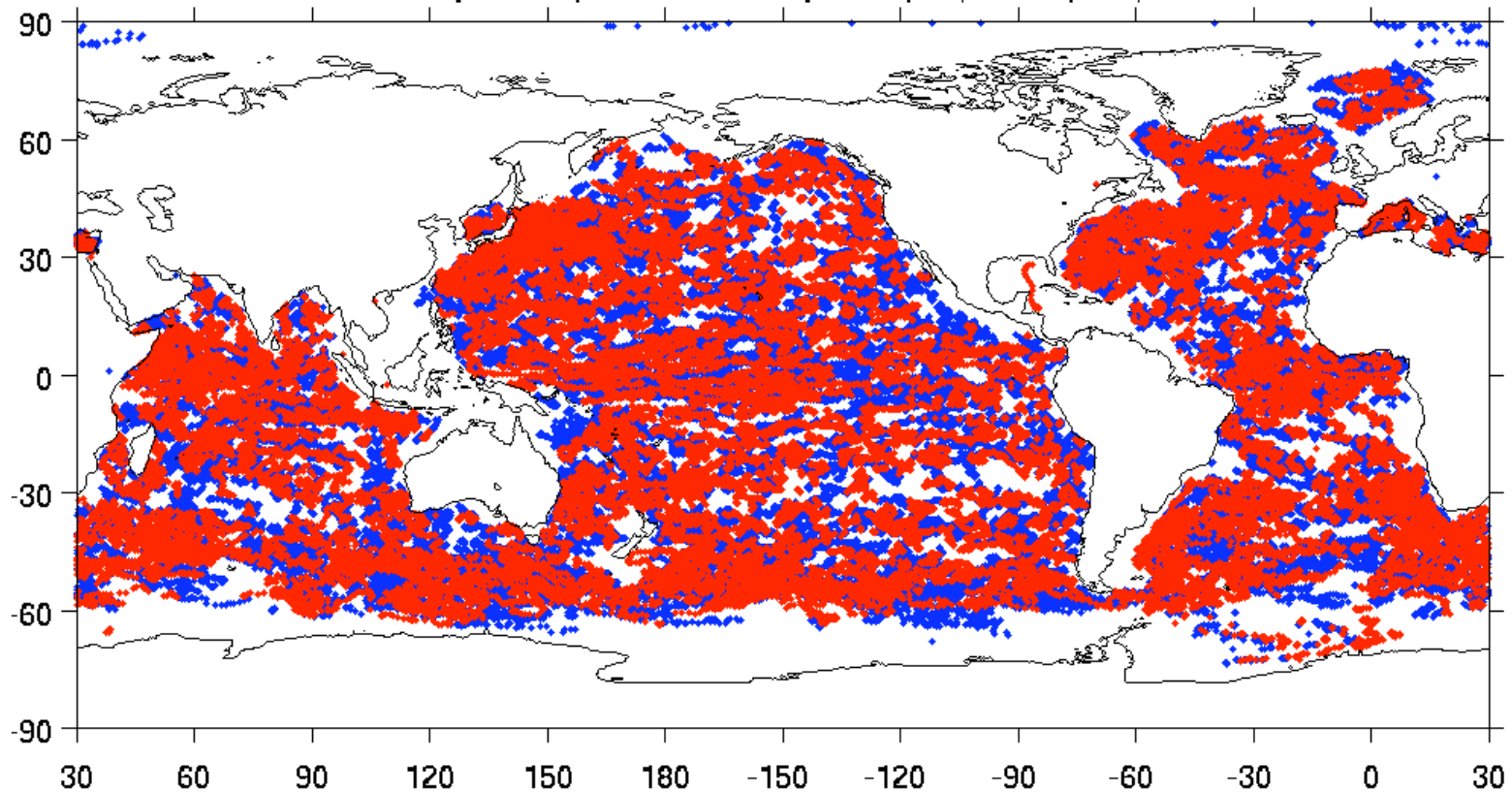


# Global Interannual Upper Ocean Heat Content (& Sea-Surface Salinity) Variability

Gregory C. Johnson (NOAA/PMEL), John M. Lyman (UH/JIMAR & NOAA/PMEL),  
& Josh K. Willis (NASA/JPL),

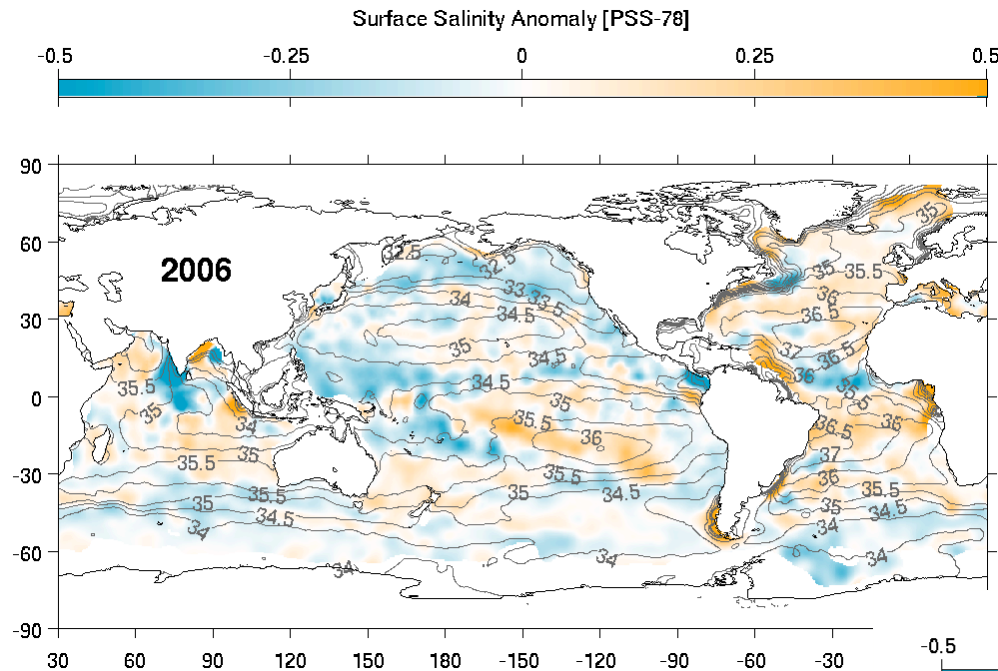
- Preliminary Sea-Surface Salinity (SSS) anomalies from Argo data
- 0- 750 m Ocean Heat Content Anomaly (OHCA) maps
  - In situ combined with satellite following Willis et al. (2004)
  - 2006 relative to 1993-2006 & 2006-2005
- Preliminary look at 0 - 750 m global OHCA interannual variations
  - In situ only following Lyman et al. (2006)
  - Preliminary XBT bias correction, still estimating sampling errors only
- Data artefacts leading to cooling estimates
  - Argo pressures
  - XBT bias
- OHCA coverage

