HIWRAP Status and Future Plans

Gerry Heymsfield *NASA/Goddard Space Flight Center*

Lihua Li, Matt Mclinden *NASA/Goddard Space Flight Center*

Stephen Guimond *U. MD/ESSIC*
Lin Tian *Morgan State Univ.*
James Carswell *Remote Sensing Solutions*

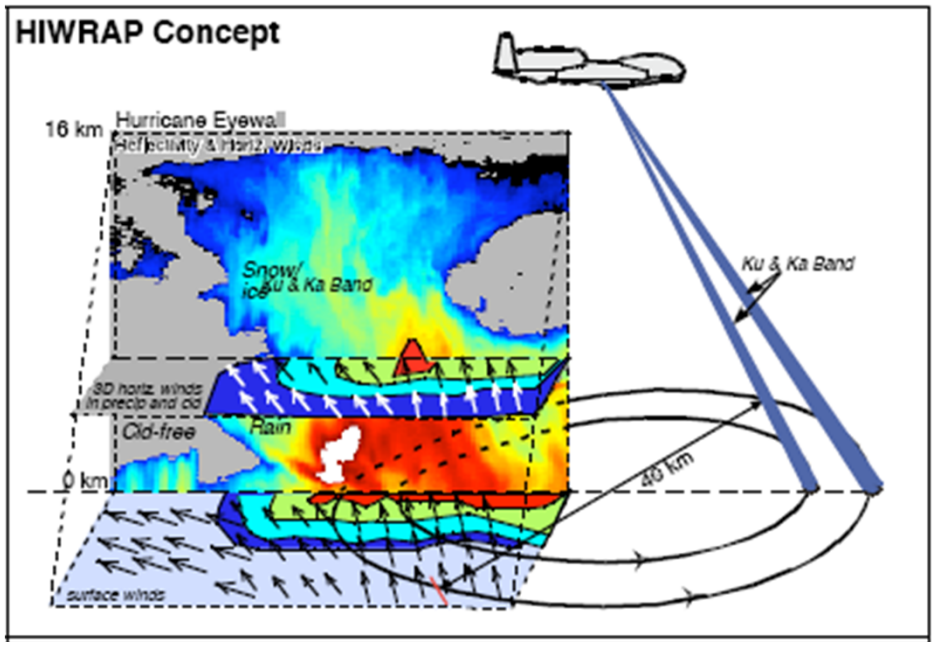
Acknowledgements:
NASA ESTO IIP
NASA HS3
NASA HSRP

High-Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP)

MEASUREMENTS GOALS:

Map the 3-dimensional winds and precipitation in precipitation regions associated with tropical storms.

Map ocean surface winds in clear to light rain regions using scatterometry.



HIWRAP Characteristics:

- *Conically scanning.*
- ***Simultaneous Ku/Ka-band & two beams @ 30 and 40 deg***
- *New technologies in radar:* ***low power solid state transmitters with pulse compression, single antenna***
- *GPM radar frequencies.*

Previous HIWRAP Flights

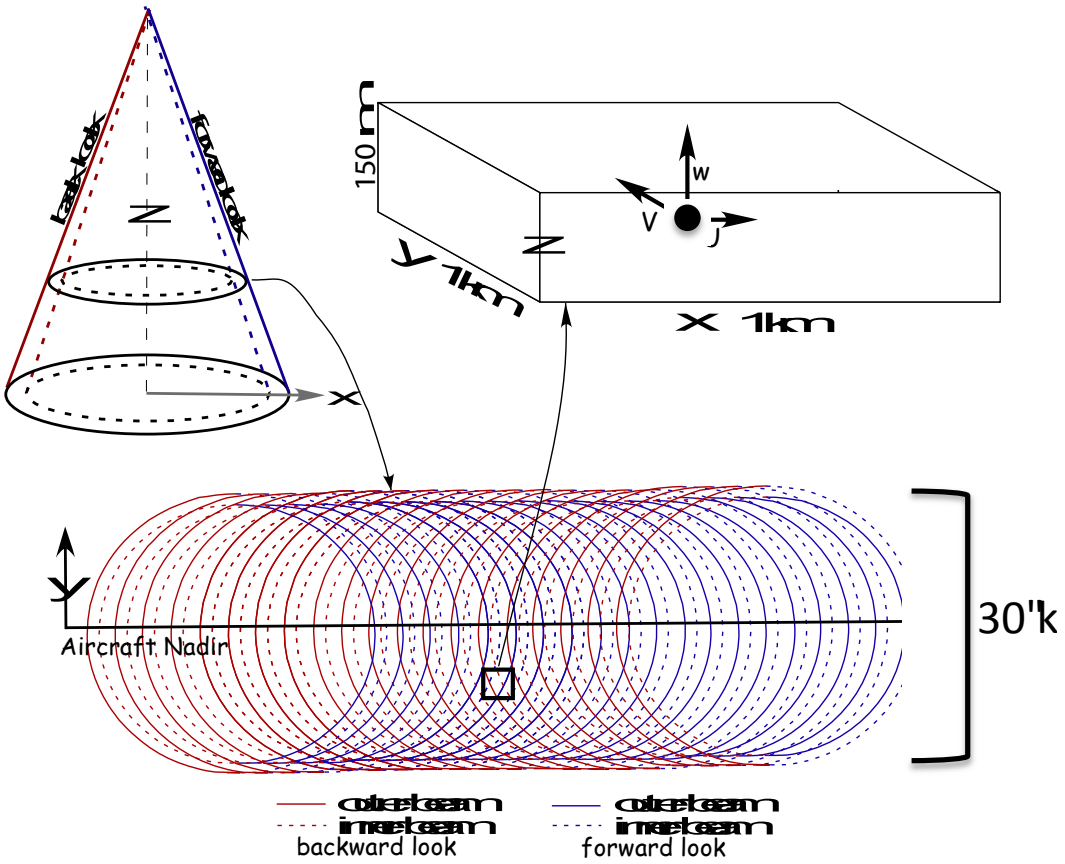
- Previous Field campaigns:
  - 2010: *GRIP AV-6*
  - 2011: *MC3E on ER-2 (non-scanning)*
  - 2012: *HS3 AV-1 test flights*

