Ocean Heat Content Metrics

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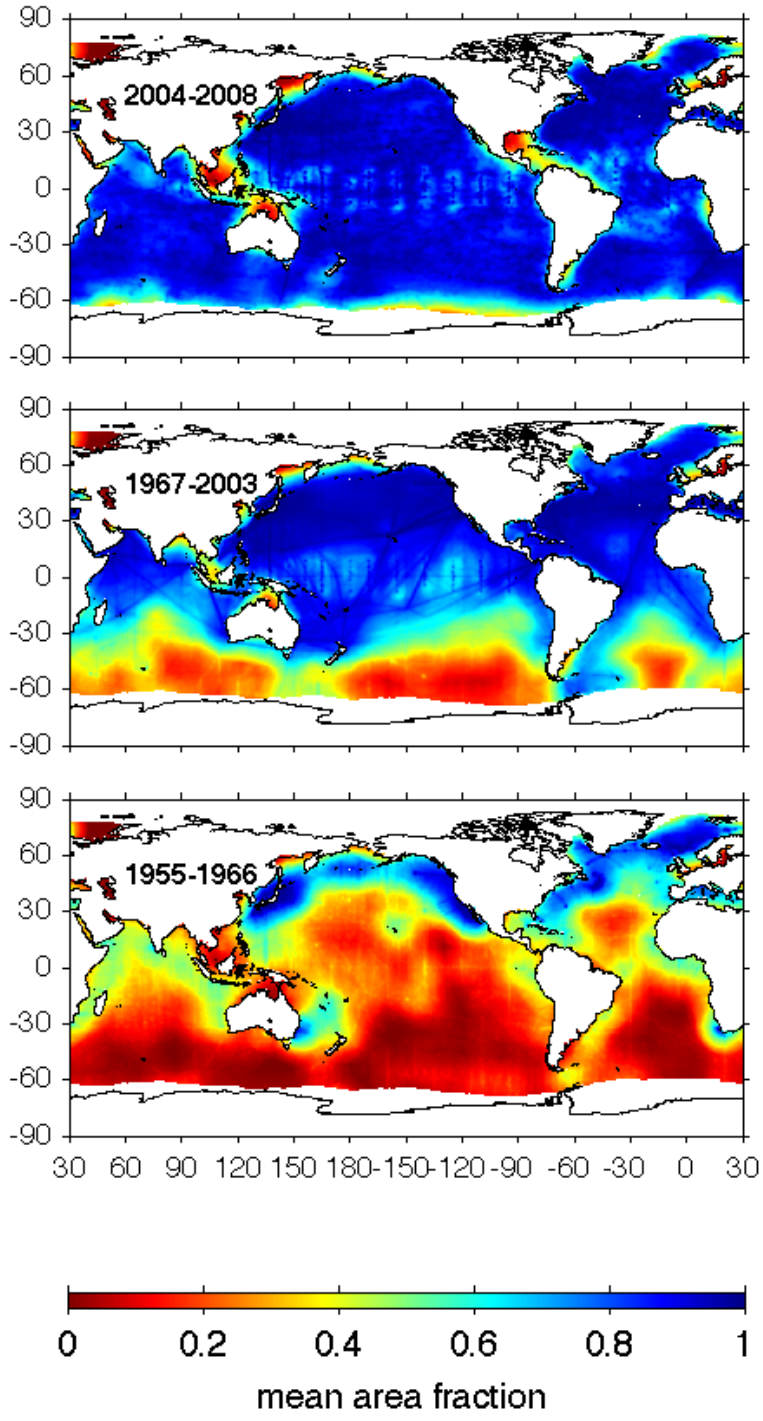
- Simple Upper Ocean Heat Content Metric
  - Percentage of upper ocean (0-700 m) area sampled
  - Based on fraction of large-scale signal objectively mapped
- ***Warning***: Simple metrics ignore bias and other uncertainties
  - XBT fall rate variations, etc.
  - Look at uncertainties during well-sampled era.
- What about the ***deep*** ocean?
  - Repeat hydrography: spatially sparse @ decadal intervals
  - Statistically significant AABW warming 1990s to 2000s.
- Simple Global Ocean Heat Content Metric
  - Percentage of global volume sampled
- Improving the global ocean sampling system

Three Upper Ocean Sampling Eras

- 2004–Present (Argo)
  - Near-global (90%) coverage to 2 km
  - year-round sampling
  - High quality data