# Sea Surface Salinity Anomalies

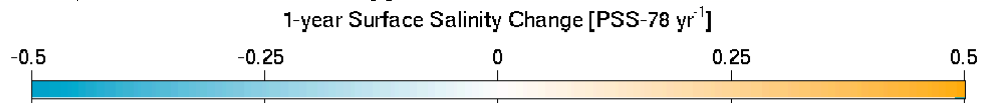


- Data Positions: 2005 (red) over 2006 (blue)
- Preliminary: mix of Delayed-Mode & Real-Time Data
- Only values  $z < 25$  m, simple statistical check
- Anomalies relative to WOA 2001 surface values
- Objectively mapped,  $6^\circ$  lat. x  $6^\circ$  long. length scales

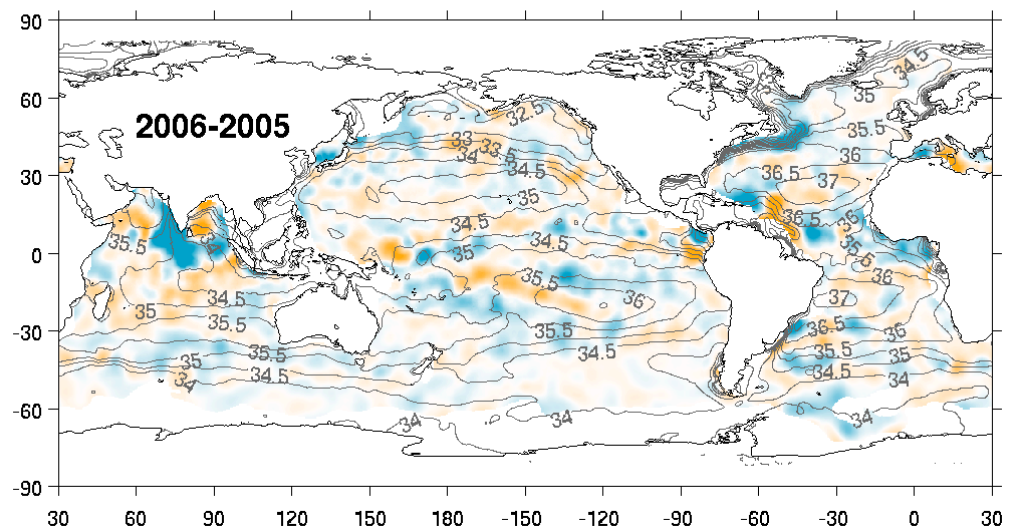
# Sea Surface Salinity Anomalies



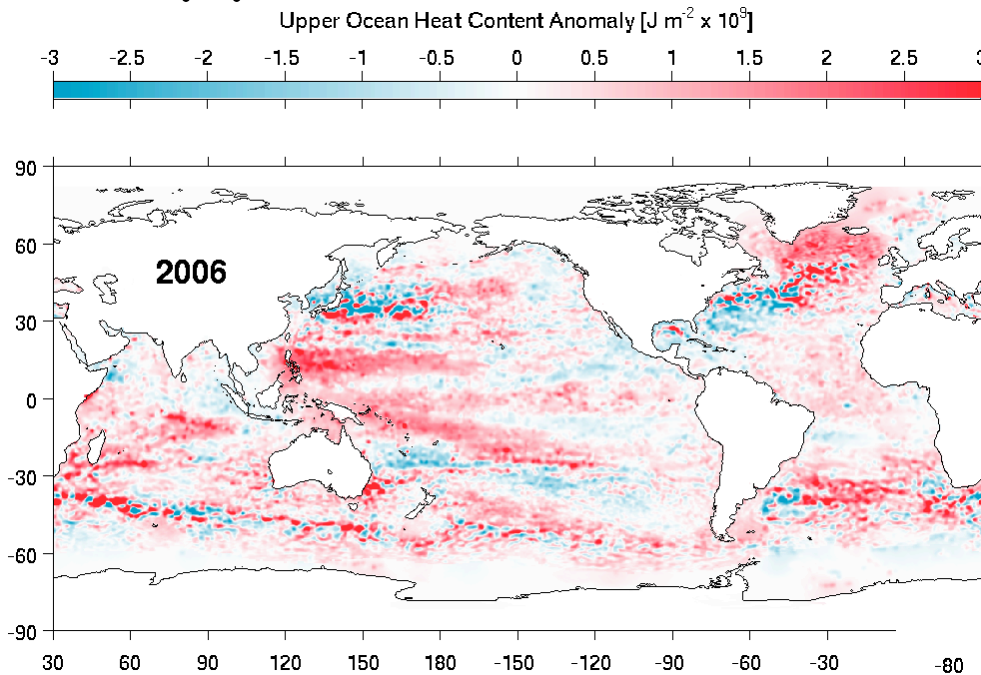
- 2006 vs. WOA 2001:
- Subtropical salinity maxima ↑
- Fresh ITCZ ↓
- Subpolar fresh regions ↓
  - Except N. Atlantic (poleward advection, Hátún et al., 2005).
- Hydrological cycle intensified?
- Or sparse data -> "flat" climatology?



- 2006 vs. 2005:
- Indian Ocean: big interannual changes
- Amazon Outflow Salty in 2006
  - Reflection of 2005 drought?
- Small spatial scale variations
  - Eddies and Fronts?

