First Operational Implementation of SAR Winds at NOAA

Fourth Conference on Transition of Research to Operations

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Serving as an

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APL
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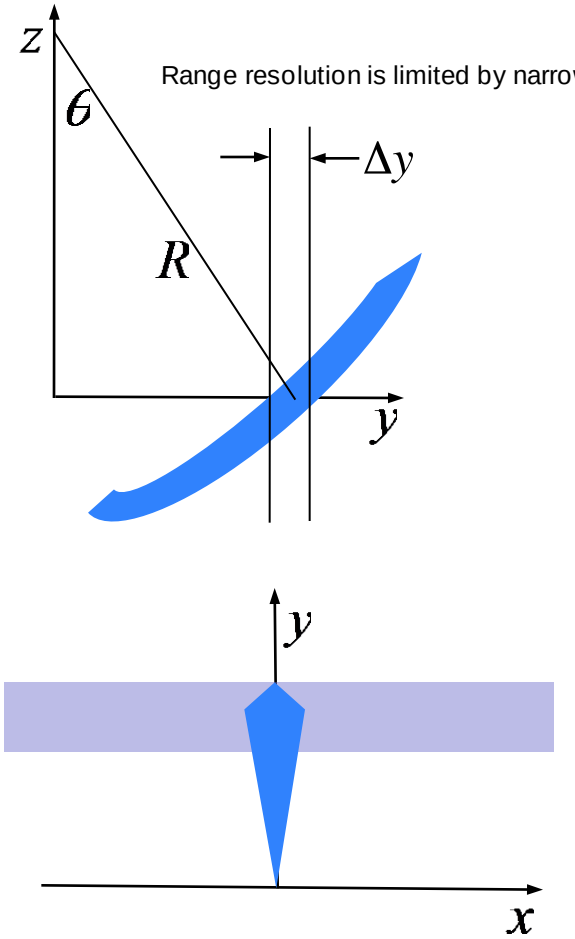
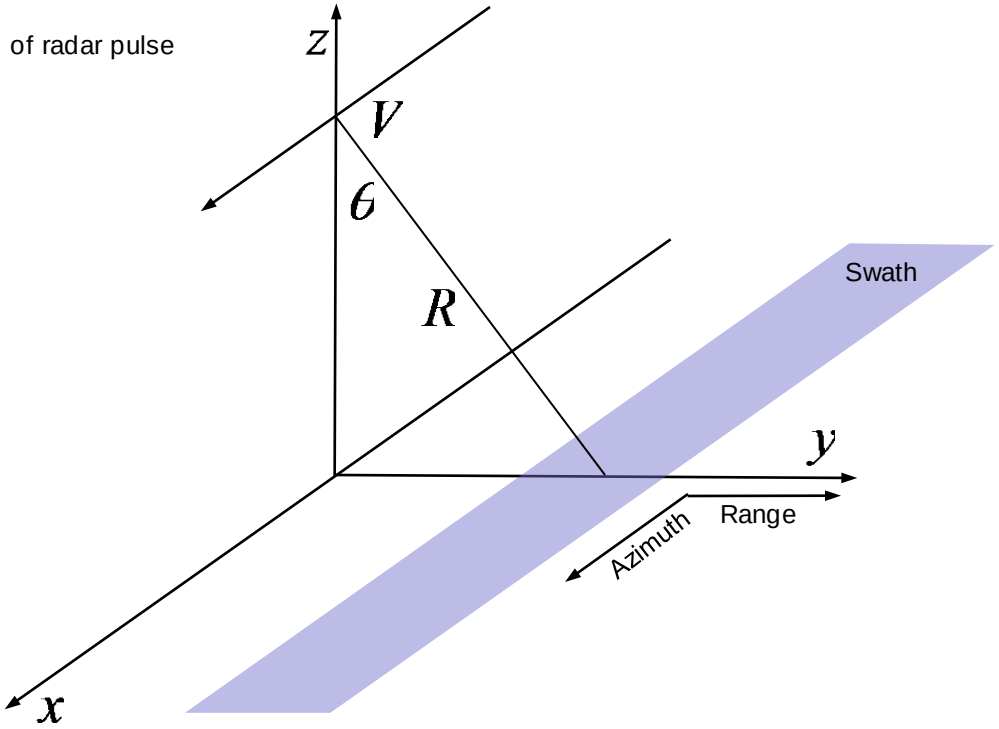
APPLIED PHYSICS LABORATORY

Bottom Line Message

- **The National Ice Center (NIC)has long used SAR (synthetic aperture radar) imagery for sea ice location and identification. NOAA STAR has routinely used SAR winds in a research mode since 2000.**
- **Operational SAR winds May 2013 at NESDIS and in parallel at NIC using ANSWRS (APL/NOAA SAR Wind Retrieval System)**
- **SAR wind imagery may help in SAR imagery interpretation at the NIC along with other applications for high-resolution winds in coastal areas.**

