Estimating rapid large-scale variability in sea level, with application to dealiasing of satellite missions

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Outline

Topic: nontidal sea level variability over the deep ocean at monthly and shorter timescales, spatial scales greater than a few hundred kilometers

Issues:
- difficulty in fully resolving sub-monthly variability given satellite relatively long repeat periods
- inaccuracies in forcing, bathymetry, and other model factors lead to errors in simulated variability

Approach:
- improve estimates of the rapid large-scale variability by using least-squares optimization procedure to fit a model to available ocean data
- analyze MIT-AER optimized solutions being produced as part of the ECCO-GODAE (Estimating the Circulation and Climate of the Ocean-Global Ocean Data Assimilation Experiment) project
- constrained by all altimeter and CTD/XBT/Argo data, SST, GRACE geoid, scatterometer winds, and other data

Summary of Results:
- data constraints have a considerable impact on the estimated rapid, large-scale variability
- optimization leads to improved estimates, as judged from comparisons with independent daily tide gauge data
- improved dealiasing correction over what current operational procedures deliver in the deep oceans
- potential use in reprocessing of altimeter data

High Frequency Variability

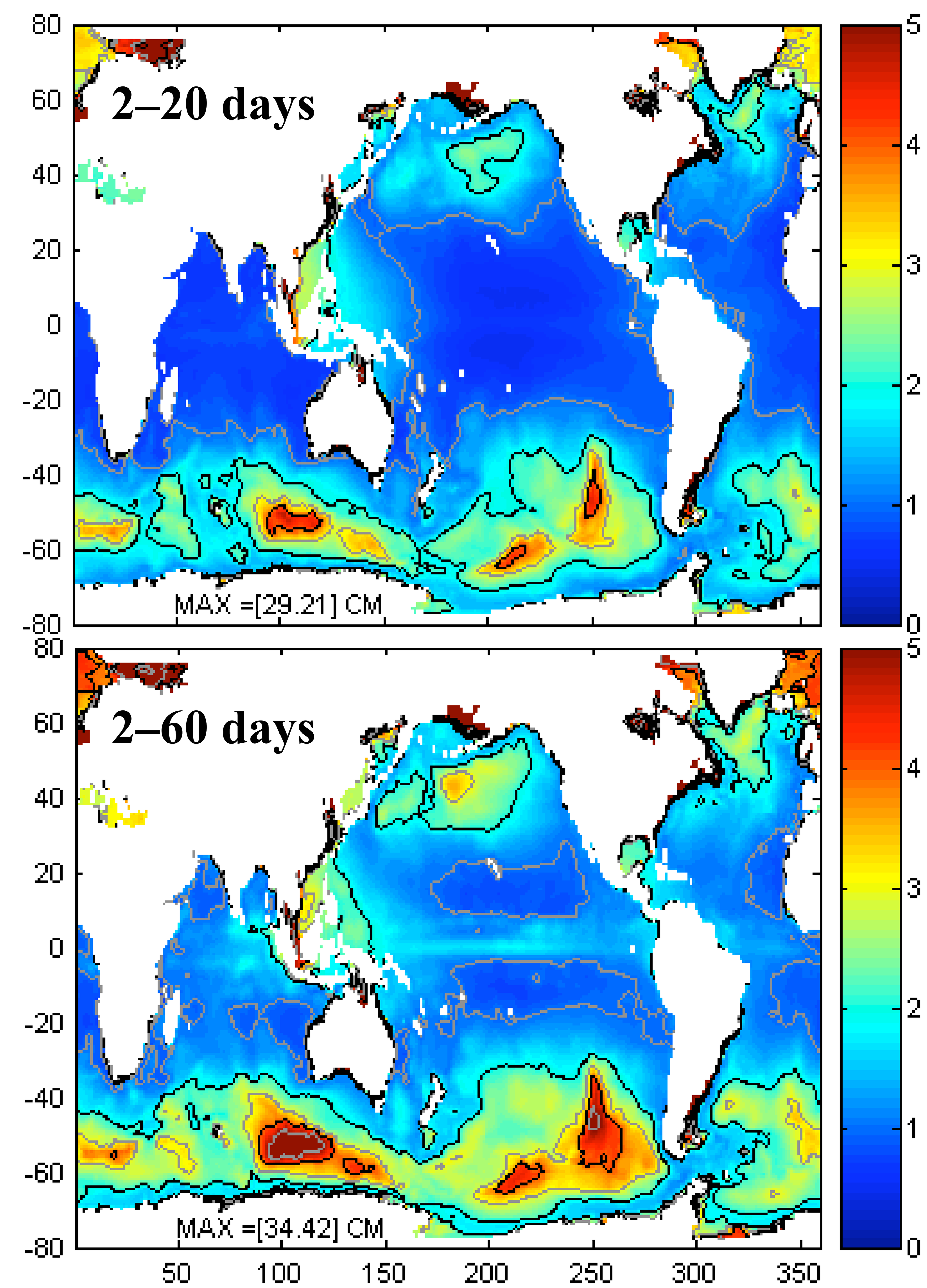

Fig. 1. Estimated standard deviation of sea level (cm) for periods of: (top) 2–20 days, aliased in Jason, T/P; (bottom) 2–60 days, aliased in Envisat.

- higher variability in shallow waters, as wind stress forcing proportional to 1/depth
- mid and high latitude maxima partly related to:
  - stronger synoptic forcing by the atmosphere
  - effects of topography on response to forcing
- enhanced tropical variability particularly at longer periods (baroclinic wave activity)

