Application of High Resolution SAR-Measured Winds to Wind Power Plant Siting

Frank Monaldo, Donald Thompson, and Nathaniel Winstead

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APL
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Calibrated SARs Can Make Quantitative Measurements

- ***"Louis Pasteur's theory of germs is ridiculous fiction."*** **− Pierre Pachet, Professor of Physiology at Toulouse, 1872.**
- ***"Heavier-than-air flying machines are impossible."*** **− Lord Kelvin, 1895.**
- ***"Who the hell wants to hear actors talk?"*** **− H. M. Warner, Warner Brothers, 1927.**
- ***"A rocket will never be able to leave the Earth's atmosphere."*** **− New York Times, 1936.**
- ***"I think there is a world market for maybe five computers."*** **− Thomas Watson, chairman of IBM, 1943.**
- ***Spaceborne SARs do not make quantitative measurements*****.**

Sometimes the conventional wisdom is wrong.

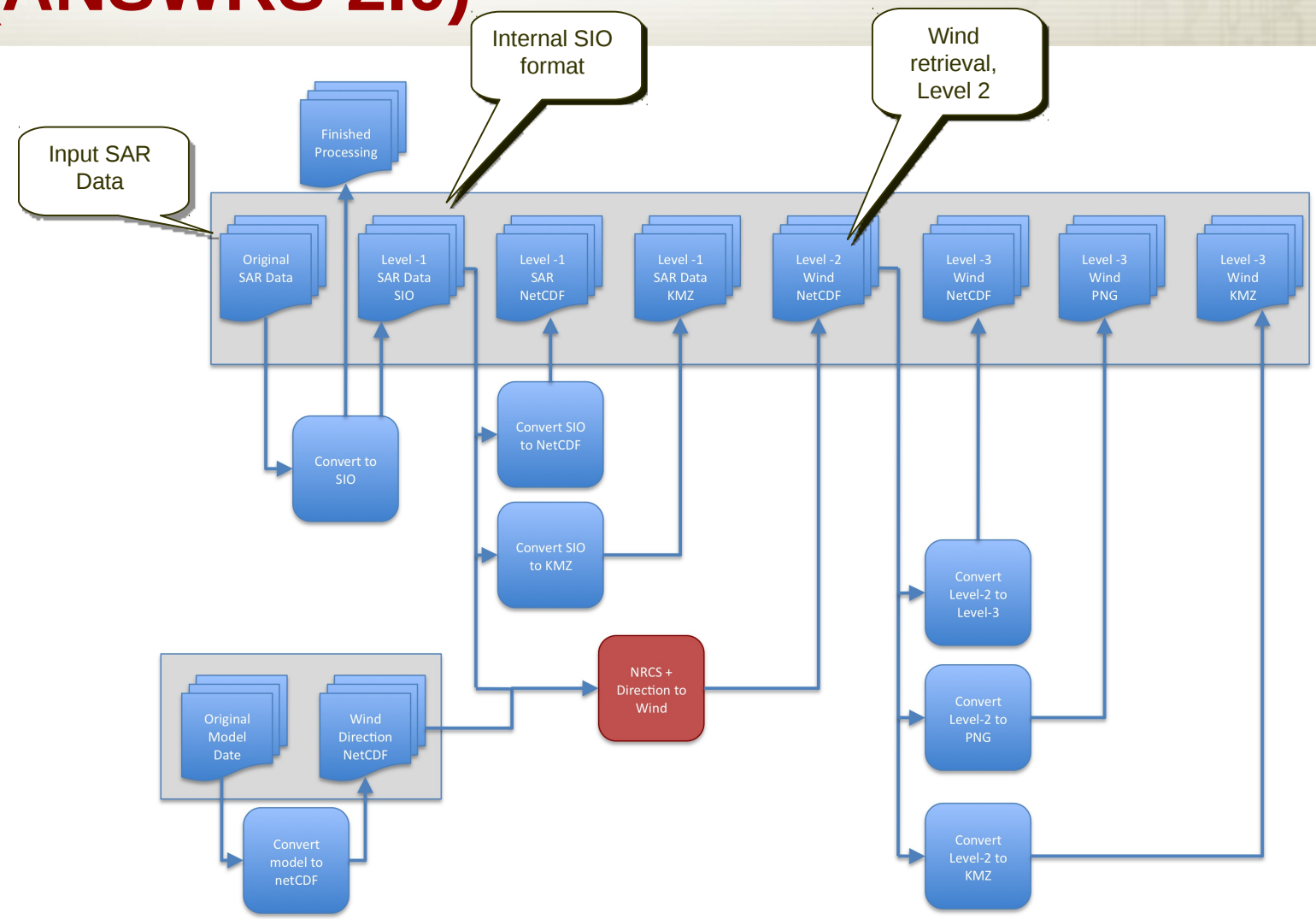
Premise

- High-resolution with retrieval is well validated, particularly at C-band.
  - Based on over 10-years of Radarsat-1 and 9 years of Envisat data. Wind speed differences of 2 m/s with respect to buoys, and less than1.8 m/s with respect to QuikSCAT.
- Mature techniques and software for bulk processing.
- Moving wind retrievals to from research to operations.
- Re-processing of real-time Radarsat data.

Outline

- Describe the ANSWRS system for operational processing.
- Describe applications to offshore wind power assessment.
- Application to wind climatology off the east coast of Maryland.
  - Ten years of Radarsat-1 data.
  - Normalization.
  - Wind speed as a function of distance from shore.
  - Wind power as a function of distance from shore.

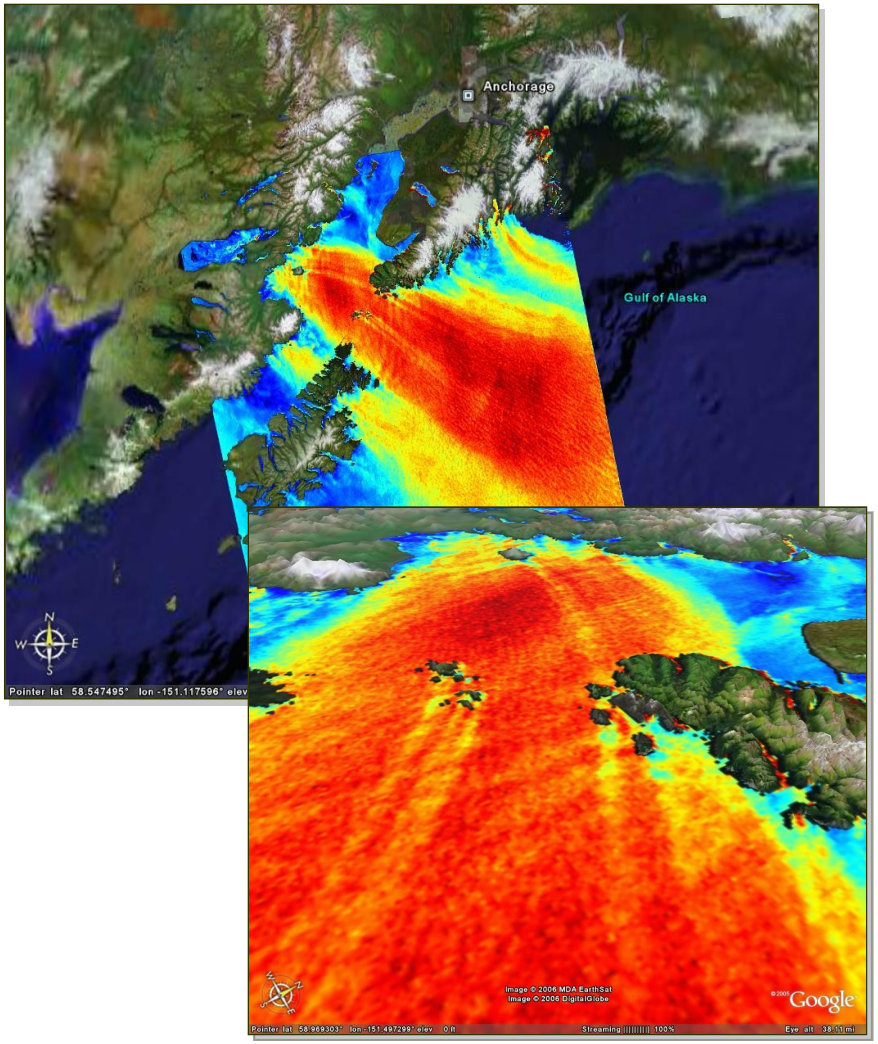
APL/NOAA SAR Wind Retrieval System 2.0 (ANSWRS 2.0)

