CYGNSS Science Team Meeting, 10/21/2015

Assimilation of GNSS-R Delay-Doppler Maps into Hurricane Models

Award under NASA GNSS Remote Sensing Science Team
(ROSES-2015 A.26)

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Proposal Summary

- Response to NASA GNSS Remote Sensing Science Team (ROSES-2015 A.26)
- 4 year - Start date Dec 31, 2015
- University of Miami (CIMAS) – Purdue Collaboration
- UK Met Office (John Eyre) and KNMI (Ad Stoffelen) collaborators
- Two Principal Goals:
  - Develop optimal assimilation of GNSS-R data into Hurricane models
  - Improve L-band bistatic model function

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Background & Motivation

- CYGNSS 25 km resolution – features may be smaller than that
- Measurements only along specular-point tracks
- Level 1X data product – Delay Doppler Map – convolution of surface roughness with C/A code ambiguity function (limiting resolution)
- Present approach – "invert" the DDM in some way – then assimilate wind speed
- Incorporates many assumptions:
  - Scattering model
  - Uniformity over 25 km region
  - Winds – to MSS relationship
- Similarity with GNSS Radio-occultation – learn from that experience

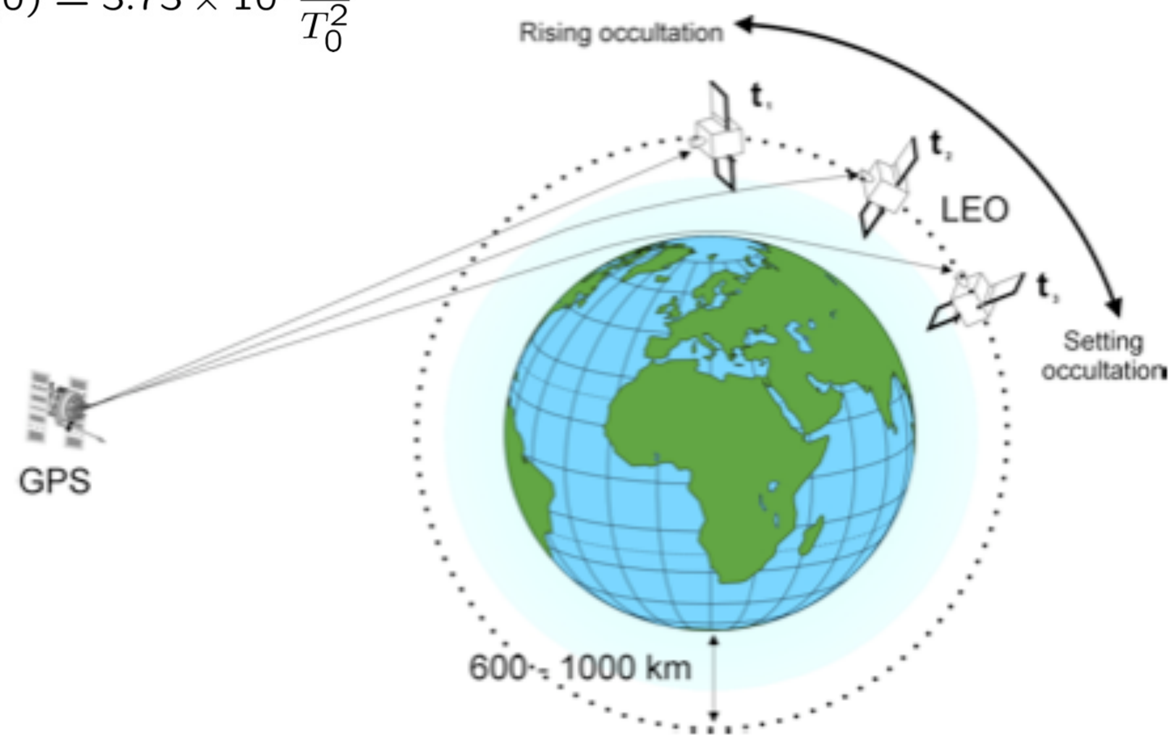
GNSS-R vs. GNSS-RO

- Radio-occultation (-RO):
  Water vapor -> Refractivity -> bending angle

$$N_d(0) = 77.64\frac{P_0}{T_0}$$

$$N_w(0) = 3.73 \times 10^5 \frac{e_0}{T_0^2}$$

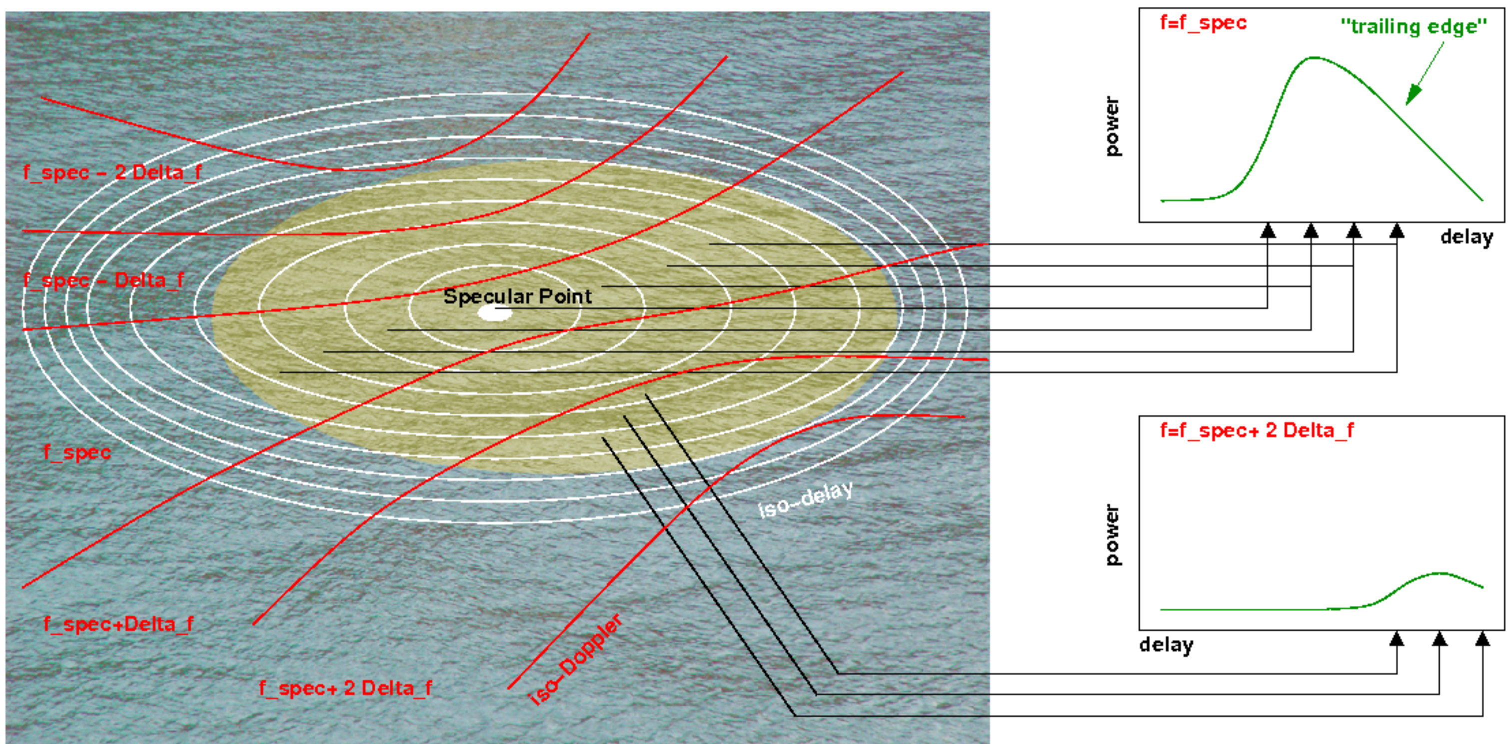
$$\rightarrow \quad \alpha(a) = 2a\int_a^\infty \frac{dn}{ndx}\frac{dx}{\sqrt{x^2 - a^2}}$$



