Ocean Model Results Forced by CCMP, Objective QSCAT and ECMWF Winds

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Part of Wendy's carbon project with main goal to see if scat winds can improve bio models.   At that same time, Joe contacted me with new wind product and wanted to see if this was comparable to Bourassa product. The question to be addressed was is there any benefit from additional data?? (Remember to thank Bourassa, Wentz)

Wind Product Description

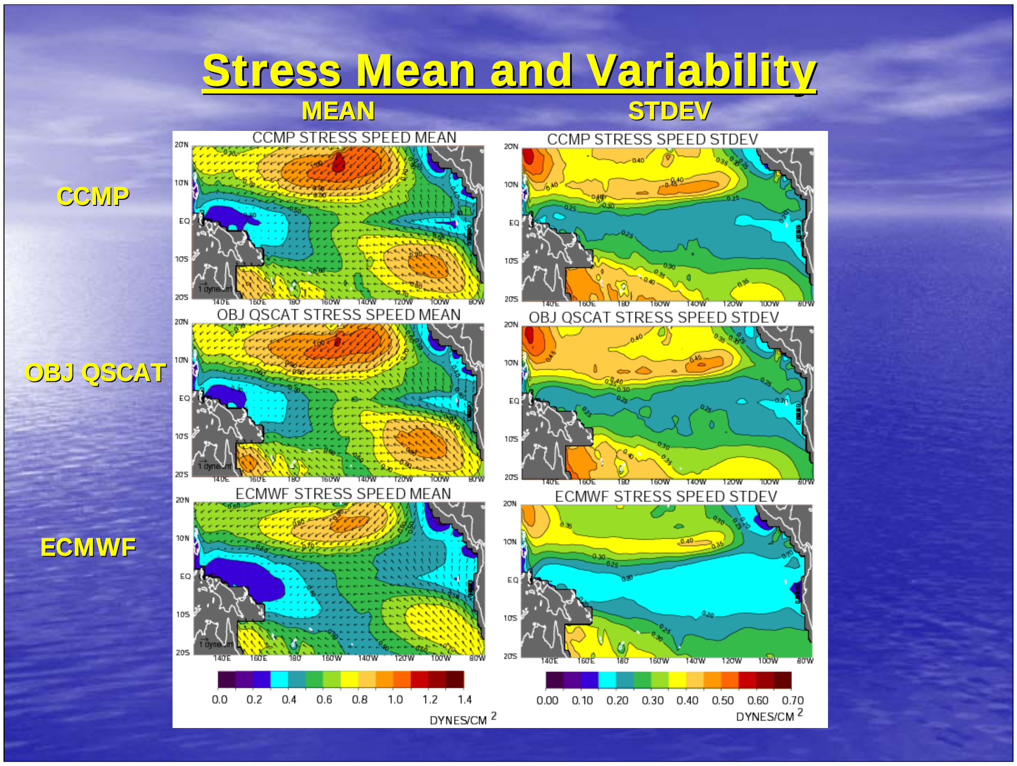
- CCMP Cross-calibrated, multi-platform product combines satellite microwave radiometer (SSM/I, AMSR-E and TRMM TMI) and scatterometer (QSCAT,ADEOS-2) wind observations (provided by F. Wentz) are combined using VAM. Only cells containing satellite information are included. An additional product (CCMP, QSCAT ONLY) is also used in this study. *(Ardizzone, J.V. et al., New Multiplatform Ocean Surface Wind Product Available, EOS, 90, 27, p. 231, 2009)*
- OBJ QSCAT – Variational approach objective technique produces QSCAT pseudo-stress (2000-2005), combined with SSM/I VAM Version 10 data (1987-1999). Tuning parameters are determined using Generalized Cross-Validation. *(Pegion, P. J., et al., Objectively derived daily "winds" from satellite scatterometer data, Monthly Weather Review, 128(9), 3150-3168, 2000)*

There are two types of rain flags - one derived from Quikscat and another derived from collocation with radiometers (i.e. SSMI, AMSRE etc). If one or both of these flags show rain, we do not use the report. In addition, we also eliminate data that is within 25km of a point where it is raining.

