Boundary Layer Studies Connecting Satellite Surface Wind and Pressure Fields to Storms, Weather and Climate

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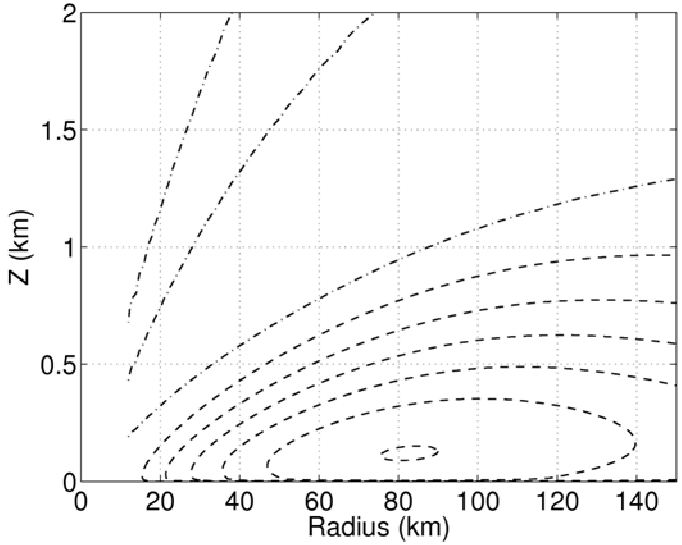
Parallel Efforts

- Develop new and improved atmospheric boundary layer models (direct and inverse)
- Applications of these models to storms analyses

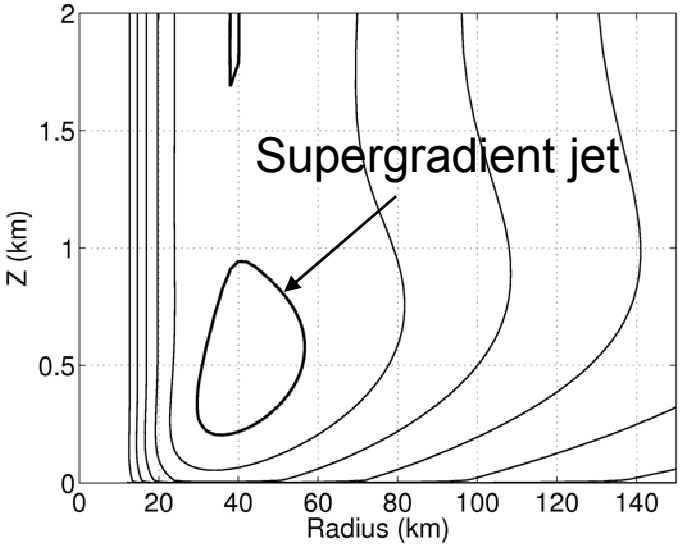
PBL Model Development

- Tropical cyclone boundary layers (TCBL)
  - New similarity TCBL model
  - Includes nonlinear advection and curvature
  - Simple to run
- TCBL roll vortices
  - Prevalent in TC BLs
  - *O*(1) effect on momentum fluxes
- Momentum advection in mid-latitude model
- PBL top entrainment (Tropics)

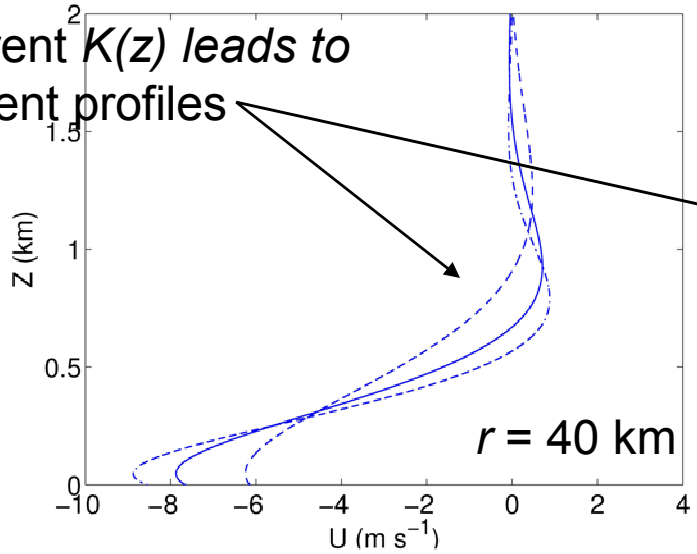
Radial (*U*)

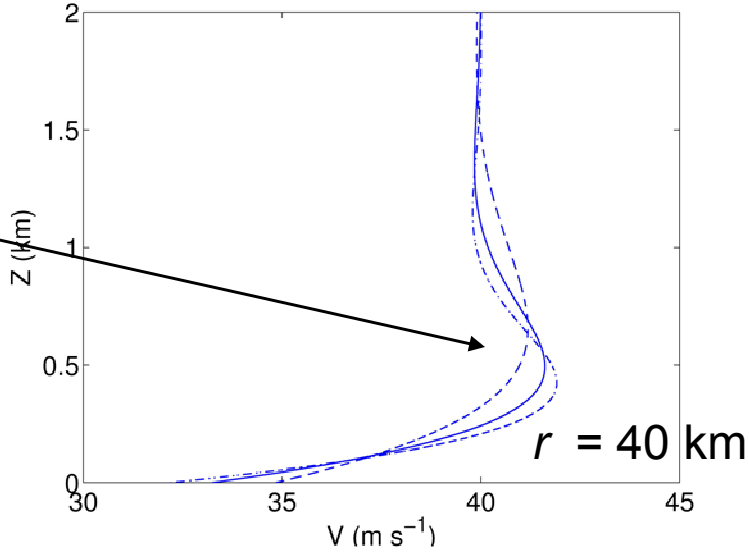


Azimuthal (*V*)



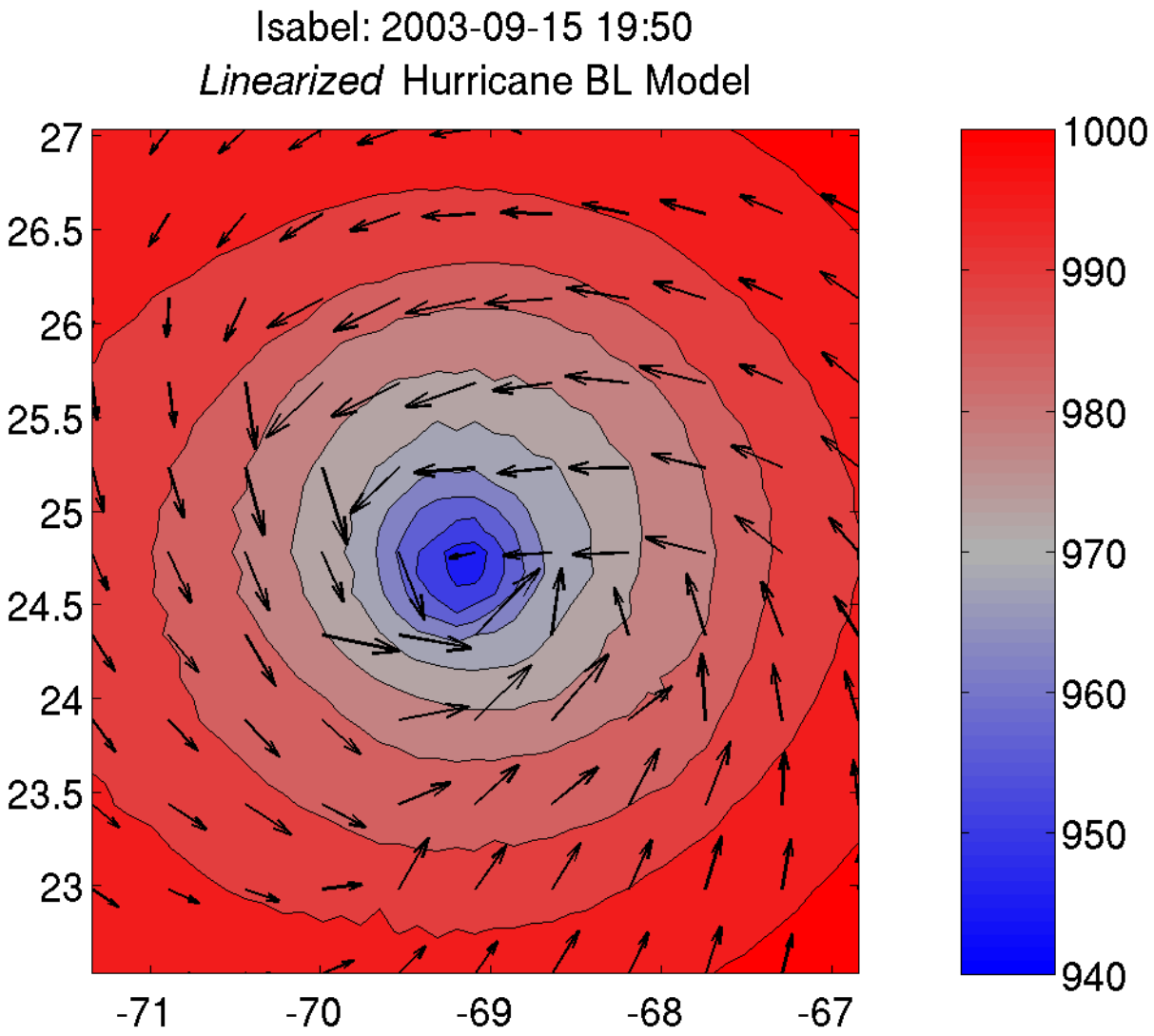
Different *K(z) leads to* different profiles





SLP from TCBL Model and OVW

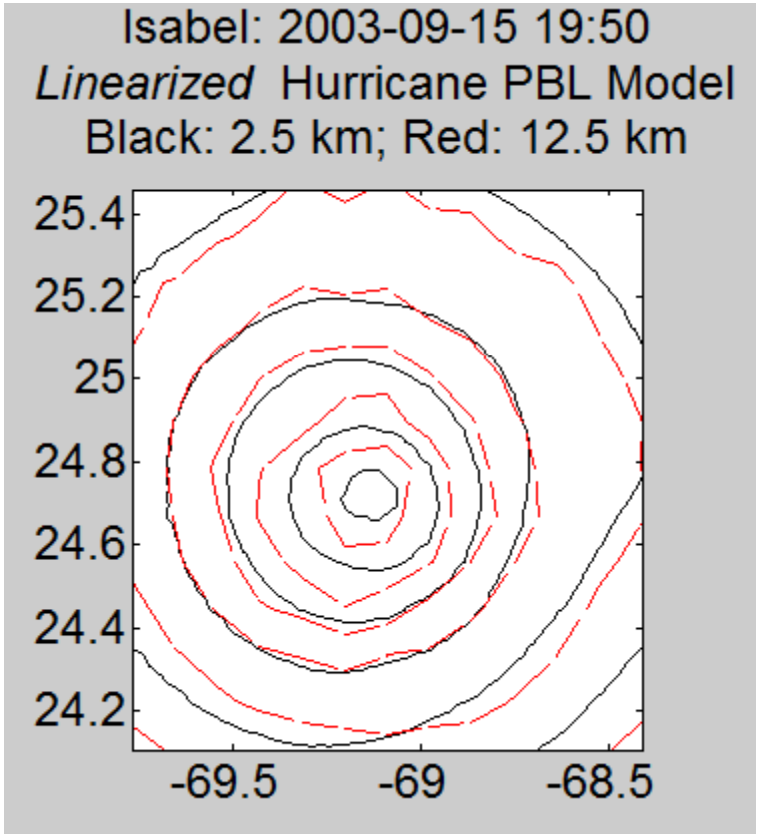
- "Inverse" model: TC U_{10} → SLP
  - *No need for ad hoc gradient wind correction*
  - (will) include *nonlinear* TCBL dynamics
  - Can produce smoothed/corrected winds
- High winds cal/val via SLP data
  - Similar to Zeng and Brown (1998) for ERS-1
- Incorporate azimuthal advection terms