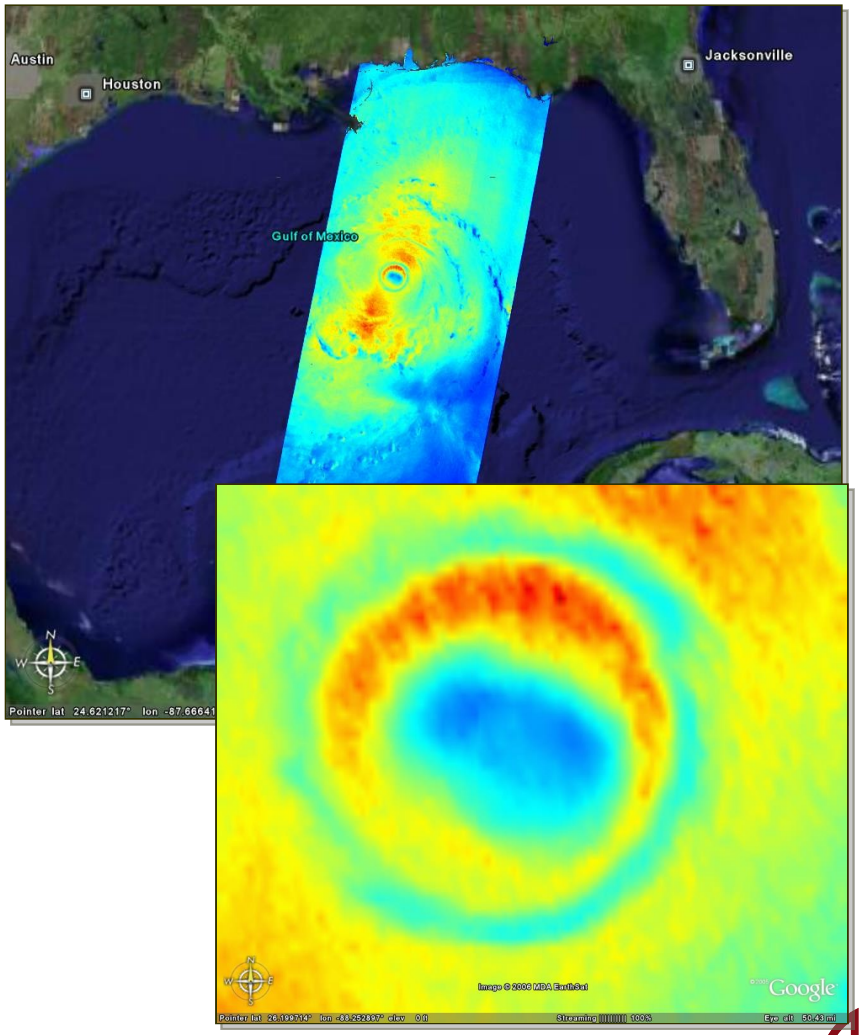


Key features

- Once an ingester is written for any new SAR system, all subsequent processing is identical.
- Scientific output in netCDF standard.
- Easy to view KMZ and PNG image output.
- Easy to switch in and out different wind vector sources.
- Easy to change geophysical algorithms.
- Level-2 netCDF file has sufficient information to re-compute the inversion.
- All processing determined from a control file.
- Easy to add on different retrievals systems: waves, ship detection.