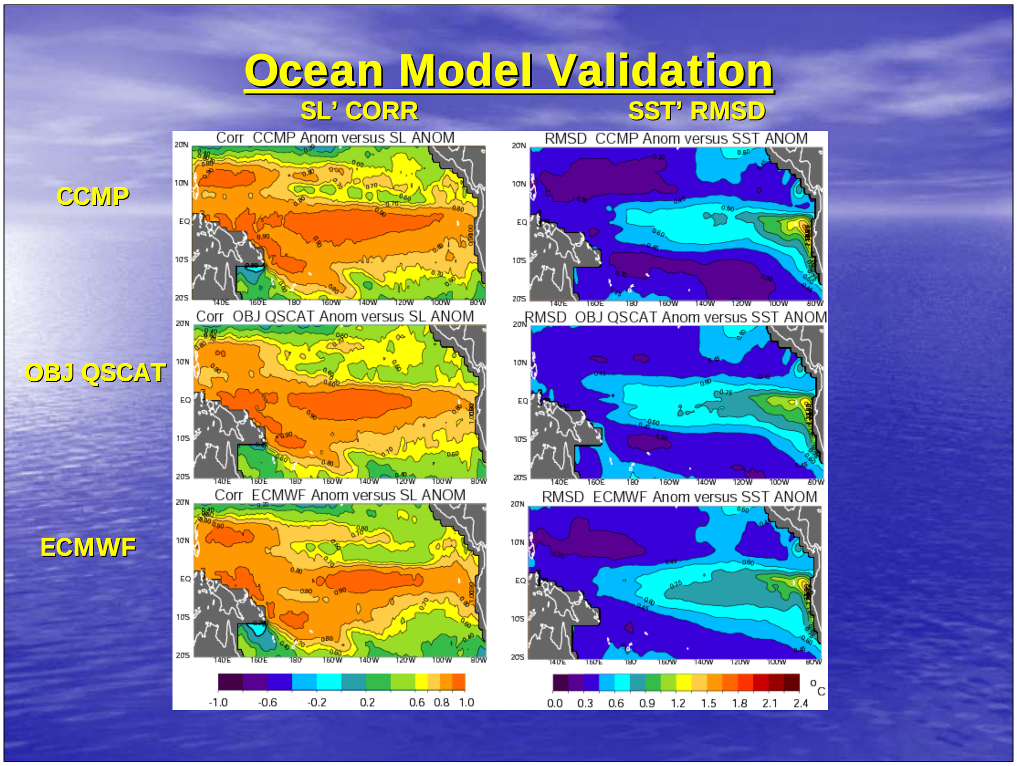
Wind Product Description (cont.)

- ECMWF – The same combination of ECMWF ERA-40 (1987-2002) and ECMWF analysis (2002-2005) matches the CCMP background.

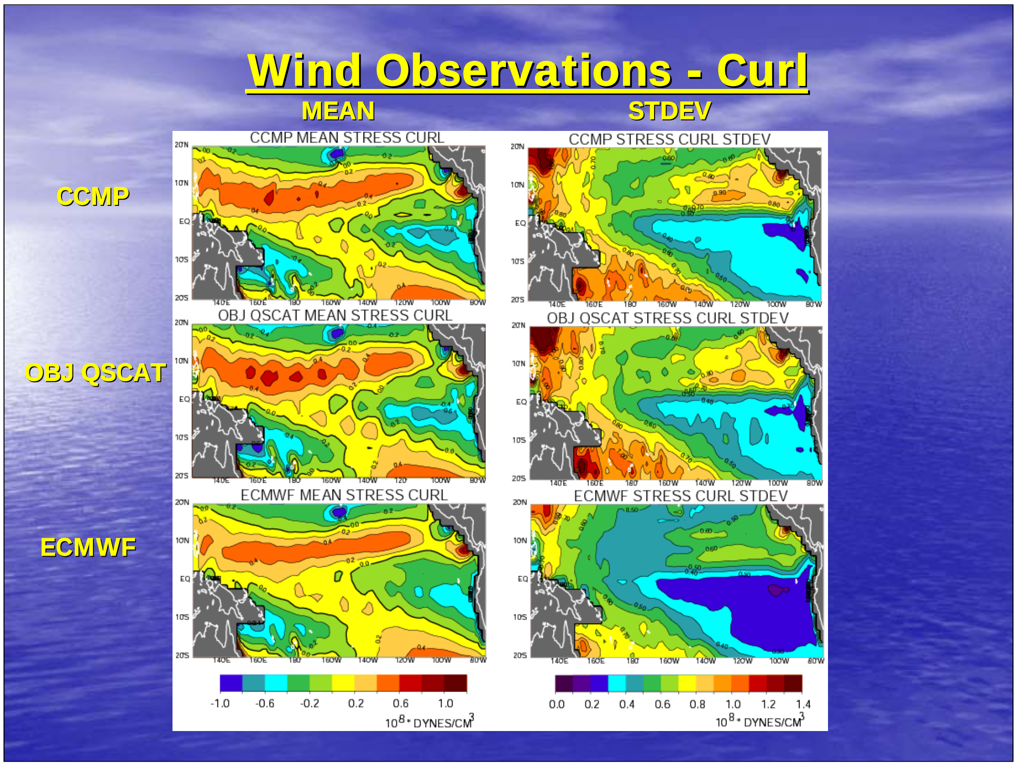
- Processing - processed onto 1ºx1ºx weekly grids, converted to stress using the bulk formula and a constant drag coefficient ($Cd=1.2x10^{-3}$).