Impact of Optimization

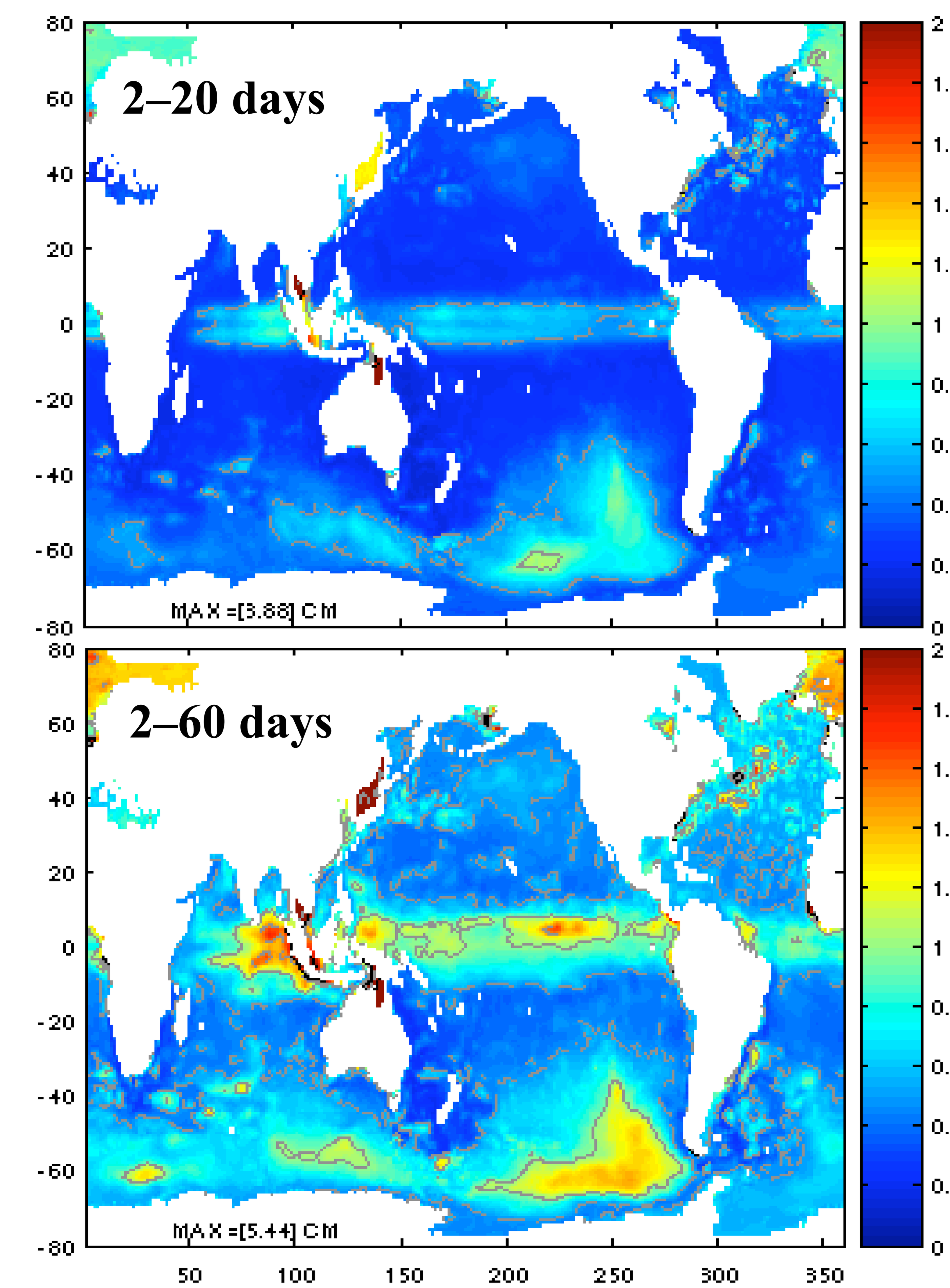

Fig. 2. RMS of sea level difference (cm) between the control run (unconstrained) and the optimized run for periods of (top) 2–20 days and (bottom) 2–60 days.

- strong effects of data constraints at low latitudes, Japan/East Sea, Southern Ocean (cf. Figs. 1 and 2)
- optimization affects shallow regions (e.g., Gulf of Carpentaria) even though no altimeter constraints applied there

