Ocean Temperature, Heat Content and Thermosteric Sea Level Rise

Susan Wijffels with input from: M. Palmer, N. Rayner, G. Goni, B. Dushaw, S. Garzoli, N. Halliday, J. Willis, D. Roemmich, H Freeland, J. Church, G. Meyers

OceanObs2009 Venice

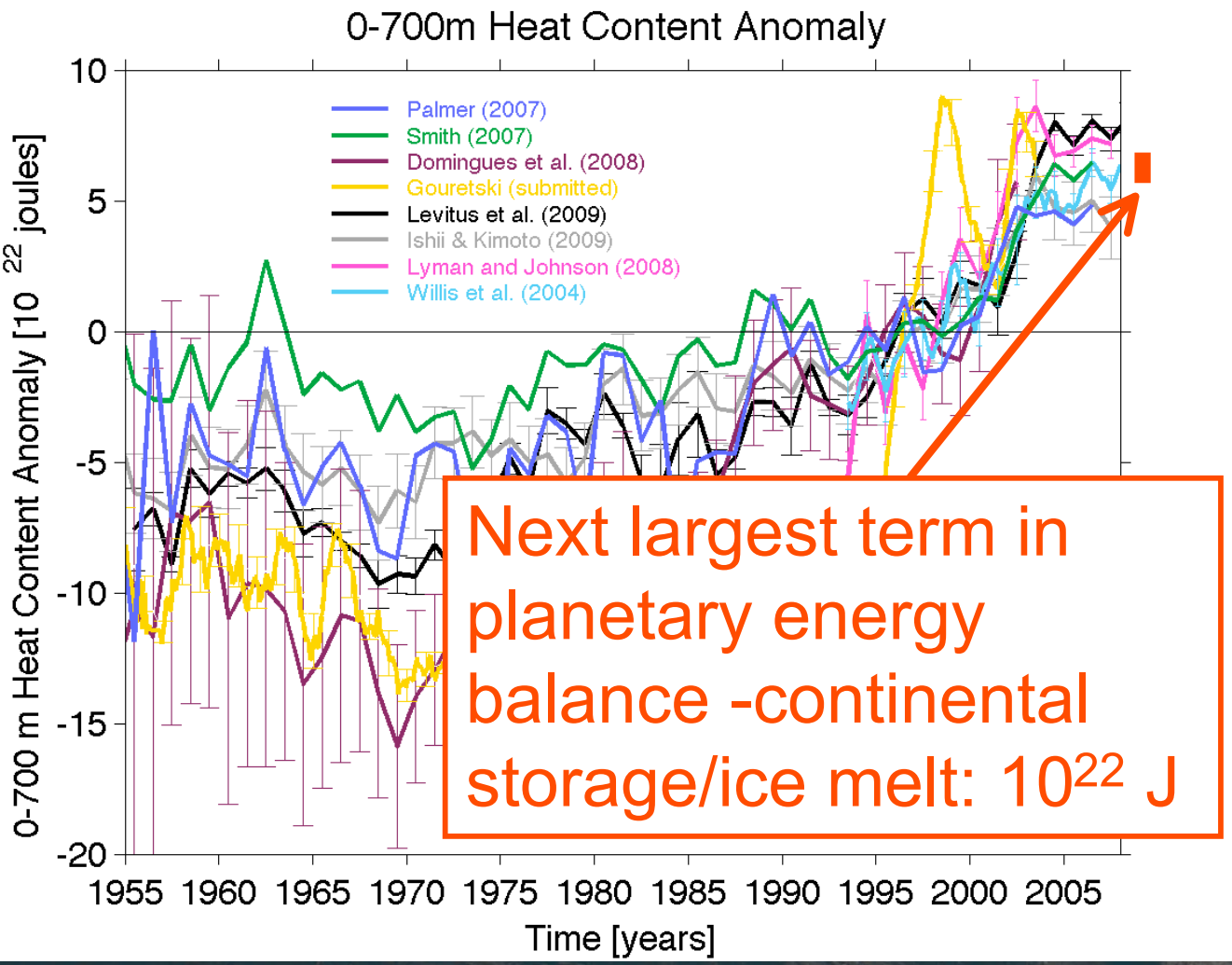
The need

- SST is a key influence on air-sea heat fluxes, underpins weather forecasting
- Ocean heat distribution is one of the primary sources of climate predictability
- The longer the time-scales the deeper we need to measure/monitor
- Marine ecosystems are sensitive to temperature change

The Grand Challenges

- Sustaining core existing systems – building on progress
- Filling major gaps: ice-covered and deep oceans; the marginal seas and coasts; developing new technologies
- Reconstructing the climate record: retrieving past data: data archaeology, digitisation, quality-control, bias removal
- Transitioning systems built for short term forecasting to service the needs of climate monitoring/prediction
- Provide clear and timely information on the state of the ocean and climate system

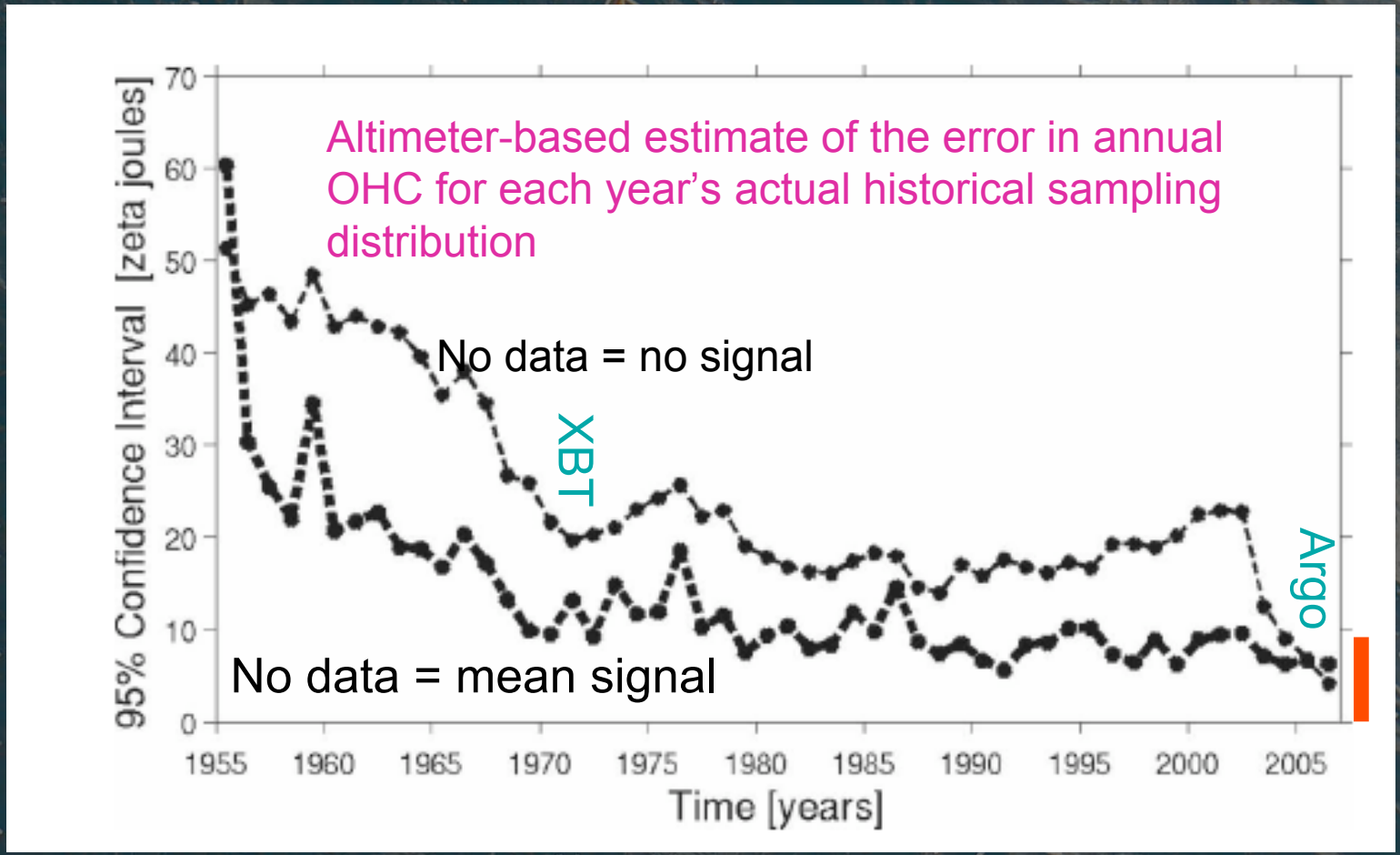
How well are we doing at tracking the planetary energy imbalance?



- Do not agree within error bars
- Note that the average 50 year warming is ~0.3 W/m^2

