Jet Propulsion Laboratory
California Institute of Technology

DopplerScatt Wind Retrieval

Alex Wineteer, Bryan Stiles, Ernesto Rodriguez

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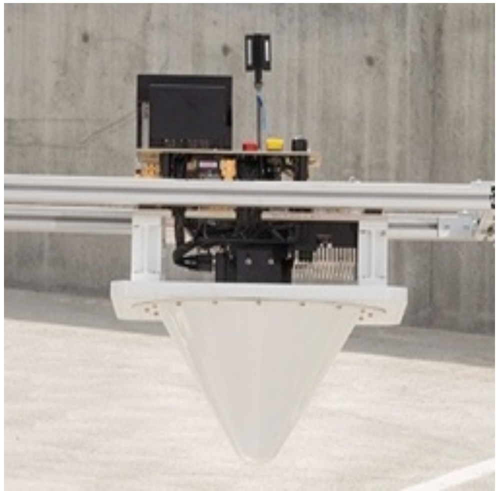
DopplerScatt Overview

- Airborne Ka-band Doppler scatterometer for the simultaneous measurement of ocean vector winds and currents from a single, spinning antenna.
- Vector winds are measured via surface backscatter (this talk)
- Vector surface currents are measured via pulse pair Doppler measurements (Ernesto’s talk)
- Flown for the last year over the Columbia river plume, Monterey Bay, Lake Tahoe, and recently the Mississippi river delta and Lake Pontchartrain.
- Technology basis for next generation space-borne Doppler scatterometer.



Scatterometer Wind Retrieval Overview

- DopplerScatt wind retrieval operates similarly to heritage NASA spinning scatterometers (QuikSCAT, RapidScat).
- Typical technique:
  - Search possible backscatter response curves (GMF) for measured values of backscatter in wind speed and wind direction space.
  - Ideally, the model backscatter closest to the measured backscatter corresponds to the correct wind speed and direction.
  - Often, spatial filtering with model direction nudging is necessary to help select the correct wind speed/direction.

- A new DopplerScatt winds processor has been developed with a new Ka-band geophysical model function (GMF).

DopplerScatt Wind Retrieval

Overview

- Wind retrieval operates using 200 meter L2A gridded data.
  - Backscatter, incidence, azimuth, flags.
- For each cell:
  - Data is averaged into four “looks.” Two fore and two aft.
  - A coarse minimization of the objective function is done over all wind speed and direction possibilities.
  - Four ambiguous speeds/directions are chosen that best minimize the objective function.
  - A fine minimization of the objective function is done nearby each of the ambiguities.
  - Four ambiguous directions and speeds are returned for each cell.
- Upon completing cell by cell wind retrieval:
  - A grid is initialized with the most likely ambiguous direction for each cell.
  - Median filtering is done during which a 7x7 median is taken about each cell and the ambiguity closest to the median for each cell is chosen.
  - Median filtering procedure is iterated until few changes occur.
  - Final gridded winds are output.

