Toward the assimilation of multiple satellite vector wind data products in a global, eddying, ocean and sea ice model

D. Menemenlis, H. Zhang, and D. Moroni

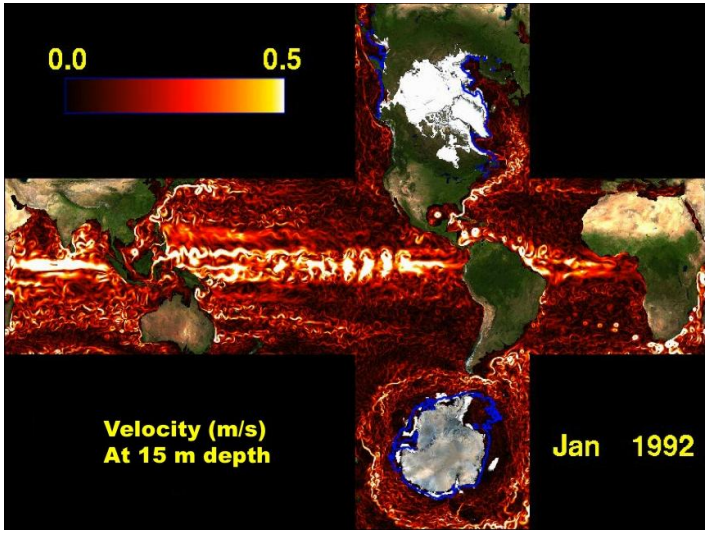
iOVWST Meeting, Kailua-Kona, Hawaii
6-8 May 2013

Outline of presentation:

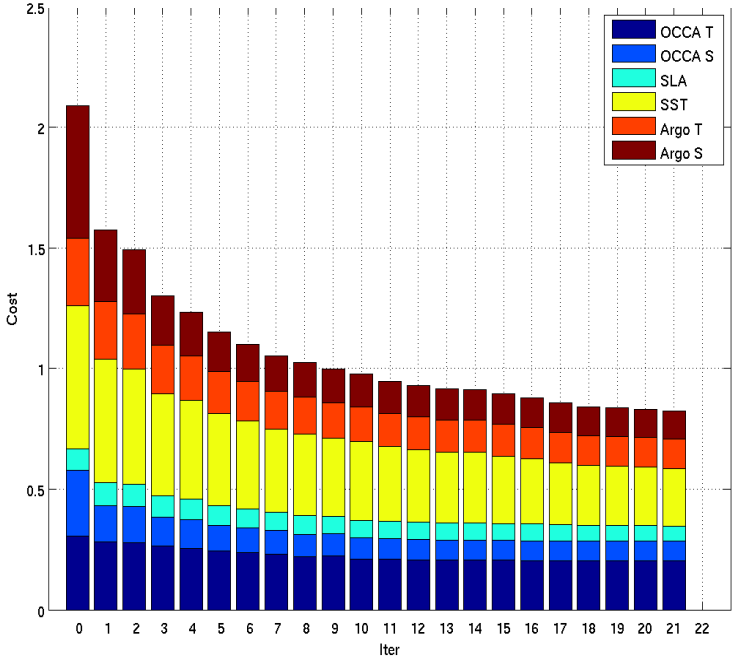
1. ECCO2 global, eddying, ocean and sea ice estimation set-up
2. Assimilation of QuikSCAT v2 surface stress retrievals in ECCO2
3. Comparison of ECCO2 baseline and optimized simulations vs. QuikSCAT v2, QuikSCAT v3, ASCAT, OSCAT, and WindSat

ECCO2: eddying global-ocean and sea-ice data synthesis

Cube sphere (CS510) model configuration



Cost function reduction per iteration



Full-depth ocean + sea ice configuration of MITgcm.

CS510 horizontal grid with ~18-km spacing.

Green-function or adjoint-method optimizations that preserve tracer properties.

Data constraints currently include JASON, AMSR-E, ARGO, and OCCA climatology.

Control variables are model parameters and initial and surface atmospheric boundary conditions.

Adjoint-method solutions have been computed for 2004-2005 and 2009-2011.

An experimental, QuikSCAT-constrained 2004-2005 solution is also available.

At last year's iOVWST I reported that:

- optimized ECCO2 solution was **NOT** closer to QuikSCAT wind stress retrievals and
- addition of QuikSCAT v2 wind stress data constraints degrades explained variance.

Since last year's meeting we have:

