Sea Surface Height Variability Observed by Pressure-recording Inverted Echo Sounders and Satellite Altimetry In the Kuroshio Extension

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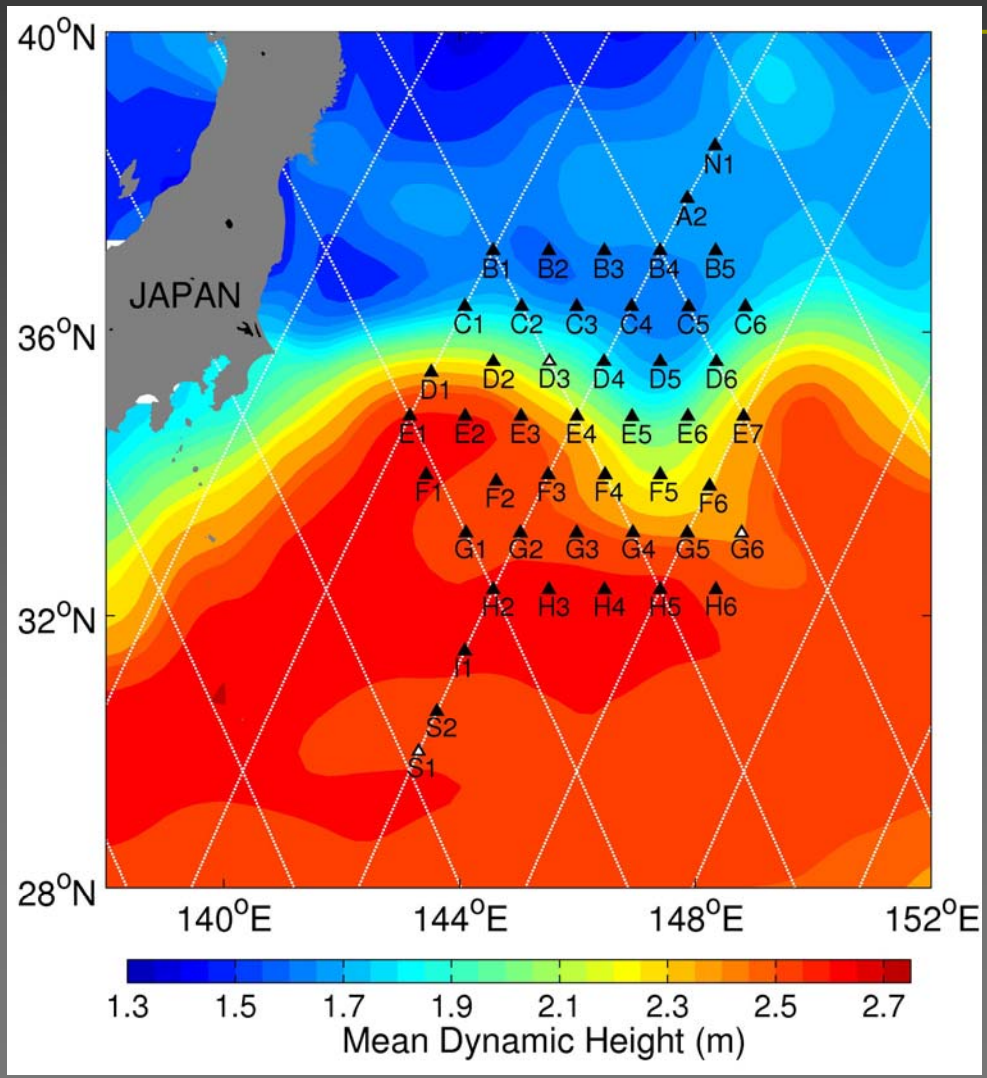
Kuroshio Extension System Study (KESS, June 2004 - June 2006)



- 46 Pressure-recording inverted echo sounders (PIESs)
- 7 moored profilers
- 48 profiling floats
- 1 moored surface buoy (KEO buoy)

PIES
(Pressure-recording Inverted Echo Sounder)

- Emits 12 kHz sound pulses
- Measures τ - round trip travel times of acoustic pulses from the bottom to the surface
- Measures bottom pressure (P_{bot}) - resolution < 1mm
- A robust empirical relationship exists between τ and vertical profiles of T and δ

➡ Dynamic height (ϕ_{4000})

Measure sea level

- From the space and the sea floor

Sea level change
= Steric + Mass-loading
(baroclinic + barotropic)

Jason-1

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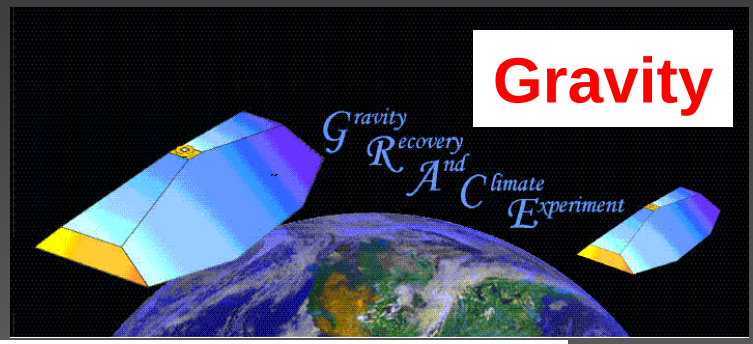