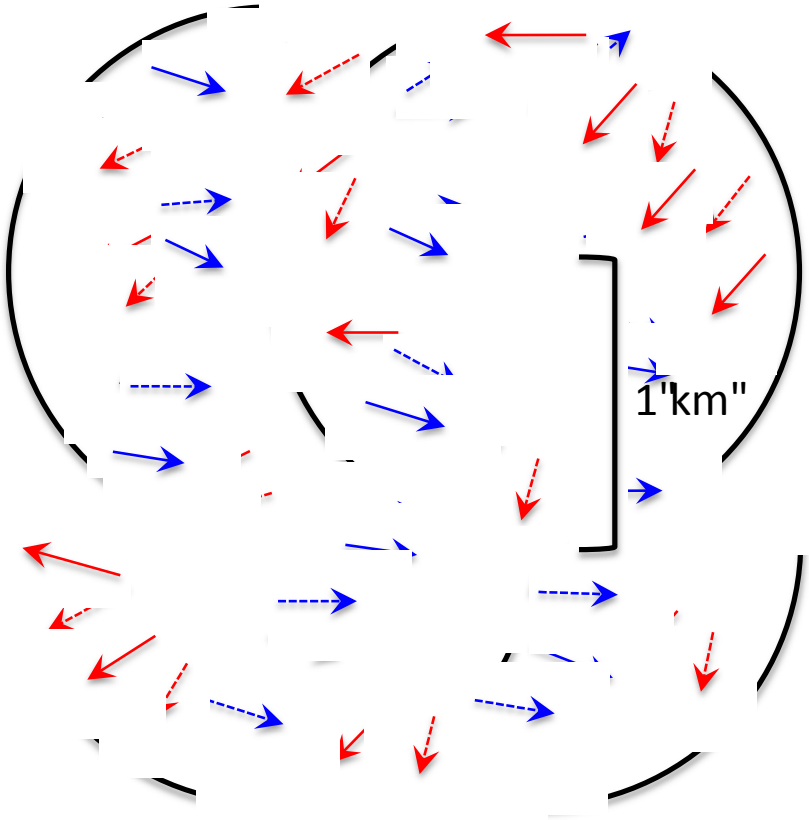
- Previous Field campaigns:
  - 2013: *HS3 AV-1 -> 2 science flights*
    - Ka-band transmitter power increased for 12 dBZ sensitivity improvement
    - New IF up/downconverters for better channel isolation
    - Improved pulse compression algorithms.

HIWRAP Wind Algorithms

- Atmospheric wind retrievals:
  - Grid-point (3D-VAR) analysis -> 3 components of wind in 3D swath
    - *Guimond et al., 2014: Wind retrieval algorithms for the IWRAP and HIWRAP airborne Doppler radars with applications to hurricanes, AMS JTech, in pre-release*.
    - Dual-Doppler Coplane analysis -> Next talk by Didlake.
  - VAD analysis -> 2D curtain of horizontal winds
    - *Tian et al., 2014: VAD and Dual-Doppler analysis of Doppler velocity for HIWRAP. Submitted JAMC.*

Swath (Grid-point) Retrievals





Iterative Method: 3D-VAR (e.g. Ziegler 1978; Gao et al. 1999 and others)

