Preliminary Satellite-Derived Estimates of the Gas Transfer Velocity

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MOTIVATION

Understanding and quantifying the flux of CO_2 between the ocean and atmosphere is necessary to obtain an accurate measurement of the uptake of CO_2 by the world's oceans. Ultimately, global measurements will require remote sensing techniques. The ability to retrieve air-sea gas fluxes using satellite methods is limited, however, due to difficulties in parameterizing the gas/chemical transfer processes and in determining the needed inputs from satellite measurements. The objective of this project is to apply direct surface measurements of gas fluxes and concentrations obtained during the 2008 and previous air-sea CO_2 exchange studies to evaluate and refine satellite-based techniques for estimating gas transfer velocities and fluxes. The ultimate goal is to provide accurate quantification of the gas transfer velocity on global scales using satellite observables. Specific tasks include:

- Implementation and evaluation of improved gas transfer parameterizations using satellite-derived inputs.
- Refinement of satellite-based retrieval techniques and the relationships between the processes affecting gas transfer and remotely observable parameters.

TRANSFER VELOCITY MODELS

Transfer velocity estimates are derived from an implementation of the physically based NOAA COARE air-sea gas transfer parameterization (Fairall et al., 2000).

- Micrometeorological approach describing the turbulent and molecular processes on both sides of the interface
- Incorporates surface renewal concepts
- Utilizes empirical bubble and wave-breaking enhancement model of Woolf (1997)
- Applies to multiple gases including CO_2, DMS, and ozone

Initial comparisons of these estimates are presented against simplified parameterizations based solely on the wind speed:

- Liss and Merlivat (1986) - Piecewise linear
- Wanninkhof (1992) - Quadratic relationship
- Wanninkhof and McGillis (1999) - Cubic relationship

