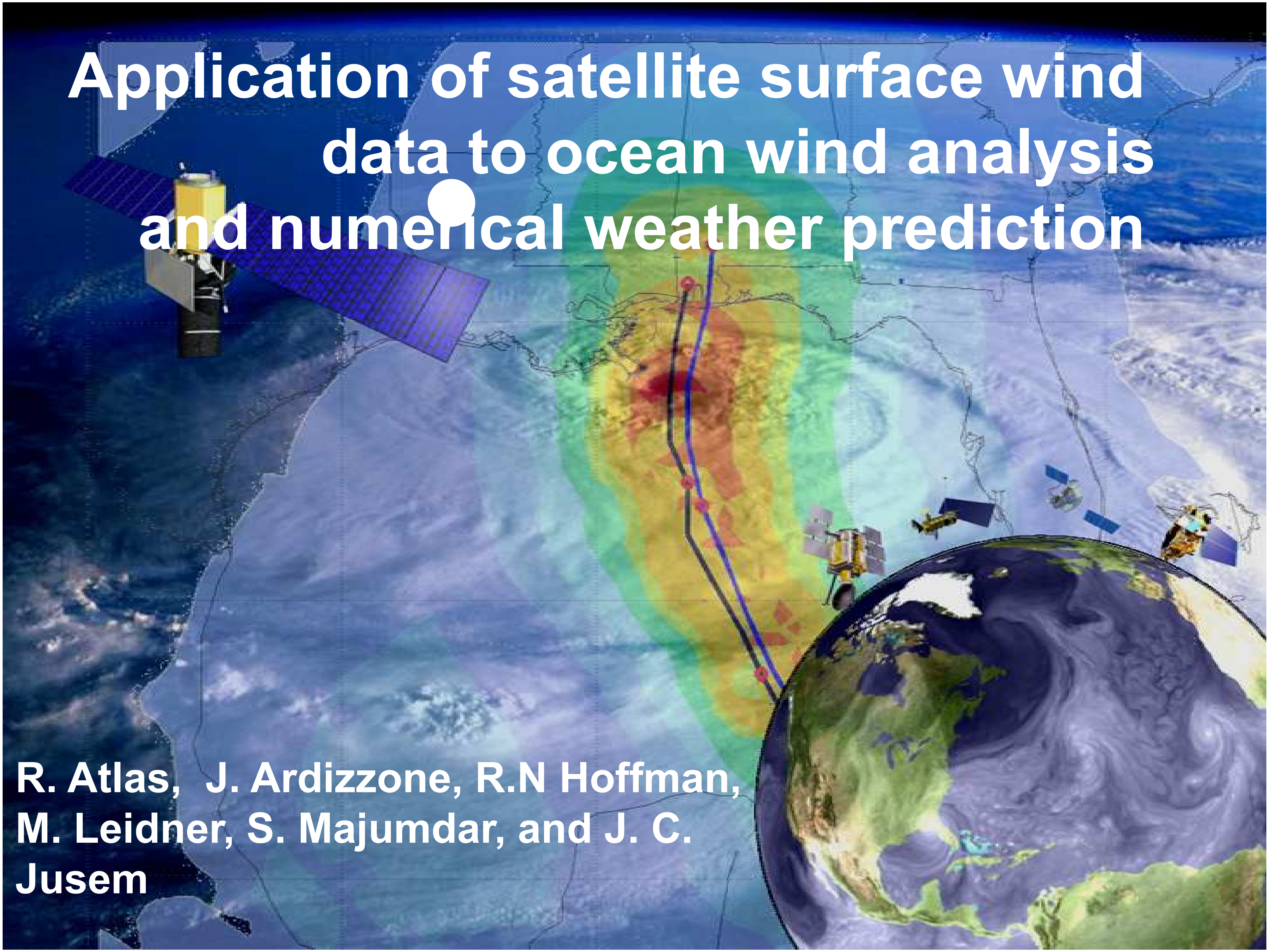
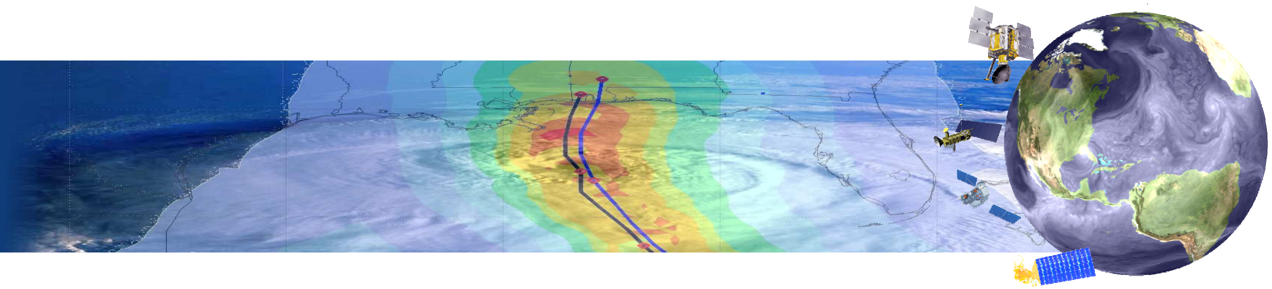


Application of satellite surface wind data to ocean wind analysis and numerical weather prediction

R. Atlas, J. Ardizzone, R.N Hoffman, M. Leidner, S. Majumdar, and J. C. Jusem

Goals



•Produce consistent oceanic surface wind data of high quality and high temporal and spatial resolution for atmospheric and oceanic research and for improved weather and short-term climate prediction. – Generation of the Cross-Calibrated MultiPlatform (CCMP) Ocean surface wind data set.

•Evaluate (and enhance) the impact of each type of satellite surface winds on ocean surface wind analyses and nwp.

Cross-Calibrated Multi-Platform (CCMP) Ocean Surface Wind Vector - (Product Preview)

MEaSUREs - Making Earth Science Data Records for Use in Research Environments ►

Products / Announcements / Citations/References / Related Publications

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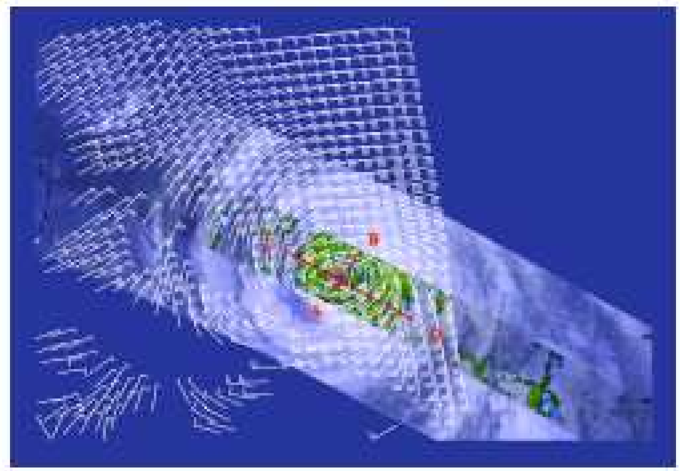
Product Description

In collaboration with private and government institutions, a team led by Dr. Robert Atlas (PI; proposal originally solicited by REASoN, and currently funded by MEaSURES through NASA) has created a cross-calibrated, multi-platform (CCMP), multi-instrument ocean surface wind velocity data set (http://sivo.gsfc.nasa.gov/oceanwinds), for the period extending from 1987 through 2007, with wide ranging research applications in meteorology and oceanography. This product was a result of an investigation funded by NASA's Making Earth Science data records for Use in Research Environments (MEaSUREs) Program.



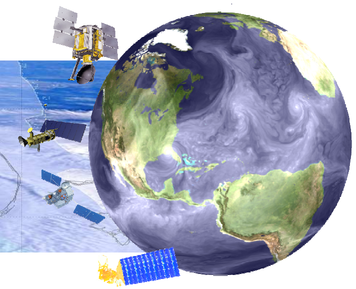
Quikscat and TRMM measurements over Hurricane Floyd on September 13, 1999.

It represents a continuation and expansion of the SSM/I surface wind velocity data set that began under the NASA Pathfinder Program (see http://podaac.jpl.nasa.gov/PRODUCTS/p079.html). This data set combines data derived from SSM/I, AMSRE, TRMM TMI, Quikscat and other missions using a variational analysis method (VAM) to produce a consistent climatological record of ocean surface vector winds at 25km resolution. The VAM requires a background (first guess) analysis of gridded U and V winds as a starting estimate of the wind field. Analysis increments are added to this background to arrive at the final analysis. Background

The methodology that is used to generate the CCMP has been previous published by Atlas et al. (1996) and is similar to that described by Hoffman (1984), with modifications to accommodate special attributes of the satellite surface wind data as well as some additional tuning of the data quality checking and filter weights.

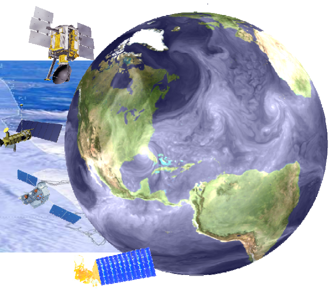
Satellite surface wind data are obtained from Remote Sensing Systems (RSS) under the DISCOVER project: Distributed Information Services: Climate/Ocean Products and

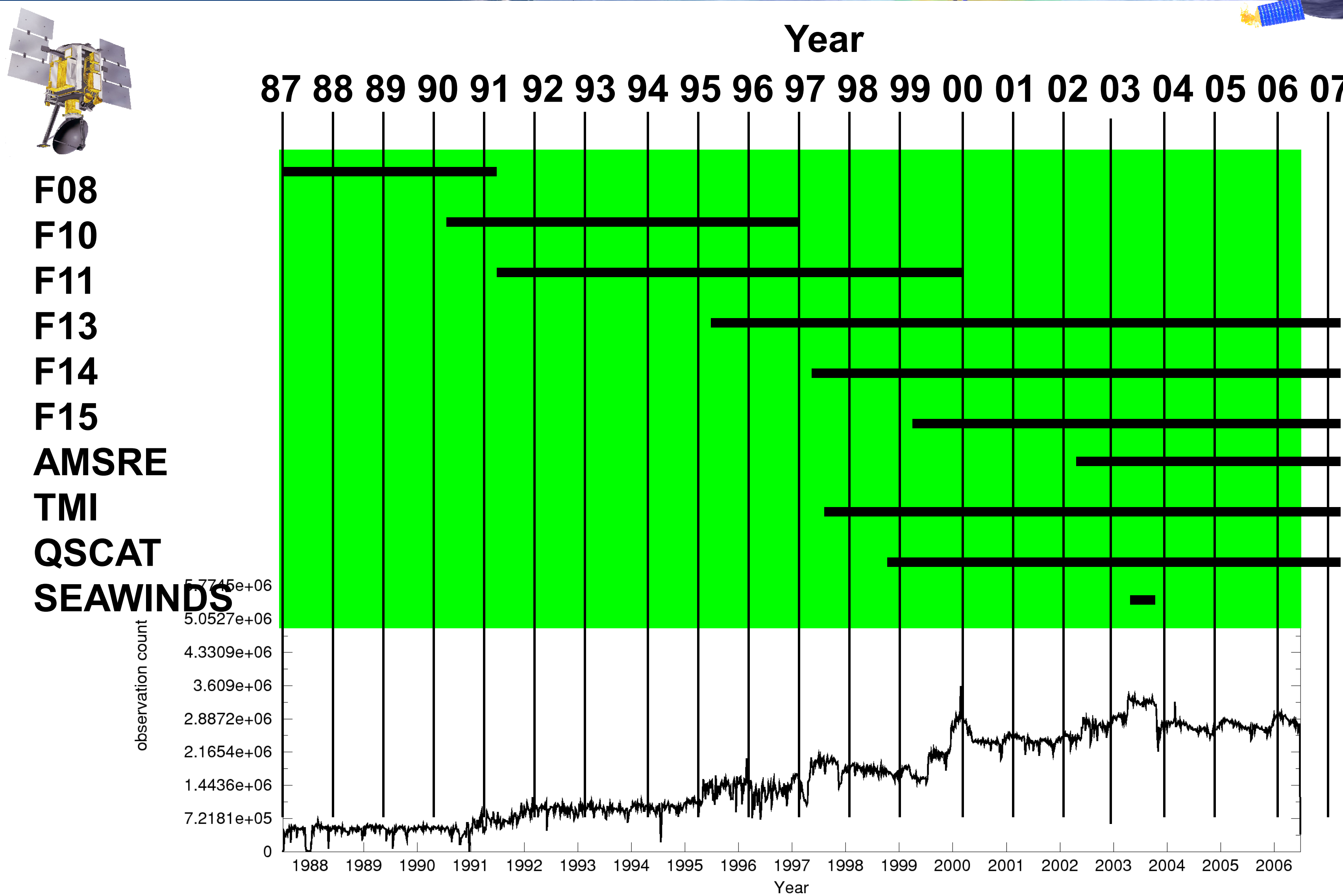
Inputs to CCMP data set



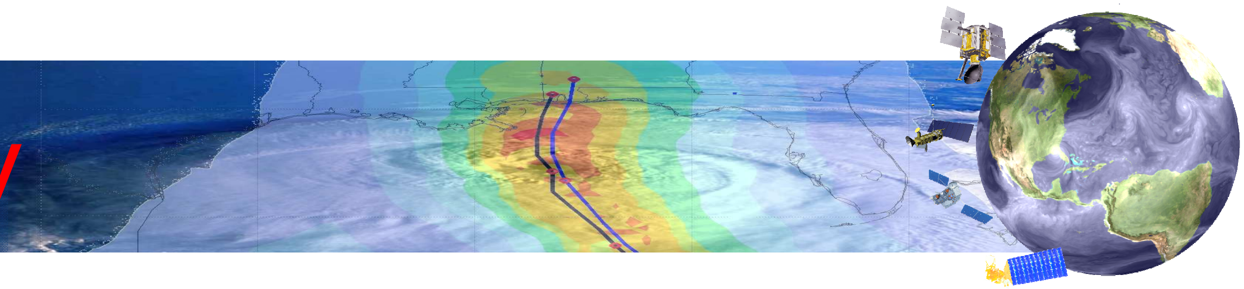
- Cross-calibrated data sets from Remote Sensing Systems
  - SSM/I, TRMM TMI, AMSRE, Quikscat, Seawinds
- In situ data
  - Conventional ships and buoys
  - Tropical Atmosphere Ocean Project (TAO) buoys
  - Pilot Research Moored Array in the Atlantic (PIRATA) buoys
- Background analyses consist of the ECMWF operational analysis (from 1999) and the ERA-40 reanalysis
  - ECMWF operational analyses are available within 6-months of real-time at 1-degree resolution.
  - ERA-40 reanalyses are available through June 2002 at a resolution of approximately 2-degrees and are more accurate than ops. thru 1998.