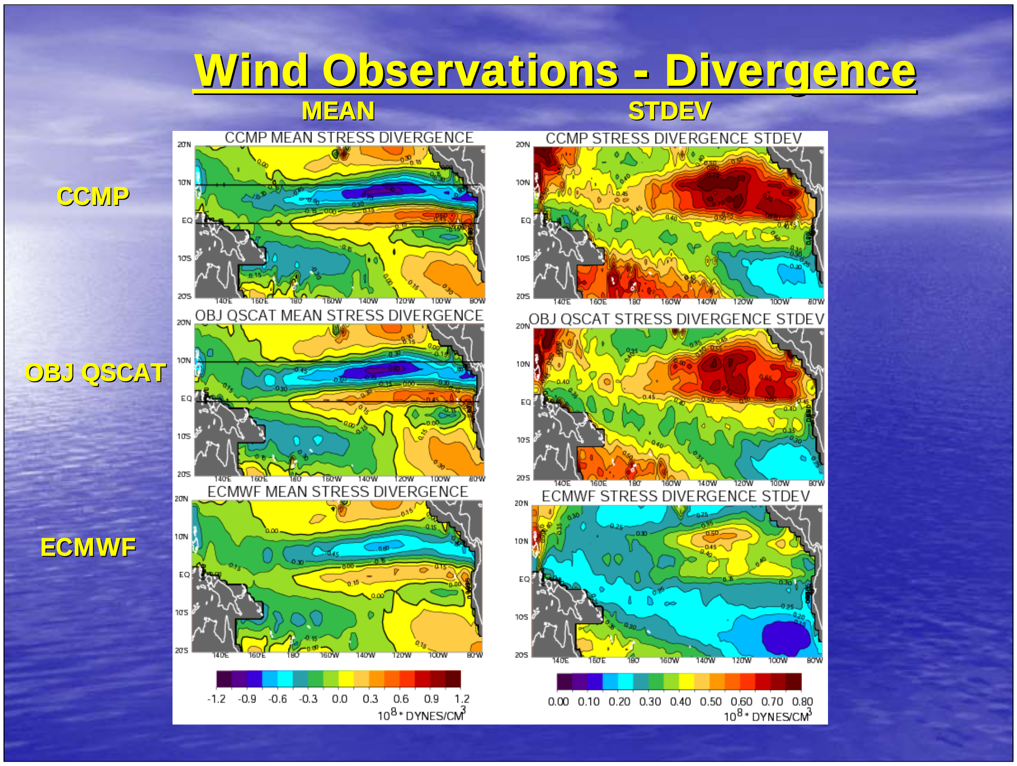
Introduction.. ECMWF magnitude significantly weaker than satellite products and satellite products differ in variability in N.H. especially west of dateline.



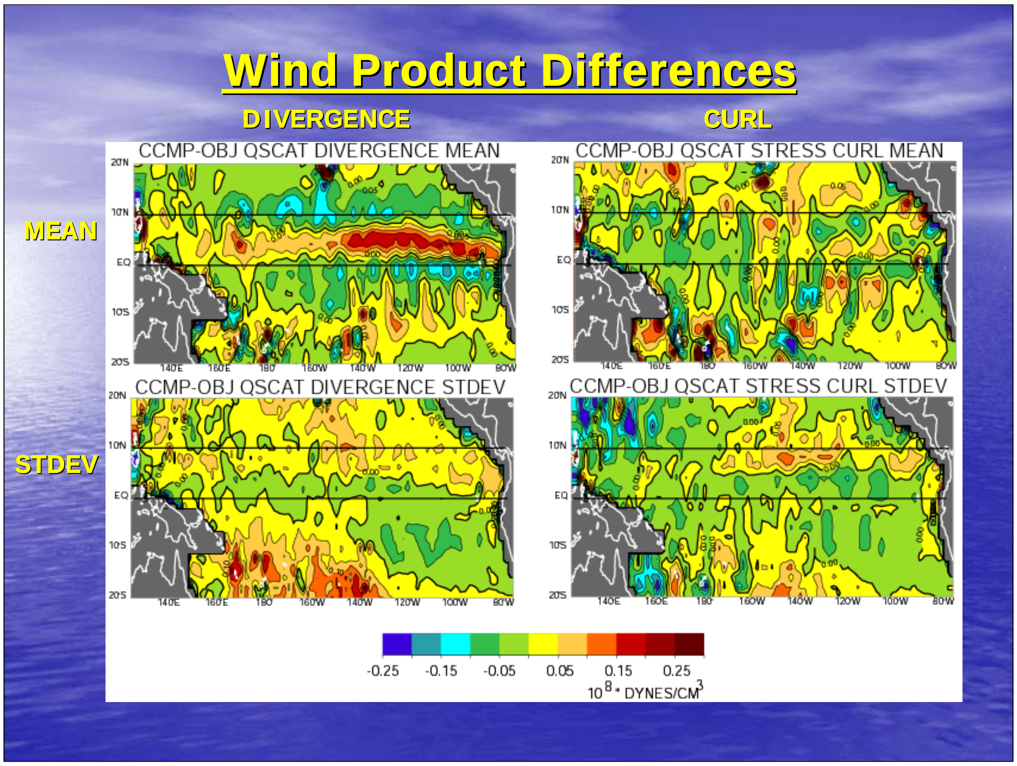
Gent and Cane Reduced-gravity, primitive-equation, sigma coordinate ocean model is forced by different wind stress products. Note that all other forcing is the same and that the model has dynamic and thermodynamic response to winds (no relaxation at ocean surface to Levitus SST or salinity). Note CCMP improves NECC SL signal and NINO3 SST anomaly – important for coupled model and coupled bio/physical models. For NINO3 SST anomalies, confidence levels exceed 81% that the CCMP is significantly better than OBJ QSCAT.