DopplerScatt GMF

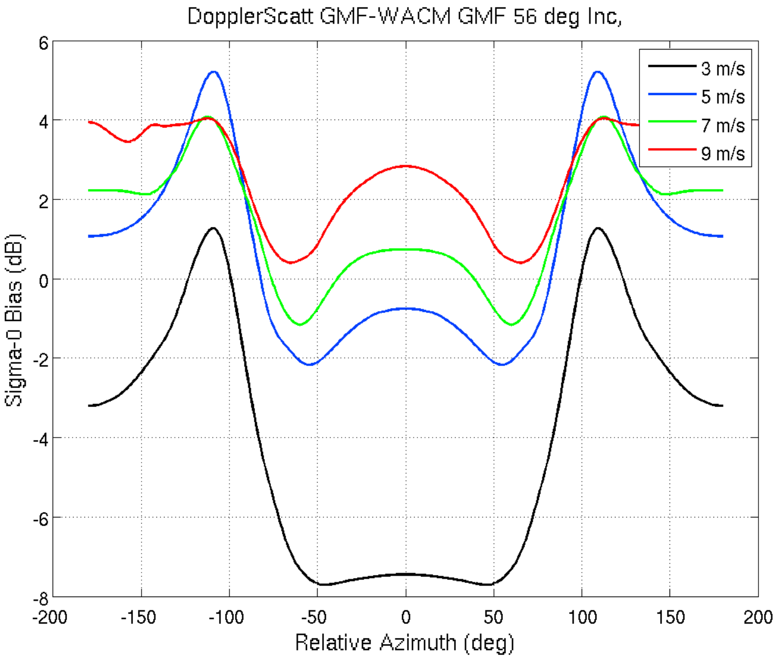
Development

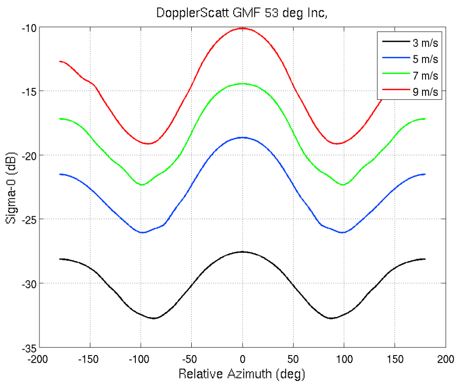
- The DopplerScatt GMF relates measured radar backscatter to wind speed, relative wind direction, and measured incidence angle.
- The GMF was trained using a neural network approach.
  - Multiple network topologies used to help smooth data prior to fitting the final network.
- Training was done on all currently available ocean data (Monterey, Oregon).
  - Flagging done for land, 5 dB down on antenna pattern.
- With a neural network made, a lookup table was generated for portability.
  - The lookup table is transparently interpolated when called.

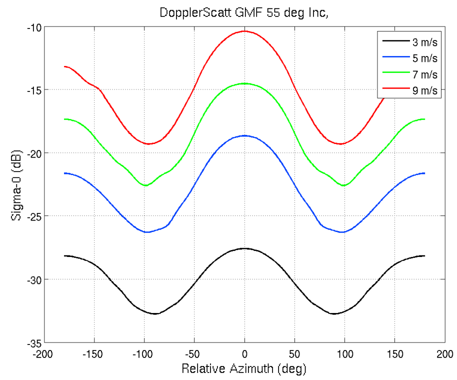
DopplerScatt GMF

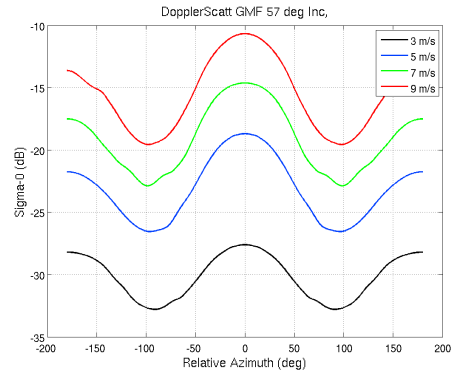
GMF Plots

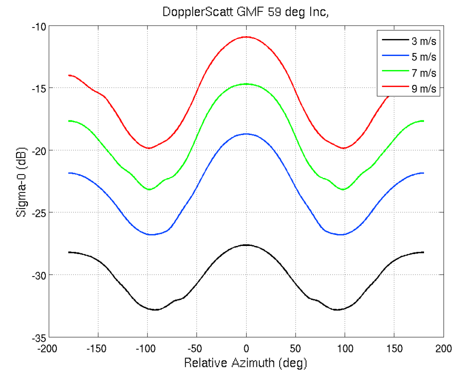
- Overall the GMF makes sense, especially given a lack of high wind speed training data.
- Compared to the WACM GMF (Masuko+6dB), the DS GMF is more spread out in backscatter. Low wind speeds have lower backscatter than WACM and high wind speeds have higher backscatter than WACM.
- Looking at recent wind retrievals of a deployment last week with high winds, the GMF saturates too early (predicts high winds too often).
  - Fixable with additional training data.











DopplerScatt Wind Retrieval

Algorithm – Objective Function

- The DopplerScatt objective function consists of two parts. One for backscatter (speed) and the other for direction. Concentrate here on the first part.
- Using the GMF, a calculated backscatter is obtained for an input grid of wind speed and direction with measured incidence.
- The left side of the objective function computes the difference between calculated backscatter and measured backscatter, then divides it by the variance in backscatter.
  - This is akin to finding the likelihood that the correct wind speed and direction have been input when calculating backscatter.
  - These likelihoods are computed for each measurement *i* in the cell and summed.
  - Ideally, minimizing this function in wind speed/direction space gives the correct winds.
  - In practice, noise sometimes makes this difficult.

