Hurricane Karl's Structure
and some thoughts for 2014 strategy

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Why Karl?

Pros:

- Karl is the only hurricane so far sampled with the flight patterns we want for HIRAD, HIWRAP, HAMSR
- Karl was rapidly intensifying from TS to Cat-3 Hurricane while crossing the Bay of Campeche

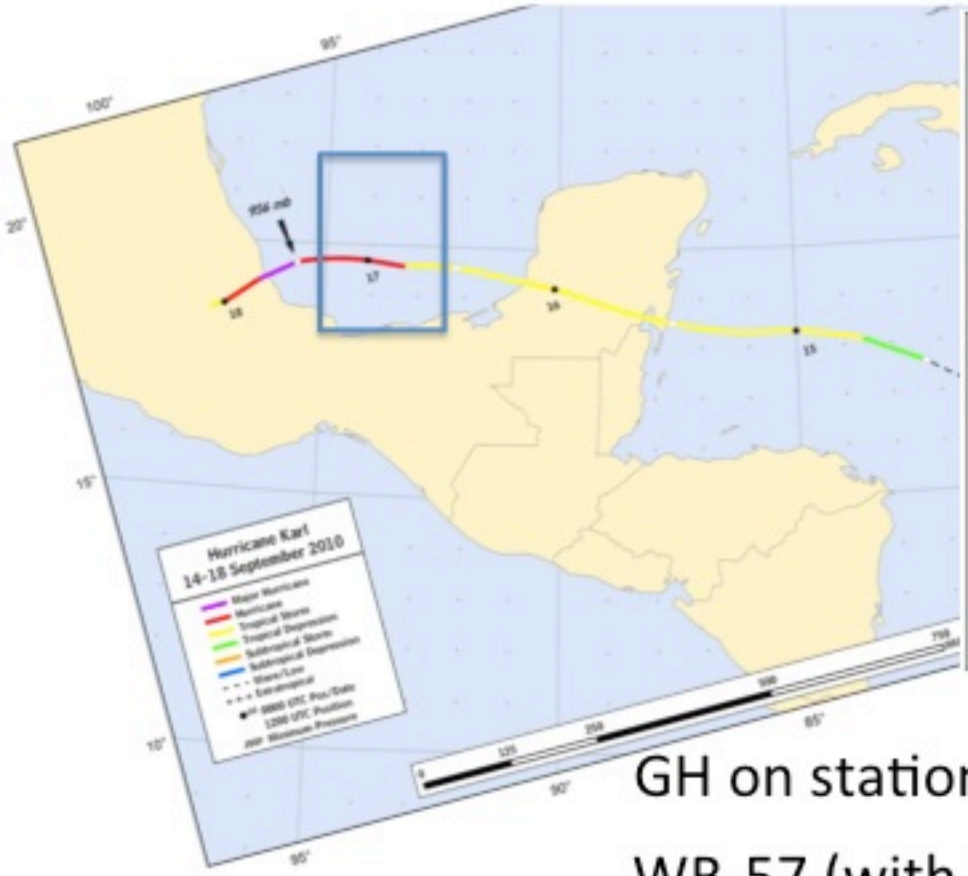
Cons:

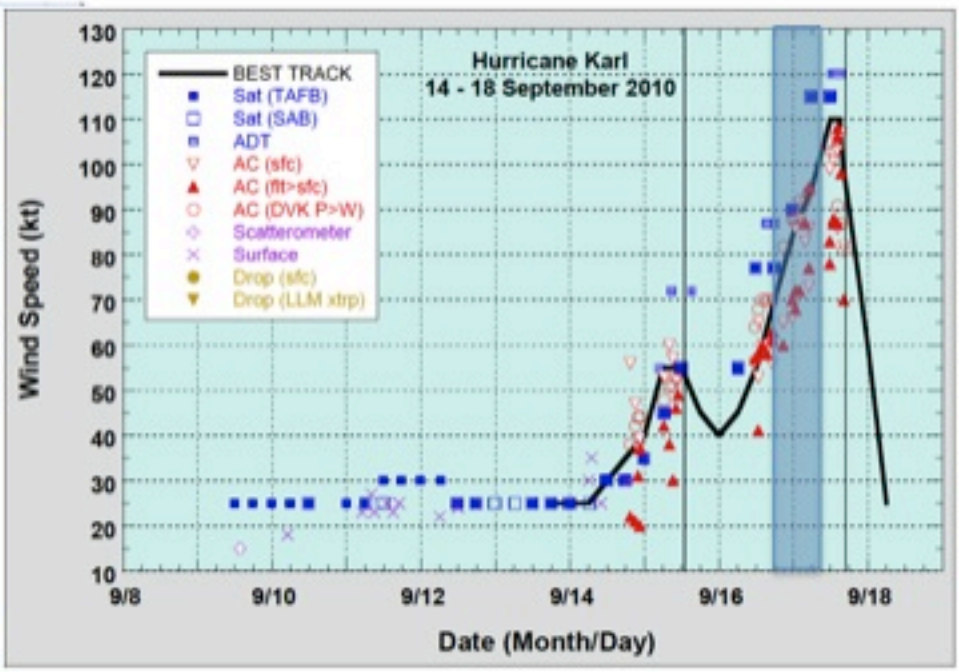
- They were not on the same aircraft (HIRAD on WB-57, HIWRAP and HAMSR on AV-6), so did not have coincident measurements
- Only a few hours of overlap between WB-57 and Global Hawk
- Retrievals from all instruments are slow to come out

Bottom Line:

This case has interesting data, but far below the standards we should be able to achieve in HS3

Best Track





GH on station 1845 – 0830 UTC 16-17 Sep 2010

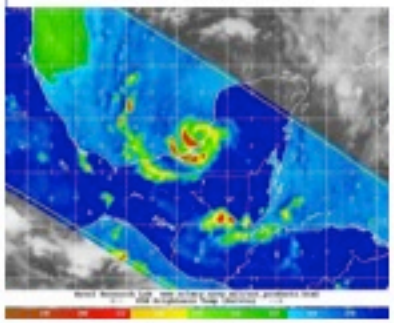
WB-57 (with HIRAD) on station only late 16 Sep

The few hours of overlap are probably the best we have so far for the HS3 Over-Storm payload (HIWRAP, HIRAD, HAMSR)