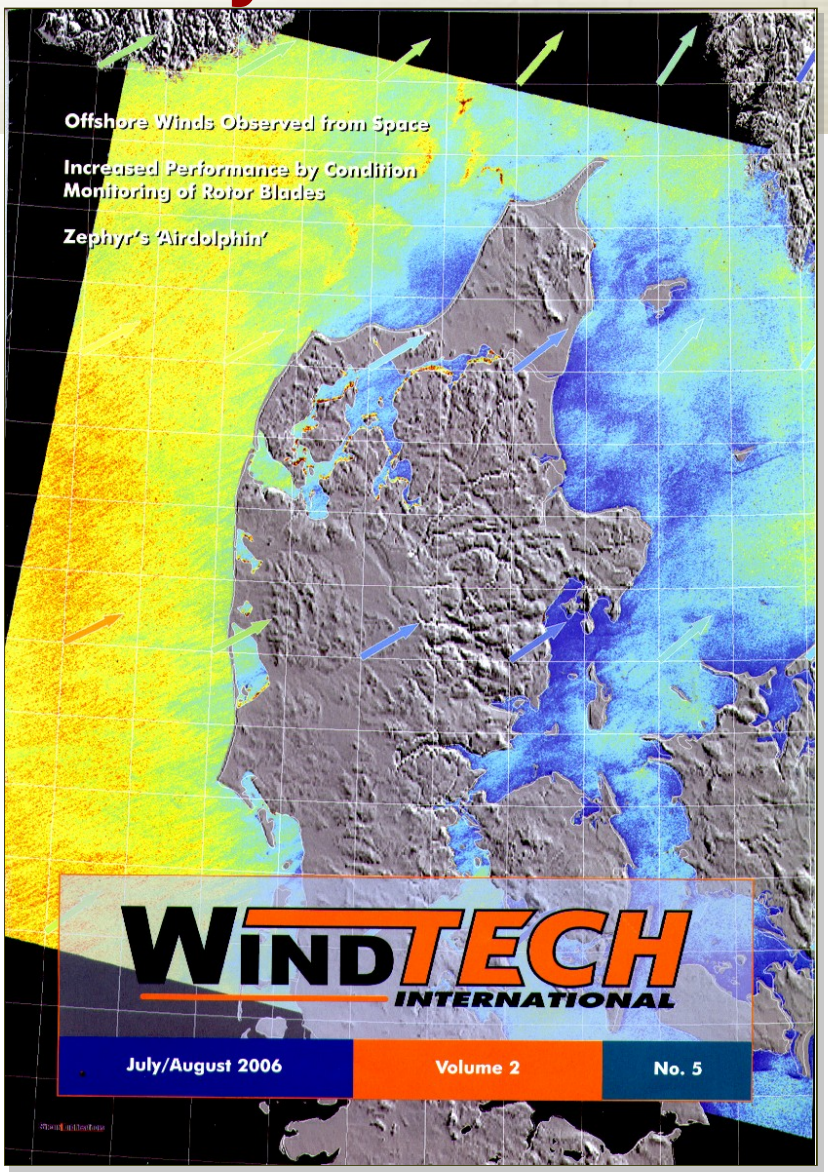
Sample ANSWRS output



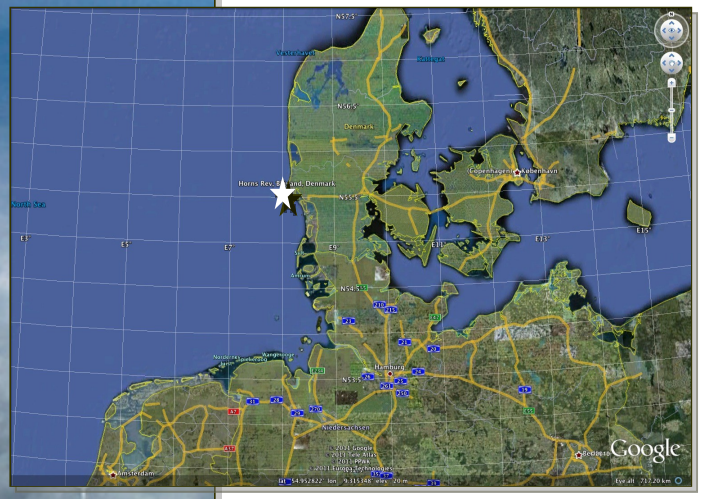


Realization of applicability for offshore wind power

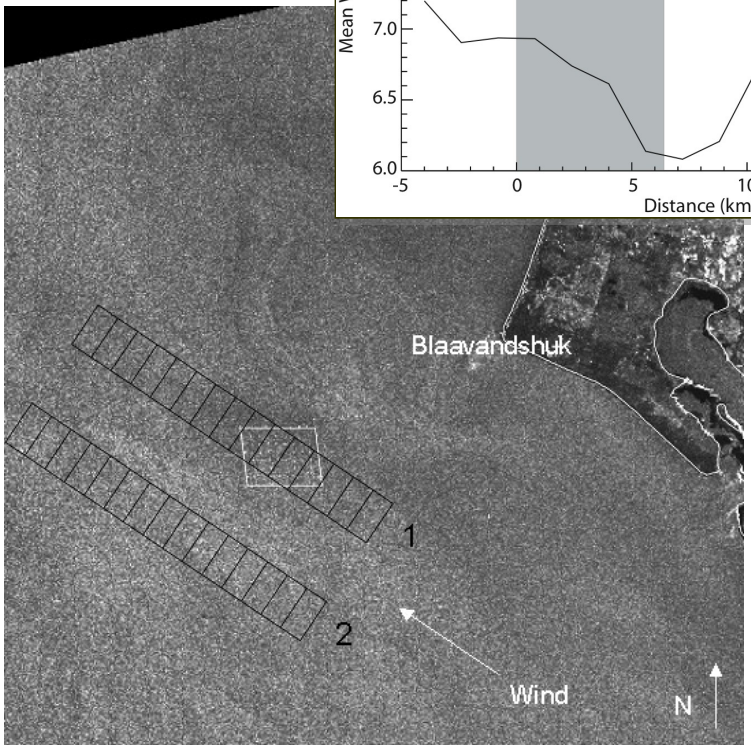
- Denmark produces 20% of its electricity from wind power.
- Goal to produce 50%.
- Used to assess offshore power production potential
- Risø National Laboratory licenses ANSWRS for wind field climatology