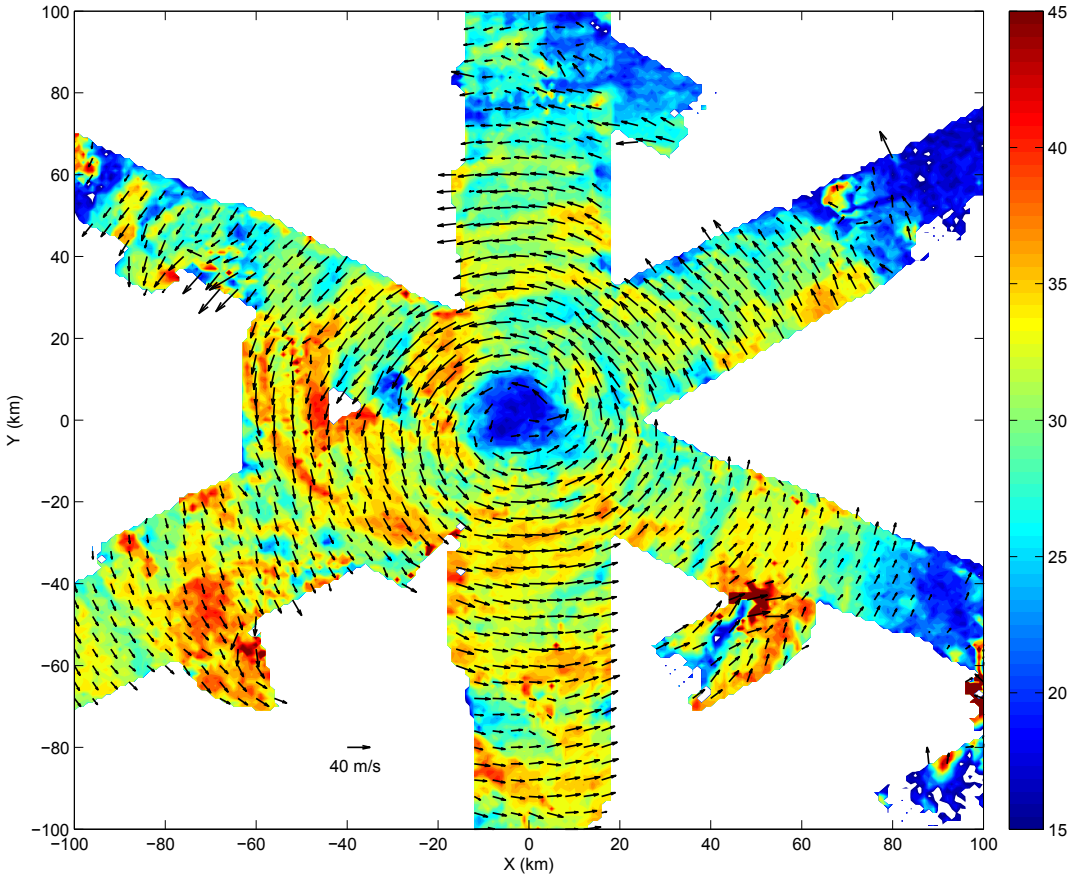
$$\mathbf{J} = \left\| W\left(y - \mathbf{E}x\right)\right\|^2 + \left\|\nabla \bullet \rho\vec{v}\right\|^2 + \left\|\nabla^2\vec{v}\right\|^2 \qquad \frac{\partial \mathbf{J}}{\partial \mathbf{x}} = 0 \longrightarrow$$ Nonlinear minimization

Conjugate gradient algorithm (CONMIN): modernized code for better flow, fewer lines

Hurricane Karl (2010)

- Provide the three Cartesian velocity components over the entire radar sampling volume at high resolution.
- Using a 3D variational solution method, the horizontal winds have an accuracy of ~ 1.5 – 2.0 m s^{-1} with a ~ 1.5 m s^{-1} error for vertical winds.

Guimond et al., 2014: Wind retrieval algorithms for the IWRAP and HIWRAP airborne Doppler radars with applications to hurricanes, AMS JTech, in pre-release.



HIWRAP wind vector retrievals at 2 km height in Hurricane Karl (2010) using a synthesis of ~ 12 h of data. Contoured reflectivity and horizonal wind vectors.

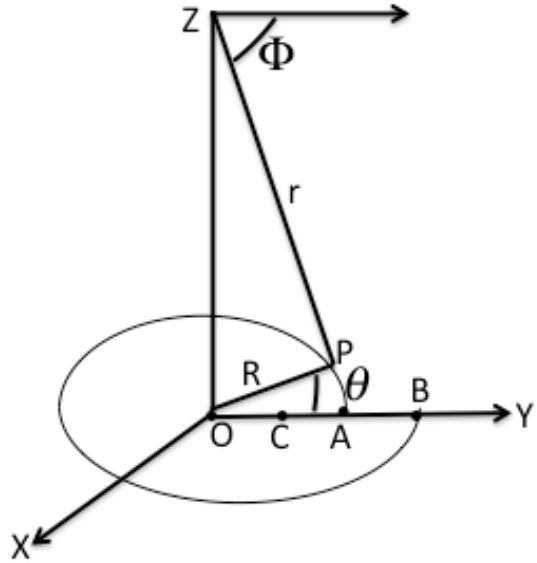
VAD Analysis for Horizontal Wind Fields from HIWRAP Observations