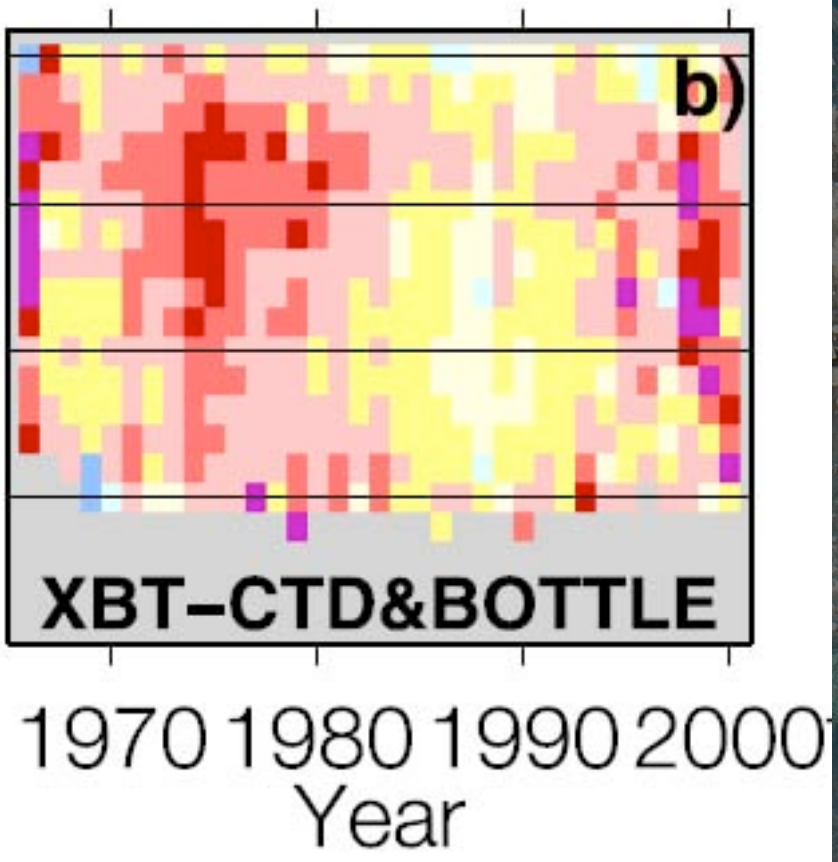
Error sources in Ocean Heat Content

- Random error and infilling assumptions

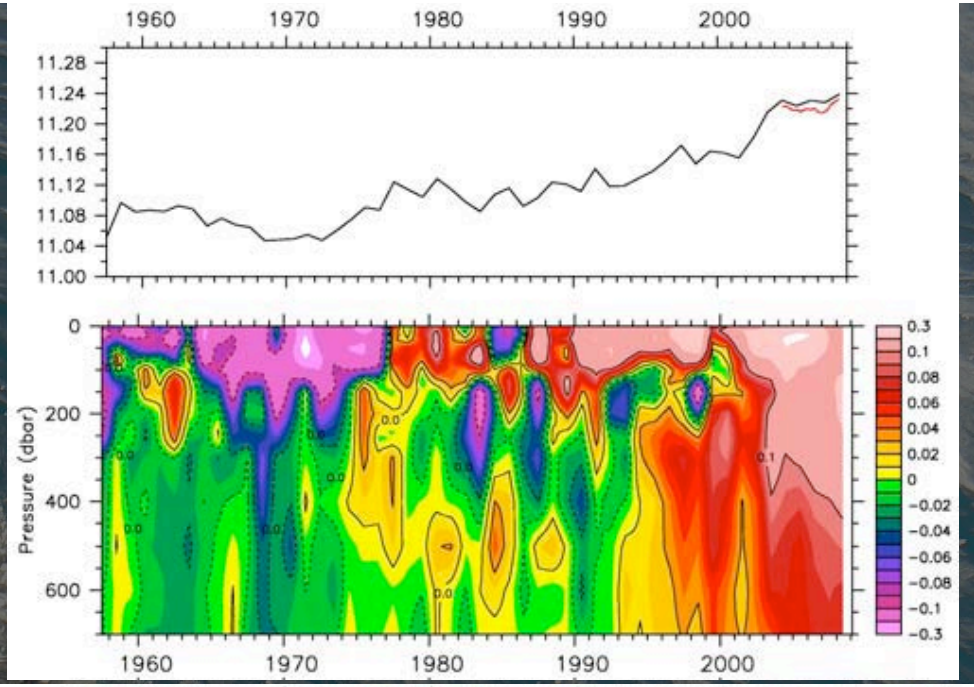


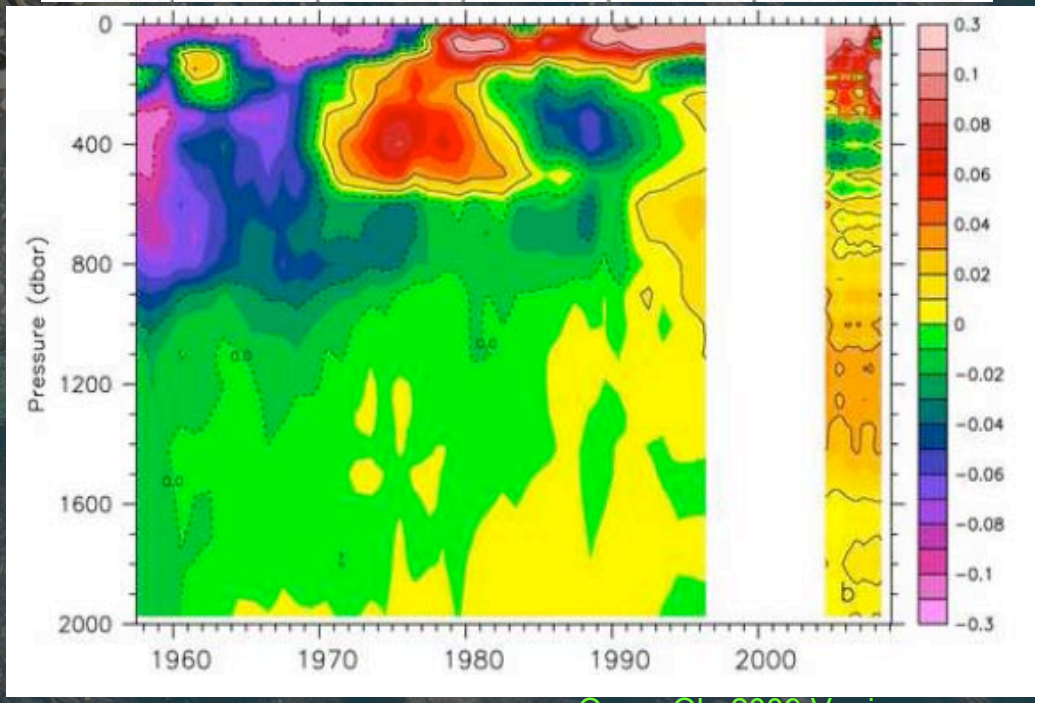
Lyman and Johnson, 2008

Impact of platform biases



Gouretski and Koltermann, 2007

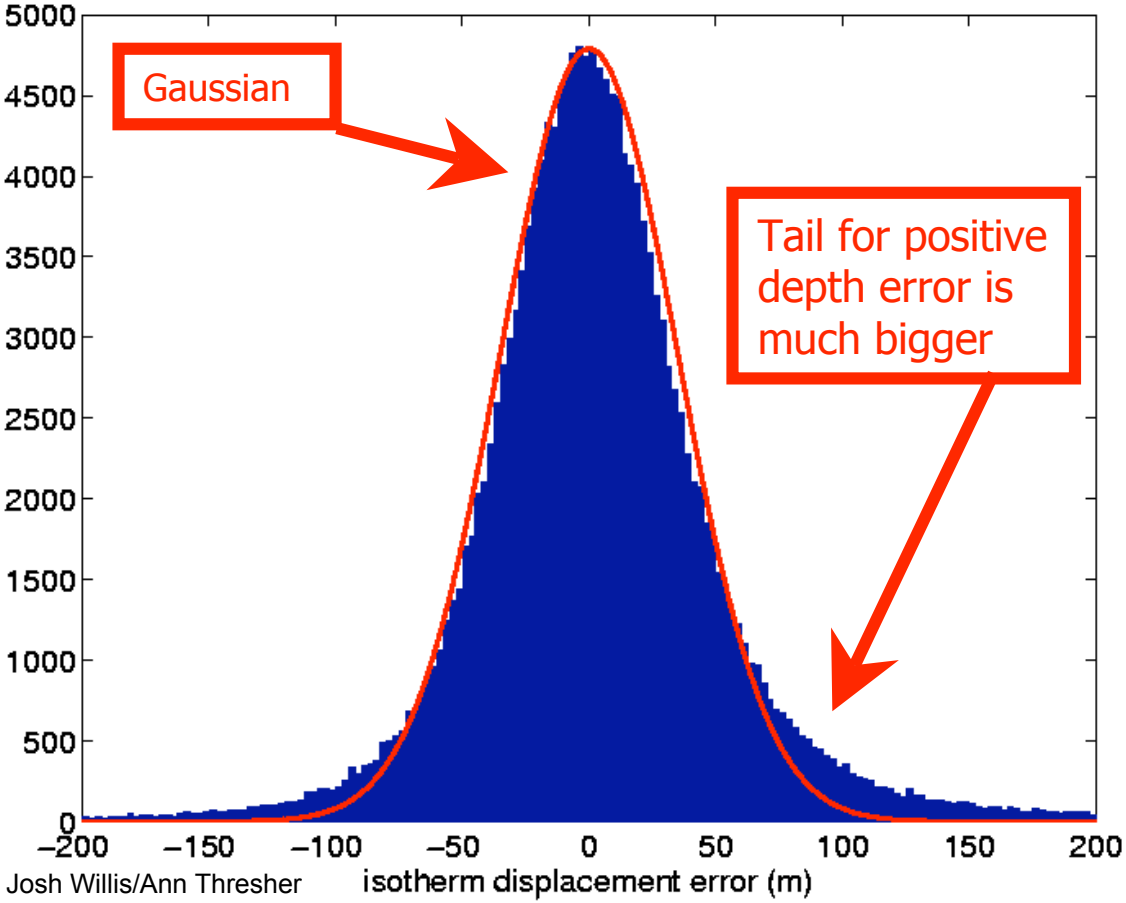




Gilson and Roemmich, 2009

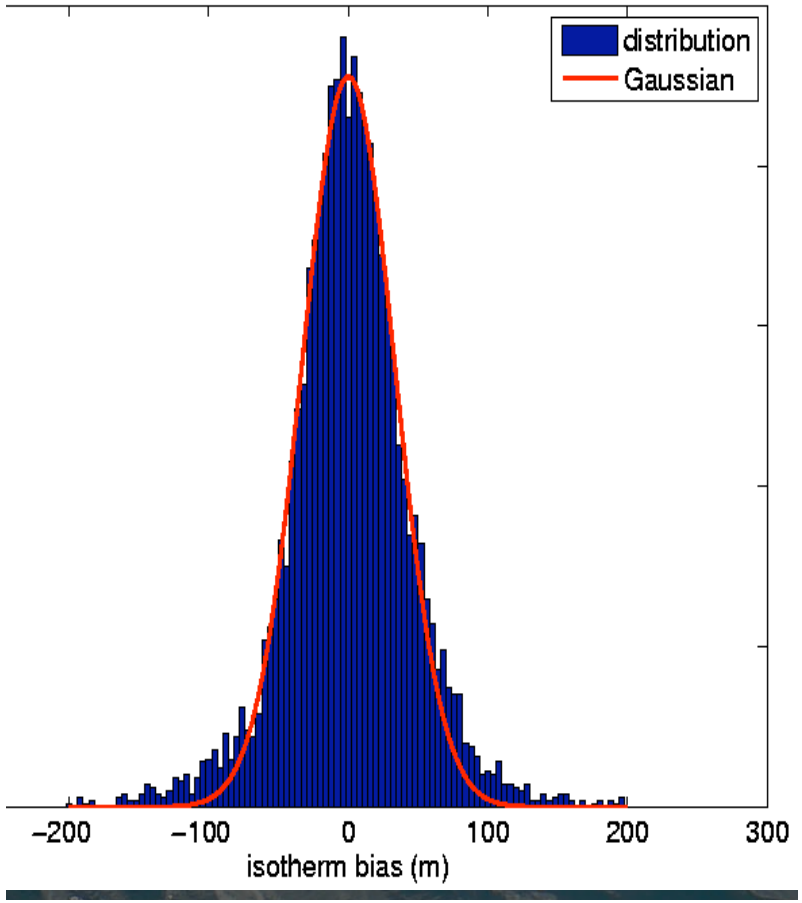
Remaining Errors: poor QC of XBT profiles results in a bias error skewing the mean

Data in global archives (WOD and GTSPP)