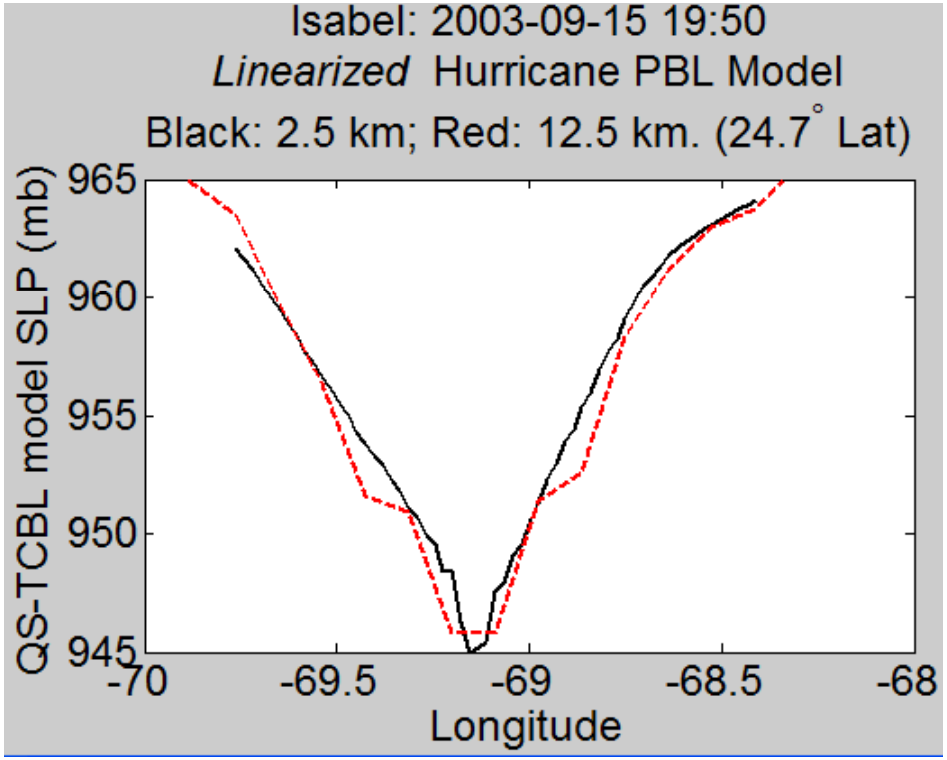


First cut at SLP from "new" TC similarity PBL model (12.5 km)

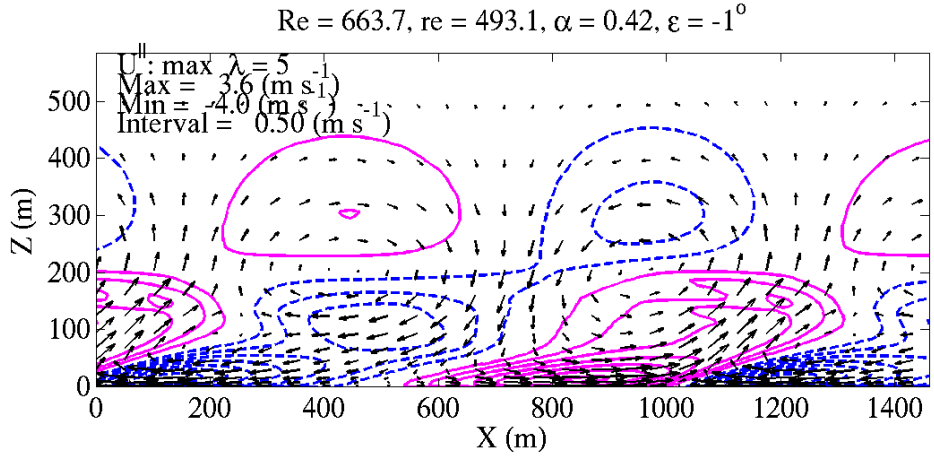
Driven with JPL 12.5 km winds

First-Cut Inverse TCBL Model



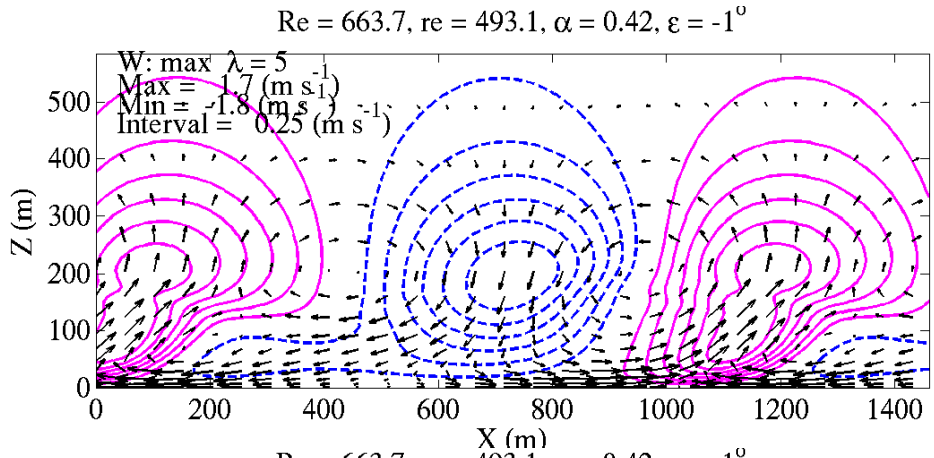


BYU 2.5 km hrwind vs. JPL 12.5 km processing

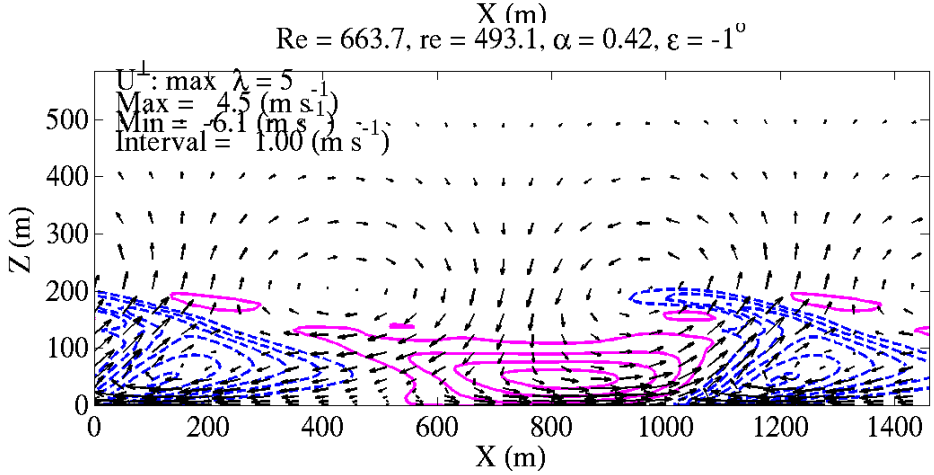


r = 30 km

Across-Roll



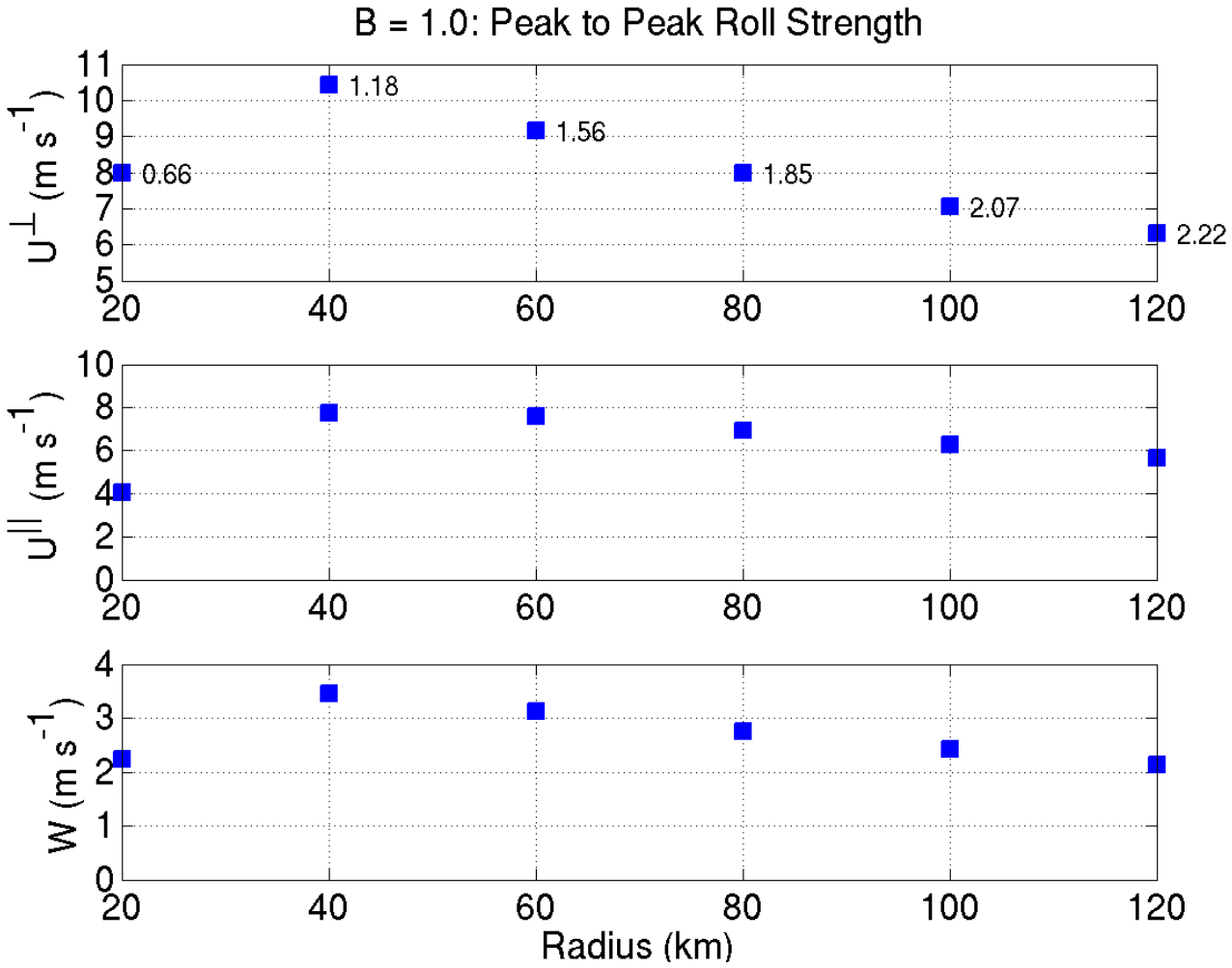
Vertical



Along-Roll

TCBL Rolls

TCBL Nonlinear Roll Strength (Velocity)