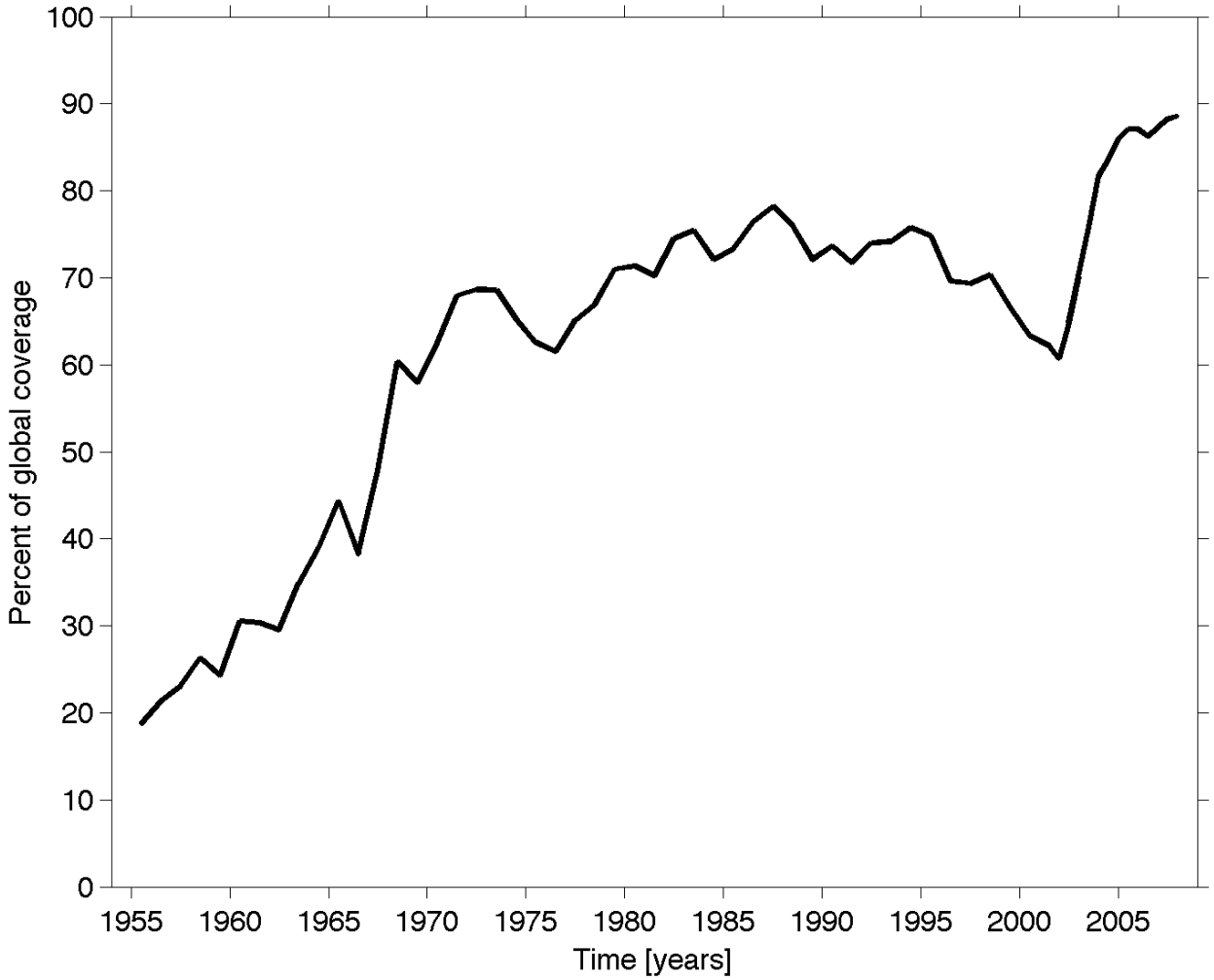
- 1967–2003 (XBT)
  - About 70% coverage to 700 m
  - Not much winter data
  - Lacks S. Ocean data (shipping lanes)
  - XBT Instrument Biases
  - Good CTD & reversing therm data

- 1955-1966 (Reversing therm & MBT)
  - About 30% coverage to 300 m
  - MBT instrument biases
  - Reversing therm. data good quality



Upper Ocean Metric (1955–2009)

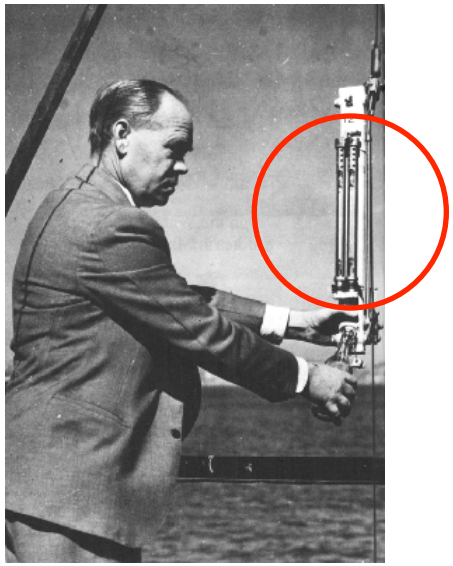
(after Lyman and Johnson 2008)



Simple metric: % of large-scale signal in yearly objective maps

Diverse Data Sources

MBT(courtesy USCG)