Increasing satellite inputs





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.

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

Term	Expression	Description of constraint
		Observation Function for the
J_{CONV}	$\sum(\mathbf{V}_{\text{A}} - \mathbf{V}_{\text{O}})^2$	• wind vectors
J_{SCAT}	$\sum(\mathbf{V}_{\text{A}} - \mathbf{V}_{\text{O}})^2$	• wind vectors
J_{SPD}	$\sum(\lvert\mathbf{V}_{\text{A}}\rvert - \lvert\mathbf{V}_{\text{O}}\rvert)^2$	• wind speeds
		Background Constraints on the
J_{VWM}	$\int(\mathbf{V}_{\text{A}} - \mathbf{V}_{\text{B}})^2$	• vector wind magnitude
J_{LAP}	$\int[\nabla^2(u_{\text{A}} - u_{\text{B}})]^2 + \int[\nabla^2(v_{\text{A}} - v_{\text{B}})]^2$	• Laplacian of the wind components
J_{DIV}	$\int[\nabla^2(\chi_{\text{A}} - \chi_{\text{B}})]^2$	• divergence
J_{VOR}	$\int[\nabla^2(\psi_{\text{A}} - \psi_{\text{B}})]^2$	• vorticity
J_{DYN}	$\int(\partial\zeta_{\text{A}}/\partial t - \partial\zeta_{\text{B}}/\partial t)^2$	• vorticity tendency

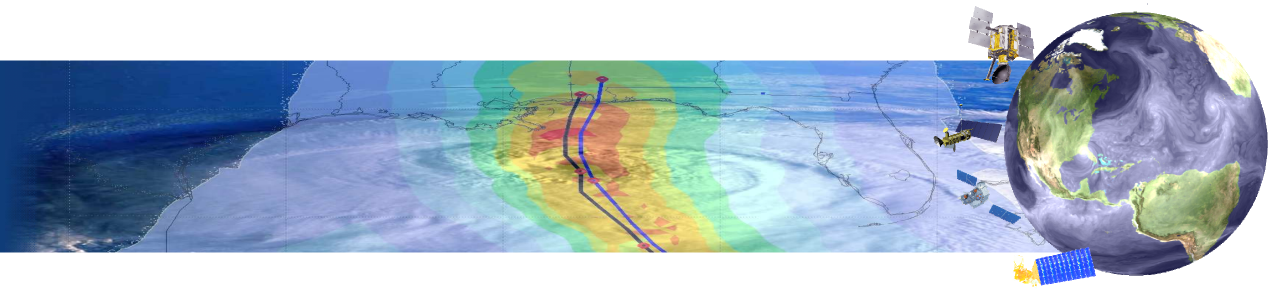
$$\mathbf{V}_{\text{A}} = \alpha \mathbf{V}_{\text{A}} + \mathbf{V}_{\delta}$$

Outputs

- Three products are produced for distribution to the community at 25km resolution:
  - Level3.0: 6-hourly global analyses (U,V)
  - Level3.5: 5-day and monthly means (U,V,W,USTR,VSTR)
  - Level2.5: Passive satellite wind speed observations (SSM/I, AMSRE,TMI) with directions assigned from the analysis (U,V)

***All products reside on the Wentz "bytemap" 25km grid.*

Validation

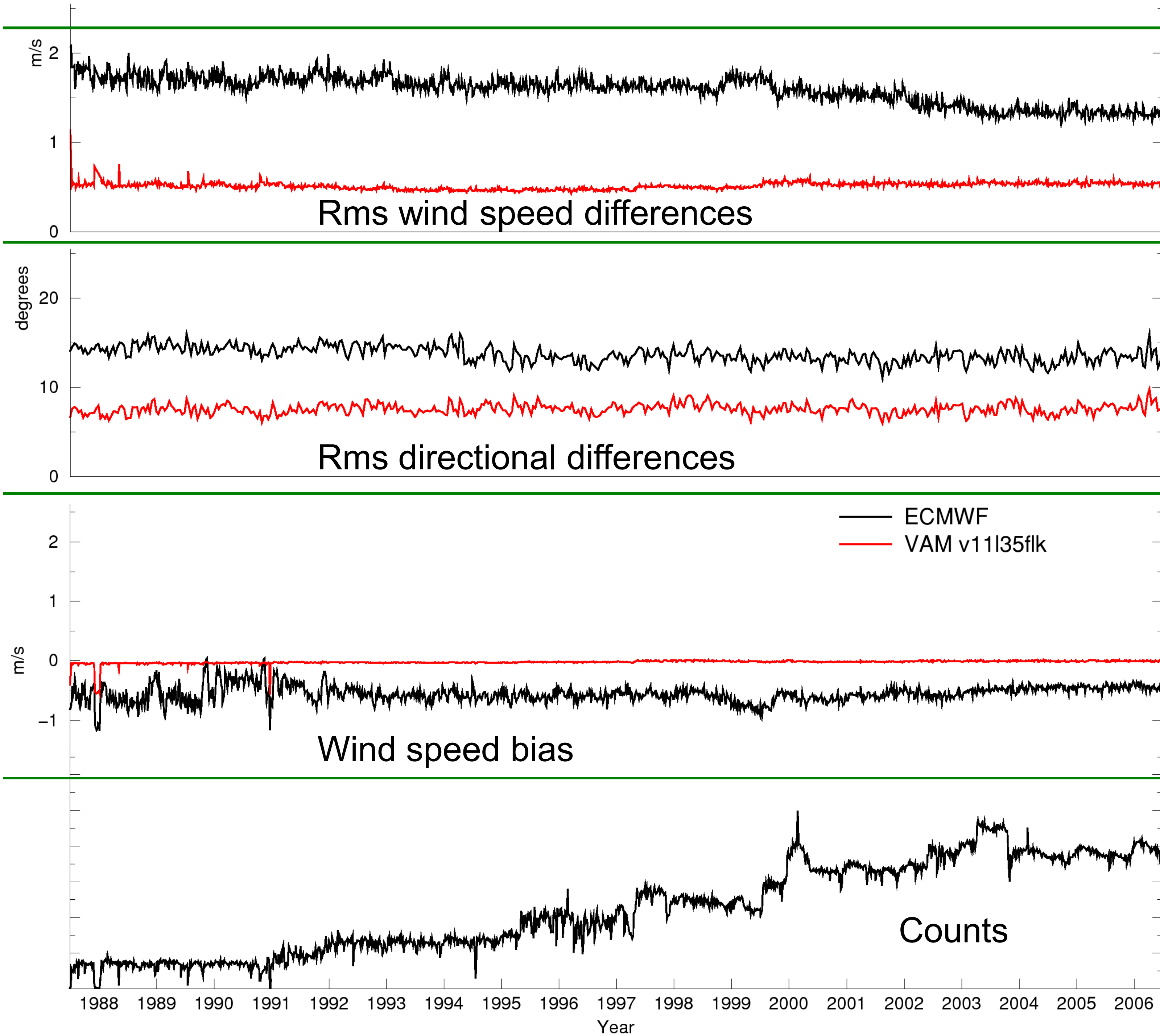


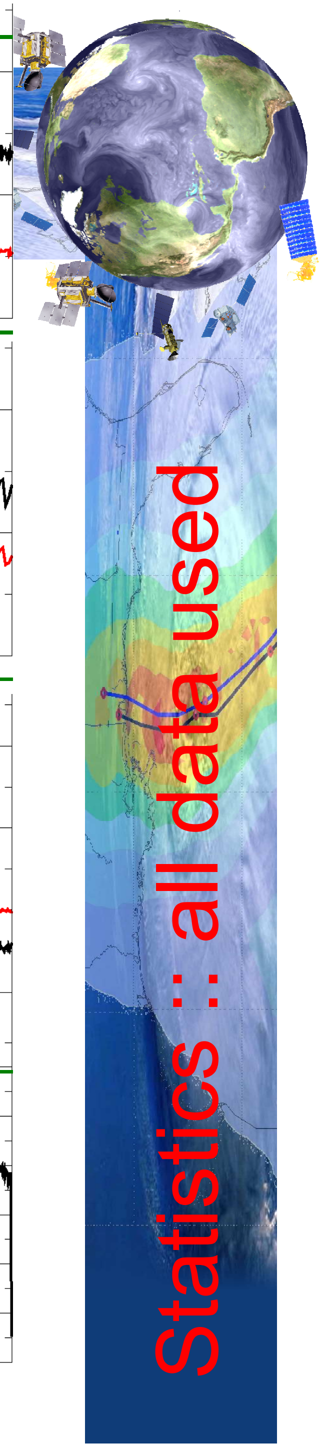
- Examine analysis fit to assimilated observations (rms, mean speed and direction differences)

- Examine the analysis fit to independent observations (eg Windsat, NSCAT, ERS)

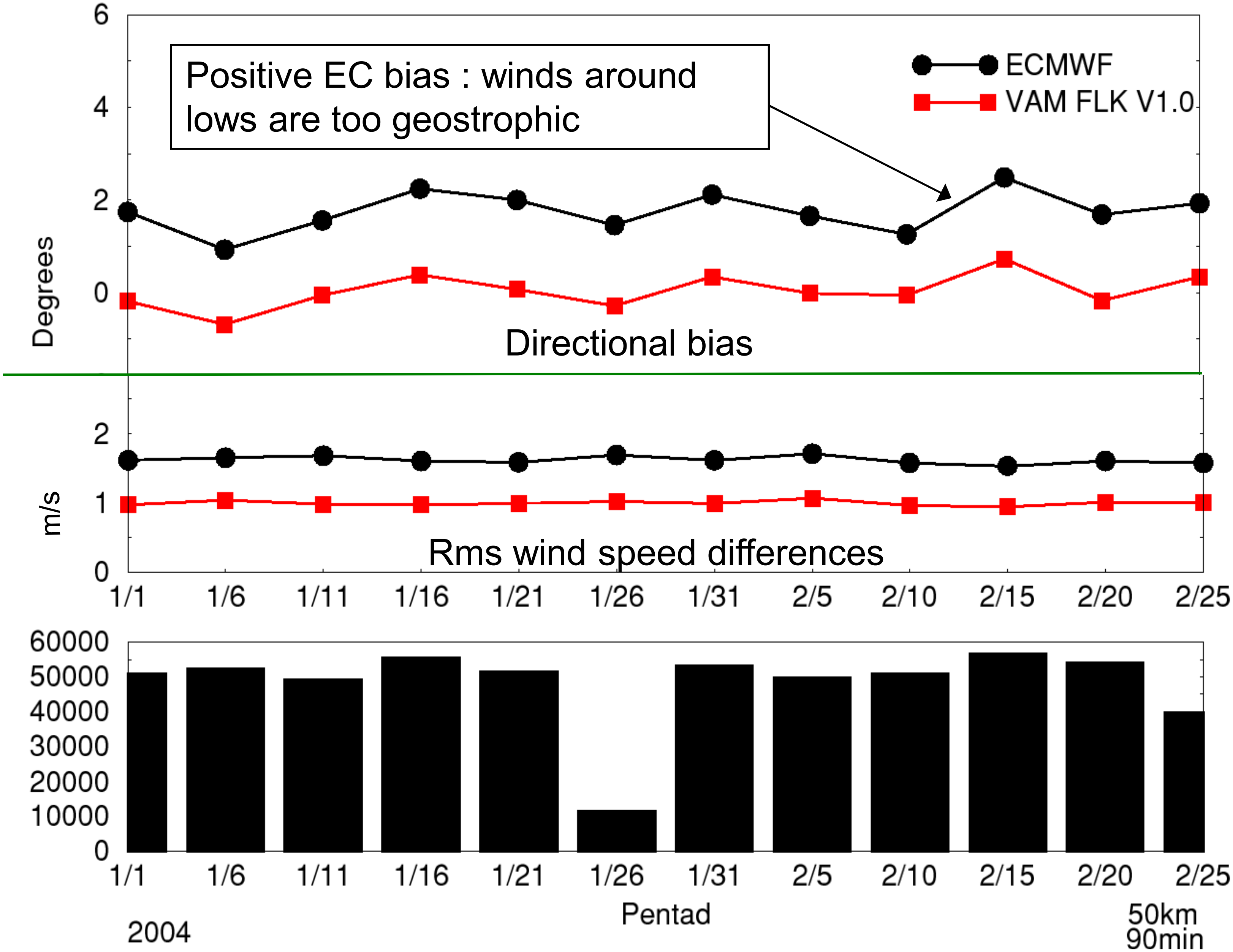
- Compare VAM analyses to operational analyses, satellite imagery, and climatologies.

