The impact of Terra, Aqua, TRMM, AVHRR, and dropsonde data on Hurricane Lili simulations

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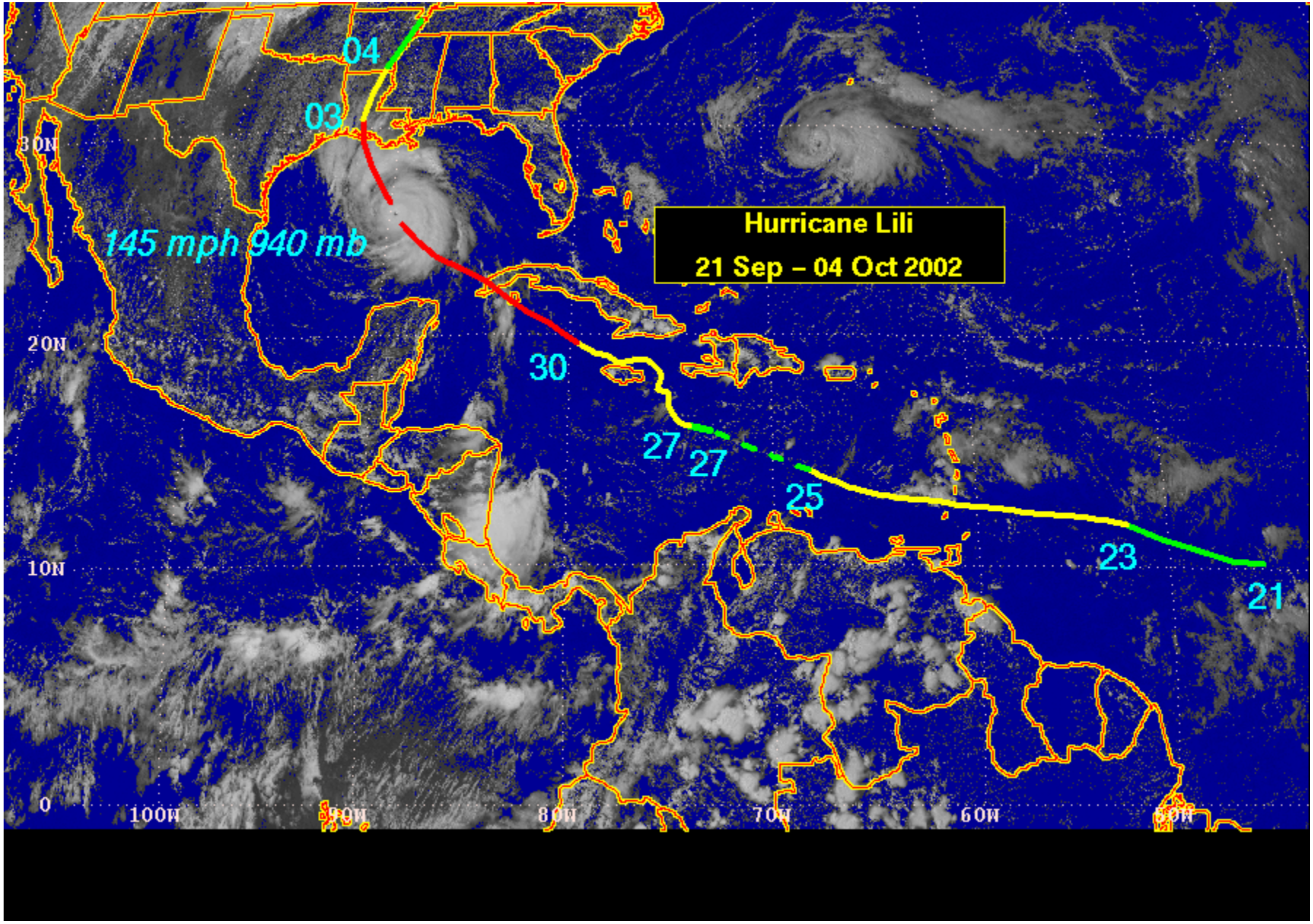
I. Background on Hurricane Lili (2002)
II. Datasets and MM5 4DVAR assimilation strategy
III. Impact of dry air
IV. Hypothesis of water temperature impact
V. Conclusions

I. Background on Hurricane Lili (2002)

HURRICANE LILI: A GOOD EXAMPLE OF THE LIMITATIONS OF OPERATIONAL INTENSITY FORECASTING



HURRICANE LILI DISCUSSION NUMBER 46
NATIONAL WEATHER SERVICE MIAMI FL
5 PM EDT WED OCT 02 2002

LILI WENT THROUGH ANOTHER BURST OF INTENSIFICATION THIS AFTERNOON... WITH THE CENTRAL PRESSURE FALLING FROM 954 MB TO 941 MB IN ABOUT 5 HR. THE HURRICANE HAS CONTINUED TO DEEPEN AT A SLOWER RATE SINCE 16Z...WITH THE CENTRAL PRESSURE FALLING TO 938 MB AT 20Z. THE MAXIMUM FLIGHT LEVEL WINDS FOUND BY THE VARIOUS AIRCRAFT SAMPLING LILI SO FAR ARE 136 KT...SO THE INITIAL INTENSITY IS SET TO 120 KT. LILI IS SHOWING SIGNS OF PEAKING...AS THE AIRCRAFT AND SATELLITE IMAGERY INDICATE THE BEGINNING OF AN OUTER EYEWALL THAT WILL LIKELY BRING A HALT TO THE CURRENT INTENSIFICATION.
(TEXT DELETED)

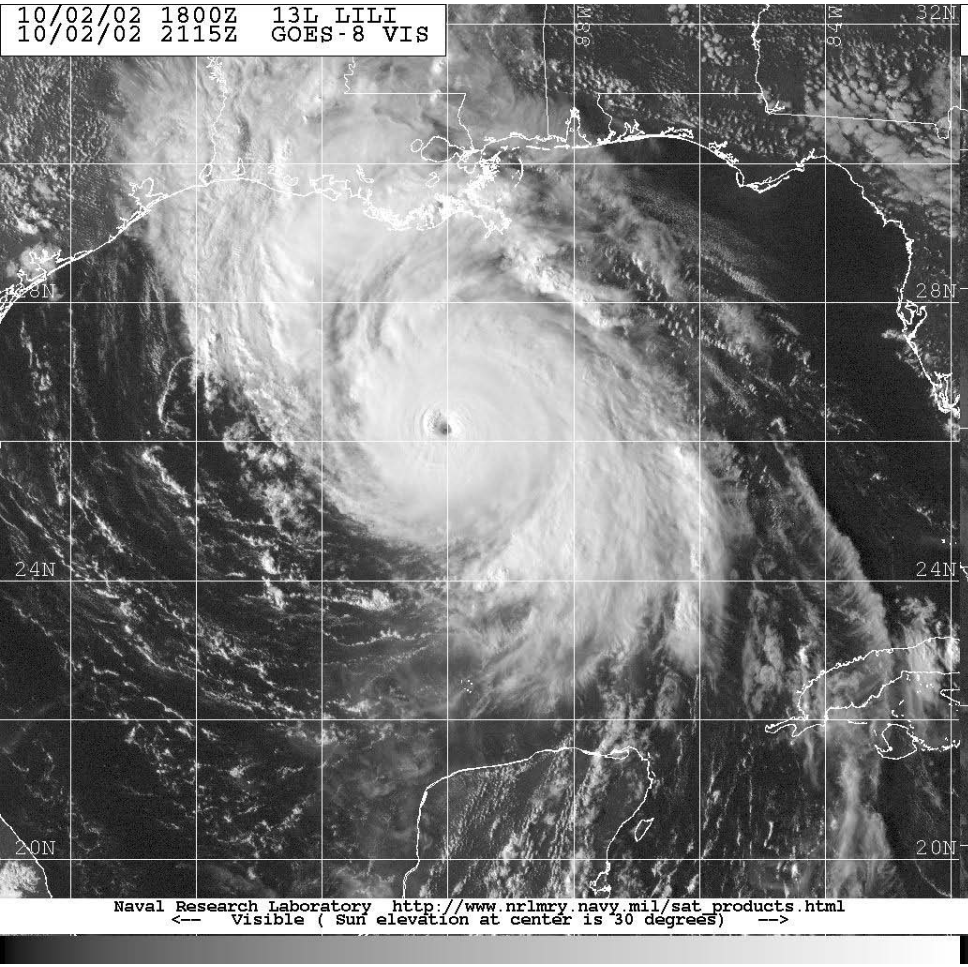
IN ADDITION TO THE CONCENTRIC EYEWALLS...THE ACTUAL INTENSITY IS CATCHING UP WITH THE SATELLITE SIGNATURE AND THE OUTFLOW IS BEING RESTRICTED TO THE WEST AND SOUTHWEST BY AN UPPER-LEVEL TROUGH. THESE THINGS SUGGEST THAT LILI SHOULD PEAK IN THE NEXT 6-12 HR THEN UNDERGO FLUCTUATIONS IN STRENGTH UNTIL LANDFALL. REGARDLESS OF THE EXACT INTENSITY...LILI SHOULD MAKE LANDFALL AS A MAJOR HURRICANE.