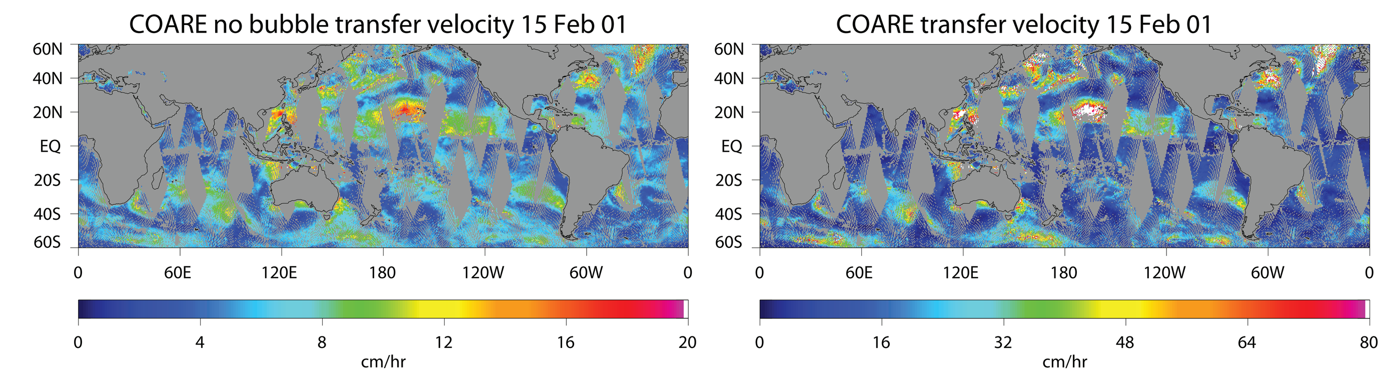
IMPLEMENTATION

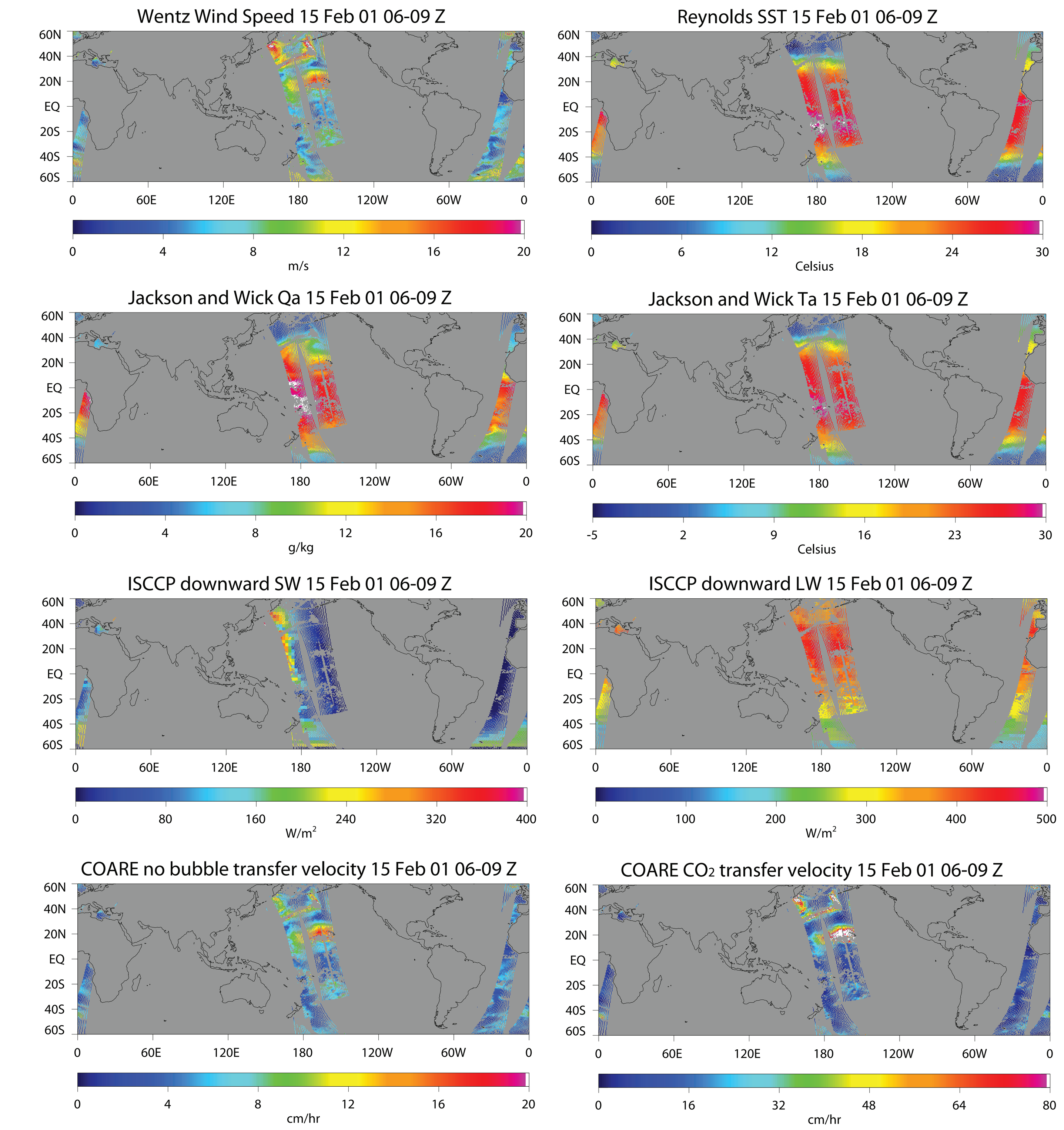
The NOAA COARE gas transfer parameterization was modified to be run on a grid with satellite-derived inputs. The input parameters include the wind speed, sea surface temperature, and additional components of the air-sea heat flux. Specific sources of the parameters are:

