **Consistency among ORAs tends to increase with time, particularly in the tropical Pacific, the tropical Indian Ocean and extra-tropical southern oceans, and is partly due to constraints from tropical mooring arrays and Argo floats.**

- **HC300 anomalies (HC300a) associated with ENSO are highly consistent among ORAs; HC300a associated with IOD are moderately consistent, and model-based analyses are superior to in situ-based analyses in the eastern pole of the IOD; HC300a associated with the Atlantic zonal mode has considerable uncertainties among ORAs, which are comparable to signals.**

- **Large multi-decadal variability and long-term trends exist in HC300. The consensus among ORAs suggests that the mean HC300 in 70°S-70°N has a brief cooling periods during early 1980s and 1992-1993 related to the volcanic eruptions of the El Chichon and Mt. Pinatubo, and a short warming in 1985-1991, and then a continuous warming in 1994-2003, followed by a persistence or weak cooling in 2004-2009.**

- **An ensemble of operational ocean reanalyses provide a tool to monitor signals and uncertainties in upper ocean heat content in real time.**

HC300 in Equatorial Atlantic (2ºS-2ºN)



HC300 Anomaly Correlation with EN3