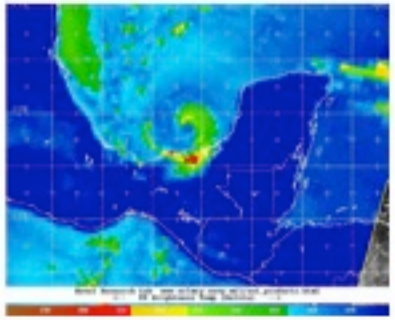
Satellite MI Snapshots

from NRL MRY TC Web Page

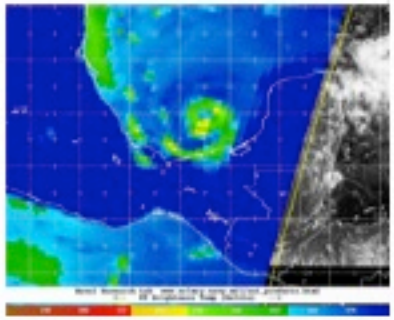
09/16 0603 TMI



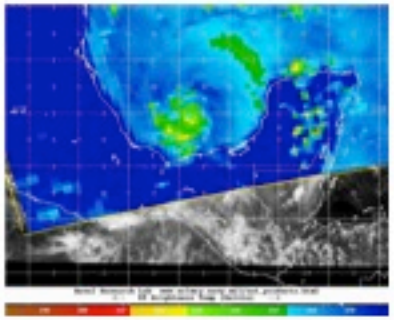
09/16 1326 N16



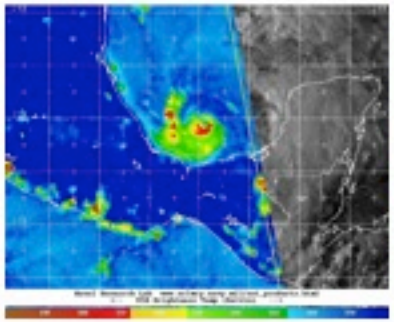
09/16 1616 METOPA



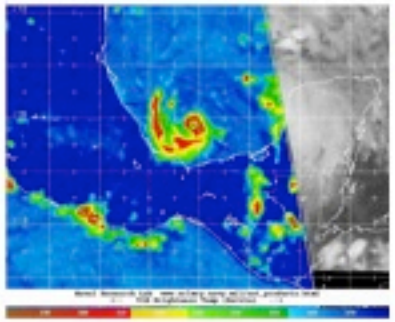
09/16 1949 N18



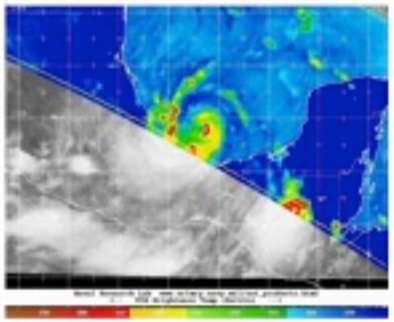
09/16 2328Z F-15



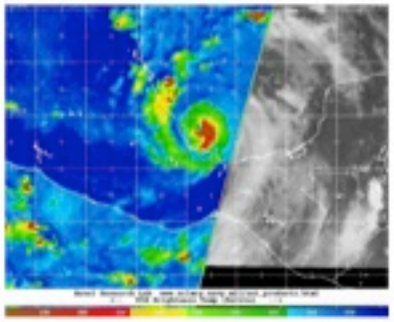
09/17 0113 Z F-16



09/17 0507 Z TMI



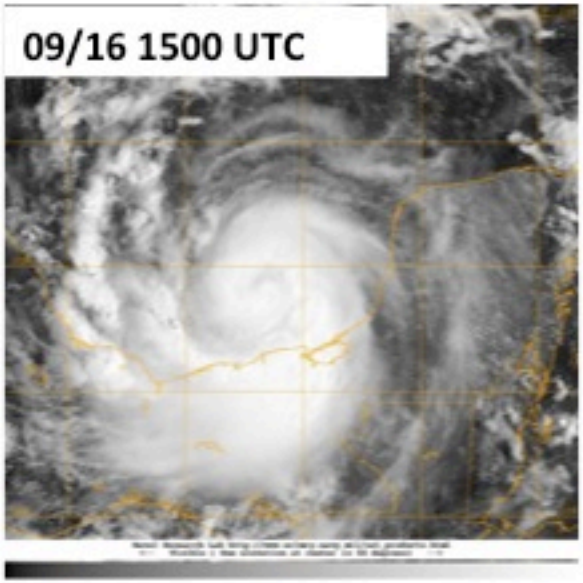
09/17 1200 Z F-15

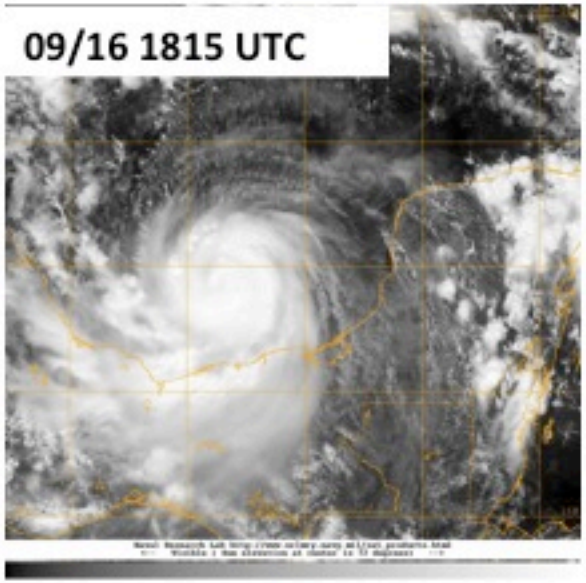


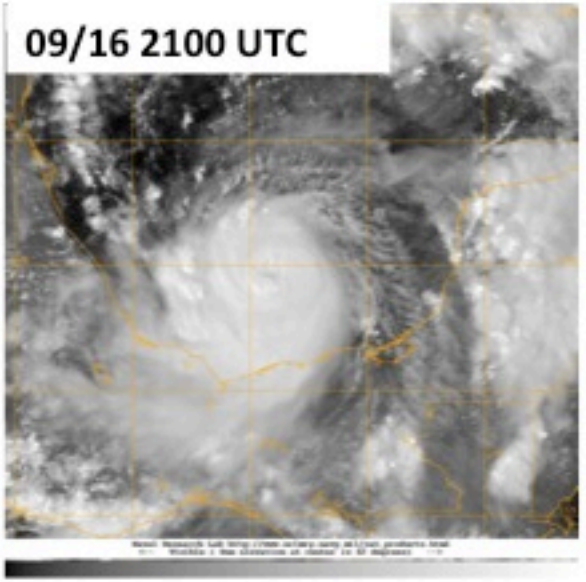
Karl was re-organizing / rapidly intensifying after crossing the Yucatan. Karl re-gained hurricane intensity just before the aircraft arrived, and peaked (110 kt) shortly after Global Hawk departed.

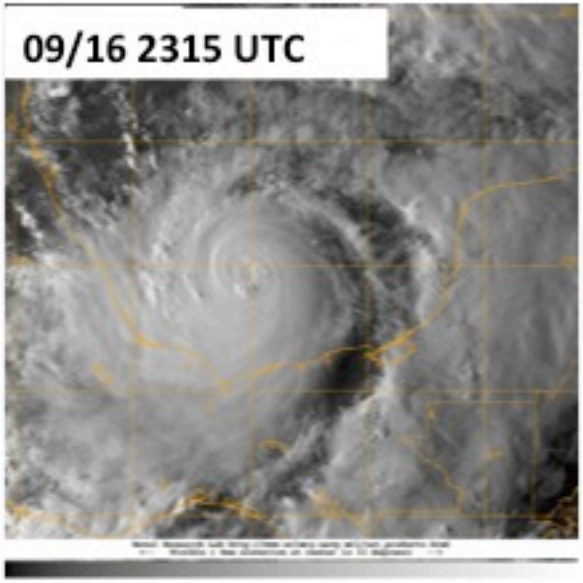
Satellite Vis Snapshots

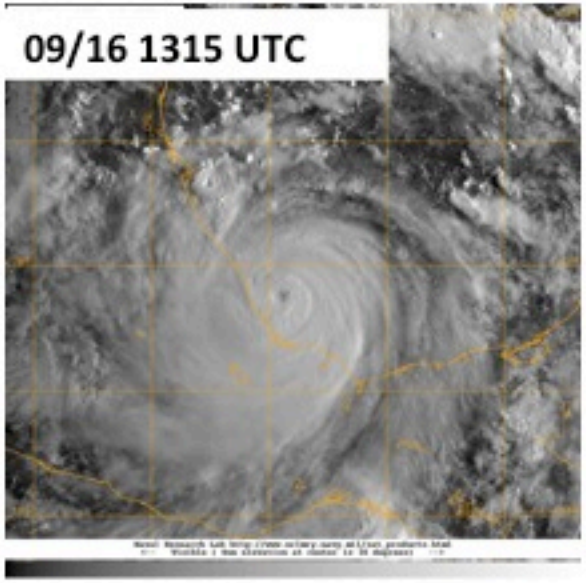
from NRL MRY TC Web Page







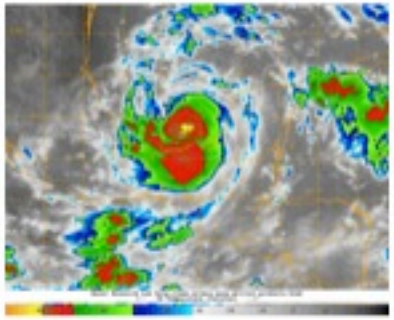




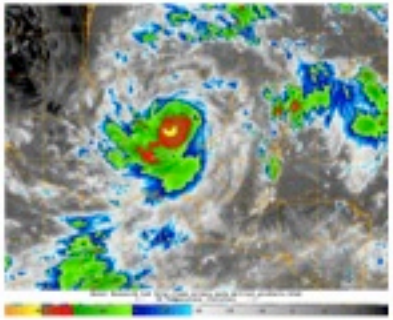
Satellite IR Snapshots

from NRL MRY TC Web Page

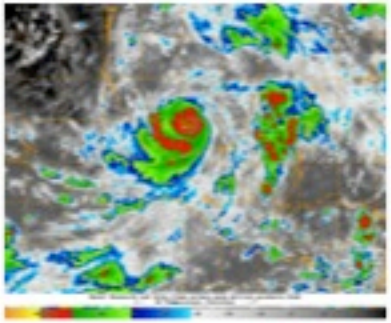
09/16 1500 UTC



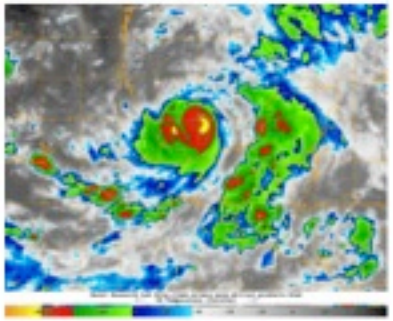
09/16 1745 UTC



09/16 2045 UTC



09/17 0000 UTC



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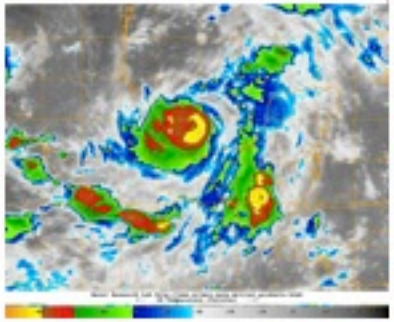