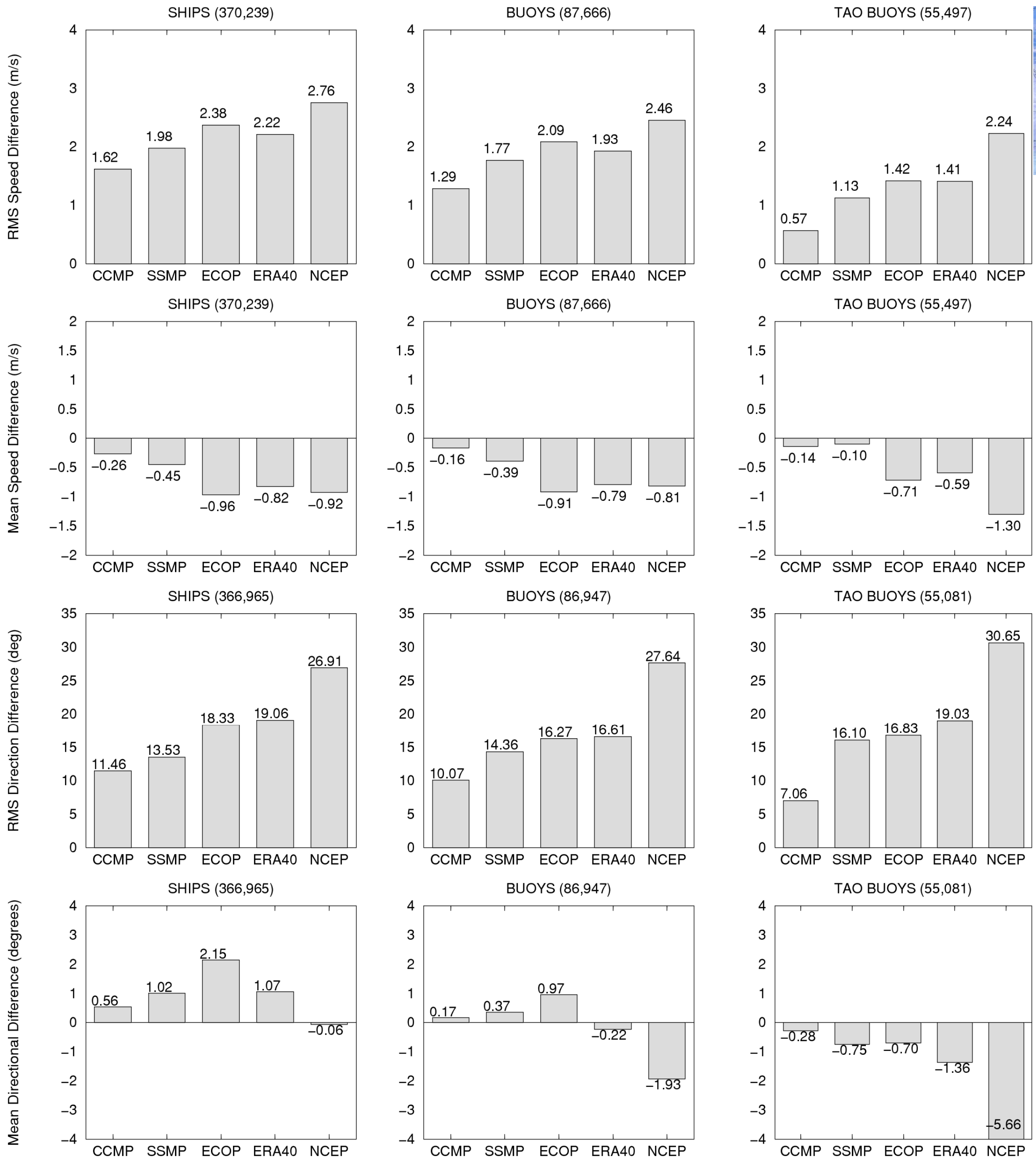
Statistics :: all data used

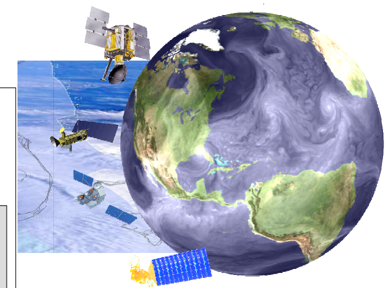




Statistics :: WindSat verification



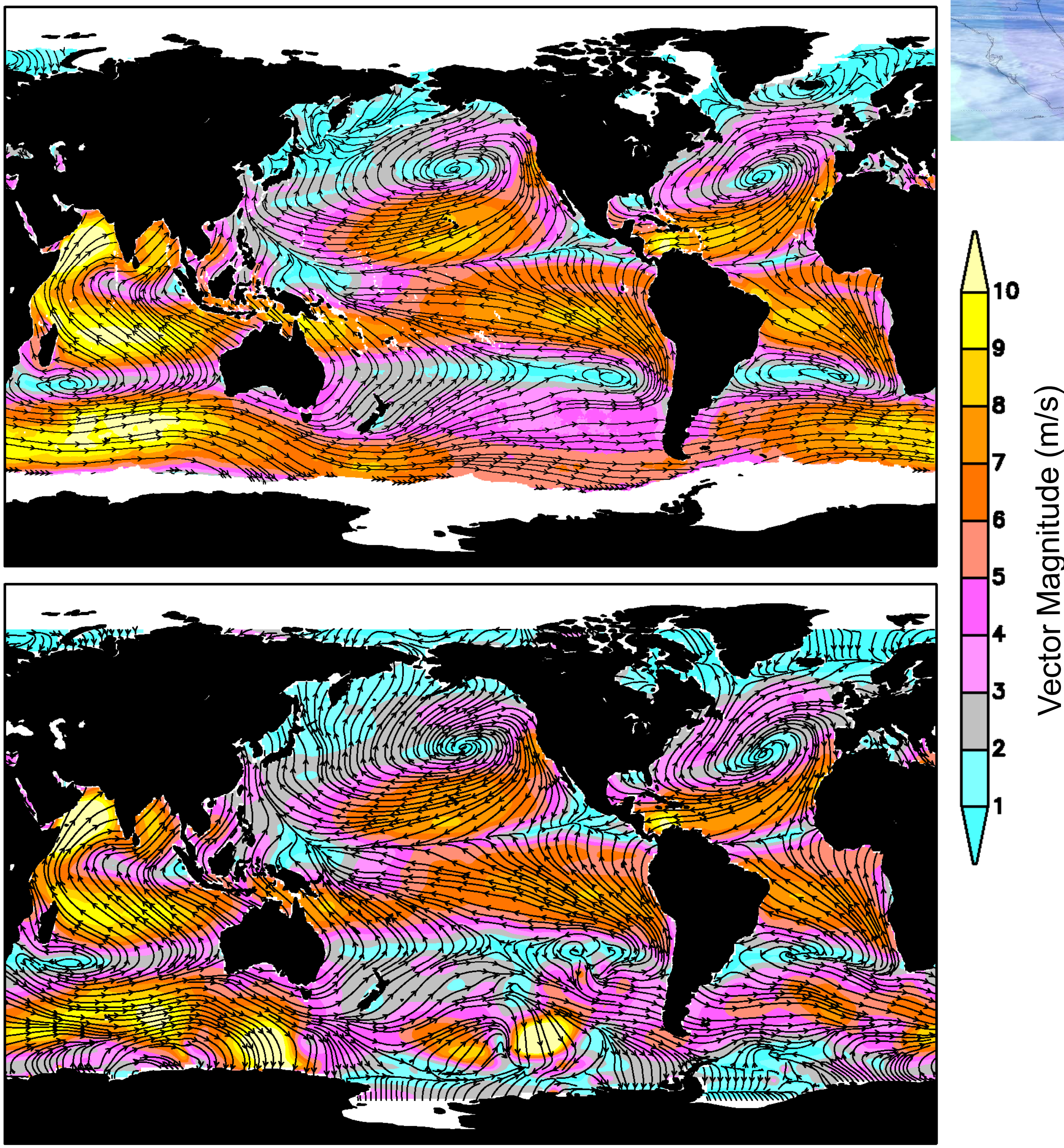

SHIPS (370,239)
BUOYS (87,666)
TAO BUOYS (55,497)
RMS Speed Difference (m/s)
1.62
1.98
2.38
2.22
2.76
1.29
1.77
2.09
1.93
2.46
0.57
1.13
1.42
1.41
2.24
CCMP SSMP ECOP ERA40 NCEP
SHIPS (370,239)
BUOYS (87,666)
TAO BUOYS (55,497)
Mean Speed Difference (m/s)
−0.26
−0.45
−0.96
−0.82
−0.92
−0.16
−0.39
−0.91
−0.79
−0.81
−0.14
−0.10
−0.71
−0.59
−1.30
CCMP SSMP ECOP ERA40 NCEP
SHIPS (366,965)
BUOYS (86,947)
TAO BUOYS (55,081)
RMS Direction Difference (deg)
11.46
13.53
18.33
19.06
26.91
10.07
14.36
16.27
16.61
27.64
7.06
16.10
16.83
19.03
30.65
CCMP SSMP ECOP ERA40 NCEP
SHIPS (366,965)
BUOYS (86,947)
TAO BUOYS (55,081)
Mean Directional Difference (degrees)
0.56
1.02
2.15
1.07
−0.06
0.17
0.37
0.97
−0.22
−1.93
−0.28
−0.75
−0.70
−1.36
−5.66
CCMP SSMP ECOP ERA40 NCEP