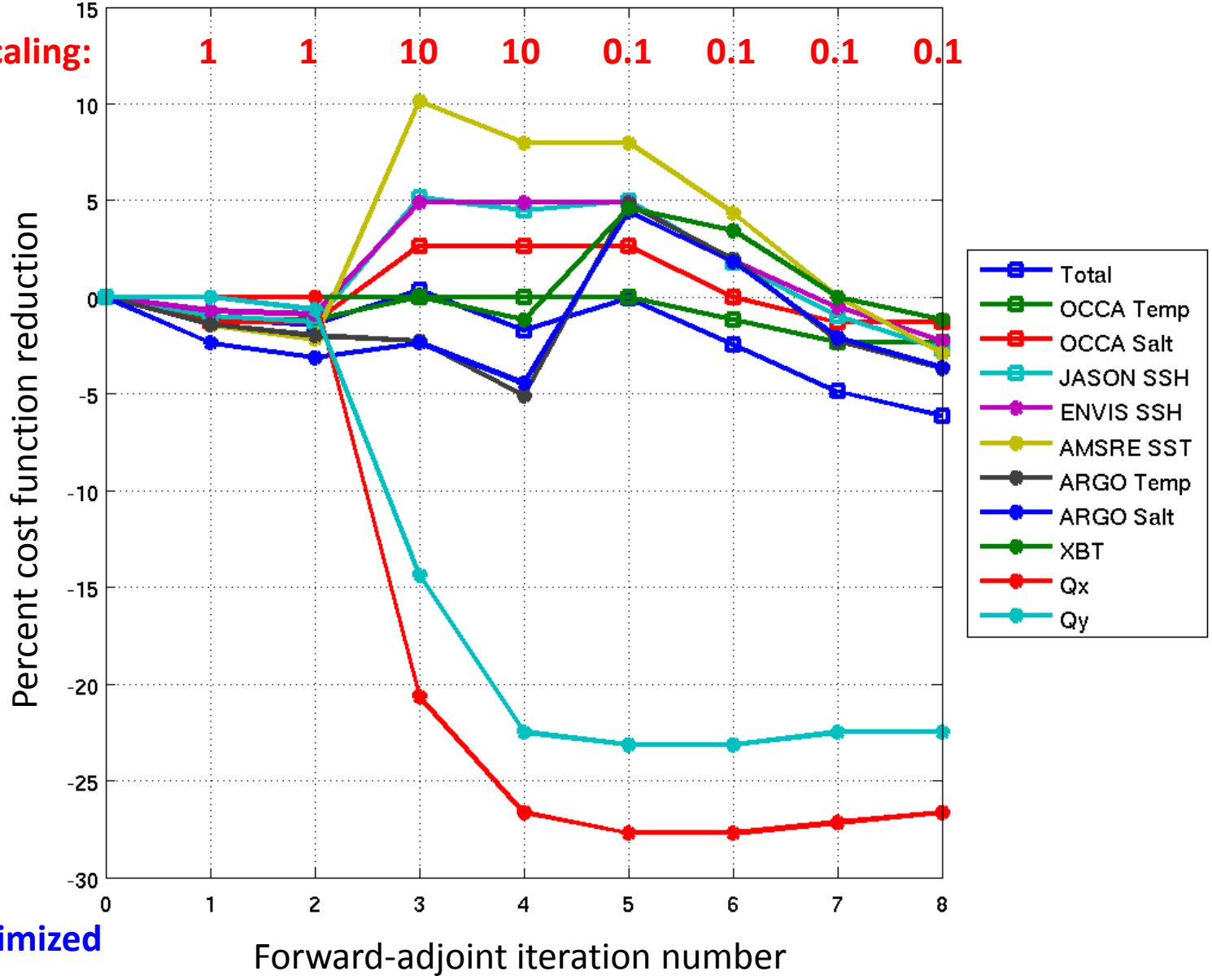
- carried out four additional forward/adjoint iterations of the QuikSCAT-constrained 2004-2005 optimization,
- obtained a 2009-2011 optimized solution, and
- evaluated ECCO2 solutions vs. QuikSCAT v2, QuikSCAT v3, ASCAT, OSCAT, and WindSat.

Using these new results, I will try to address following questions:

- is primary cause of discrepancy reported at last year's meeting a problem with ECCO2 model configuration and estimation methodology or a problem with QuikSCAT wind stress retrievals, in particular,
- can ECCO2 results be used to evaluate and improve ocean vector wind stress retrievals, and/or, conversely,
- can ECCO2 simulation results be improved by the assimilation of ocean vector wind stress data products?

ECCO2 cost function reduction with assimilation of QuikSCAT v2 wind stress data

QuikSCAT cost scaling: 1 1 10 10 0.1 0.1 0.1 0.1



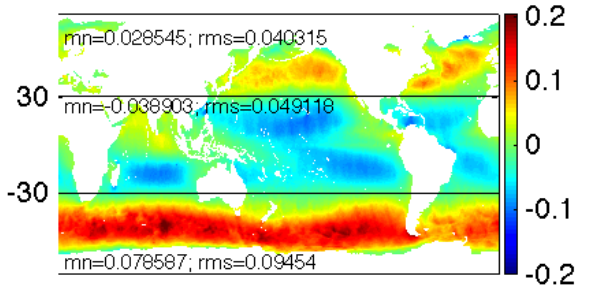
iteration 0 is optimized ECCO2 solution excluding QuikSCAT data

Comparison of 2004-2005 and 2009-2011 baseline and optimized ECCO2 solutions with satellite vector wind data products