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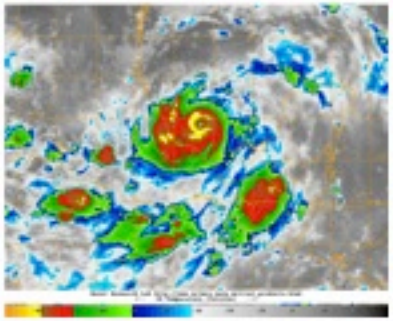

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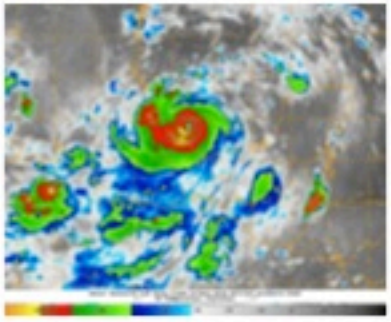
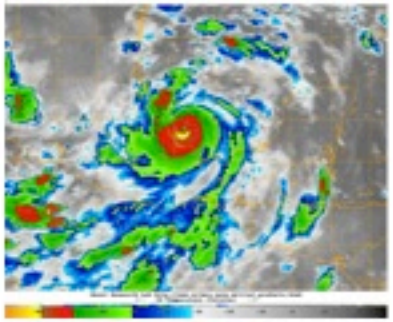
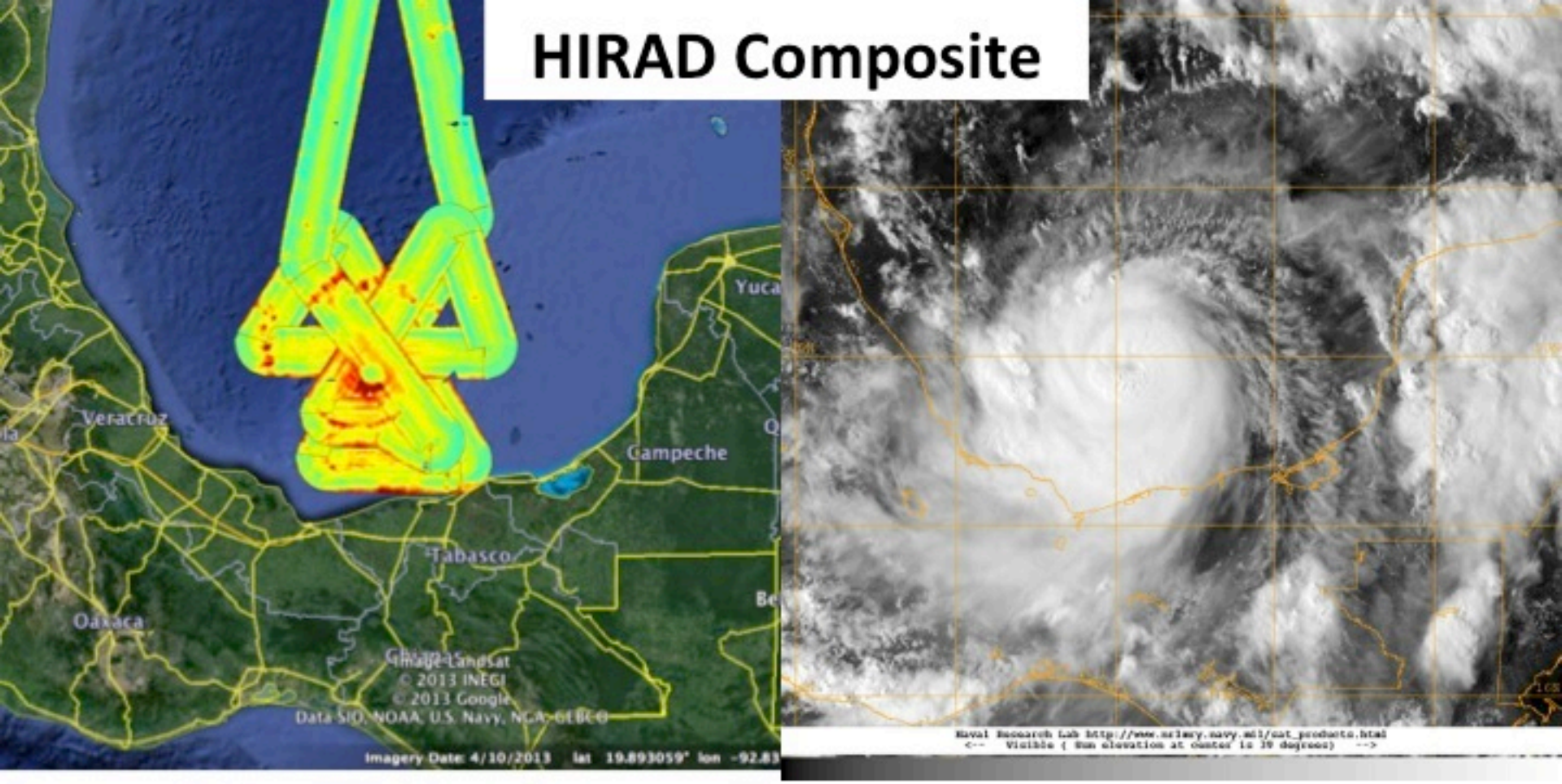


09/17 1200 UTC

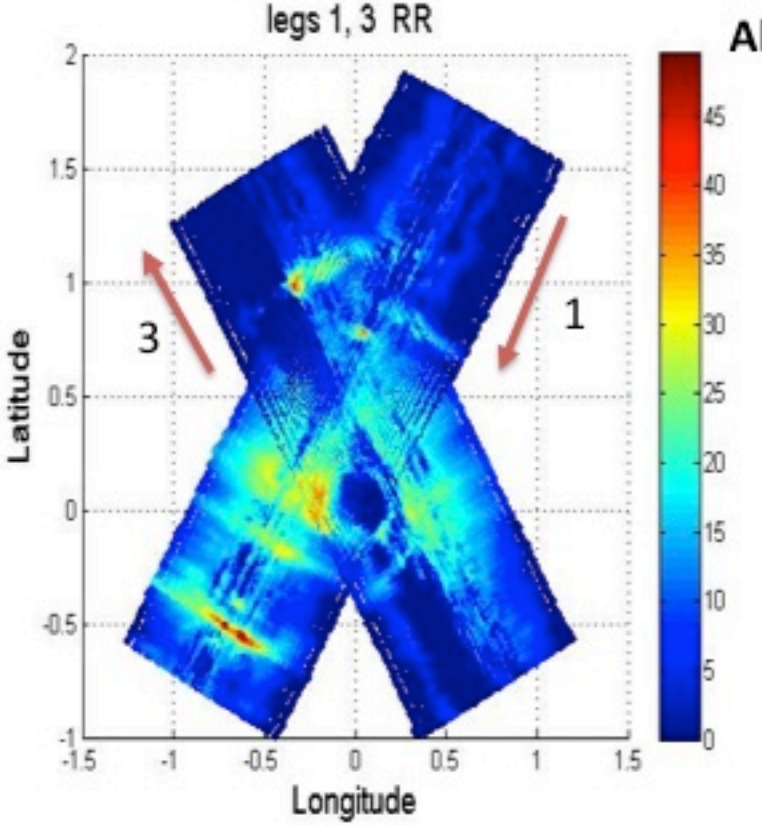




Hurricane Karl (2010) as seen by Hurricane Imaging Radiometer (HIRAD) (left) and conventional visible satellite imagery (right). HIRAD flies over hurricanes on high-altitude aircraft to measure the surface wind speed. Red shades denote the strongest winds and heaviest rains.