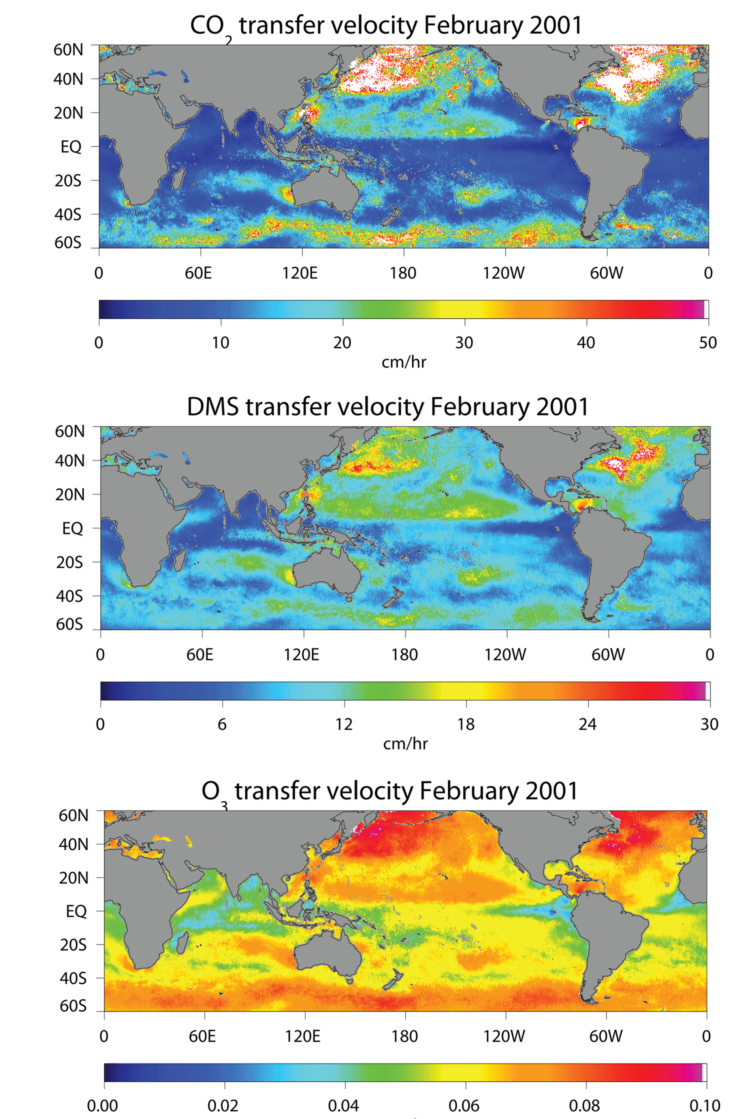
- Wind speed from the 0.25-degree SSM/I products distributed by Remote Sensing Systems (composited for the F-13, F-14, and F-15 satellites)
- Sea surface temperature (SST) from the daily 0.25-degree blended analysis of Reynolds et al. (2007) based on AVHRR data
- Near-surface specific humidity and air temperature generated at 3-hourly, 0.5-degree resolution using a combination of SSM/I and AMSU data using an improved version of the retrievals presented by Jackson et al. (2006)
- Downwelling longwave and solar radiation from the ISCCP FD-SRF products available 3-hourly on a 280-km equal area grid

Initial global estimates of the transfer velocity were computed for CO_2, DMS, and ozone for several months in 2001. The estimates were originally produced at 3-hourly, 0.5-degree resolution and then averaged to daily and monthly estimates.

Panels to the right show the individual input parameters as well as the derived transfer velocity for a 3-hour period on 15 February 2001. Separate results are shown for the transfer velocity both with and without the added bubble enhancement. Note that the variations in transfer velocity most closely match those in wind speed. The corresponding daily averaged transfer velocities are shown in the panels below.