Gravity

= Steric

Radar ➡ Steric + mass-loading

Acoustic echo time ➡ Steric

Bottom pressure ➡ Mass-loading

AVISO data

- Monomission product
  - Delayed-time along-track sea level anomalies (Mono-SLA)
  - Jason-1

- Note that T/P was moved to a new orbit midway of its original ground tracks to give a way to Jason-1 during 09/2002-10/2005.
- Peak numbers of altimeters flying.

- Multimission products
  - Delayed-time "Reference" gridded sea level anomalies (Ref-MSLA)
  - Jason-1 + Envisat

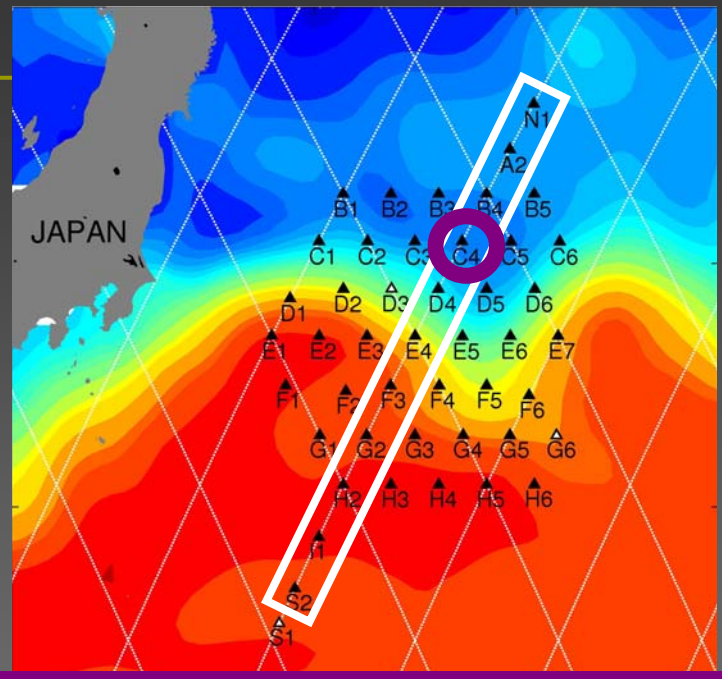
  - Delayed-time "Up-to-date" gridded sea level anomalies (Upd-MSLA)
  - Jason-1 + Envisat + GFO + TOPEX/Poseidon

Comparisons of PIES-derived SSH with altimetry measurements

- **How well do they agree?**

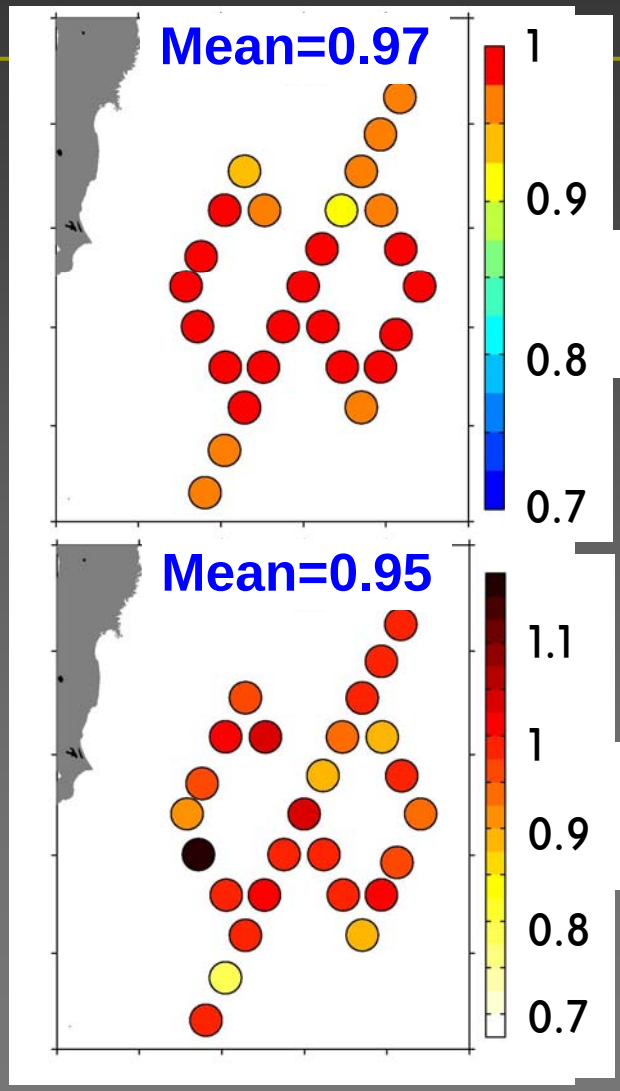
  - Error range of AVISO SLA : 4.6-5.1 cm
  - Error range of PIES-derived SSHA : 3.8-8.7 cm