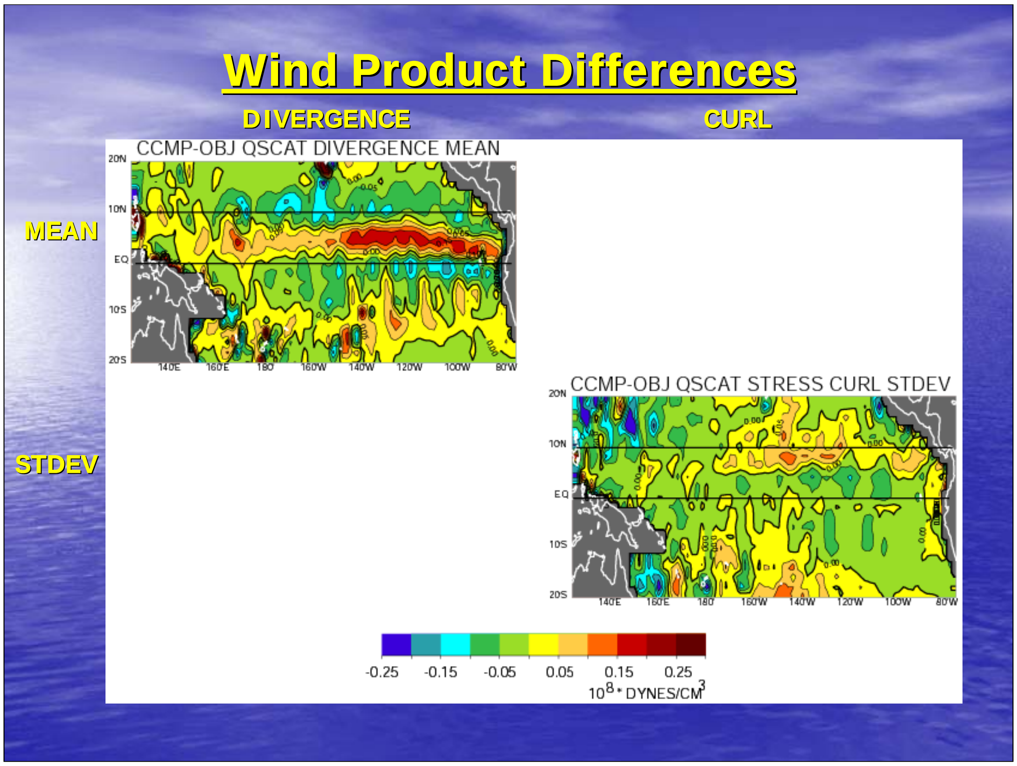
Curl important for ocean modeling through Ekman pumping off-equator and impact on mixed layer etc.. Note curl variability differences in N.H. in eastern Pacific.



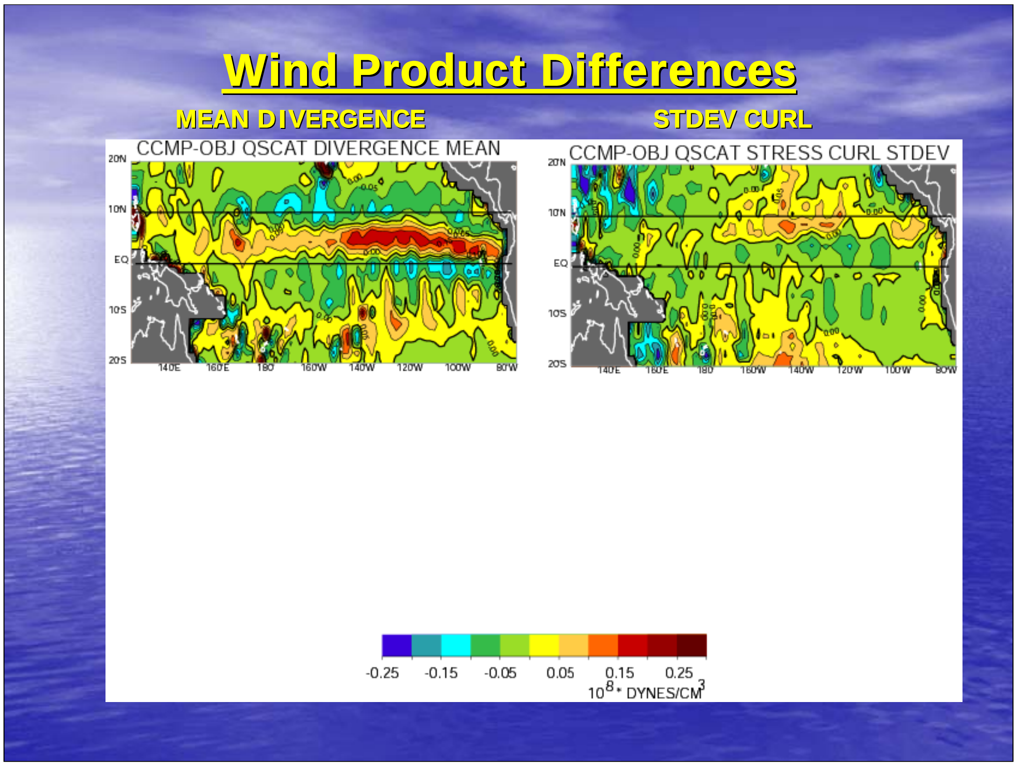
Divergence important especially near the equator for SST. Divergence patterns - point out conv, divergence, convergence from 5S-2N-8N and note CCMP has higher variability in N.H. eastern Pacific. Hard to tell differences between products so next plot is differences between CCMP-OBJ QSCAT



Curl mean differences (top right) shows no coherent structure so not so interesting. For Divergence standard deviation difference (bottom left) this pattern is simply amplification of divergence for CCMP with same pattern as mean… so not interested….