Josh Willis/Ann Thresher

Expert QC data for the Indian Ocean



Deep Ocean Warming

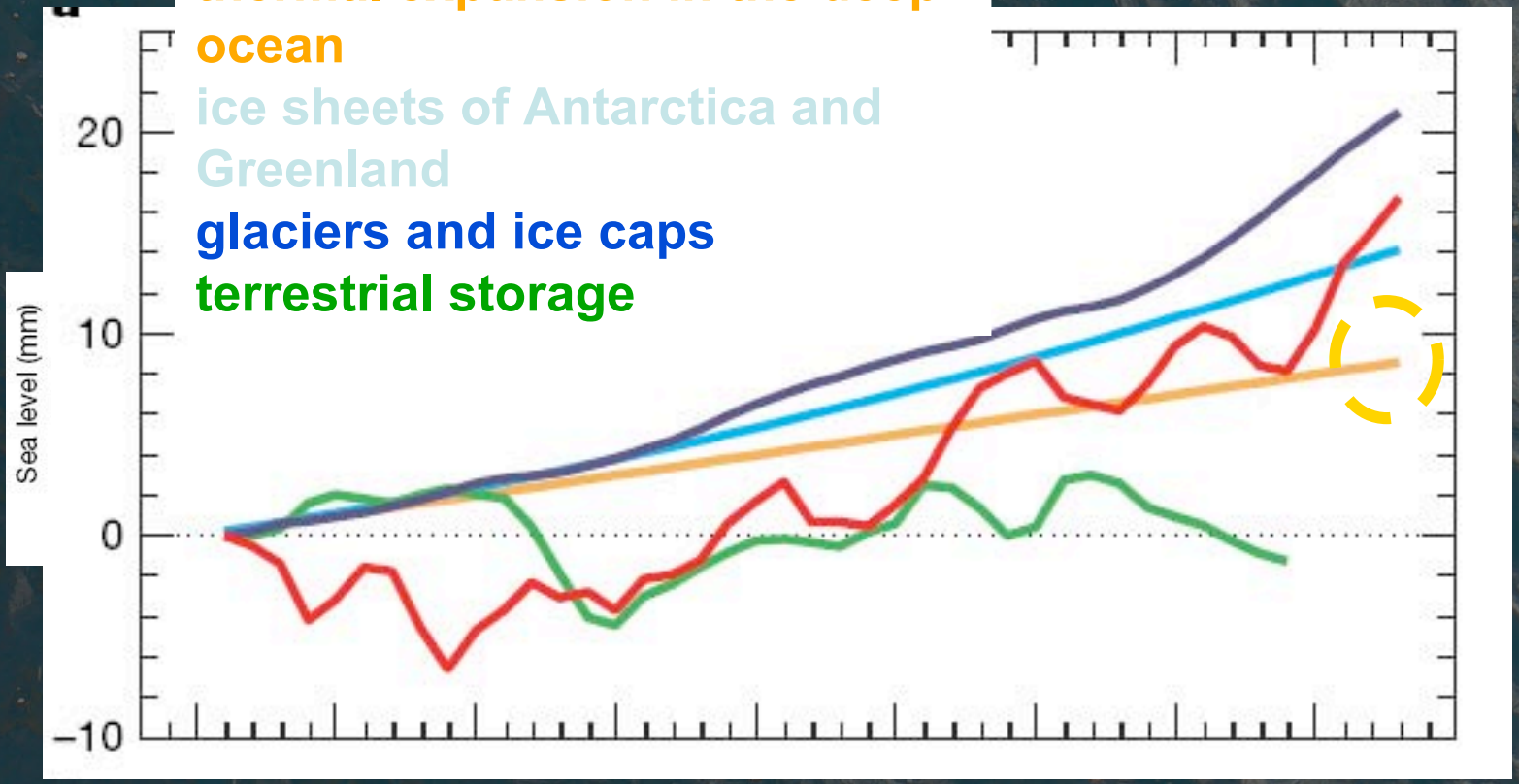
thermal expansion in the upper 700m

thermal expansion in the deep ocean

ice sheets of Antarctica and Greenland

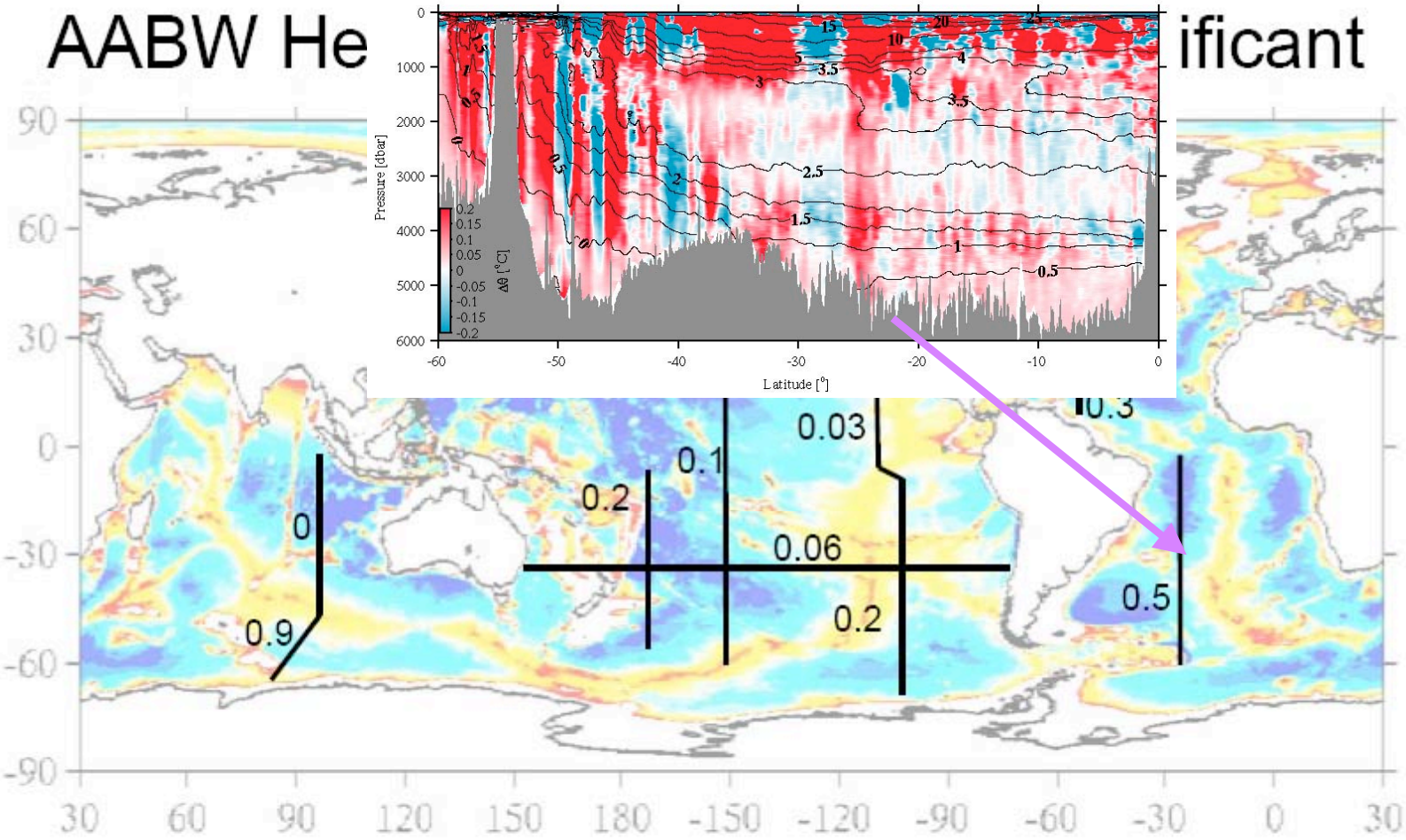
glaciers and ice caps

terrestrial storage



Domingues et al 2008.

AABW He ificant



- Section-averaged heat content change (W m^{-2}) below 3000 m
- The closer to AABW sources, the larger the heat gain.
- Compare to recent upper ocean changes ~0.6 W m^{-2} ***(global)***

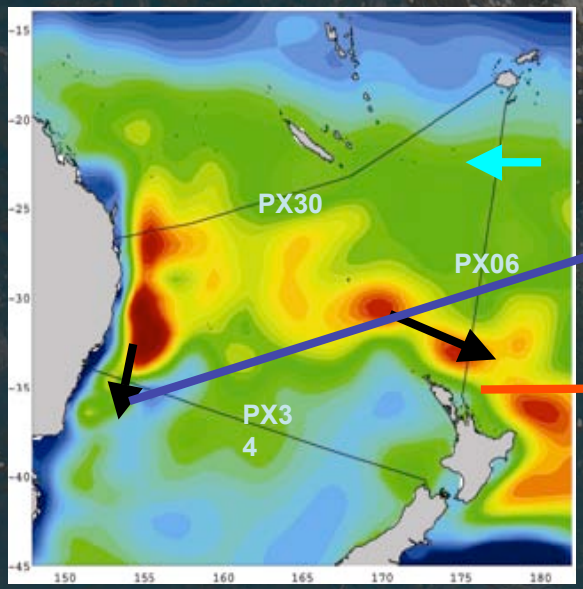
From Greg Johnson

Progress in the last 10 years

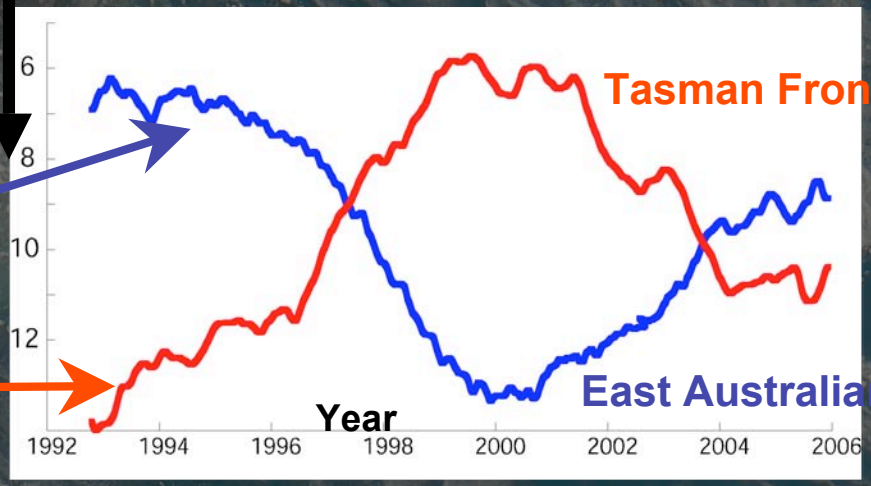
- Argo close to design density: 2800 active of 3000 needed
- Improvement in global distribution and number of surface drifters for SST
- Continuous high precision satellite altimetry
- Extension of coverage of the tropical moored arrays
- GHRSST Project – reinvigorated the science of SST estimation – new and better SST products (with errors)