Mono-SLA and PIES-derived SSHA



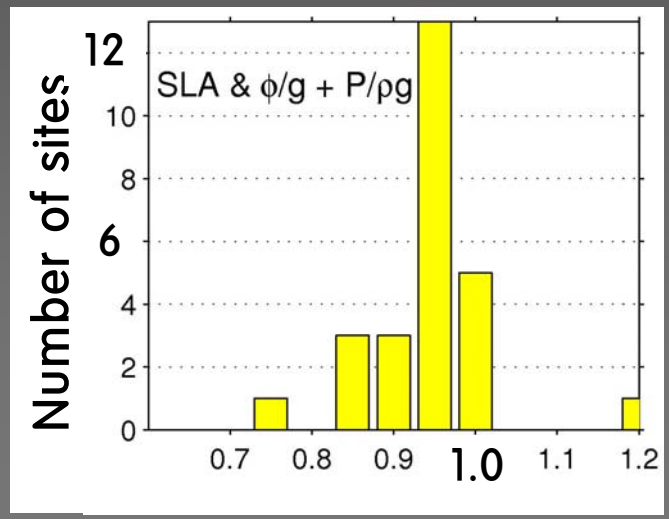
- Lowest correlation (0.91) at C4
- Low SSH signal reduces S/N ratio, and hence correlation