GNSS-R vs. GNSS-RO

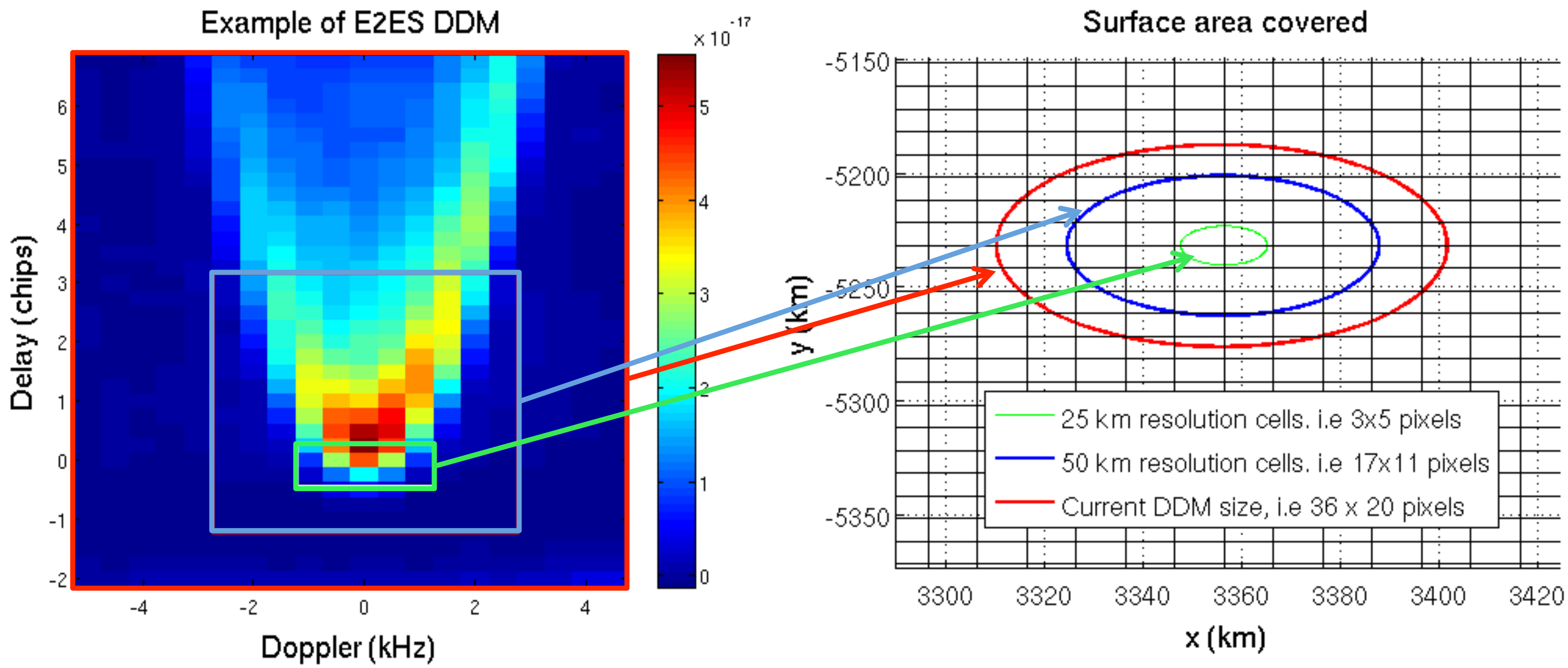
- Reflectometry (-R):
  Winds -> MSS -> DDM

$$\sigma_i^2 = 0.45\left(0.003 + 0.00508 f(U)\right), \rightarrow R(\tau, f) = C \iint \frac{|G(\vec{\rho})|^2}{4\pi R_I^2 R_S^2} \sigma_0(\vec{\rho}) \left|\chi(\tau, f, \vec{\rho})\right|^2 d\vec{\rho}^2$$



Problem Statement

- 25 km resolution requirement: **3 X 5 pixels** used in L2 retrieval
- Downloaded to the ground: **17 x 11 pixels** around specular point
- SGI-ReSI Receiver – Much larger DDM generated on board