FORECASTER BEVEN

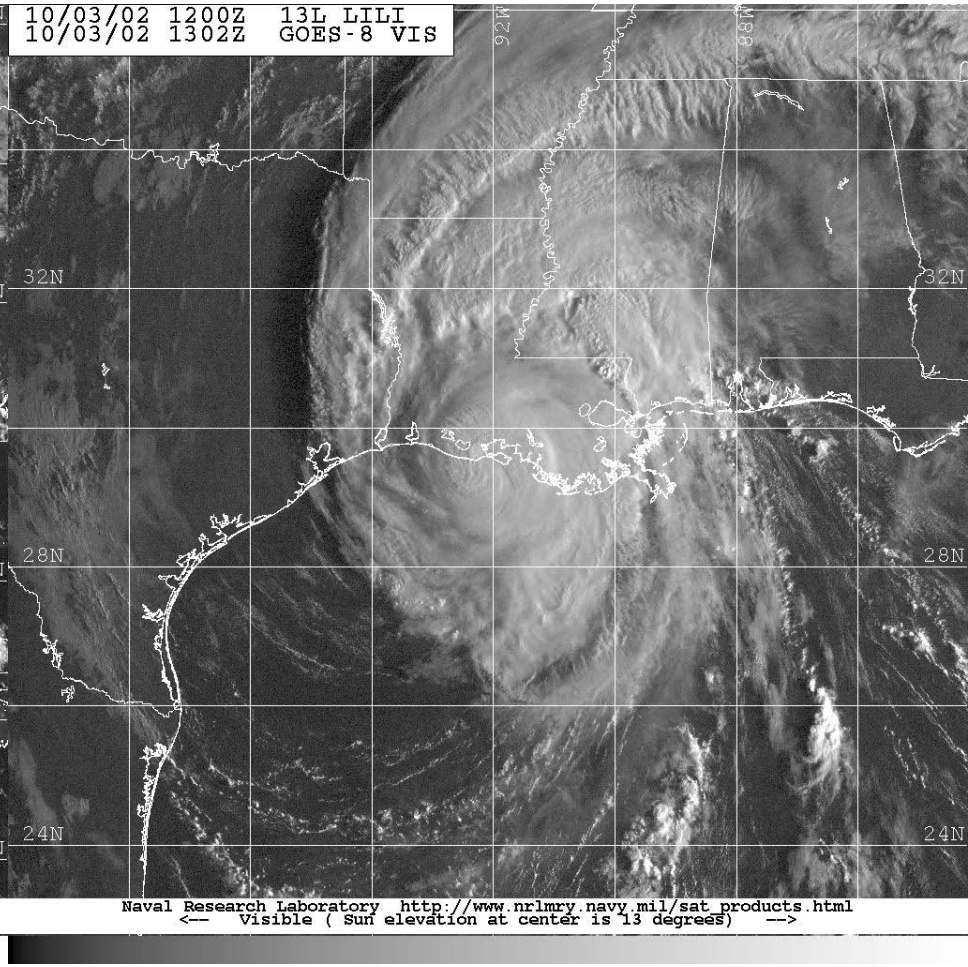
FORECAST POSITIONS AND MAX WINDS

INITIAL	02/2100Z	25.9N	90.0W	120 KTS
12HR VT	03/0600Z	27.5N	91.4W	125 KTS
24HR VT	03/1800Z	29.8N	92.3W	125 KTS...INLAND
36HR VT	04/0600Z	32.2N	91.9W	65 KTS...INLAND
48HR VT	04/1800Z	36.1N	89.0W	35 KTS...INLAND EXTRATROPICAL
72HR VT	05/1800Z	45.0N	74.0W	30 KTS...INLAND EXTRATROPICAL

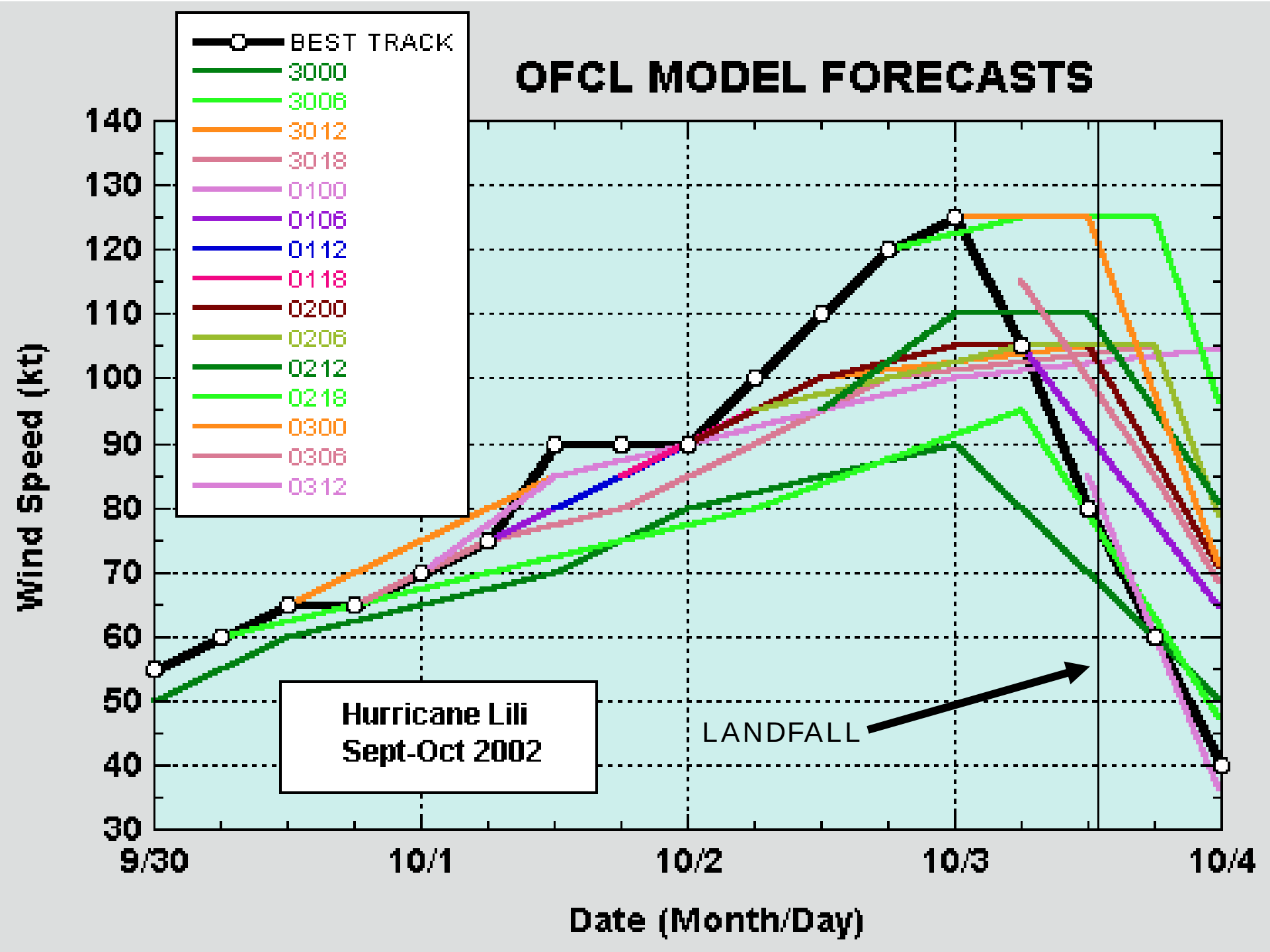
AFTER QUICKLY STRENGTHENING TO A STRONG CAT. 4 HURRICANE, LILI WEAKENED EVEN MORE RAPIDLY THAN IT HAD INTENSIFIED



LILI NEAR ITS MAXIMUM INTENSITY OF 145 MPH



LILI MAKING LANDFALL AS A CAT. 1 HURRICANE


OFCL MODEL FORECASTS
BEST TRACK
3000
3006
3012
3018
0100
0106
0112
0118
0200
0206
0212
0218
0300
0306
0312
Hurricane Lili
Sept-Oct 2002
LANDFALL
Wind Speed (kt)
140
130
120
110
100
90
80
70
60
50
40
30
9/30
10/1
10/2
10/3
10/4
Date (Month/Day)

LILI'S RAPID WEAKENING JUST BEFORE LANDFALL IS NOT WELL UNDERSTOOD.

WAS IT CAUSED BY:

- AN INTERNAL (INNER CORE, E.G. EYEWALL) MECHANISM?

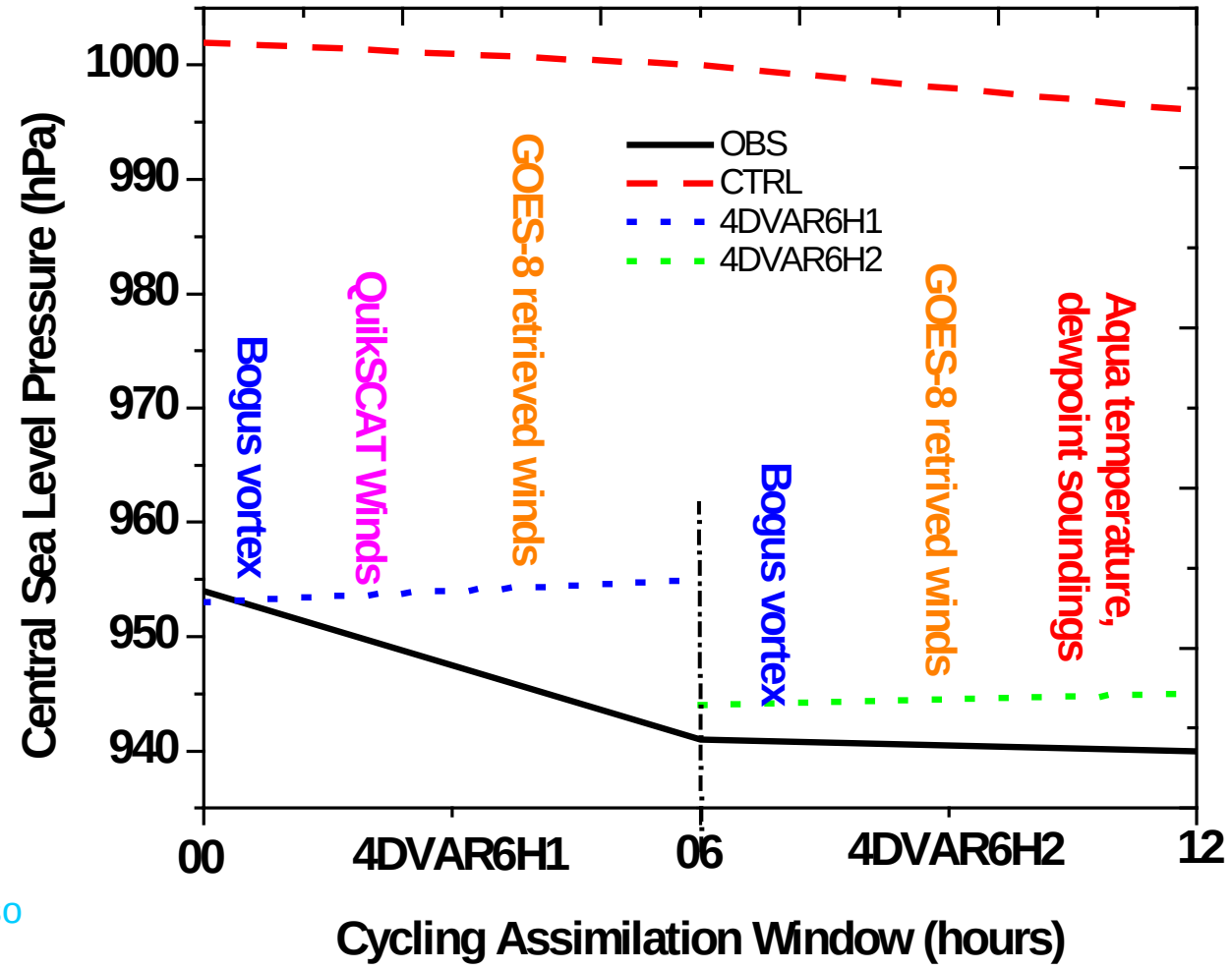
- VERTICAL WIND SHEAR, OR OTHER ENVIRONMENTAL INFLUENCES SUCH AS MOISTURE, STABILITY?