Assumptions:

- Linear horizontal wind within the scan circle

- Constant Doppler velocity at given height;

- Center of the scan circle does not move;



$$V_r(\theta) = a_0 + a_1\cos\theta + b_1\sin\theta + a_2\cos(2\theta) + b_2\sin(2\theta) + E(\theta, U_a, \tau)$$

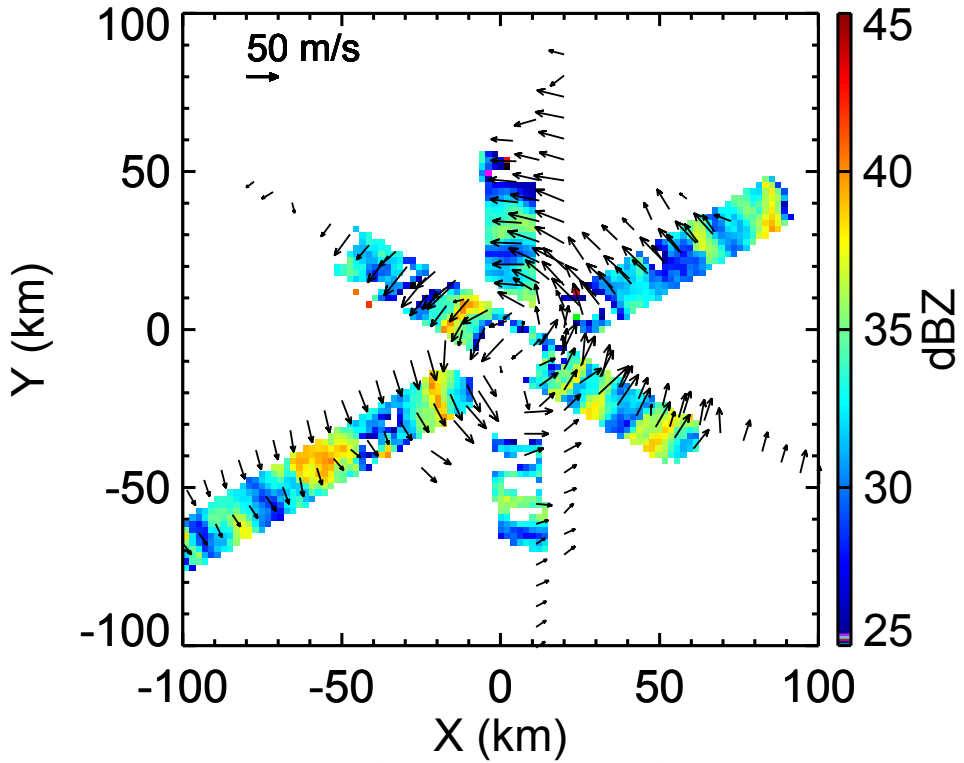
$$a_0 = W_0\cos\Phi + DIV\frac{R\cos\Phi}{2} \quad , \quad a_1 = u_0\cos\Phi \quad , \quad b_1 = v_0\cos\Phi$$