Synthetic Aperture Radar (SAR) Geometry

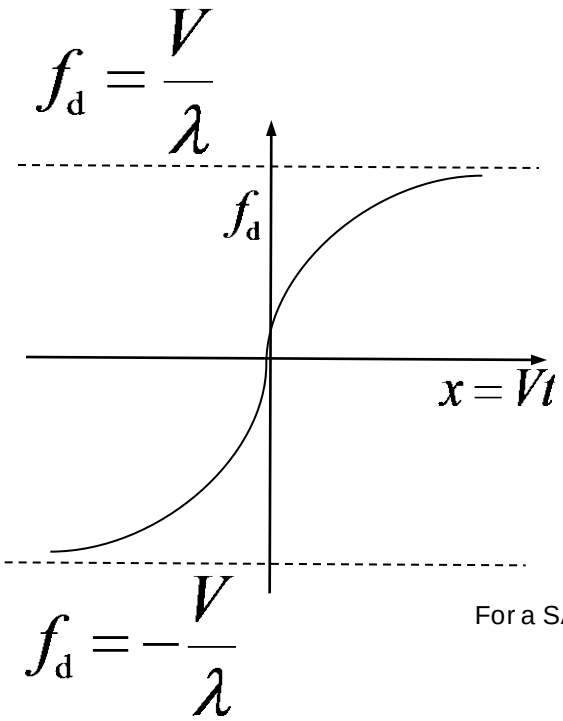


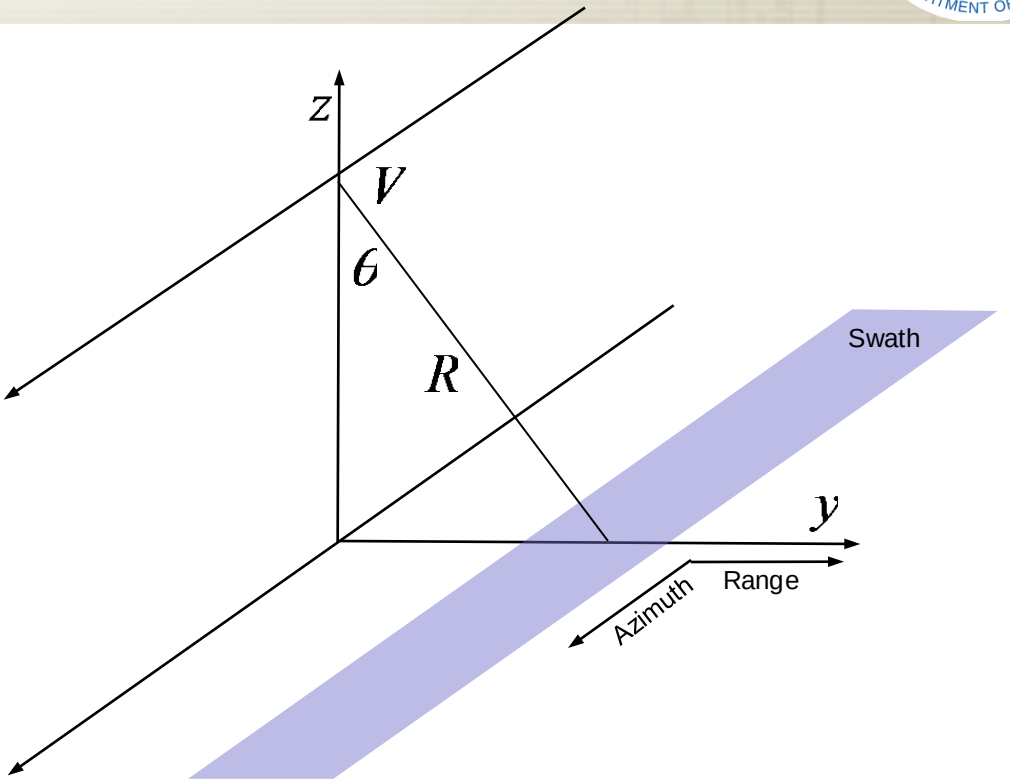


For a real aperture radar, azimuth resolution is limited by the beam width of the antenna. A SAR is different

A Doppler View of SAR

$$f_d = \frac{v_{rel}}{\lambda}$$ Doppler Equation





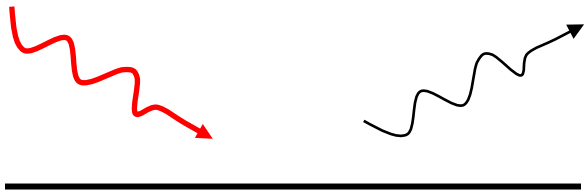
For a SAR azimuth resolution is determined by how well we can determine the Doppler frequency shift.

Sources of SAR data

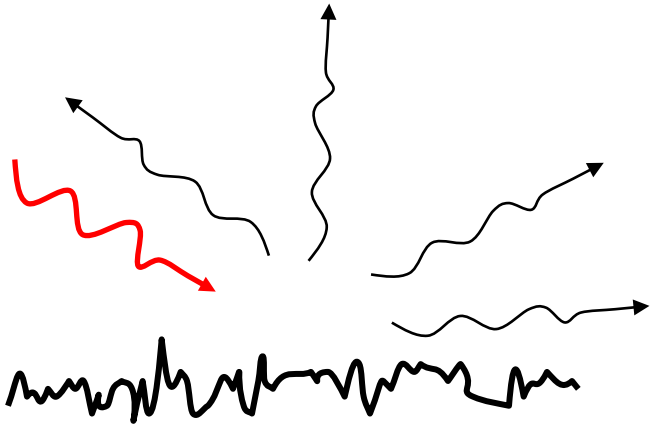
	Satellite	Launch	Frequency	Polarization	Resolution
USA	Seasat	1978	L	HH	25 m
USA	SIR-B	1984	L	HH	16-58 m
	ERS-1	1991	C	VV	25 m
	JERS-1	1992	L	HH	18 m
USA	SIR-C	1994	L, C, X	Full-Pol (L,C); VV(X)	10-50 m
	ERS-2	**1995**	**C**	**VV**	**25 m**
	Radarsat-1	**1995**	**C**	**HH**	**25-50 m**
USA	SRTM	2000	C, X	HH, VV (C); VV (C)	30 m
	Envisat	**2002**	**C**	**VV, HH, VV/HH, HV/HH, VH/VV**	**30-1000 m**
	ALOS	**2006**	**L**	**Full-Pol**	**7-88 m**
	TerraSAR-X	**2007**	**X**	**Full-Pol**	**3 m**
	Radarsat-2	**2007**	**C**	**Full-Pol**	**3-100 m**
	Cosmo SkyMed	**2007**	**X**	**Full-Pol**	**3 m**
	Sentinel-1A/B	**2013**	**C**	**VV,/VH, HH/HV**	**5-20 m**

Ocean surface scattering

Specular scattering from a smooth surface: Most of the energy is reflected away.

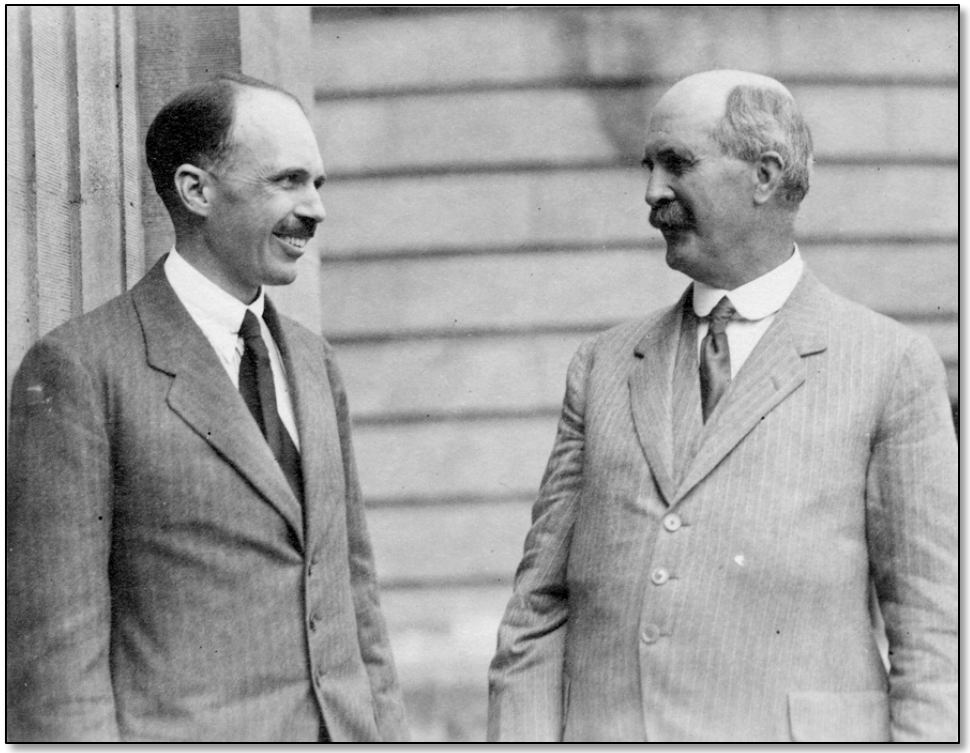


Diffuse Scattering from a rough surface: Energy is reflected in all directions.