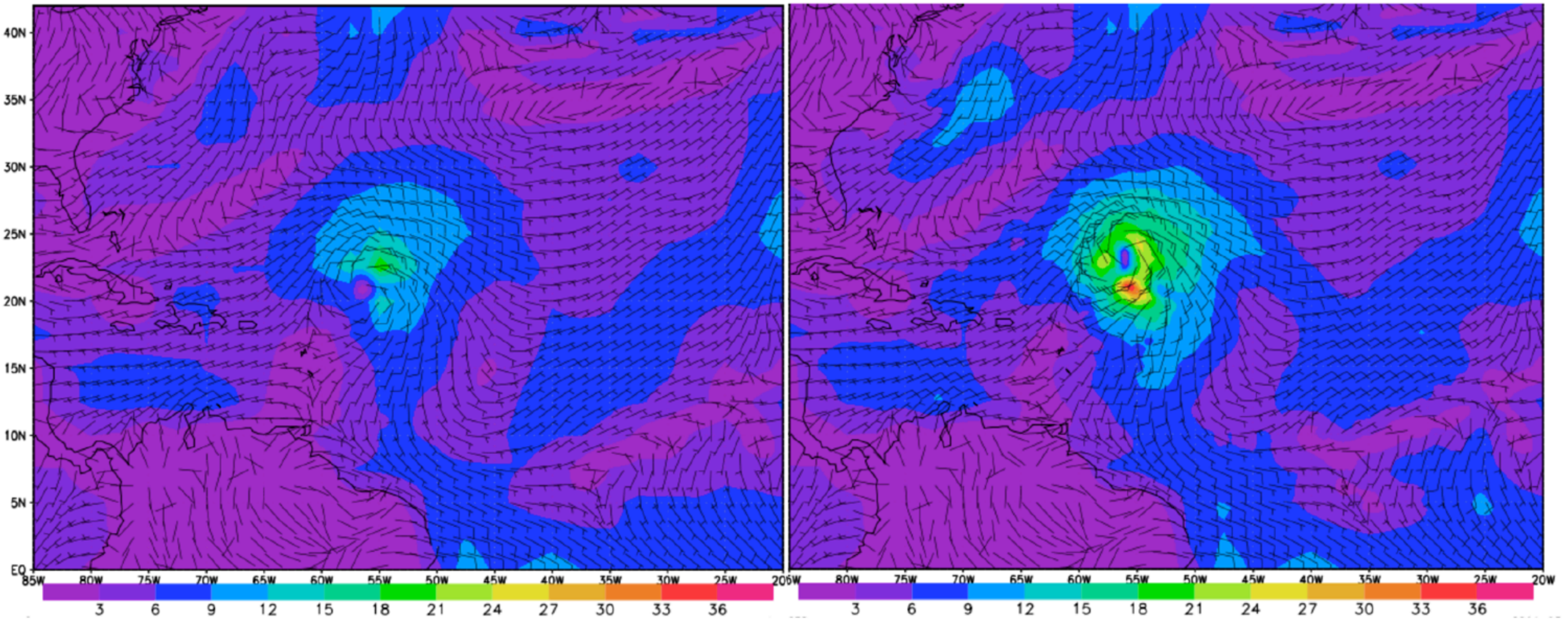
Model Assimilation

- DDM model will be used to derive an observation operator (forward model) and adjoint (Jacobian) at discrete steps in delay and Doppler
- Nominally – work in a "state" of scattering cross-section – linear in the forward model
- VAM – Variational Analysis Method – 2D VAR ocean surface wind assimilation method - Integrated with NCEP's HWRF

$$J(\mathbf{x}) = \frac{1}{2}\left(\mathbf{y} - h(\mathbf{x})\right)^T \left(\mathbf{P}_O + \mathbf{P}_h\right)^{-1} \left(\mathbf{y} - h(\mathbf{x})\right) \frac{1}{2}\left(\mathbf{x} - \hat{\mathbf{x}}(-))\right)^T \mathbf{P}_{\hat{\mathbf{x}}}^{-1} \left(\mathbf{x} - \hat{\mathbf{x}}(-)\right) + J_c(\mathbf{x}) \qquad (8)$$

- Nonlinearities in DDM will be incorporated into VAM first – without need to modify HWRF.
- OSSE will be used study different scales – using simulated CYGNSS data

Model Assimilation



Evaluation of Optimal Data for Assimilation

Initial look: three levels of data:

- CYGNSS Level 1b DDM
- Bistatic scattering cross-section extracted from EKF
- CYGNSS Level 2 wind product