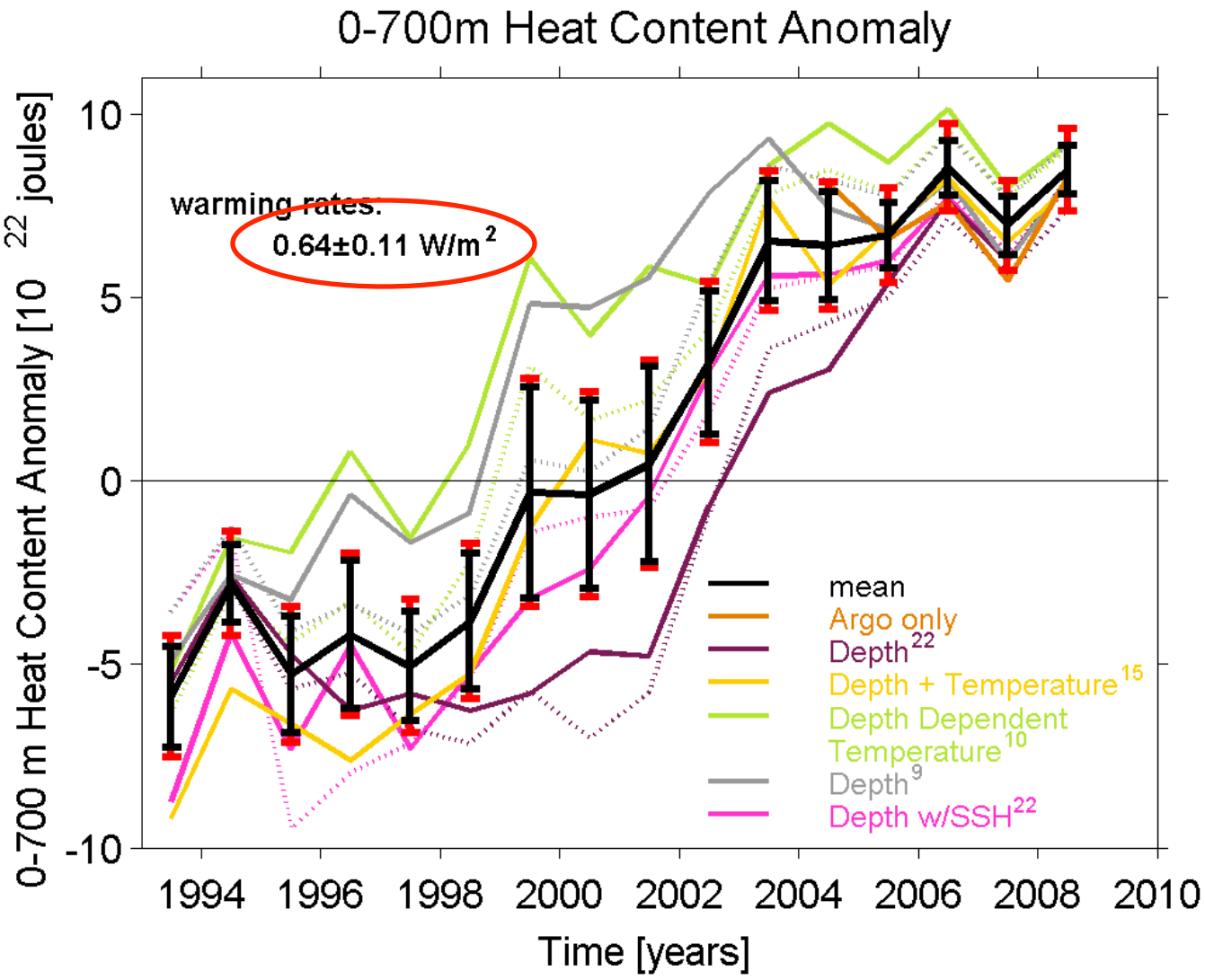
Reversing Therm. (courtesy SIO)

XBT (left) & Argo Float (right)

Conductivity, Temperature, Depth (CTD)

Upper Ocean Heat Content (1993–2008)

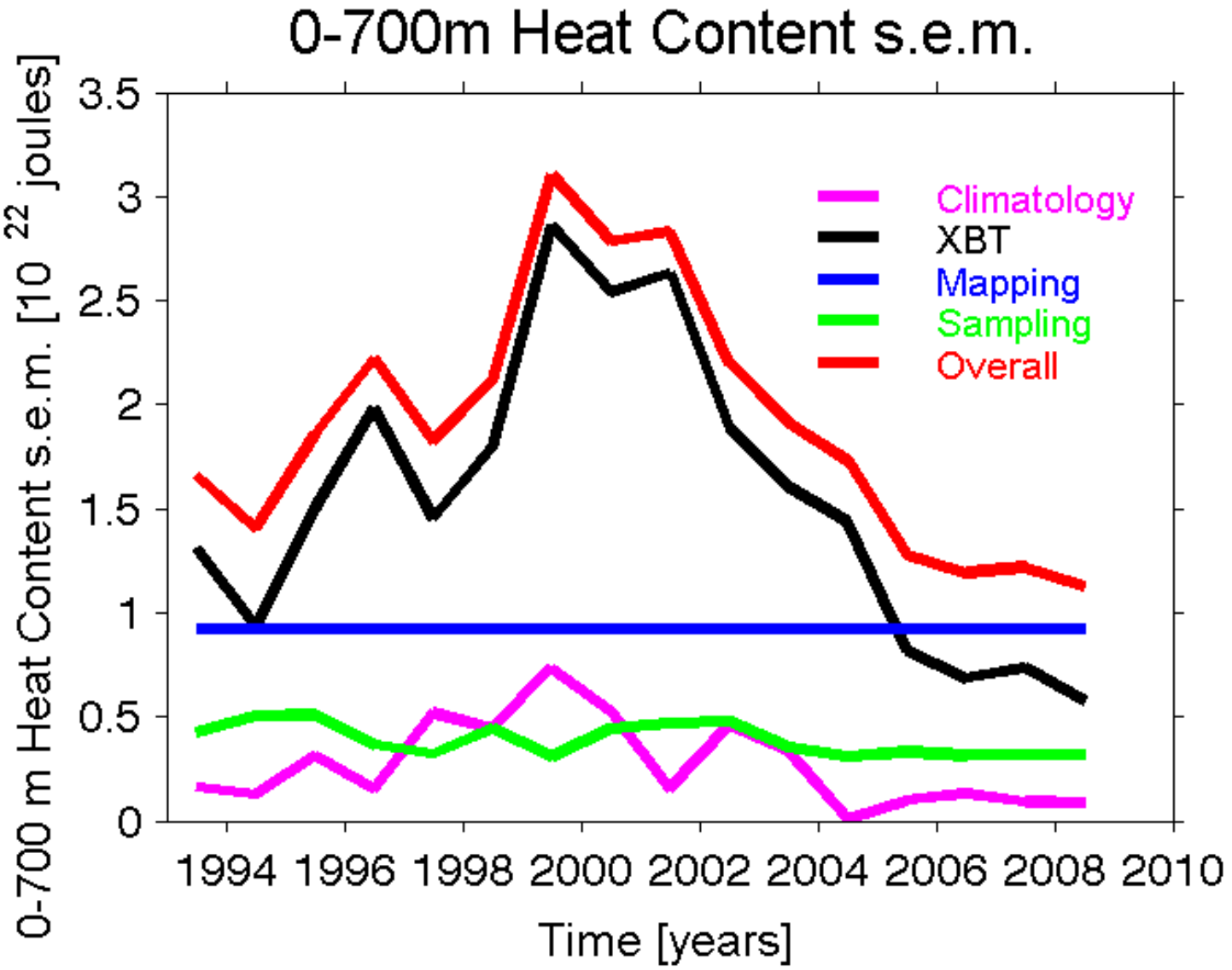
(Lyman et al. 2010)