Mono-SLA and PIES-derived SSHA

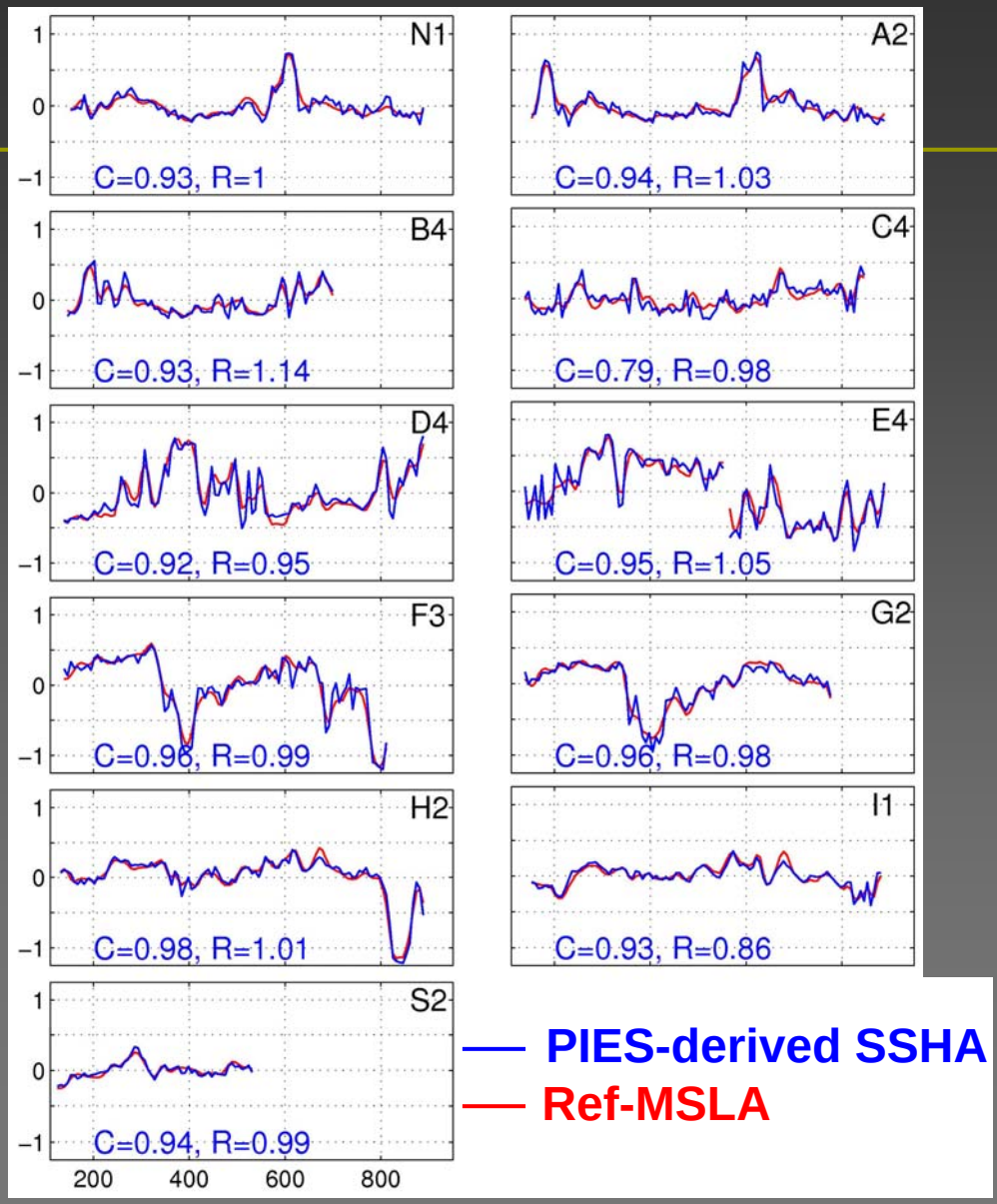


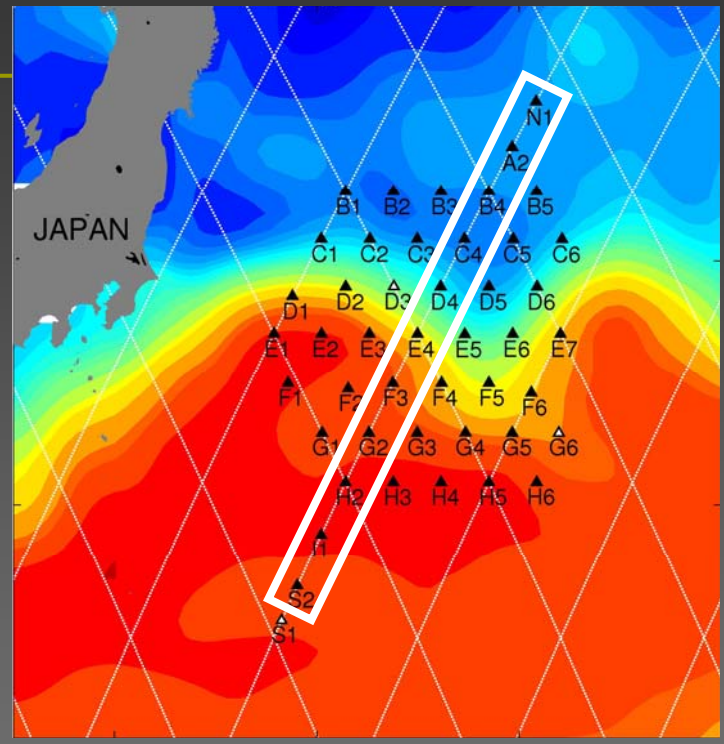
Correlation Coefficients

Regression Coefficients (slope)