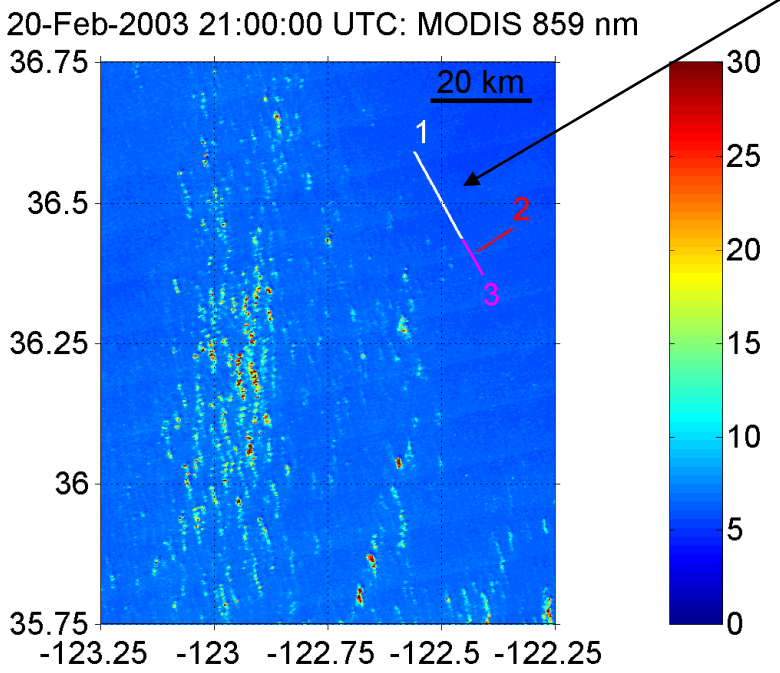
Along-Roll

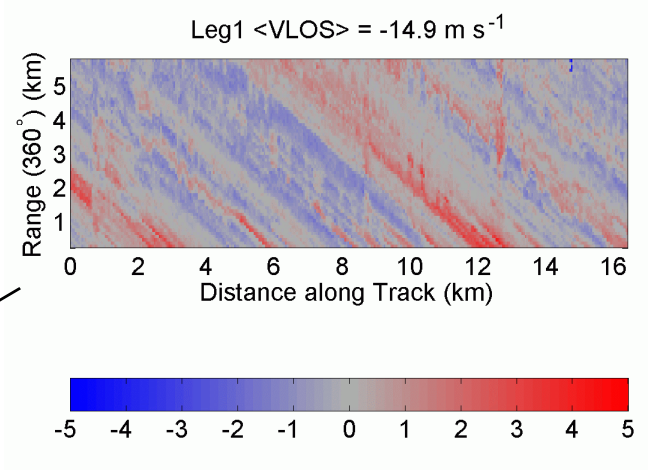
Across-Roll

Vertical

Mid-Lat Roll Theory vs. Doppler Lidar

20 Feb 2003 MODIS 250 m pixel IR radiance near Monterey Bay. Near time of TODWL flights.





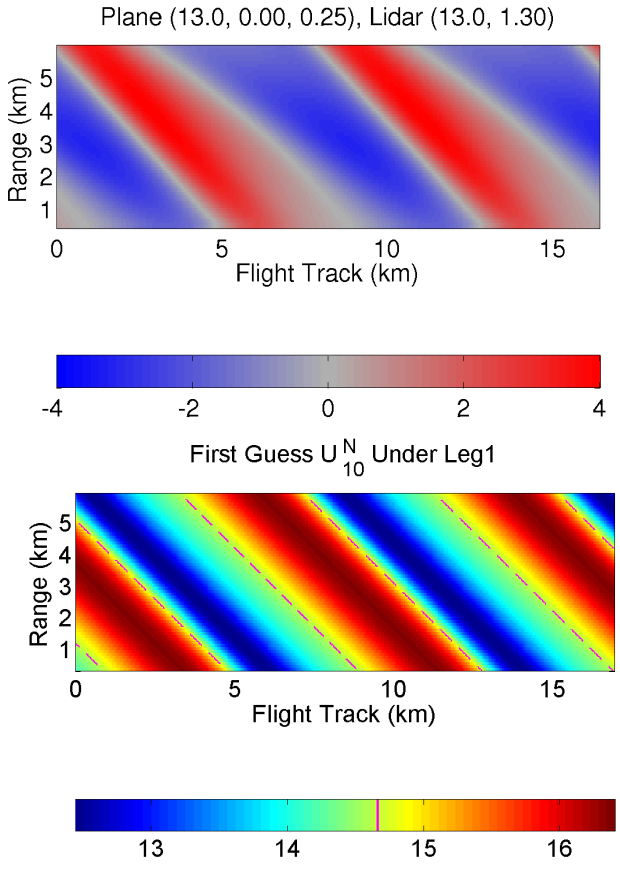
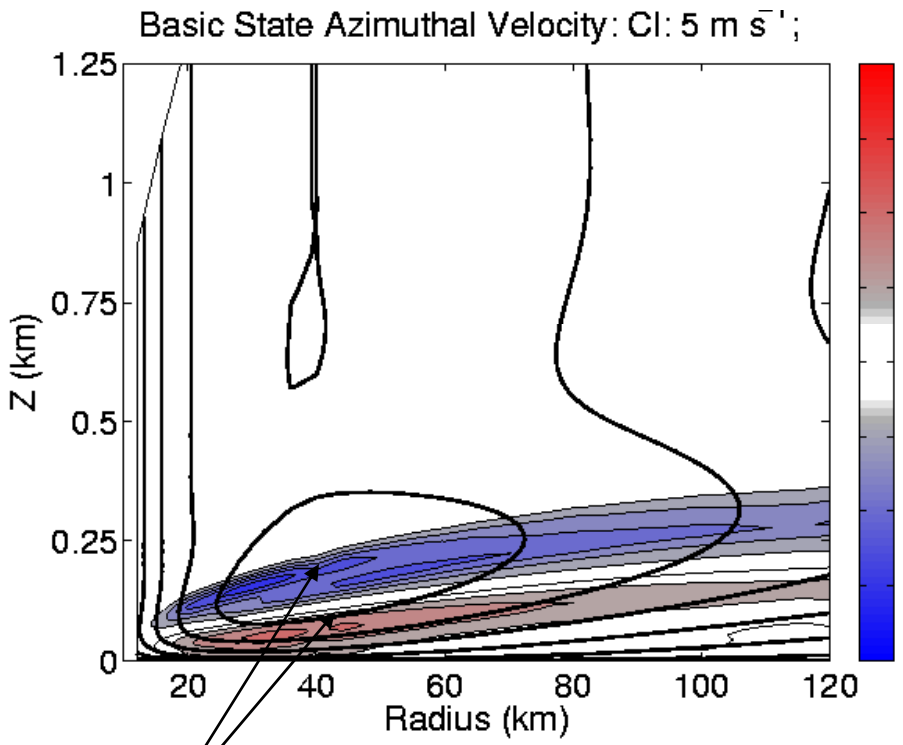
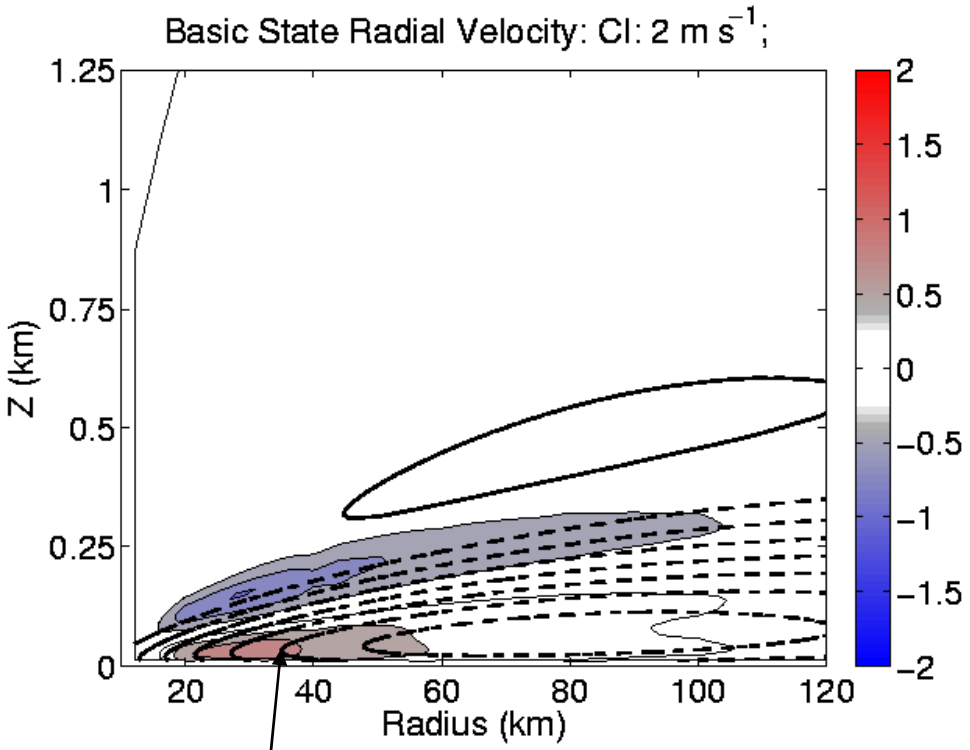


Figure 2: (a) TODWL line of sight (LOS) perturbation winds from a forward stare leg at 30 m flying along the mean wind. (b) Simulated LOS winds from model of Foster (1996, 1997, 2004). (c) Estimated U10N from Foster's model and standard surface layer models.

Roll-Induced Modification of the Mean Flow





Transfer of Super-Gradient
Jet momentum towards surface

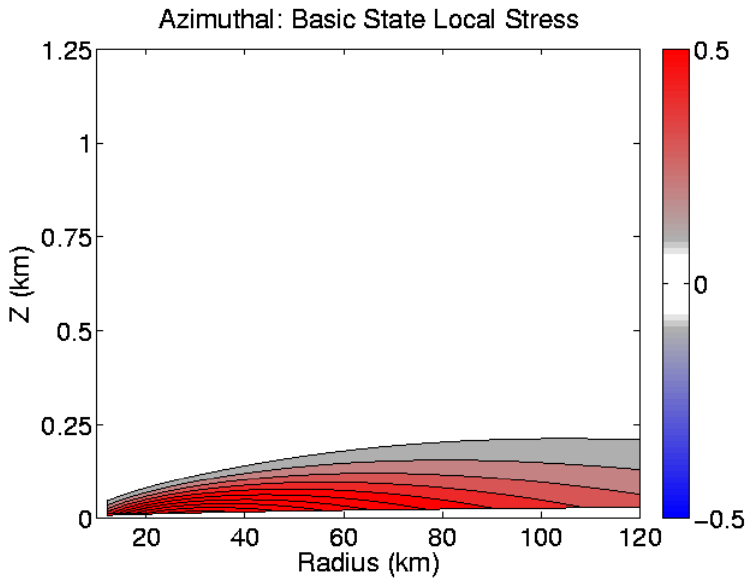
Weakened near-surface
inflow near and inside RMW

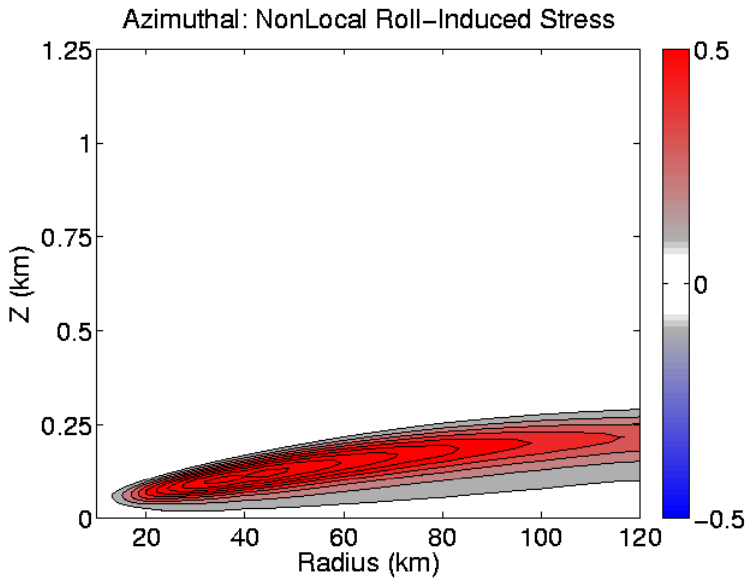
Momentum Flux

Local Flux
(**In** numerical models)