$$f(u,p) = \sum_{i}^{n} \left(\frac{\sigma_{0_i} - \sigma'_{0i}(i,\phi)}{\sigma_i} \right)^2 + \sum_{i}^{n} \left(\frac{\phi_m - \phi}{\sigma_\phi} \right)^2$$

DopplerScatt Wind Retrieval

Nudging

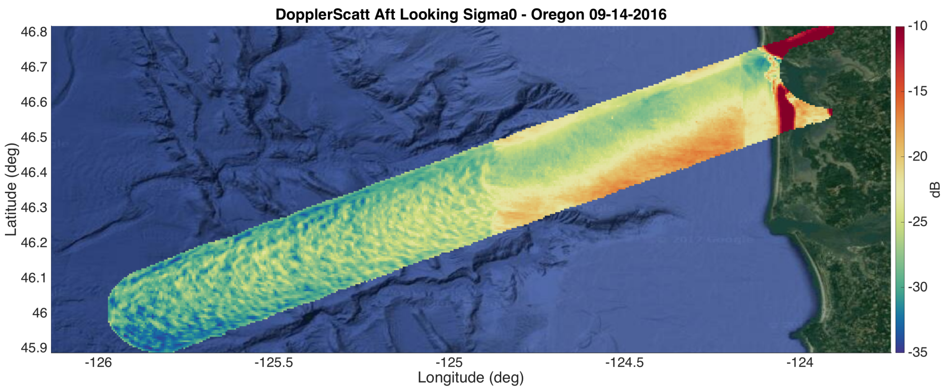
- Depending on availability, either model wind speeds or spatially averaged DopplerScatt surface currents are used for nudging.
- A second parameter is added to the typical scatterometer objective function.

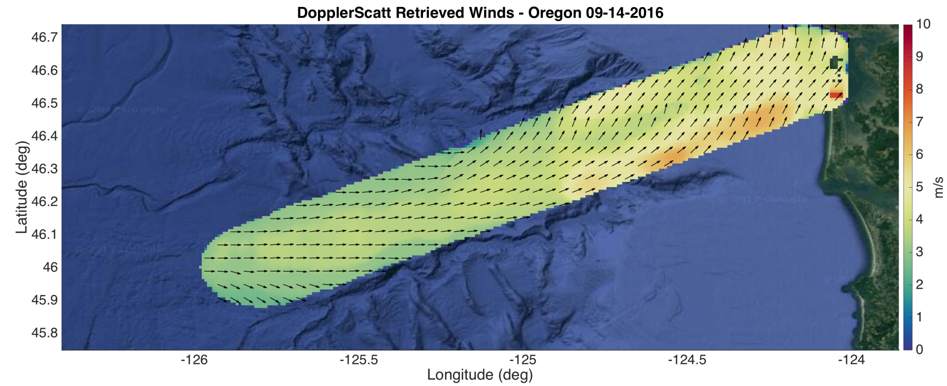
$$f(u,p) = \sum_i^n \left(\frac{\sigma_{0_i} - \sigma'_{0i}(i,\phi)}{\sigma_i} \right)^2 \boxed{+ \sum_i^n \left(\frac{\phi_m - \phi}{\sigma_\phi} \right)^2}$$

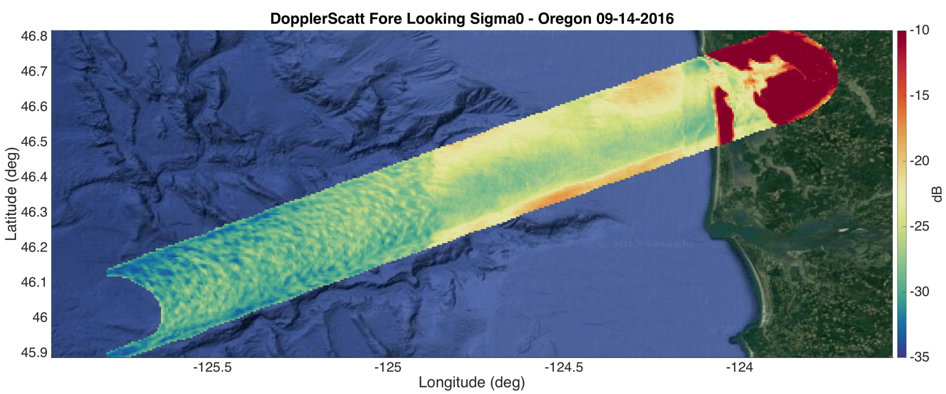
- This second parameter helps to nudge the overall objective function towards the "nudge wind direction," $\varphi_{m.}$ Plain φ is the trial wind direction.
- The expected wind direction "variance," σ_φ in the denominator is a tuned parameter, set such that the nudge term gives about 5-10% contribution on average to the overall objective function.
- This helps ensure we are not just picking the nudge direction, but still taking it into account.