E - error due to movement of scan circle

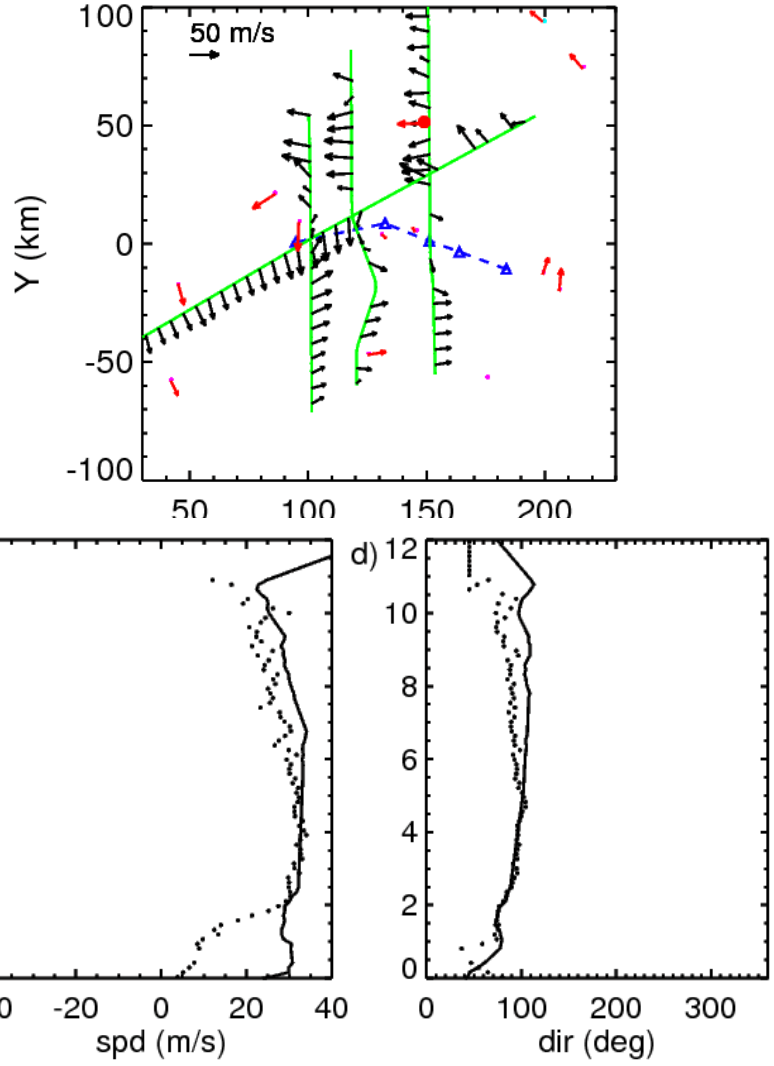
Tian et al. 2014, submitted to JAMC

VAD Winds of Hurricane KARL

Composite of VAD derived wind fields (0000-0811 UTC, 17 Sep 2010



Comparison of horizontal winds between VAD (black) and dropsondes (red) shows general agreement

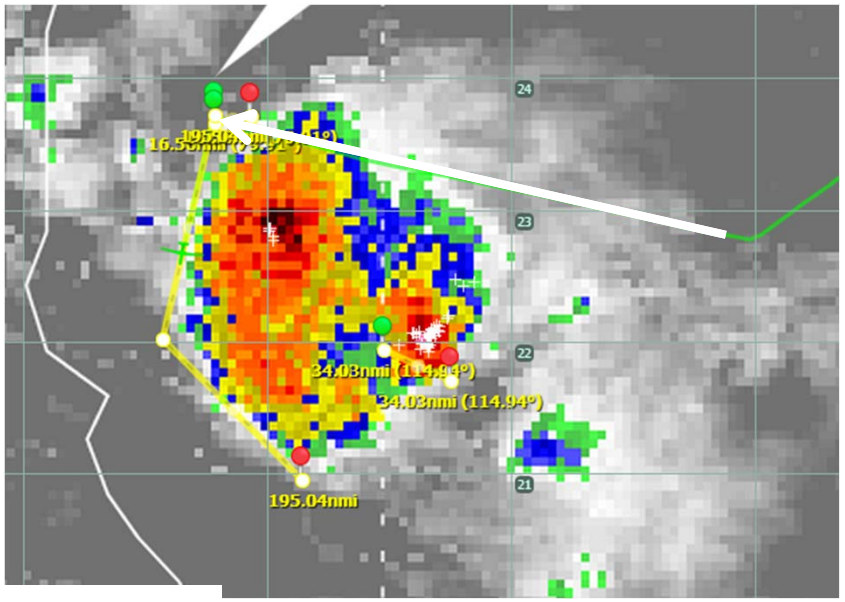


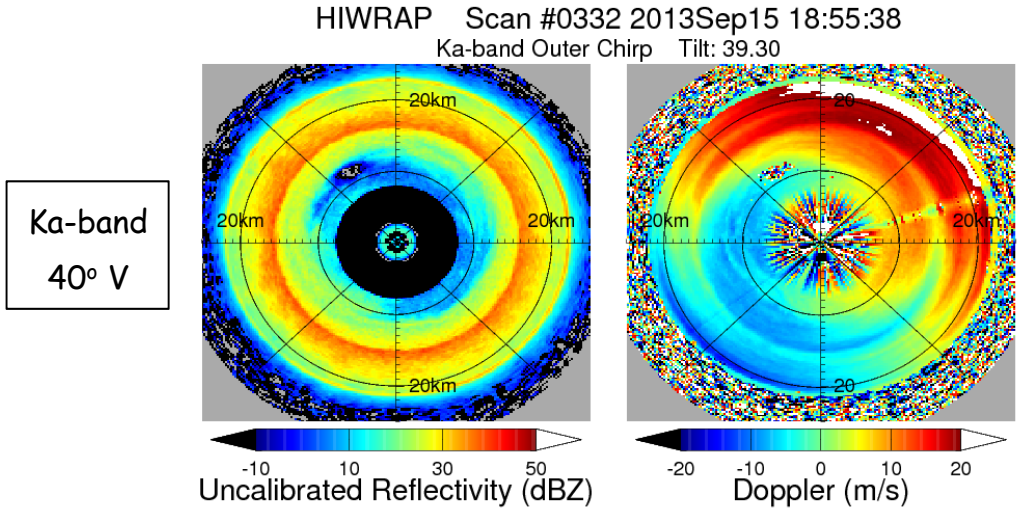
- ***VAD winds capture the vortex structure of Hurricane Karl;***
- ***Provides valuable information for data assimilation***