Not just about metrics: Uncertainties more complex but key

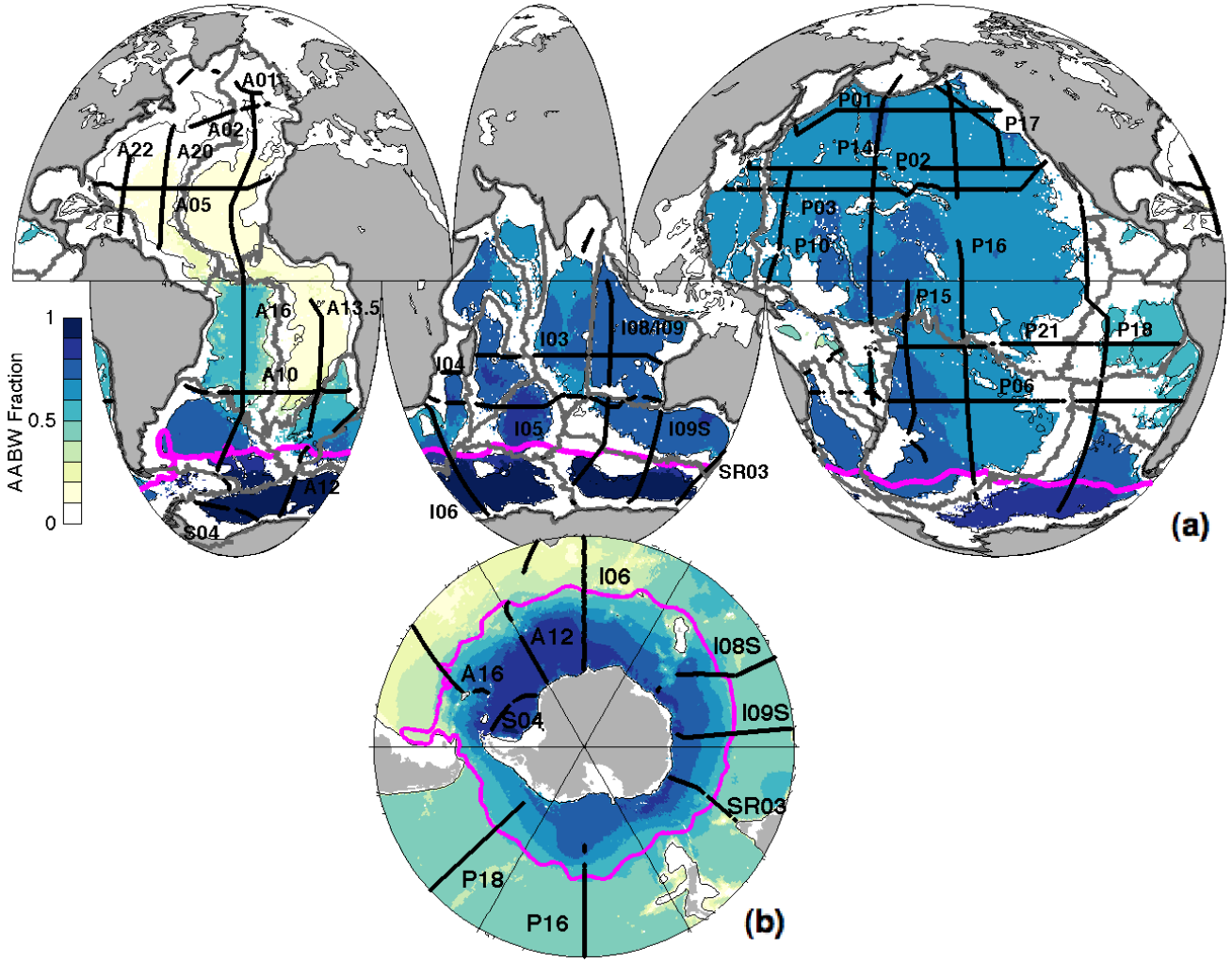
Upper Ocean Heat Content Uncertainties

(Lyman et al. 2010)