Transition of XBT network towards Frequent or High Density sampling

- Complement Argo/altimetry
- Transport monitoring, mesoscale resolving
- Several lines are reaching past 20 years of sustained sampling giving precious insight into decadal variability



increasing



From Ken Ridgway, CSIRO

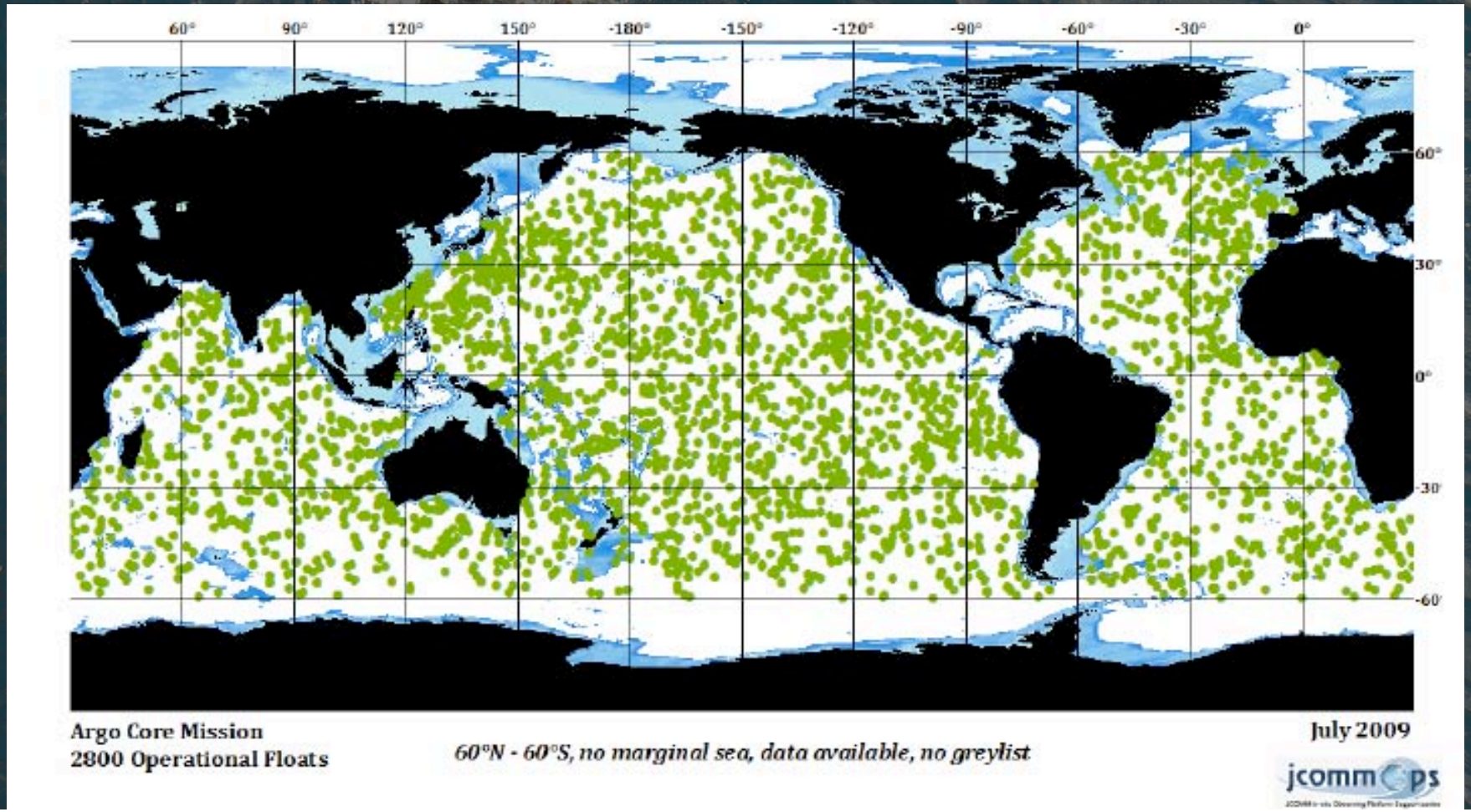
Key Actions: sustain

- Complete and sustain the Argo core mission
- Complete and sustain the global surface drifter array
- Sustain multiple platform and sensor approach to satellite SST missions
- Sustain high precision and global mesoscale resolving satellite altimetry
- Ensure adequate mission overlap to intercalibrate the sensors for a seamless record

Key Actions: Gaps

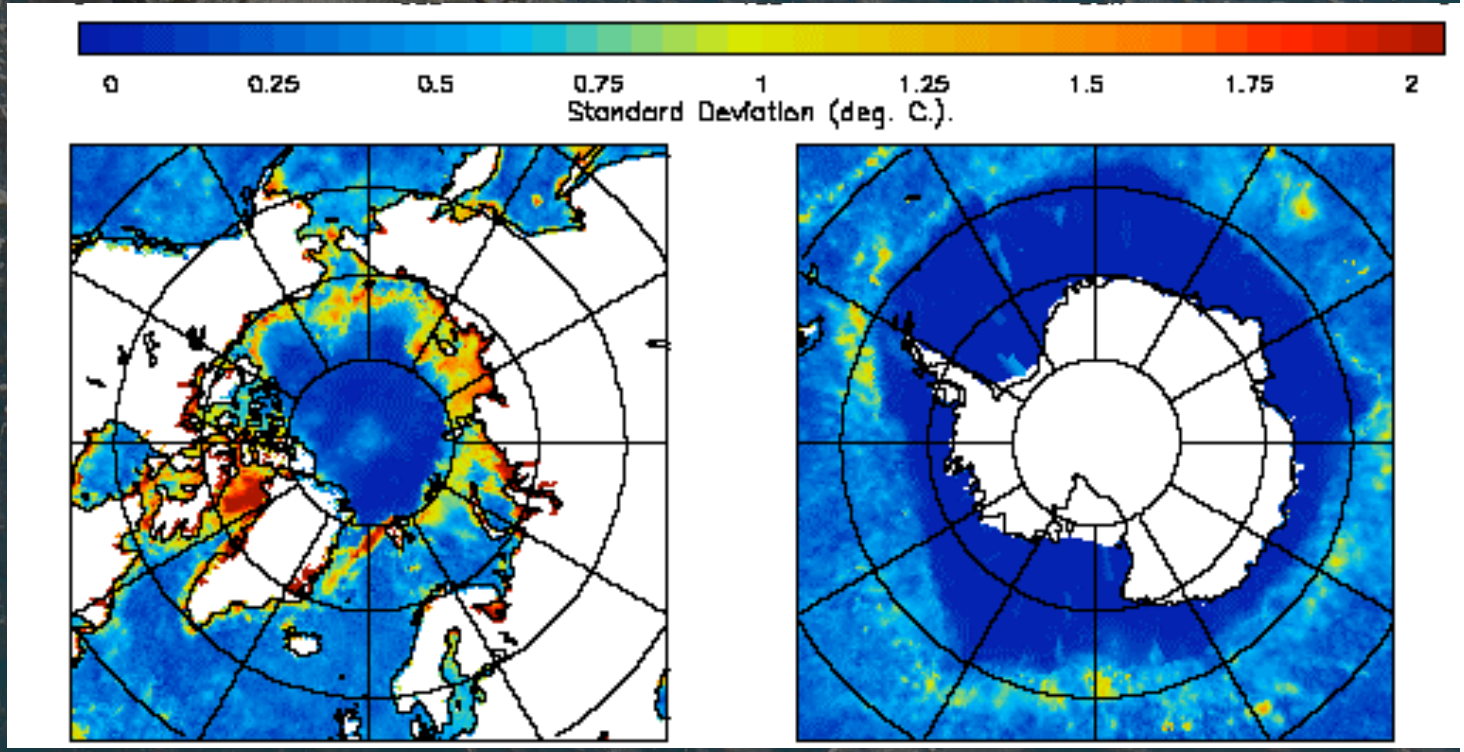
Argo has not achieved its core mission of 1 float every 3 x 3 degrees in the ice-free open ocean

Need 3000 active good platforms, but we only have 2800 operating - the Southern Hemisphere remains undersampled



Gaps: seasonal and fast ice zone

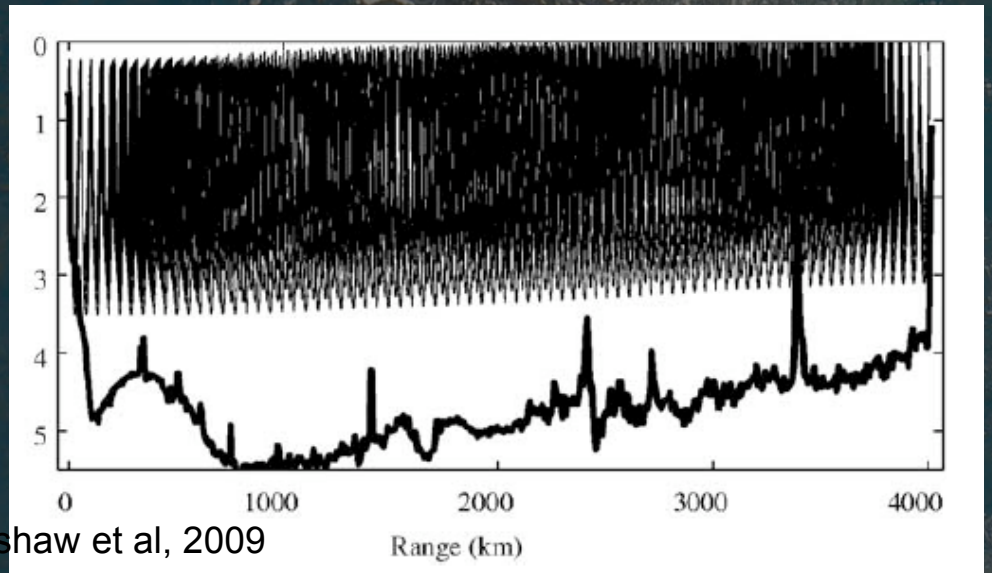
- little subsurface profile data – winter climatology poorly known let alone the variability
- few SST measurements – difficulty in using satellite data streams here



Donlon et al, CWP

Key Actions: gaps

- Extend Argo to the seasonal ice zone combined with animals as platforms program
- Develop and pilot broad-scale deep ocean monitoring technologies to inform a global future strategy. Optimize the mix of deep moorings, deep profiling floats and gliders, ocean acoustic thermometry



Dushaw et al, 2009

Key Actions: gaps

- Target major marginal seas for the design and implementation of an observing system
- Implement high-resolution near surface profiling on Argo for better calibration of satellite SST
- Complete the global surface drifter array with particular attention to high latitude oceans

Reconstructing the Climate Record

- Data archaeology and quality control are Cinderella sciences
- QC of historical archives requires expert manpower and is thus expensive
- It is a pre-requisite for reconstructing past history of the ocean state – the community is investing large amounts in reanalysis/assimilation machinery – we need comparable investment in assembly and QC of the feeder data sets

Key Actions: The Climate Record

- Need more platform and system intecomparisons/syntheses: WOD (T(z)) vs ICOADS T(Om), satellite SST, T(z) vs altimetry
- Establish stronger effort in digitising and quality-controlling historical SST and T(z) data – this must cease to be a cinderalla activity
- Establish (or re-establish) delayed-mode QC systems for data streams that do not have them – XBT, surface drifters, ???