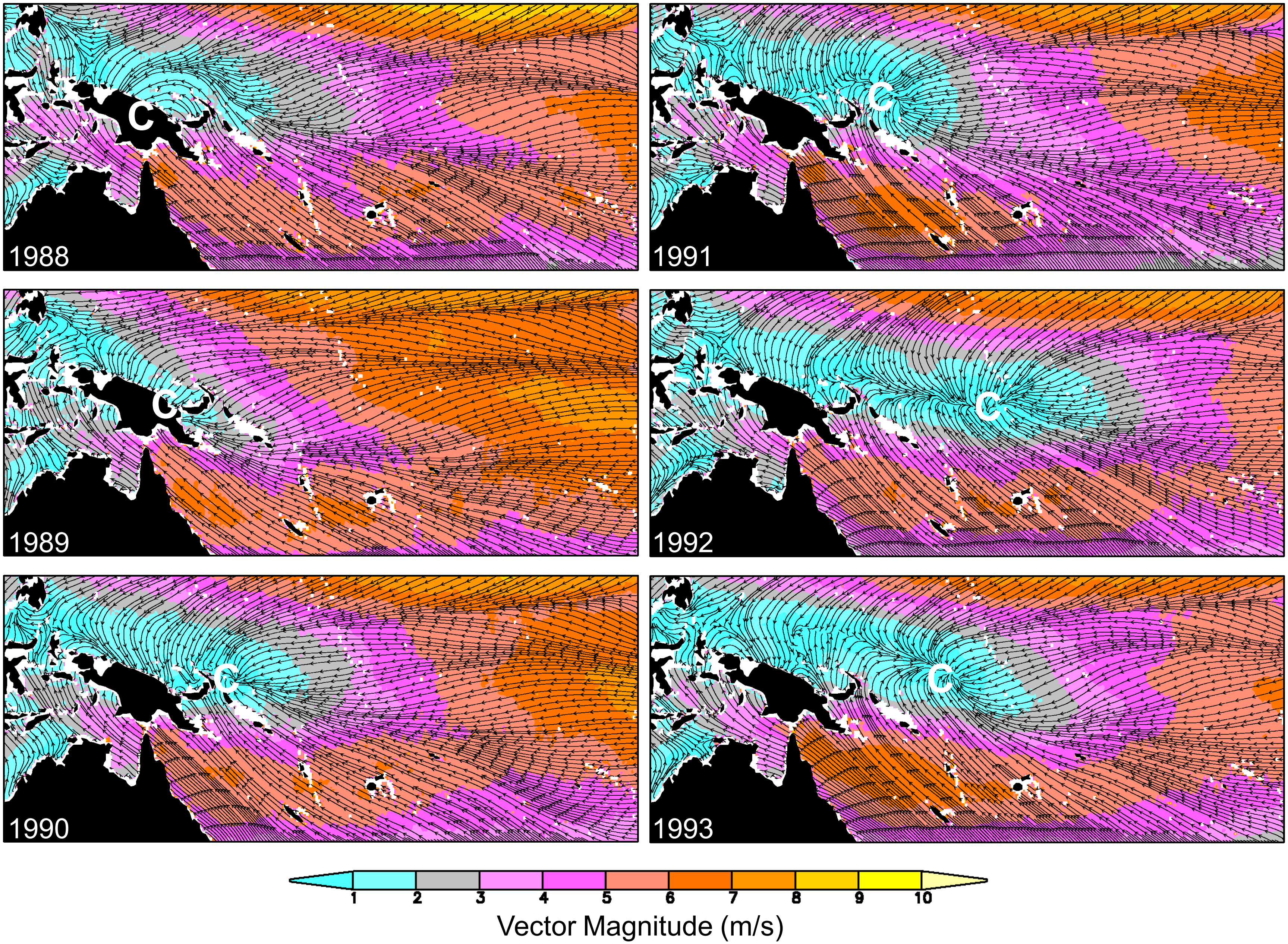
July

CCMP
1987-2007

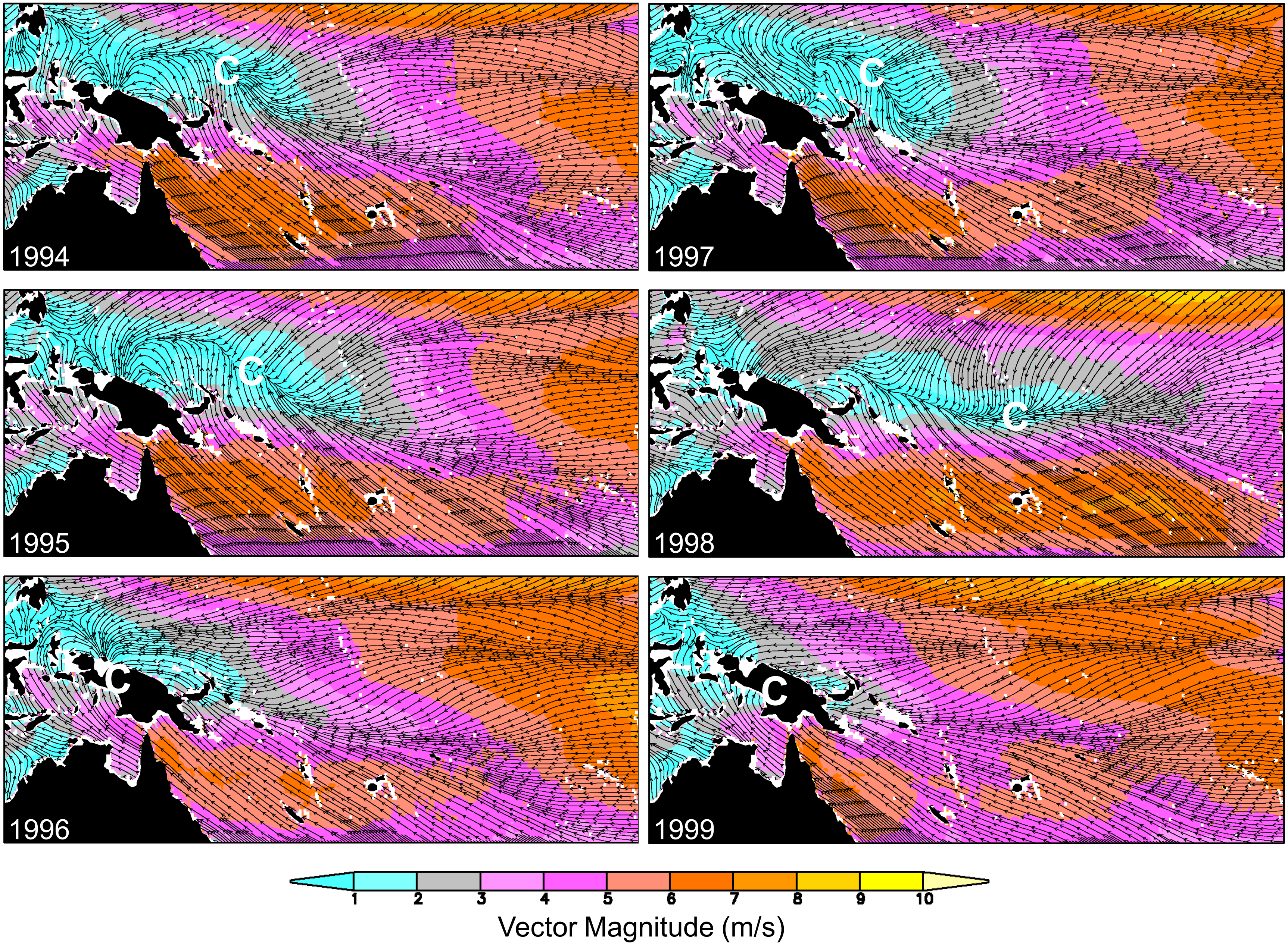
COADS



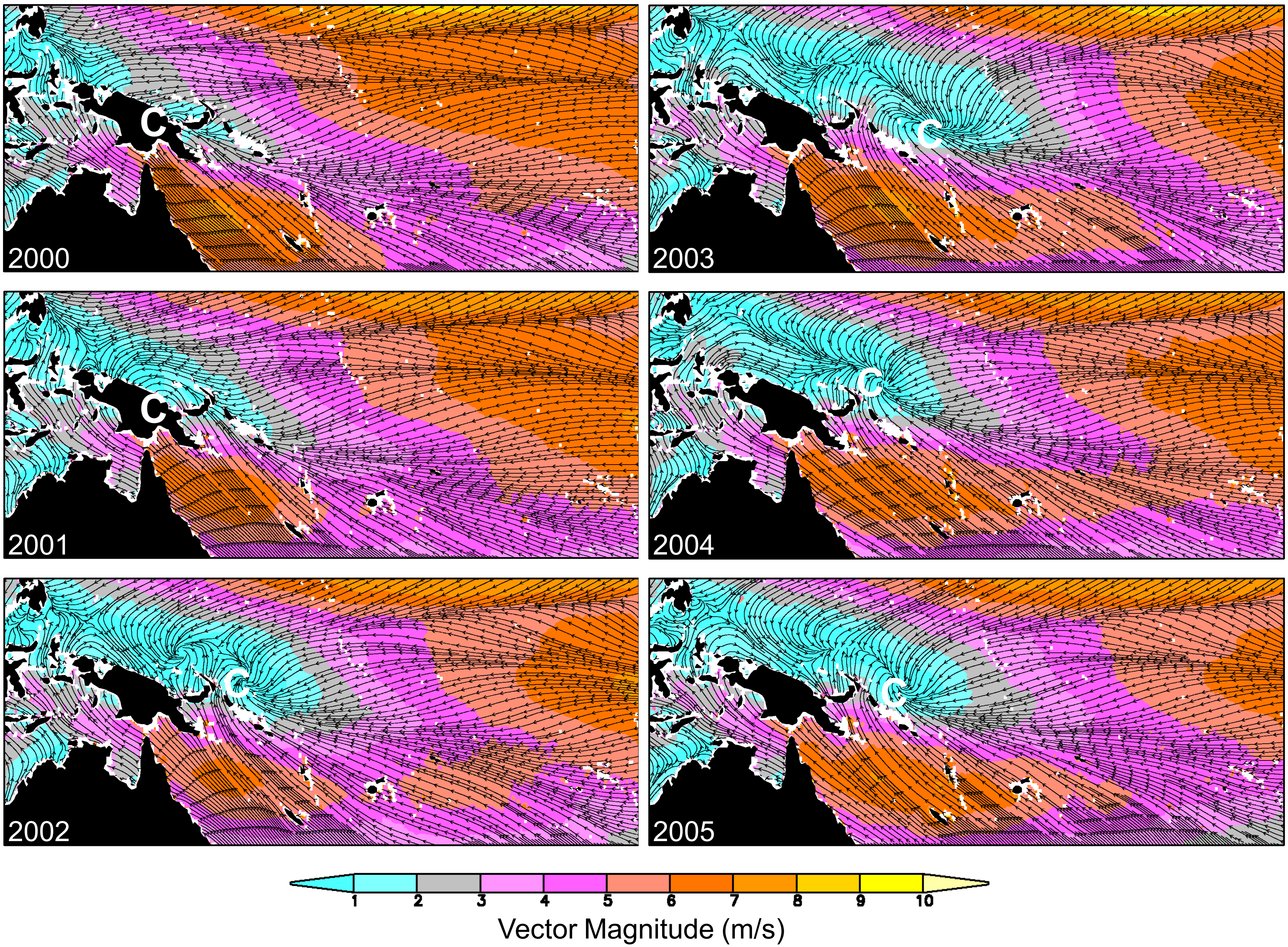
CCMP Annual Mean Streamlines and Vector Magnitude



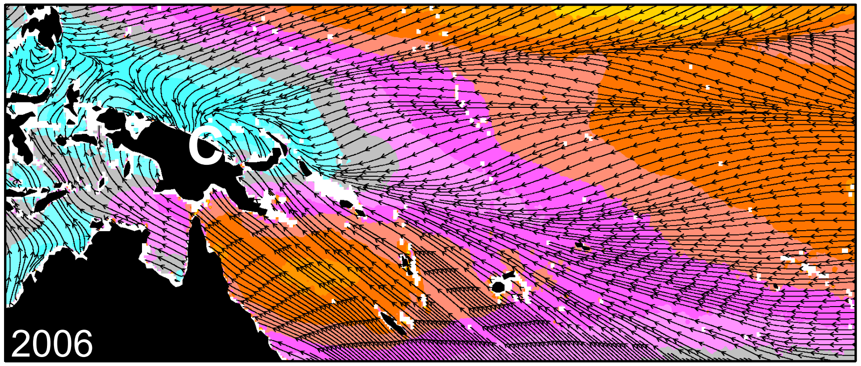
CCMP Annual Mean Streamlines and Vector Magnitude

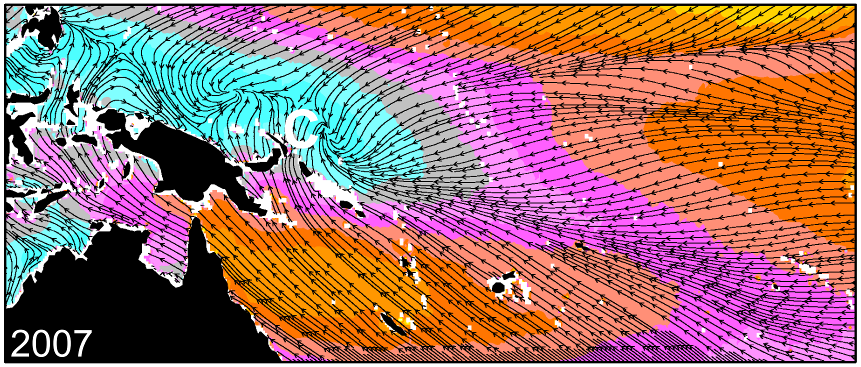


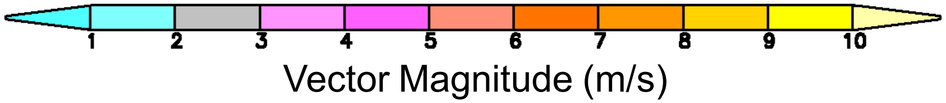
CCMP Annual Mean Streamlines and Vector Magnitude



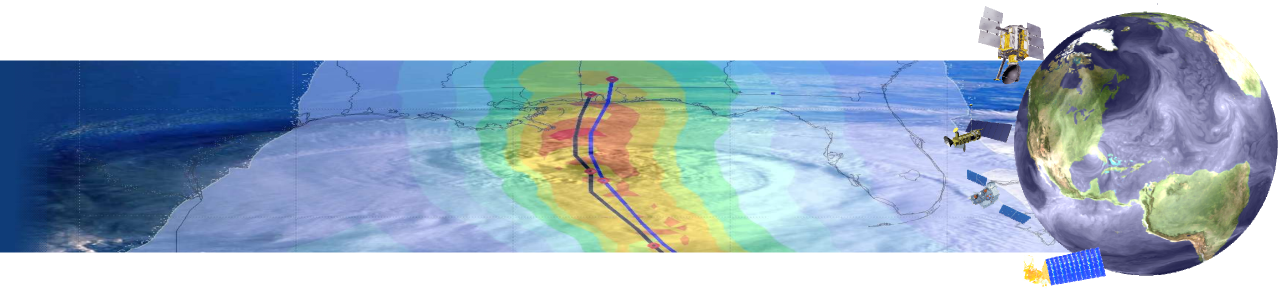
CCMP Annual Mean Streamlines and Vector Magnitude