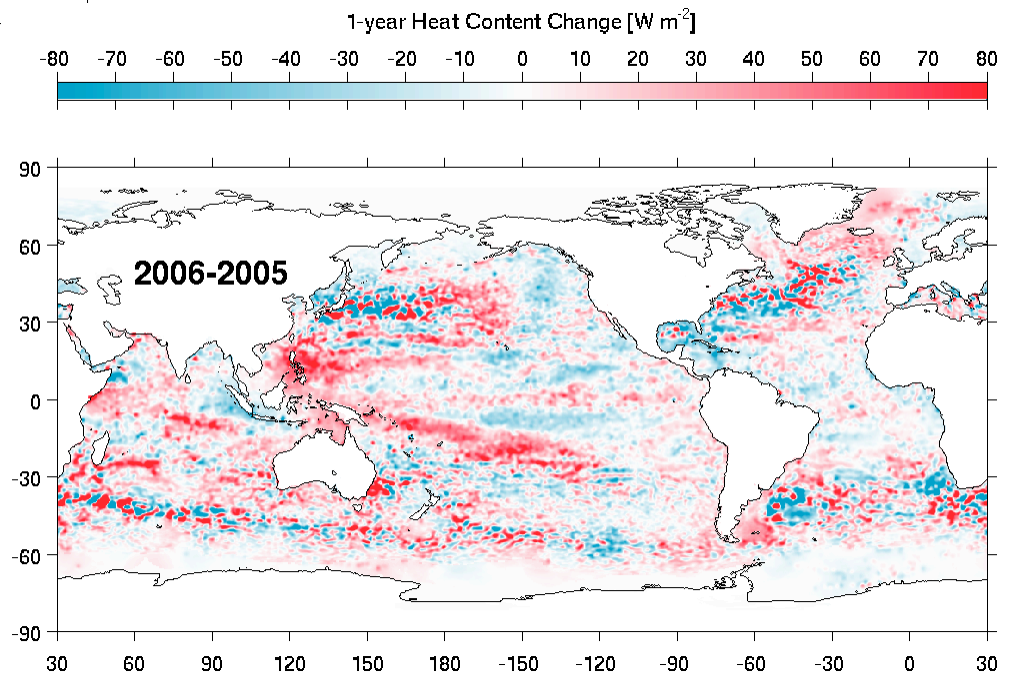


# Upper Ocean Heat Content (Combined)



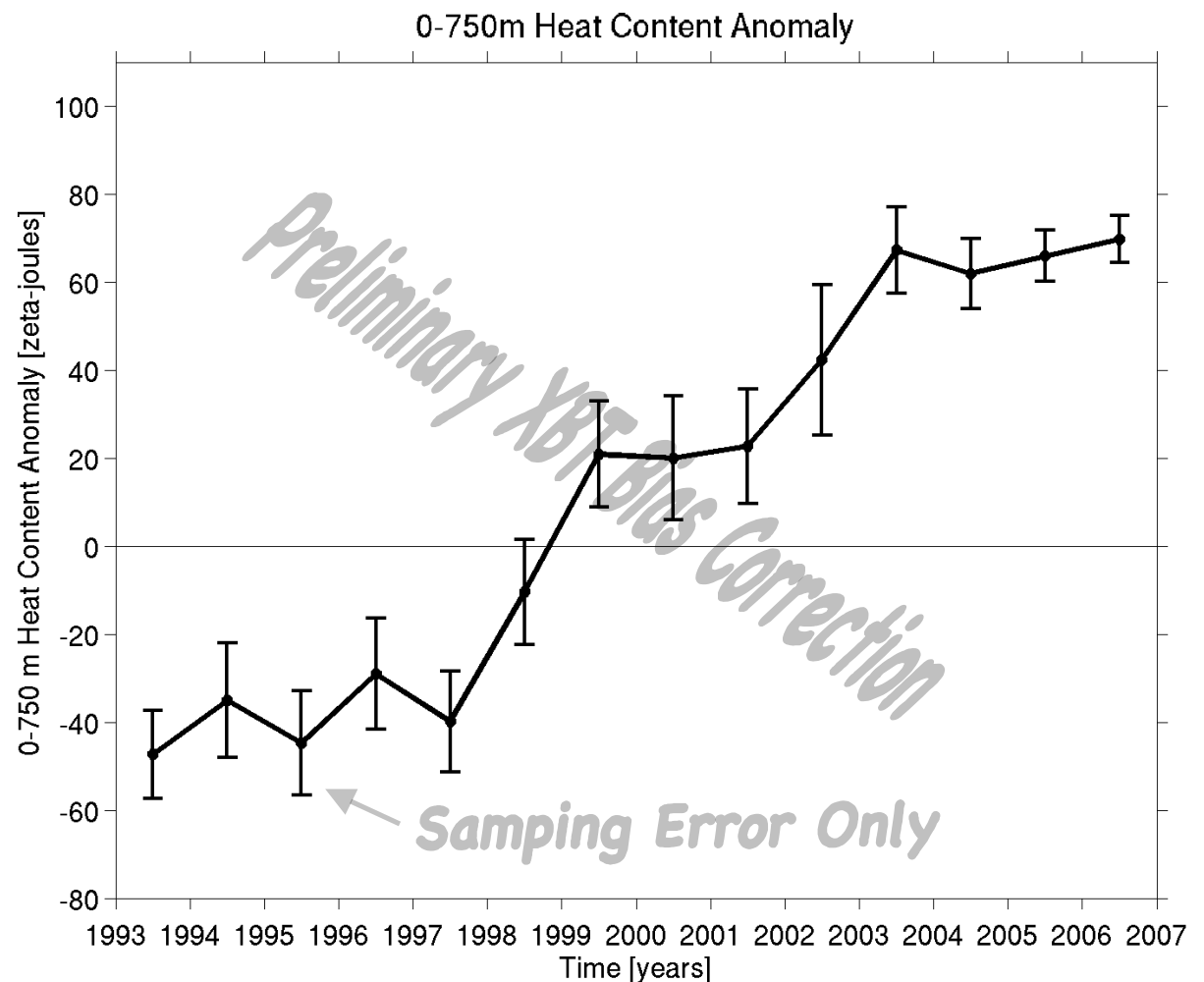
- 2006 relative to 1993-2006 ->
- Warming overall
- Warm Subpolar N. Atl, (NAO)
- Warm S. Ocean band (SAM)
- Warm Eq. Pacific (EL Niño)

- 2006-2005 (Short Time-Scale) ->
- Large-amplitude small-scale:
  - Ocean advection
  - Equatorial Pacific warming
  - Weak El Niño
  - OHCA decrease in Gulf of Mexico, Caribbean, & surrounds



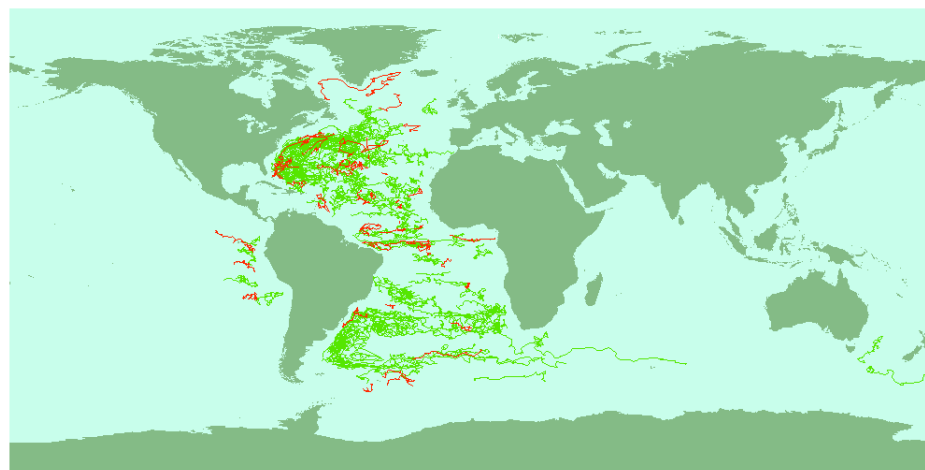
# Annual Global Upper OHCA Variations

- 2003–2005 decrease reported by Lyman et al. (2006) mostly artefact
- Misreported pressures
  - 6% of Argo profiles
  - Cold bias
  - Faulty profiles removed
  - Corrections in progress (next slide)
- XBT warm bias
  - Fall rate variations?
  - Compare CTD to XBT
  - Rate: 97.7% original
- Not full error budget!
  - Sampling error only
  - Instrument Biases?
  - Climatology Biases?
- Trend:  $0.6 \pm 0.1 \text{ W m}^{-2}$



# The recent Argo data problem and corrective actions

Map from Argo Information Centre of FSI/SOLO (Argo Program WHOI) instruments.  
Green = active, Red = inactive.