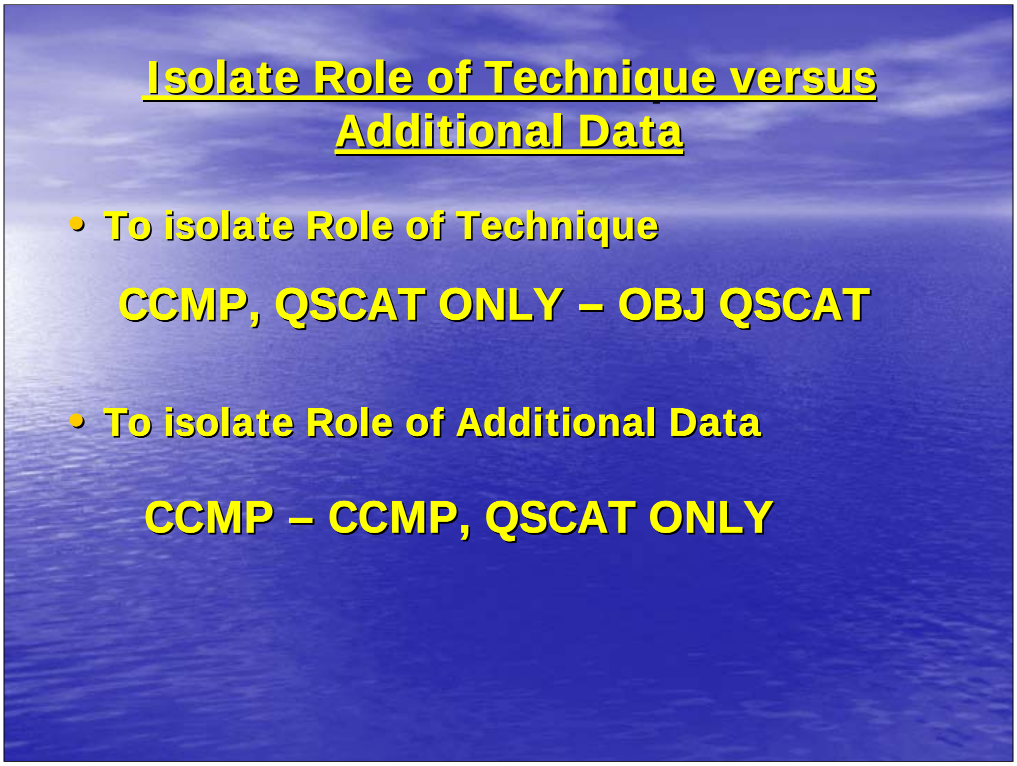


However, mean divergence differences and curl standard deviation differences show interesting features so I'll concentrate on these….

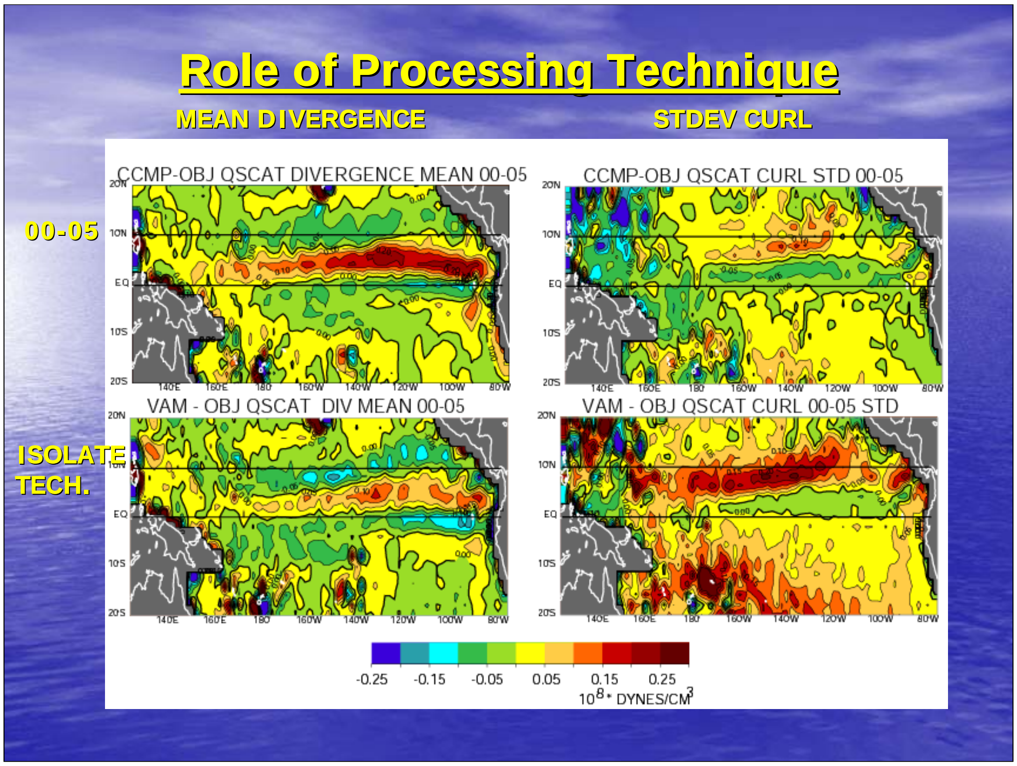


The divergence mean difference plot shows convergence, divergence, convergence going north from the equator. However, it is important to note that this is not an amplification of the mean but instead the maximum divergence differences (+ values) corresponds to region of transition of convergence to divergence (flip back two plots for confirmation).