The rougher the surface the greater the backscatter, the brighter the SAR image.

Bragg Scattering

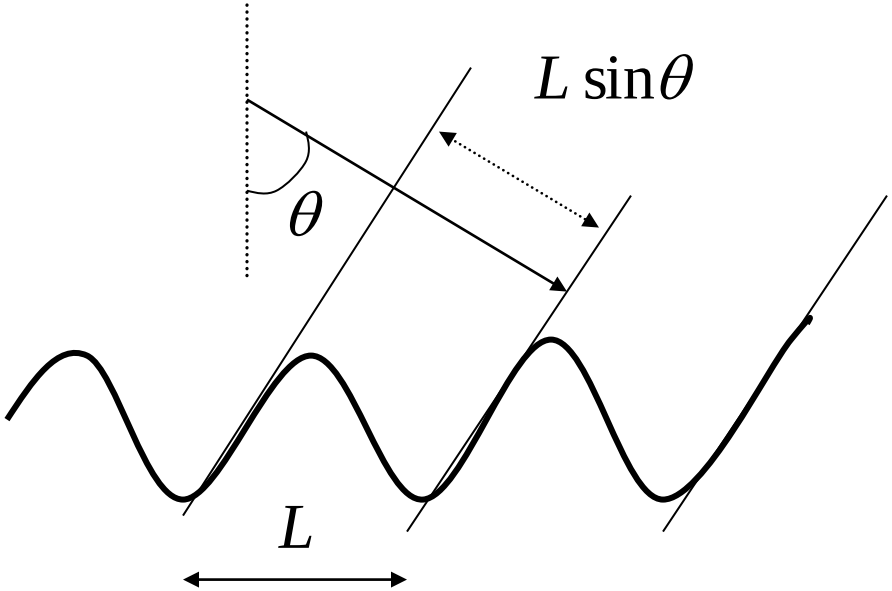


Sir William Lawrence and Sir William Henry Bragg

Bragg resonance was discovered in the context of scattering from crystal structures.

A periodic structure will set up a resonance for waves that match the Bragg condition.

$$\lambda = 2\,L\,\sin\theta$$



Geophysical Model Function

$$\sigma_V^0(U,\theta,\phi) = A(\theta)U^{\gamma(\theta)}[1 + B(\theta)\cos\phi + C(\theta)\cos 2\phi]$$

where

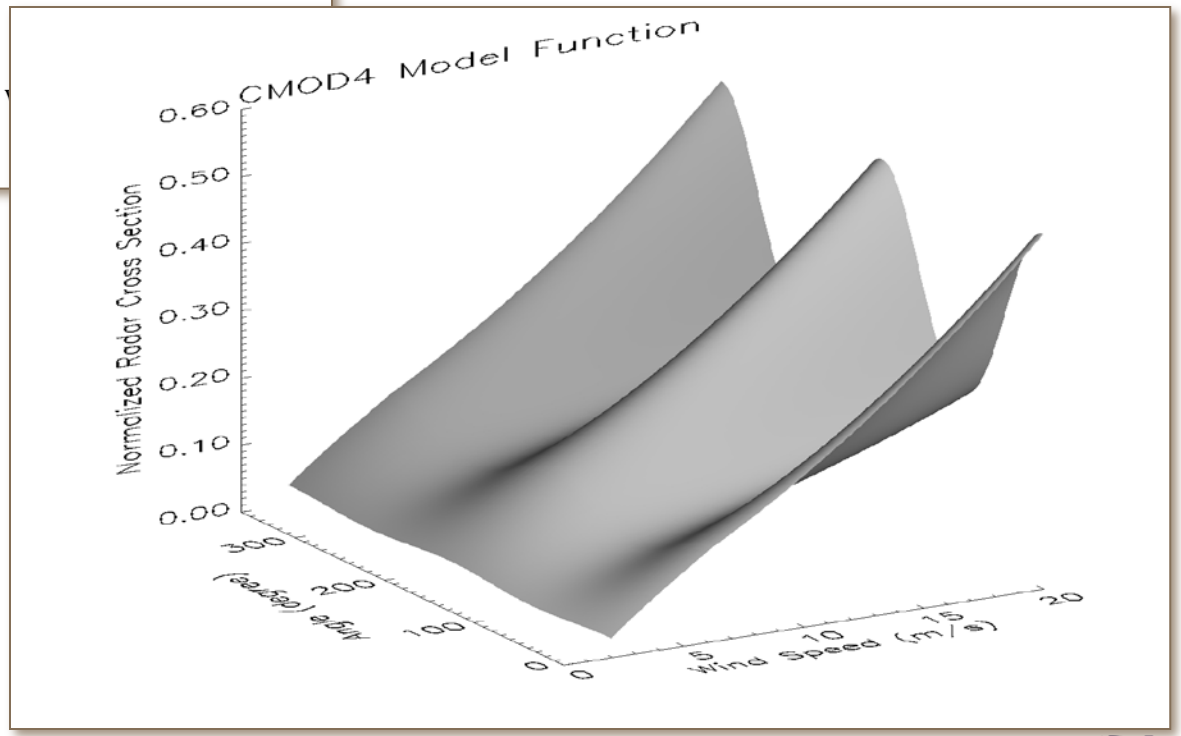
σ_V^0 is normalized radar cross section at vertical polarization.

U is wind speed.

θ is nadir incident angle.