Deep Ocean: Repeat Hydrography

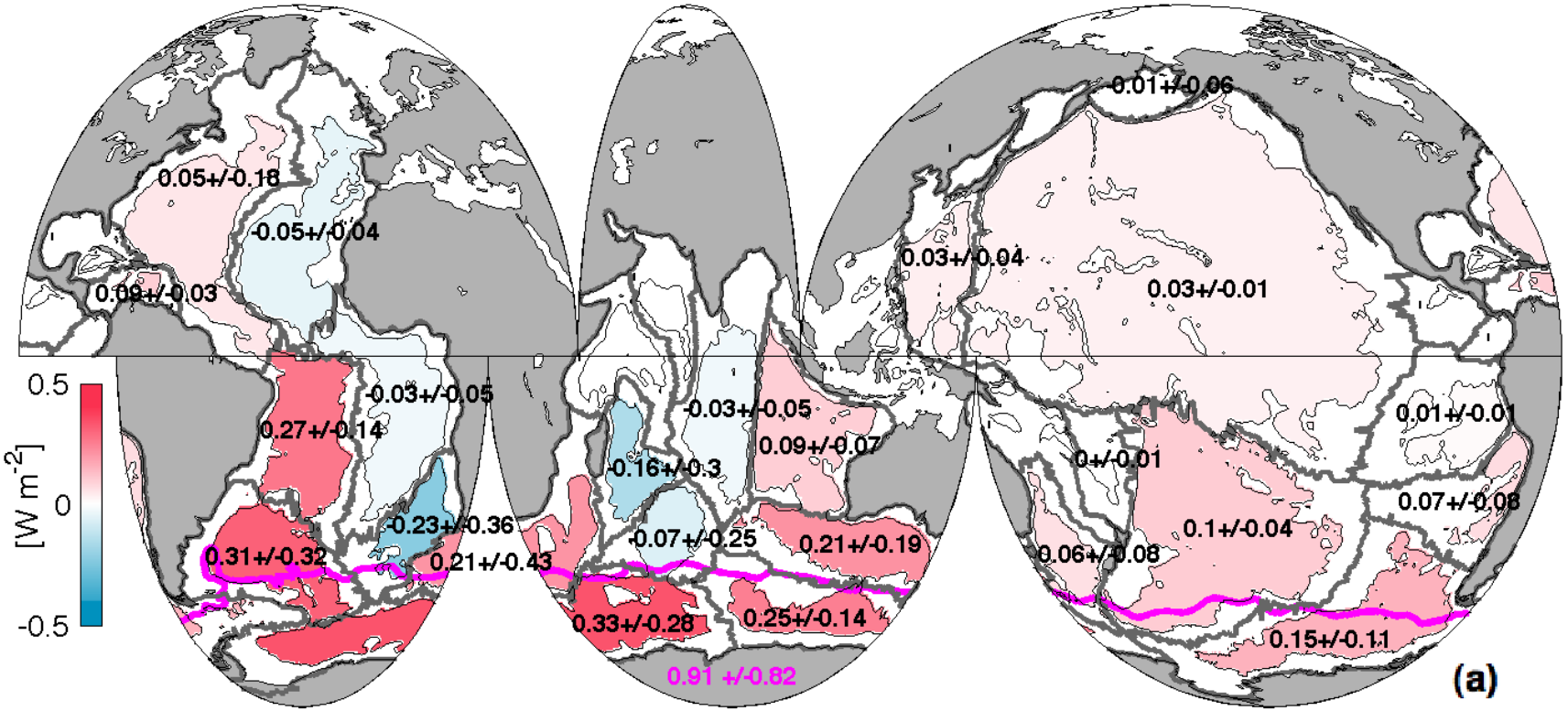
(Purkey & Johnson, in press)



- Decadal repeats (black lines) sparsely sampled in space
- Allow qualitative description of deep temperature changes

Abyssal & Deep Heat Content Changes

(Purkey & Johnson, in press)