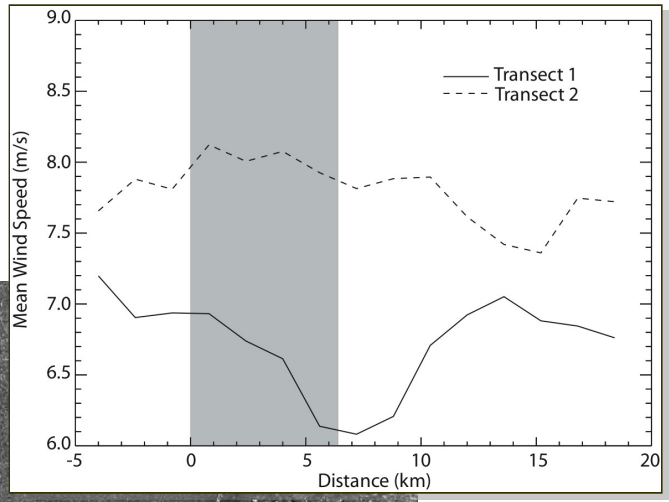


Assessing the impact of one wind turbine on another: Horns Rev

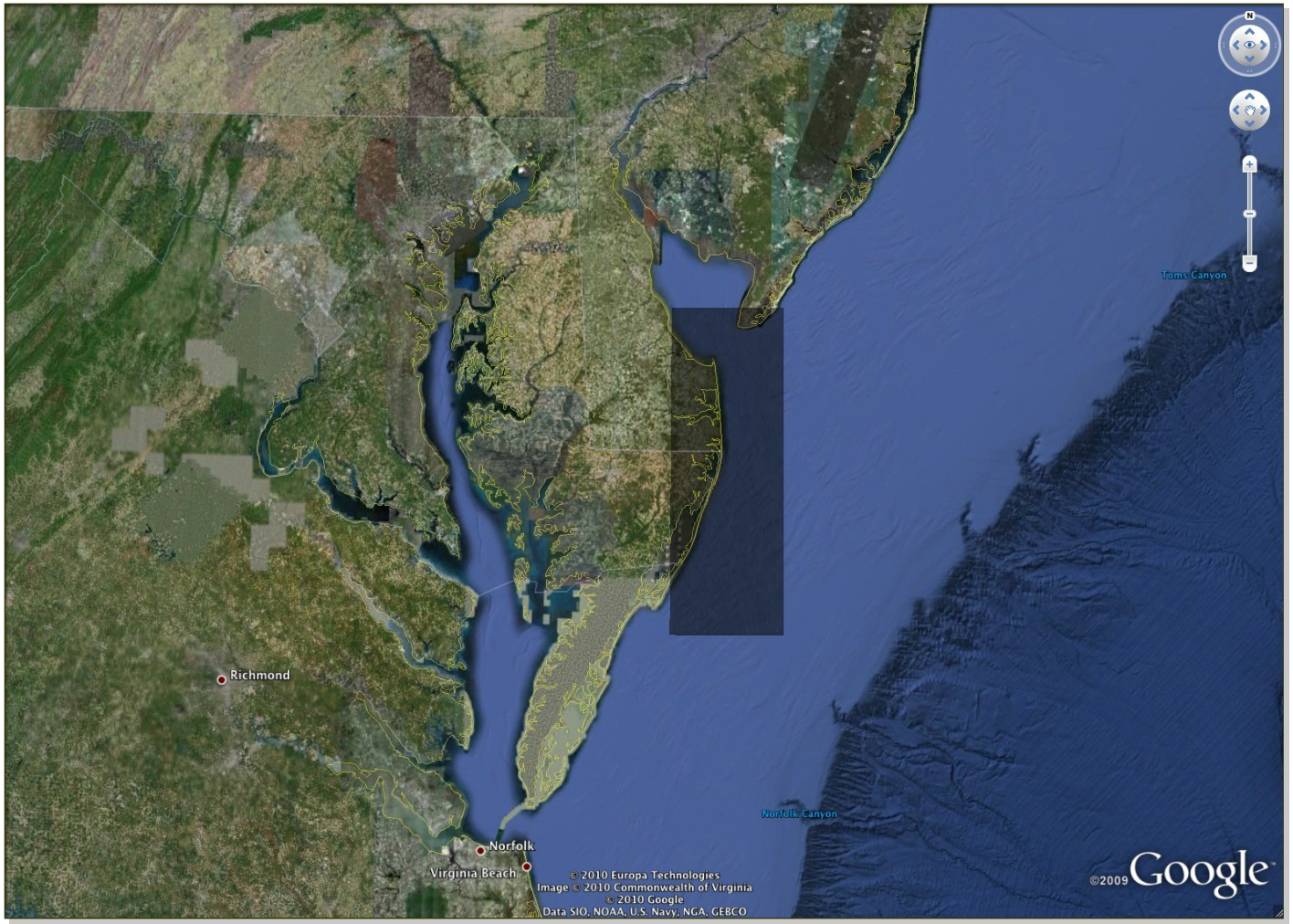


Drop in wind speed across Horns Rev



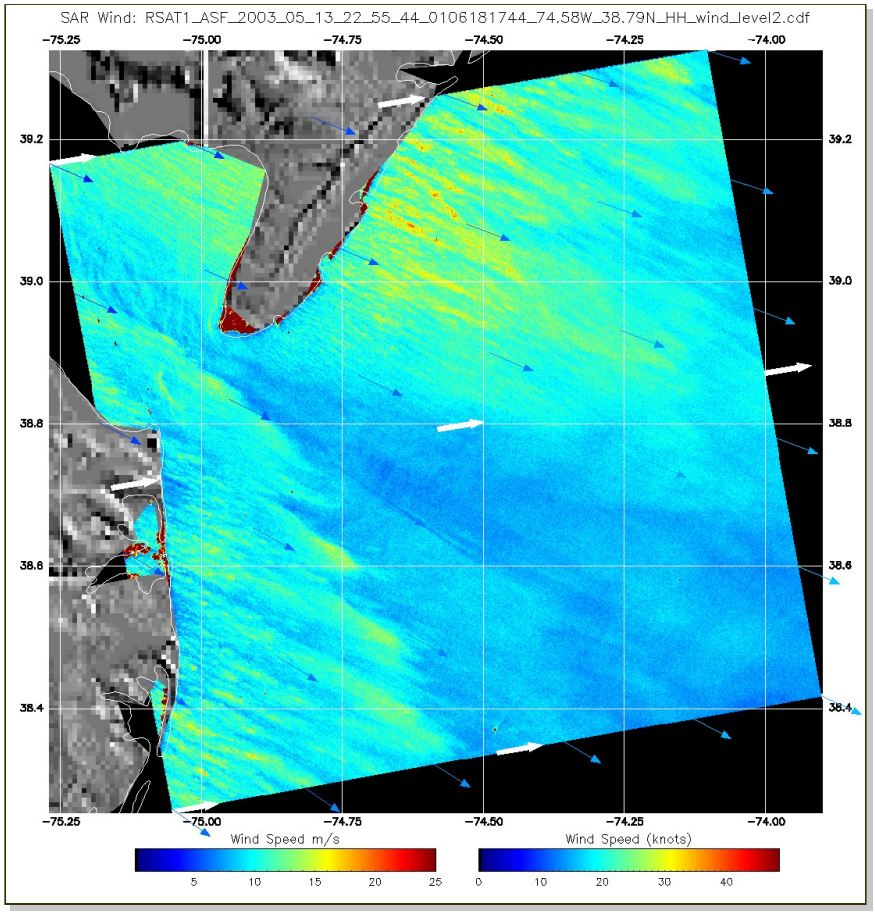


State of Maryland

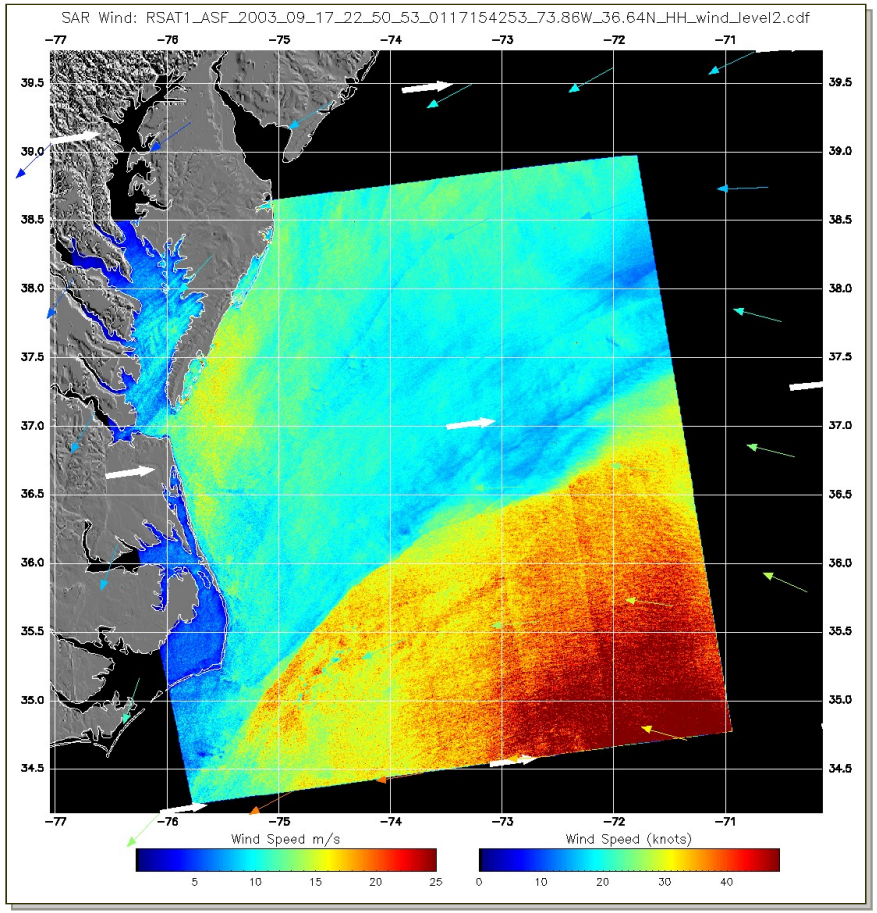


75.30°W to 74.75°W
37.75°N to 39.00°N

Sample images.
Data sample into 250 m pixels