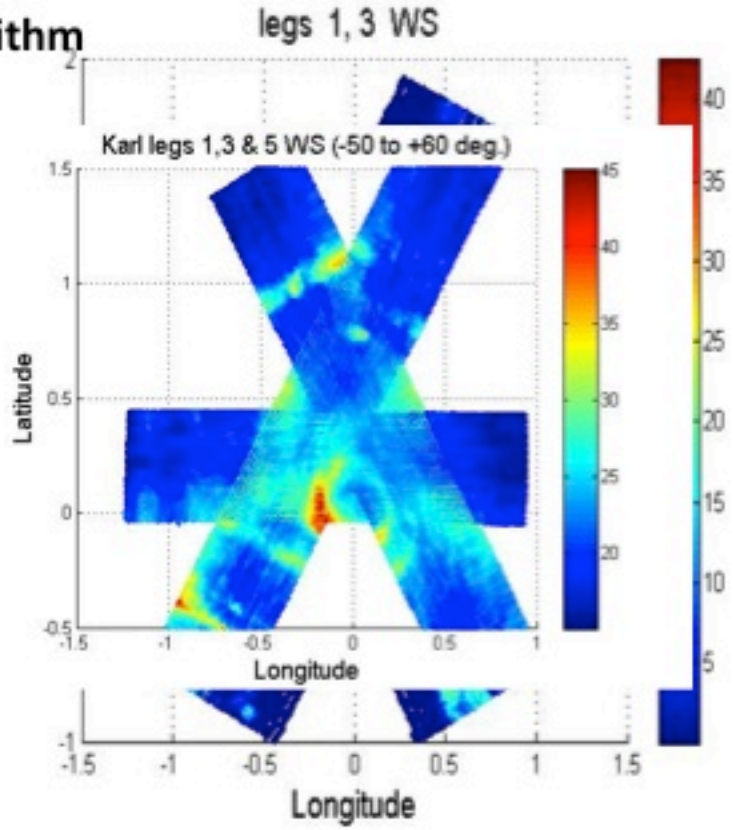
HIRAD Legs 1, 3, 5

Rain Rate



From UCF MLE Algorithm

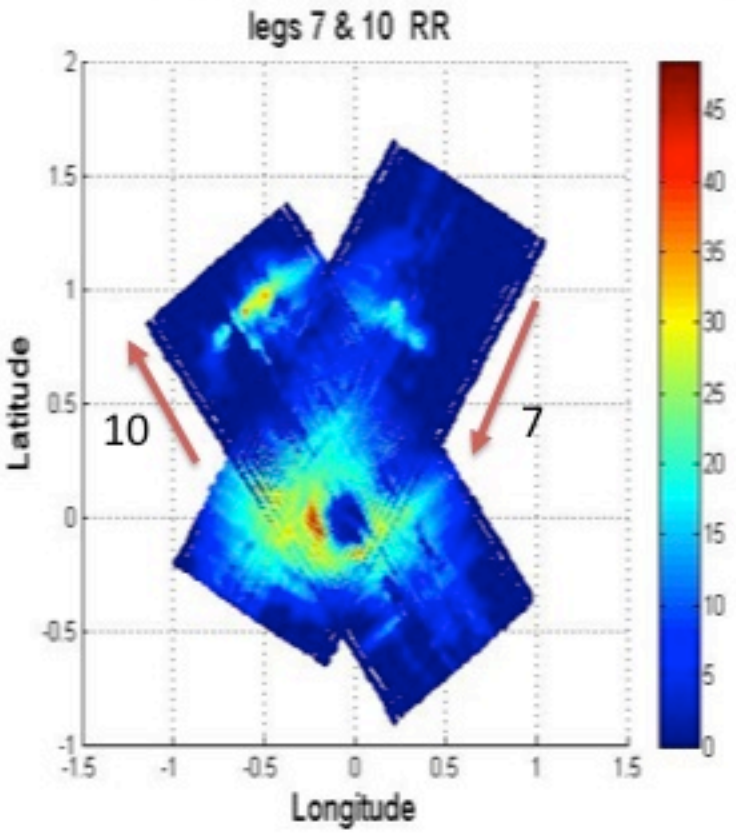
Wind Speed



HIRAD depicts strongest winds, heaviest rain from NW side cyclonically around to S / SE side