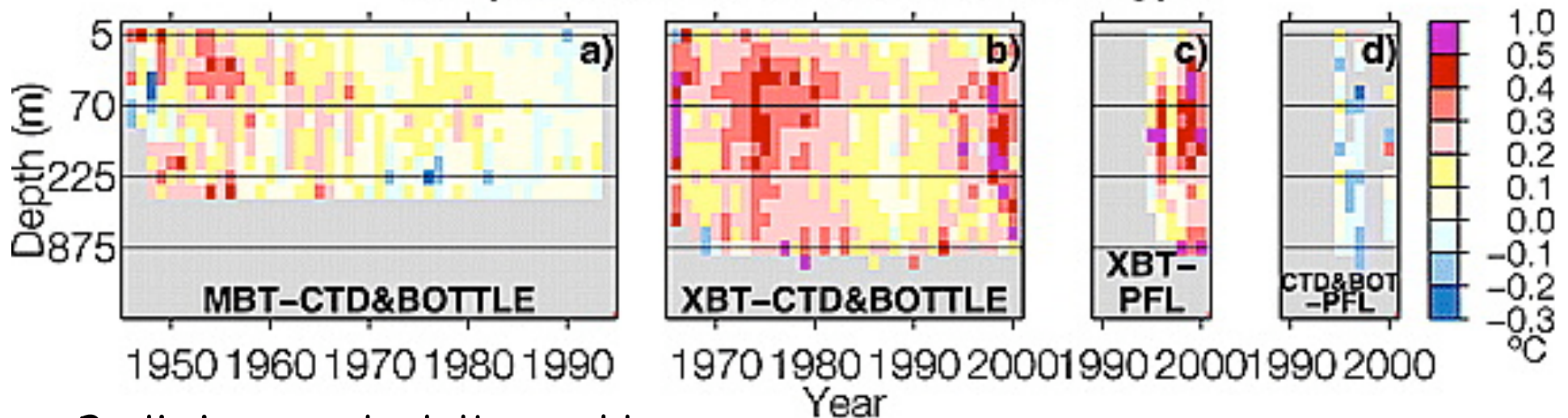


- Early this year, a systematic problem (incorrect pressure bins) was detected in FSI/SOLO (Argo Program WHOI) Argo floats. For details see Section 6.1 of the AST-8 meeting report at <http://www-argo.ucsd.edu/iast8.pdf> .
- All problematic instruments (211 active as of May 2007) have been greylisted and excluded from GTS transmission since early March (for a list see [http://www-argo.ucsd.edu/Acpres\\_offset.html](http://www-argo.ucsd.edu/Acpres_offset.html) ).
- Approximately 1/3 of ~12000 problematic profiles are correctable by automated procedure using engineering data, and replacement files have been submitted to the US Argo DAC.
- The remainder are correctable through expert examination and will be submitted within a few months.
- The Argo project has instituted new procedures to ensure more rapid detection and correction of systematic problems (see AST-8 meeting report).
- Users of Argo data are cautioned that the real-time data stream has been subjected to only coarse automated quality control.

# Instrument Biases

(plot from Gouretski and Koltermann, 2007)

## Temperature Offsets between Data Types

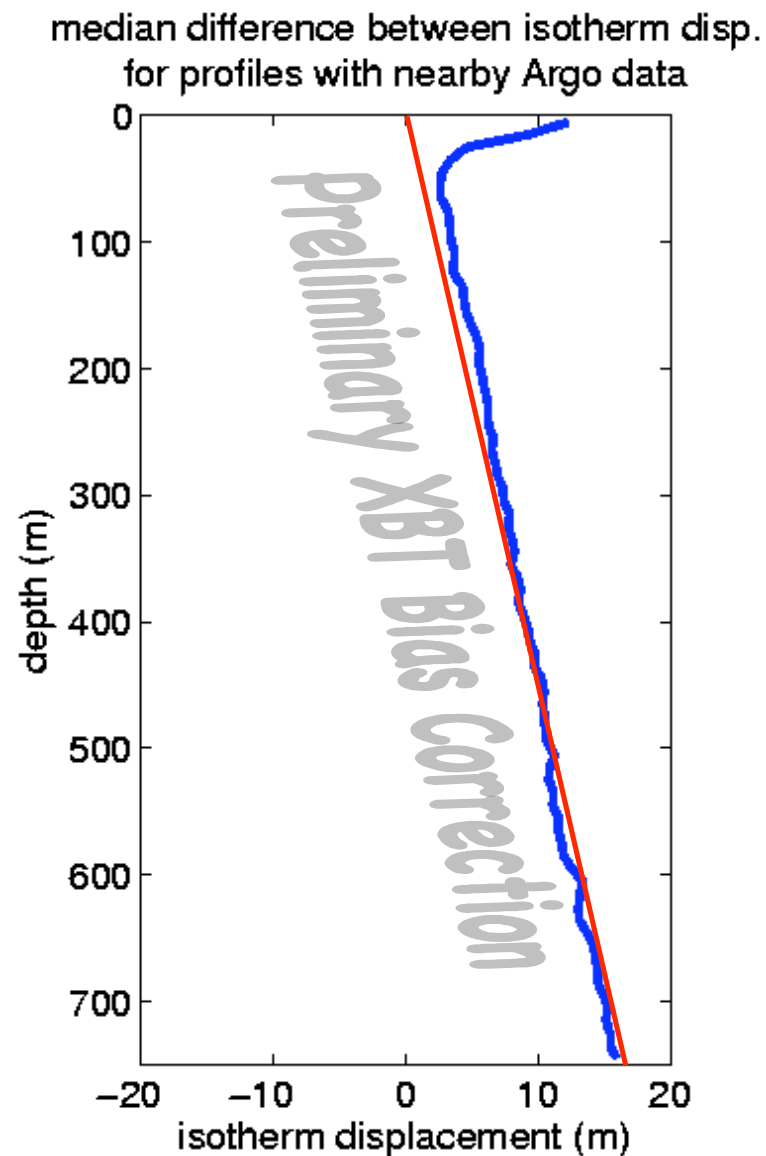


- Preliminary cut at the problem
  - XBTs 0.28°C warm on average of CTDs & Bottles.
  - Big difference!
  - Time-dependent?
  - Fall rate error?
    - Not so modeled by G&K 2007
- Wijffels et al. (in prep)
  - Interdecadal fall-rate variations from 0% to 5-6%
  - T4 corrections variations bigger than T7