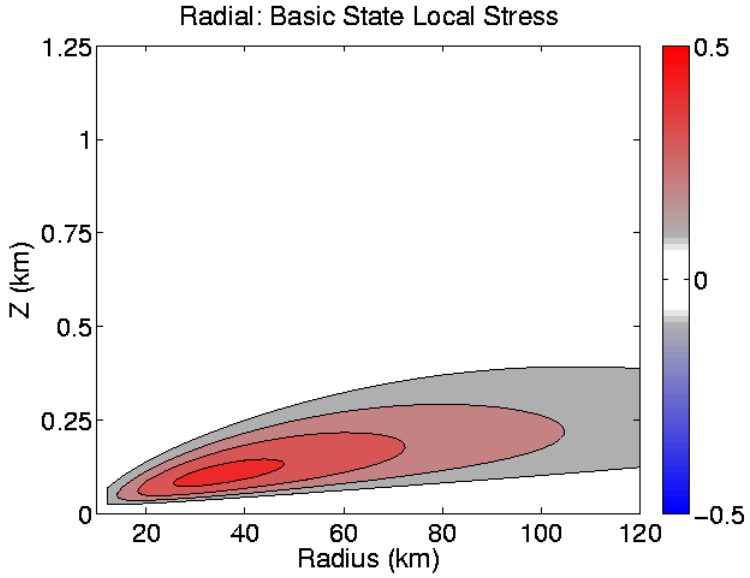
Nonlocal Roll Flux
(**Not** in numerical models)

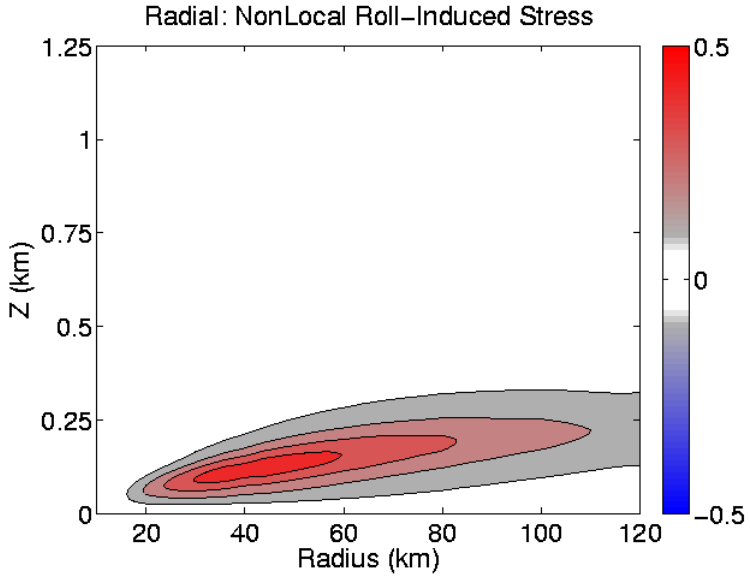
Azimuthal



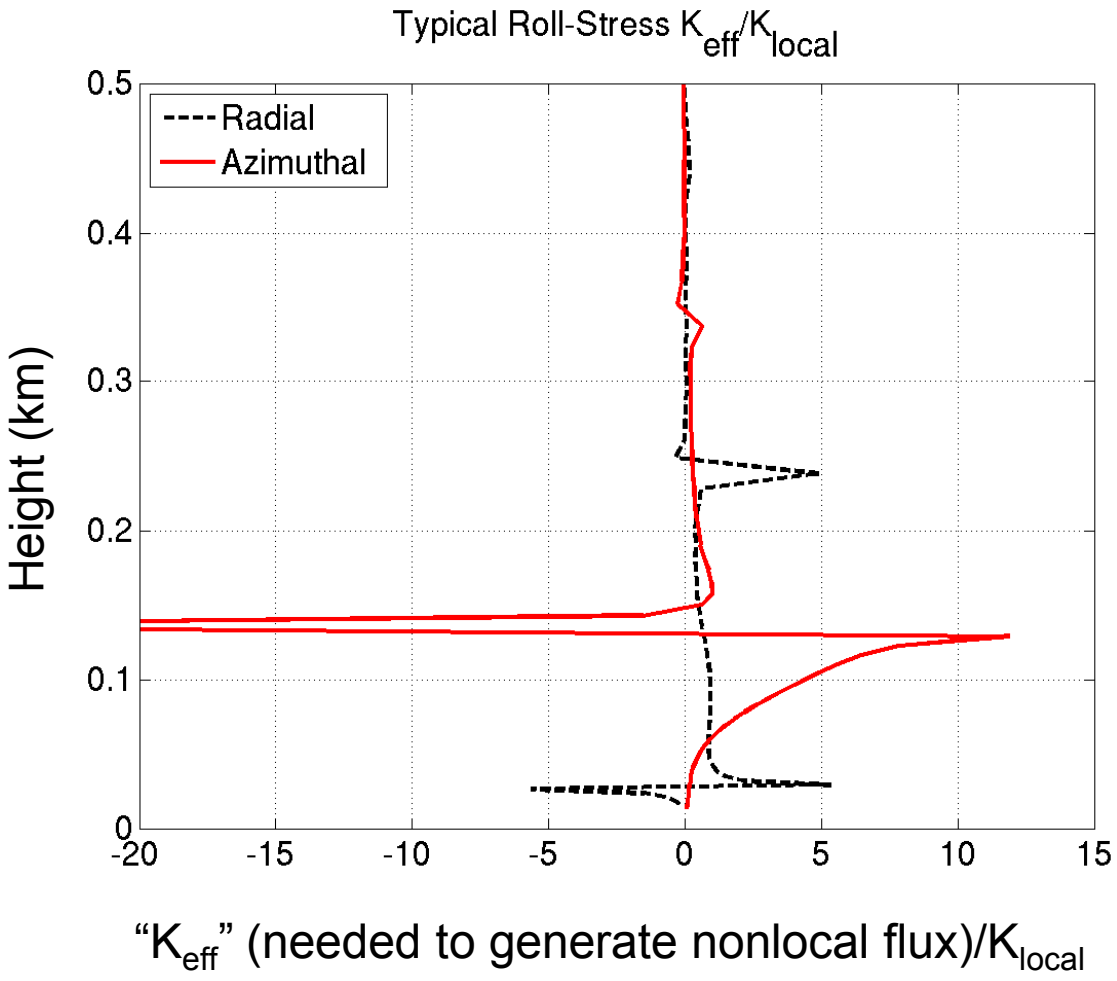


Radial





Nonlocal Roll-flux CANNOT be parameterized using standard methods!



- Negative *K* is unphysical
- "K_{eff}" different for Radial and Azimuthal flow
- Requires very large values and rapid changes

Rolls and SAR TC Winds

GEOPHYSICAL RESEARCH LETTERS, VOL. 32, L22801, doi:10.1029/2005GL023992, 2005

Can synthetic aperture radars be used to estimate hurricane force winds?

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Received 5 July 2005; revised 23 August 2005; accepted 6 October 2005; published 16 November 2005.

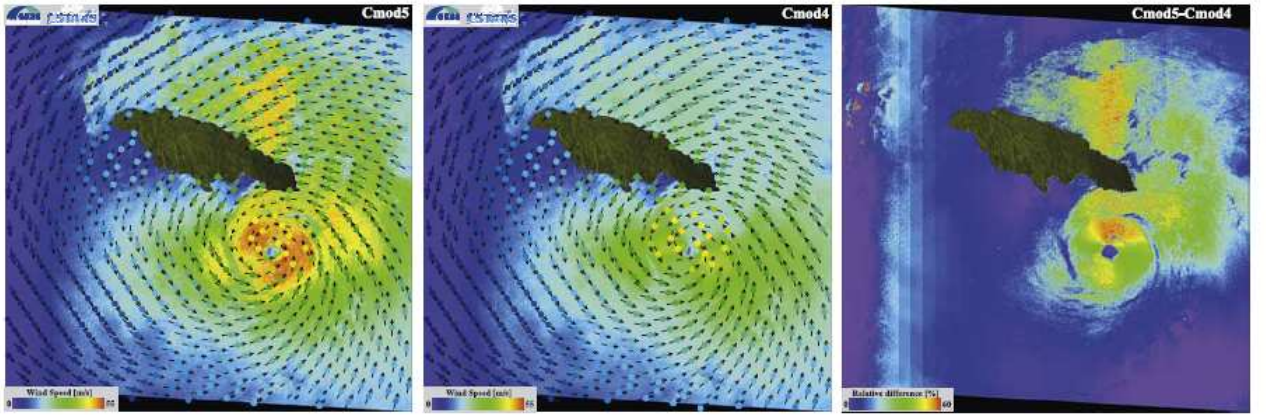


Figure 3. SAR wind map from the Cmod5 inversion (left panel), from Cmod4 (center panel), and the differences Cmod5 – Cmod4 (right panel). For both inversions, we have used the LG-Method to determine the wind directions and the polarization ratio according to *Thompson et al.* [1998].

- Assumes: wind direction = roll direction
  Not True! (We can evaluate)
- (Future) Comparison with QS-SLP corrected winds

Some Applications of OVW-SLP

- Improved surface winds
- Blended wind fields
- Storm chasing
- Altimeter SLP corrections
- Operational analysis