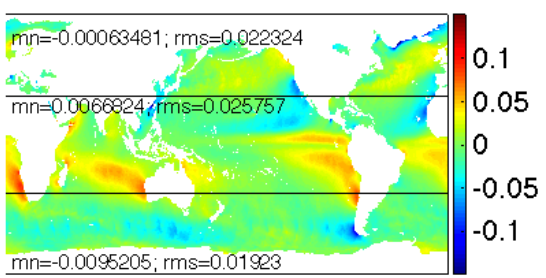
- QuikSCAT L2B v2 25 km, 6AM-ascending and 6PM-descending (JPL PO.DAAC)
- QuikSCAT L2B v3 12.5 km, 6AM-ascending and 6PM-descending (JPL PO.DAAC)
- OSCAT L2B v2 12.5 km, 12PM-ascending and 12AM-descending (JPL PO.DAAC)
- ASCAT L2 25km, 9:30PM-ascending and 9:30AM-descending (OSI SAF)
- WindSat Level 3 v7 0.25°, 6PM-ascending and 6AM-descending (REMSS)

- Derived using Bourassa (2006) bulk parameterization.
- Consistent quality filtering for scatterometer-based products, i.e., land, ice, rain, and azimuth diversity.
- Drag coefficient is held constant at wind speeds greater than or equal to 30 m/s.
- Wind stress greater than 3 N/m^2 is excluded from analysis.
- All-weather winds used from REMSS WindSat product; no quality flags available.
- No cross-track or atmospheric bias-correction was applied for QuikSCAT v3 or OSCAT v2 L2B stress products.
- All model-data comparison carried out using 6-hourly, 0.25° bins.
- Optimized ECCO2 solutions do “not” include wind stress constraints.

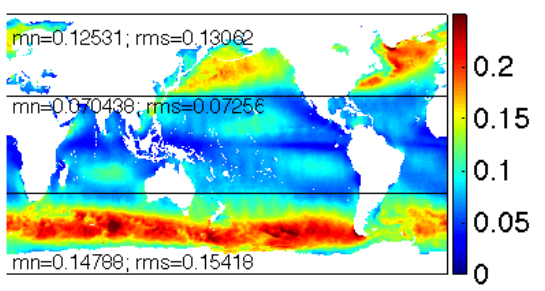
OScat, 2010-2011 mean(τ_x)



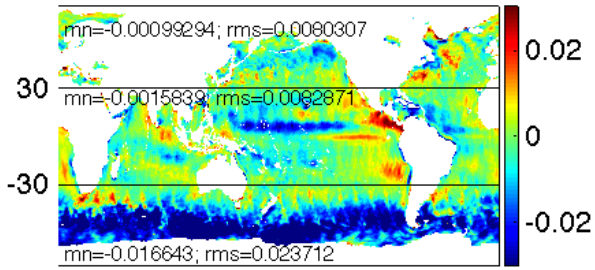
OScat, 2010-2011 mean(τ_y)



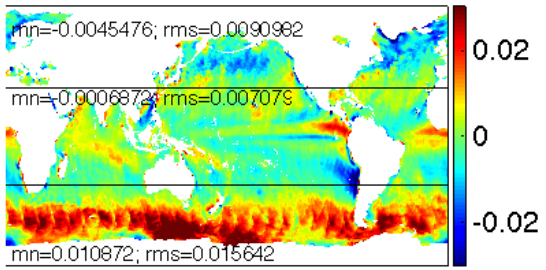
OScat, 2010-2011 mean(|τ|)