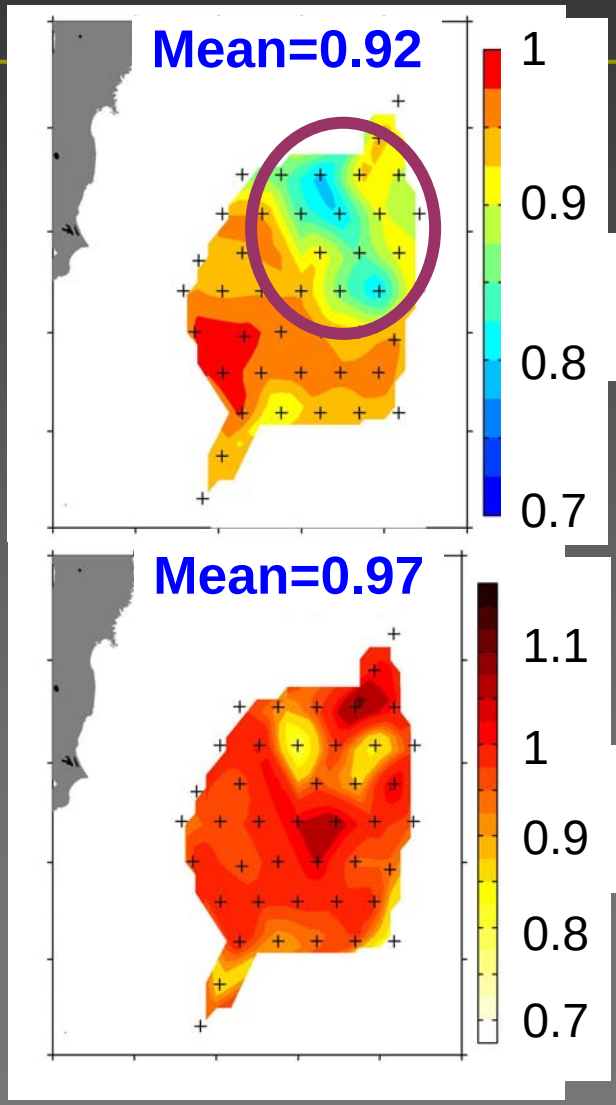


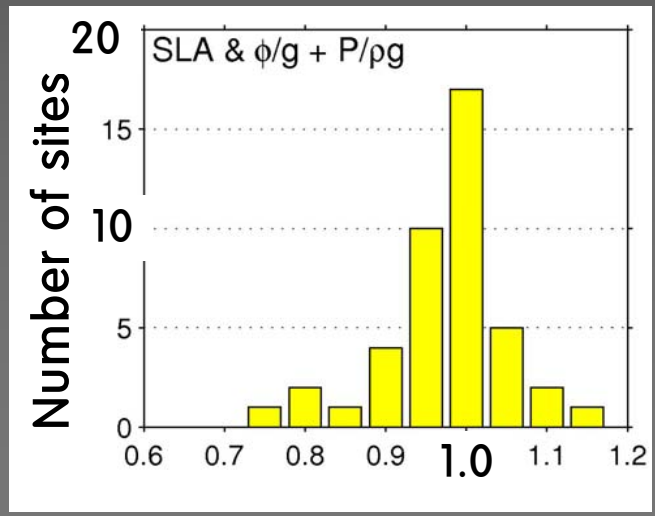
Ref-MSLA and PIES-derived SSHA



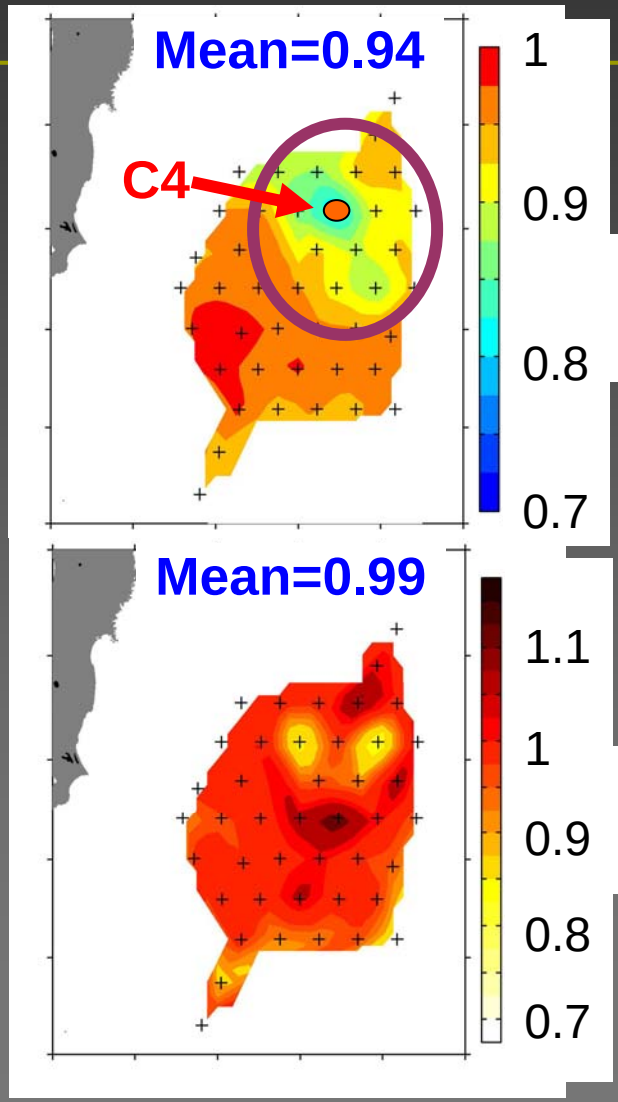


Ref-MSLA and PIES-derived SSHA



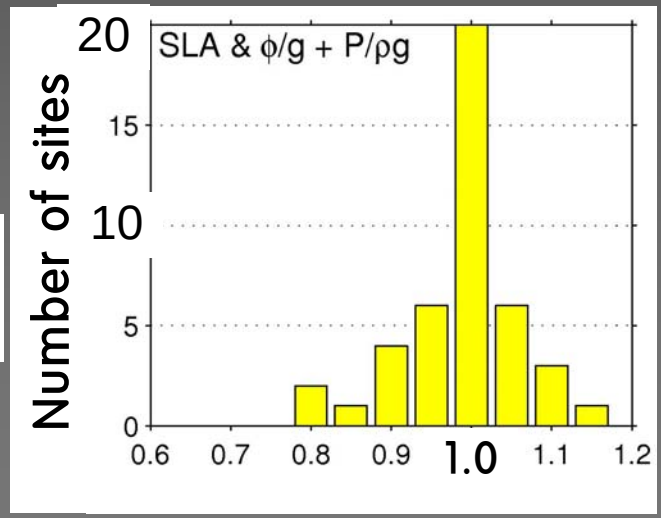