OR

-THE OCEAN, SUCH AS ISIDORE'S WAKE AND/OR COOLER SHELF WATERS?

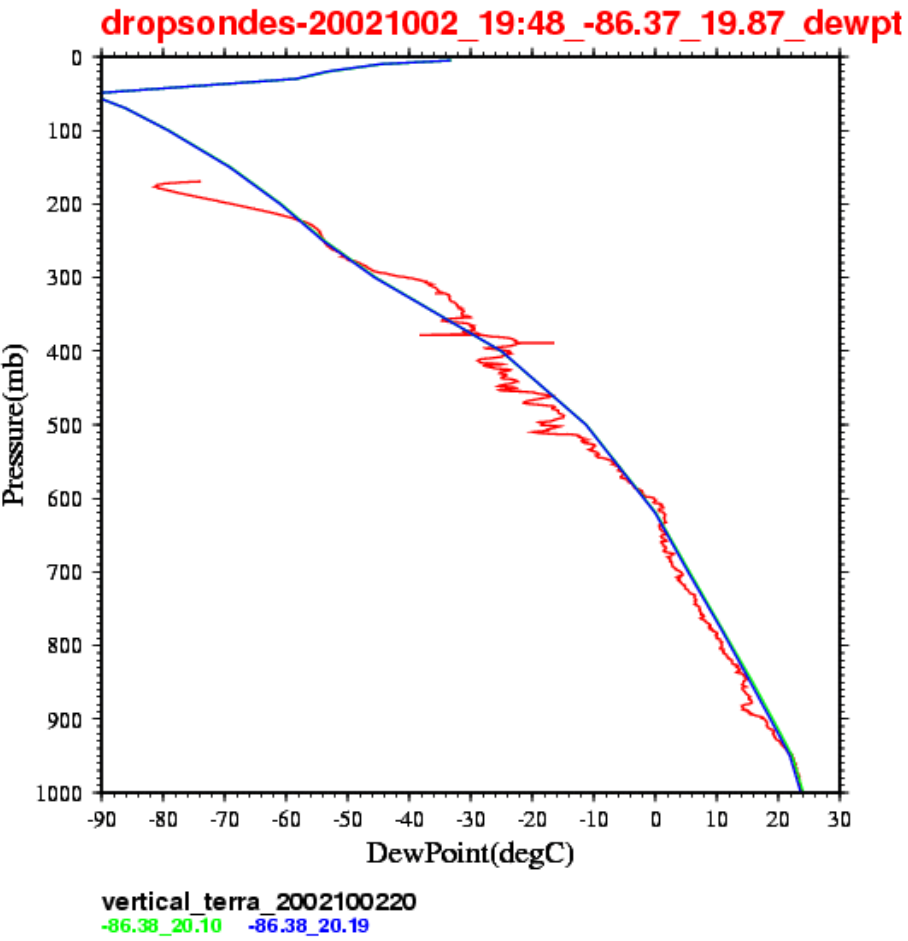
II. Datasets and MM5 4DVAR assimilation strategies

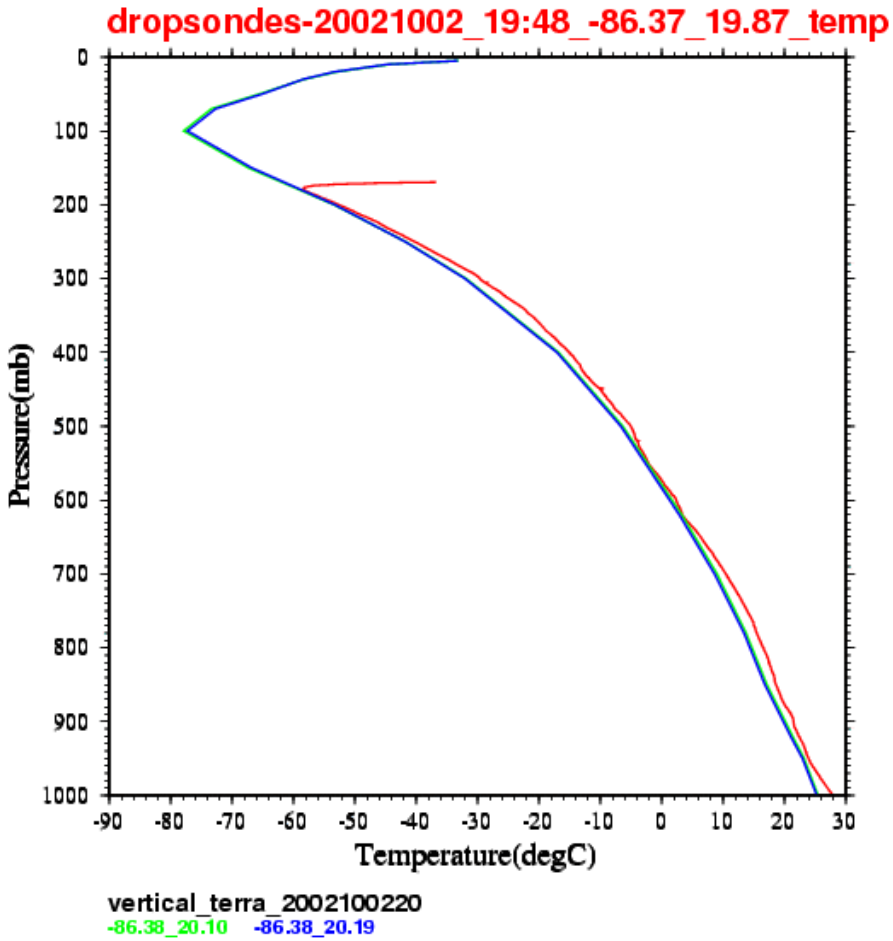
4DVAR strategy



Conventional observations also assimilated

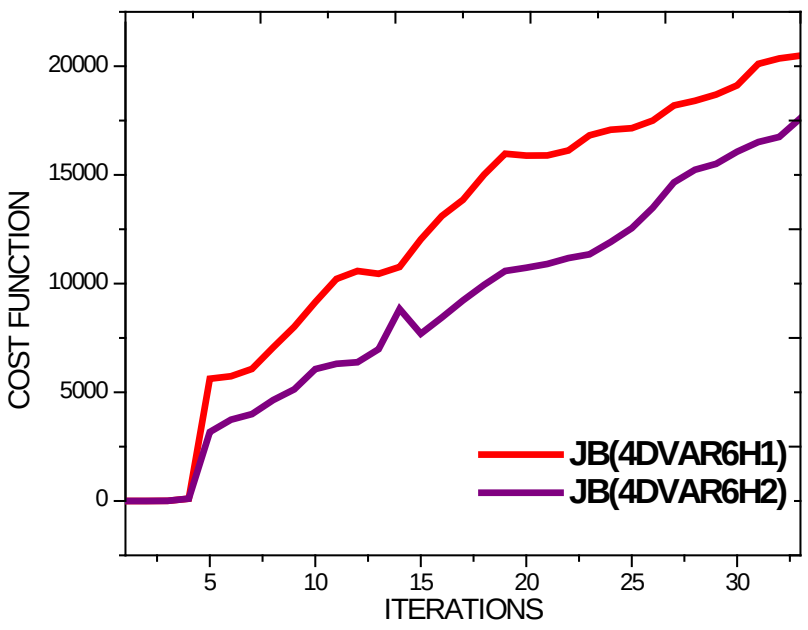
Comparison of Aqua and aircraft dropsondes