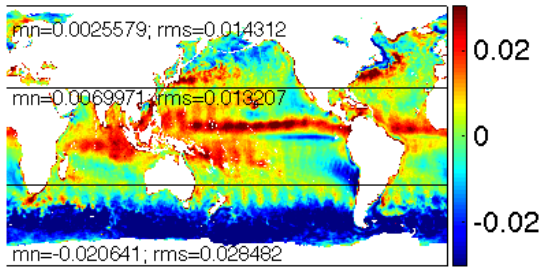
observations - baseline



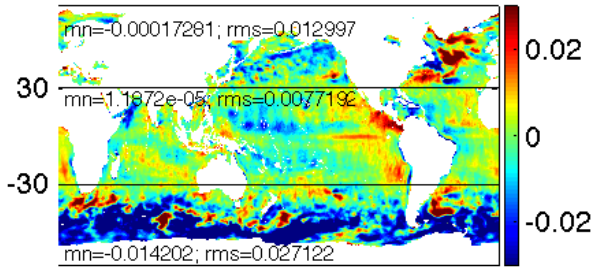
observations - baseline



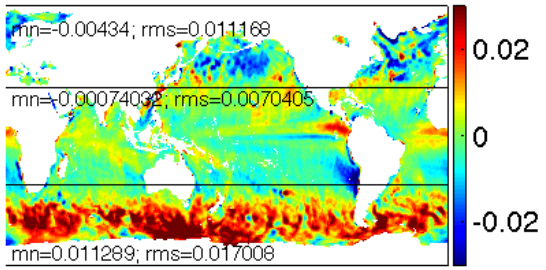
observations - baseline



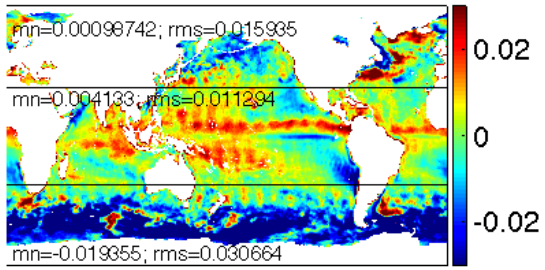
observations - optimized



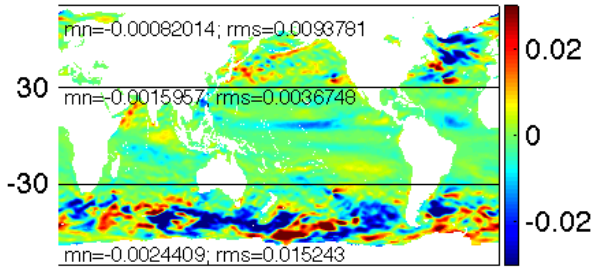
observations - optimized



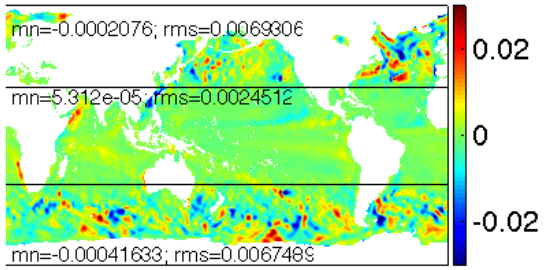
observations - optimized



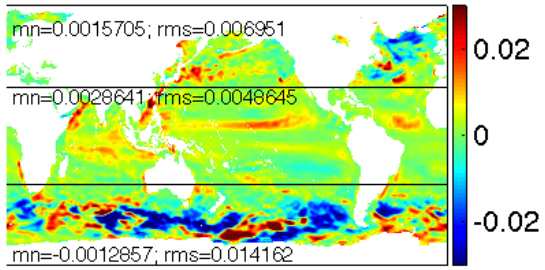
optimized - baseline

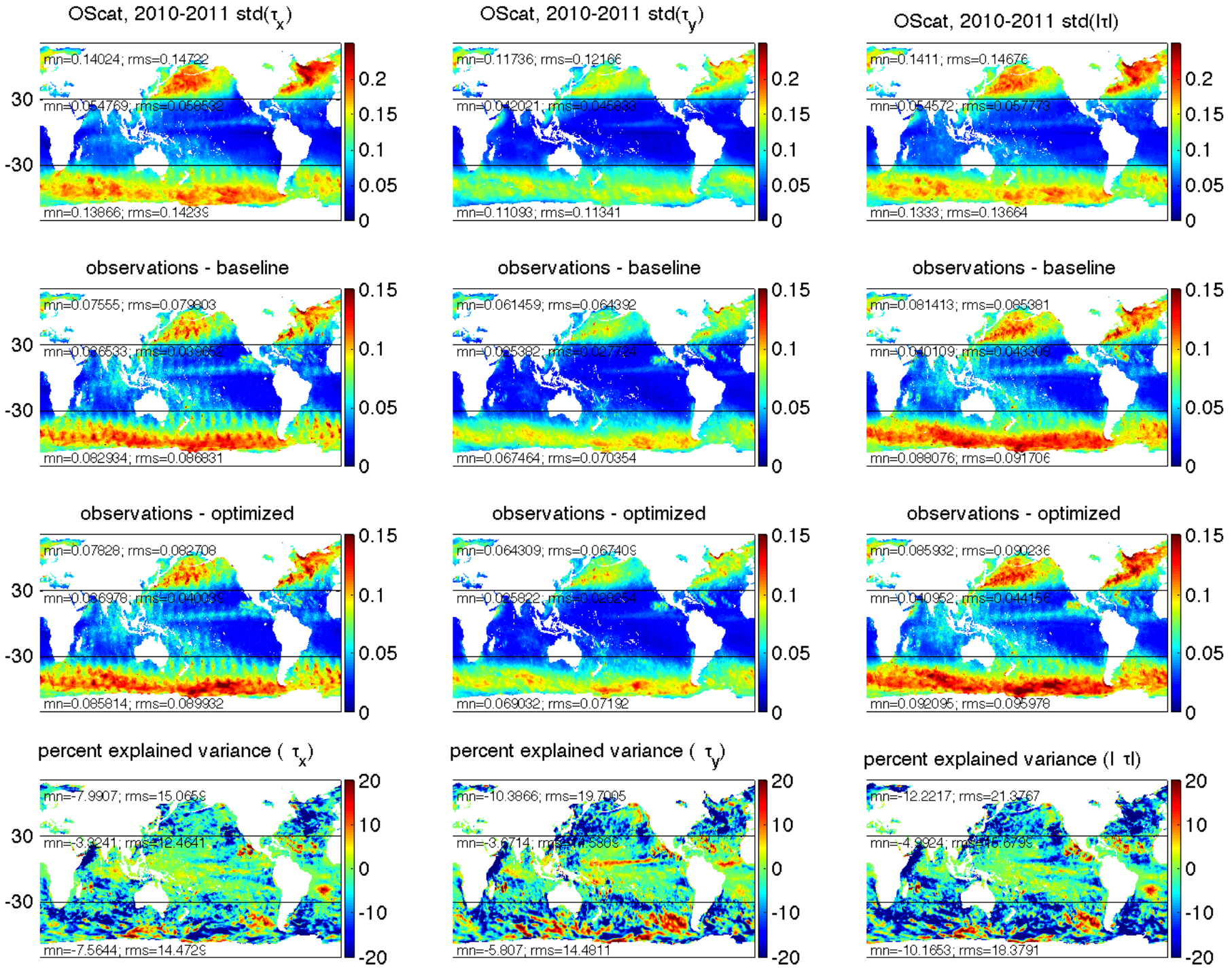


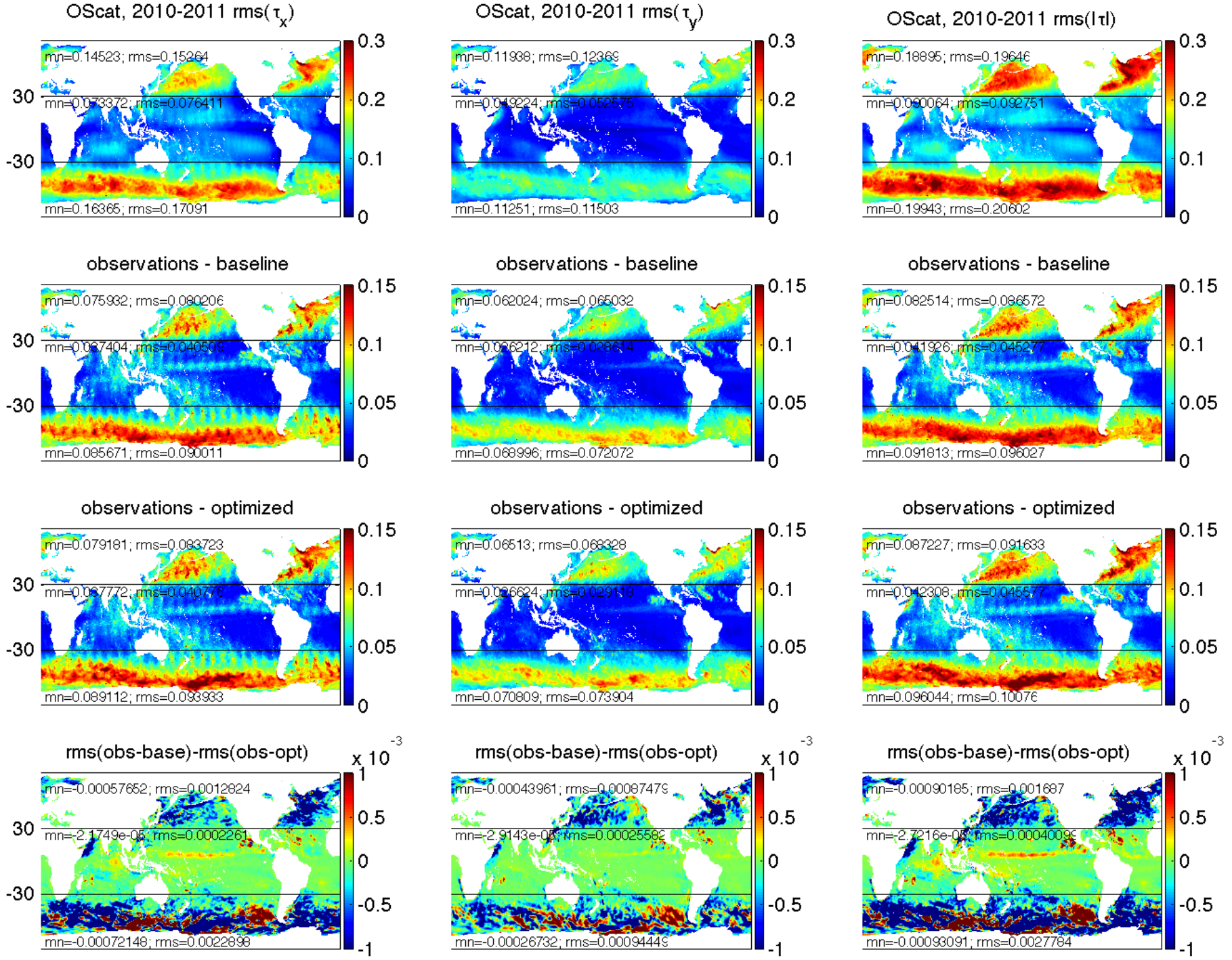
optimized - baseline



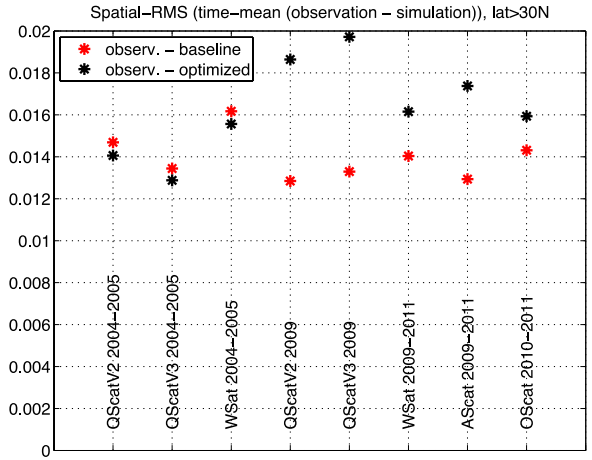
optimized - baseline



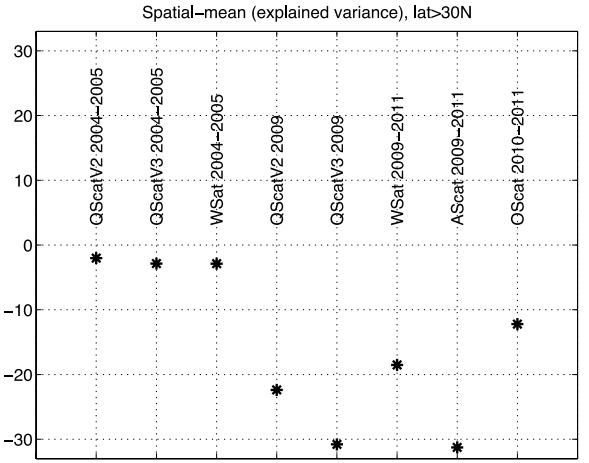

OScat, 2010-2011 std(τx)
mn=0.14024; rms=0.14722
mn=0.054769; rms=0.058532
mn=0.13866; rms=0.14239
OScat, 2010-2011 std(τy)
mn=0.11736; rms=0.12166
mn=0.042021; rms=0.045833
mn=0.11093; rms=0.11341
OScat, 2010-2011 std(|τ|)
mn=0.1411; rms=0.14676
mn=0.054572; rms=0.057773
mn=0.1333; rms=0.13664
observations - baseline
mn=0.07555; rms=0.079803
mn=0.036533; rms=0.039662
mn=0.082934; rms=0.086831
observations - baseline