Tian et al. 2014, submitted to JAMC

HS3 25 Sept 2013 – Hurr. Ingrid Flight

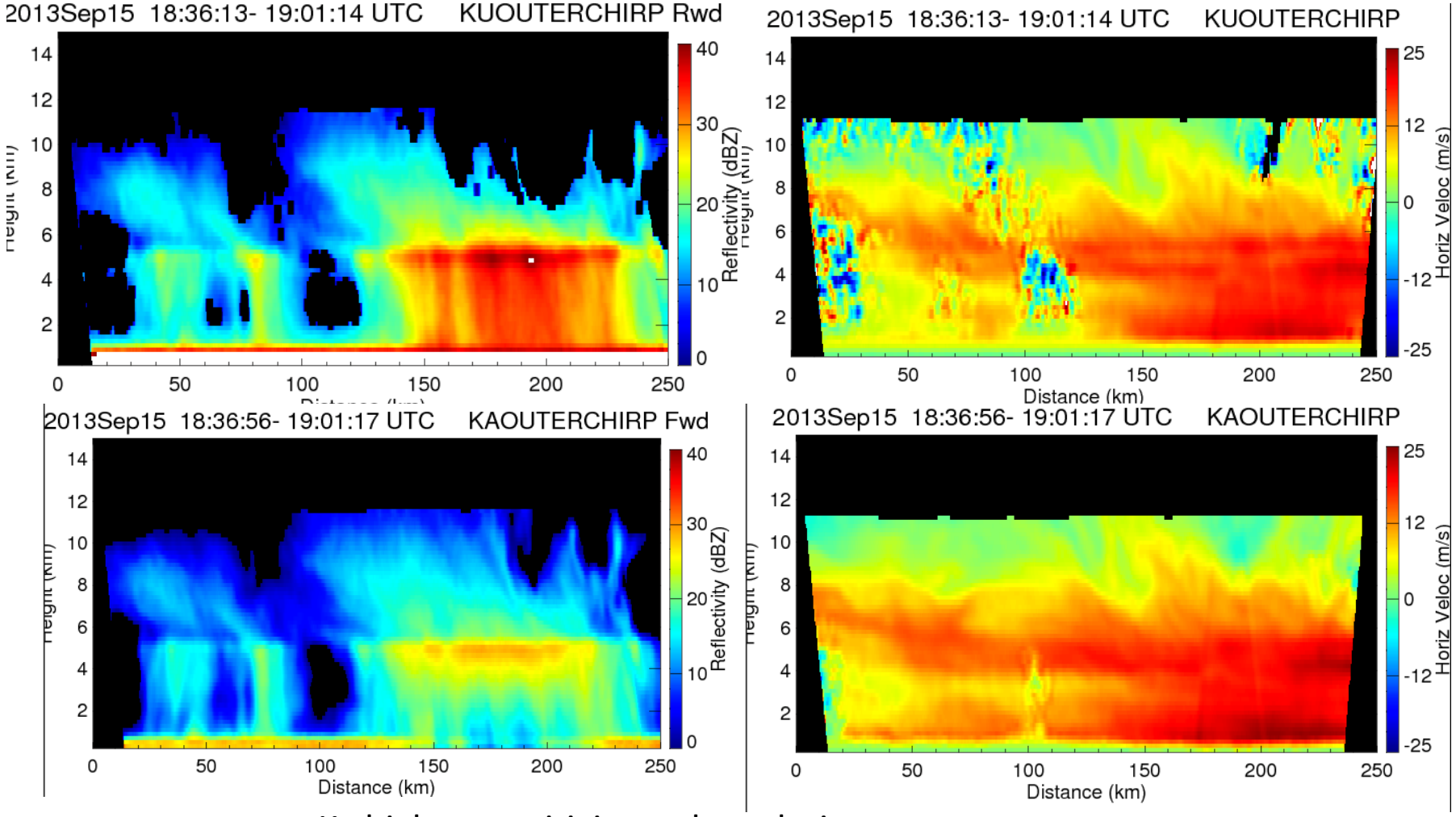
- Global Hawk circumnavigated storm because storm top was too high
- About 3.5 hours on storm (~1800 – 2130 UTC).
- Fuel temperature was too low so flight cut short.
- Only flight during 2013 with significant precipitation.
- Mostly stratiform on a few flight legs





HS3 25 Sept 2013 – Hurr. Ingrid Flight

Northern Edge of Hurricane Ingrid – Outer beam (40 degree)