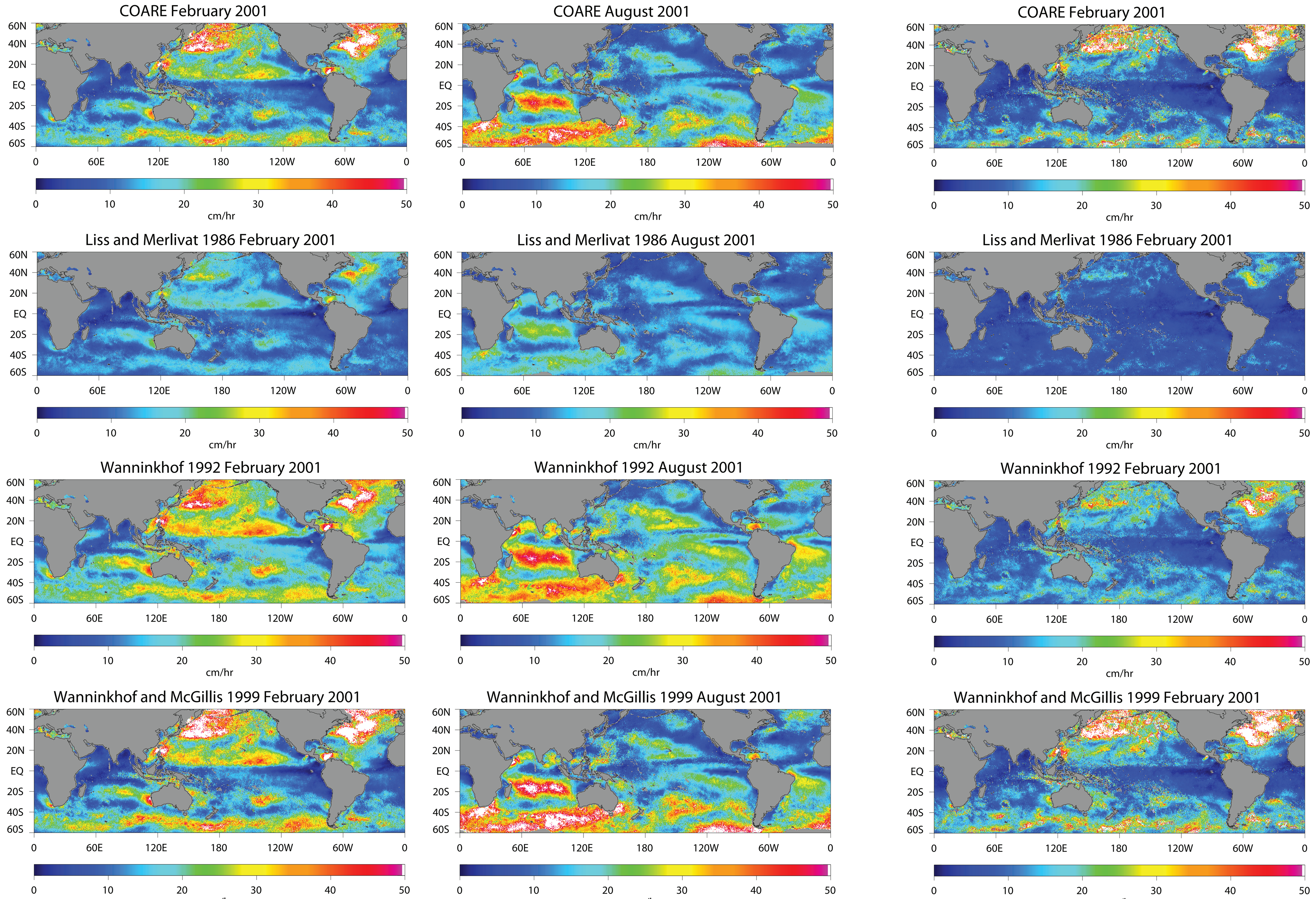


The panels above show the monthly-averaged gas transfer velocity computed independently for CO_2, DMS, and ozone. While all patterns are similar, the relative importance of parameters other than wind speed is greater for ozone.