ϕ is the radar look angle with respect to the

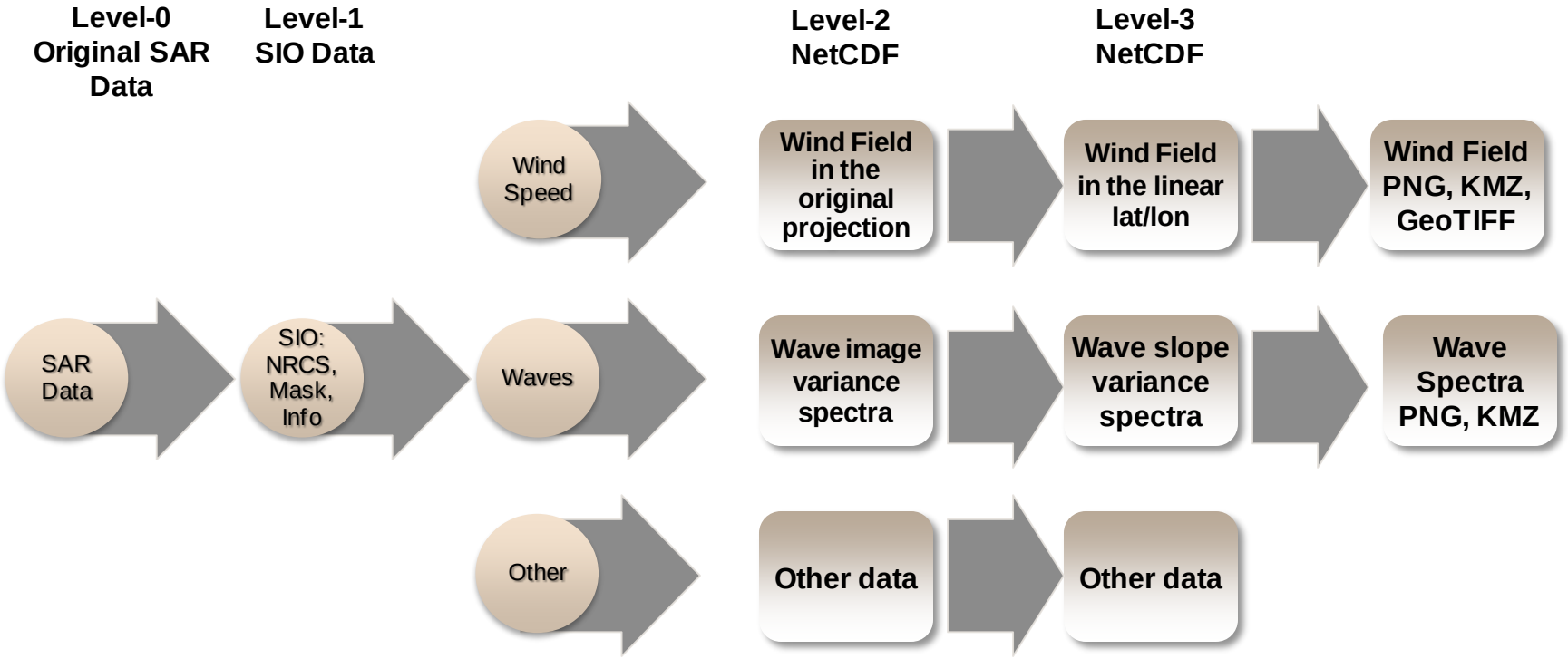
A, γ, B, C are empirical parameters.



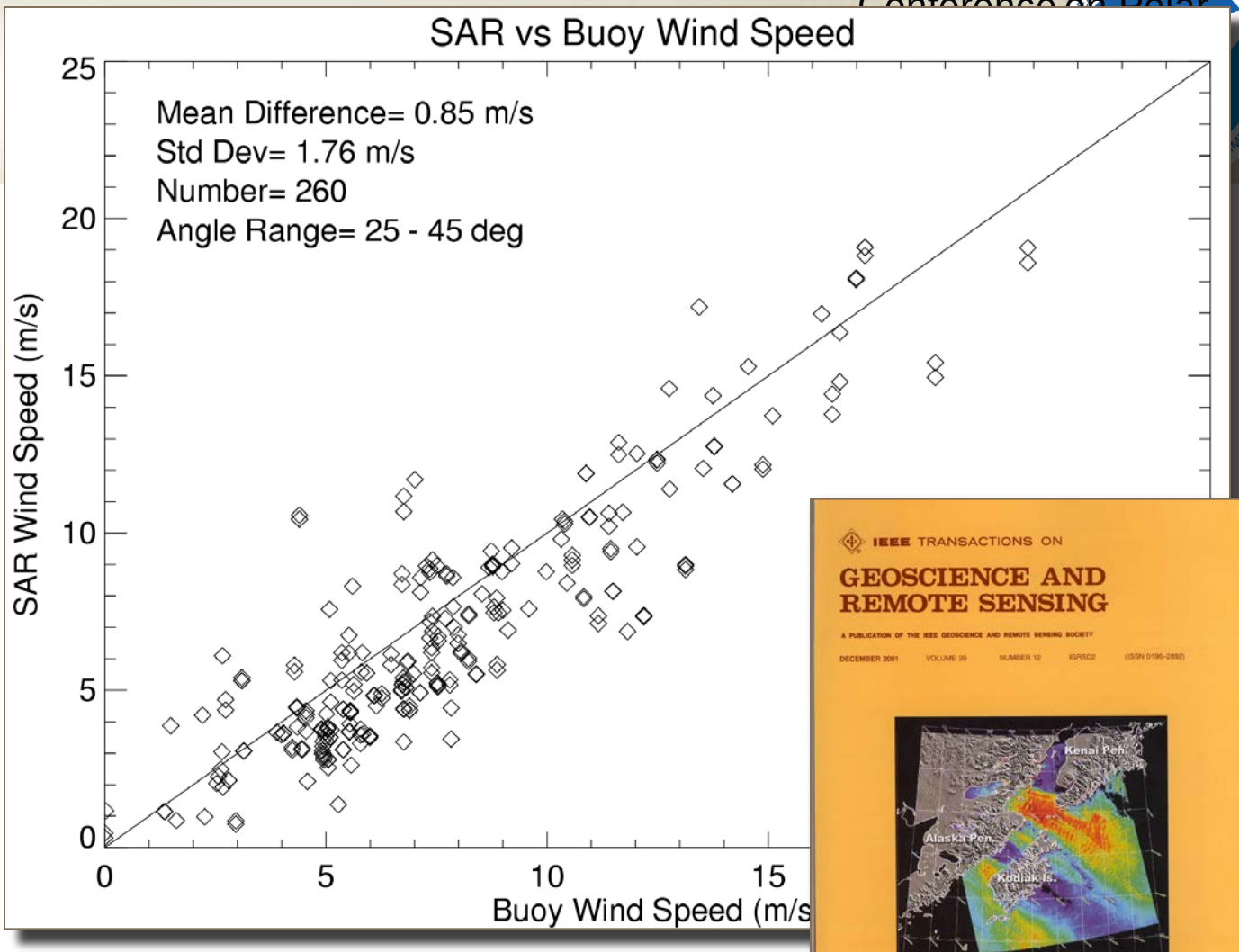
Geophysical Model Function

- Radar cross section increases with wind speed.
- Given a wind speed and direction, can estimate radar cross section.
- Given a radar cross section, there are many combinations of wind speed and directions
- Using an estimate of wind direction, we can estimate wind speed.
  - Numerical model predictions of wind direction
  - Linear features (scale 2-10 km) associated with wind direction.