Upd-MSLA and PIES-derived SSHA



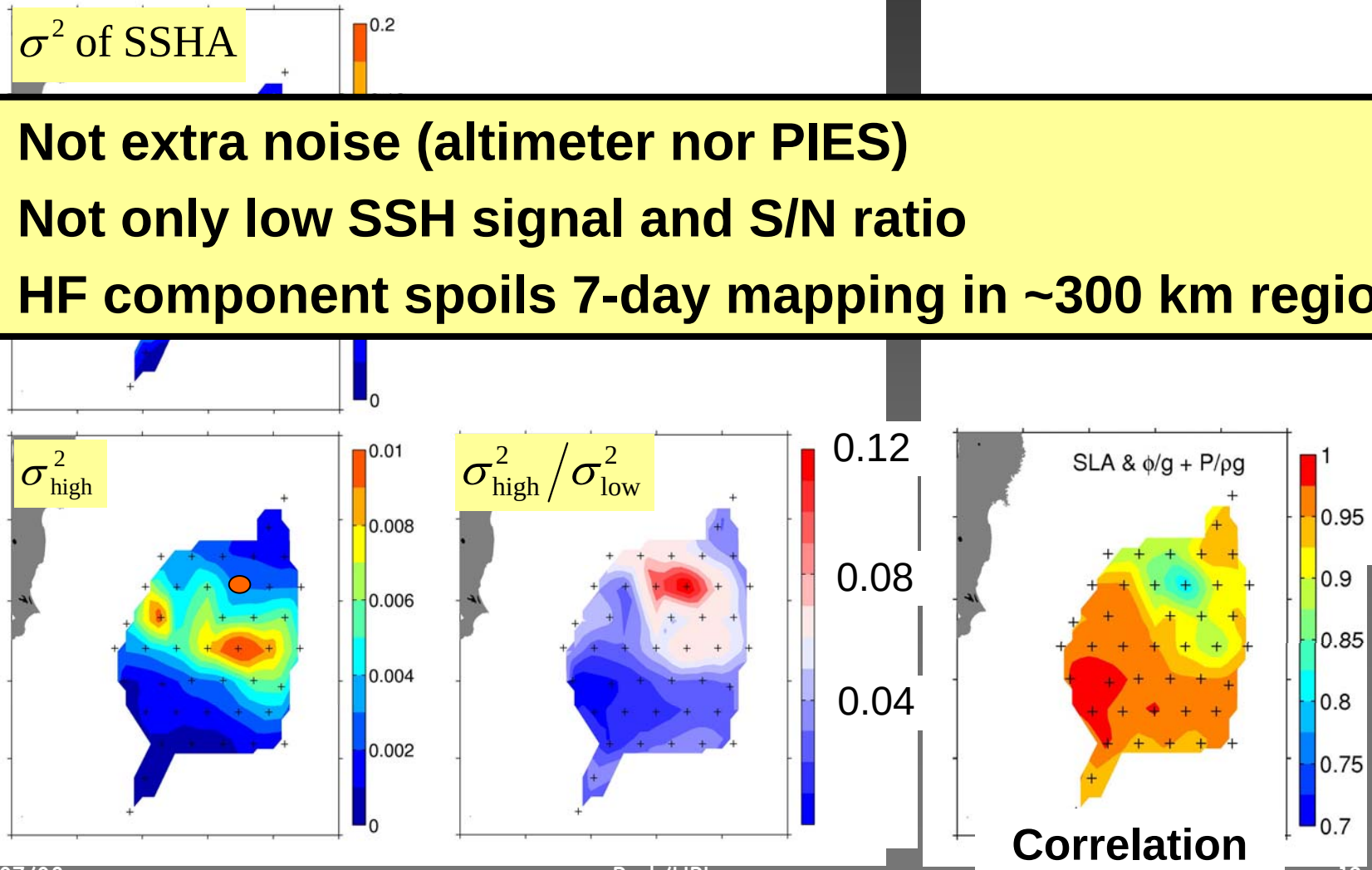
Correlation Coefficients

Regression Coefficients (slope)

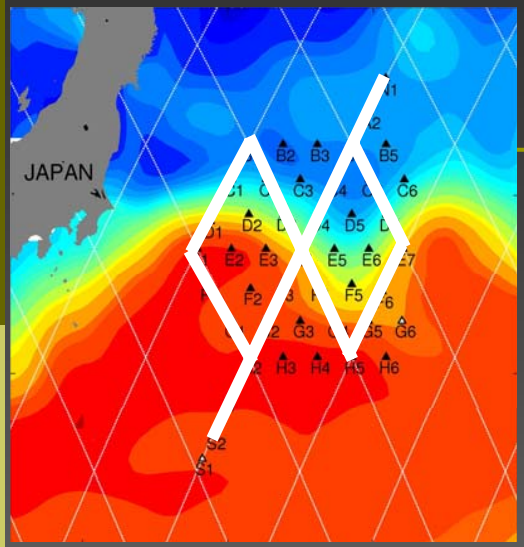


Why does the lowest correlation occur around C4?