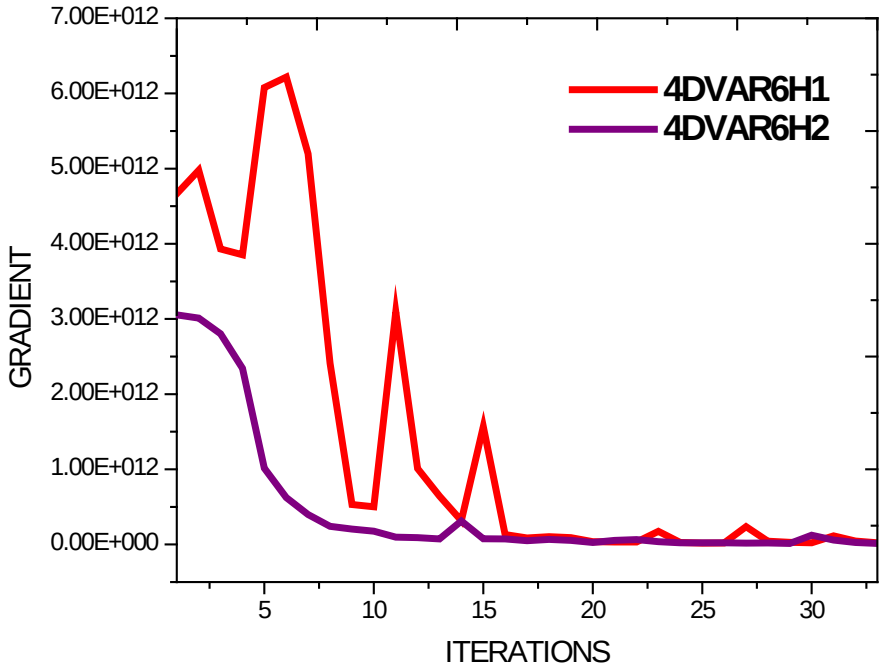




Used in determining cost function weights

Cost function and gradient in 4DVAR6H1 and 4DVAR6H2



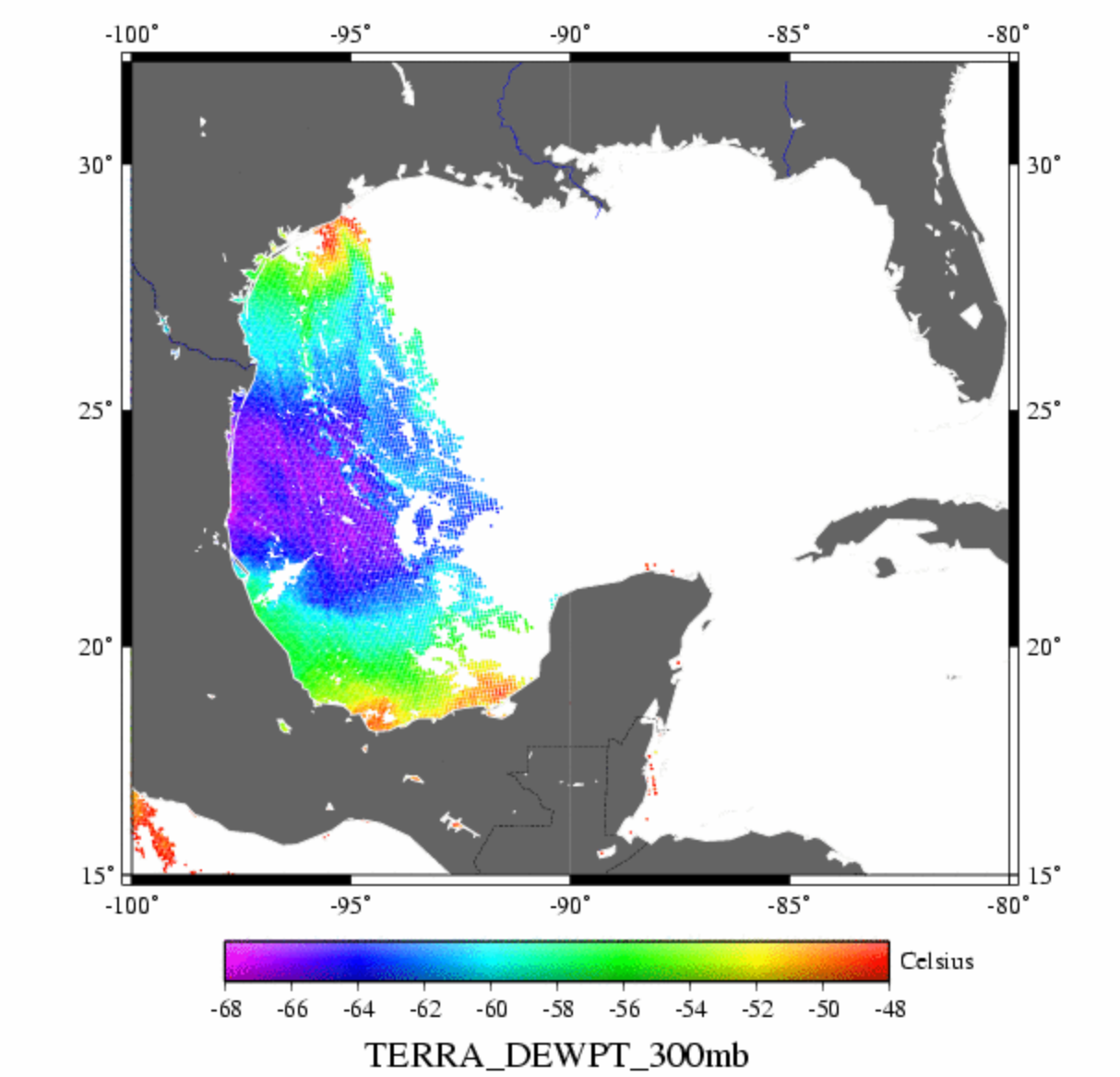


Gradient for both 4DVAR6H1 and 4DVAR6H2 have good convergence, which show all data were assimilated well.

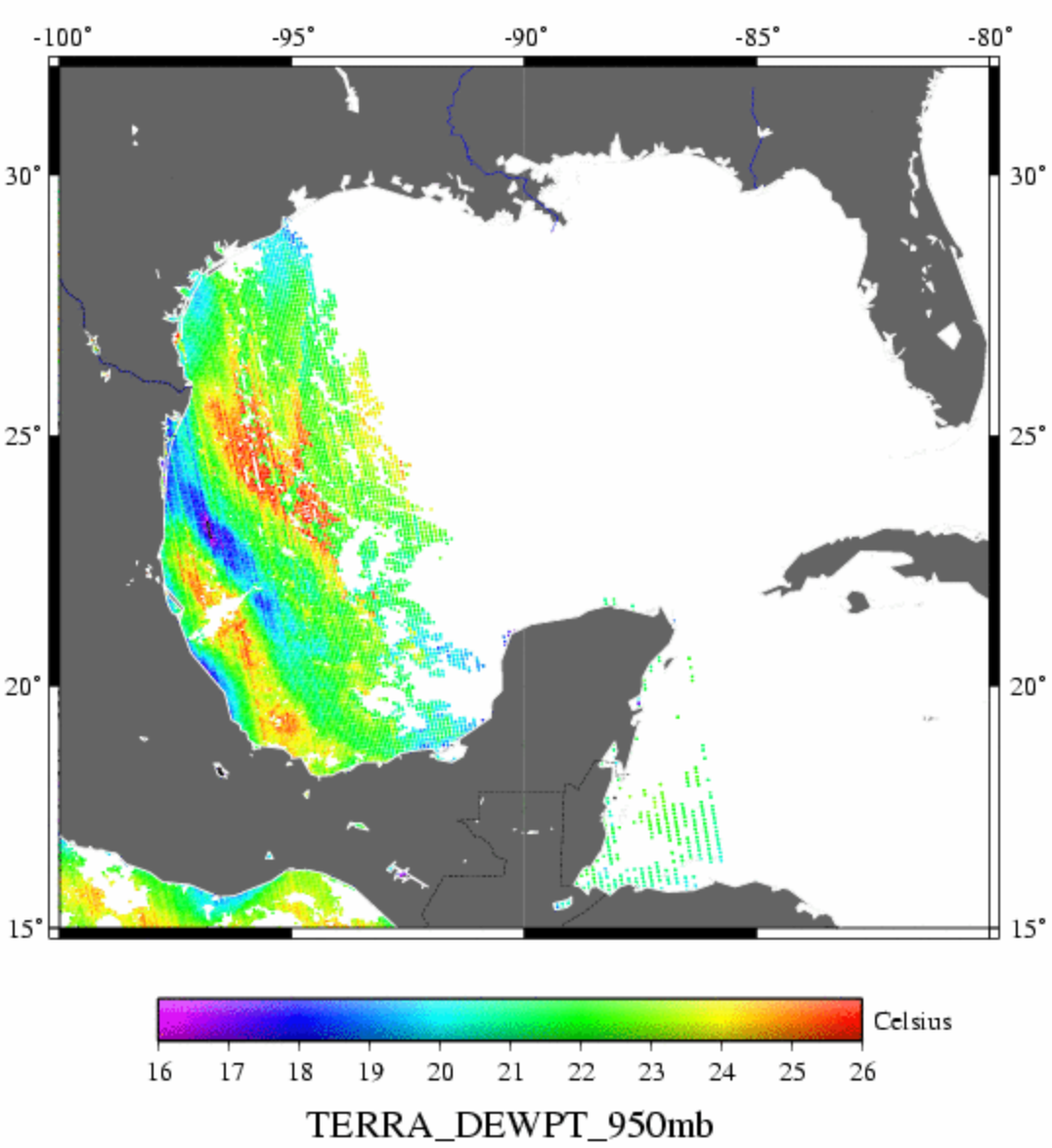
30 iterations were integrated in each 4DVAR assimilation window. Each iteration takes about 5 hours.