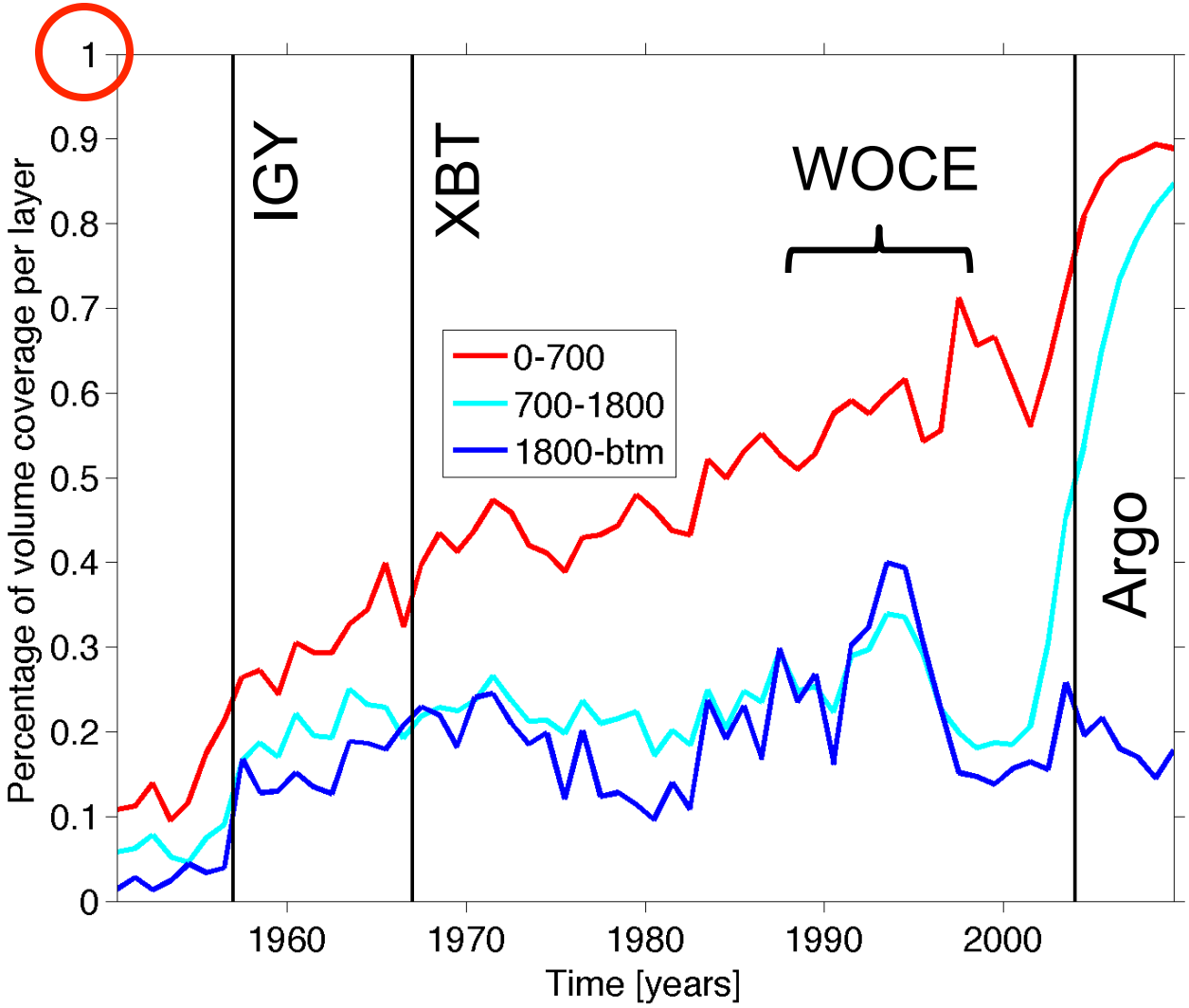


Region	Global Heat Gain (W m^{-2})
Abyssal Ocean (z > 4 km)	0.027 (±0.009)
Southern Ocean (1 > z > 4 km)	0.068 (±0.062)
Total (Abyssal + Southern)	0.095 (±0.062)

- Deep ocean warming ~1/7th of upper ocean 1990s to 2000s

Global Ocean Metric (1950–2009)

(adopted from Lyman and Johnson 2008)



Metric: % of large-scale signal for yearly objective maps

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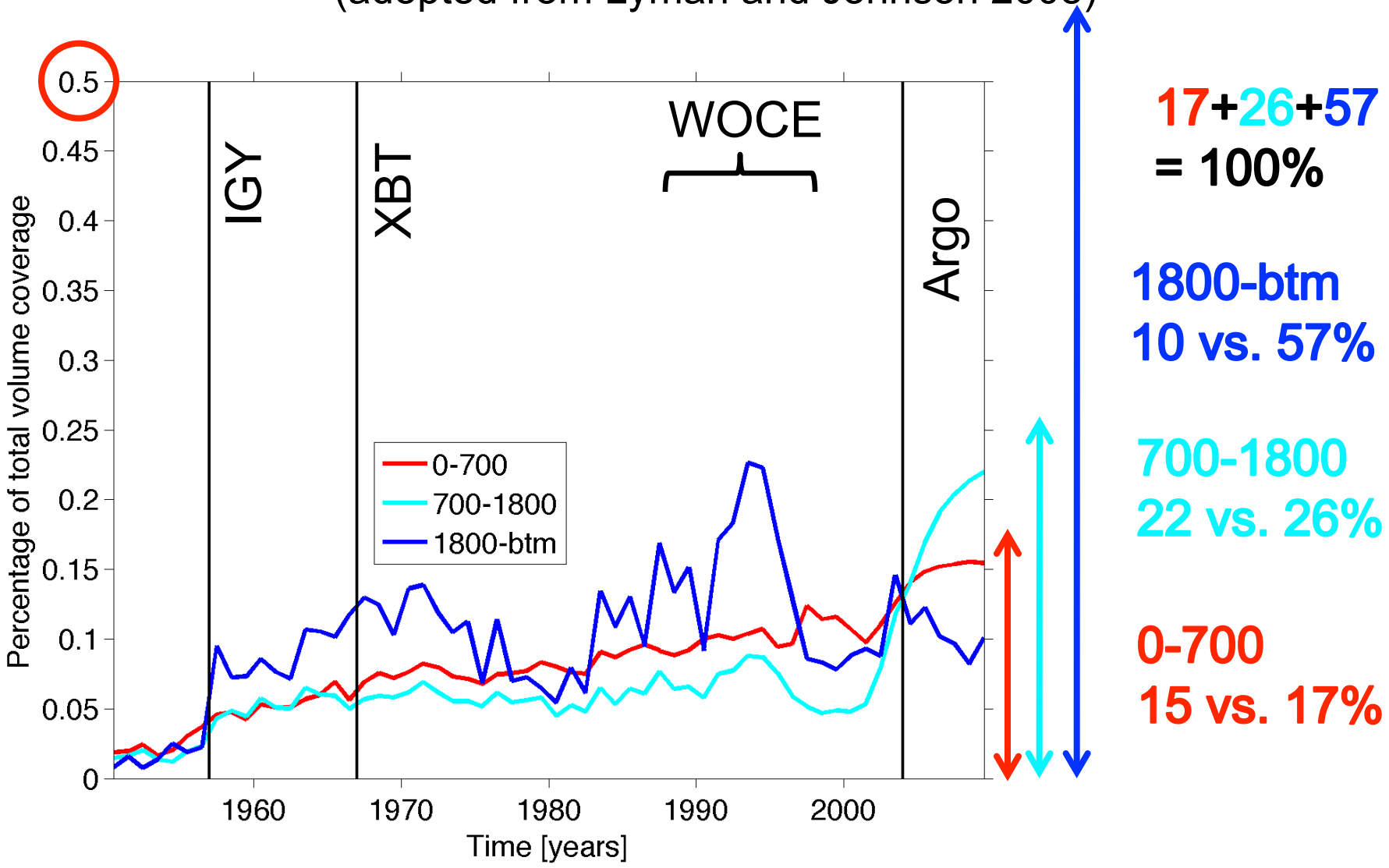