# XBT Bias

(from Josh Willis)

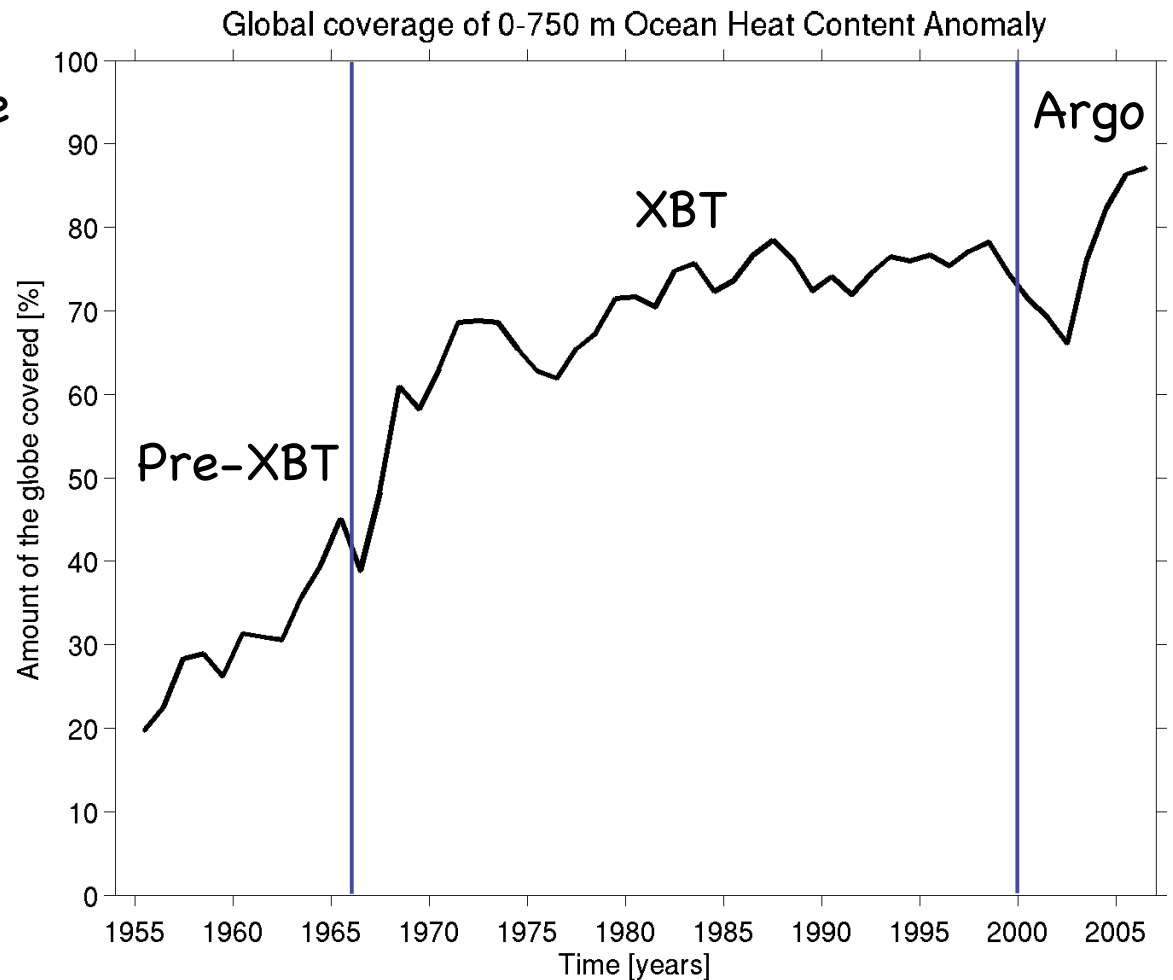
- CTD vs. Argo (not shown) no bias
- XBT vs. Argo & CTD shows bias ->
  - Consider 1990 - 2006
  - 2° lat., 4° lon., 90 days
  - Over 9,000 profiles
  - Mostly from Argo vs. XBT
    - Late in the record
  - Find differences of T anomalies
  - Use  $DT/dz$  to get depth anomalies
  - Yields ~97.7% of original rate
- More investigation required
  - Double and/or non-corrections?
  - Probe type & Manufacturer?
  - Interannual variations?
  - Ship-speed dependent?
  - Groups working on this problem



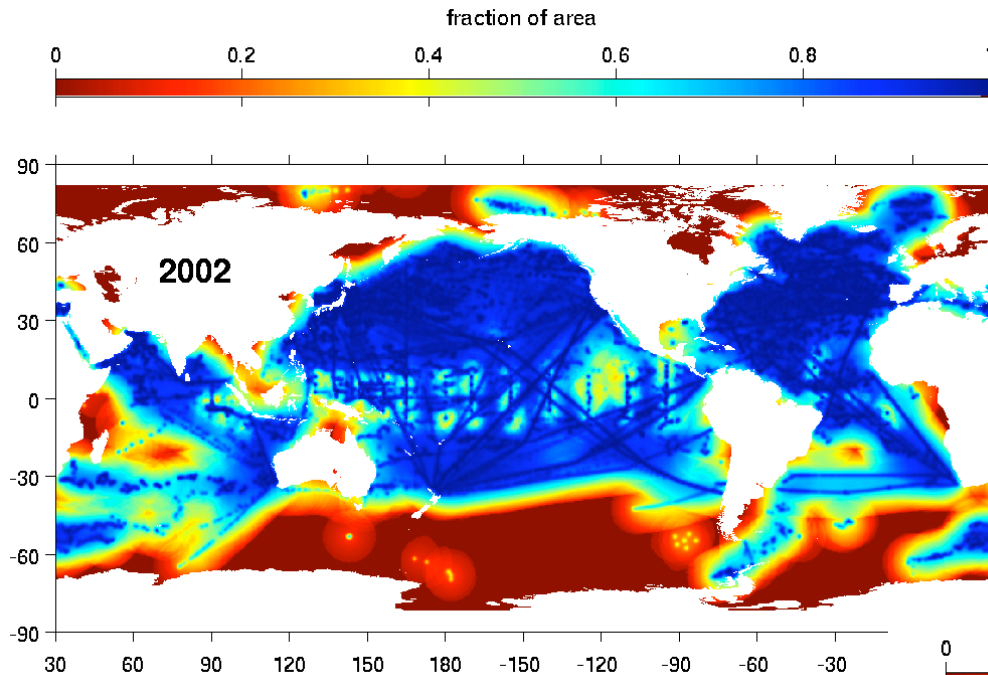


# Interannual Global Coverage Values

- Measure of in situ coverage
  - Data Distribution
  - Mapping parameters
- Three different regimes
  - Pre-XBT < 50%
  - XBT < 80 %
  - Argo already > 87%
    - Not yet 3000 floats
    - Not yet evenly distributed