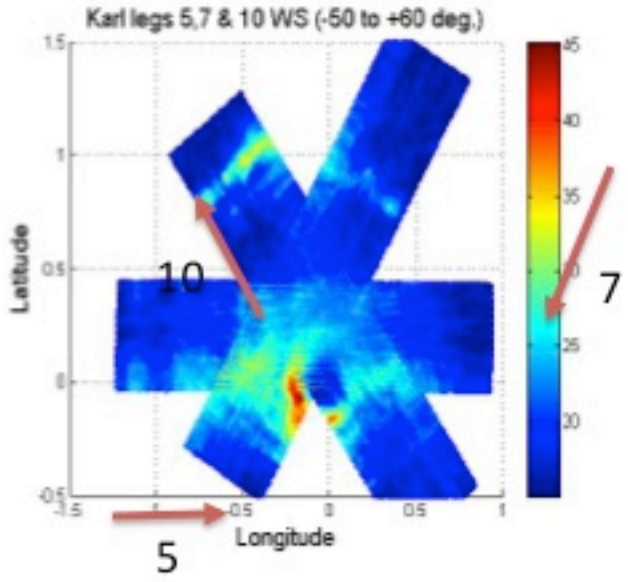
HIRAD Legs 5, 7, 10

Rain Rate



From UCF MLE algorithm

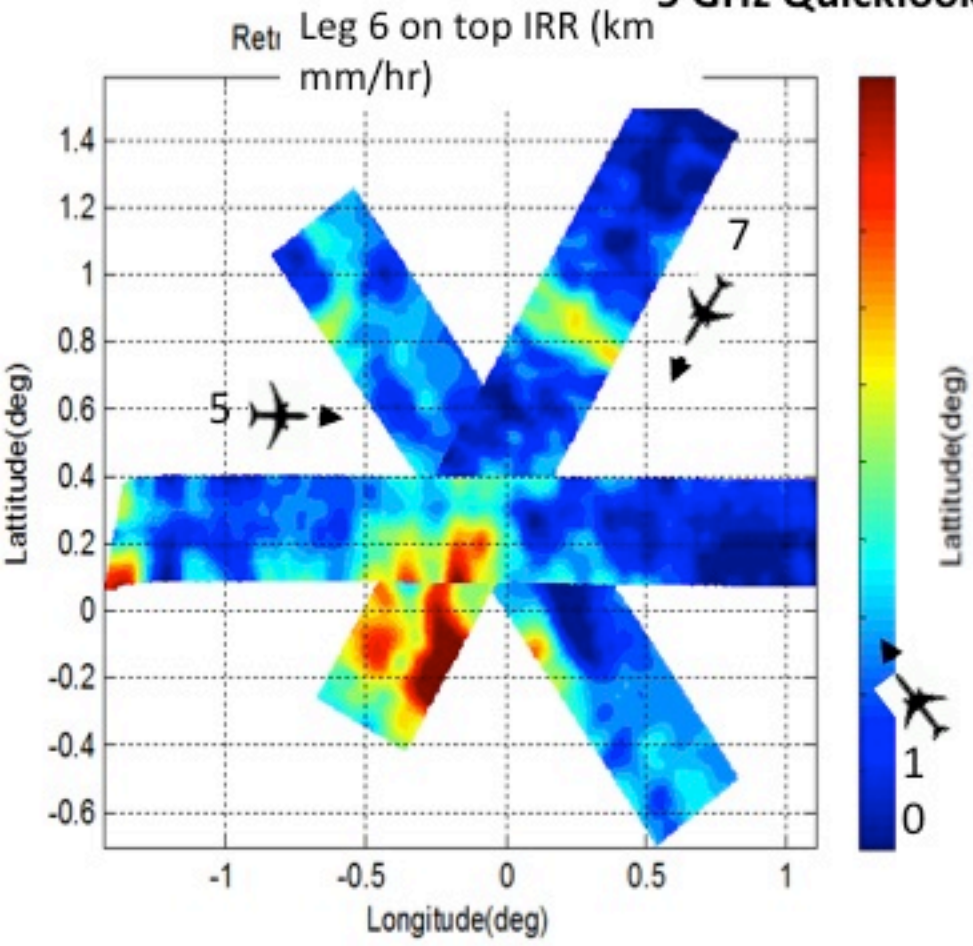
Wind Speed

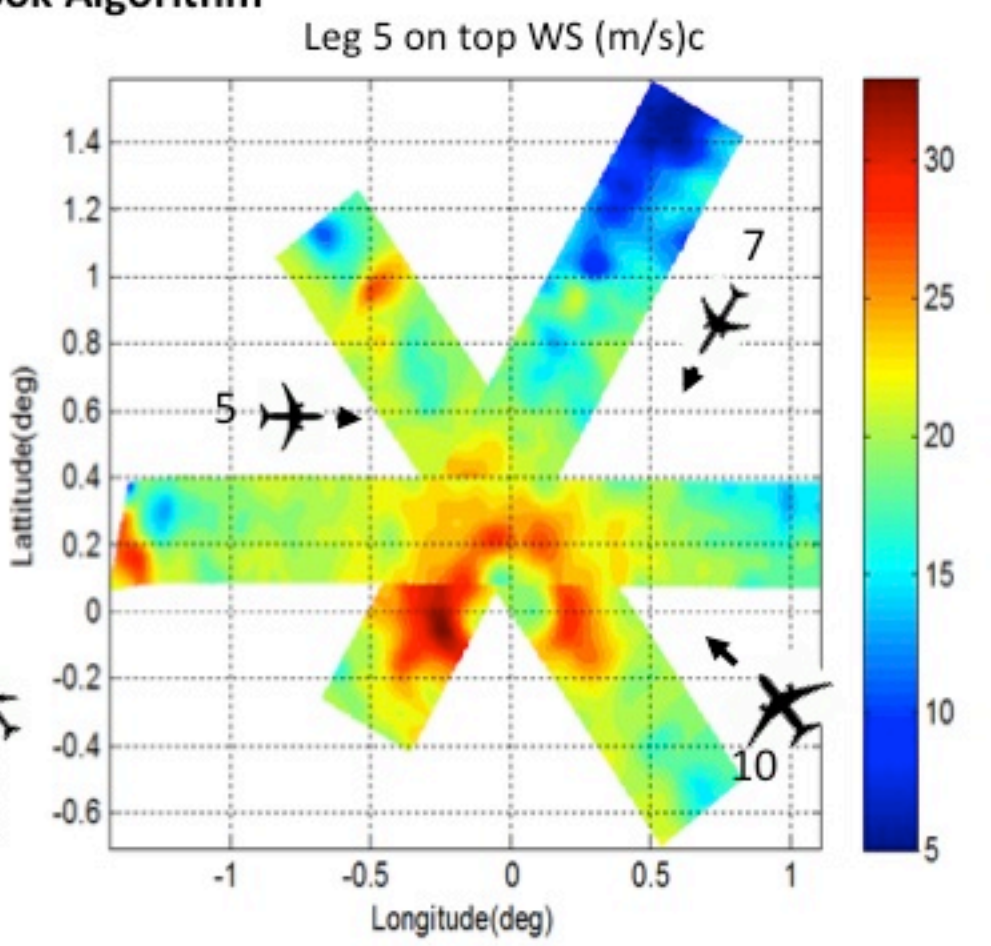


HIRAD depicts strongest winds, heaviest rain from NW side cyclonically around to S / SE side

HIRAD Legs 5, 7, 10

5 GHz Quicklook Algorithm

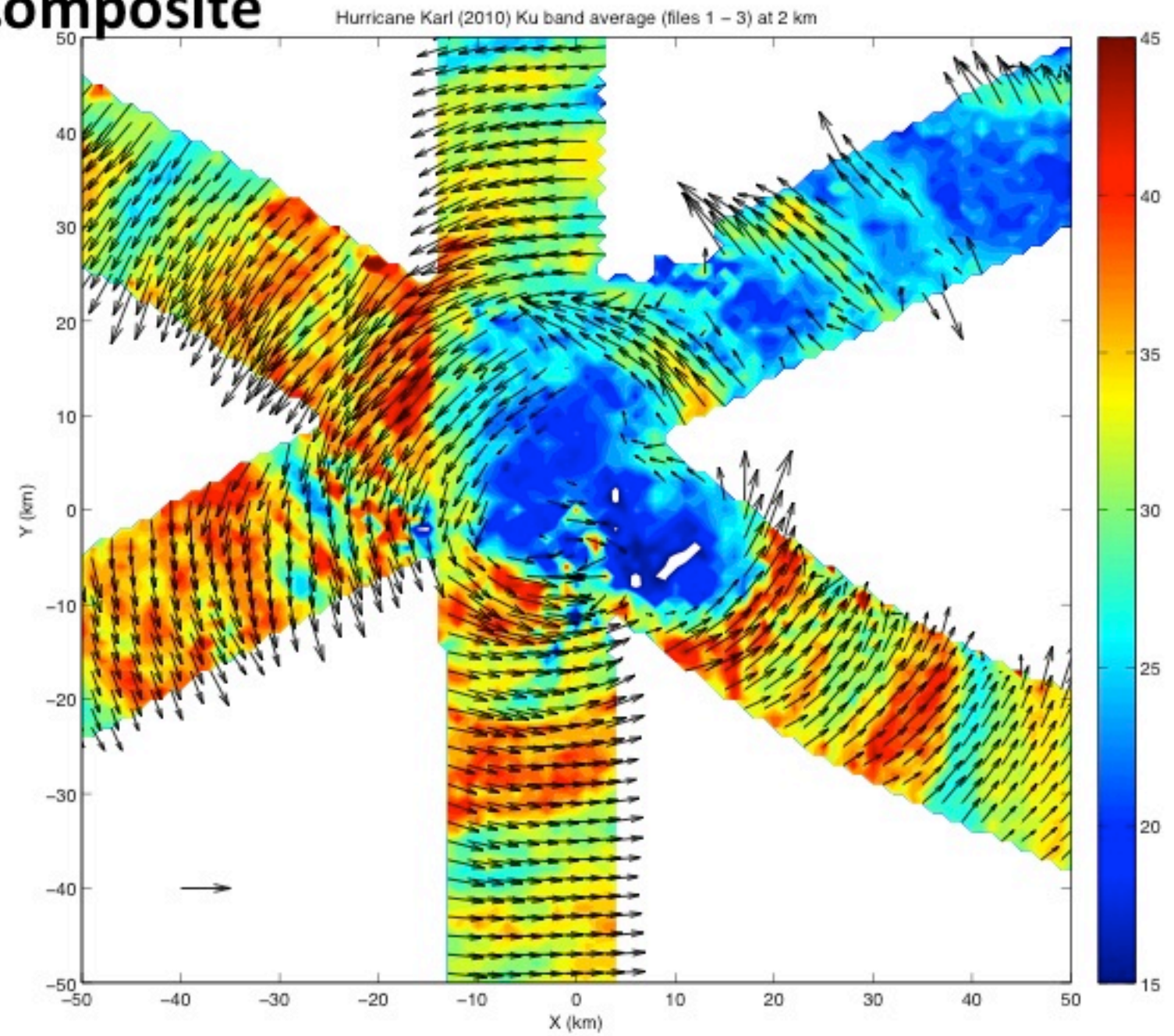




HIWRAP Composite at 2 km

From Steve Guimond

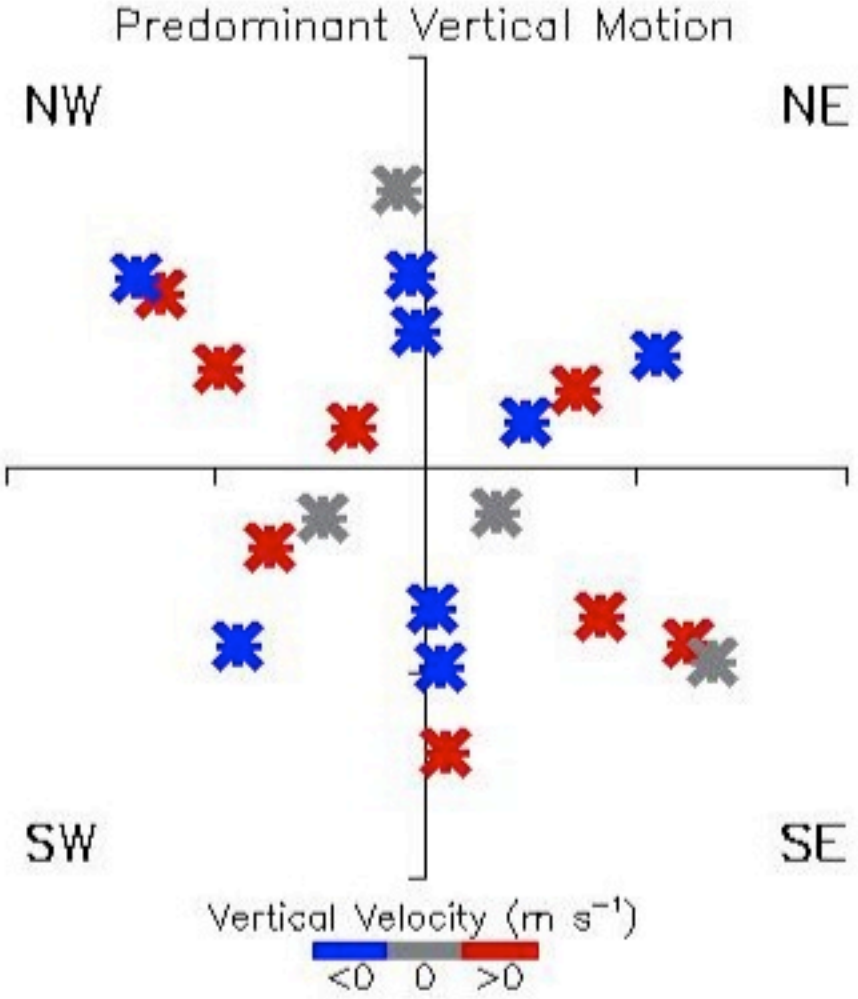
Also shows heaviest rain, strongest winds from NW around through SE sides



Inner core vertical motion

From HIWRAP vertical velocity cross-sections, qualitatively depicting whether eyewall / inner core had predominantly **upward motion (red)** or **downward motion (blue)**

Azimuths depict the quadrants sampled, but plotted radius depicts duration of time into flight



How do we get better over-storm cases in HS3 2014?