III. Impact of dry air

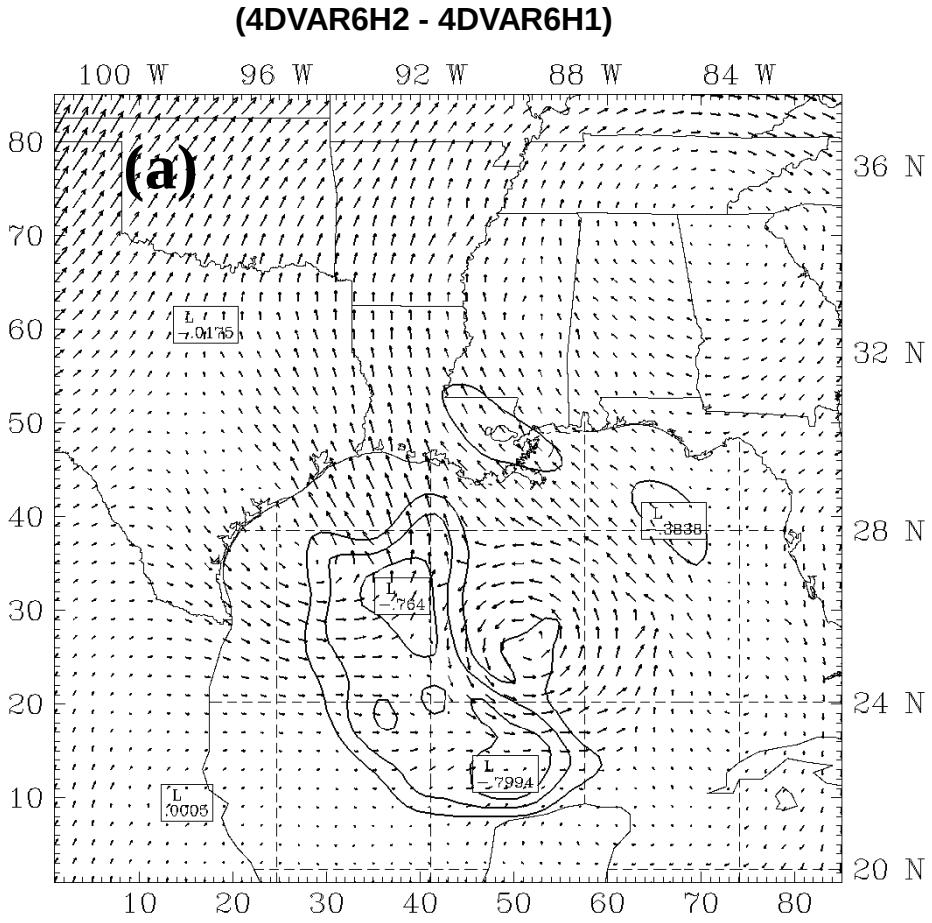
Aqua 300-mb T_d on 2 Oct at 20Z



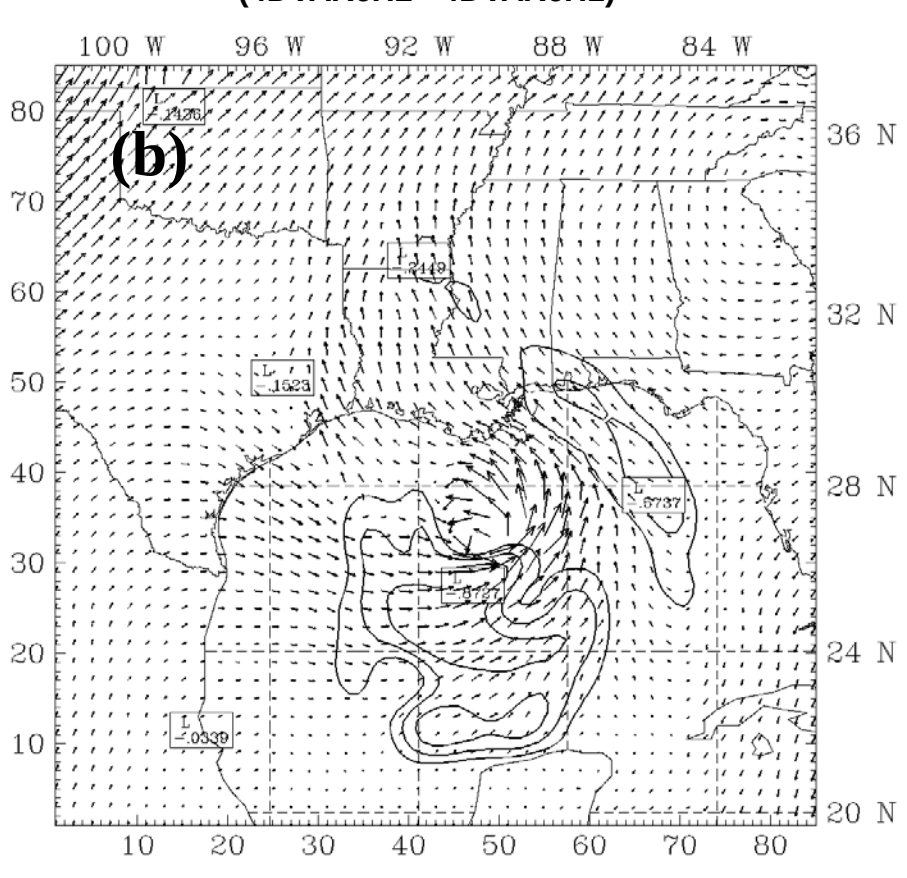
Aqua 950-mb T_d on 2 Oct at 20Z



Difference of mixing ratio (solid line) and wind vectors at 300 mb between first 6-h 4DVAR and second 6-h 4DVAR



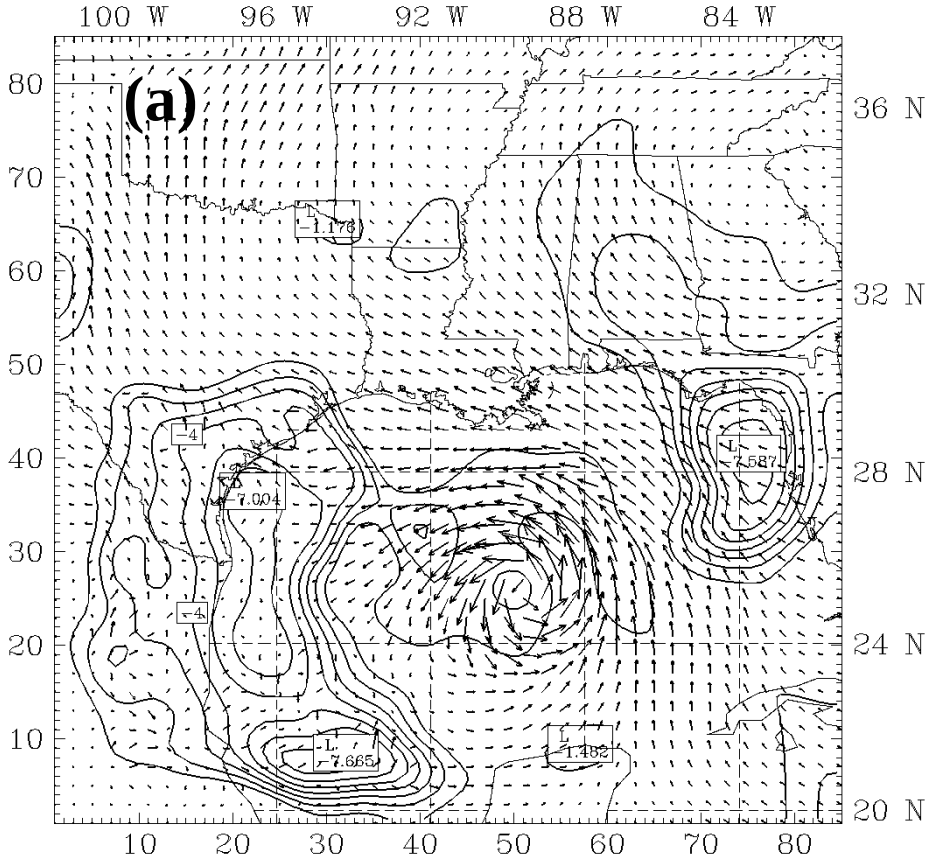
18Z, 2 October



00Z, 3 October

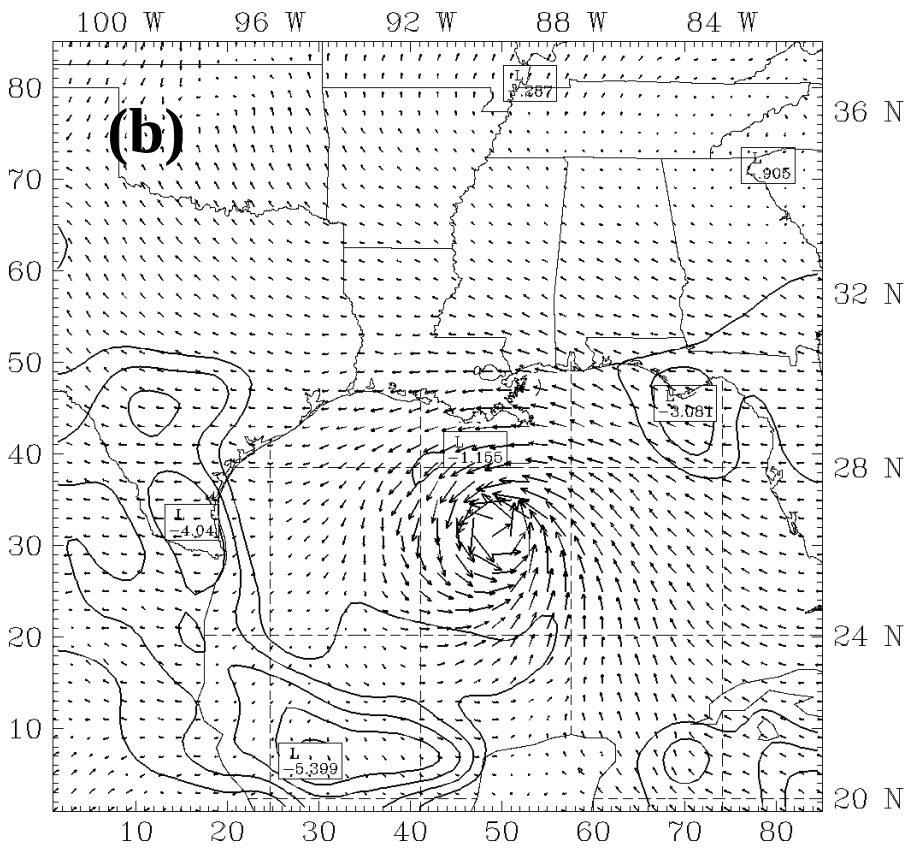
Difference of mixing ratio (solid line) and wind vectors at 950 mb between first 6-h 4DVAR and second 6-h 4DVAR