# Interannual Variations in Global Coverage

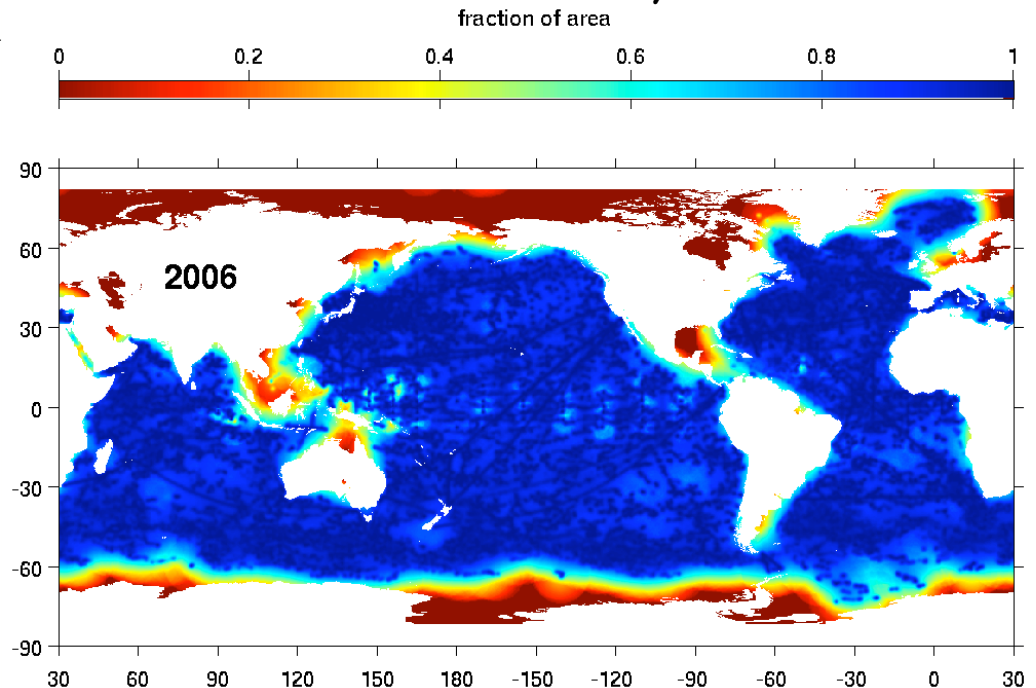


## •2002

- Blue high, Red low
- WOCE ↓ before Argo spun up
- Mostly XBTs & moorings
- Little S. Ocean coverage
- Will improve as NODC collects data
- Satellite altimetry fill

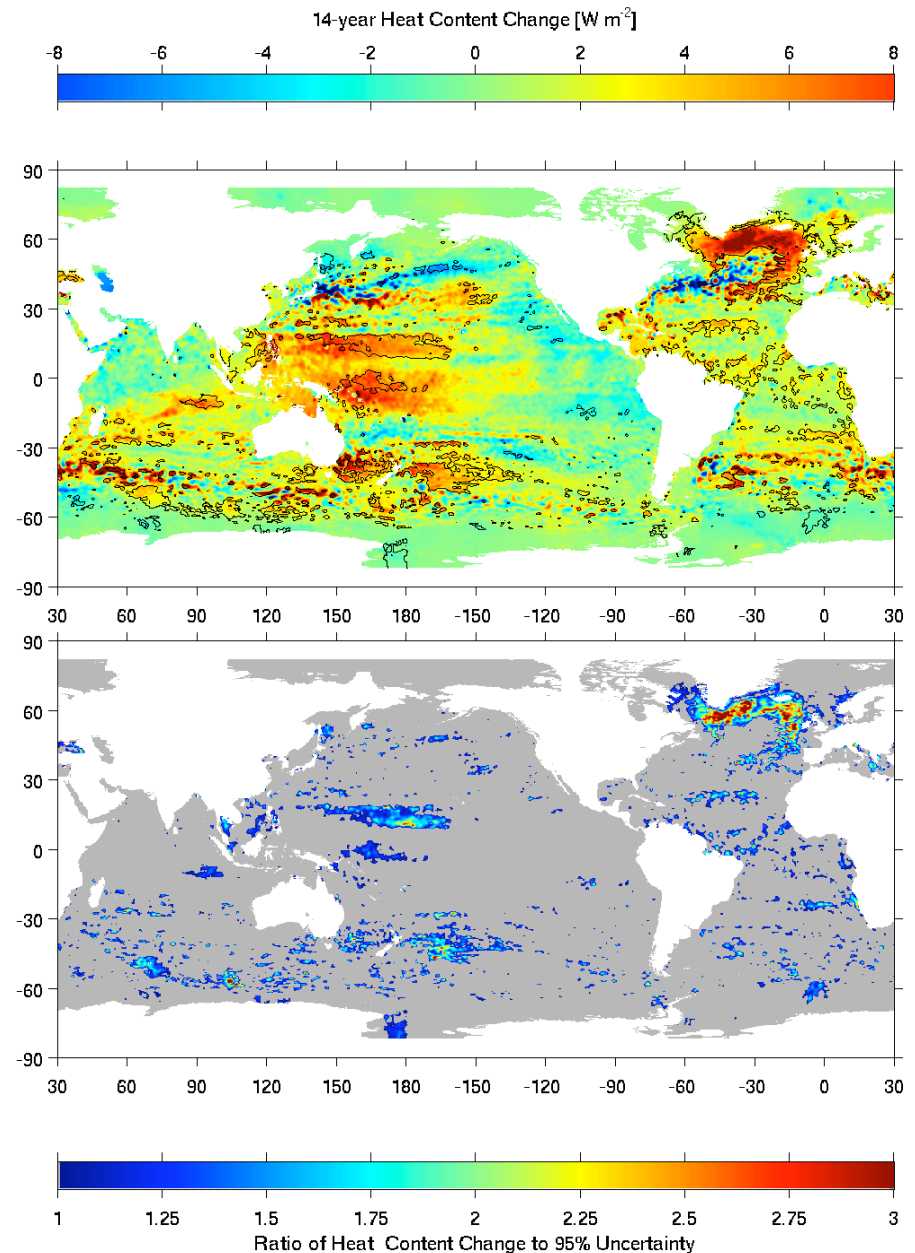
## •2006

- Argo spun up, mostly floats
- Climate Quality System
- Even spatial distribution
- Even temporal distribution
- Few gaps
  - Ice
  - EEZs
  - Shallow Seas