DopplerScatt Wind Retrieval

Backscatter to wind speed



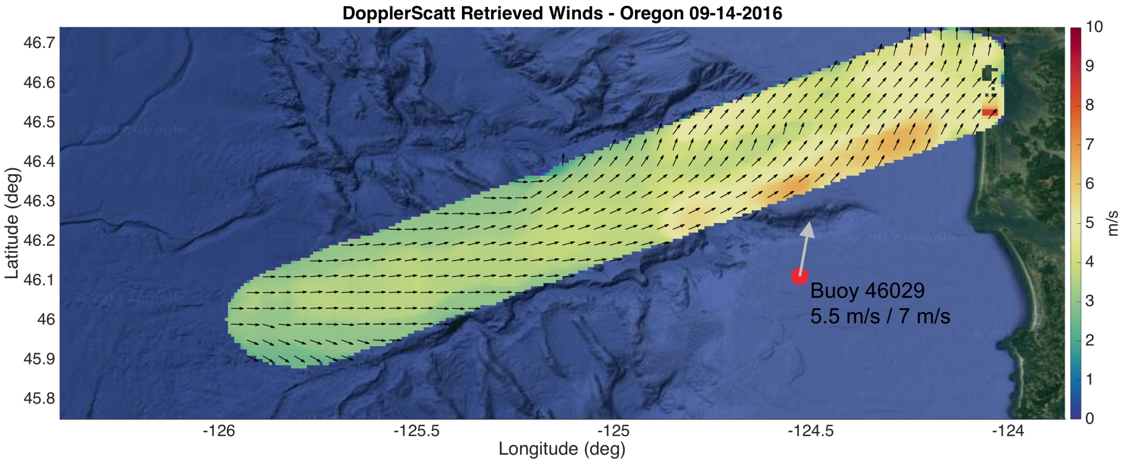


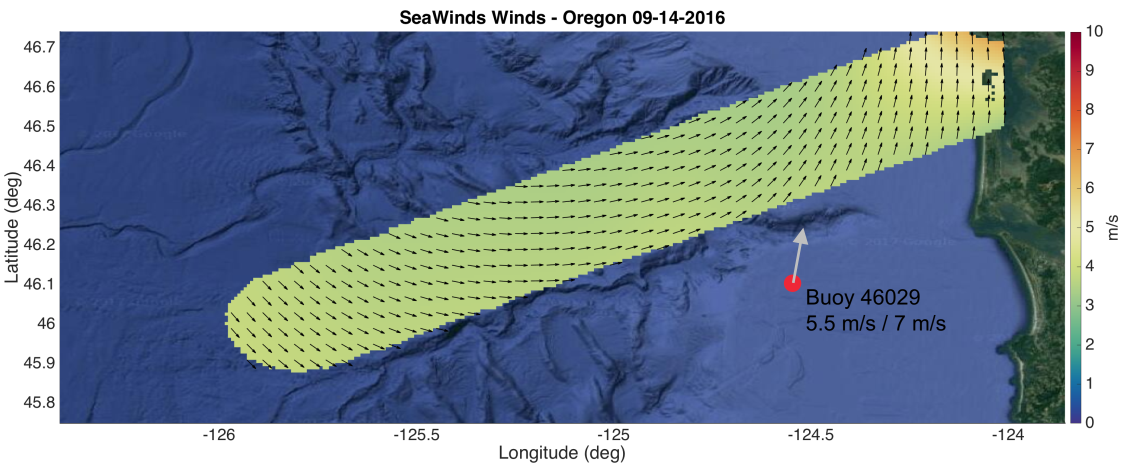


- Examples shown from Oregon data just off the coast of the Columbia river.
- There should be a front moving through at about -124.8 deg latitude.
- Areas of higher backscatter typically correspond to areas of higher winds.