- **Not extra noise (altimeter nor PIES)**
- **Not only low SSH signal and S/N ratio**
- **HF component spoils 7-day mapping in ~300 km region**



Rms Errors (along-track 26 sites)



- Observed rms differences
  - Mono-SLA 6.8 cm
  - Ref-MSLA 9.4 cm
  - Upd-MSLA 9.1 cm

- Predicted rms difference

$$\sqrt{(4.6 \text{ to } 5.1)^2 + (3.8 \text{ to } 8.7)^2 + 1.4^2} = \textbf{6.1 to 10.2 cm}$$

when error caused by geographical position mismatch between Jason-1 and PIES = 1.4 cm (1 km offset)

- Error Budget for AVISO : 4.6-5.1 cm

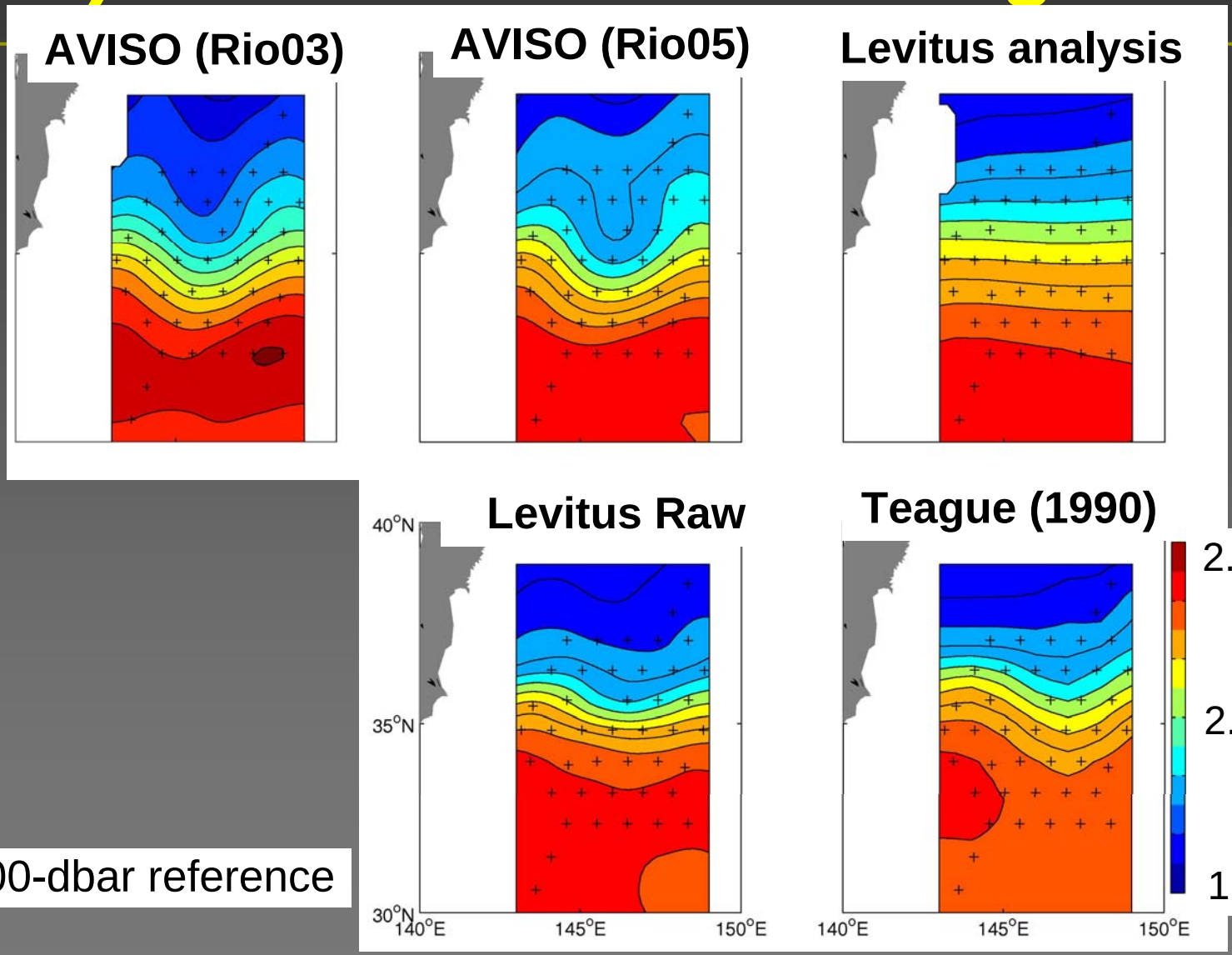
GDR Corrected SSH	3.3 cm
Post-processing - IB	2.5-3.0 cm
- Tides	2.0-2.5 cm

From Baker-Yeboah (2008)