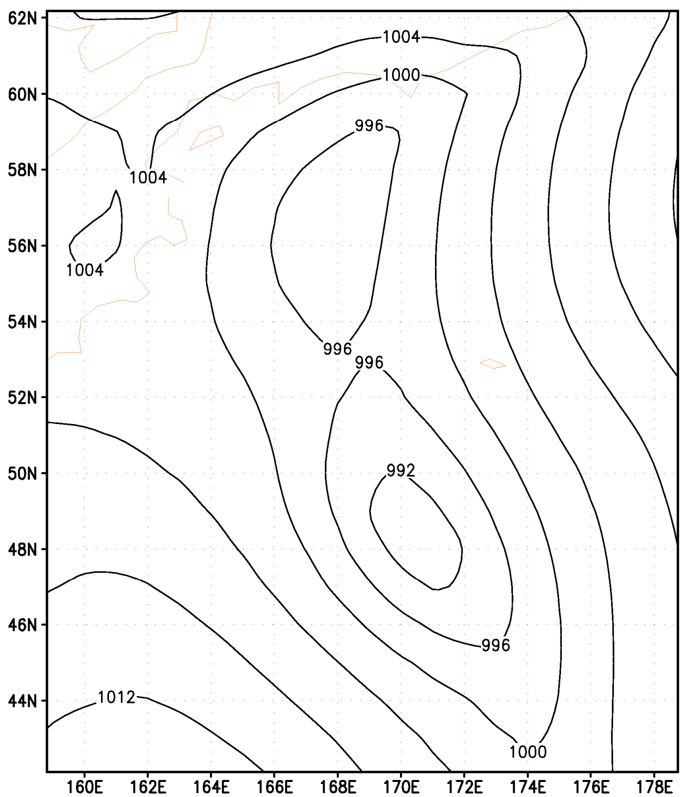
Case Study

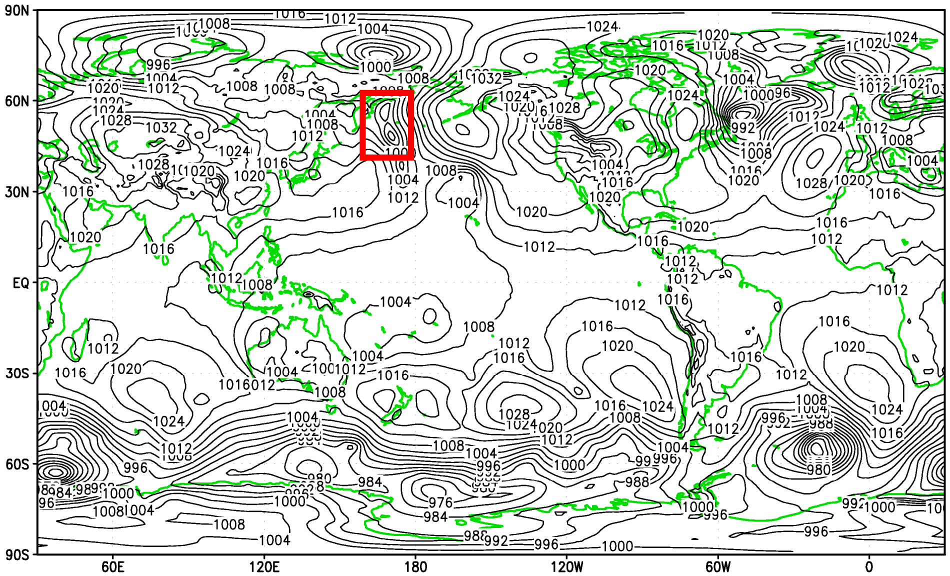


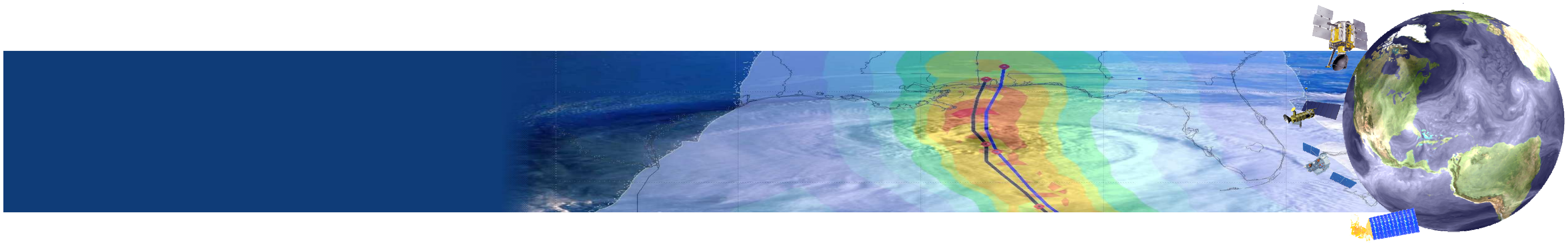
Feature: Cyclone

Time: January 2, 2004 6Z

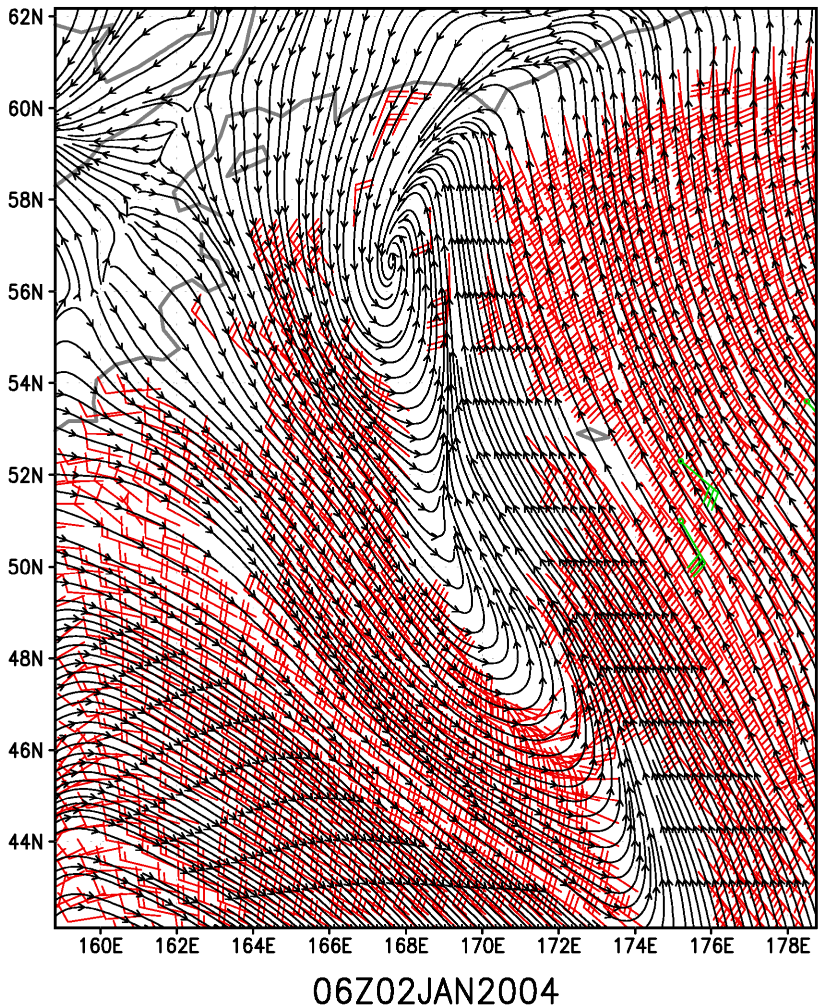
Location: North Pacific (48N,172E)