For the difference between the Curl standard deviation note that the biggest differences are found near 8N where CCMP variability is larger than OBJ QSCAT (i.e. positive values). Next question "is this due to processing or the additional data found in CCMP"?

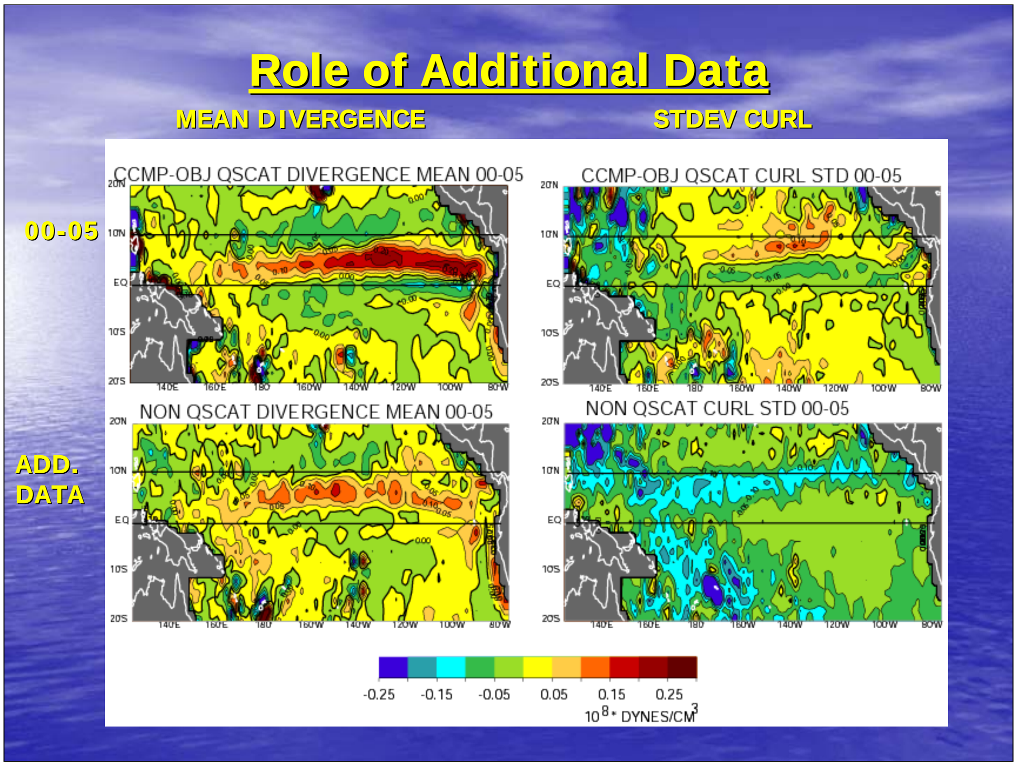


To address this question we can isolate the role of technique versus data. Joe provided me with a version of the CCMP that uses QSCAT only. Therefore we can use this product to isolate the role of technique by differencing CCMP,QSCAT ONLY-OBJ QSCAT. In addition, we can do the same for the role that additional data (AMSR-E, SSM/I, TRIMM TMI and ADEOS-2) play by differencing CCMP (with all the data) – CCMP, QSCAT ONLY.



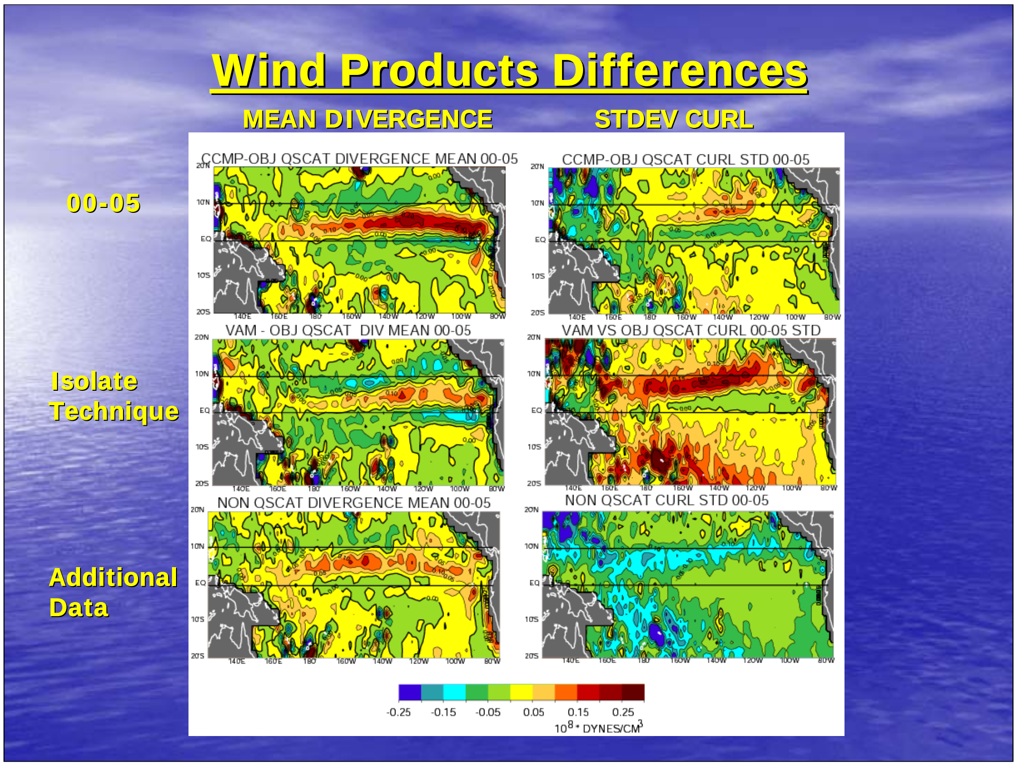
The top 2 plots are the previous data limited to 2000-2005 (QSCAT period). These show similar amplitude and patterns as full 1993-2005 period. Bottom 2 plots show the results of the role of processing technique. Note that the processing shows the same pattern and accounts for about half the amplitude for the divergence differences. Convergence in the eastern Eq region works to reduce upwelling and mitigate the well know cold bias of the ocean model.