mn=0.061459; rms=0.064392
mn=0.025382; rms=0.027724
mn=0.067464; rms=0.070354
observations - baseline
mn=0.081413; rms=0.085381
mn=0.040109; rms=0.043309
mn=0.088076; rms=0.091706
observations - optimized
mn=0.07828; rms=0.082708
mn=0.036978; rms=0.040039
mn=0.085814; rms=0.089932
observations - optimized
mn=0.064309; rms=0.067409
mn=0.025822; rms=0.028254
mn=0.069032; rms=0.07192
observations - optimized
mn=0.085932; rms=0.090236
mn=0.040952; rms=0.044156
mn=0.092095; rms=0.095978
percent explained variance (τx)
mn=-7.9907; rms=15.0659
mn=-3.3241; rms=12.4641
mn=-7.5644; rms=14.4729
percent explained variance (τy)
mn=-10.3866; rms=19.7095
mn=-3.6714; rms=14.5809
mn=-5.807; rms=14.4811
percent explained variance (| τ|)
mn=-12.2217; rms=21.3767
mn=-4.9924; rms=16.6795
mn=-10.1653; rms=18.3791
30
-30
0.2
0.15
0.1
0.05
0
20
10
-10
-20

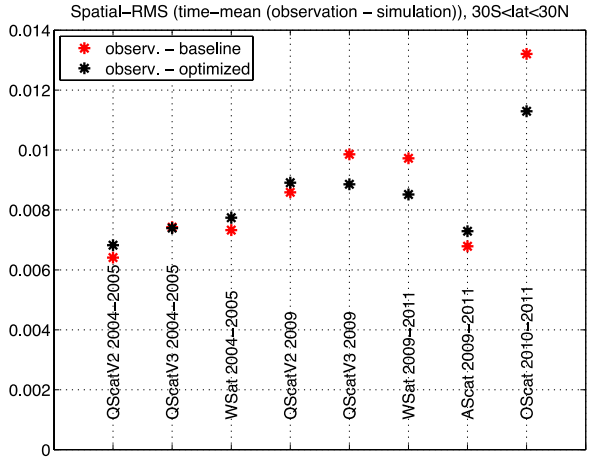

OScat, 2010-2011 rms(τx)
mn=0.14523; rms=0.15264
mn=0.073372; rms=0.076411
mn=0.16365; rms=0.17091
OScat, 2010-2011 rms(τy)
mn=0.11938; rms=0.12369
mn=0.049224; rms=0.052575
mn=0.11251; rms=0.11503
OScat, 2010-2011 rms(|τ|)