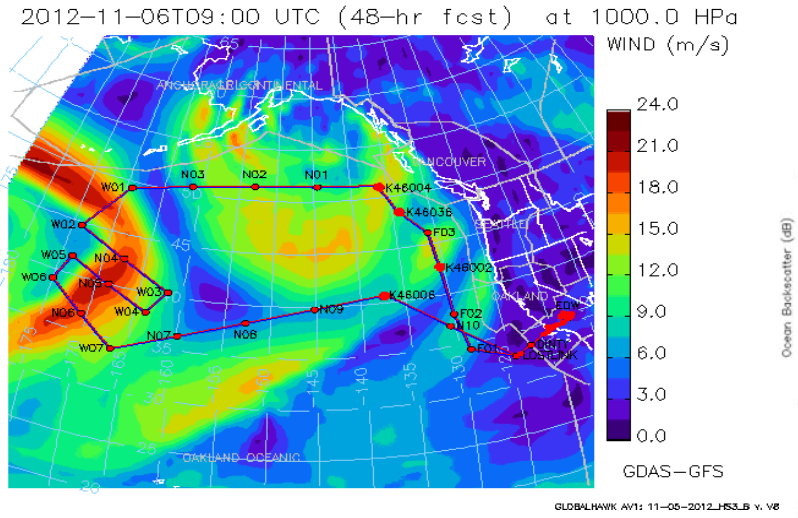
-> Ka higher sensitivity and resolution.

-> Doppler comparable between frequencies.

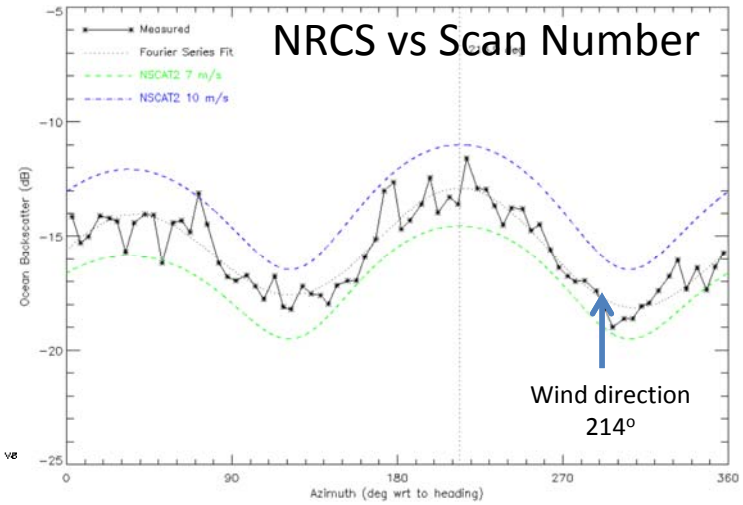
-> Scattering and attenuation at Ka-band.