Also the processing shows similar pattern but amplified values for the standard deviation of the curl.



Now for the isolation of the role of additional data… Again the data show a similar pattern for the mean divergence. However, convergence is weaker and moved westward so local model SST' improvements are probably not due to additional data (but off-equatorial divergence at 5N may play a role). For the curl standard deviation differences, data show overall negative values, offsetting the strong positive from the Role of processing. So the additional data serve to reduce the curl variability in the ITCZ and SPCZ. (To me this looks like a mean rain pattern).

These results have implication for potential added benefit provided by DFS onboard GCOM-W2 mission that will have both Ku and C band scatterometer instruments observing coincident wind stress. The improved wind stress variability brought about by additional views of the wind field in rainy regions using multiple satellites may potentially duplicate the improvement brought about by DFS.



Here is a summary of the results showing both effects on the same plot….

Conclusions

- CCMP forces improved ocean model simulations (eg. NINO3 SST' - coupled and bio modeling implications).
- Differences in technique and additional information provided by multi-satellite observations (i.e. SSM/I, AMSR-E, TRMM TMI and ADEOS-2) contribute equally to the differences in divergence.
- Additional data in CCMP tends to reduce the curl variability especially in rain contaminated regions

Conclusions (cont.)

- Improvements in ocean model simulations are probably due to improved curl variability in the eastern ITCZ and more accurate divergence/convergence patterns near the equator afforded by multi-product CCMP winds.

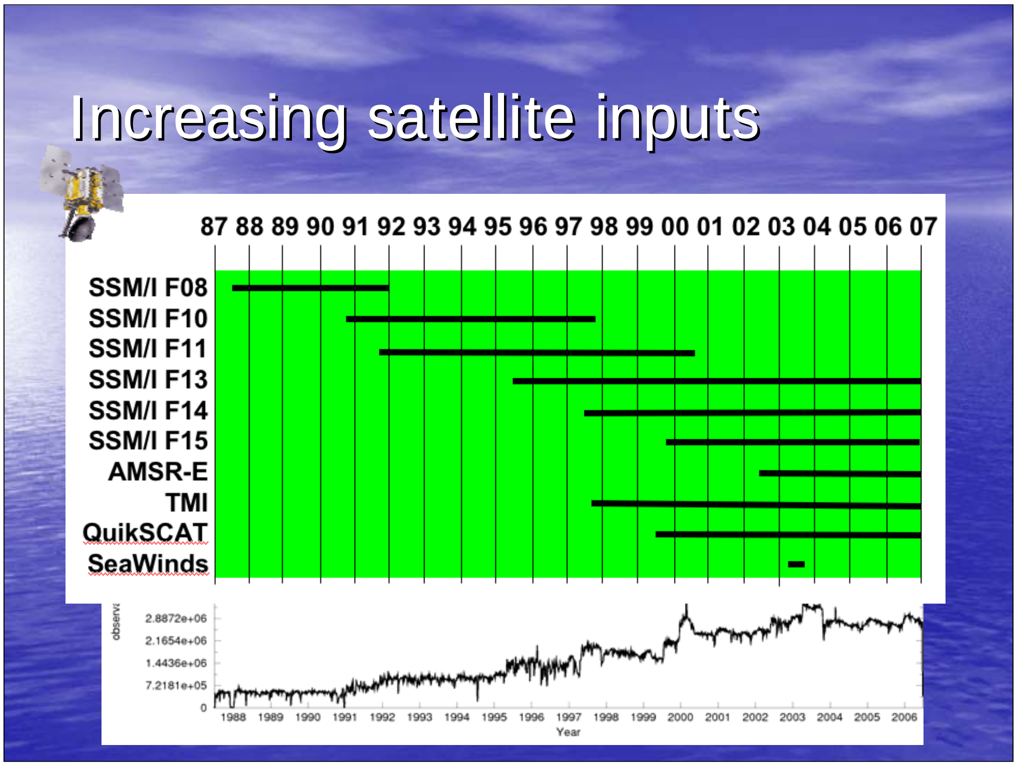
Future Work

- Complete biological / physical coupled model results using CCMP, OBJ QSCAT
- Examine impact of CCMP versus other wind forcing on mixed layer physics
- CCMP will be expanded to include additional data NSCAT, WindSAT, ASCAT and extended through 2012