Key Actions: The Climate Record

- Rehabilitation and digitisation of historical data – GODAR, other projects
- Some redundancy is needed to ensure intercalibration of platforms and satellite missions
- Encourage both model (re-analyses) and statistical syntheses - historical and in near-real time (reveal platform inconsistencies and QC problems)

System Transition

Some of our *in situ* network and associated data distribution and management systems were designed and are still operated for the purpose of short-term numerical weather forecasting

- use once and discard
- gross and automated QC
- low accuracy
- meta-data poor
- little involvement of research community

System Transition

The demands for climate monitoring and forecasting are very different

- keep forever and use many times
- stringent QC
- high accuracy
- meta-data rich
- strong involvement of research community

We must transition our legacy data streams to include the needs of climate

We must ensure our new data streams serve both short-term forecasting needs and climate applications e.g. Argo

The Grand Challenges

- Sustaining core existing systems – building on progress
- Filling major gaps: ice-covered and deep oceans; the marginal and coastal seas; developing new technologies
- Reconstructing the climate record: retrieving past data: data archaeology, digitisation, quality-control, bias removal
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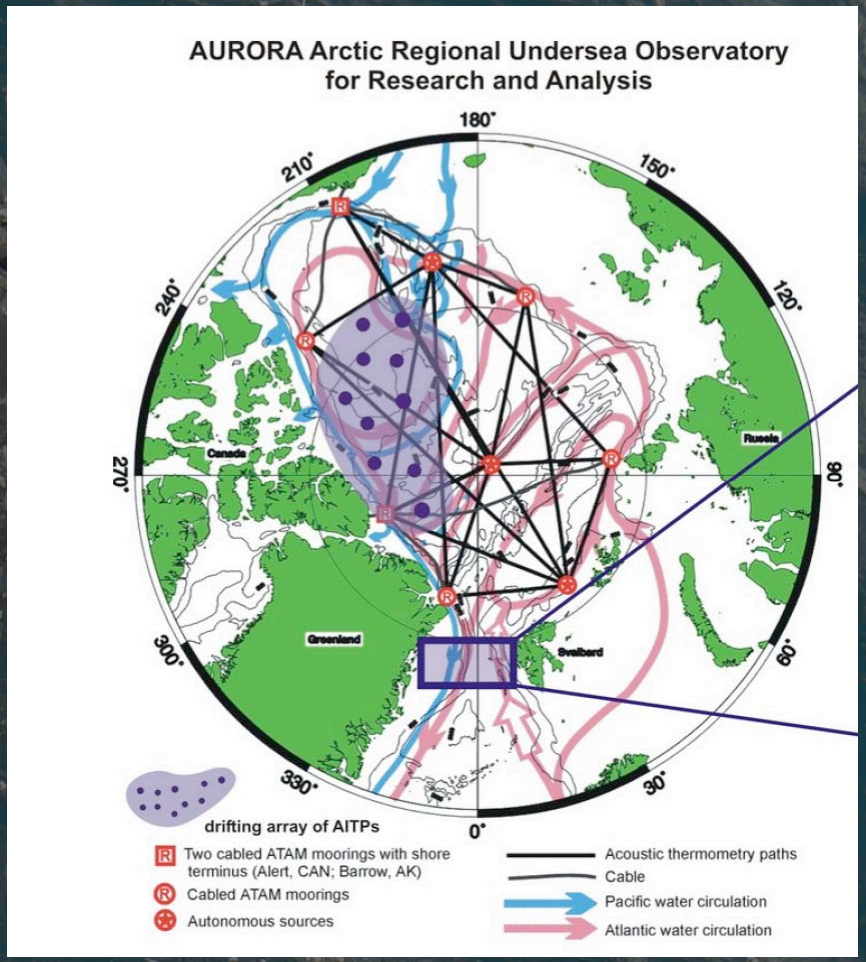
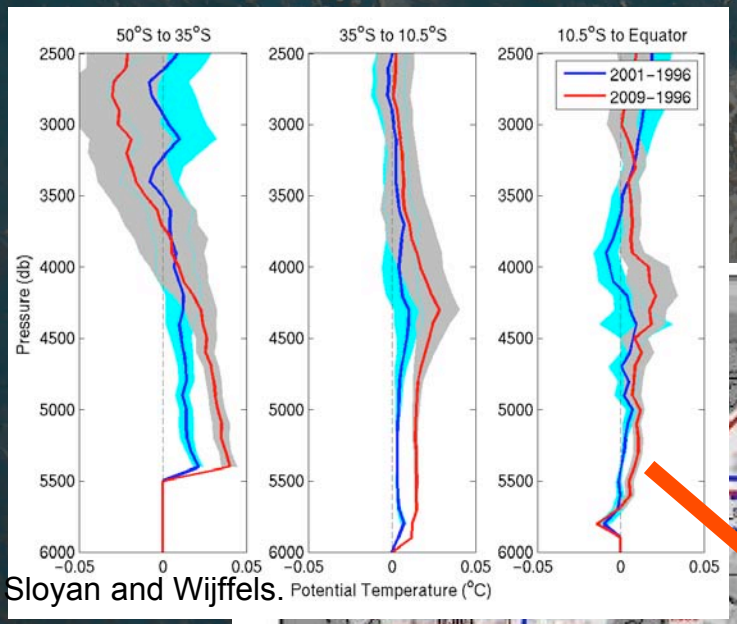
END OF TALK

- Extra slides follow

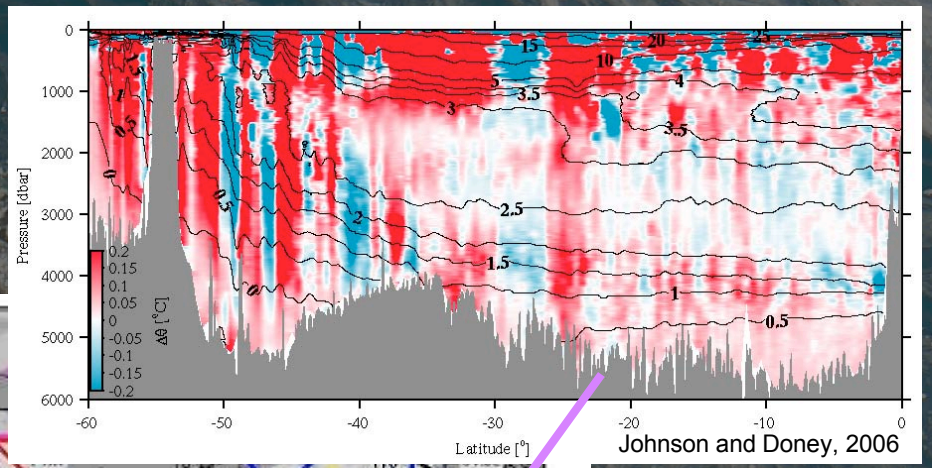


OceanObs2009 Venice

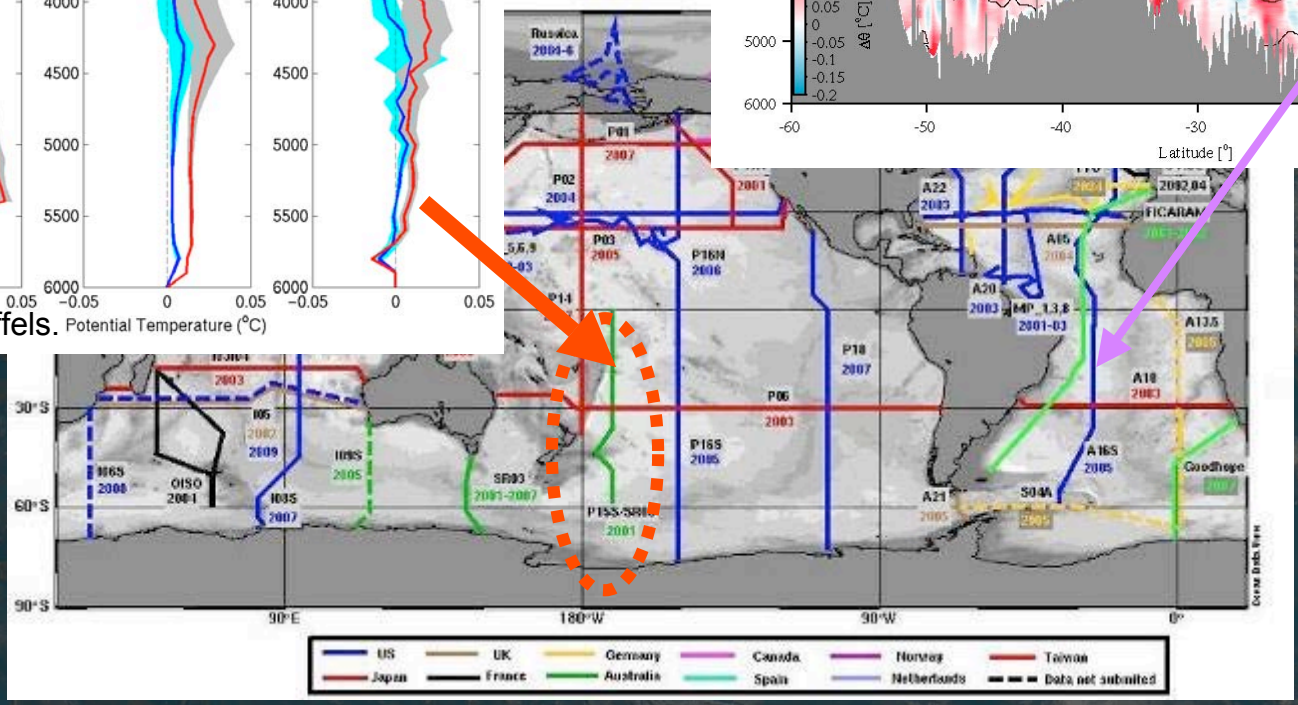
Gaps: the ocean below 2000m



Sloyan and Wijffels.