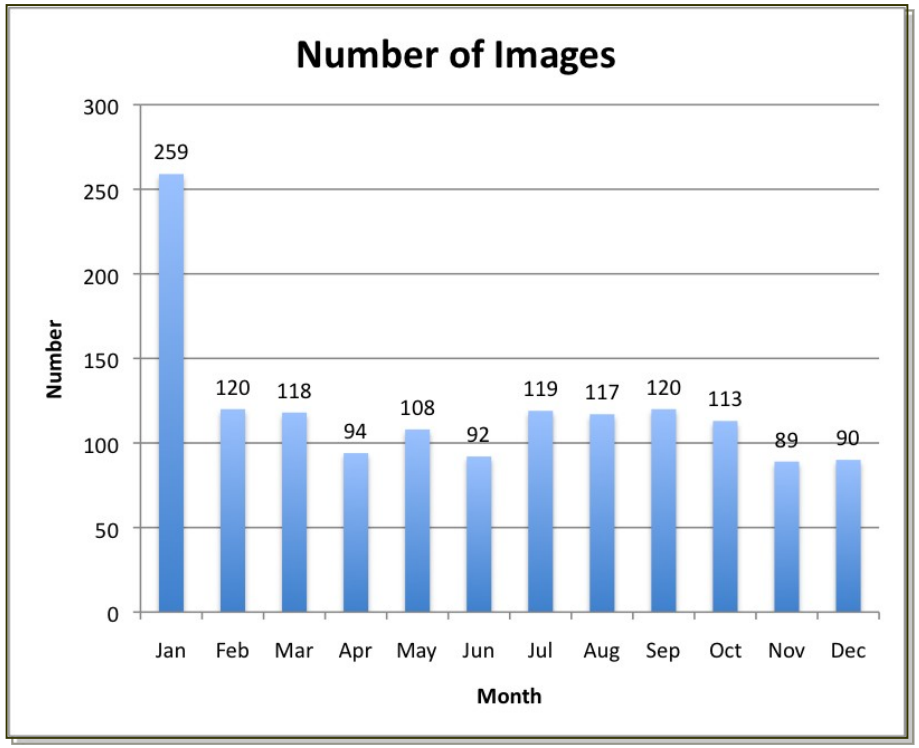
Wide Swath 50 m resolution



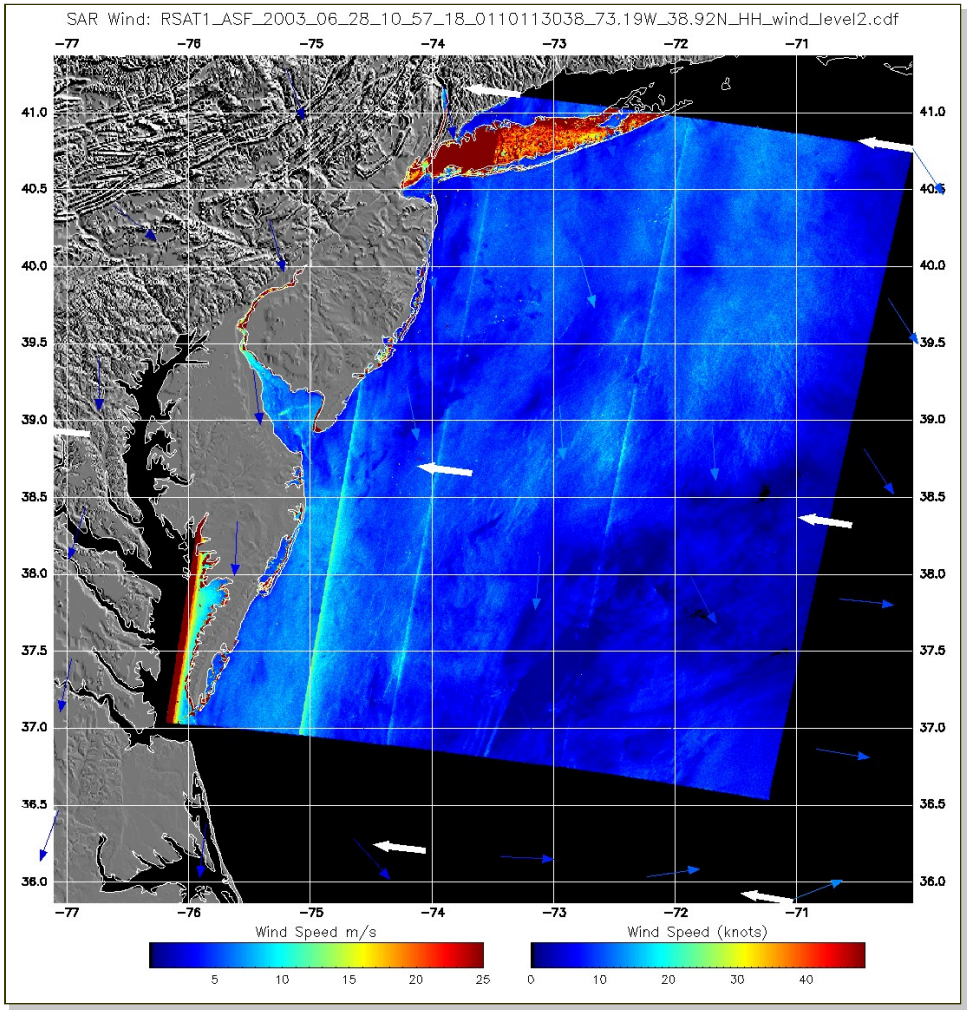
Standard Mode24 m resolution

Temporal sampling issues

Year	Number	Processed	Used
1996	10	9	5
1997	29	31	15
1998	126	119	118
1999	137	137	134
2000	141	140	283
2001	214	205	180
2002	223	215	195
2003	162	144	133
2004	89	89	76
2005	73	69	63
2006	145	145	126
2007	128	130	93
2008	18	18	18
Total	1495	1451	1439