HS3 5-6 Nov 2012 Flight Ocean Winds

Calibration ongoing

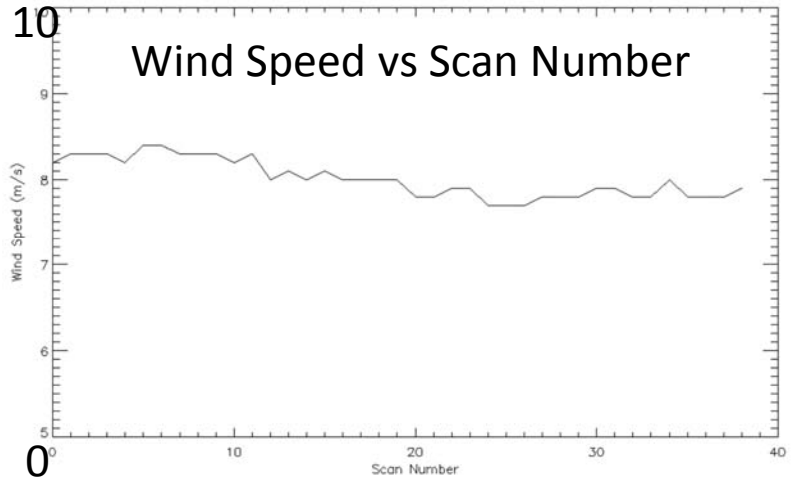


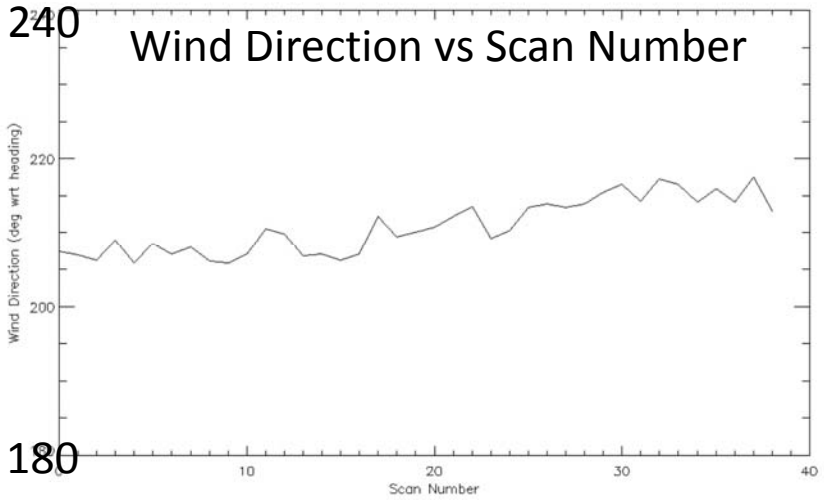
One radar scan near a buoy



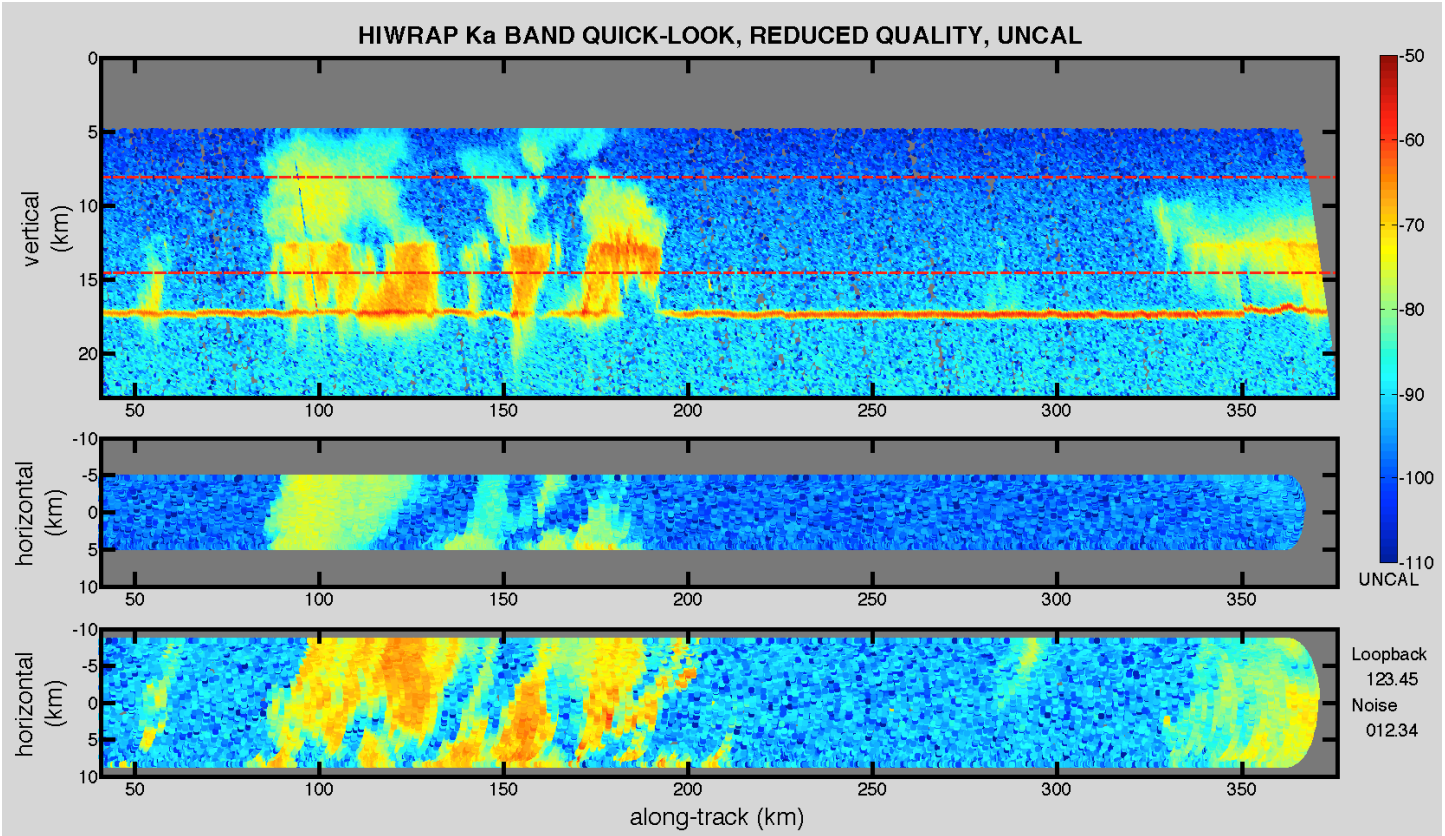
Calib. NRCS at 40° incidence angle bounded by 7 and 10 m/s NSCAT2 Geophys. Model Function

40 scans





Real-time Data



Future -> need more on board processing

- Wind products (gridded, VAD, ..)
- Doppler data for assimilation
- Ocean surface wind vector

Future Work

- Hardware upgrades
  - Ku-band transmitter power increase for 10 dBZ sensitivity improvement.
  - Onboard Pulse Pair processing.
- Ocean surface winds (Use 25 Sept 2013 HIWRAP data coordinated with NOAA43)
- Improved real-time data

Questions?