mn=0.18895; rms=0.19646
mn=0.090064; rms=0.092751
mn=0.19943; rms=0.20602
observations - baseline
mn=0.075932; rms=0.080206
mn=0.037404; rms=0.040509
mn=0.085671; rms=0.090011
observations - baseline
mn=0.062024; rms=0.065032
mn=0.026212; rms=0.028614
mn=0.069996; rms=0.072072
observations - baseline
mn=0.082514; rms=0.086572
mn=0.041926; rms=0.045277
mn=0.091813; rms=0.096027
observations - optimized
mn=0.079181; rms=0.083723
mn=0.037772; rms=0.040776
mn=0.089112; rms=0.093933
observations - optimized
mn=0.06513; rms=0.068328
mn=0.026624; rms=0.029118
mn=0.070809; rms=0.073904
observations - optimized
mn=0.087227; rms=0.091633
mn=0.042308; rms=0.045577
mn=0.096044; rms=0.10076
rms(obs-base)-rms(obs-opt)
x 10^-3
mn=-0.00057652; rms=0.0012824
mn=-2.1749e-05; rms=0.0002261
mn=-0.00072148; rms=0.0022898
rms(obs-base)-rms(obs-opt)
x 10^-3
mn=-0.00043961; rms=0.0008747
mn=-2.9143e-05; rms=0.00025582
mn=-0.00026732; rms=0.0009444
rms(obs-base)-rms(obs-opt)
x 10^-3
mn=-0.00090185; rms=0.001687
mn=-2.7216e-05; rms=0.00040098
mn=-0.00093091; rms=0.0027784
30
-30
0.3
0.2
0.1
0
0.15
0.05
1
0.5
-0.5
-1