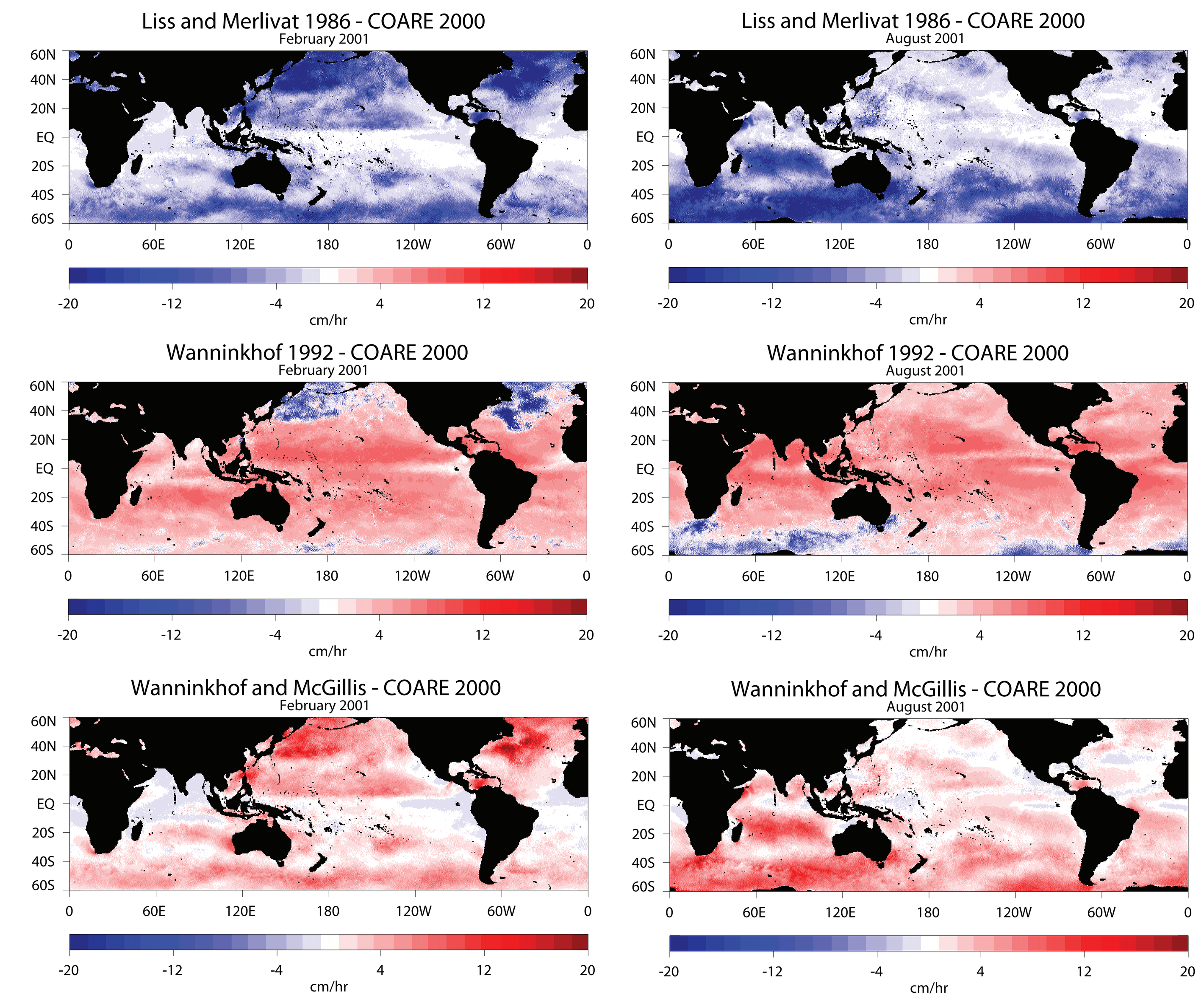
TRANSFER VELOCITY ESTIMATES

Monthly Means

Standard Deviations



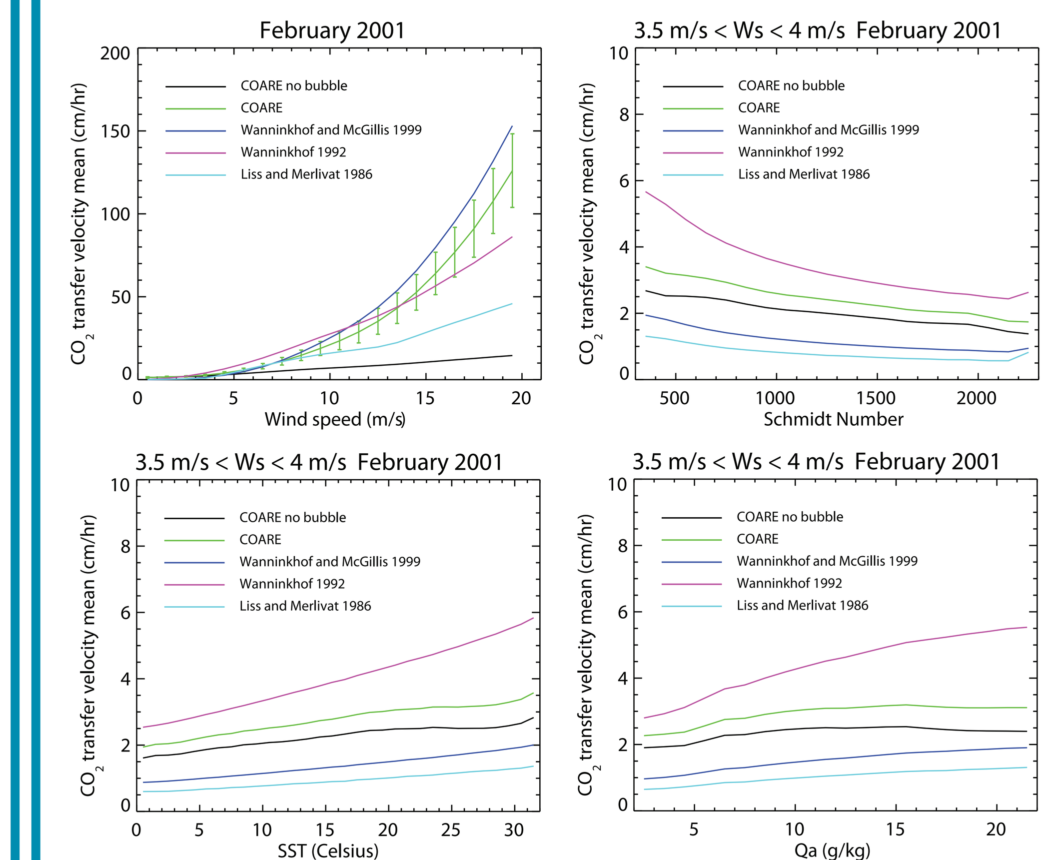
TRANSFER VELOCITY DIFFERENCES



Average differences were computed between the COARE results and the estimates of the simplified parameterizations for February and August 2001. The spatial and seasonal variations in the differences closely follow the average wind speed. Significant differences are observed with respect to each of the parameterizations though the mean bias is least with respect to Wanninkhof and McGillis.

In the box at left, the standard deviations are observed to be very similar to the mean values because of the enhanced contribution to the transfer velocity at high wind speeds. Variability is not significantly enhanced for the COARE results relative to the other models.

COMPARING FUNCTIONAL DEPENDENCIES



Panels to the right compare the dependence of the different transfer velocity estimates on the wind speed and other input parameters. For parameters other than wind speed, the wind speed is confined to a small range in an attempt to isolate the wind speed dependence.

The strongest dependence for the COARE model is on wind speed as for the simplified parameterizations. The COARE model most closely matches the cubic dependence. The dependence on SST and Qa is correlated and linked primarily to the Schmidt number.

ONGOING WORK

- Intercomparison and evaluation of the transfer velocity estimates with direct observations from the GasEx cruises
- Further investigation of the seasonal and spatial variations within and among the different models
- Construction of a detailed error budget for the gas transfer velocity estimates
- Exploration of refinements to both the COARE model and retrieval techniques for the satellite-derived inputs

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