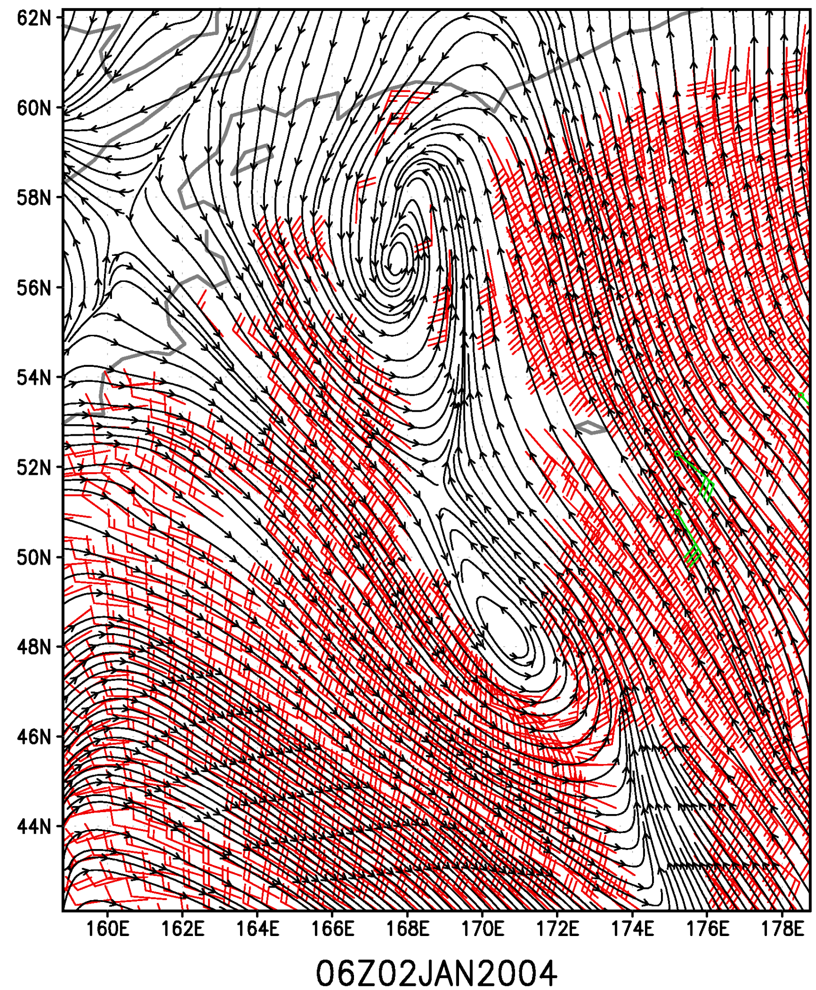


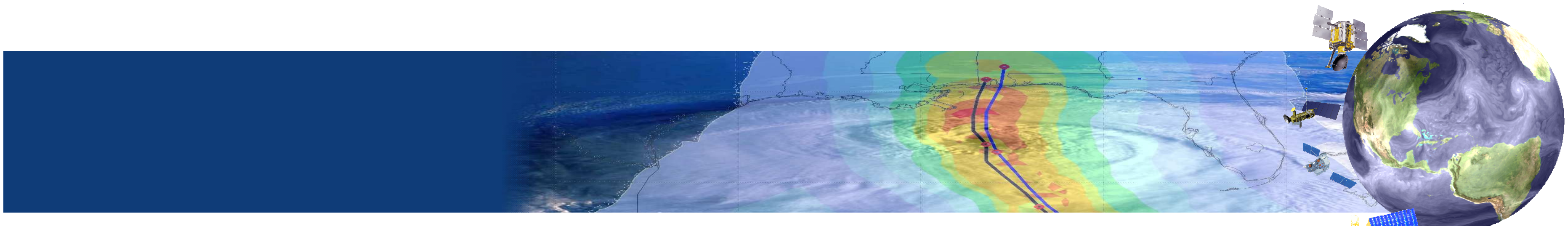


ECMWF 10m Winds

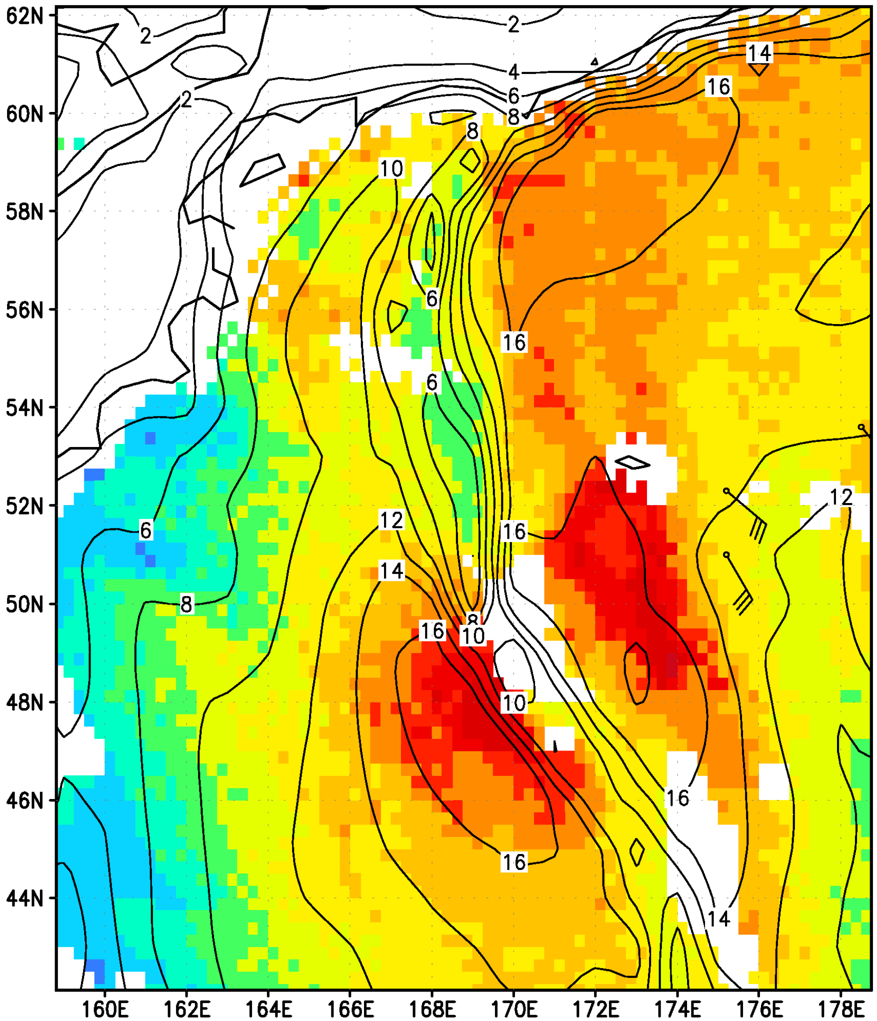


VAM FLK V1.1 Winds



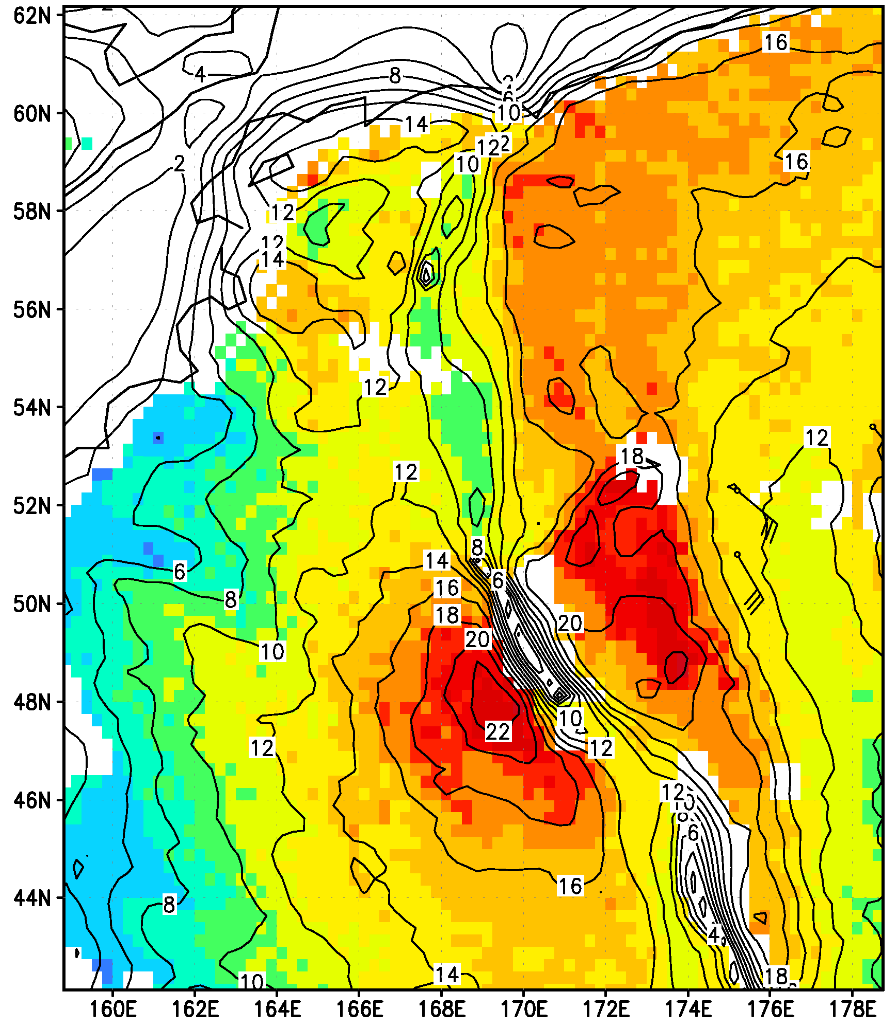


ECMWF Analysis

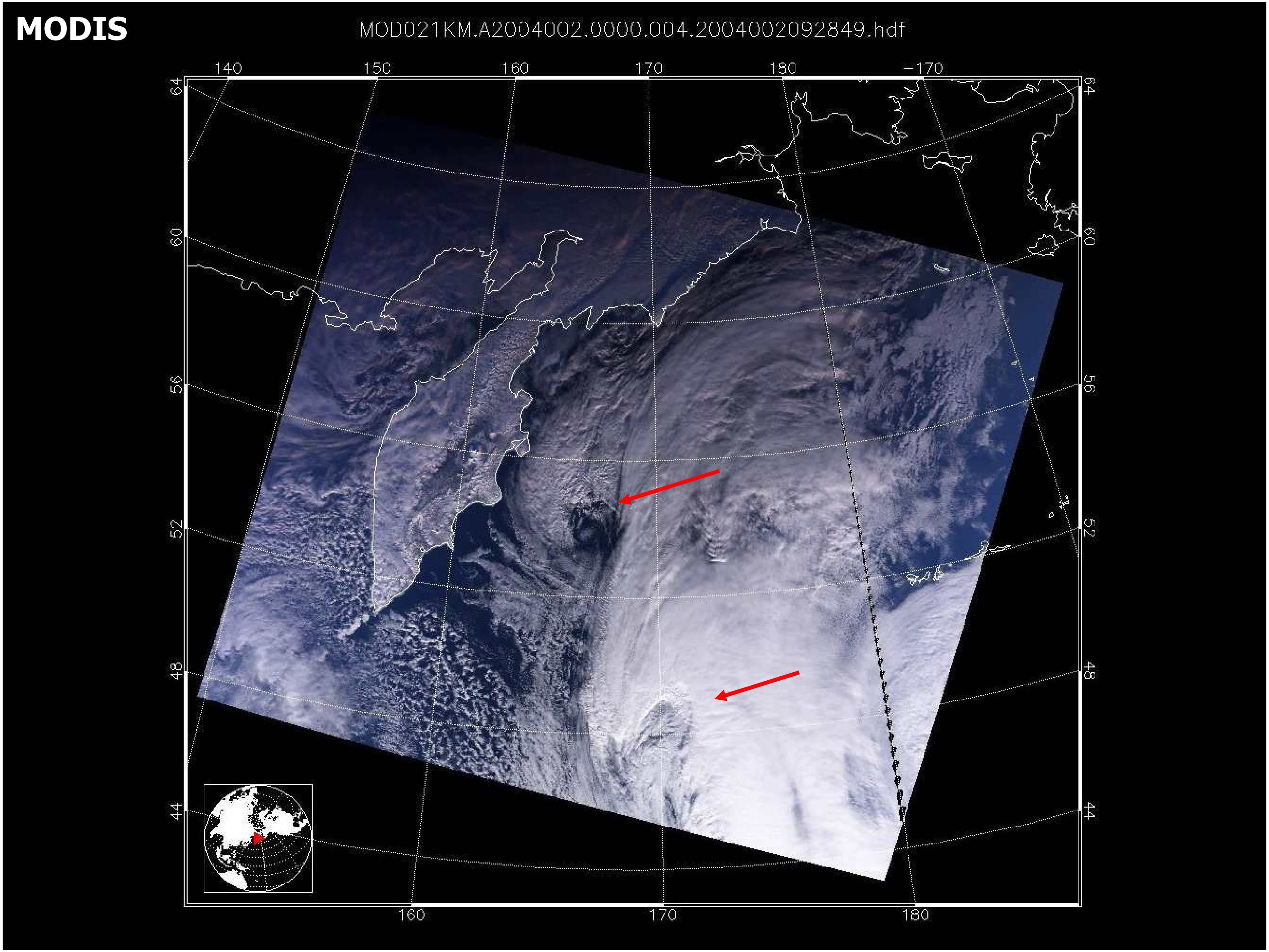


06Z02JAN2004

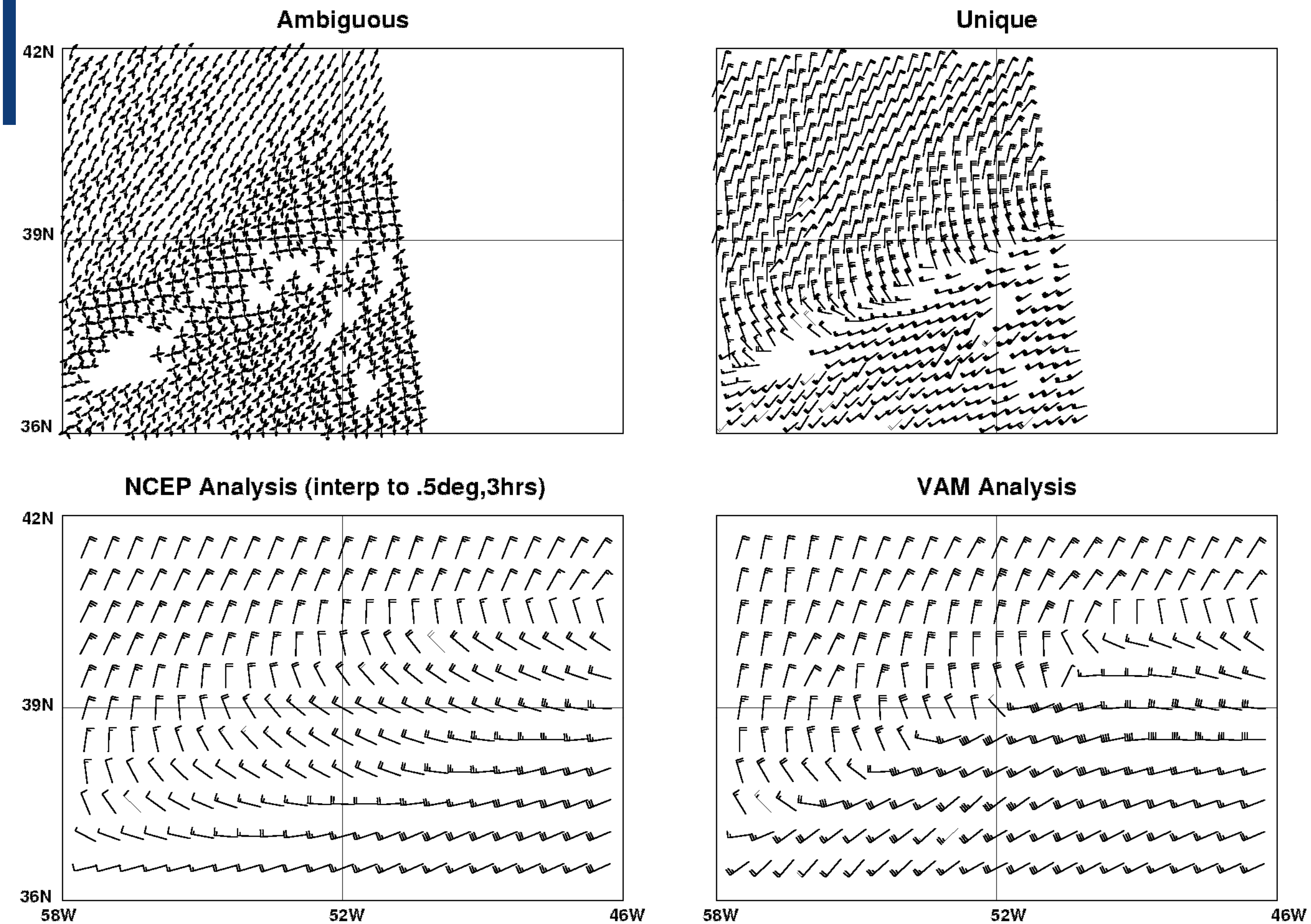
VAM FLK V1.0 Analysis



06Z02JAN2004

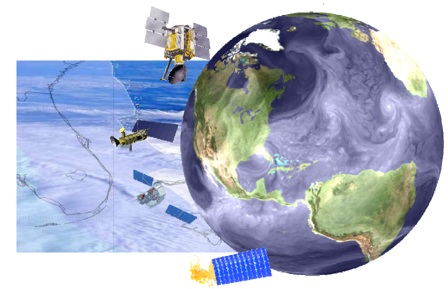

MODIS
MOD021KM.A2004002.0000.004.2004002092849.hdf
140
150
160
170
180
−170
64
60
56
52
48
44
160
170
180

Impact of Seawinds on VAM Analysis



April 11, 2003 3Z

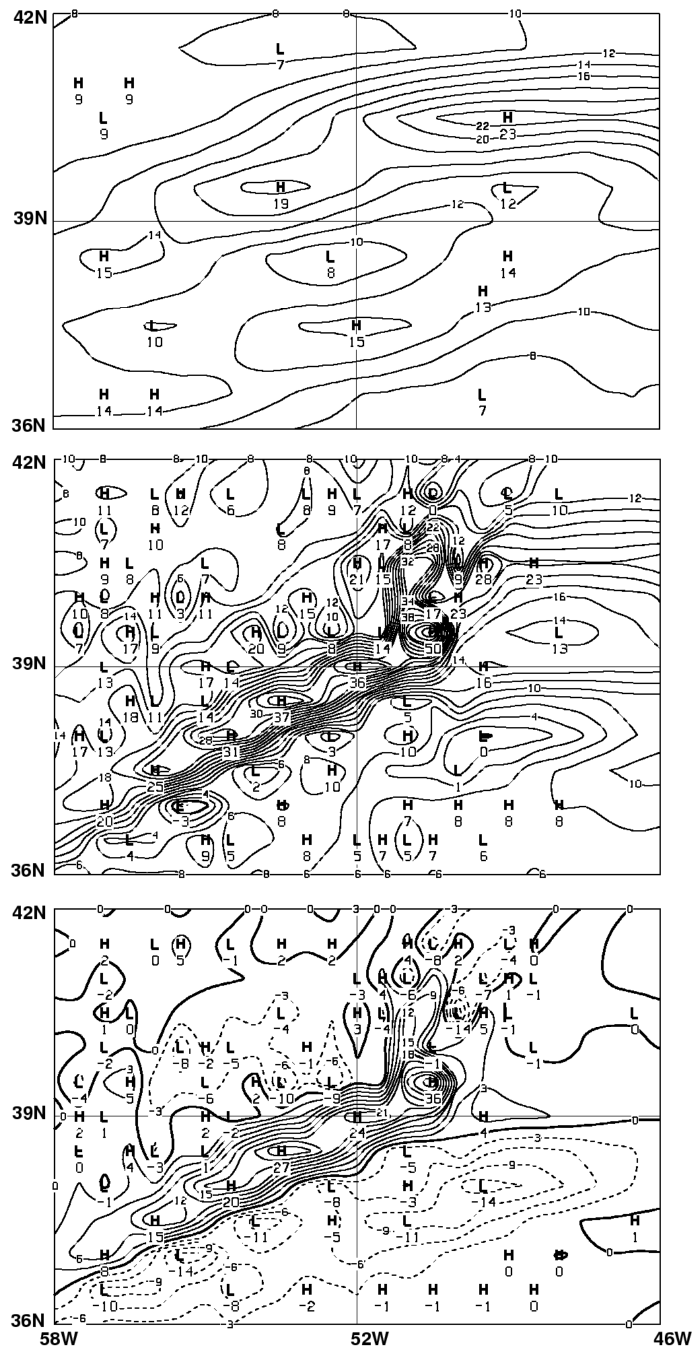
Impact of Seawinds on VAM Vorticity Analysis