Dan's Soapbox

Fly the Over-Storm aircraft over the storm

- Do not approach thunderstorms within 25 nm during flight at FL500 or below.
- Aircraft should maintain at least ***5000 ft vertical separation from significant convective cloud tops*** except:

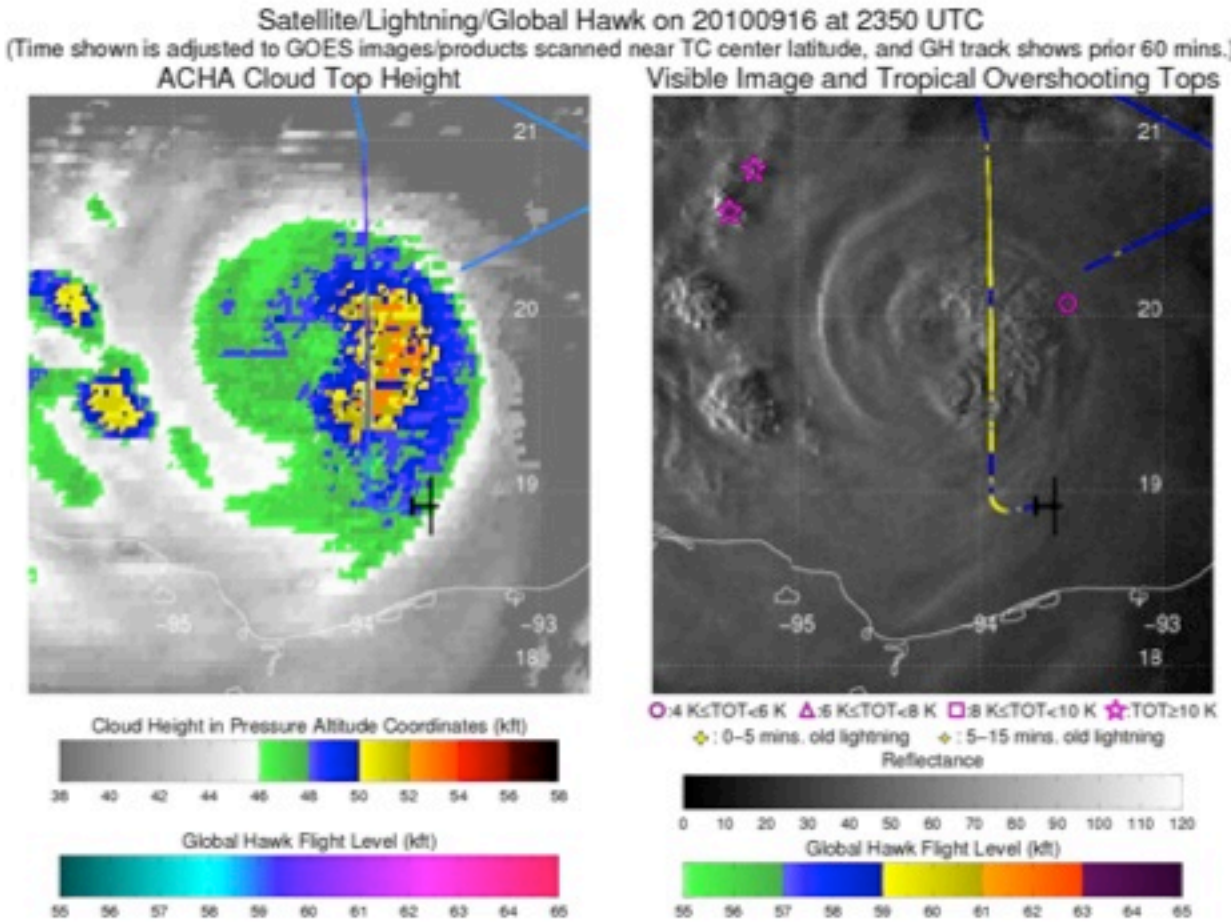
  a) When cloud tops above FL500: Do not approach reported significant lightning activity or indicators of significant overshooting tops within 25 nm.

  b) When cloud tops are below FL500, maintain 10000 ft separation from reported significant lightning or indicators of significant overshooting tops.
- No flight into forecasted or reported icing conditions

Open the East Pacific as an option

- We have 3+ months until science flights – there should be time to work it out.
- NHC has a Mexican Air Force representative during the summer to coordinate clearances
- Potential El Nino favors East Pac over Atlantic
- Even without El Nino, HS3 2013 would have been better served by flying the East Pacific

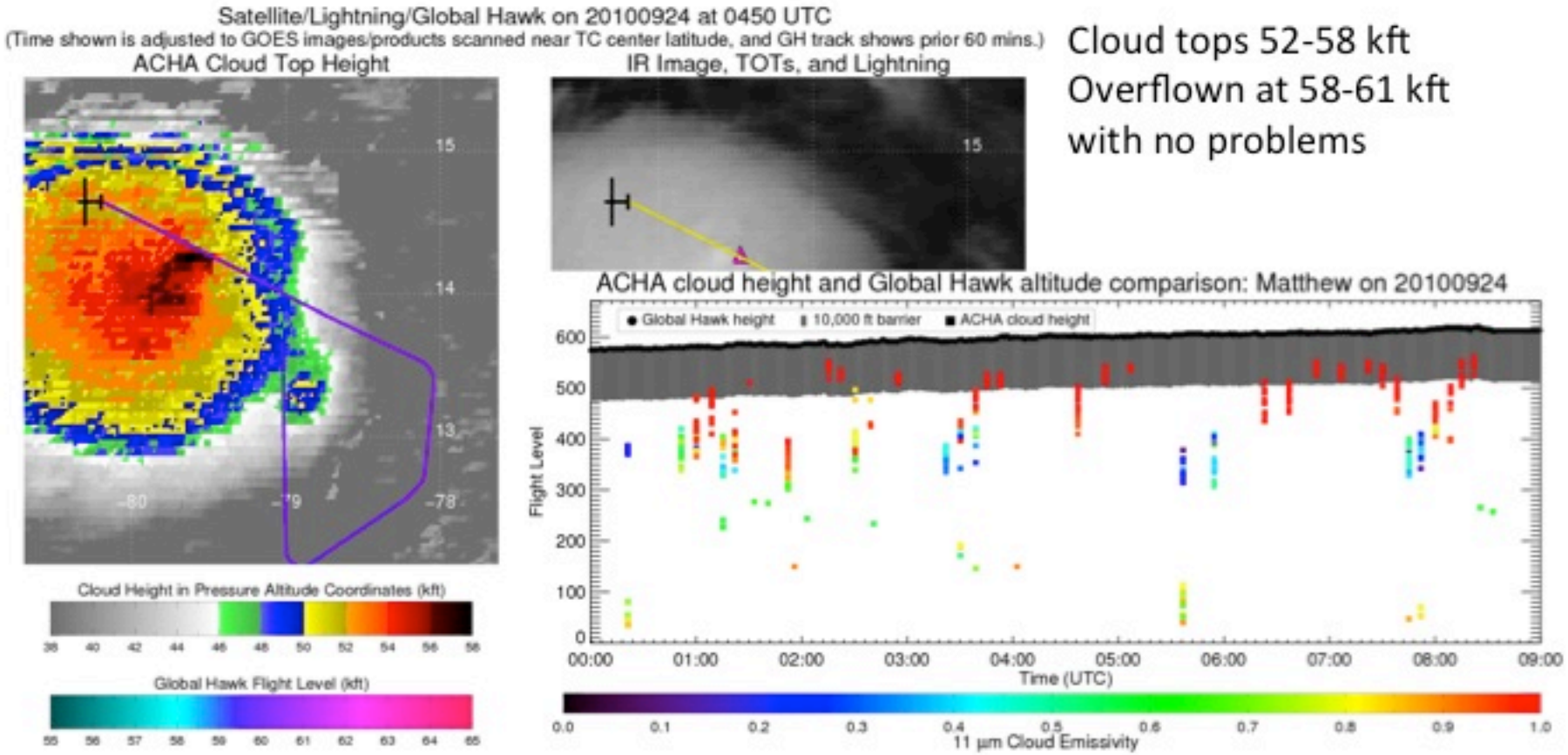
Karl and the flight rules



Cloud tops 50-54 kft
Overflown by AV-6 with no problems
Recall from Zipser, Houze presentations (and several papers) that ***convection occupies a small percentage of the area under the hurricane's cloud shield***

Figures from Sarah Monette and Chris Velden, from the 2013 flight rules white paper