WindSAT Example

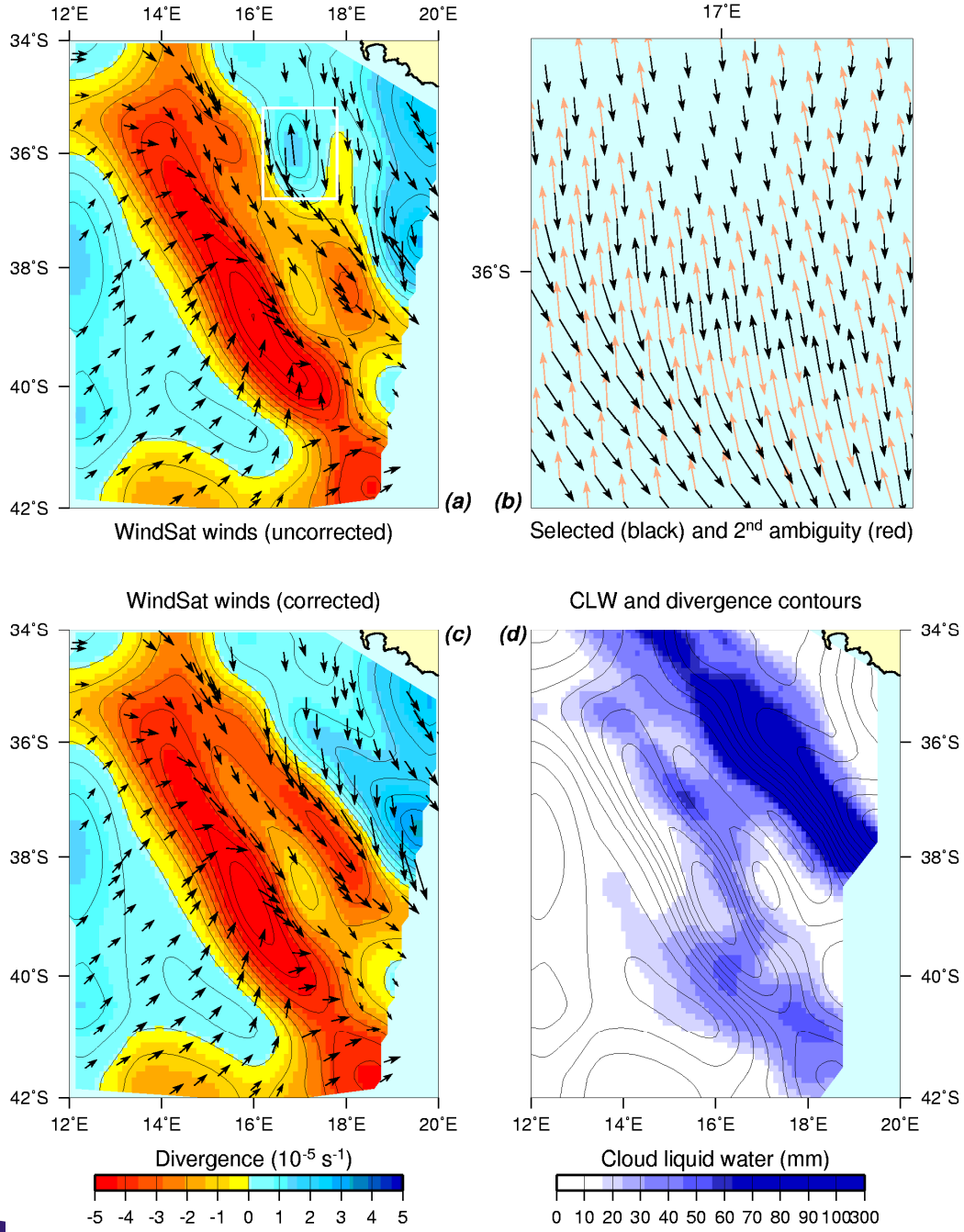
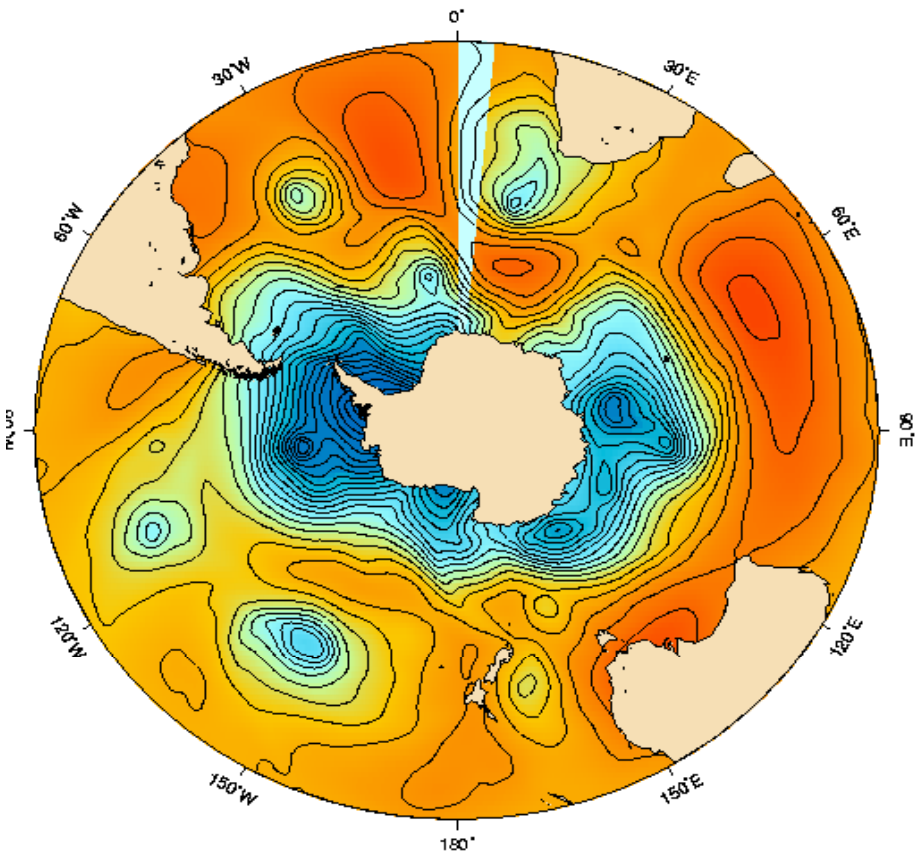
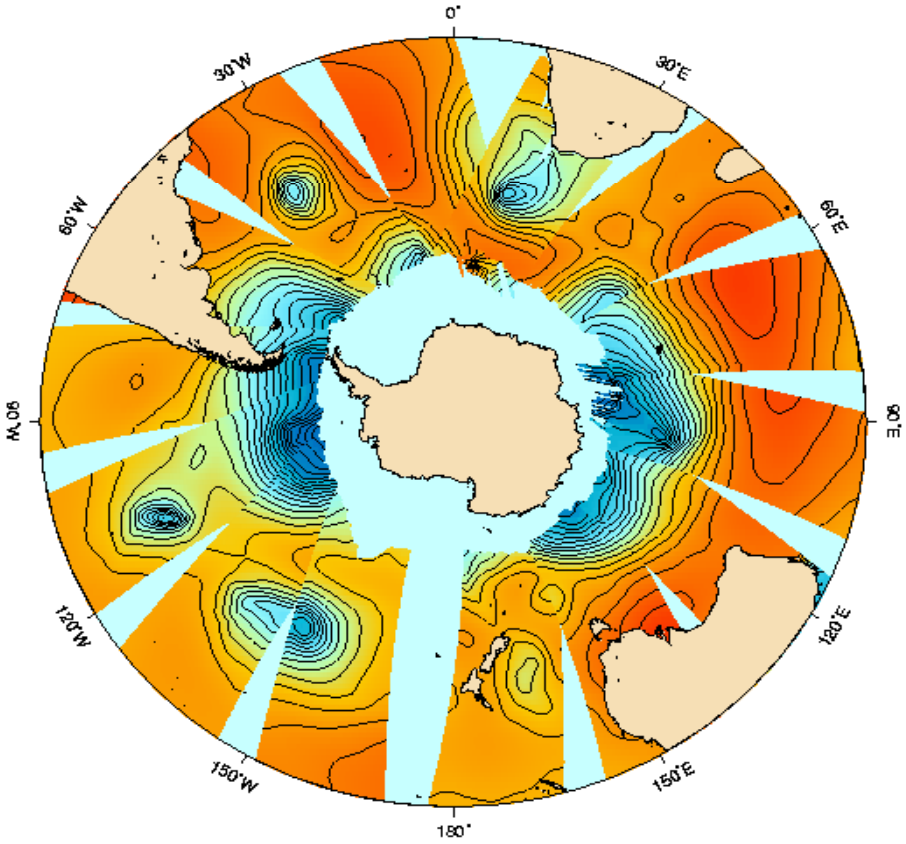
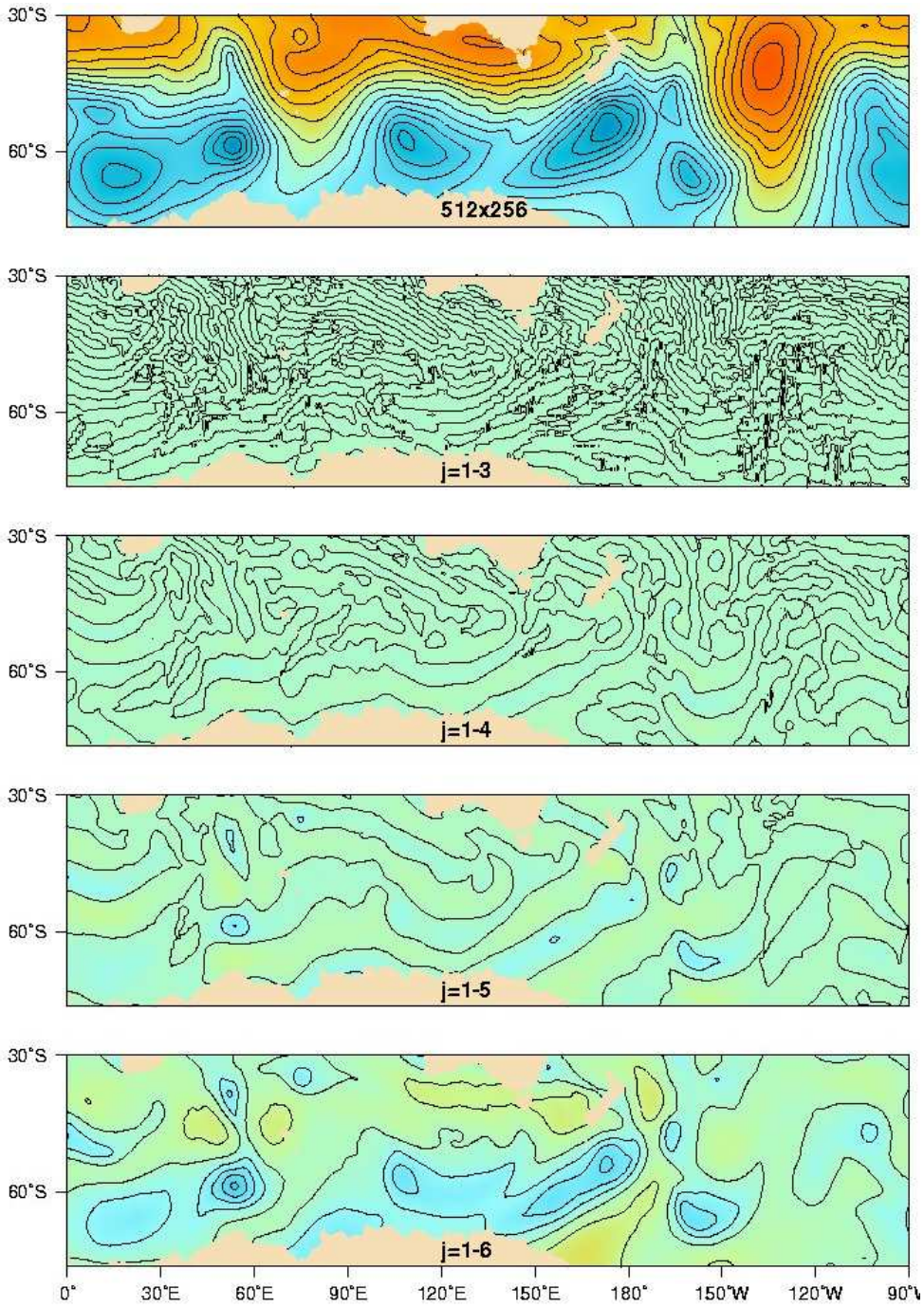


Figure 2: Details in the double-front zone. (a) Divergence calculated using WindSAT selected vectors. (b) Selected and 2nd ambiguities. (c) Model-corrected WindSAT vector selection and corrected divergence field. (d) Corrected divergence and WindSAT cloud liquid water. (Only 1 in 20 WindSAT vectors plotted.)



1 August 99 - 12:00 UTC



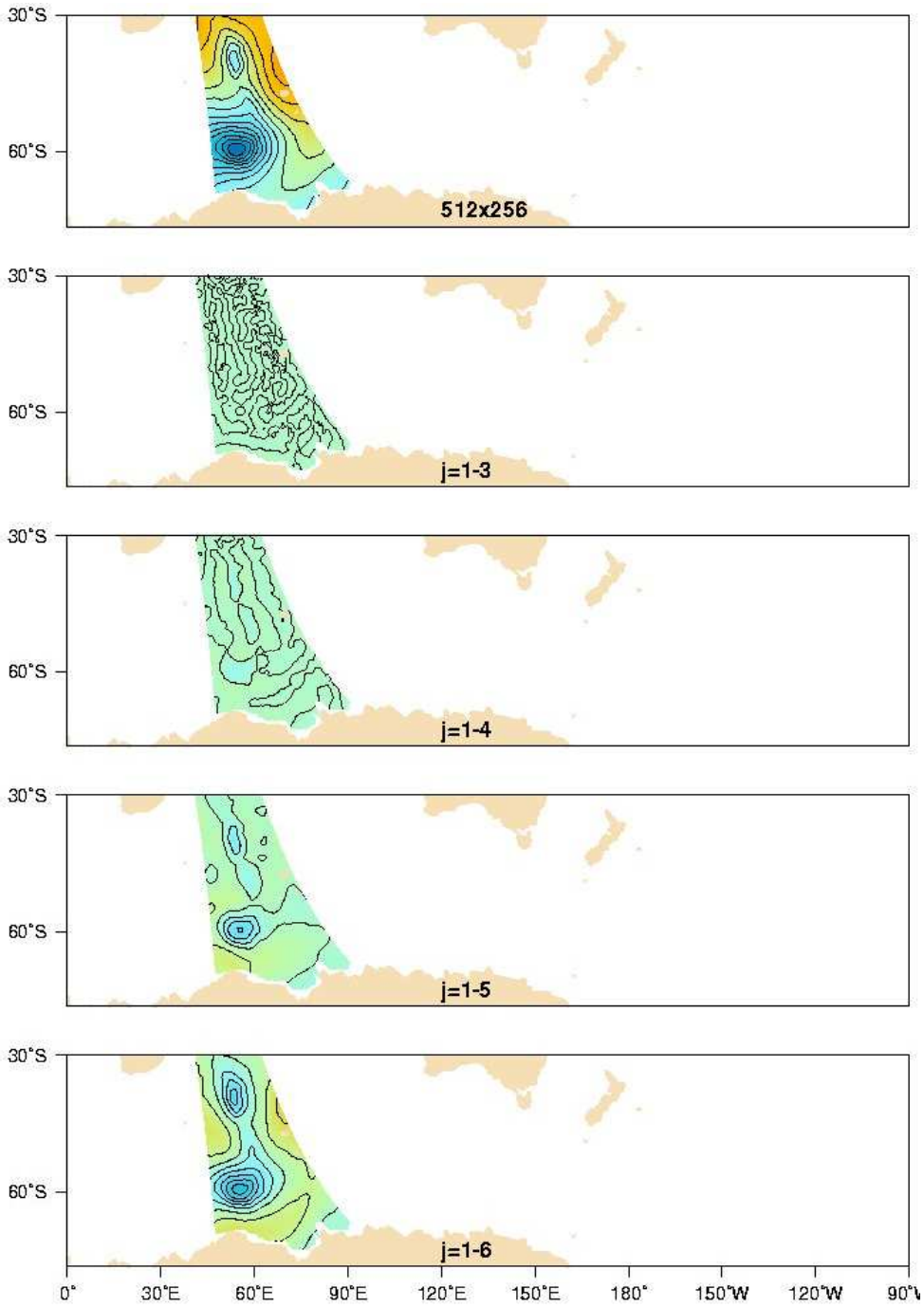


Wavelet decomposition of the ECMWF pressure field

Sum of smallest scale details (levels 1 to 3).