(4DVAR6H2 - 4DVAR6H1)



18Z, 2 October

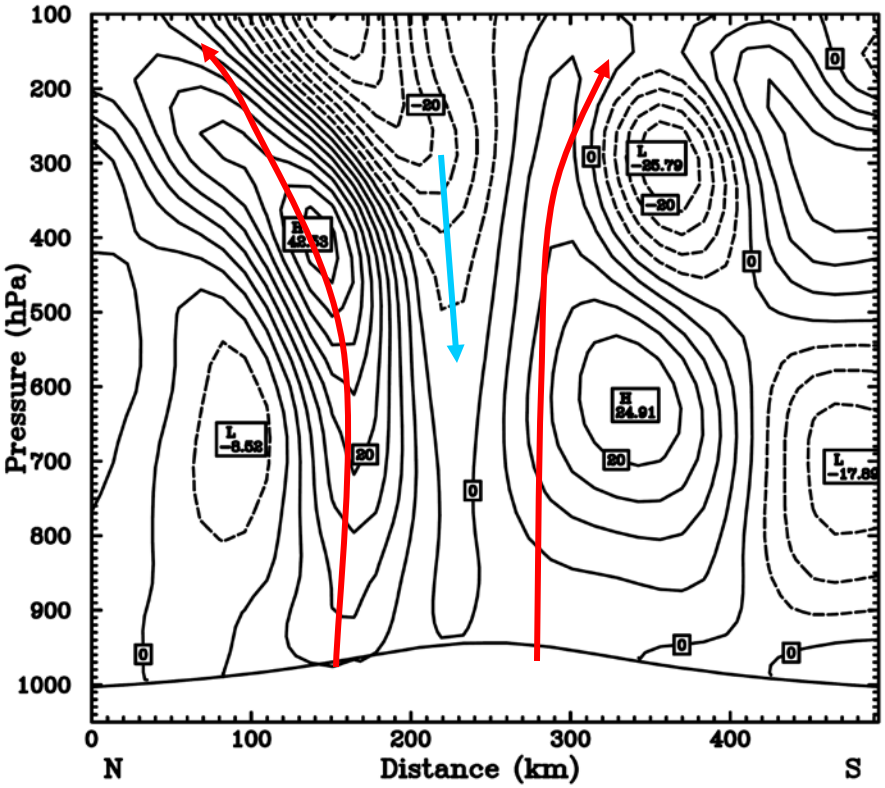
(4DVAR6H2 - 4DVAR6H1)