ANSWRS 2.0 Structure

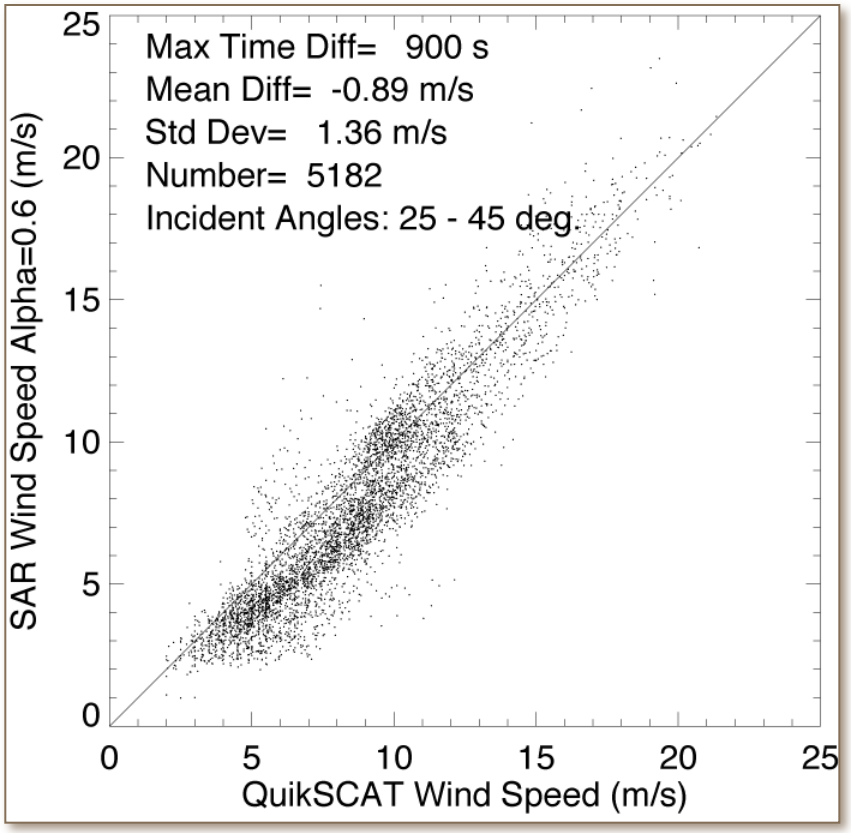


Include angles > 25°
The standard deviation is ***1.76*** m/s.

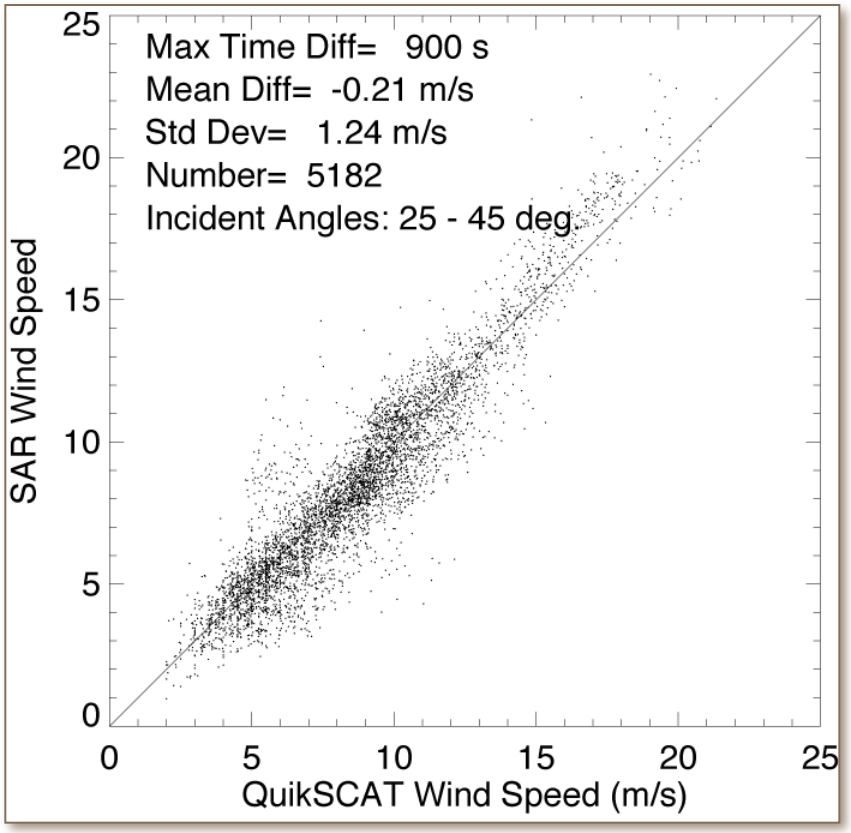


IEEE Transactions Geoscience and Remote Sensing, December 2001.