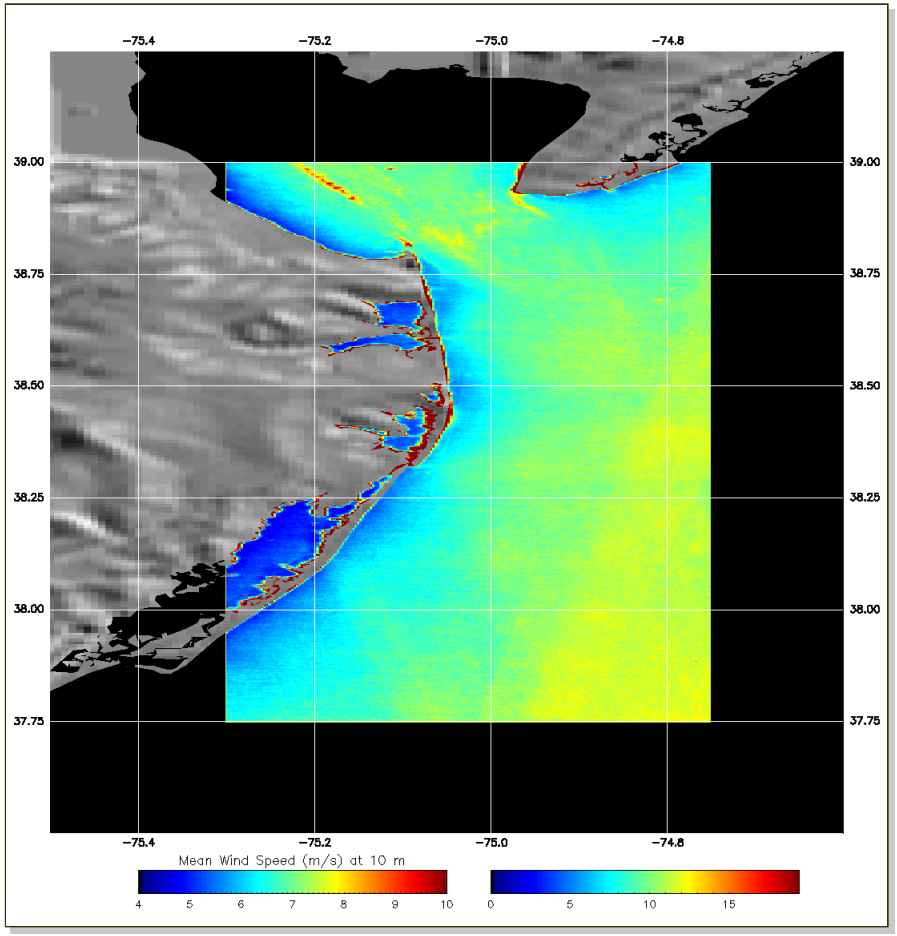


Typical unused image

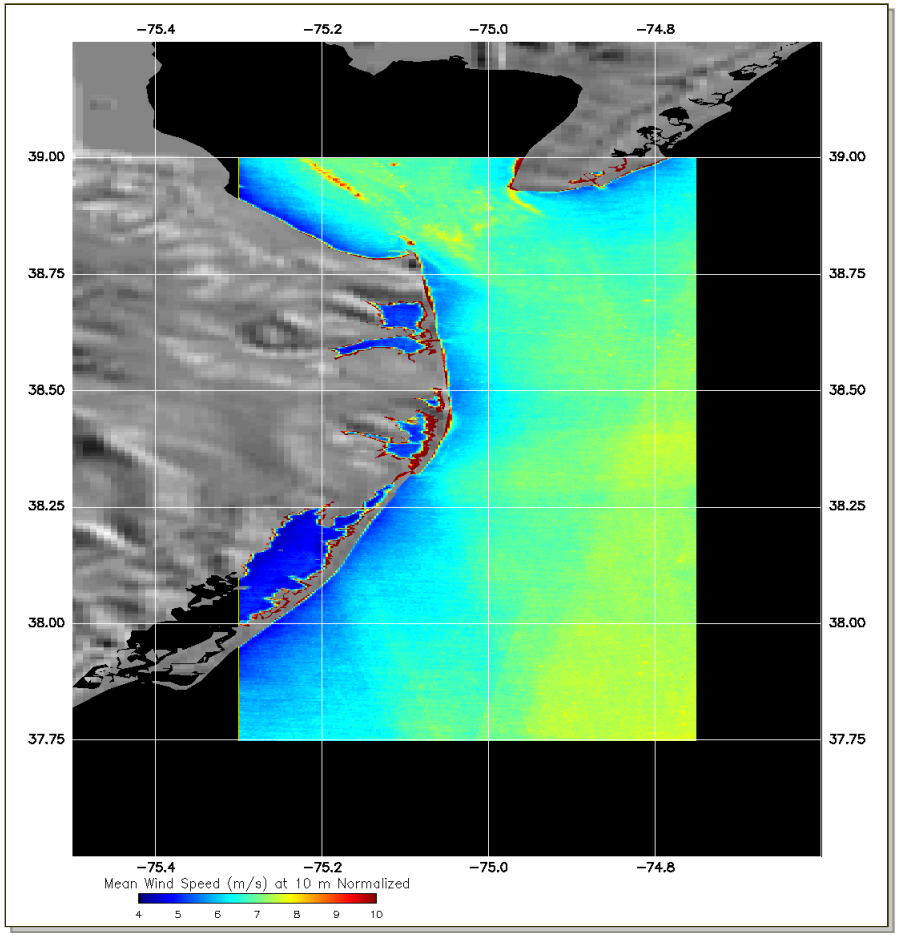


Discard images with seam boundaries in the area of interest.