Spatial-rms (time-mean (observation – simulation))

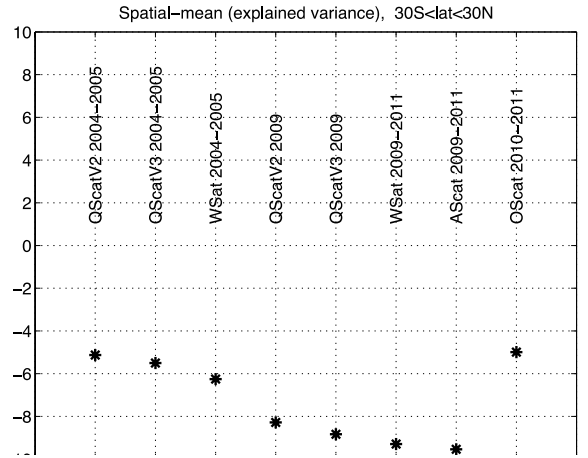


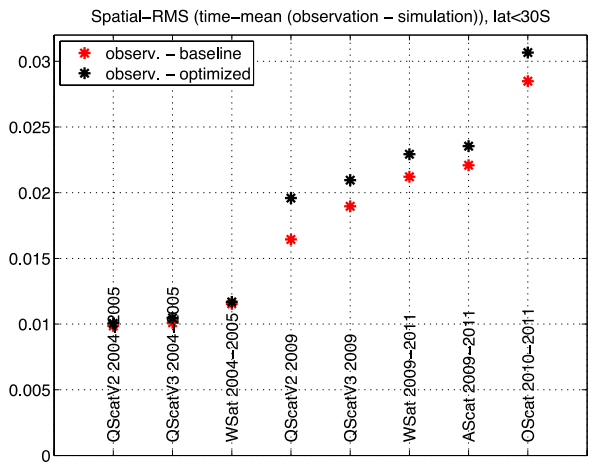
latitude>30°N



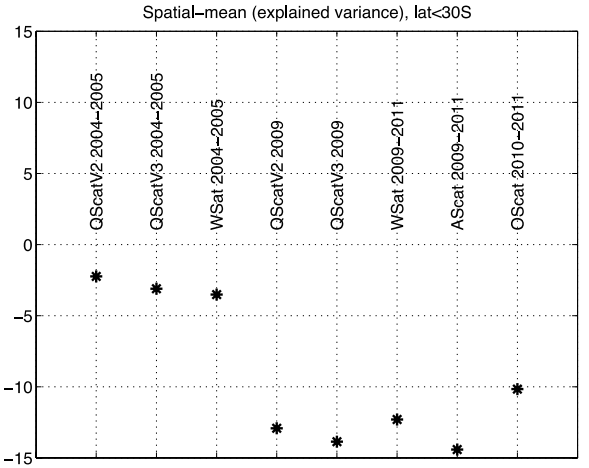


30°S<latitude<30°N





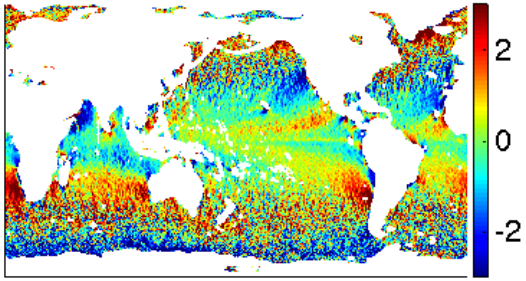
latitude<30°S



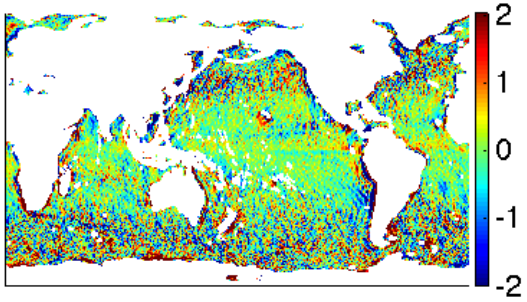
Spatial-mean (explained variance)

Wind stress curl comparison of 2009-2011 baseline and optimized ECCO2 solutions with ASCAT

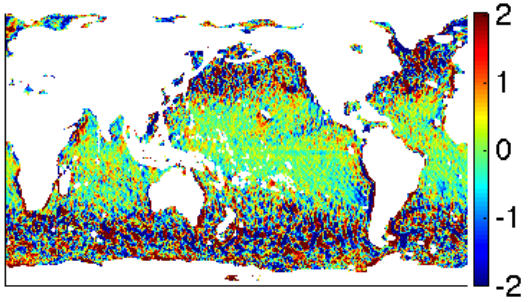
AScat, 2009-2011 curl(τ), N/m^2 per 10^4 km