# Long Time-Scale (14-Year) Linear Trends

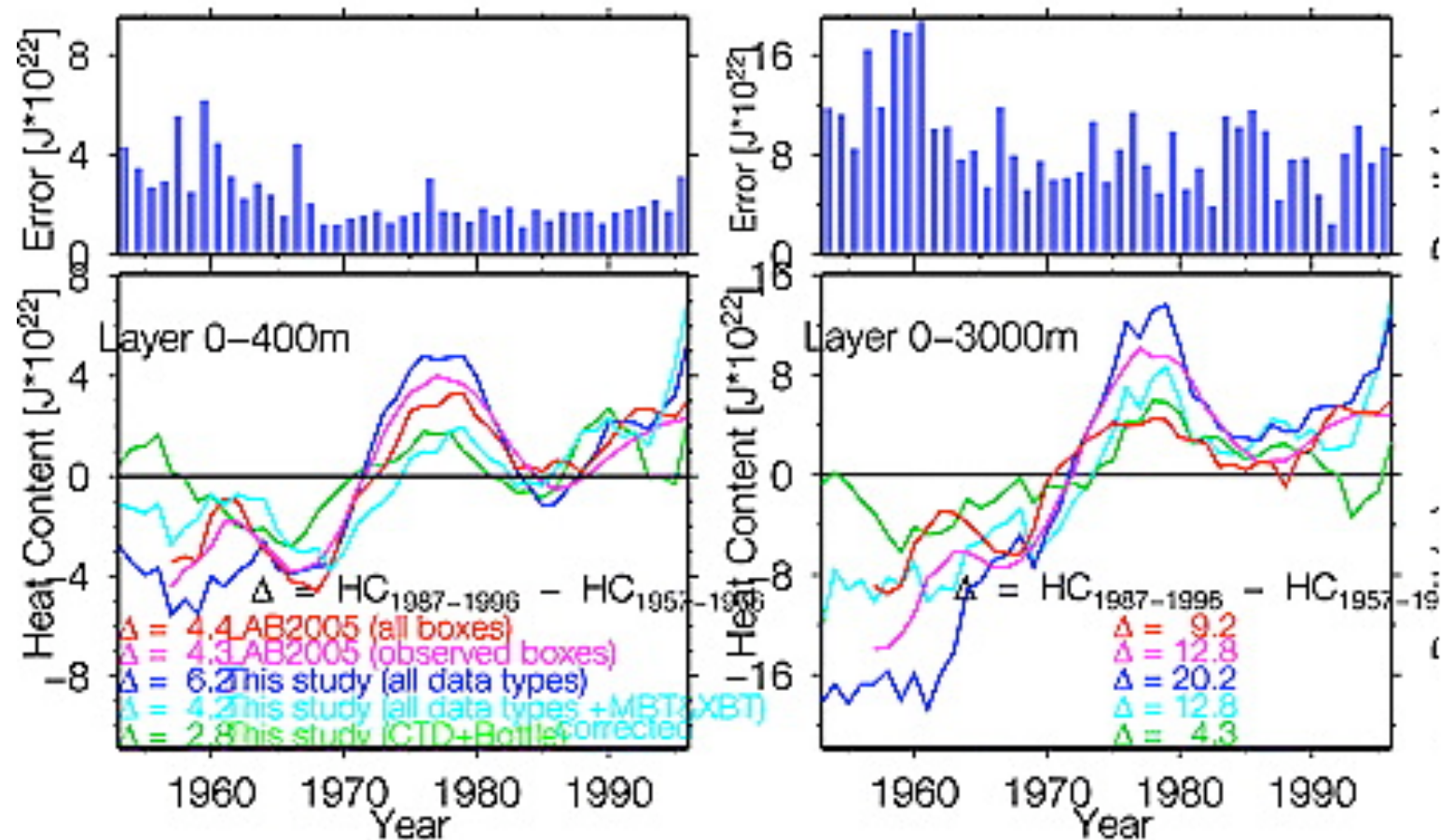
- Longer time-period (1993-2006)->
- Smaller amplitude & larger scale
- Big N. Atlantic Change
  - NAO 1996 shift in winds
- Big Southern Ocean Changes
  - SAM Large-scale wind shifts
- Smaller N. Pacific Change
  - PDO Large-scale wind shifts
- Overall warming trend?
  - ~ 5% of area at 95% CI
  - Hmm . . .
  - Look at global integral . . .



# Instrument Biases & Global OHCA

(plot from Gouretski and Koltermann, 2007)