Johnson and Doney, 2006



- Widespread and rapid warming is being detected

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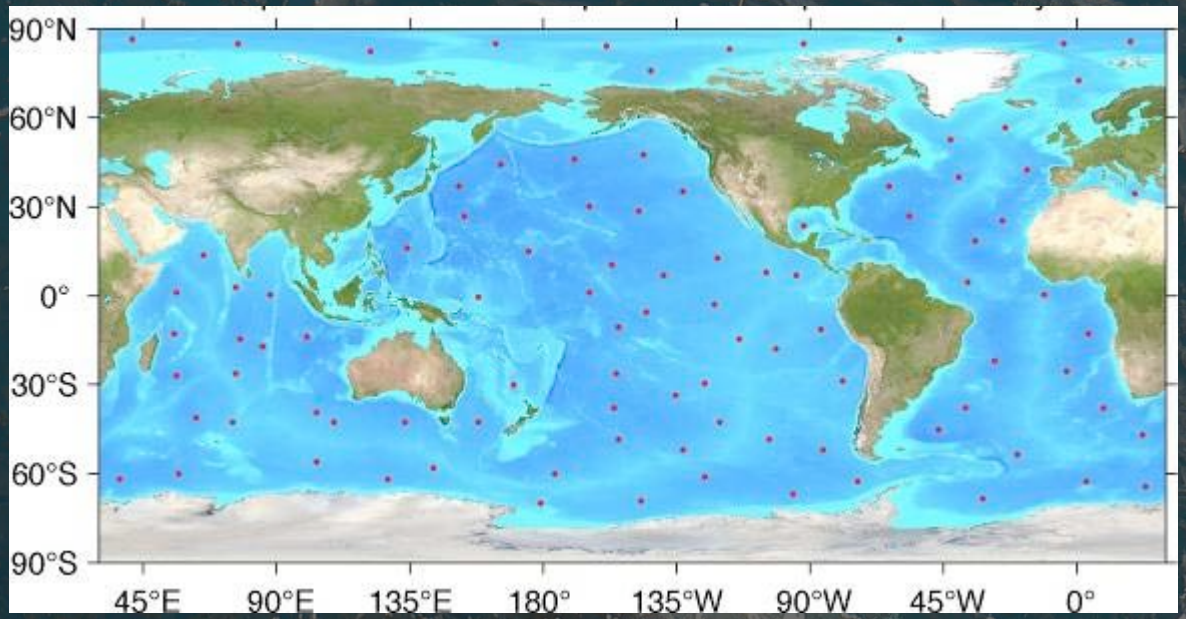
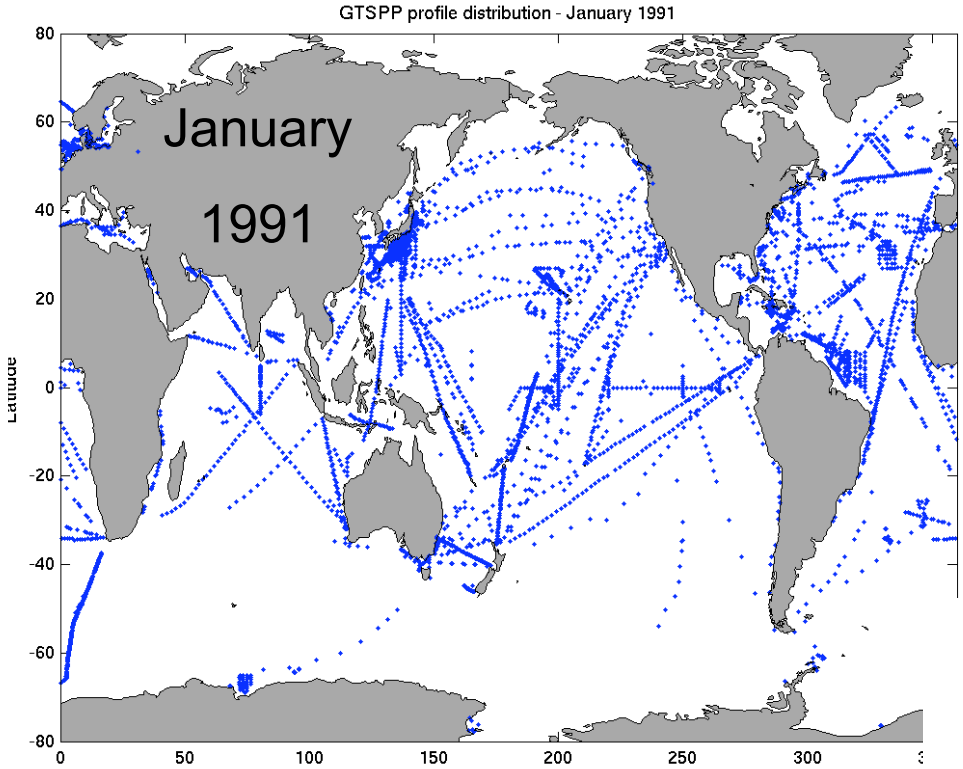
Expansion of the existing observing system to quantitatively measure the ocean heat content below 2000 m on a more routine basis is critically needed in order to obtain a truly global estimate of ocean heat content and its relationship to climate change.

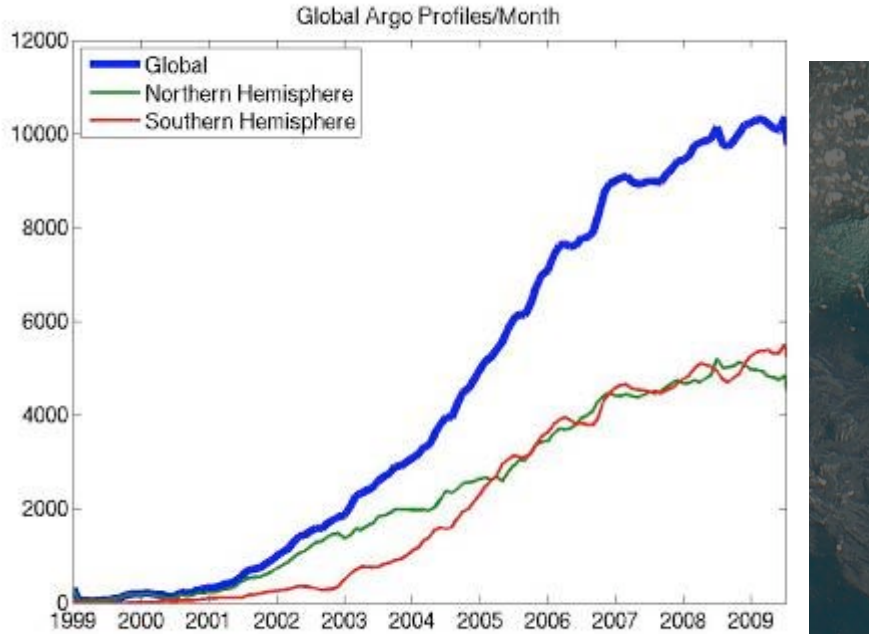


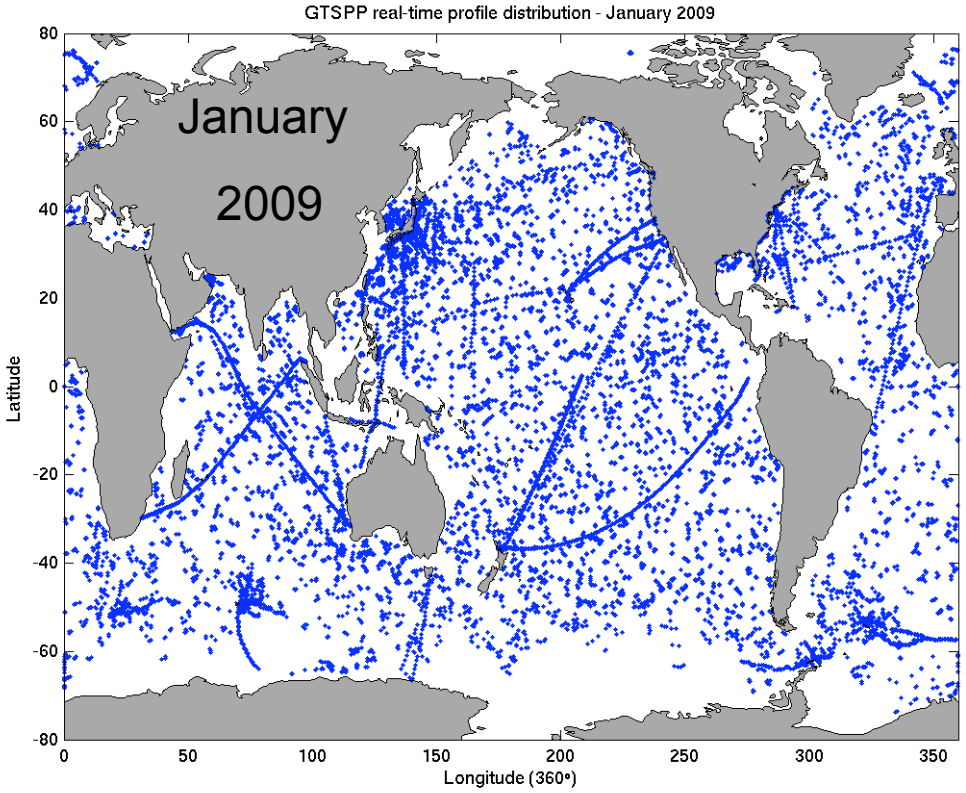
It is critical to monitor flow rates and properties of deep water at sites where upper ocean waters are injected into the deep ocean and where these waters are exchanged between sub-basins.

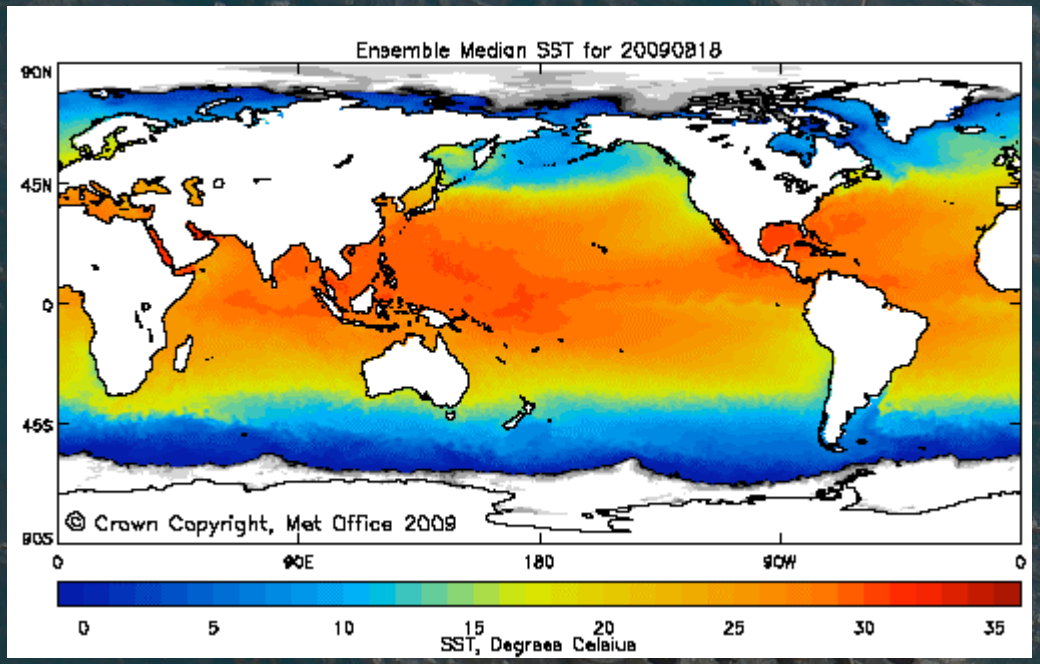
Idealized recommendation for a network of sites where deep temperature and salinity observations should be collected. A more dense array of measurements are envisioned at the locations of the deep circulation sites. The actual number of measurements required to quantify global changes in heat and freshwater storage may be more than indicated in this schematic.