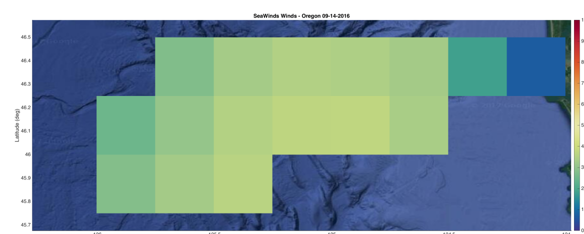
DopplerScatt Wind Retrieval

Retrieved winds vs SeaWinds

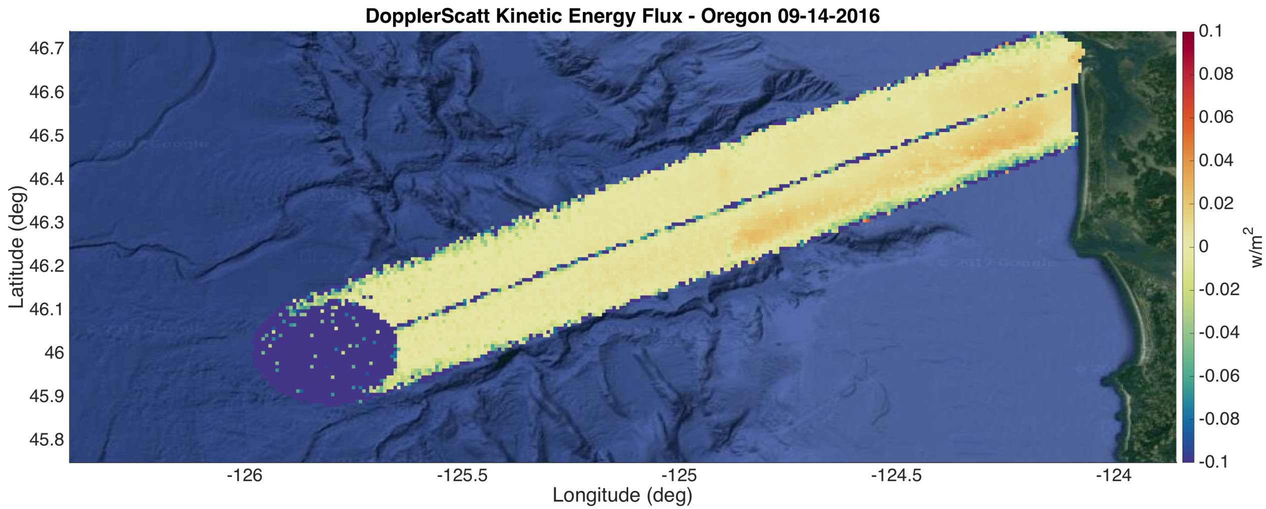




- NOAA SeaWinds data set compared to DopplerScatt winds.
- DopplerScatt has much higher resolution, less smoothing. (200m vs .25 degree)
- This SeaWinds time step is slightly behind in time – the lower left corner should be closer to eastbound in direction.
- Interesting areas of concentrated high winds to the north-east.
- There is a front moving through at about 124.8 west longitude.
  - Winds blowing to the east in the west and to the north in the east.
- Buoy 46029 shows 5.5 m/s sustained winds blowing towards about 15 degrees north-east. Gusts of up to 7 m/s – consistent with the areas of concentrated high winds in DS!



DopplerScatt Kinetic Energy Flux



- DopplerScatt is unique in that it can measure high resolution simultaneous ocean vector winds and currents.
- This means that the winds and currents are not decorrelated in time!
- We can compute instantaneous kinetic energy flux.
  - Instantaneous kinetic energy flux into the ocean tends to be much larger in summation due to correlation of wind and current directions.

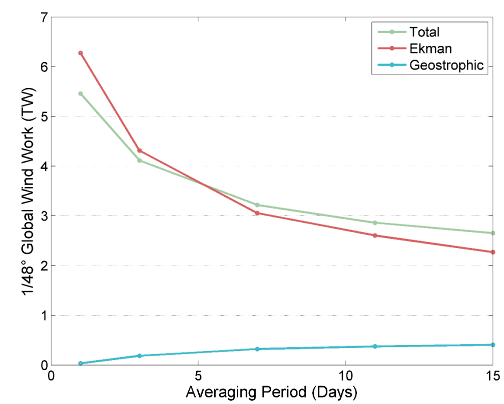


Figure 27: The effect of averaging period on global wind work. Data used from 1/48th degree ECCO2 MITgcm model.

Future Work

- Improve GMF with addition of more (higher wind speed) data.
- Make algorithm operational and faster.
- Continue validation effort on both GMF and wind retrievals.

Thanks!