Systematic SAR-QuikSCAT comparisons

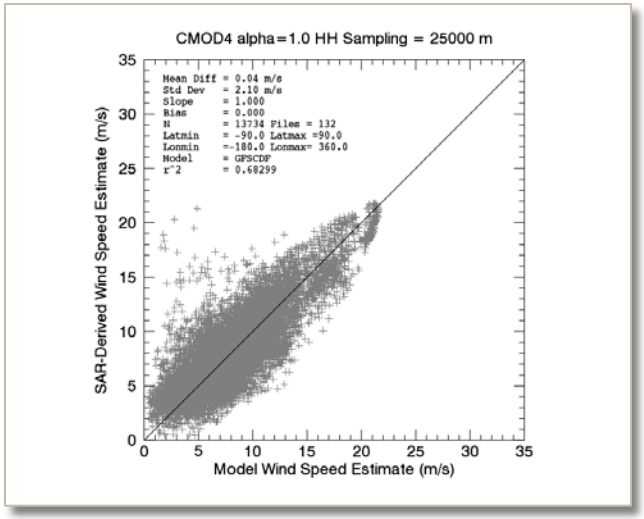


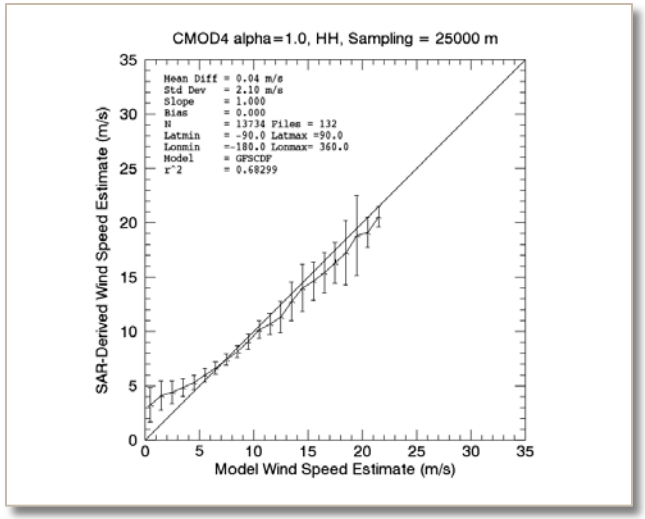
Model directions for SAR wind retrieval

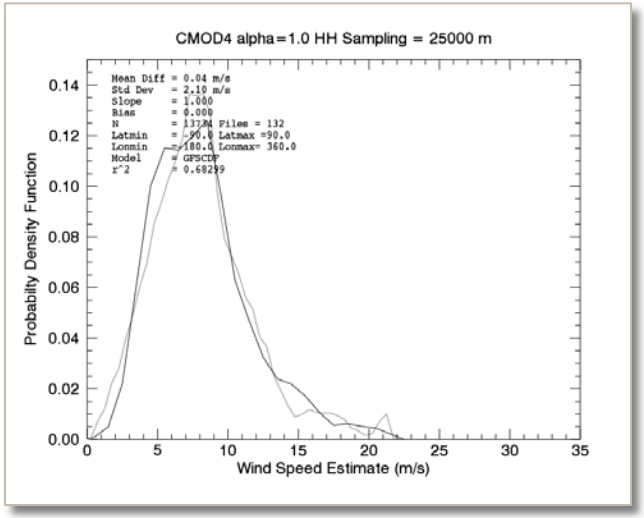


QuikSCAT directions for SAR wind retrieval

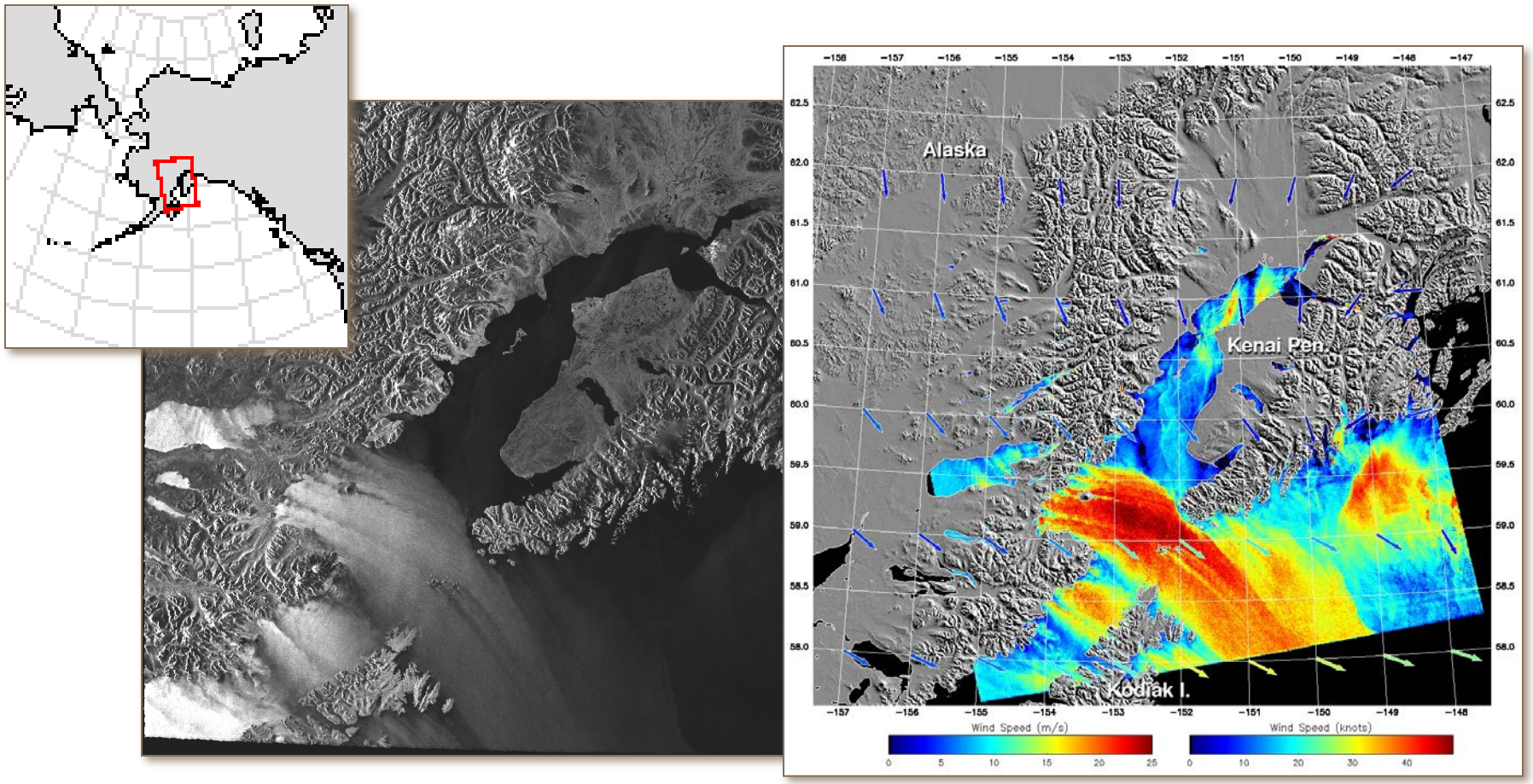
Radarsat-2 Winds vs GFS Model