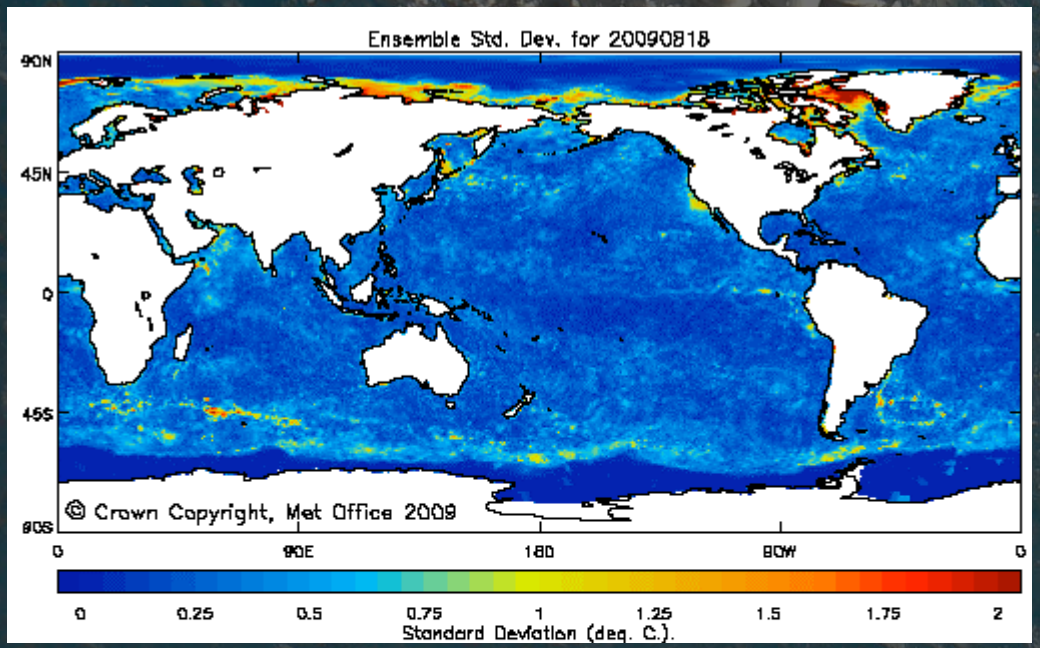


Major progress in real-time subsurface observing:
the implementation of Argo
- true global coverage
- extend sampling from 700m to 2000m





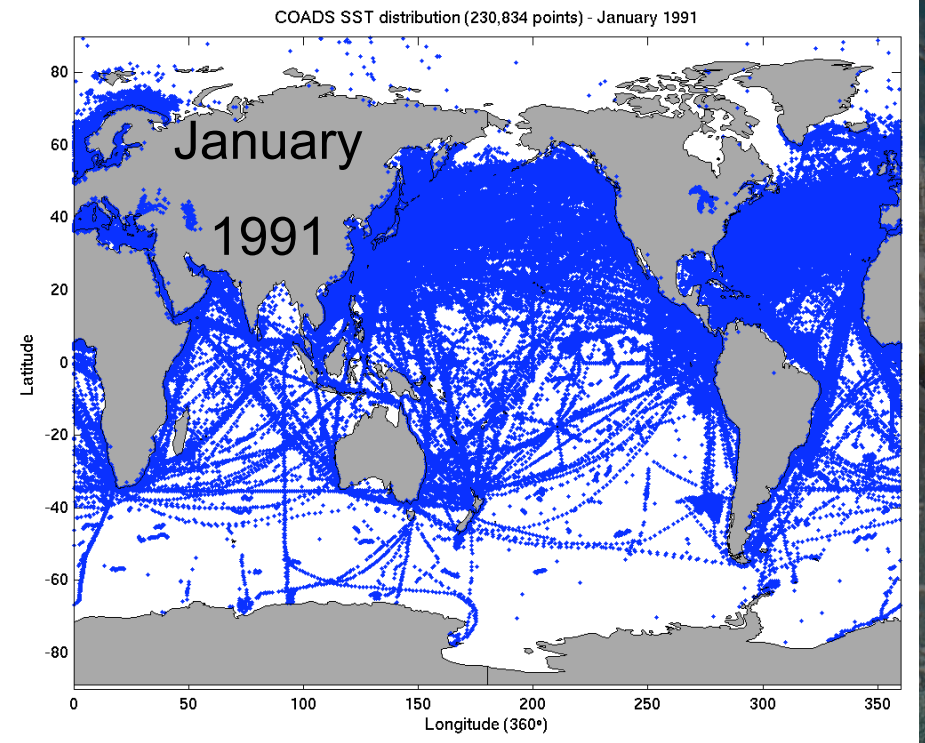




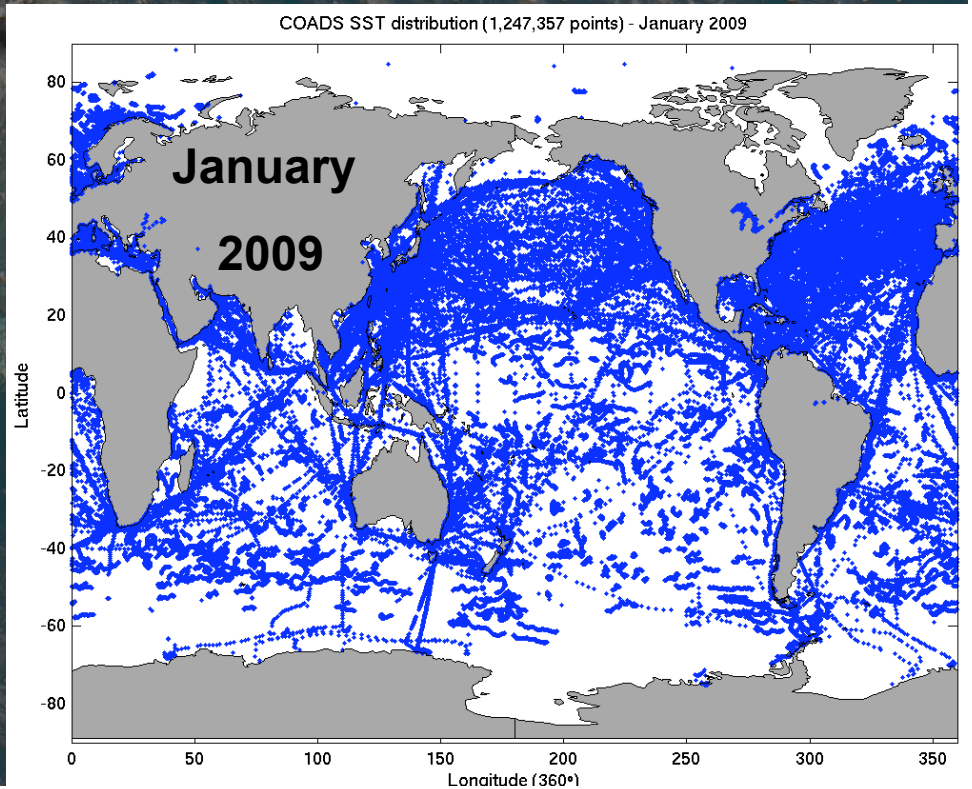
Progress: Global High Resolution-SST Project

- Re-engaging the research community in the science of SST measurement
- Exploiting multi-satellite/sensor mission
- Community consensus approaches to satellite/*in situ* synthesis and error estimation

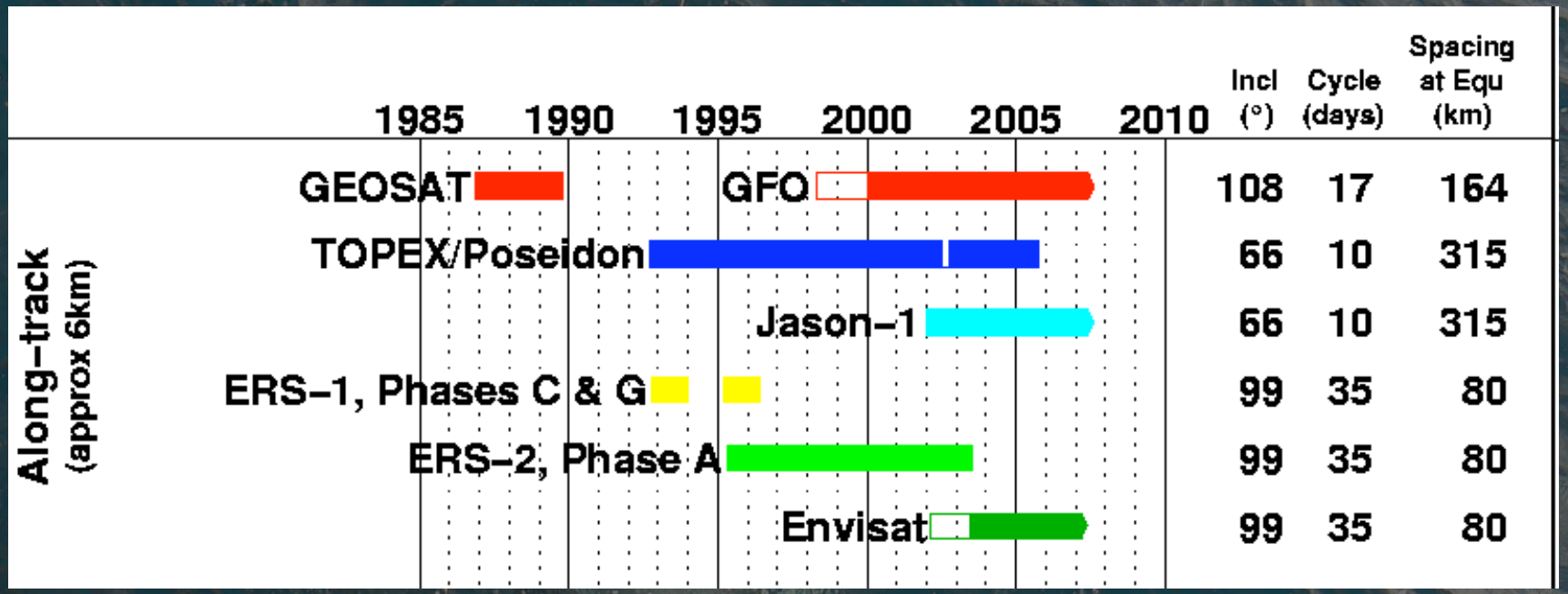
Steady growth and better global coverage of *in situ* SST returns