Tide Gauge Analyses

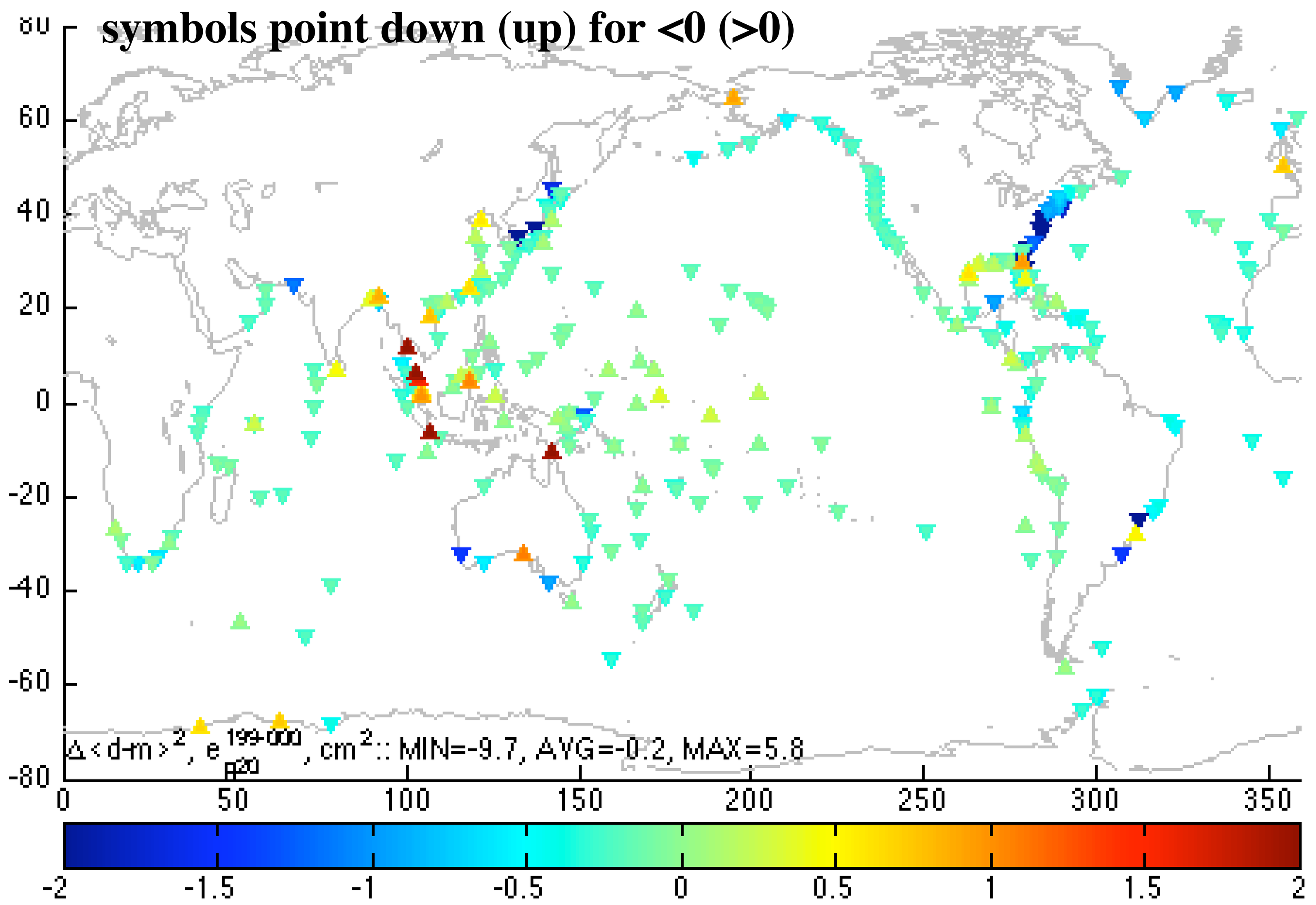

Fig. 3. Tide gauge sea level variance (cm^2) accounted by the control sea level estimates with 2–20 day periods minus that accounted for by the optimized estimates. Mostly negative values indicate the latter is closer to the tide gauge data, which were not used in the optimization.