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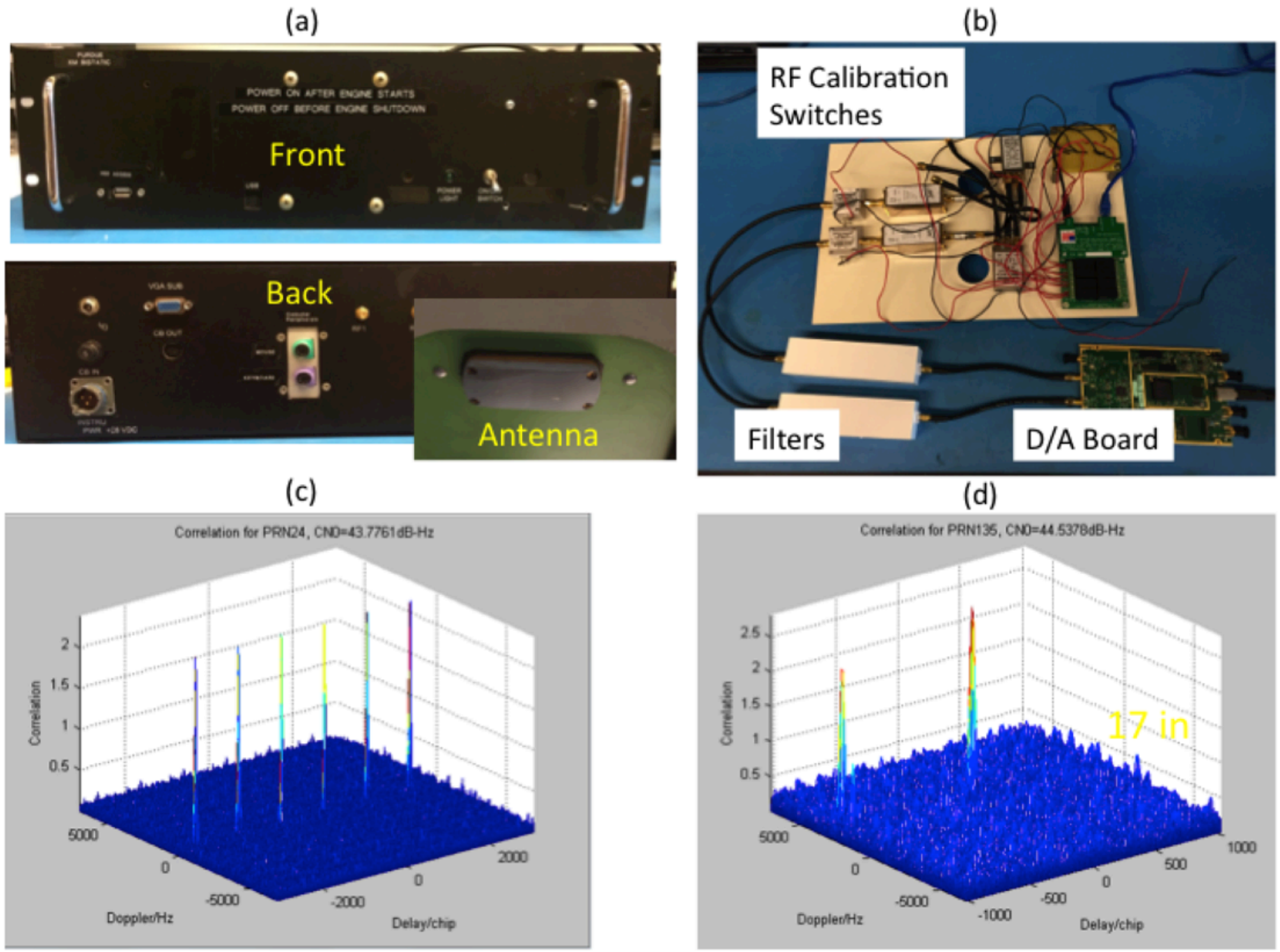
Improvement of L-band model functions

- Retrievals of winds – empirical model from Katzberg, et al.
  - Derived from > 10 years of airborne experiments – C/A code single-channel DMR.
  - Isotropic slope PDF
  - Limited to high-elevation satellites
  - Parameterized using wind only.

- Upgrade of S-band signals-of-opportunity (SoOp) recorder for flight on NOAA P-3
- Software-Defined Radio (SDR) approach to extract all satellites in view, including Galileo.
- Larger experimental data set for fitting model functions.

Improvement of L-band model functions



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Proposed Project Schedule

				2016				2017				2018				2019		
			PY1				PY2				PY3				PY4			
			Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Task 1	Purdue/NOAA	Collect wideband GNSS data				■	■											
Task 2	Purdue	Develop Bi-directional Empirical PDF Model					■	■	■	■								
Task 3	Purdue/Miami	Derivation of forward model and adjoint (V1)	■	■	■													
Task 4	Miami	Integration of forward model			■	■	■	■	■	■	■	■						
Task 5	Purdue/Miami	Derivation of forward model and adjoint (V2)							■	■	■	■	■					
Task 6	Miami	OSSE study of assimilation variables										■	■	■	■			
Task 7	Purdue/Miami	Processing of first CYGNSS data								■	■	■	■	■	■	■	■	
Task 8	Purdue/Miami	Prepare final report and recommendations															■	■
Events		First CYGSS Data						■										
		P-3 campaign				■	■			■	■			■	■			