NCEP Analysis

VAM Analysis

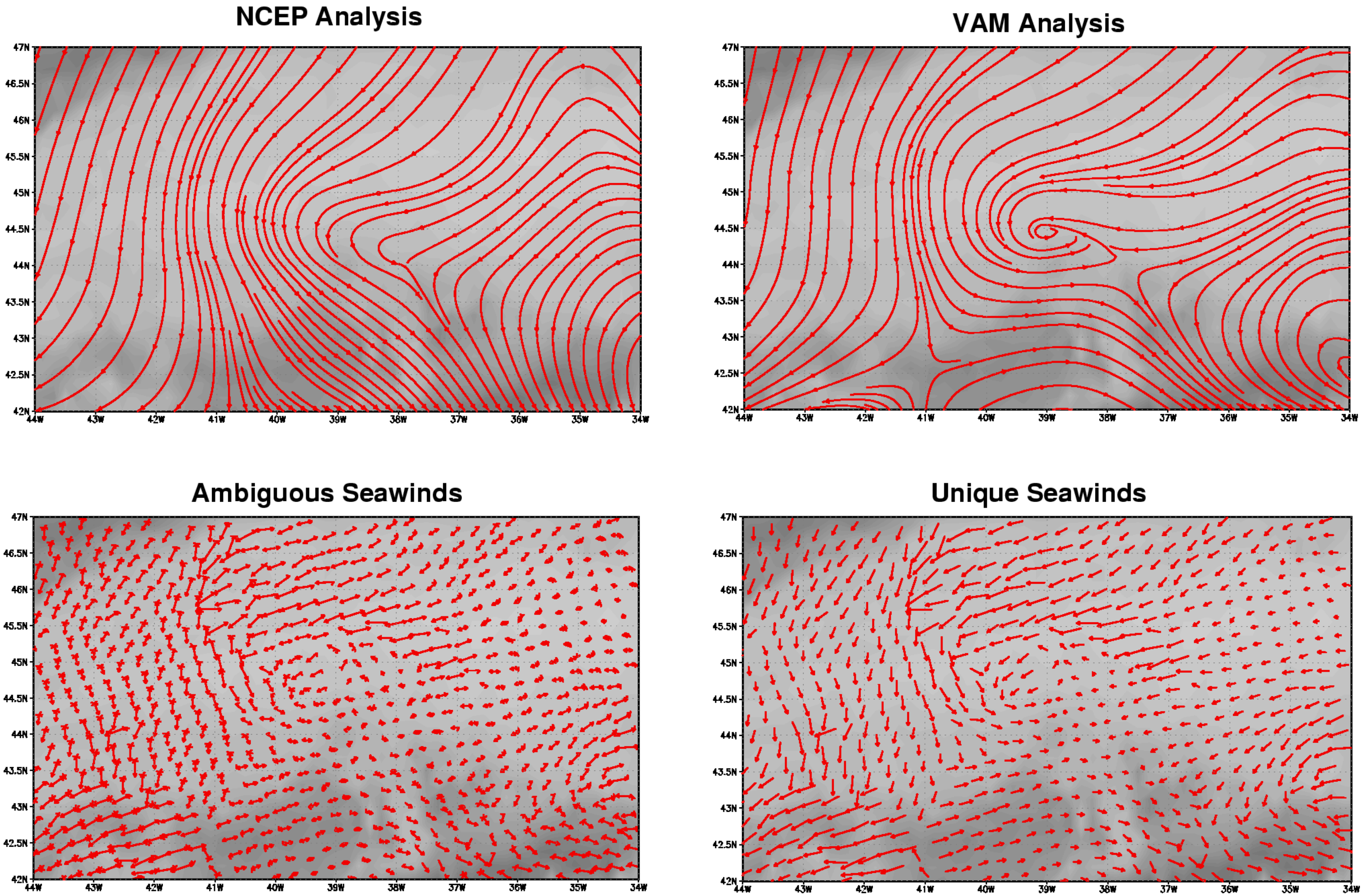
Difference



April 11, 2003 3Z

Example of a Cyclone Added by Seawinds in the North Atlantic

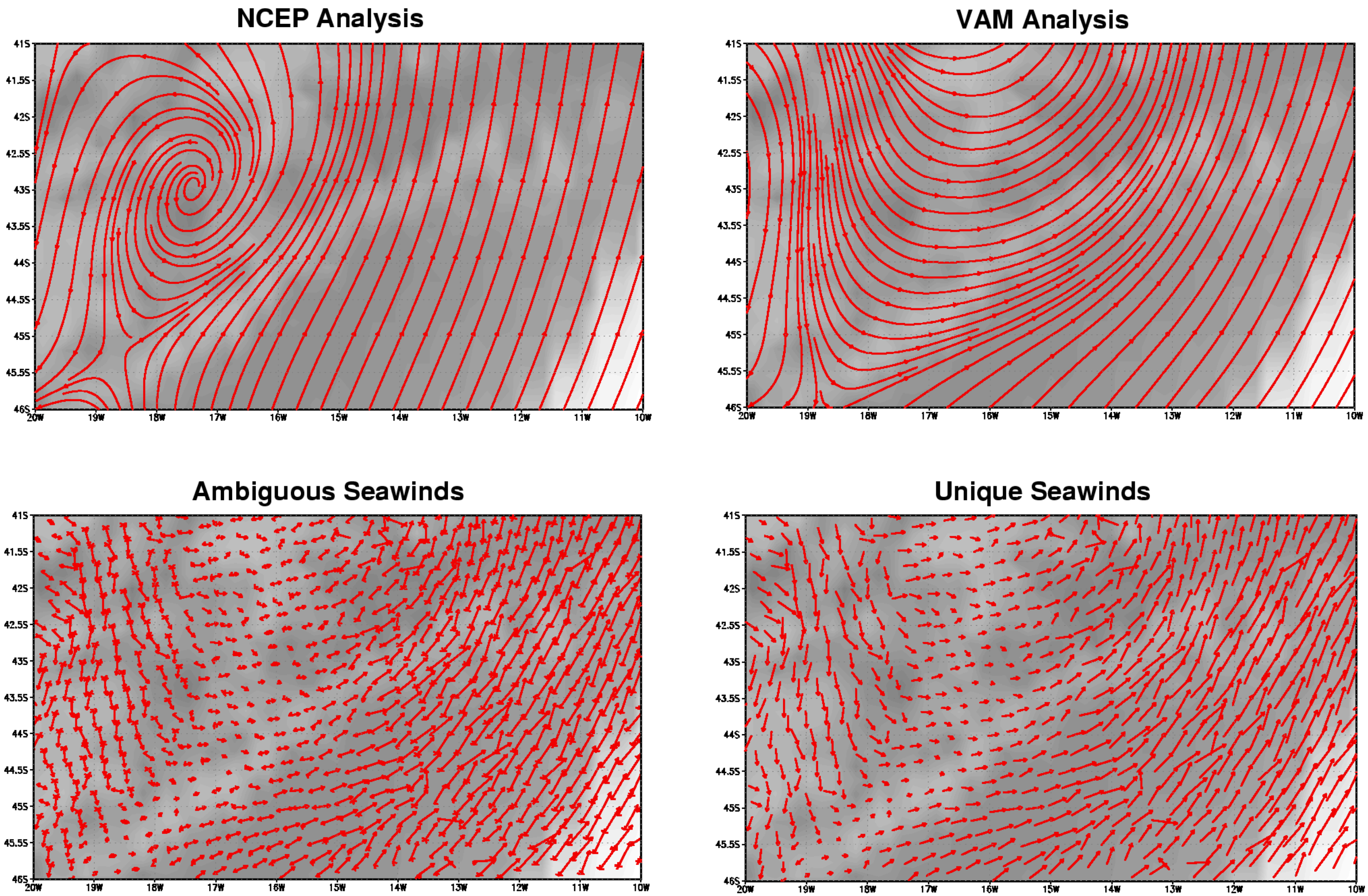
(shaded field represents clouds from GOES East IR4)



April 11 2003 00Z

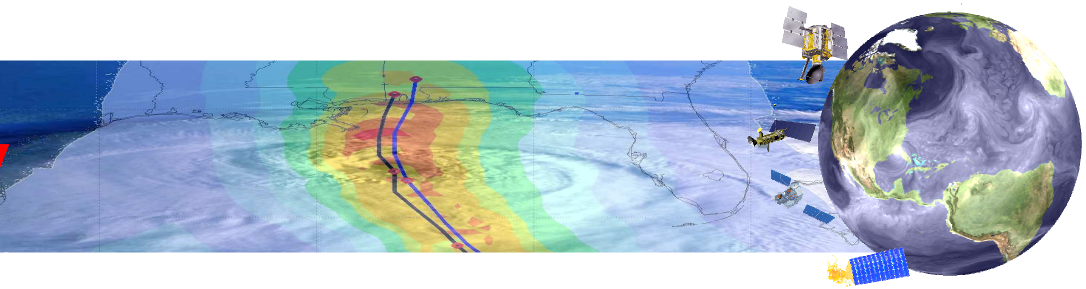
Example of an Anticyclone Deleted by Seawinds in the South Atlantic

(shaded field represents clouds from GOES East IR4)



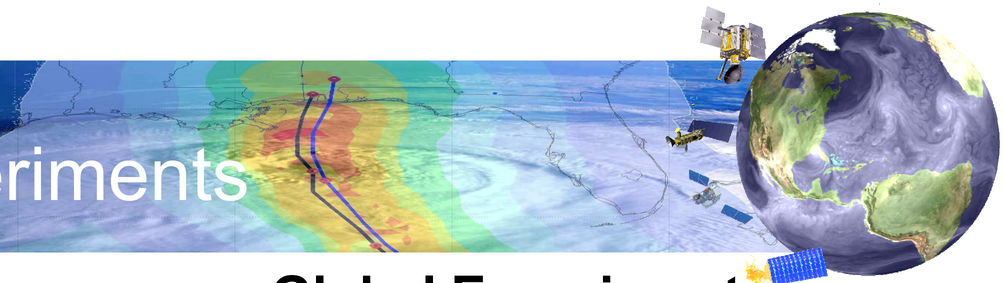
April 11 2003 00Z

CCMP Summary



- 20 years of CCMP ocean surface wind velocity data at 6 hour intervals and 25 km resolution have been generated.
- The VAM analyses fit the cross-calibrated data sets very closely with significant improvements in the location and structure of meteorological features.
- Further validation is needed in oceanographic and meteorological applications; especially at sub-synoptic scales:
  - High resolution bio/geochemical/physical ocean model
  - Statistical SST/Taux/Tauy model for examining Tropical Instability Waves
  - Global and Regional Mesoscale Models as tools for examining sub-synoptic scale phenomena in the analyzed wind fields.
- CCMP winds appear to provide improved forcing for the OGCM.
- The infrastructure is in place to rapidly reprocess based on recommendations from the OVW community with the goal of producing the best possible product.

NWP Impact experiments



Datasets

QSCAT SLP (QSLP)
QSCAT Gradient Level Winds (QGLW)
QSCAT Sea Level Winds (QSLW)

ASCAT SLP (ASLP)
ASCAT Gradient Level Winds (AGLW)
ASCAT Sea Level Winds (ASLW)

SSM/I, TRMM TMI, AMSRE, Windsat

Global Experiments

GEOS-5 (QSLW)
GEOS-5 (QSLP)
GEOS-5 (QGLW)
GEOS-5 (All QSCAT)

GEOS-5 (ASLW)
GEOS-5 (ASLP)
GEOS-5 (AGLW)
GEOS-5 (All ASCAT)

NCEP (QSLW)

VAM (QSLW)
VAM (ASLW)
VAM (All SSWs)

Regional Experiments

WRF (QSLW)
WRF (QSLP)
WRF (QGLW)
WRF (All QSCAT)

WRF (ASLW)
WRF (ASLP)
WRF (AGLW)
WRF (All ASCAT)

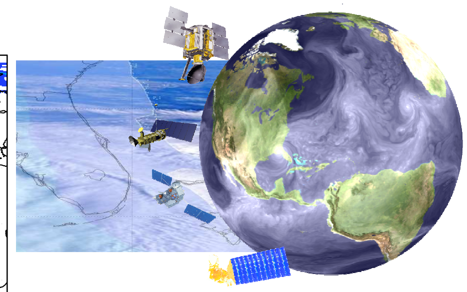
WRF (All Datasets)

Regional Impact Studies

2005
Katrina (8/23-8/30)
Ophelia (9/6-9/18)
Phillipe (9/17-9/23)

2006
Ernesto (8/24-9/3)
Gordon (9/11-9/20)
Helene (9/12-9/24)

2008
Gustav (8/25-9/4)
Hanna (8/28-9/7)
Ike (9/1-9/15)



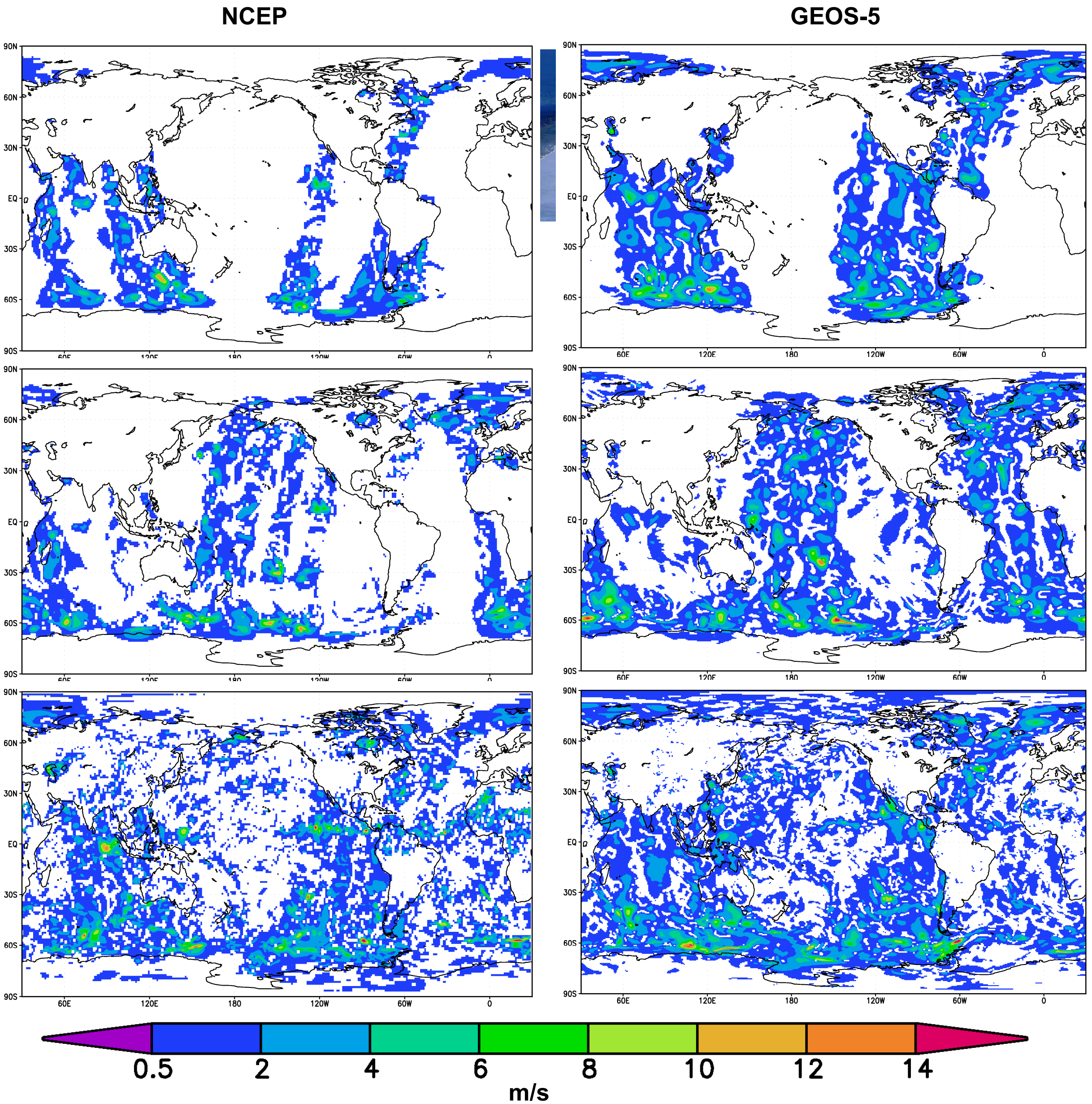
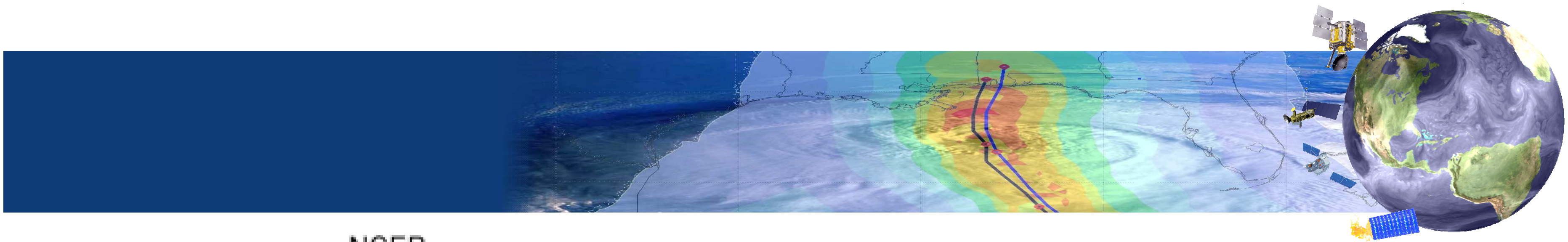


Figure 6 Impact of Quikscat winds on the NCEP and GEOS-5 surface wind analysis at the initial insertion time (top), 6-hours into the assimilation (middle) and 1-week (bottom). Shaded colors indicate the magnitude of the vector difference between the control and control+quikscat experiments.