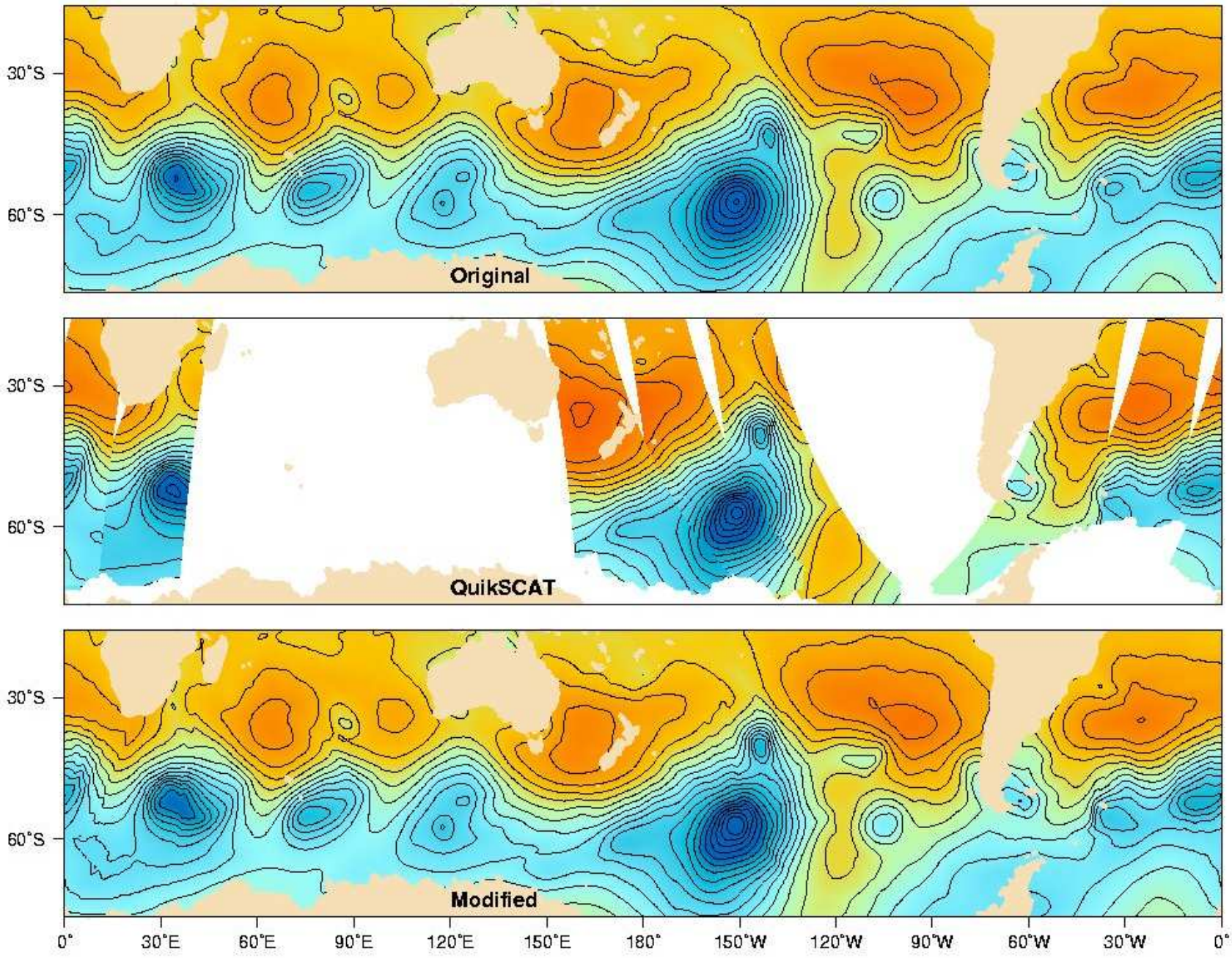
- By adding more detail at successively larger scales, the signal is reconstructed.
- Scale doubles each step from initial size of 25 km.
- We stop before reconstructing the synoptic scale.

Sum of levels 1 to 6 (25 to 800 km) details.



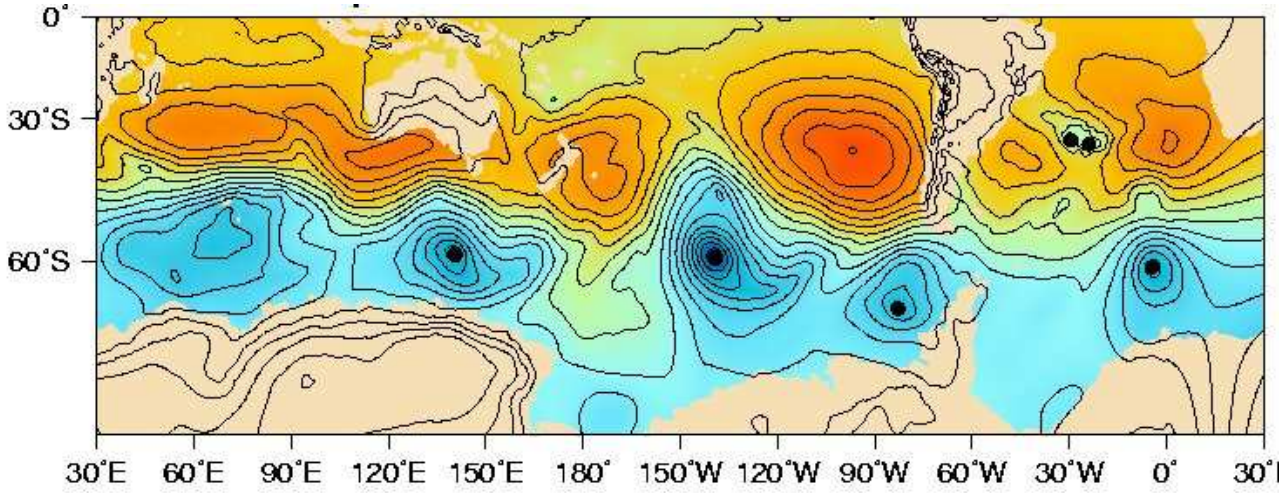
Wavelet decomposition of the QuikSCAT pressure field

Same thing…



- Replace ECMWF wavelet coefficients with those from QS-SLP (a' la Milliff for winds)

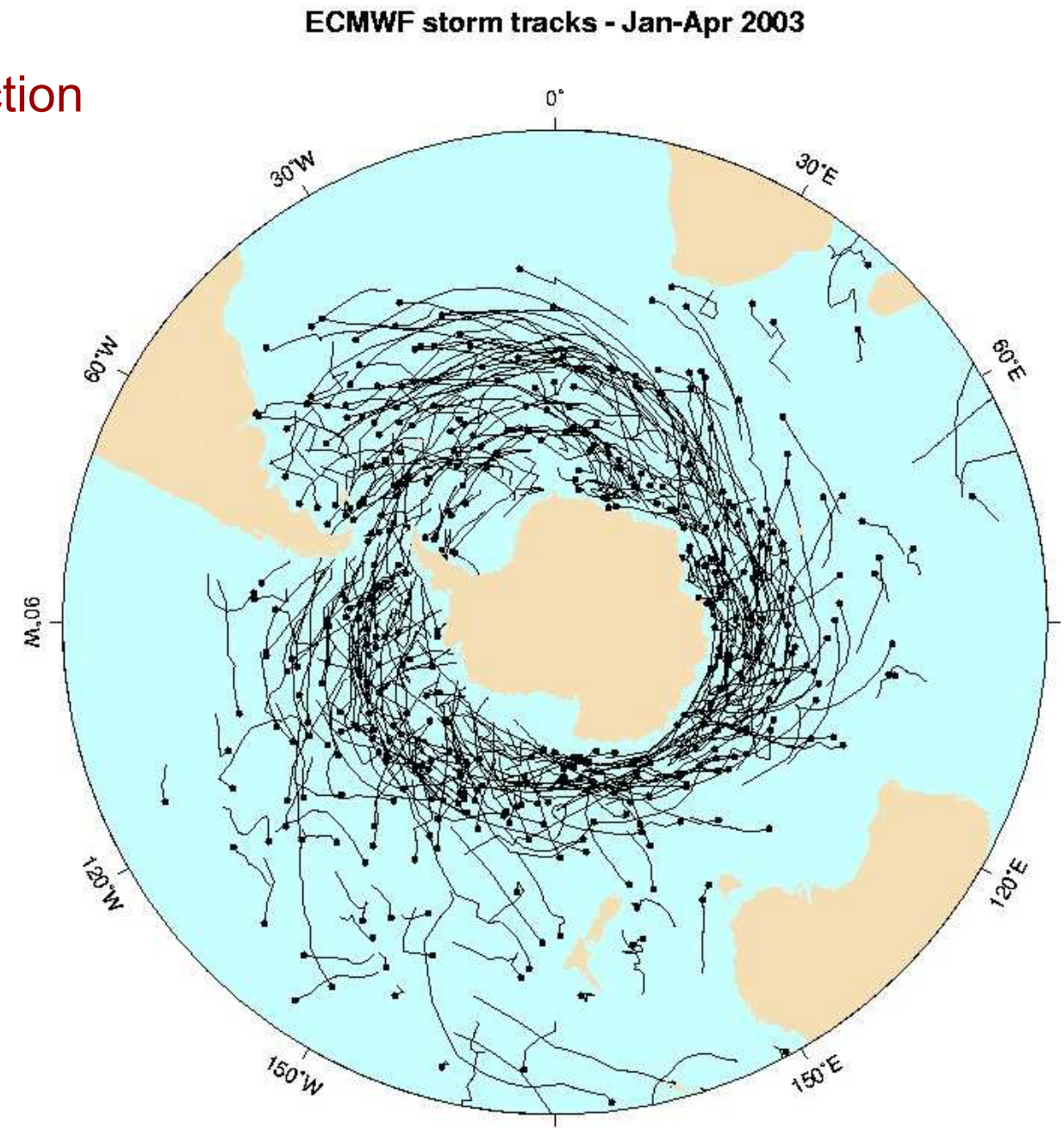
STORM CHASING



Systematic detection of low pressure centers

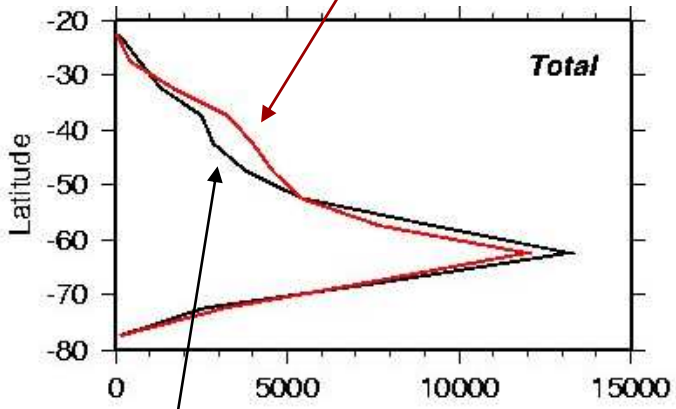
- July 1999 – June 2005
- 4 synoptic periods per day (00:00, 06:00, 12:00, 18:00 UTC)
- in parallel on ECMWF and modified pressure fields

…and reconstruction of storm tracks.