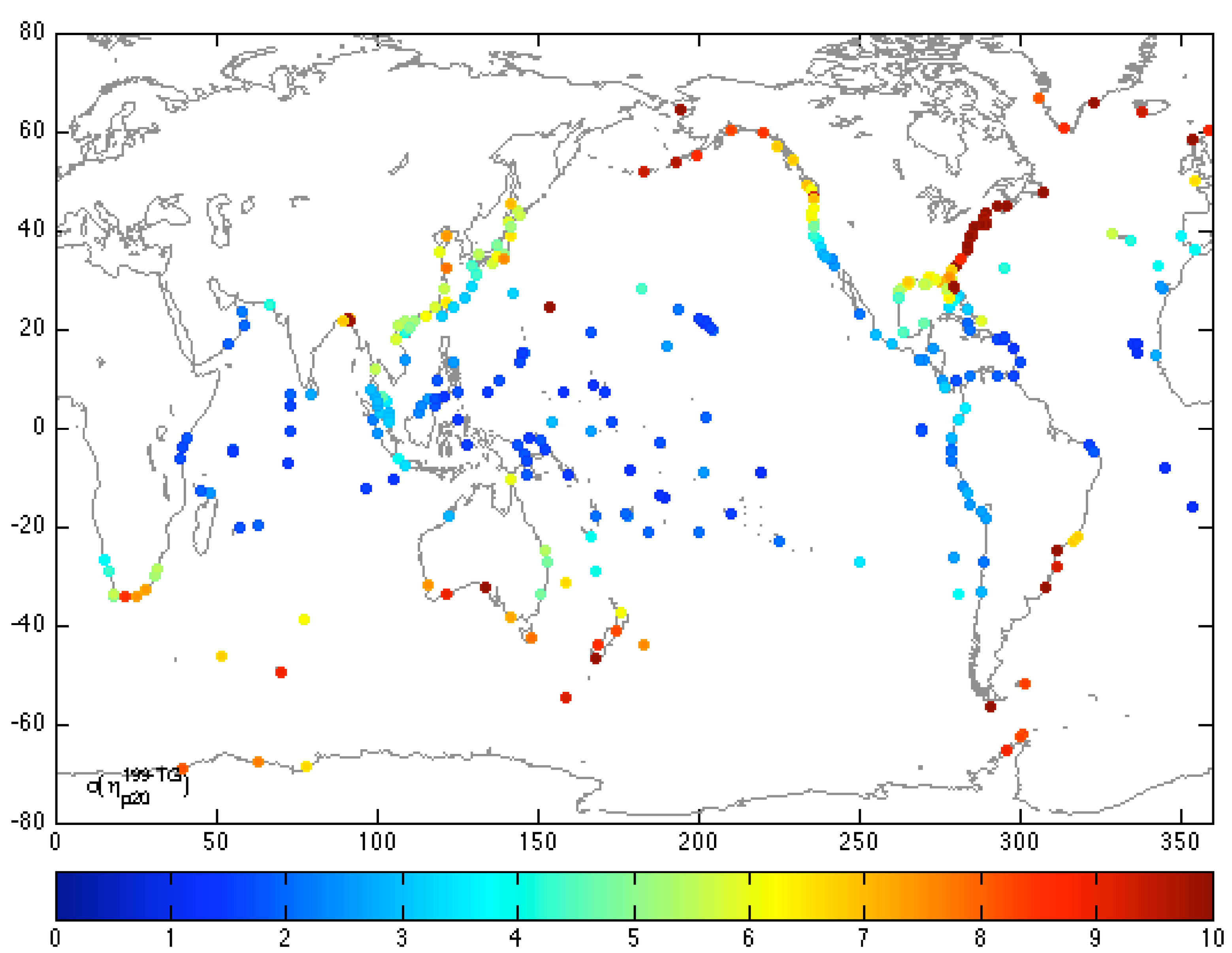

Fig. 4. RMS difference (cm) between optimized estimates and tide gauge data for 2–20 day periods. Values can be taken as crude upper bound on the errors:

- RMS difference includes instrument noise
- no altimeter constraints applied at depths < 1000 m
- likely large "representativeness" errors in coastal records, as large-scale model cannot represent well details of coastal domain