Additional Slides

Model and Forcing

- **Reduced-gravity, primitive equation, sigma coordinate model** *[Gent and Cane, 1989]*
- **Hybrid variable depth mixed layer** *[Chen et al., 1994]*
- **Natural boundary condition for fresh water flux** *[Huang, 1993]*
- **Advective AML coupled to OGCM** *[Seager et al., 1995]*
- **Realistic coastlines for tropical Pacific (124°E-280°E, 30°N-30°S), 20 layers**
- **Forcing:**
  - a) **Xie and Arkin + GPCP rainfall anomalies added to ISCCP seasonal cycle**
  - b) **NCEP reanalysis clouds**
  - c) **ERBE solar radiation**



To date we have assimilated all of the SSMIs, AMSRE, TMI QSCAT and Seawinds data for 1987 to June 2006. This data set will be extended into …

Methodology

The variational analysis method (VAM) generates a gridded surface wind analysis which minimizes an objective function (J) measuring the misfit of the analysis to the background, the data and certain a priori constraints.

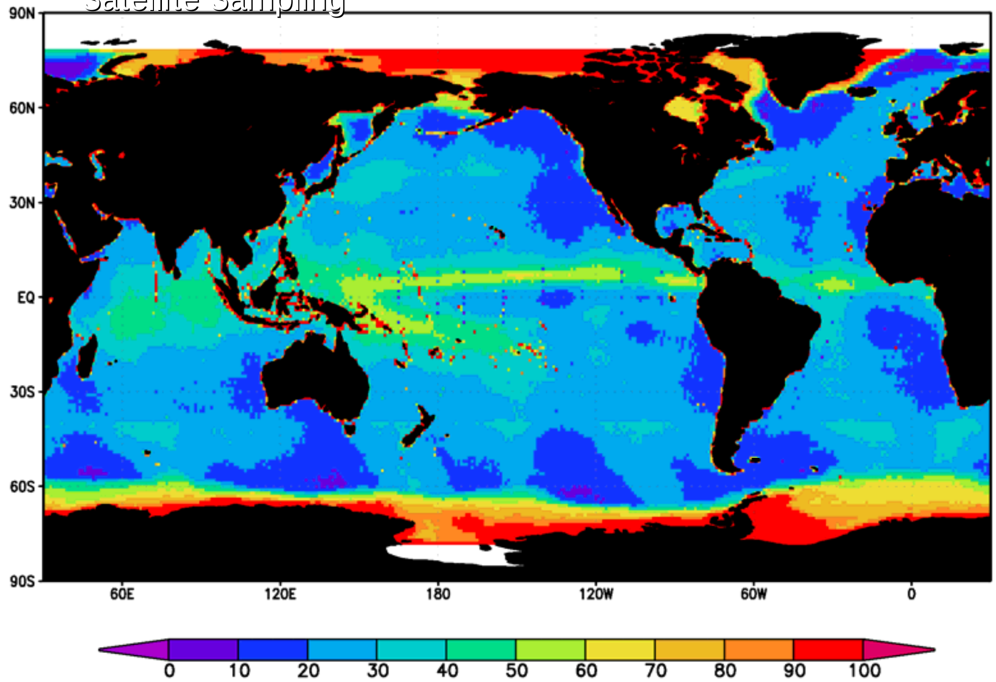
$$J = \lambda_{\mathrm{CONV}} J_{\mathrm{CONV}} + \lambda_{\mathrm{SCAT}} J_{\mathrm{SCAT}} + \lambda_{\mathrm{SPD}} J_{\mathrm{SPD}} + \lambda_{\mathrm{VWM}} J_{\mathrm{VWM}} + \lambda_{\mathrm{LAP}} J_{\mathrm{LAP}} + \lambda_{\mathrm{DIV}} J_{\mathrm{DIV}} + \lambda_{\mathrm{VOR}} J_{\mathrm{VOR}} + \lambda_{\mathrm{DYN}} J_{\mathrm{DYN}}$$

Term	Expression	Description of constraint
		Observation Function for the
J_{CONV}	$\sum(\mathbf{V}_A - \mathbf{V}_O)^2$	• wind vectors
J_{SCAT}	$\sum(\mathbf{V}_A - \mathbf{V}_O)^2$	• wind vectors
J_{SPD}	$\sum(\lvert\mathbf{V}_A\rvert - \lvert\mathbf{V}_O\rvert)^2$	• wind speeds
		Background Constraints on the
J_{VWM}	$\int(\mathbf{V}_A - \mathbf{V}_B)^2$	• vector wind magnitude
J_{LAP}	$\int[\nabla^2(u_A - u_B)]^2 + \int[\nabla^2(v_A - v_B)]^2$	• Laplacian of the wind components
J_{DIV}	$\int[\nabla^2(\chi_A - \chi_B)]^2$	• divergence
J_{VOR}	$\int[\nabla^2(\psi_A - \psi_B)]^2$	• vorticity
J_{DYN}	$\int(\partial\zeta_A/\partial t - \partial\zeta_B/\partial t)^2$	• vorticity tendency

$$\mathbf{V}_A = \alpha\mathbf{V}_A + \mathbf{V}_\delta$$

The influence of each term in the objective function is determined by lamda weights which are subjectively tuned to achieve the desired analysis fit.

Satellite Sampling



Role of Additional Data