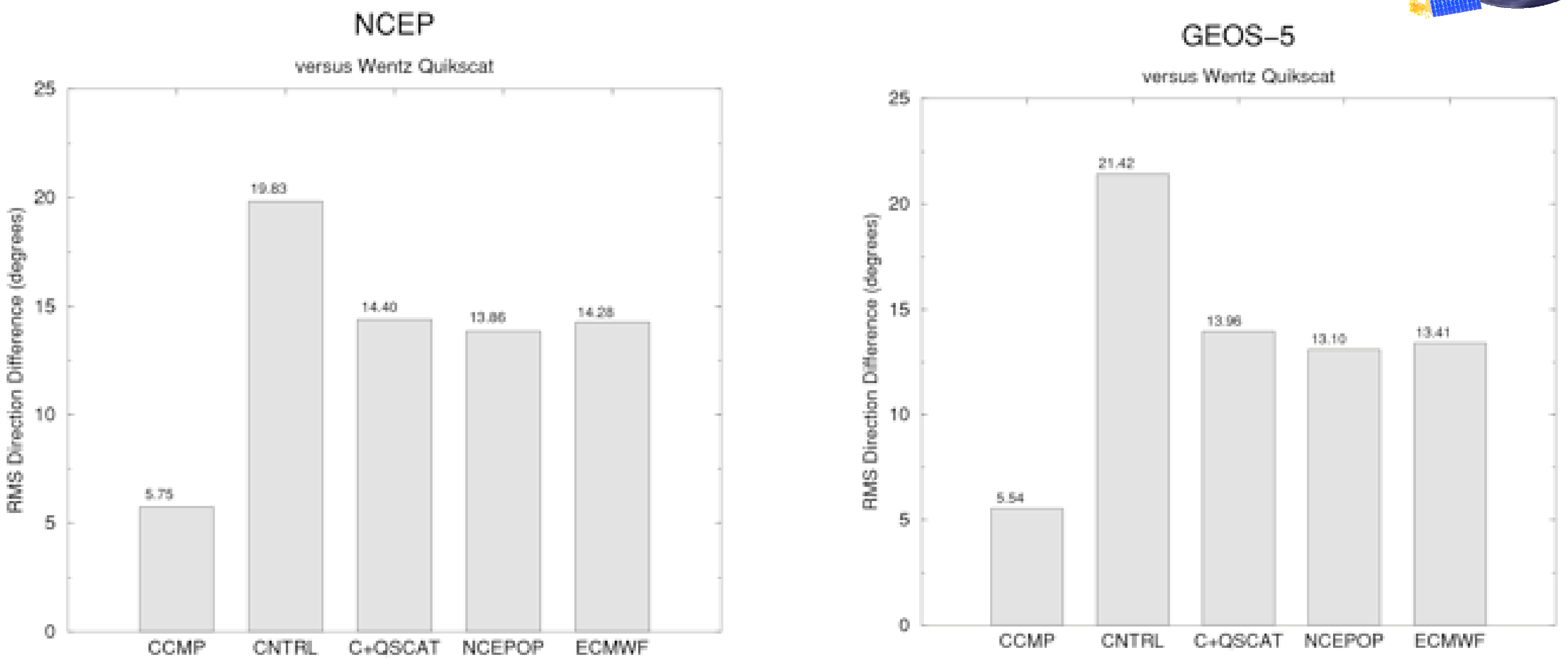
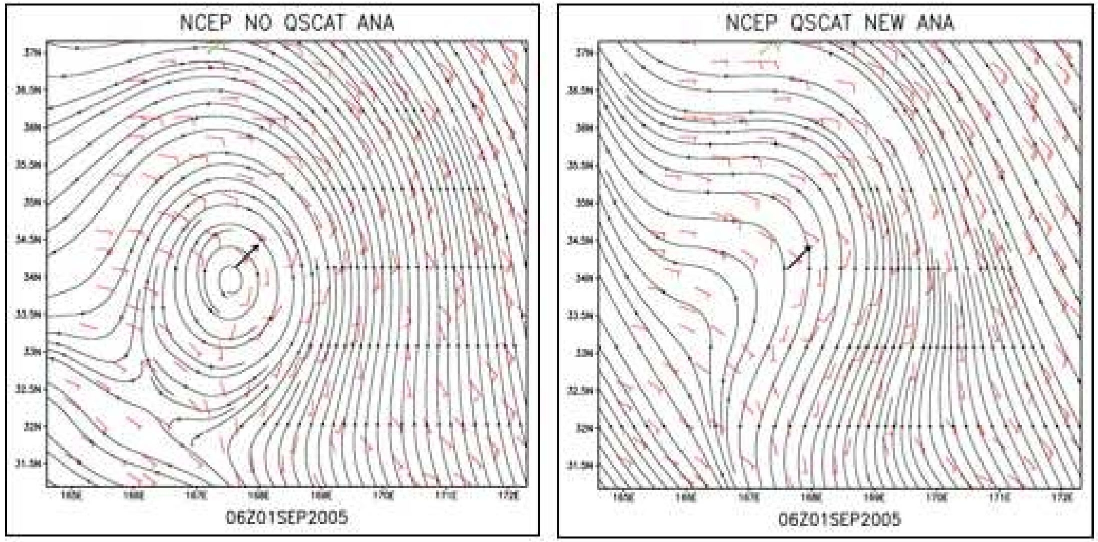


Figure 10 RMS fit of the NCEP and GEOS-5 analyses to Quikscat for July 2005 and September 2006 respectively. The NCEP and ECMWF operational analyses are shown for comparison. The recently created Cross-Calibrated Multi-Platform (CCMP) surface wind analysis is also shown. The CCMP data set represents the best fit to Quikscat since it is a high resolution analysis (25 km) with less constraints for smoothness.

Analysis	Cyclones Added	Cyclones Deleted	Position Impact Avg (km)	Position Impact Max	Vorticity Impact Avg	Vorticity Impact Max	Max Wind Impact Avg (m/s)	Max Wind Impact Max
NCEP	155	346	89	186	-0.4	2.4	0.5	2.4
GEOS-5	309	379	100	251	0.1	4.5	0.7	3.0



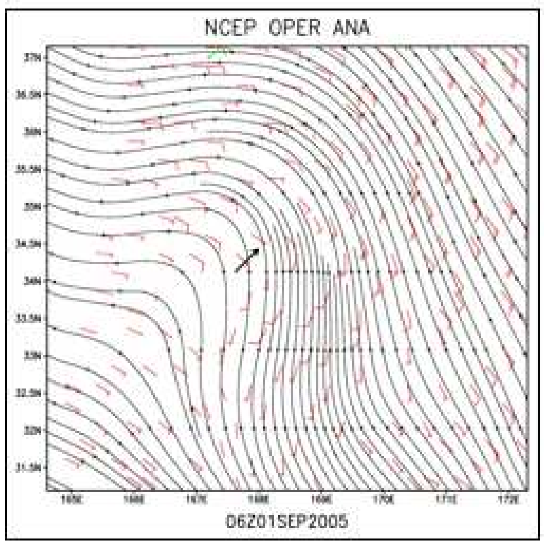
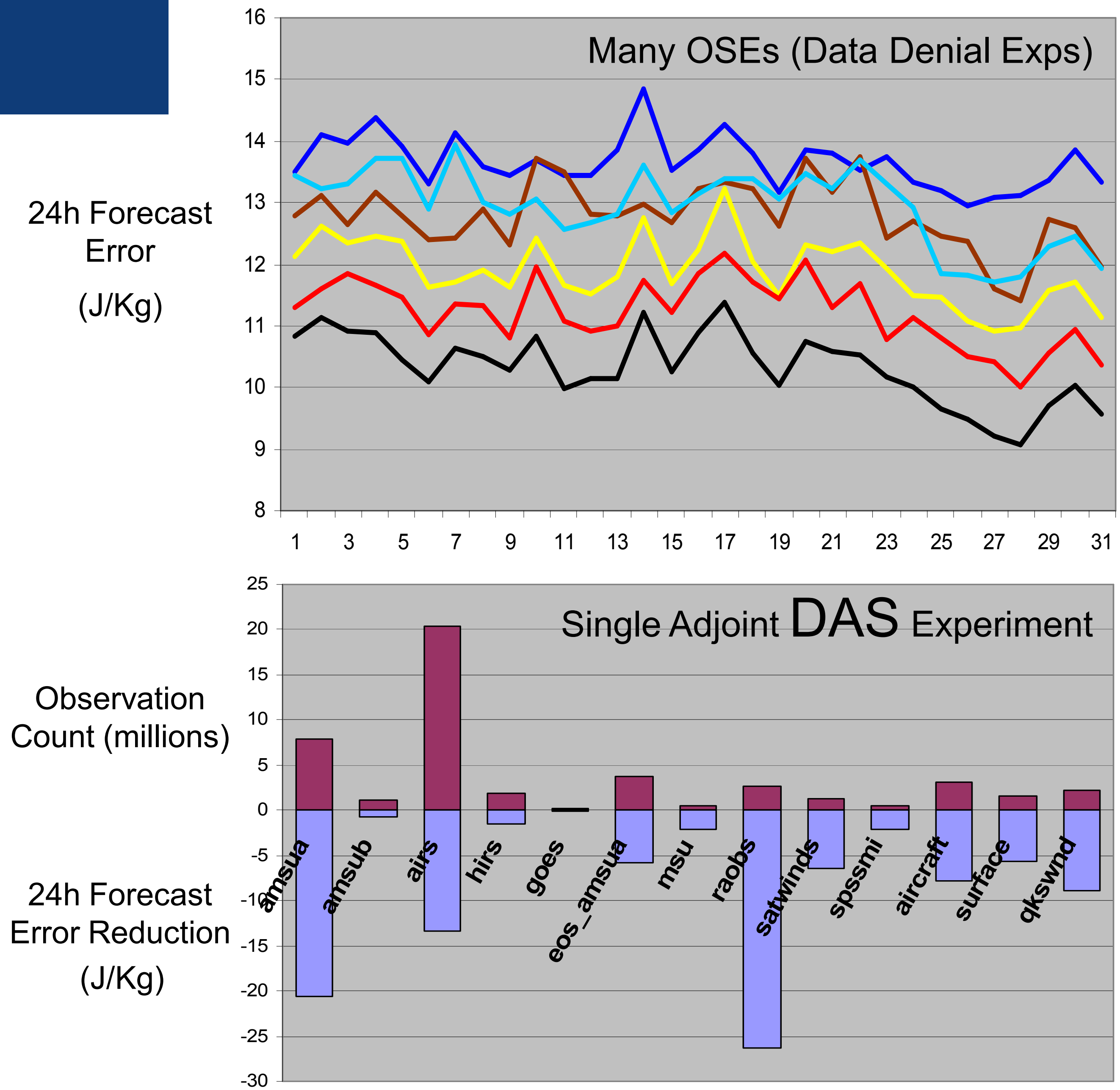


Figure 12 NCEP 1000mb wind analysis on September 1, 2005 6Z. The top left panel shows the NCEP Control analysis (no Quikscat) depicting a closed circulation center (located at the endpoint of the vector marker). Quikscat wind barbs (red) are show for reference. The top right panel shows the 1000mb wind analysis for the NCEP analysis that assimilated the Quikscat winds. The NCEP operational analysis (bottom left) is shown for comparison. In general, the assimilation of Quikscat in the NCEP DAS results in many more deleted cyclones than added as can be seen in this example.

Estimation of Observation Impact on NWP



NASA GEOS-5 July 2005 00z

Gelaro, Zhu, …

NWP Summary

- The assimilation of Quikscat winds improves NASA and NCEP model analyses of ocean sfc wind; the impact on model forecasts is positive but smaller than previously obtained. The impact is limited by competing data, superobing, and various aspects of the GSI analysis.

- The in-depth analysis is ongoing, with a focus on the influence of QuikSCAT data on analyses and forecasts of surface winds, and the vertical dynamic and thermodynamic structure.

- Modifications to quality control, error specification, and data thinning will be tested.

- Quikscat derived sea level pressure and gradient level winds will be assimilated using the GEOS-5, NCEP and WRF models in combination with the Quikscat surface winds to assess the potential for increased beneficial impact of Quikscat as mass and wind data.

- Quikscat data have been used successfully in the development of the 1/8 and 1/12 degree versions of the fvGCM, and this application will continue as we go to even higher model resolution.