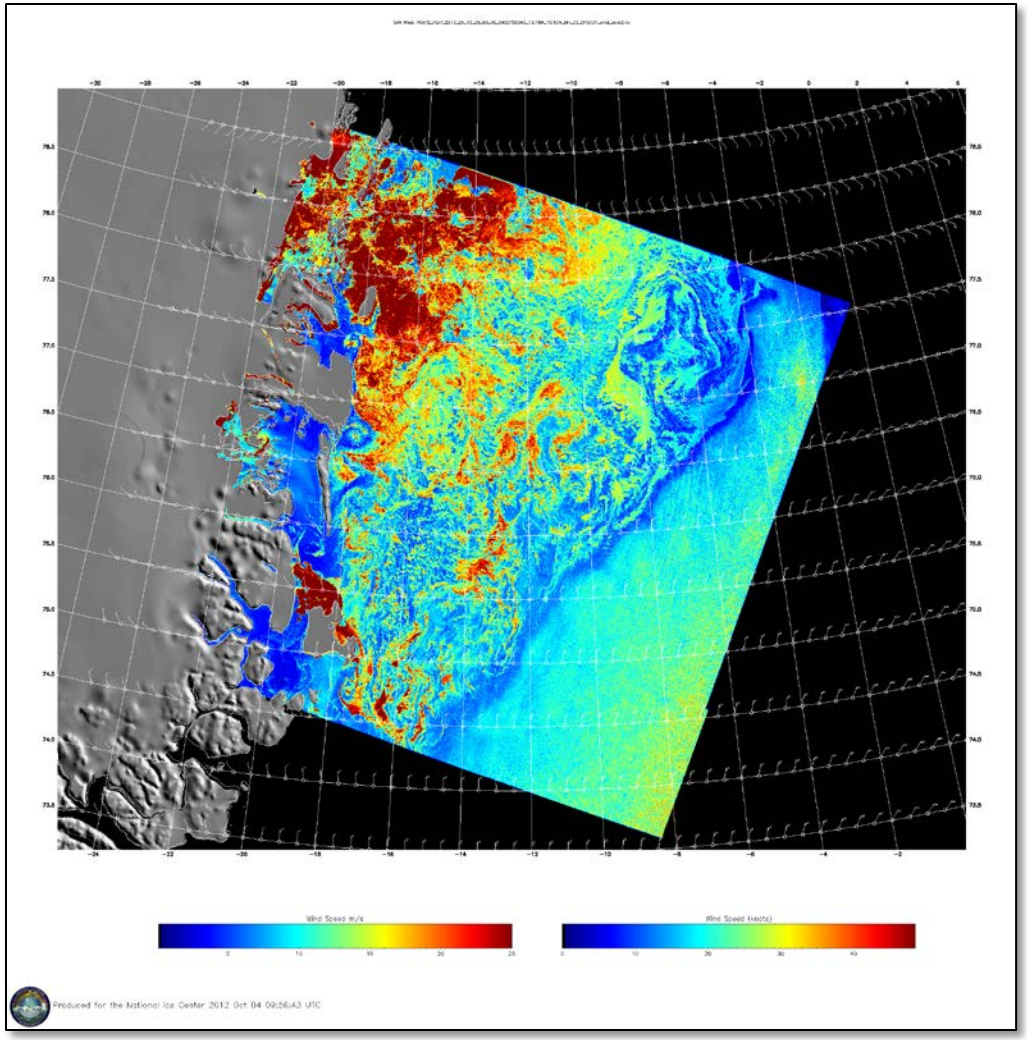


Radarsat-1 SAR NRCS image to wind image



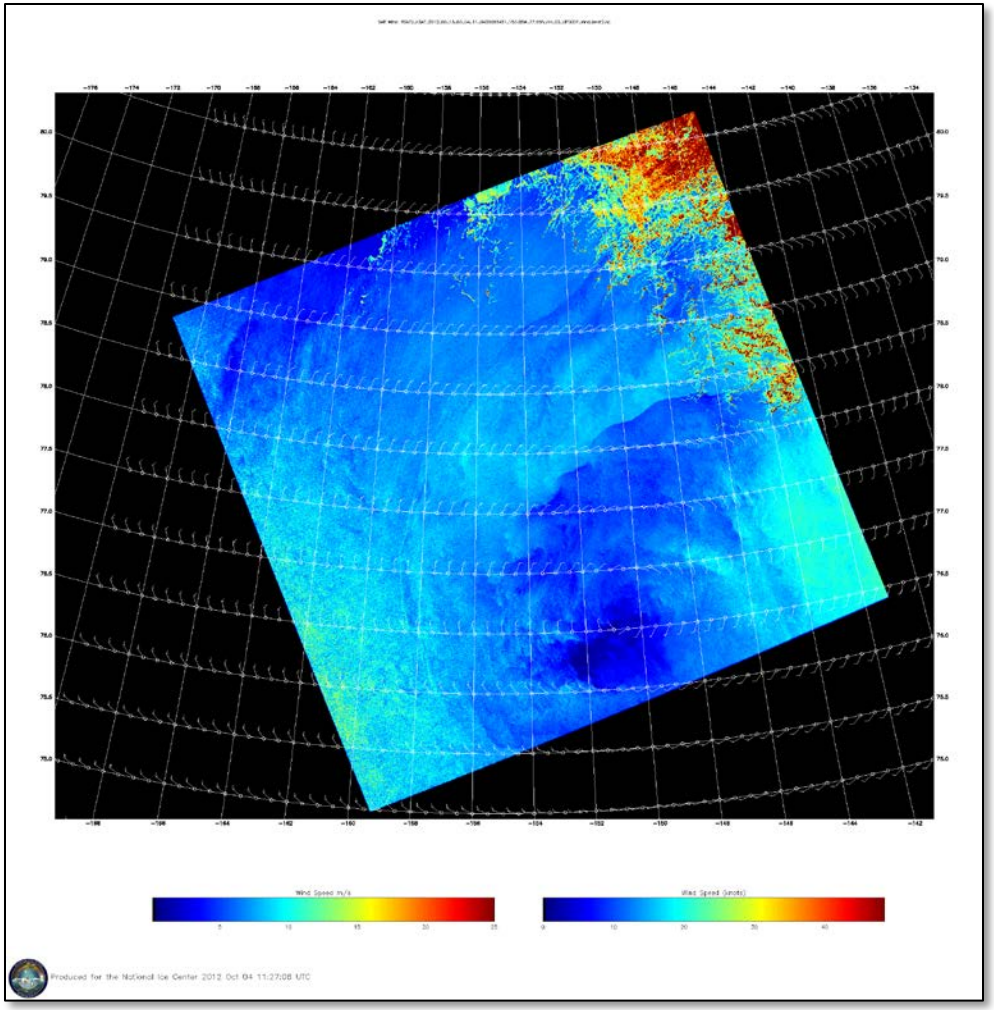
2000 Oct 31 03:44:24 UTC

Sample Radarsat-2 data PNG/TIFF image

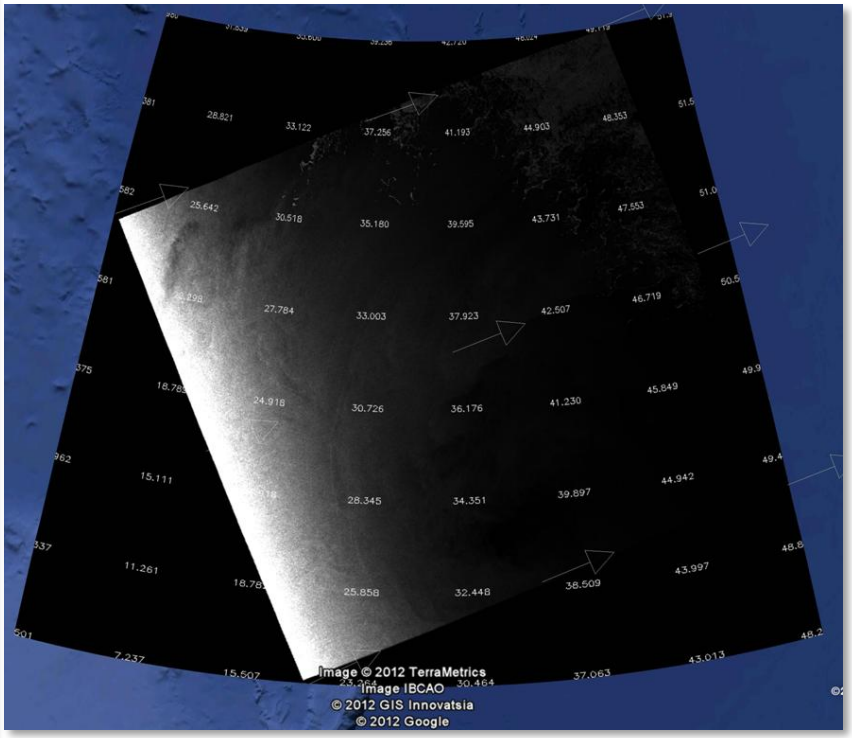


2012-09-12 08:00:46 UTC
13.78° W 76.50° N

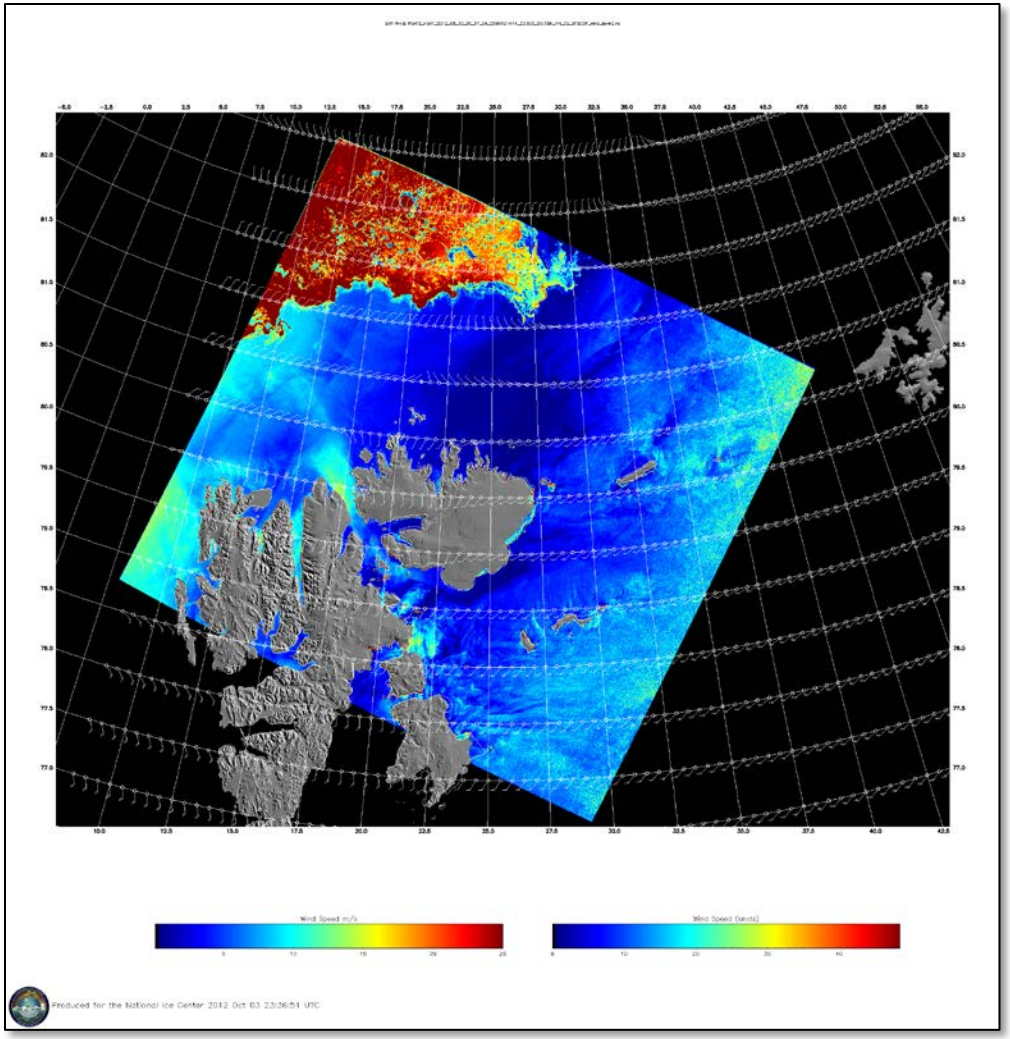