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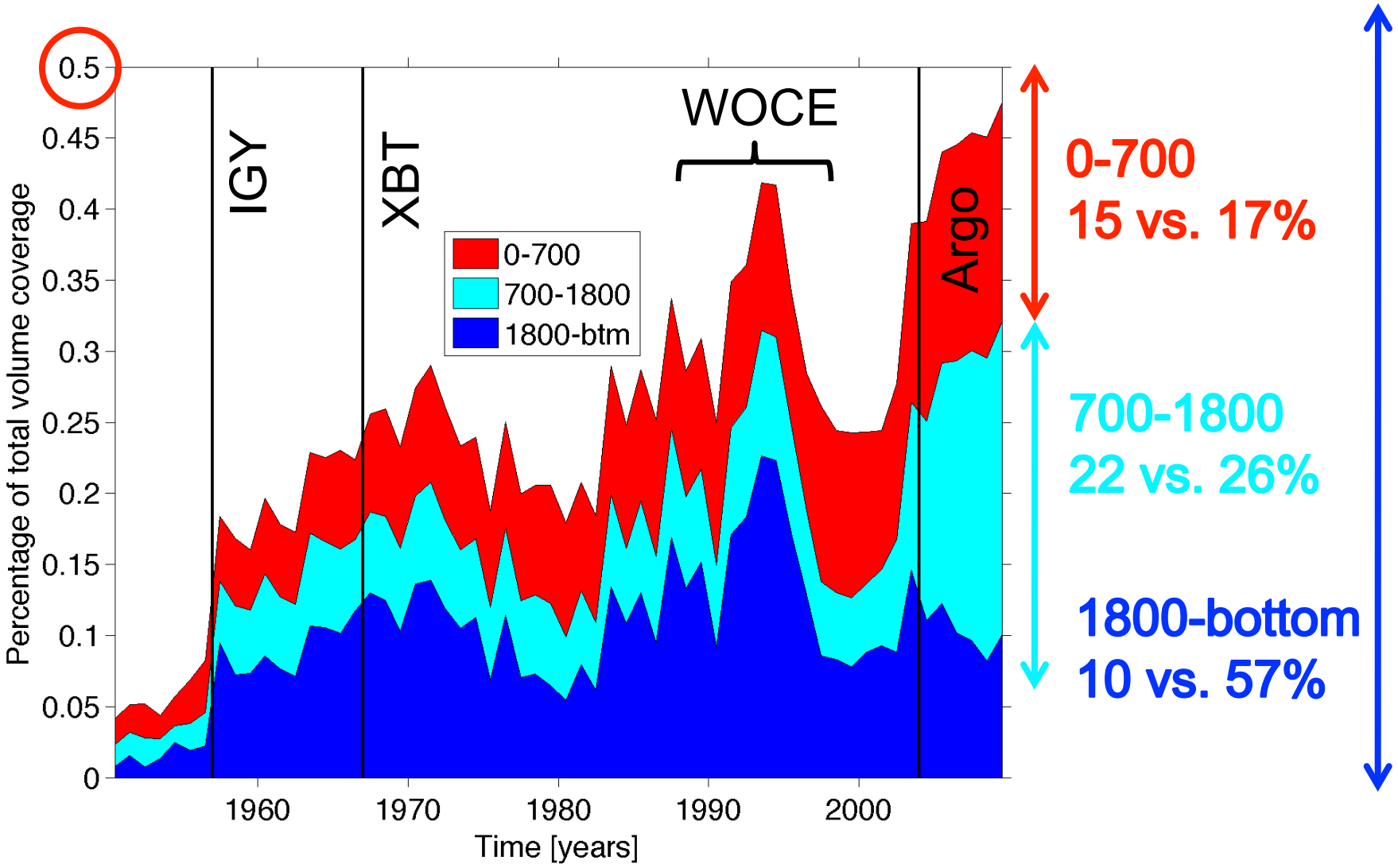
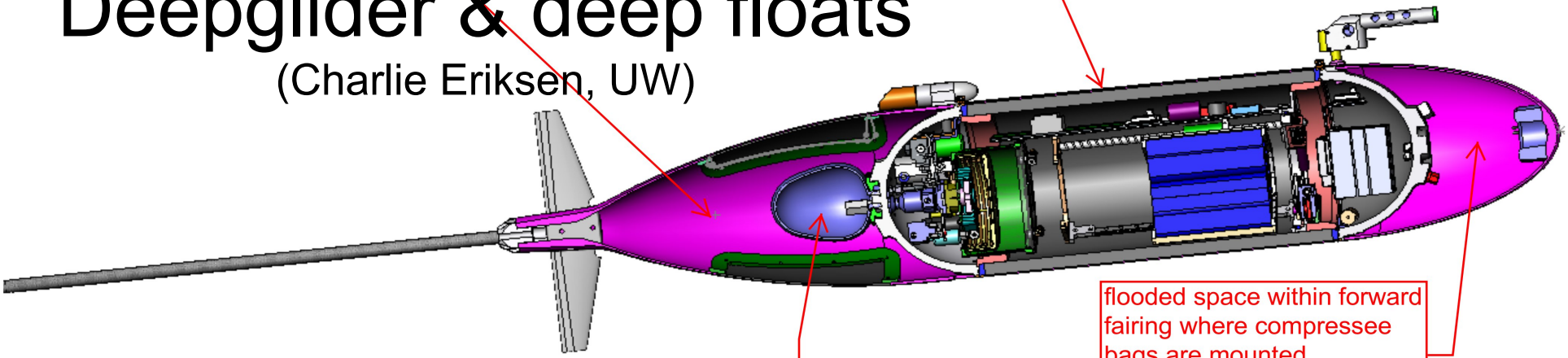
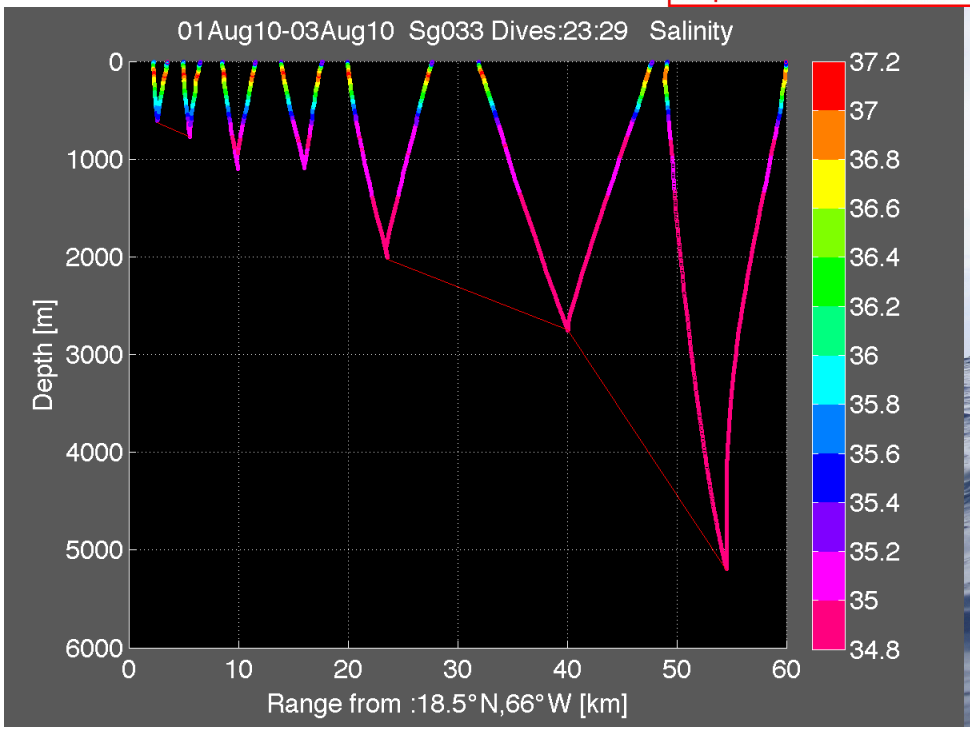


Metric: % of large-scale signal for yearly objective maps

Deepglider & deep floats

(Charlie Eriksen, UW)





Conclusions

- The upper ocean absorbs much of planetary energy imbalance
  - Close to global coverage nearly to 2000 m.
- Simple metric shows great progress in upper ocean temp obs.
  - Neglects instrument biases (XBT, MBT) & other uncertainties
  - Does not translate directly into an uncertainty
- However, the deep ocean has been warming 1990s to 2000s
  - Can only assess decadal time-scales
  - Large uncertainties even on that estimate (sparse sampling)
  - Deep ocean warming is ~1/7th of upper ocean warming
  - Remarkably Antarctic-centric warming
- Full ocean depth metric shows:
  - Post-WOCE observation gap
  - Argo filling in upper & mid-depths
  - No deep ocean recovery yet from post-WOCE let-down
- Need to observe the full-depth ocean (not just upper half) to fully characterize ocean heat uptake (Deepgliders & deep floats?).