- Error Budget for PIES : 3.8-8.7 cm

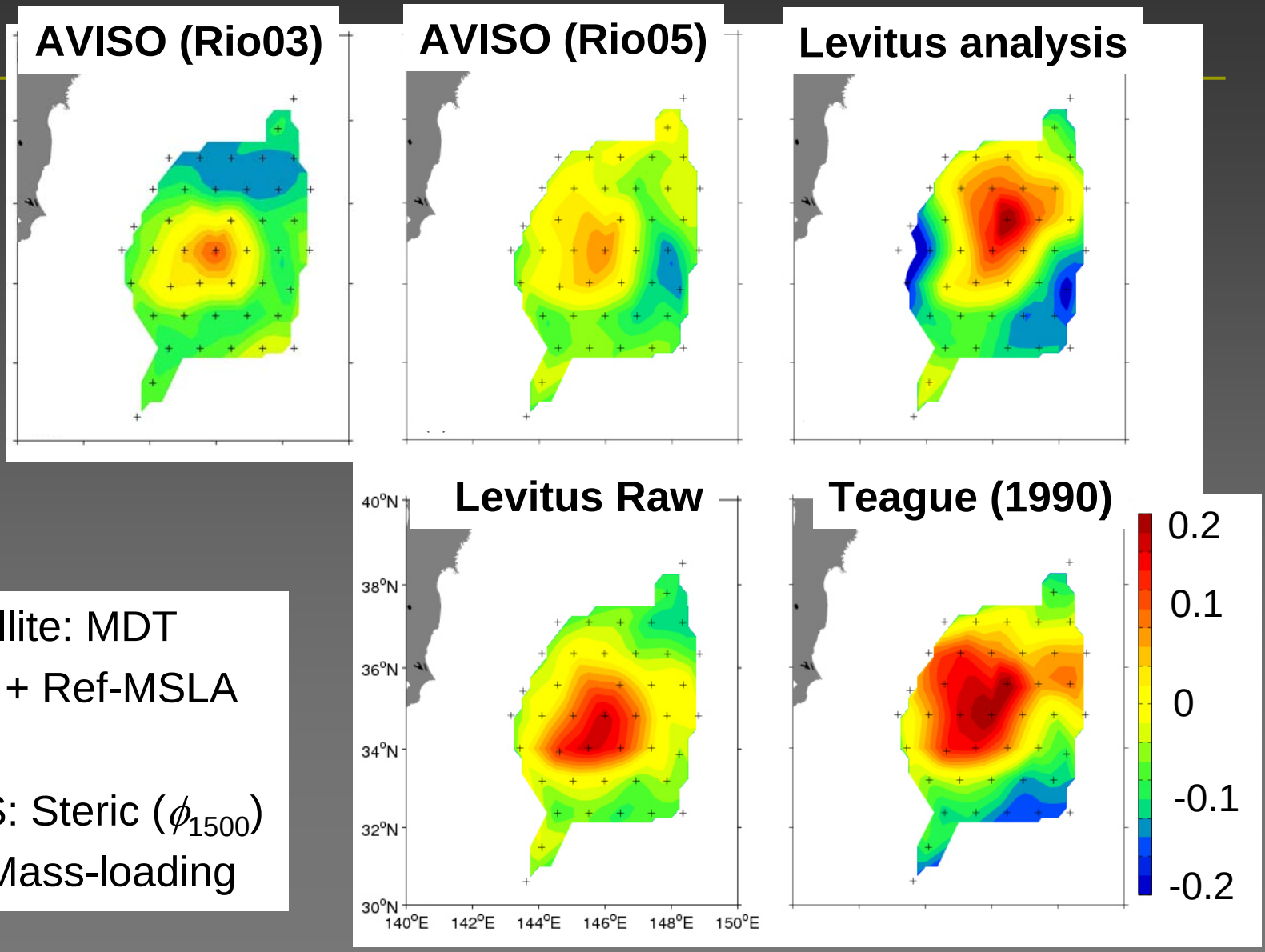
Sea state scatter	0.2 cm
Sea state bias	0.1 cm
Tides	0.1 cm
Pressure drift	1.0 cm
Mooring motion	0.2 cm
Spline-curve Lookup	3.7-8.6 cm

What Mean Dynamic Topography (MDT) works best in this region?



1500-dbar reference

Mean differences (Satellite – PIES)



- Satellite: MDT
  + Ref-MSLA
- PIES: Steric (ϕ_{1500})
  + Mass-loading

Summary

- The SSH measurements from PIES and from altimetry agree with high correlations in the Kuroshio Extension. Rms differences between them are all within predictable error bars.
- High-frequency variability can reduce correlations in the merged products.
- Up-to-date SLA product (Upd-MSLA) shows the best mapped agreement with PIES-derived SSHA.
- Rio05 mean dynamic topography (MDT) works best in this region to reference altimeter SLA.