Mean wind speed at 10-m neutral stability

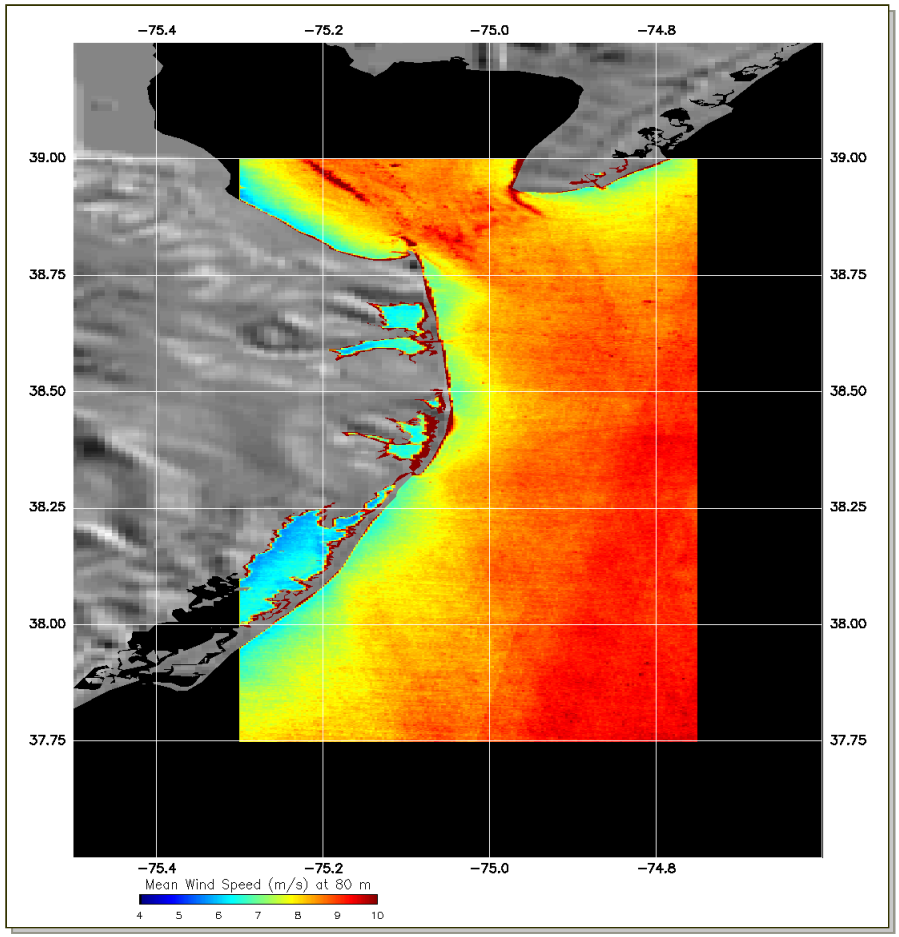


All data

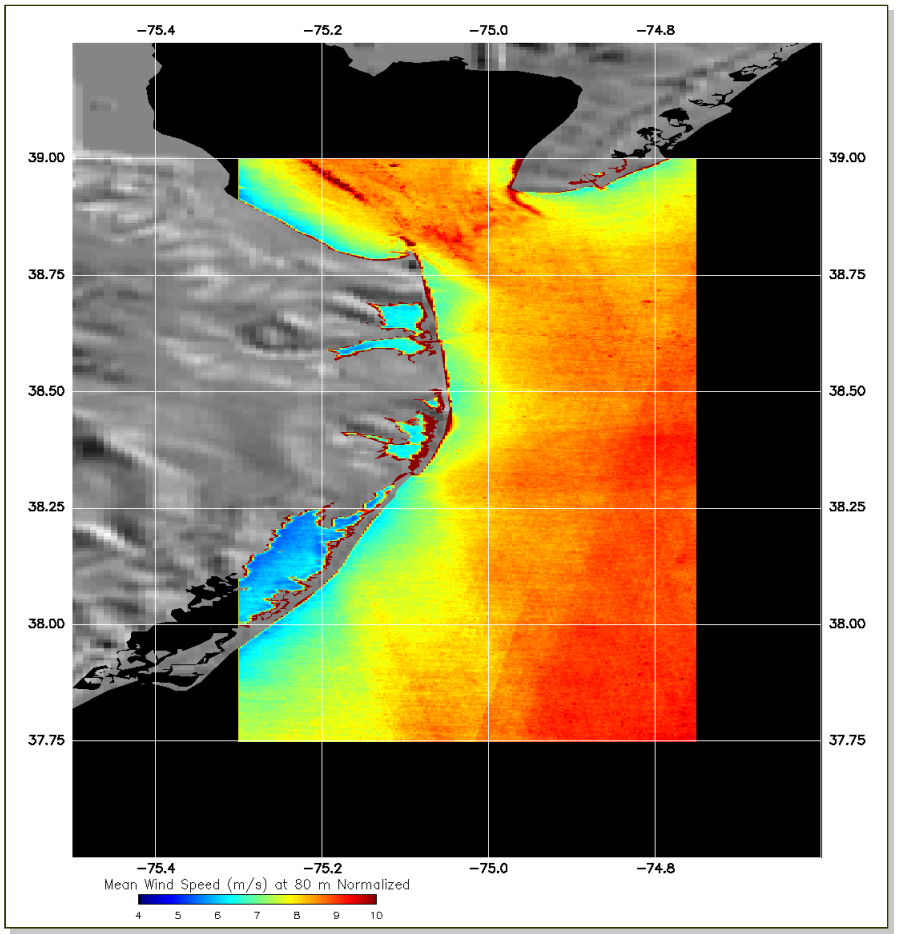


All data, normalized by month

Mean wind speed at 80 m, neutral stability 23% correction, z_0=0.001

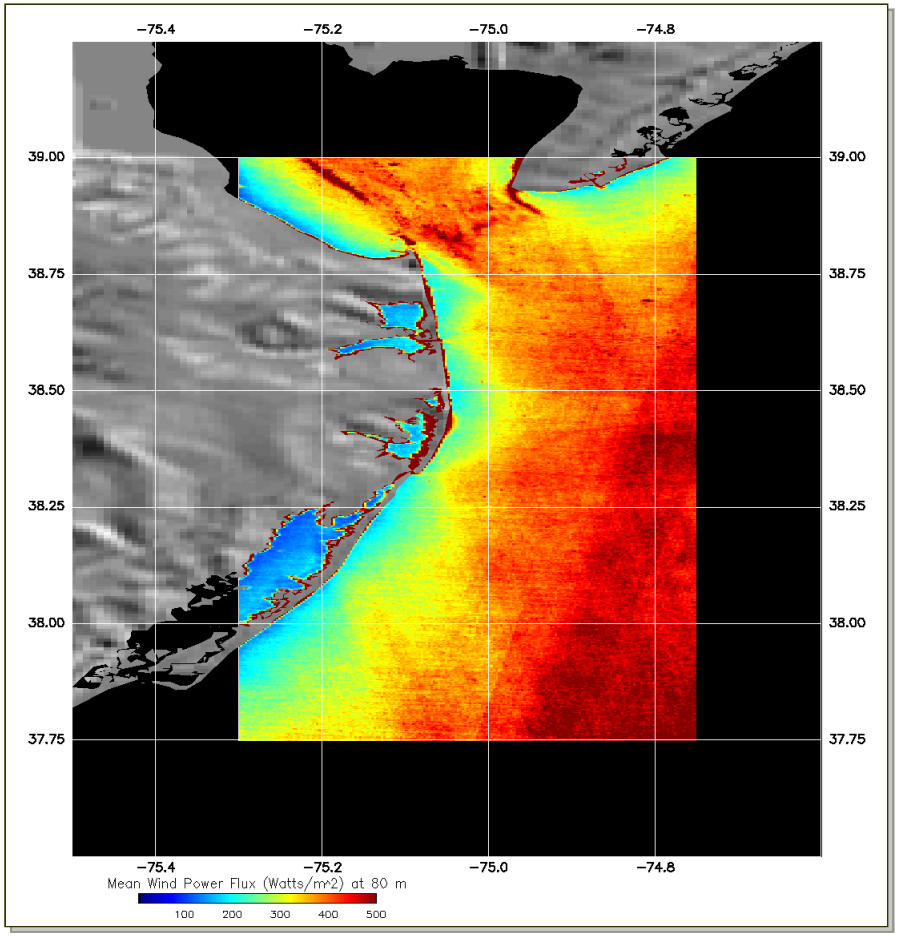


All data

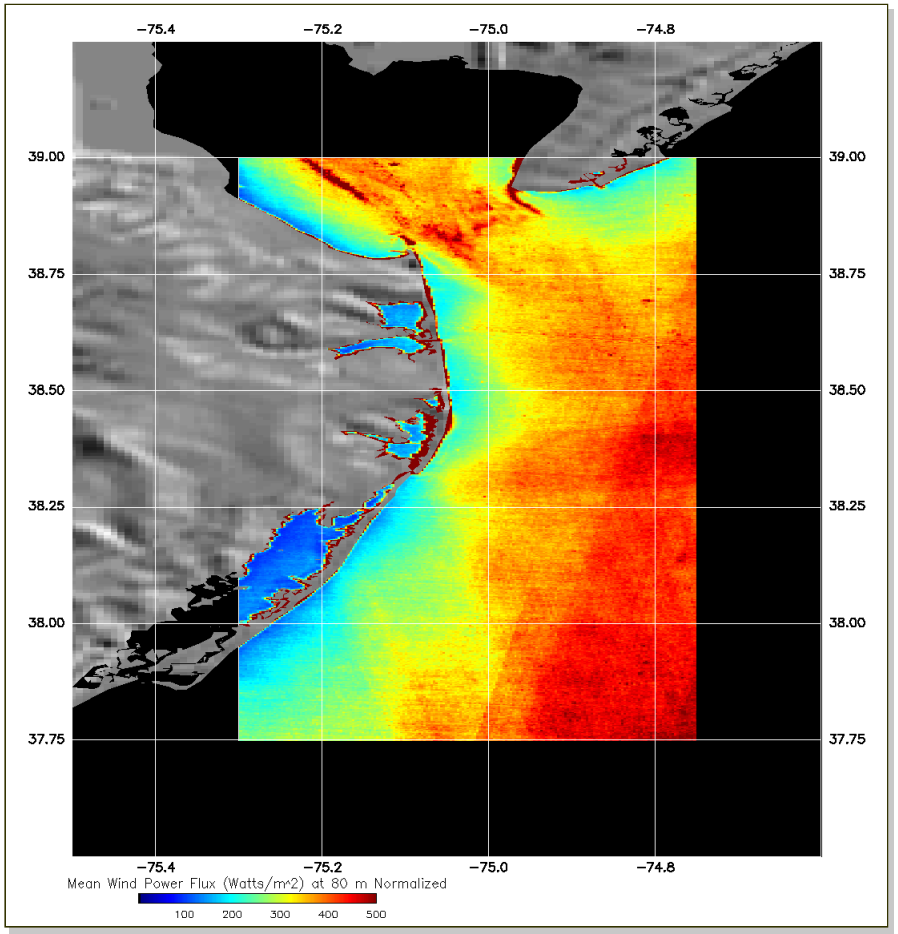


All data, normalized by month

Wind power flux, $P = \rho\, u^3 / 2$ [Watts/m^2] at 80-m hub height

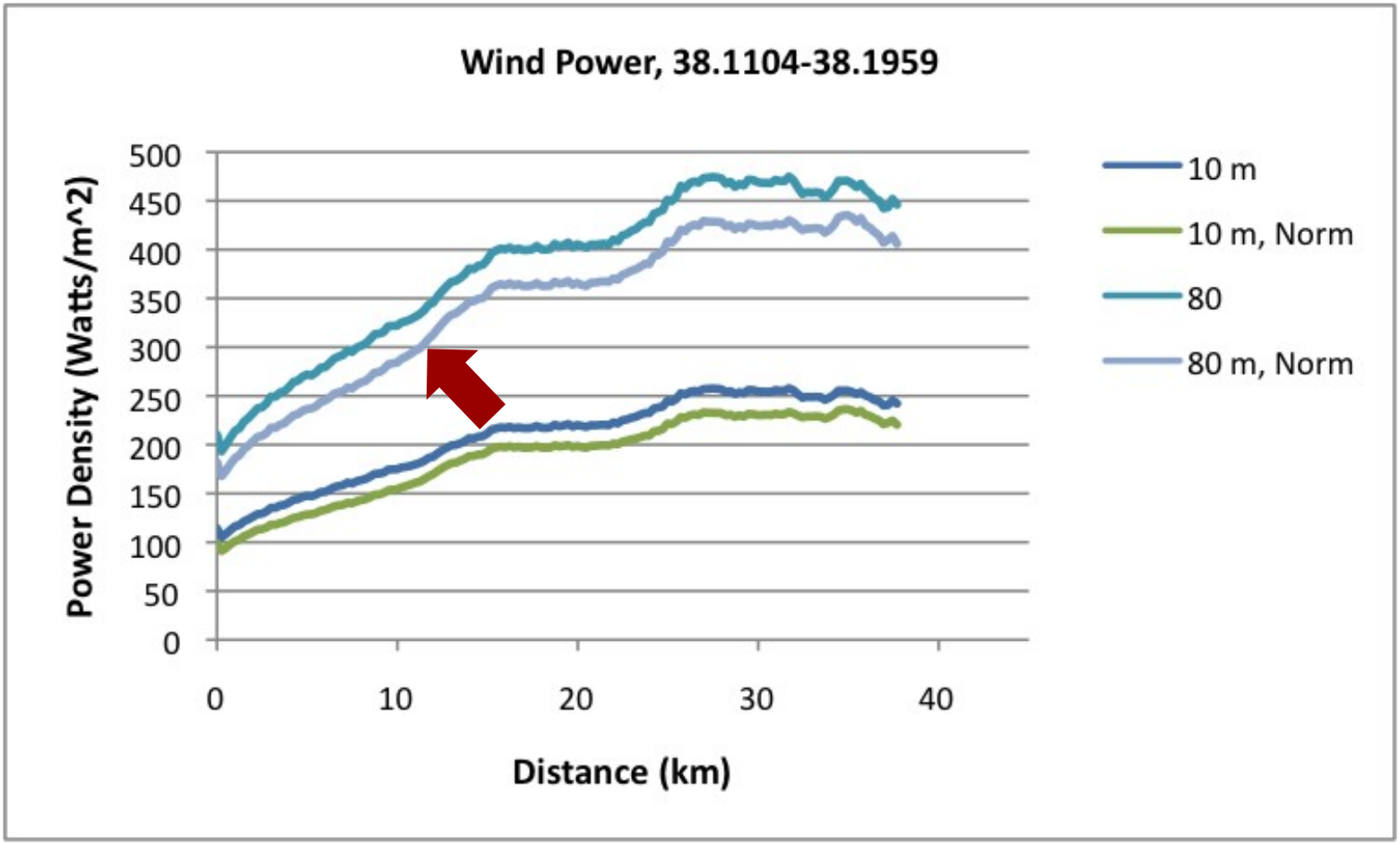


All data

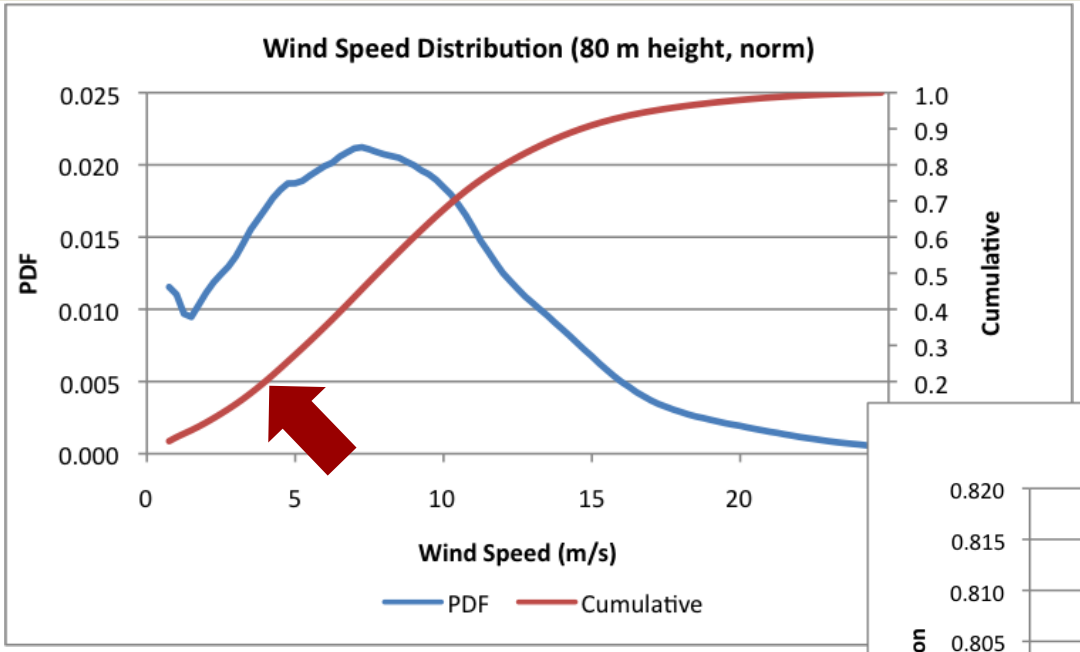


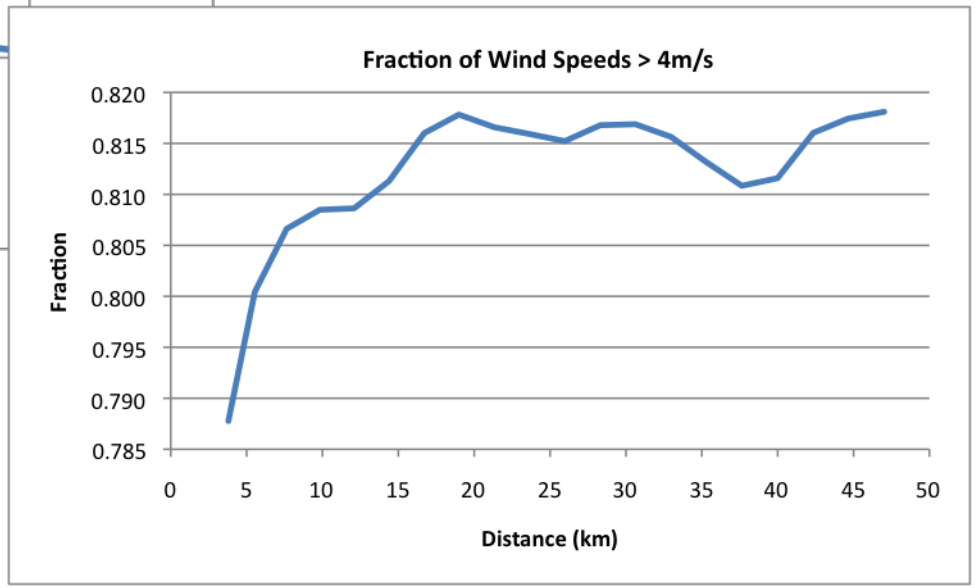
All data, normalized by month

Wind power flux as a function of distance from shore



4 m/s threshold





Conclusions

- SAR over the last decade has developed into a validated quantitative instrument.
- ANSWRS 2.0 is an operational SAR wind tool.
- SAR used for offshore wind power assessment
  - Effect of turbines on flow to other turbines
  - High-resolution wind speed climatology
    - Area distribution of wind power flux
    - Wind power flux as a function of distance from shore
    - Fraction of time wind speed exceeds wind turbine minimum operating speed.