Dealiasing TOPEX/Poseidon Data

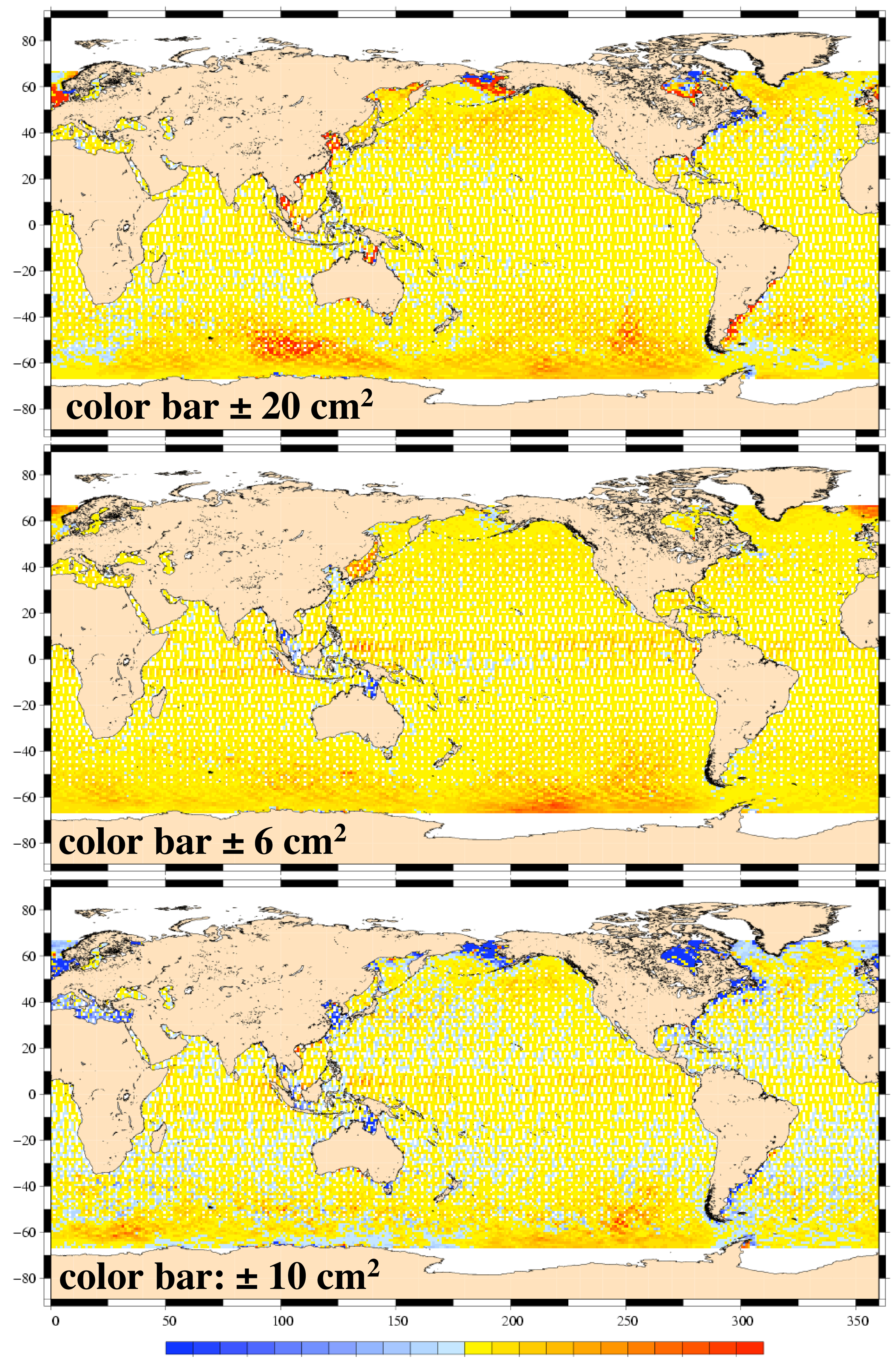

Fig. 5. TOPEX/Poseidon sea level variance accounted by the optimized estimates at 2-20 day periods minus that accounted by:
(top) simple inverted barometer model;
(middle) the control estimates;
(bottom) the current operational dealiasing correction based on a barotropic model with no data assmilation.

Things to note:

- dealiasing corrections based on optimized fields are much more effective at removing aliased variability in TOPEX/Poseidon data than a simple inverted barometer correction

- optimization accounts for a few extra cm^2 of rapid variability in the data, compared to the control fields

- optimized fields also fare better than current operational dealiasing correction, over most of the tropical oceans and high variability regions in mid and high latitudes

- operational correction better in shallow coastal regions (much better grid resolution in finite element barotropic approach, also no altimeter data constraints in shallow areas in optimized solution examined here)

Final Remarks

Combining data and models in optimization procedures provides a sound methodology for improving estimates of the rapid, poorly sampled variability (Figs. 2, 3, 5), but substantial misfits remain as suggested by the comparisons with tide gauge data (Fig. 4) and further improvements are warranted.

More information on the ECCO-GODAE ocean state estimates used here, together with a list of relevant publications, is available at **http://www.ecco-group.org/**