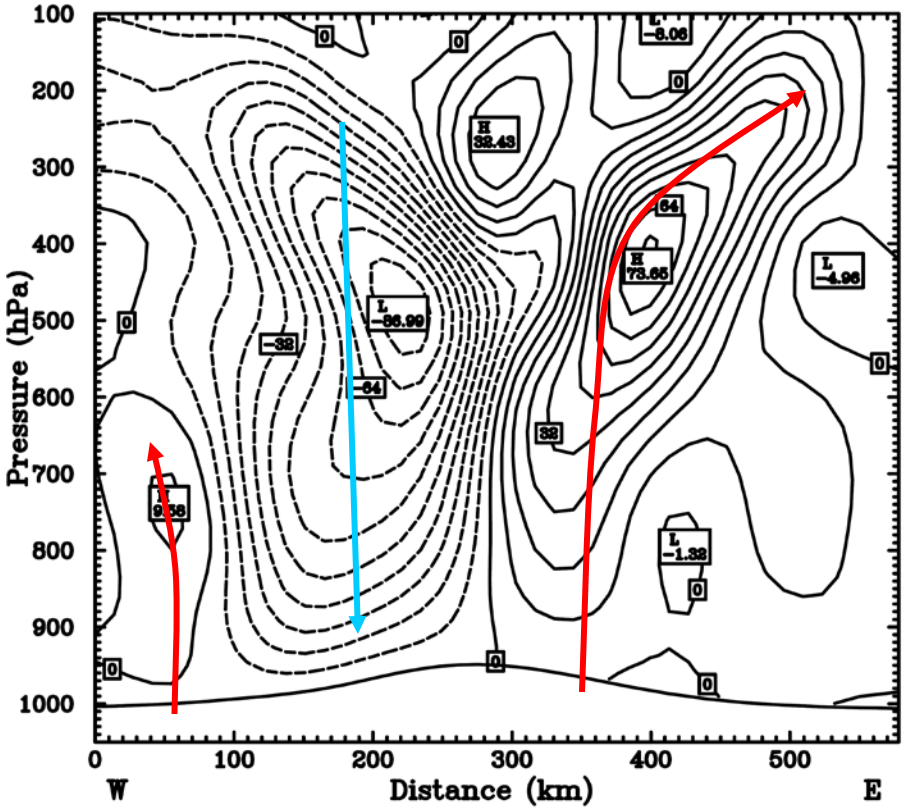
00Z, 3 October

Cross sections of vertical velocity

18Z, 2 October

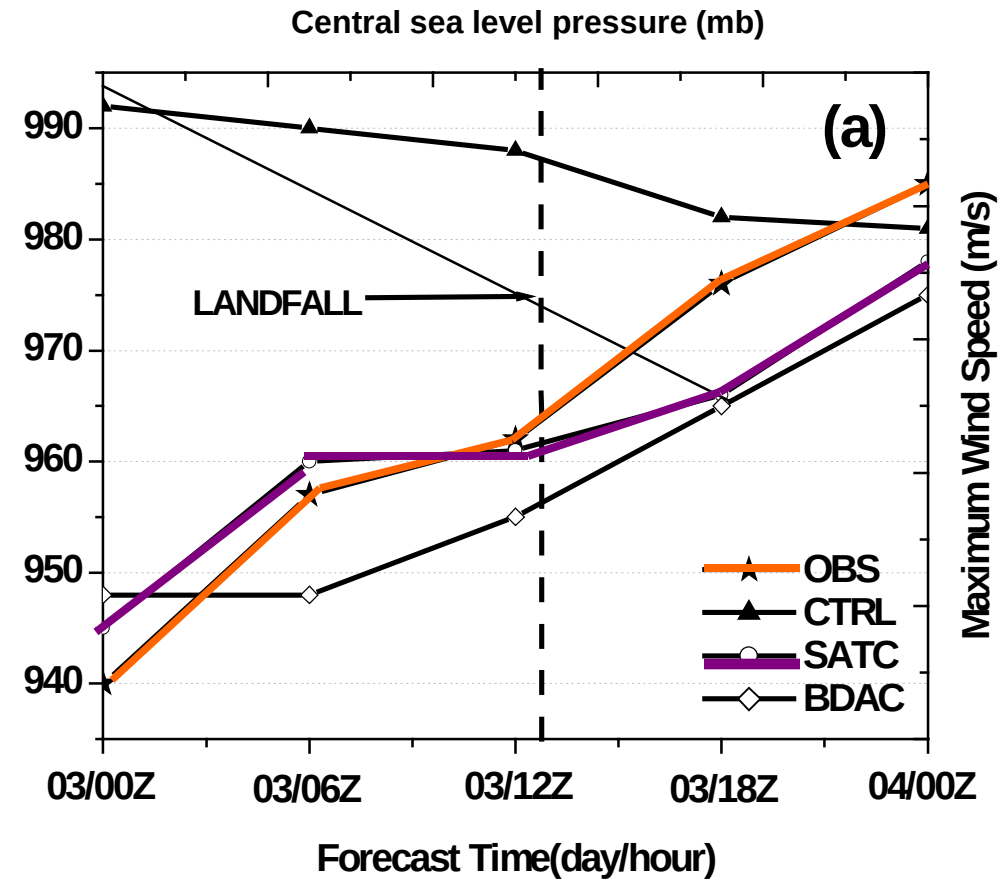


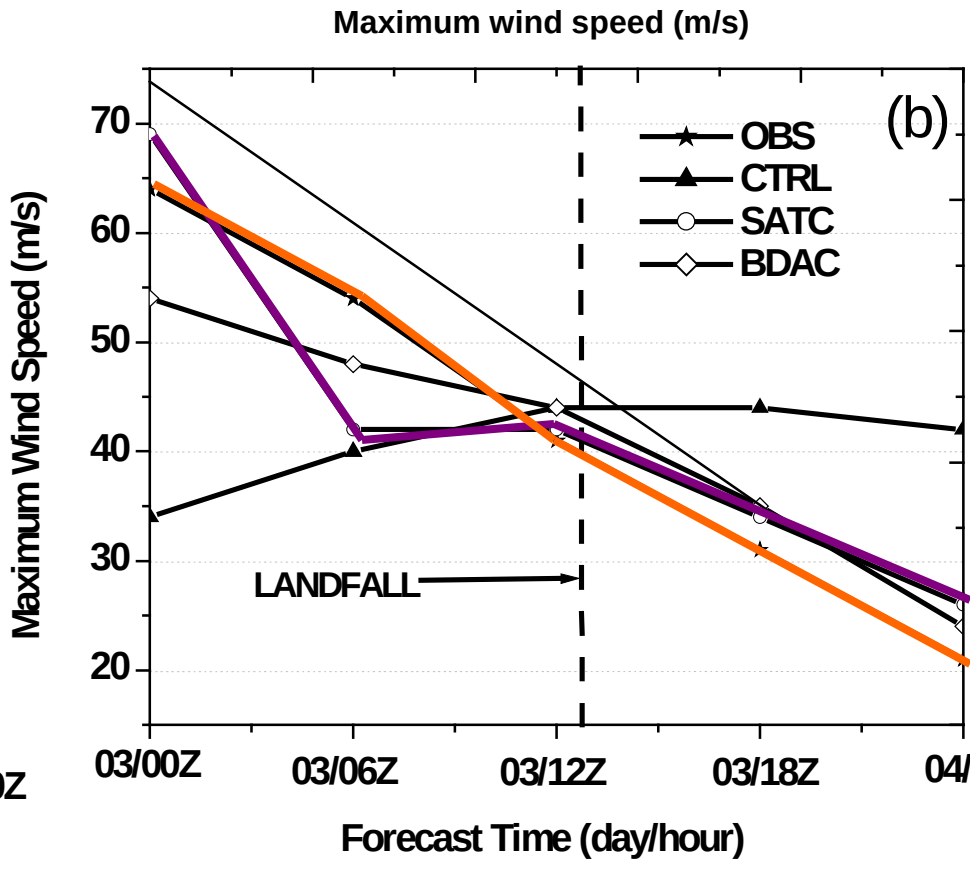
00Z, 3 October



Western eyewall has collapsed

24-h intensity prediction starting 00Z, 3 October





1) *Initial 00Z intensity using satellite bogus 4DVAR closest to observed*
2) *6-h CSLP change of satellite/bogus 4DVAR matches observed trend*
3) *6-h CSLP stays constant first 6 h for bogus 4DVAR only.*
4) *V_{max} trends comparison not as clear, but 6-h change in satellite/bogus 4DVAR consistent with pressure change*

IV. Hypothesis of water Temperature impact

Created time evolving gridded SST dataset

Satellites
- Aqua and Terra – NASA EOS "Level 2" 2-km global data
- AVHRR - NASA JPL 4-km global data
- TRMM

Buoys

Methodology

Filled in data points within satellite swath by averaging nearest neighbors within 55 km

Filled in data points between satellite passes using least square polynomial with different orders

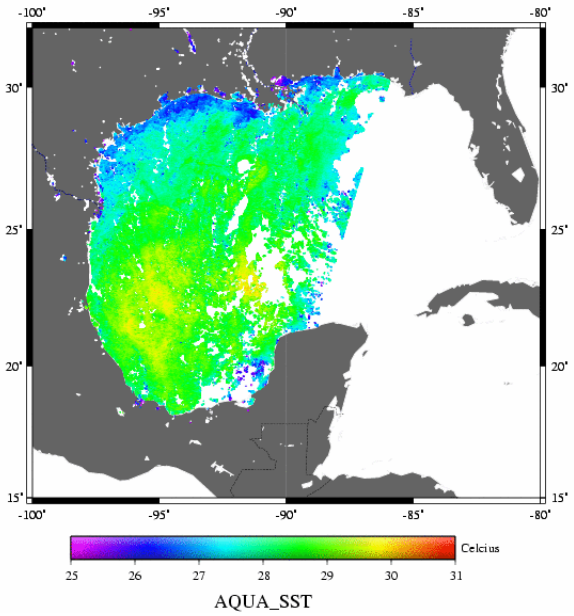
Climatology thresholds

Buddy checks (to detect low-level cloud contamination

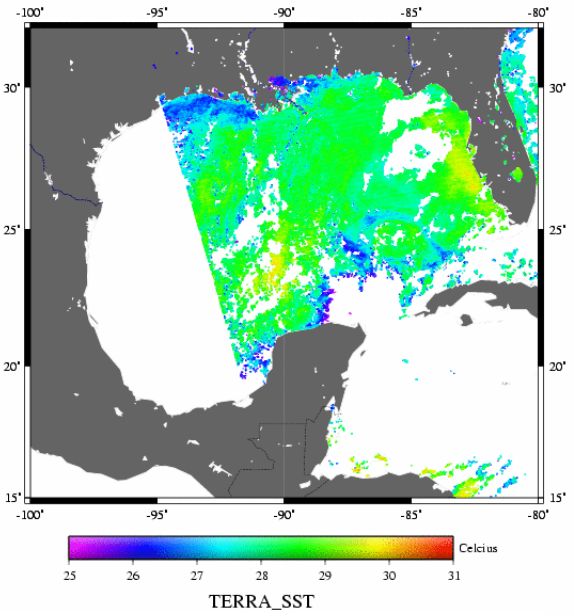
NOAA QC flags

Aqua, Terra, AVHRR, TRMM SST (before & after processing)

AQUA_SST October 01, 2002 08Hrs

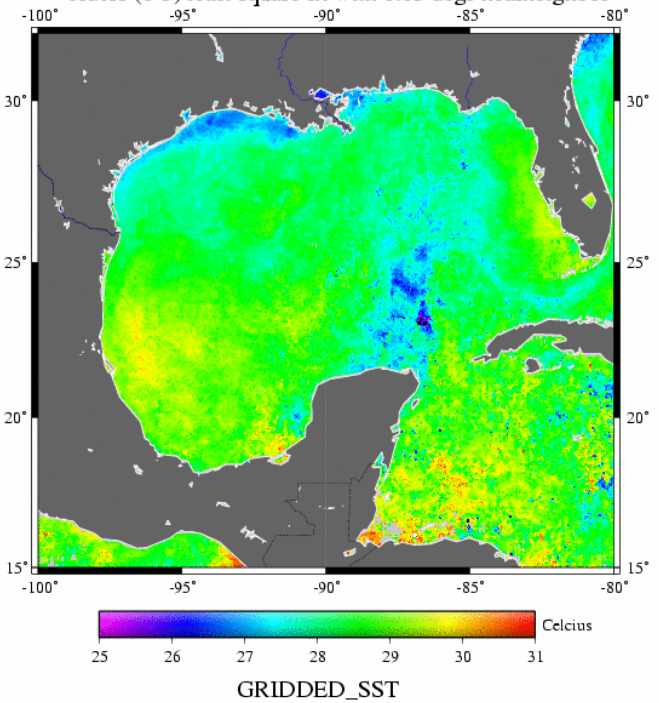


TERRA_SST October 01, 2002 04Hrs

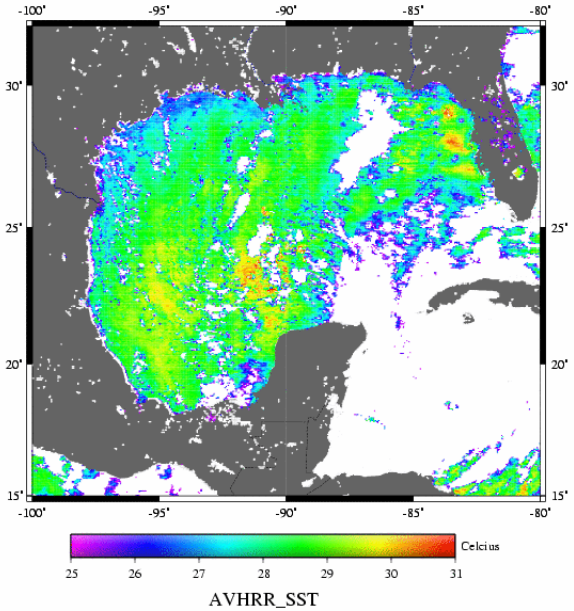


GRIDDED_SST October 1, 2002 08Hrs

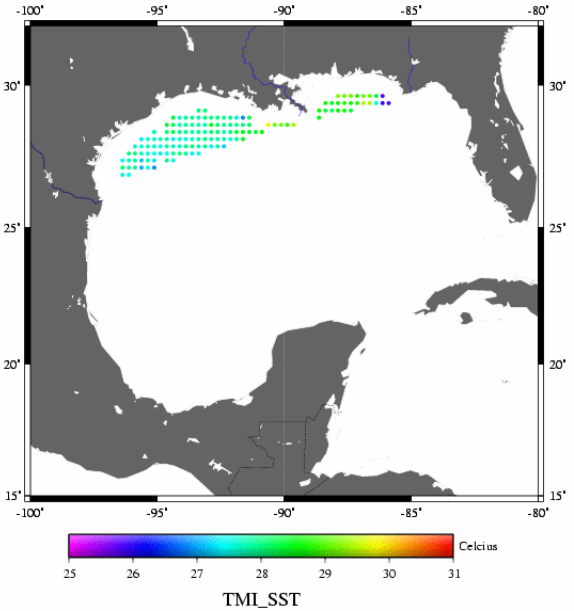
orders (1-5) least square fit with 0.05 degs nearneighbor