- Largely achieved through growth of surface drifter array

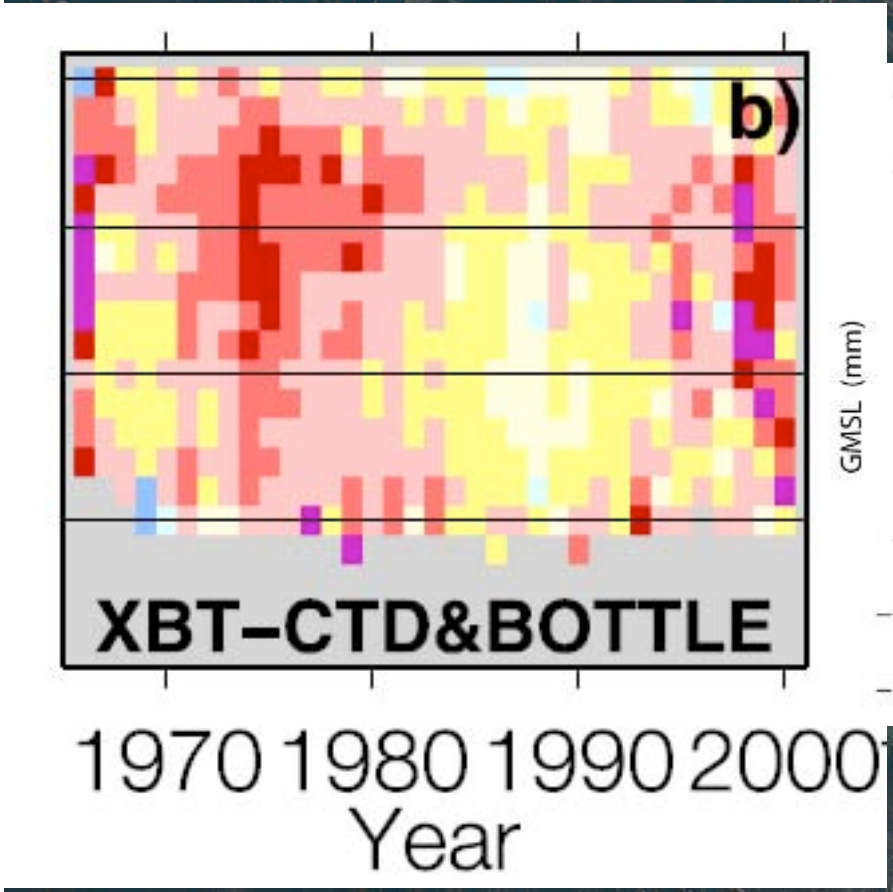


Progress:10 years of multiple satellite altimetric mission

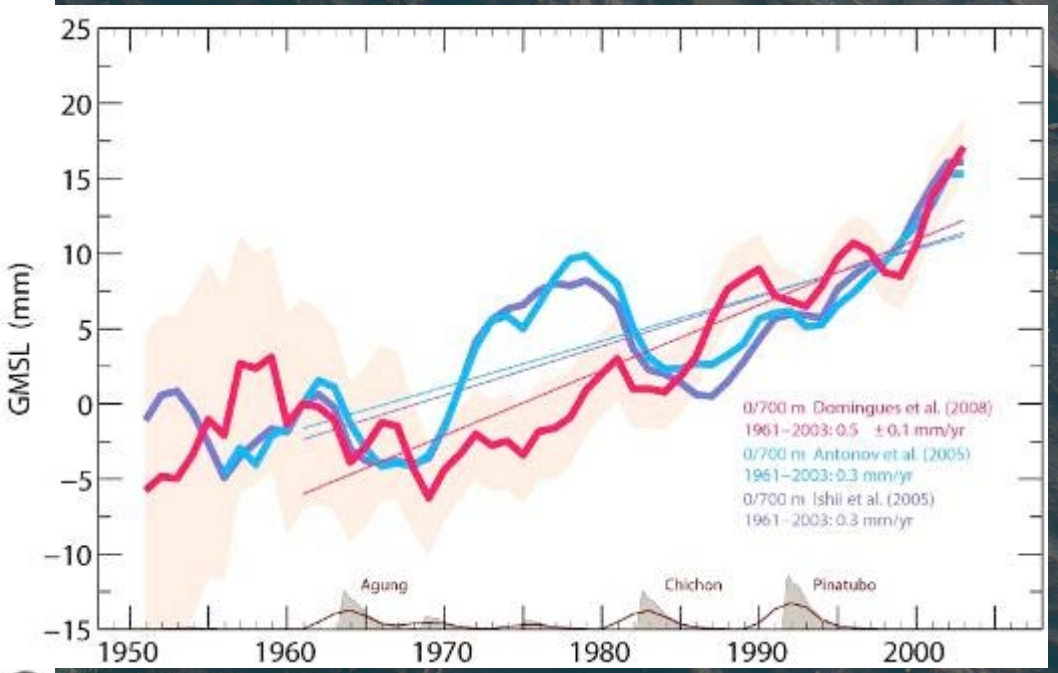


- Essential for resolving the mesoscale and extrapolation of the sparse in situ data

Platform biases and observing system transitions remain a challenge

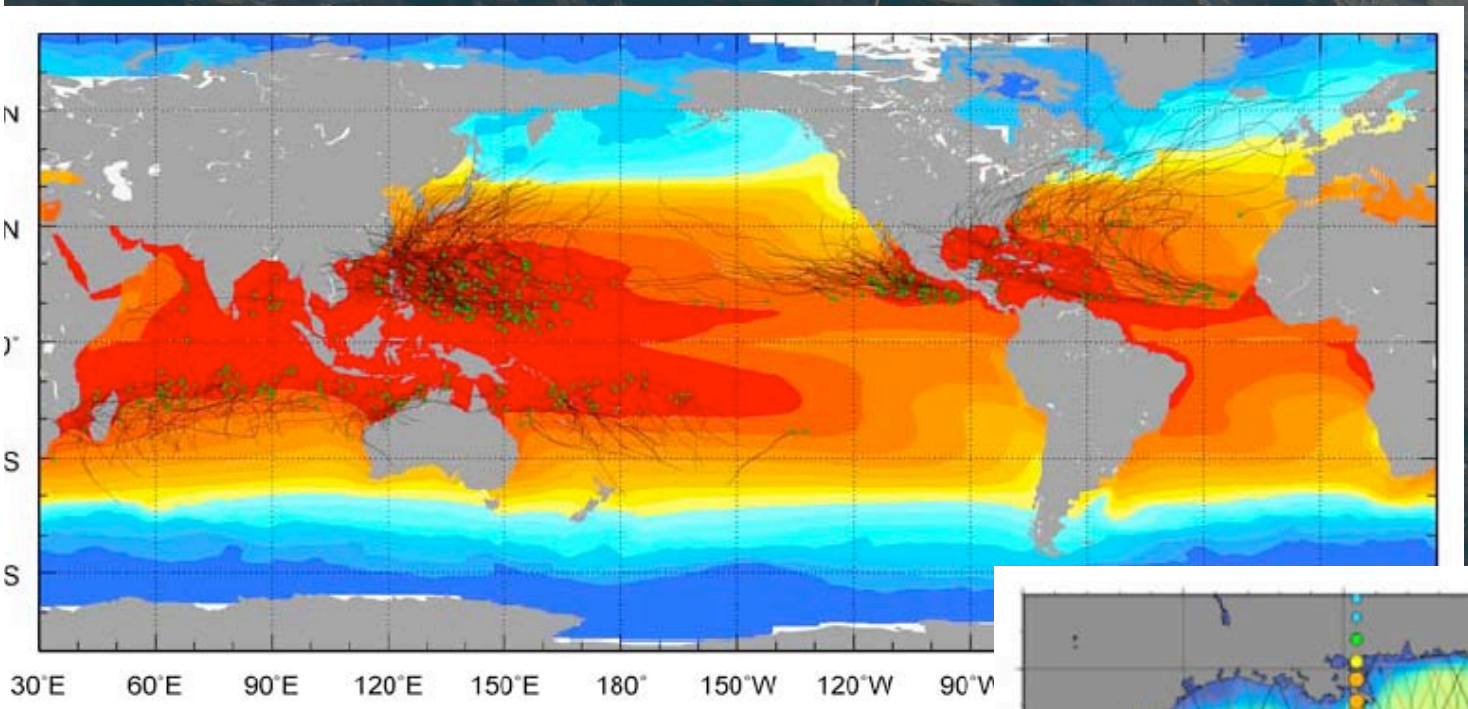


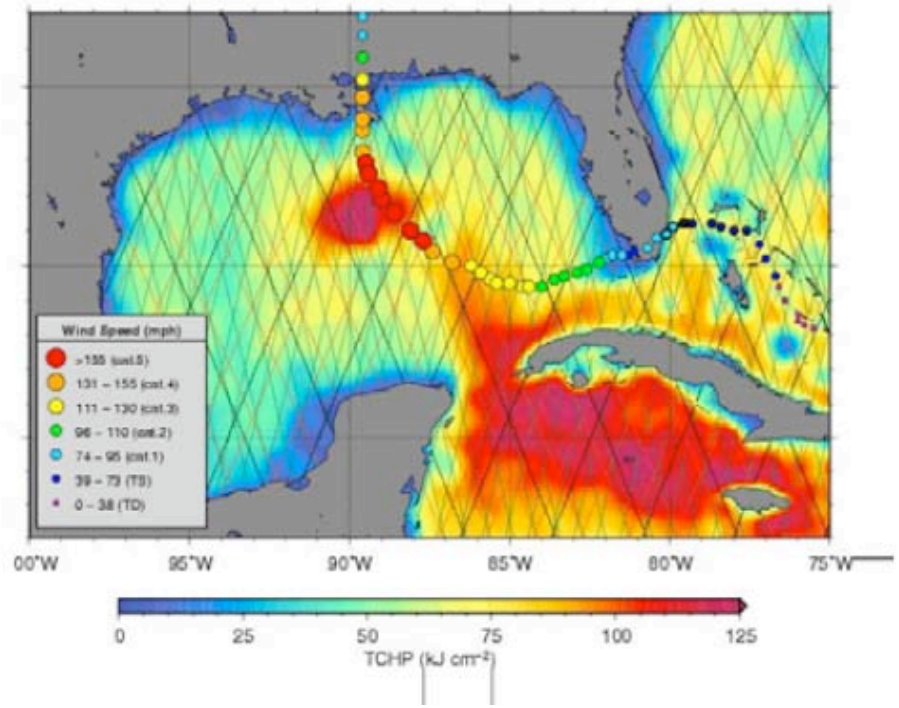
Gouretski and Koltermann, 2007



Domingues et al, 2009

Mesoscale


30°E
60°E
90°E
120°E
150°E
180°
150°W
120°W
0
10
20
30
Mean SST 2000–2008 [°C]


Wind Speed (mph)
>155 (cat.5)
131 – 155 (cat.4)
111 – 130 (cat.3)
96 – 110 (cat.2)
74 – 95 (cat.1)
39 – 73 (TS)
0 – 38 (TD)
00°W
95°W
90°W
85°W
80°W
75°W
0
25
50
75
100
125
TCHP (kJ cm⁻²)