Evaluation of CYGNSS winds retrieved using an Extended Kalman Filter (EKF) and direct assimilation of Delay-Doppler Maps (DDMs)

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GNSS+R Workshop
Ann Arbor, MI
May 23-25, 2017
Overview

• Comparison of EKF / Level 2 winds just getting underway
  • no results yet (L2 data released on 5/18)
• Preparatory work for direct assimilation of Level 1 DDMs
  • Why assimilate DDMs?
  • Progress toward a modular DDM forward model
  • Example simulated DDMs from around Cyclone Enawo
• Summary
Why assimilate DDMs?

Measurement geometry

Hi-resolution DDM from raw Intermediate Frequency (IF) data

Low-resolution with 3x5 sampling region for L2 winds
Why assimilate DDMs?
Assimilate DDMs by use of Jacobian, $\mathbf{H}$ in VAM

$$(x_a - x_b) = \mathbf{B} \mathbf{H}^T (\mathbf{H} \mathbf{B} \mathbf{H}^T + \mathbf{R})^{-1} (y - Hx_b)$$

Data Assimilation:
Given

-- an observed DDM, $y$,
-- a simulated DDM, $Hx_b$,
-- an analytical Jacobian of the forward model, $\mathbf{H}$,
-- an estimate of background error covariance, $\mathbf{B}$,
-- an estimate of observation error covariance, $\mathbf{R}$,

the increment to the wind model $(x_a - x_b)$ can be computed.
Validate the forward model with measured CYGNSS L1 data

- HWRF analysis
- Gridded 90x90km wind field
- Antenna pattern
- Forward model
- Tx, Rx Geometries
- Simulated 17x11 DDM
- Jacobian H matrix
- CYGNSS L1a DDM
Cyclone Enawo
cyg02 – X

high wind speed
HWRF U10 ~ 40 m/s

cyg04 – X

cyg02 – X
high wind speed
HWRF U10 ~ 40 m/s

X – cyg05
moderate wind speed
HWRF U10 ~ 8 m/s

X – cyg02
flat wind field
HWRF U10 ~ 9 m/s
High and moderate wind speed examples
effect of CYGNSS antenna pattern
Enawo HWRF operational analysis, 1800 UTC 03062107

2.22 km resolution
HWRF nested domain (d02)
2.22 km resolution
HWRF nested
domain (d03)
High wind speed (~40 m/s) example:

Power Bias and differences in DDM pattern will effect Data Assimilation results.
-- variational data assimilation requires mean unbiased (observation – model) statistics
Moderate wind speed (~8 m/s) example:

CYGNSS DDM

Forward Model: Isotropic Antenna

Forward Model: updated Antenna
Low wind speed example
effect of CYGNSS antenna pattern
Enawo HWRF d02 operational analysis, 1800 UTC 03062017

HWRF 13.88 km resolution domain (d02)
Enawo HWRF d02 operational analysis, 1800 UTC 03062017

HWRF 13.88 km resolution domain (d02)
cyg05 – X
near-calm wind speed
HWRF U10 ≤ 2 m/s
Near-Calm wind (< 2 m/s) example:

CYGNSS DDM

Forward Model: Isotropic Antenna

Forward Model: updated Antenna
Flat wind field (near uniform) example
asymmetric CYGNSS DDMs
Flat wind field (~9 m/s) asymmetric example:

- CYGNSS DDM
- Forward Model: Isotropic Antenna
- Forward Model: updated Antenna
Potential sources of differences between observed and simulated DDMs:

• transmitter power / gain / eirp are not precise
• Receiver antenna pattern is not accurate
• HWRF differs from the real wind
• forward model contains errors (empirical model between MSS and wind)
• The observed DDM is under refinement
Summary

• Exercising a path to generate simulated DDMs from NWP wind fields
  — An important step toward data assimilation
• Qualifying the forward model results
  — Resolve L/R difference between observed and simulated DDMs
  — Examine a larger population
• Develop a software path forward for modularizing
• Deploy forward model inside a 2-dimensional variational vector wind field model.
  • Compare to results assimilating L2 CYGNSS winds