AVHRR_SST October 01, 2002 12Hrs

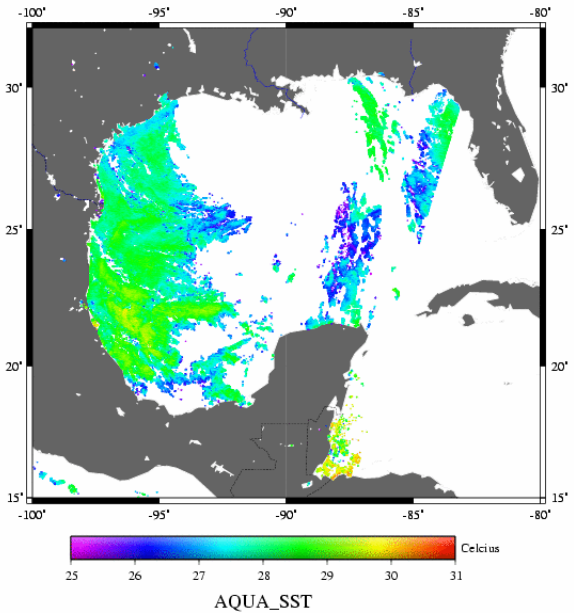


TMI_SST October 01, 2002 08Hrs

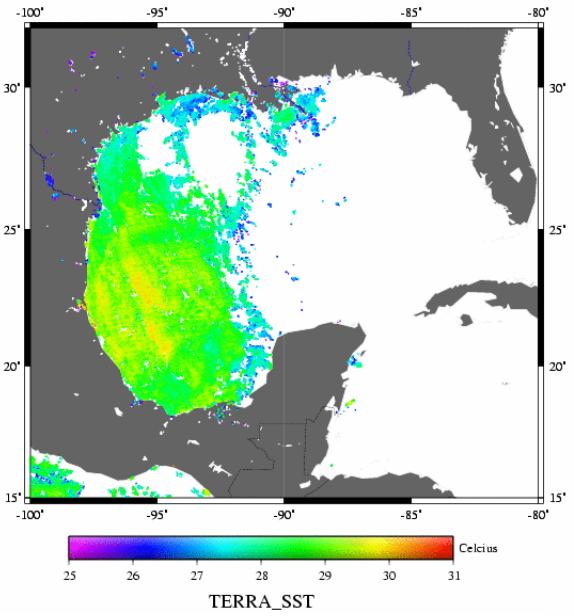


Aqua, Terra, AVHRR, TRMM SST (before & after processing)

AQUA_SST October 02, 2002 08Hrs

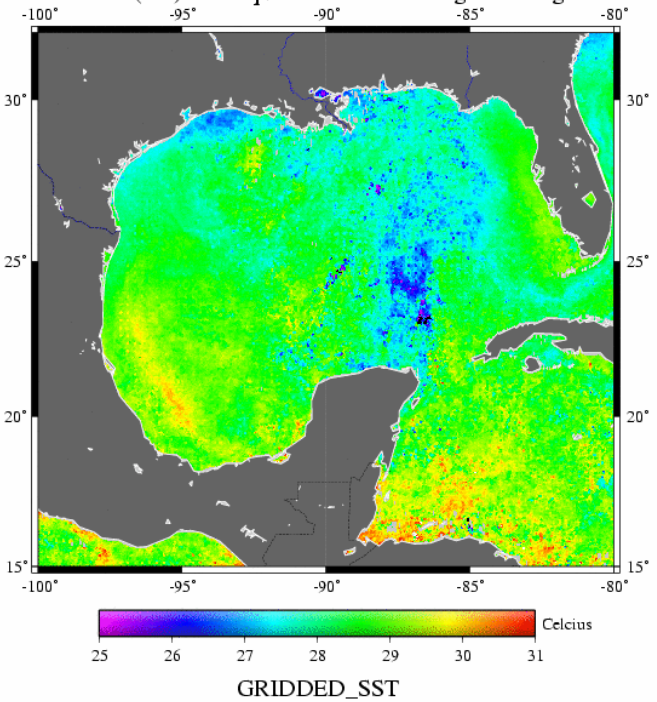


TERRA_SST October 02, 2002 05Hrs

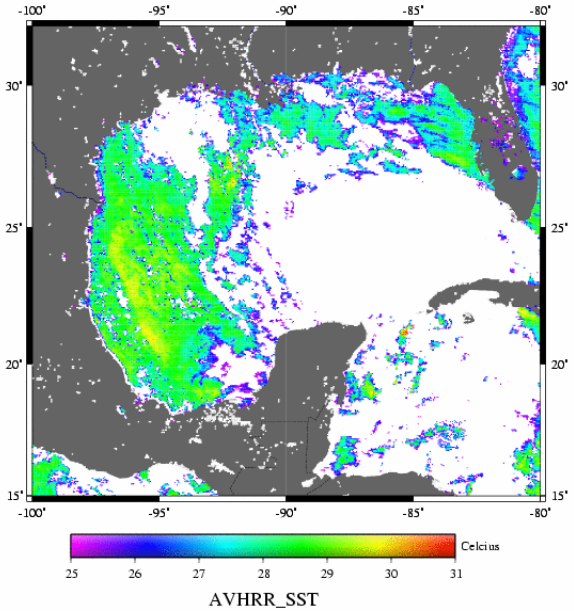


GRIDDED_SST October 2, 2002 08Hrs

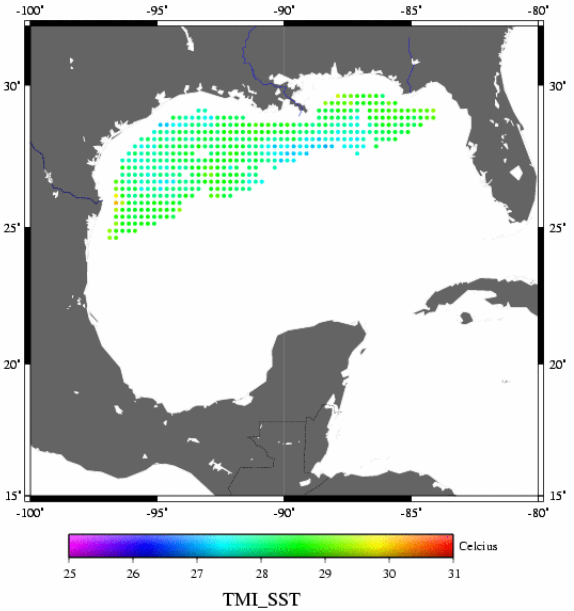
orders (1-5) least square fit with 0.05 degs nearneighbor



AVHRR_SST October 02, 2002 08Hrs

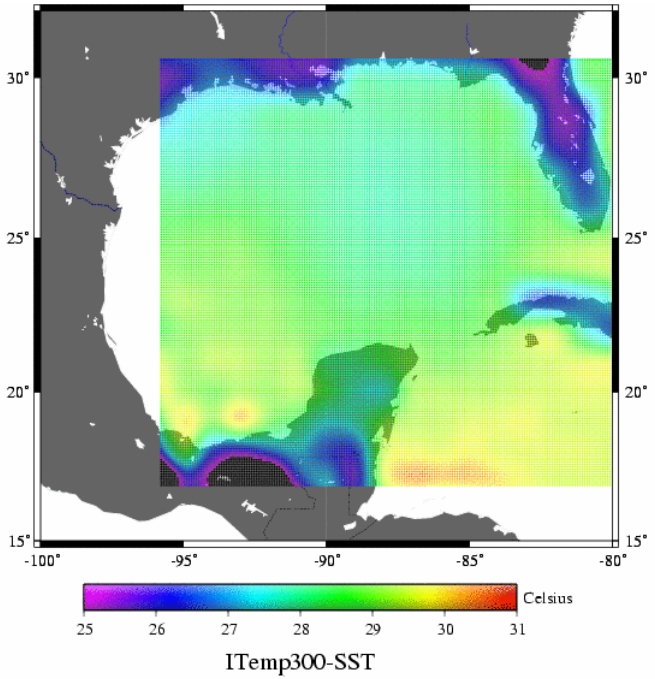


TMI_SST October 02, 2002 08Hrs



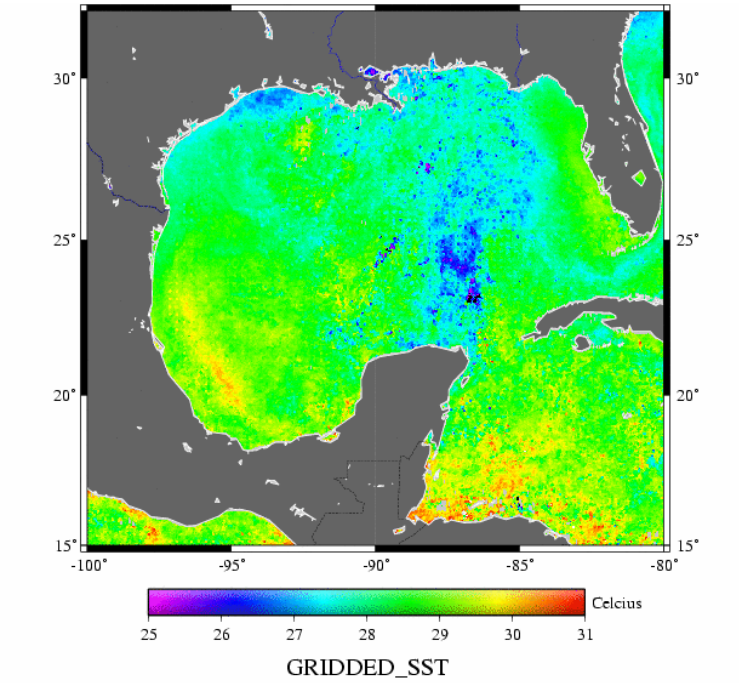
GFS SST versus satellite SST, Oct 2

GFS SST



GFS SST lacks details and SST extremes
Smoothness due to a 7-day running mean, and
an e-folding time of 90 days to dampen anomalies

New SST



Note cold water off central Louisiana (contributed to Lili's weakening?)
Note cold wake behind Lili
Note warm water northwest of Yucatan (caused Lili's intensification?)

V. Summary

Conclusions

1) The satellite data, particularly the Aqua data, makes an immediate impact on the hurricane intensity prediction beyond normal bogussing procedures. The satellite data assimilation matches the rapid weakening process for the first 6 h, while the 4DVAR with only bogussing keeps the intensity constant for the first 6 h.

2) Air on the hurricane's west side is drier after including the Aqua MODIS sounding data in 4DVAR. This simulation suggests dry air intrusion played a component in Lili's rapid weakening. The collapse of the western eyewall in the model after 4DVAR also supports this conclusion.

3) It is hypothesized….and new gridded satellite SST datasets show….that cold shelf water off the central Louisiana coast may have also contributed to Lili's fast demise. Model coupling experiments are underway to examine this theory.

4) The track forecast with the satellite data is also more accurate than just using bogussing alone (not shown).