Matthew (2010) and the flight rules



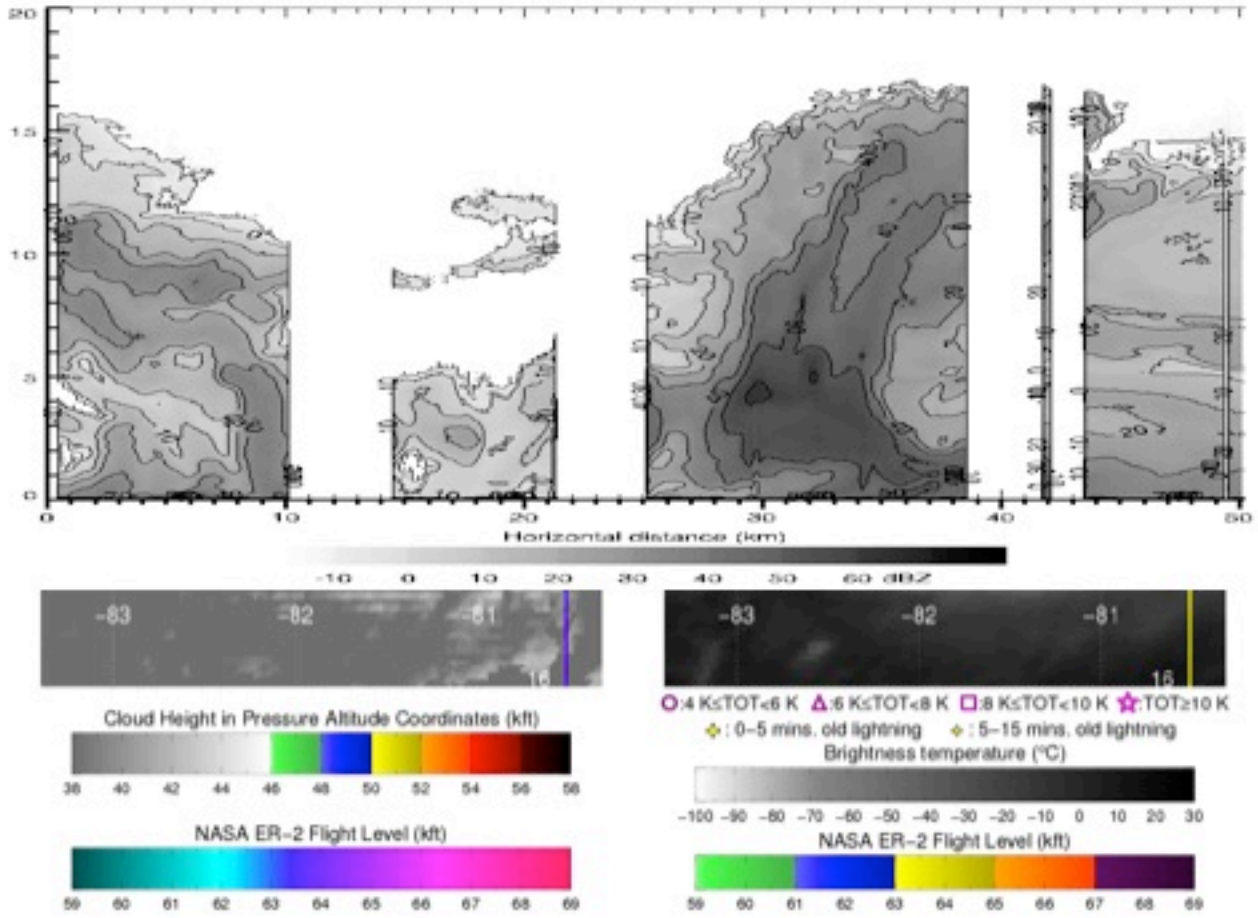
Cloud tops 52-58 kft
Overflown at 58-61 kft
with no problems

- Aircraft should maintain ***at least 5000 ft vertical separation from significant convective cloud tops*** except:

a) When cloud tops above FL500: Do not approach reported significant lightning activity or indicators of significant overshooting tops within 25 nm.

b) When cloud tops are below FL500, maintain 10000 ft separation from reported significant lightning or indicators of significant overshooting tops.

Emily and the flight rules
(ER-2 case, GH rules don't apply)

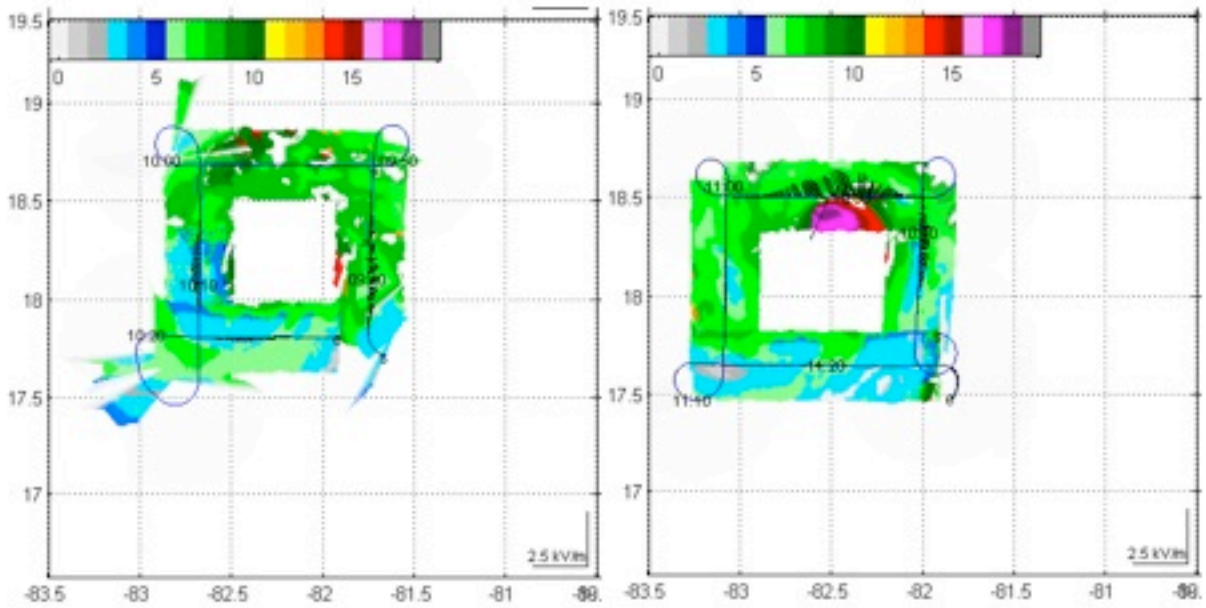


ER-2 overflew broad area of high cloud tops on SE side with no problem

Turbulence when overflying a new cell that emerged on inner edge of the western eyewall

Several lightning flashes, beginning just before the ER-2 got to the wrong place at the wrong time

Emily box pattern



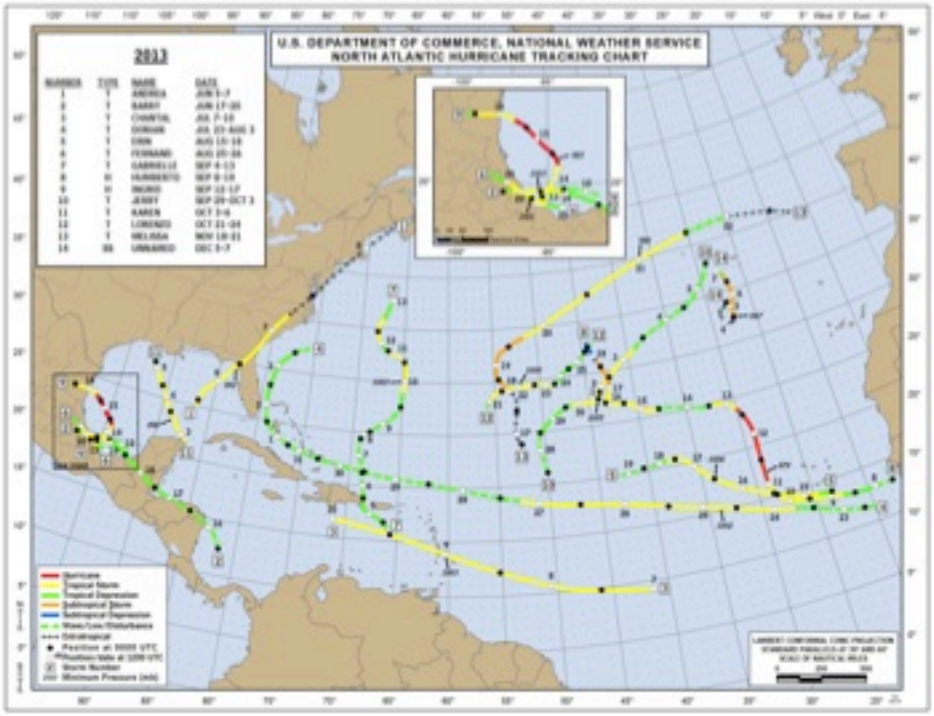
After the turbulence, we flew a box pattern just outside the eyewall.