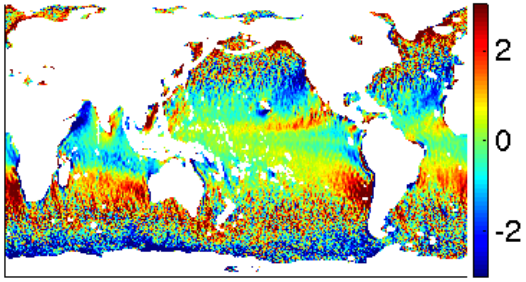
curl(Observ. - Baseline)



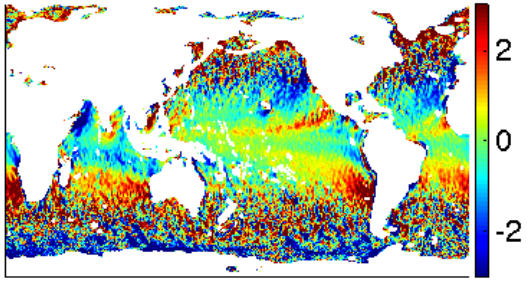
curl(Observ. - Optimized)



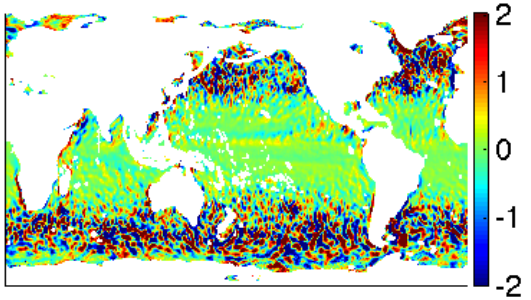
baseline curl(τ)



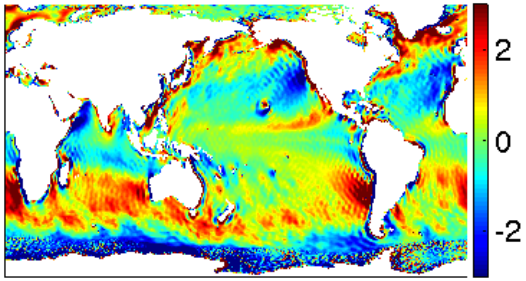
optimized curl(τ)



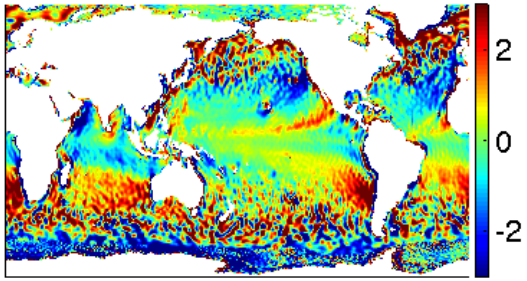
curl(Optimized. - Baseline)



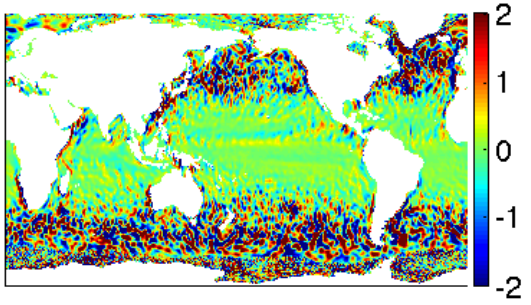
"full" baseline curl(τ)



"full" optimized curl(τ)



curl(Optimized. - Baseline)



Concluding remarks

- A global, eddying, ocean and sea ice circulation estimate can be constructed such that it is simultaneously closer with QuikSCAT, altimetry, SST, and Argo data and consistent with prior uncertainty estimates for each of these data sets.

- The assimilation of ocean vector wind data products in atmospheric analyses and reanalyses (e.g., ECMWF and JRA-25) appears to extract most of the information that is useful for driving large-scale ocean circulation in the ECCO2 model configuration.

- In the tropical oceans, especially in the Equatorial Pacific, the optimized ECCO2 solution is statistically closer to unassimilated ocean vector wind data products than is the baseline ECCO2 solution.

- At higher latitudes, incoherent eddy variability is a “representation error” that limits utilization of ECCO2 results for evaluating satellite wind retrievals and, conversely, amount of information that can be extracted from ocean vector wind data products.

- With above caveats in mind, the global ECCO2 optimized solutions are not inconsistent with ocean vector wind data products but there are many regional details that merit further investigation …

Planned work

Continue to look for conclusive evidence that

(i) satellite ocean wind vector products can improve ECCO2 solutions above and beyond the use of satellite-wind-constrained atmospheric (re)analyses and/or that

(ii) ECCO2 solutions can be used to evaluate ocean vector wind stress retrievals by:

- studying in more detail regions that display pronounced similarities (e.g., Pacific Equatorial Currents and Southern Ocean east of Chile) or differences (e.g., Kuroshio region and Arabian Sea),

- comparing ECCO2 baseline and optimized results with improved wind stress data products, e.g., by applying cross-track, atmospheric bias, or diurnal corrections on QuikSCAT v3 and OSCAT v2 L2B wind stress products, and

- accounting for episodic events and data space/time sampling issues and for sea surface current and SST anomalies caused by incoherent eddy activity between the model solution and the real ocean.