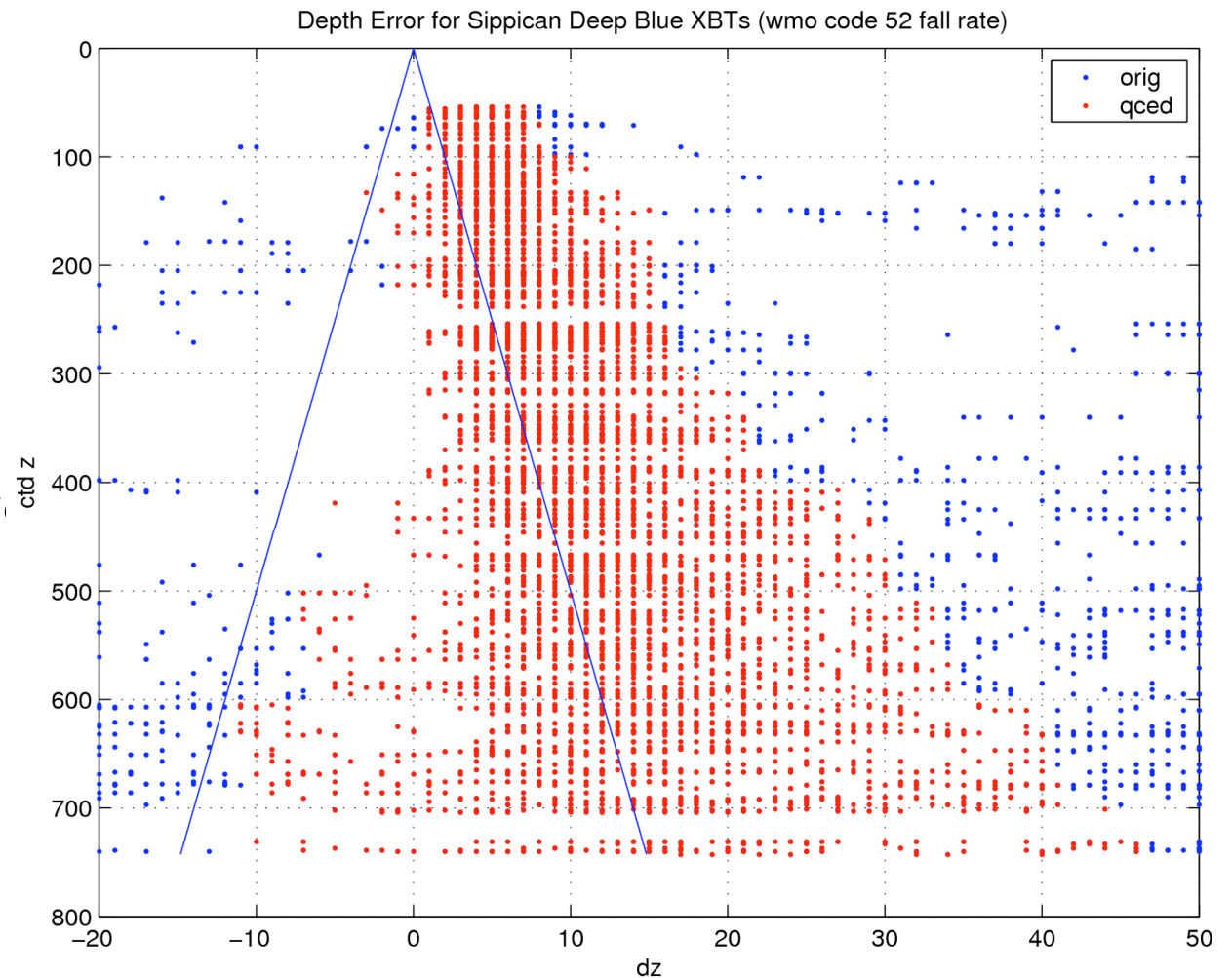
a) Global Ocean Heat Content Anomaly



- First cut bias correction (cyan vs. magenta)
- Reduces early 1980's downturn
- Increases significance of linear trend fit

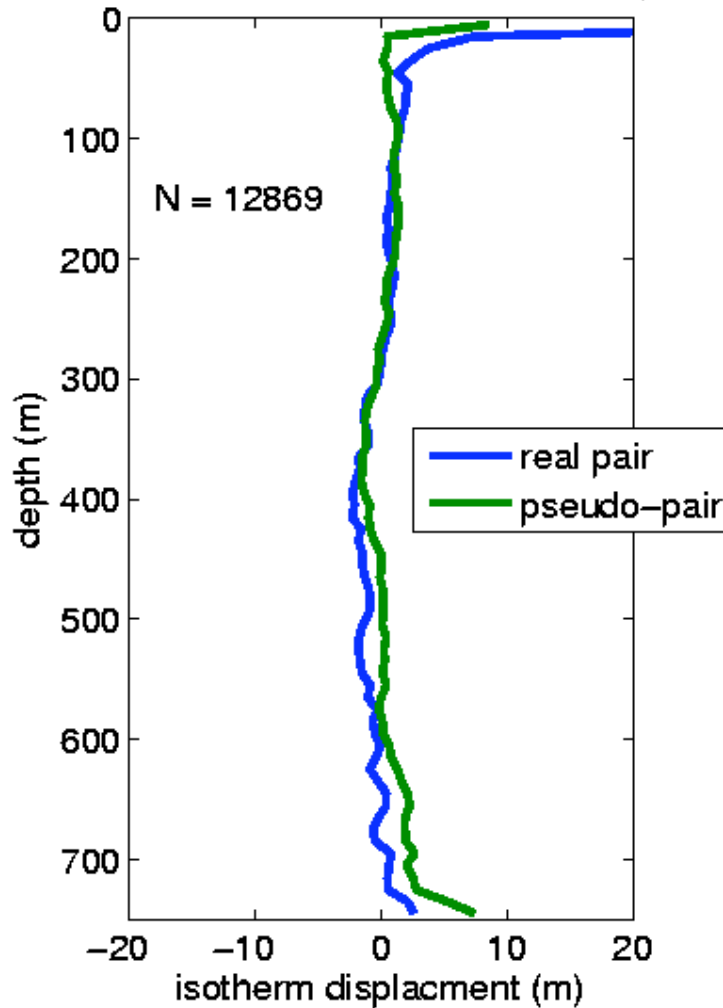
# Snowden, Goni, & Baringer XBT Evaluation

- 2005 intercomparisons
  - XBT launchers
  - Acquisition Systems
    - A to D boards
  - Significant
    - (Note caveat)
- Compare XBT to CTD data
  - Seven CTD casts
  - Dozens of XBT drops
- Hanawa (1995) fall rate about 3% too fast?



# Josh Willis' XBT Correction by SSH

median difference between isotherm disp.  
for corrected XBTs with nearby CTD pairs



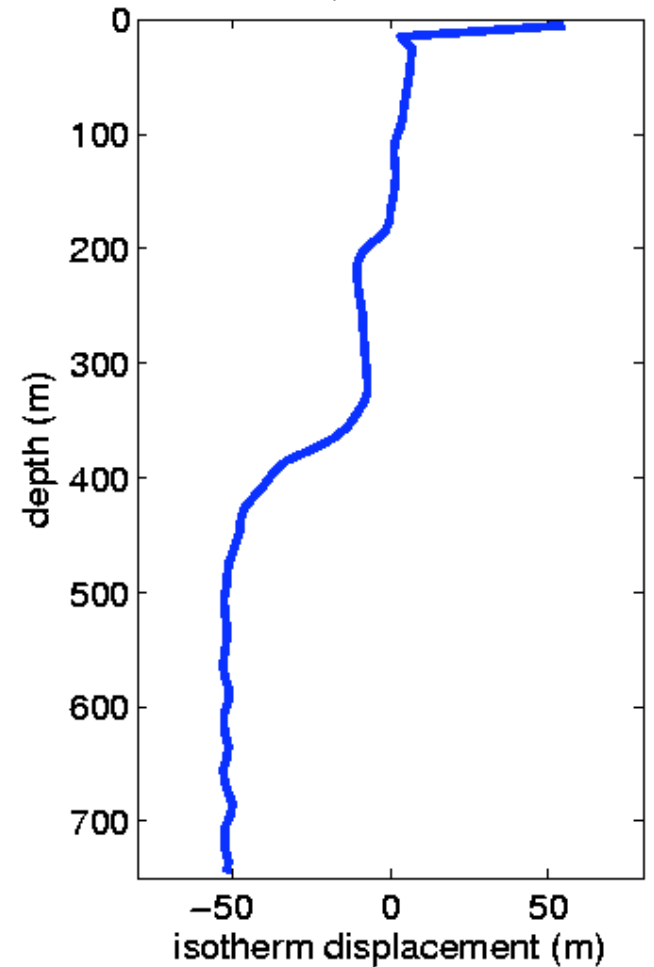
- Regress SSH to Argo temp data in x,y, & z.

- Compare various XBT types (by WMO number) to get year-by-year corrections

<- Real CTD/XBT pairs vs. pseudo-pairs after corrections applied

- Correction recommended for WHOI/SOLO/FSI floats ->

bias in isotherm displacement  
of FSI/SOLO floats  
based on comparison with altimetry



# Interannual OHCA with Willis' Time-Dependent XBT Correction

- Discard WHOI/SOLO/FSI floats
- Discard XBTs with lacking metadata
  - Increases sampling errors
  - Fewer data -> maps to zero
- Apply Willis time-dependent XBT correction
  - Warming reduced
- Four different climatologies
  - Remove means ->  $\sim 3 \times 10^{15}$  J std. deviations (small)