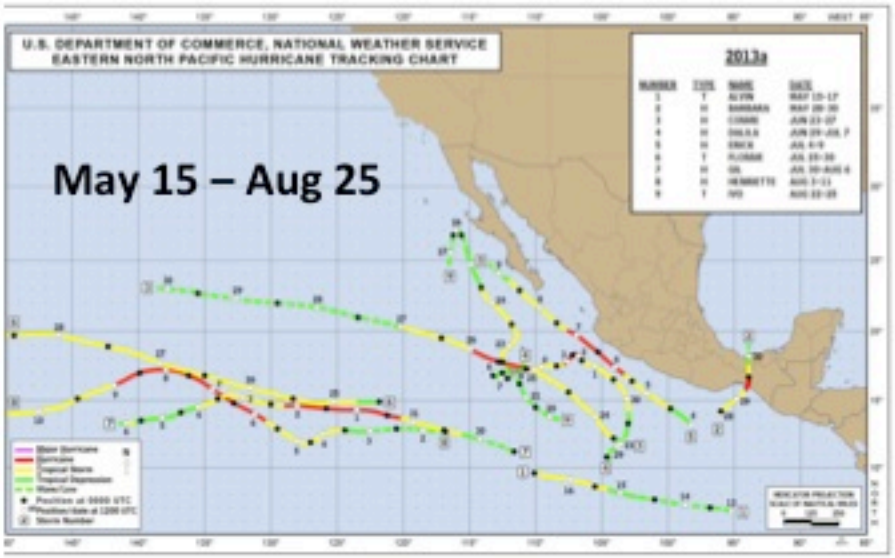
No problems, pilot edged closer to the eyewall as he grew more comfortable

If we cannot overfly a given eyewall due to significant convection, we should be able to fly the adjacent region

Significant convection is rare there, even under very high cloud shield – think Molinari, Corbosiero, Cecil, Houze, etc

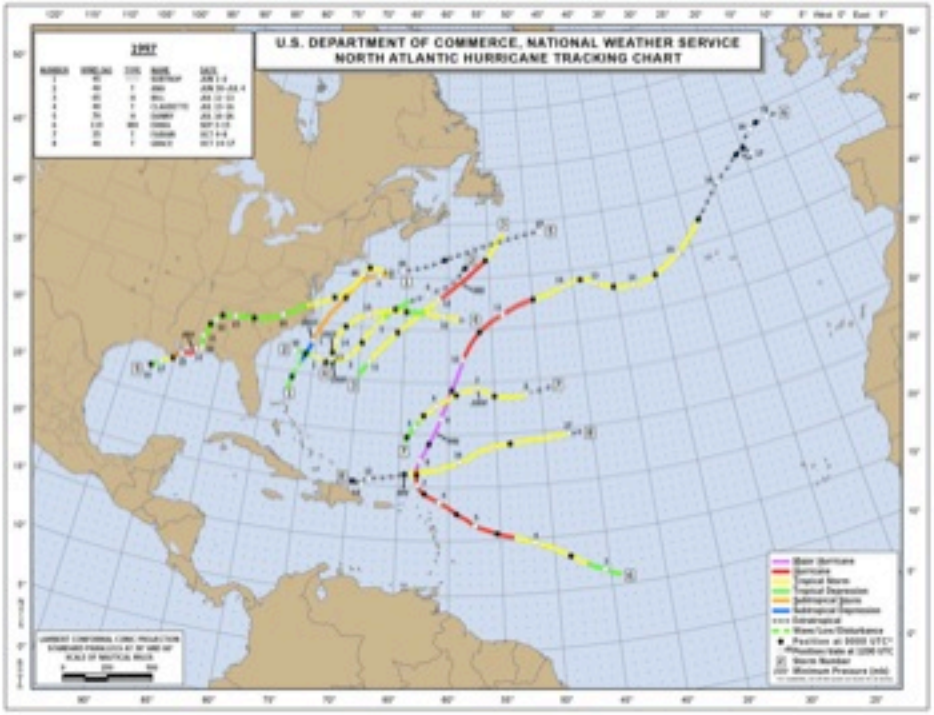
2013

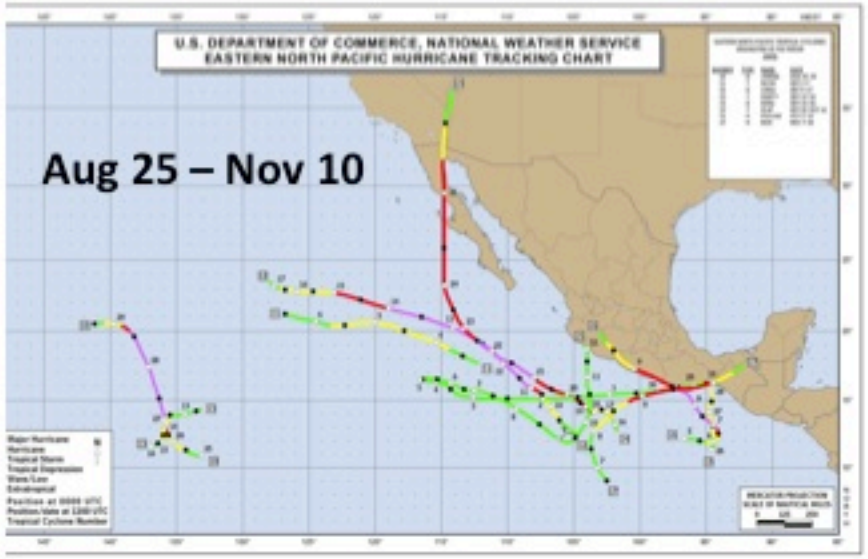

U.S. DEPARTMENT OF COMMERCE, NATIONAL WEATHER SERVICE
NORTH ATLANTIC HURRICANE TRACKING CHART
2013


U.S. DEPARTMENT OF COMMERCE, NATIONAL WEATHER SERVICE
EASTERN NORTH PACIFIC HURRICANE TRACKING CHART
2013a
May 15 – Aug 25


EASTERN NORTH PACIFIC HURRICANE TRACKING CHART
Aug 28 – Nov 4

1997 (El Nino)

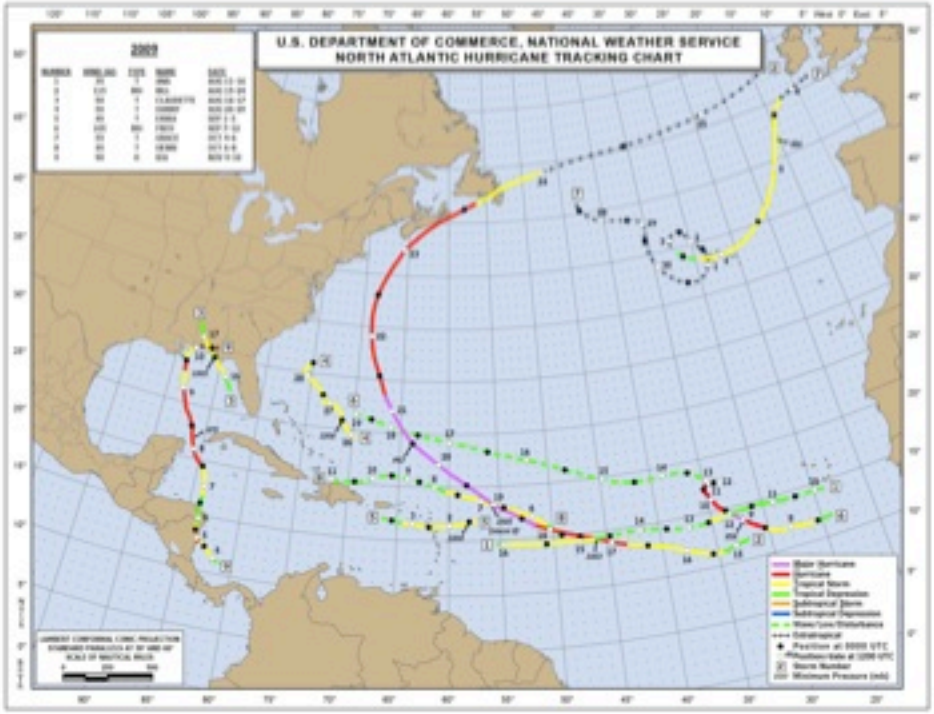




3 Major Hurricanes + 2 TS
Aug 25 – Sep 26 in E. Pac.

5 W. Atlantic storms in June-July
0 for August
1 C. Atlantic Hurricane (Erika) in Sept
2 TS in October

2009 (El Nino)



Atlantic: 2 short-lived TS and 1 Major Hurricane (Fred, east of 35°) Aug 26 – Sep 29

E. Pac: 3 TS and 2 Hurricanes (1 major, Jimena) Aug 26 – Sep 29

Summary

Karl has interesting data, but far below the standards we should be able to achieve in HS3

We need to fly AV-1 over hurricanes in 2014

Most of the cold cloud shield in the inner core of hurricanes should be safe for AV-1 to fly. Significant convection occupies a small region, but we sometimes unnecessarily apply the 5000-ft separation rule to the entire cold cloud shield.

We should make the East Pacific a viable option. There are 3+ months to work out clearances, which NHC should be able to facilitate.

I am *not* advocating that we give up on the Atlantic, just that we should be prepared to fly across Mexico to East Pacific targets