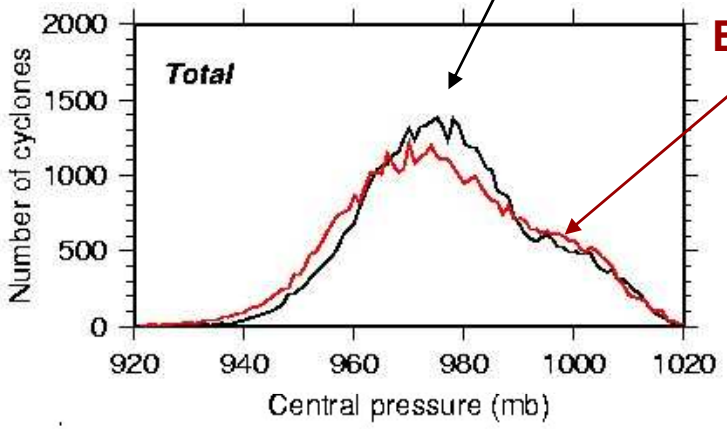
SOME STATISTICS

ECMWF with Injected QuikSCAT (E+QS)

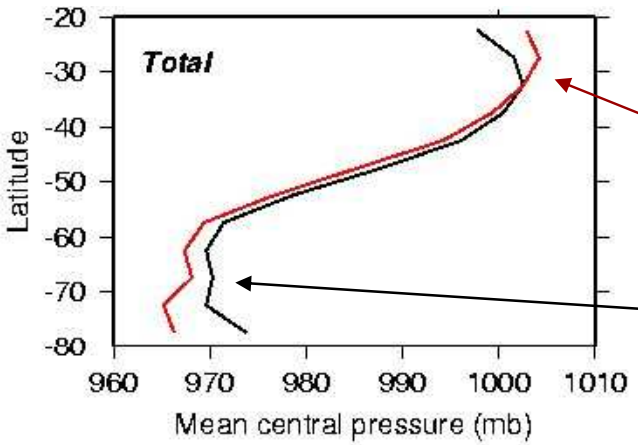


ECMWF

ECMWF

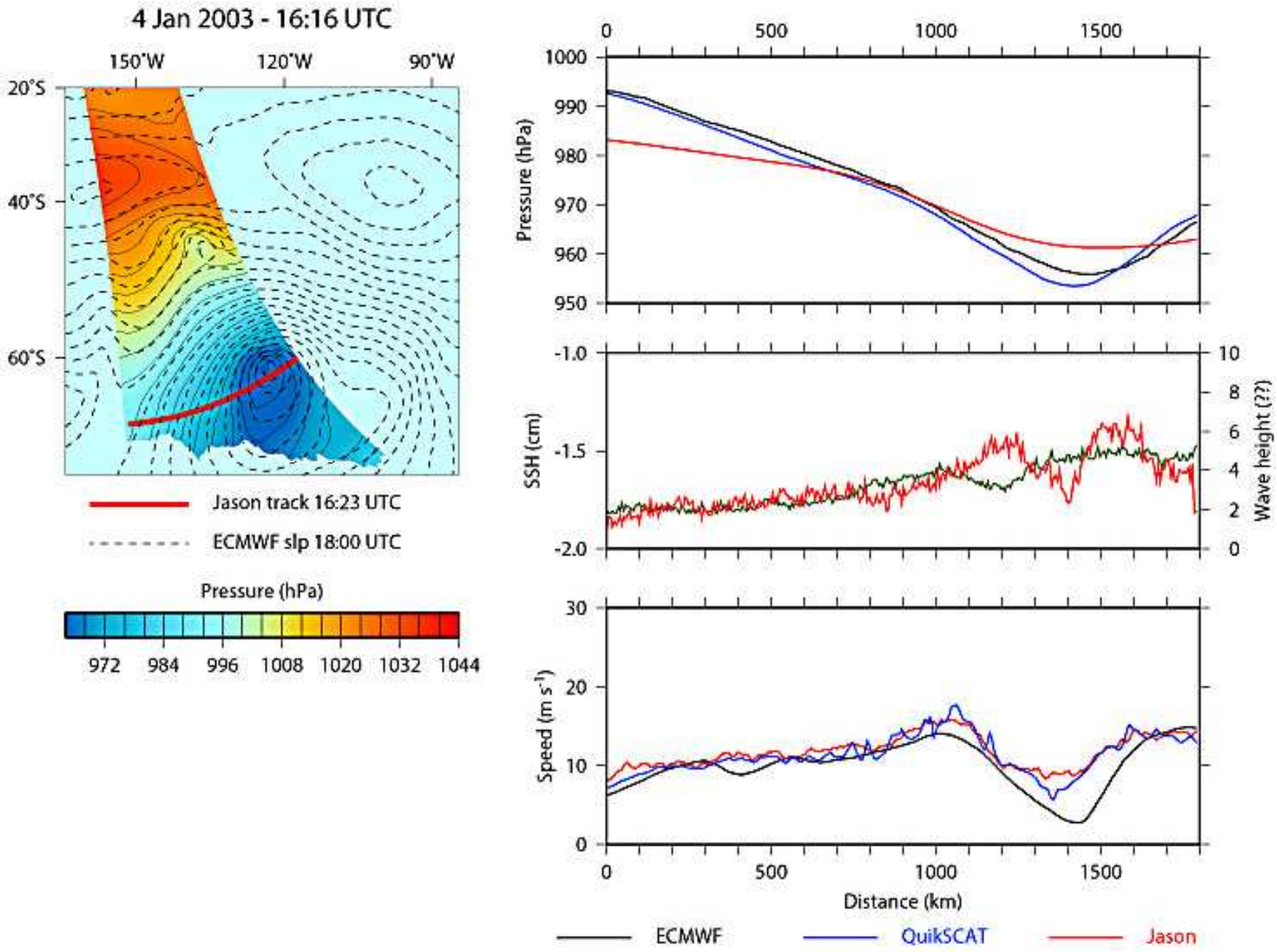


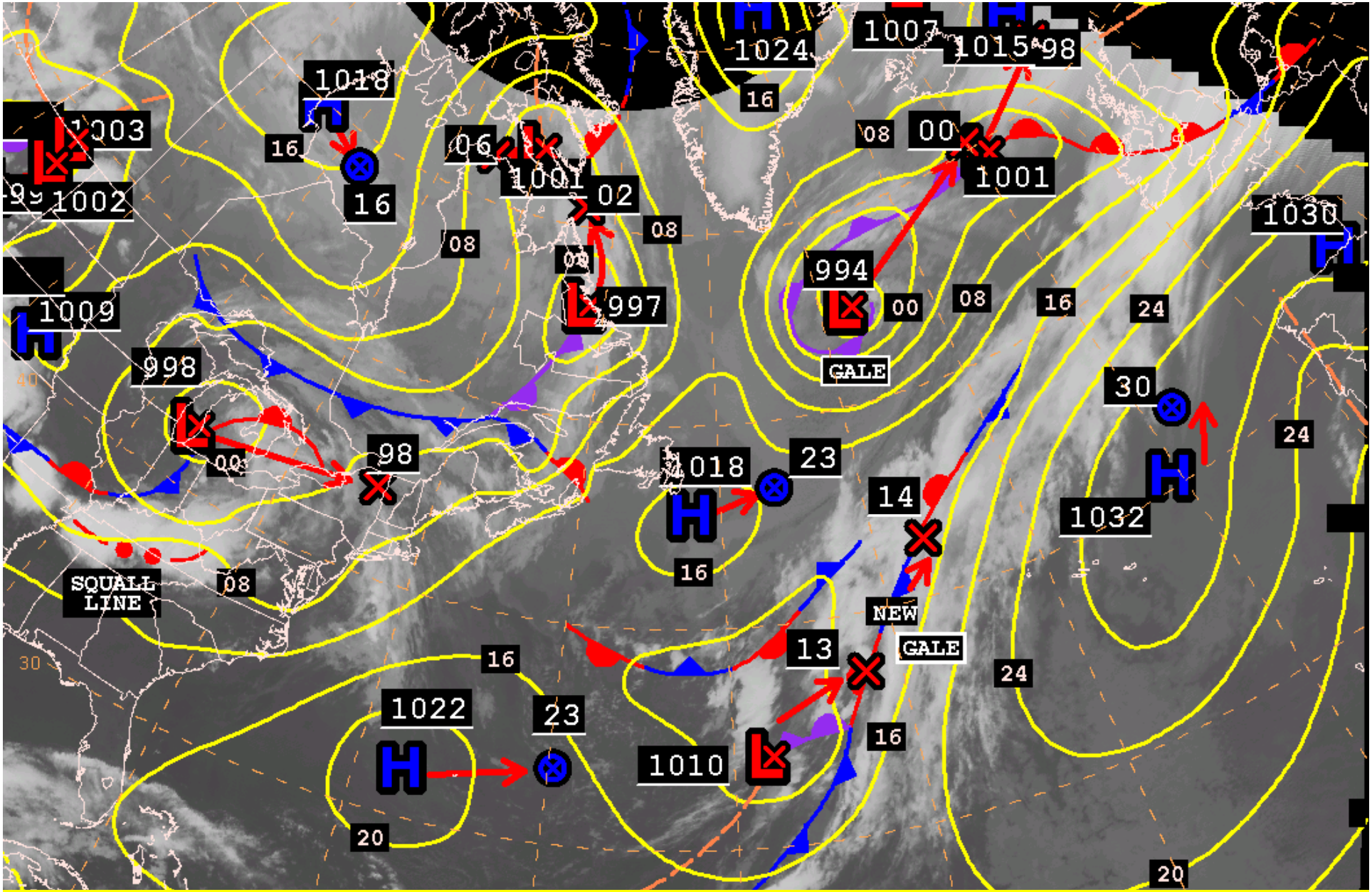
E+QS



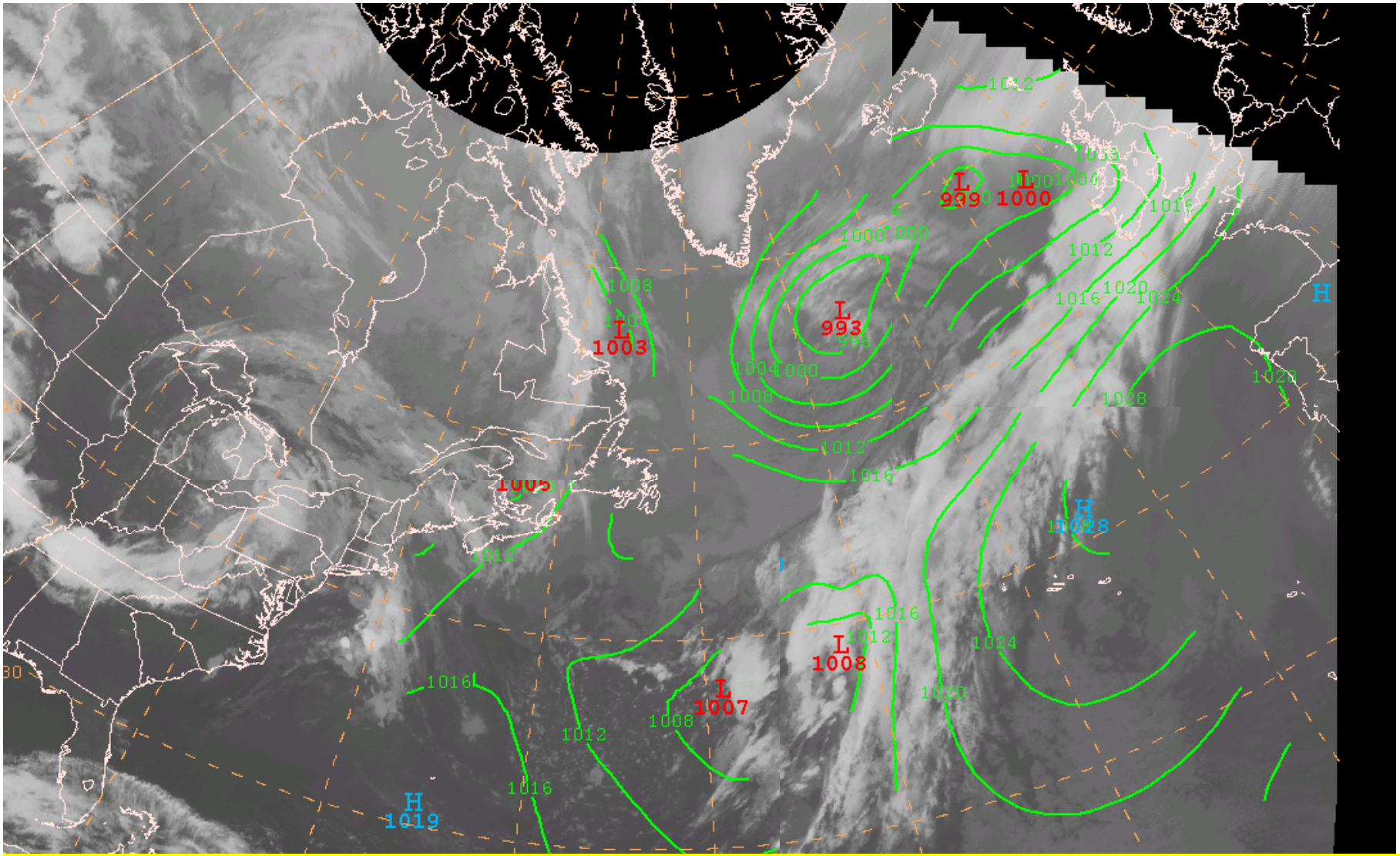
E+QS

ECMWF

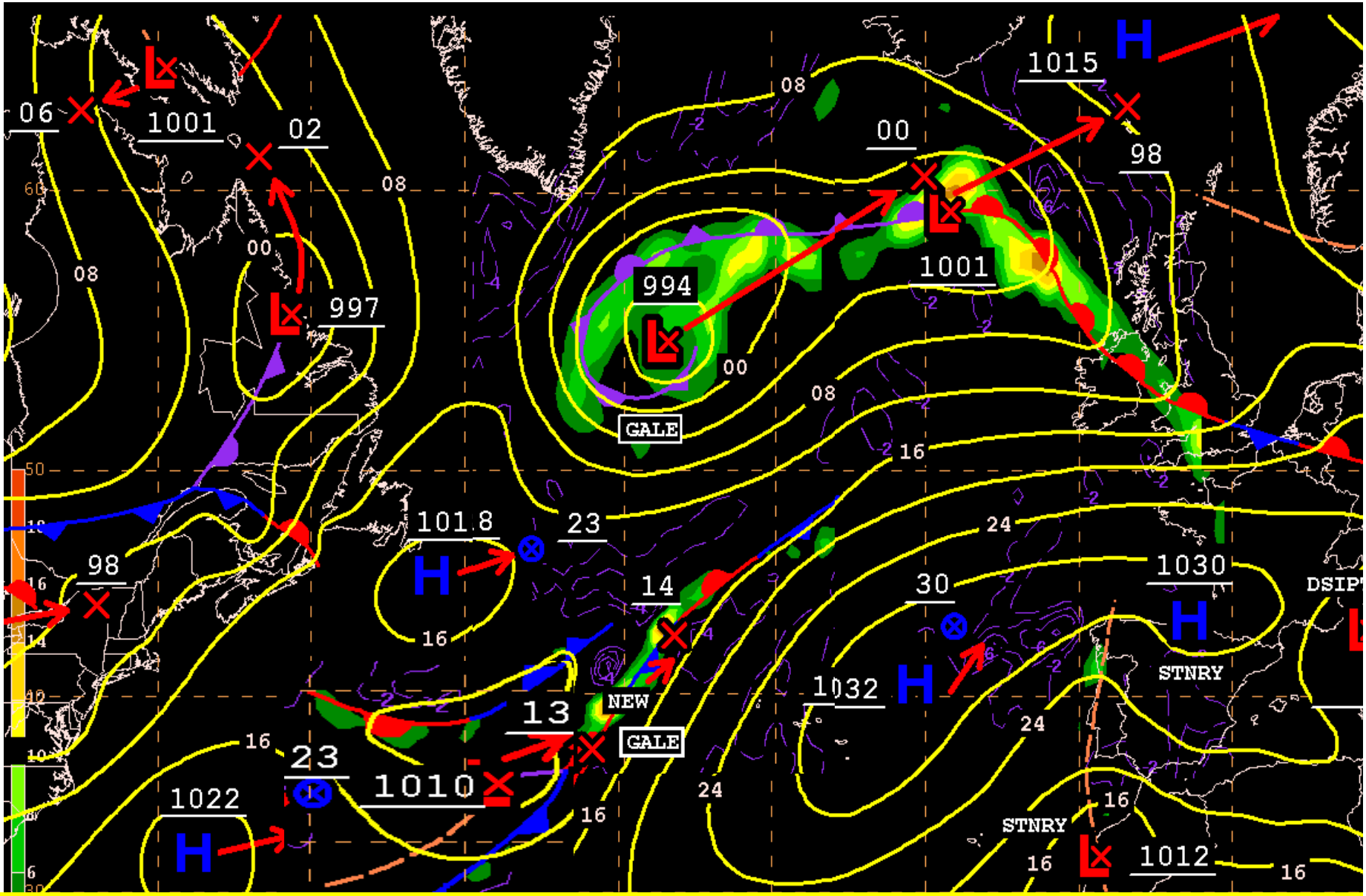

4 Jan 2003 - 16:16 UTC
150°W
120°W
90°W
20°S
40°S
60°S
Jason track 16:23 UTC
ECMWF slp 18:00 UTC
Pressure (hPa)
972
984
996
1008
1020
1032
1044
0
500
1000
1500
Pressure (hPa)
1000
990
980
970
960
950
SSH (cm)
-1.0
-1.5
-2.0
Wave height (??)
10
8
6
4
2
0
Speed (m s-1)
30
20
10
0
Distance (km)
ECMWF
QuikSCAT
Jason



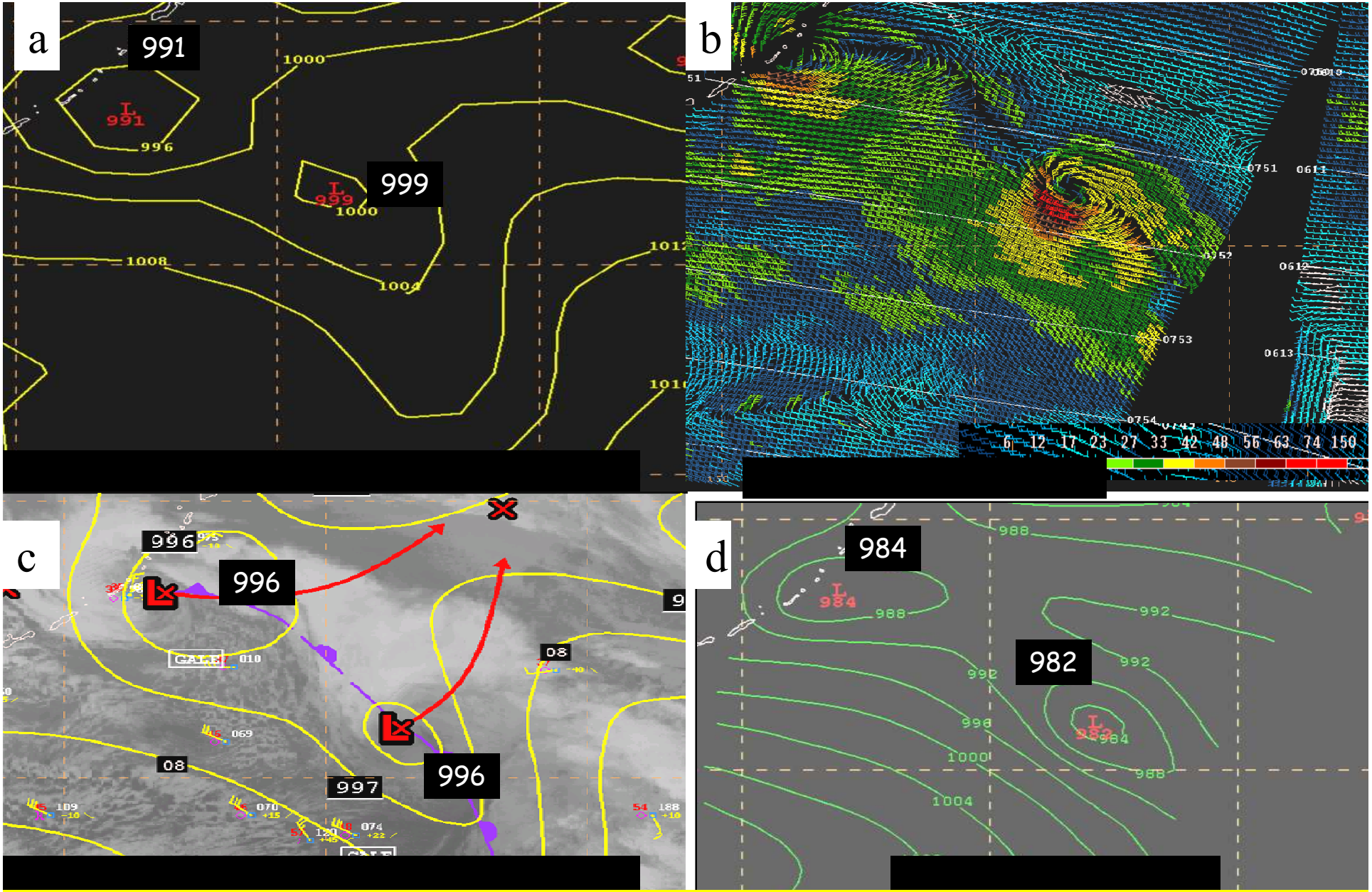
his is the 0600 UTC Ocean Prediction Center hand drawn surface analysis uperimposed over the GOES12 0615UTC Image.



This is the composite of three consecutive runs of the uwpbl model using the 0543, 0648 and 0834 QuikSCAT passes superimposed on the GOES 12 image from 0645 UTC



This is the Ocean Prediction Center hand drawn surface analysis 0526 0600 UTC with the surface vorticity field from the uwpbl model overlaid. The vorticity field is a composite of three passes (0543, 0648 and 0834 UTC); it shows the locations of the frontal zones well.



This example is from 10 January 2005 0600UTC. Numerical guidance from the 0600UTC GFS model run (a) indicated a 999 hPa low at 43N, 162E. QuikScat winds (b) suggested strong lows --- OPC analysis uses 996. UW-PBL analysis indicates 982.

Summary

- Continuing PBL model development
  - TCBLs (SLP, rolls and TC SAR winds)
  - Improved roll parameterization (TC and mid-latitudes)
  - entrainment (tropics)
  - momentum advection (storms and fronts)
- Continuing storms analyses
  - Storm tracking
  - Altimeter corrections
  - Frontal dynamics
- Collaborations (Kelly/APL, NOAA/OPC, FSU/COAPS, IFREMER, Lamont-Doherty, GKSS)
- SLP, improved wind fields and programs available (~2007) from

  http://pbl.atmos.washington.edu