Radarsat-2 example of an atmospheric low



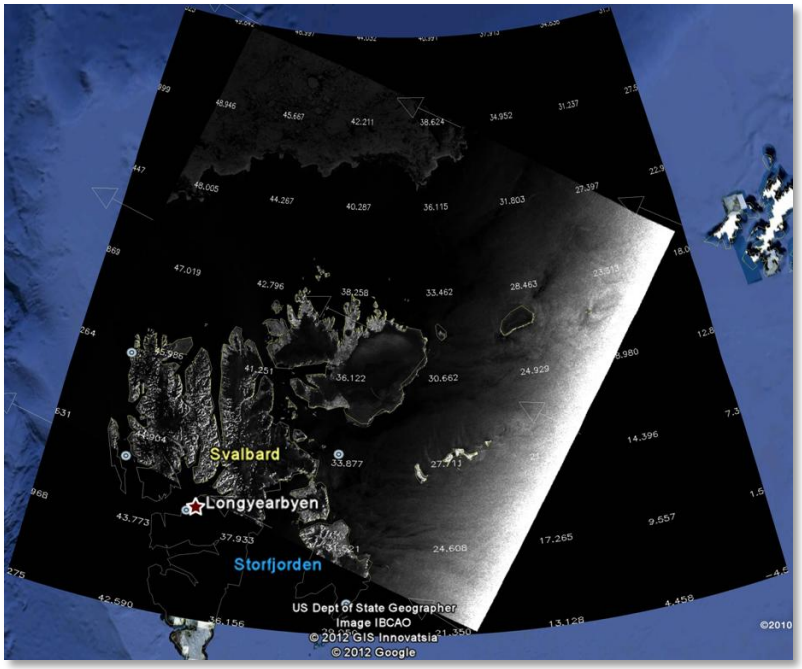
2012-09-15 03:04:11 UTC
153.85° W 77.95° N



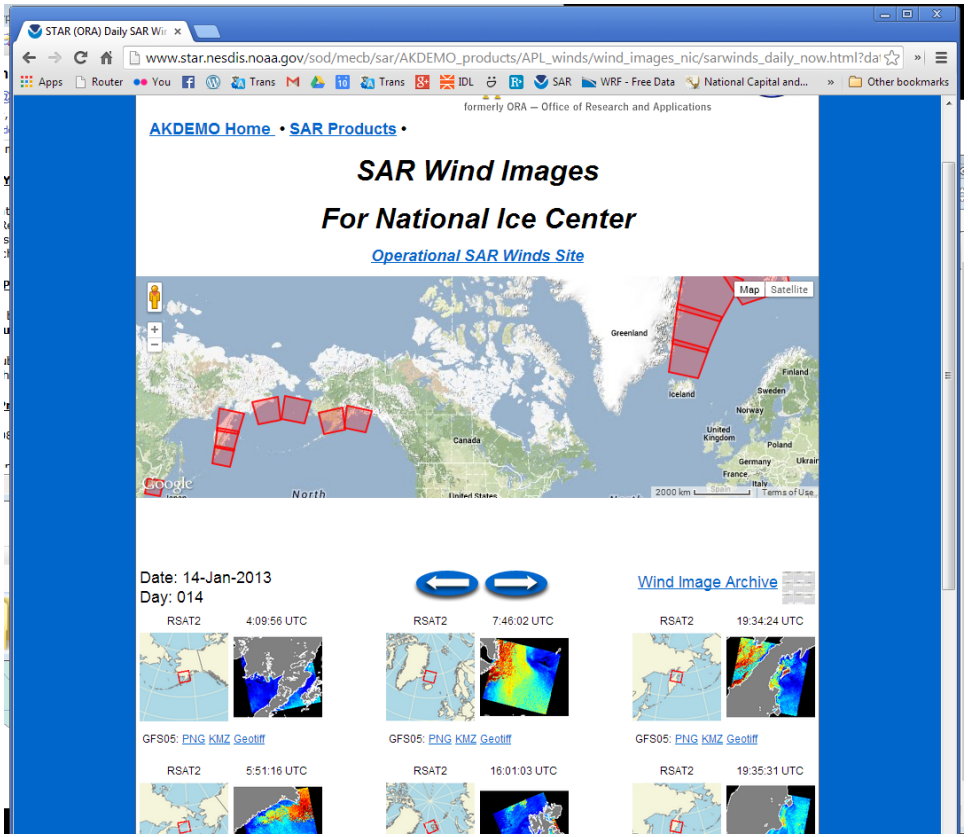
Radarsat-2 example of gap flow



2012-08-30 05:57:54 UTC
23.80° E 80.18° N



Webpage at the Office of Satellite and Product Operations (OSPO)



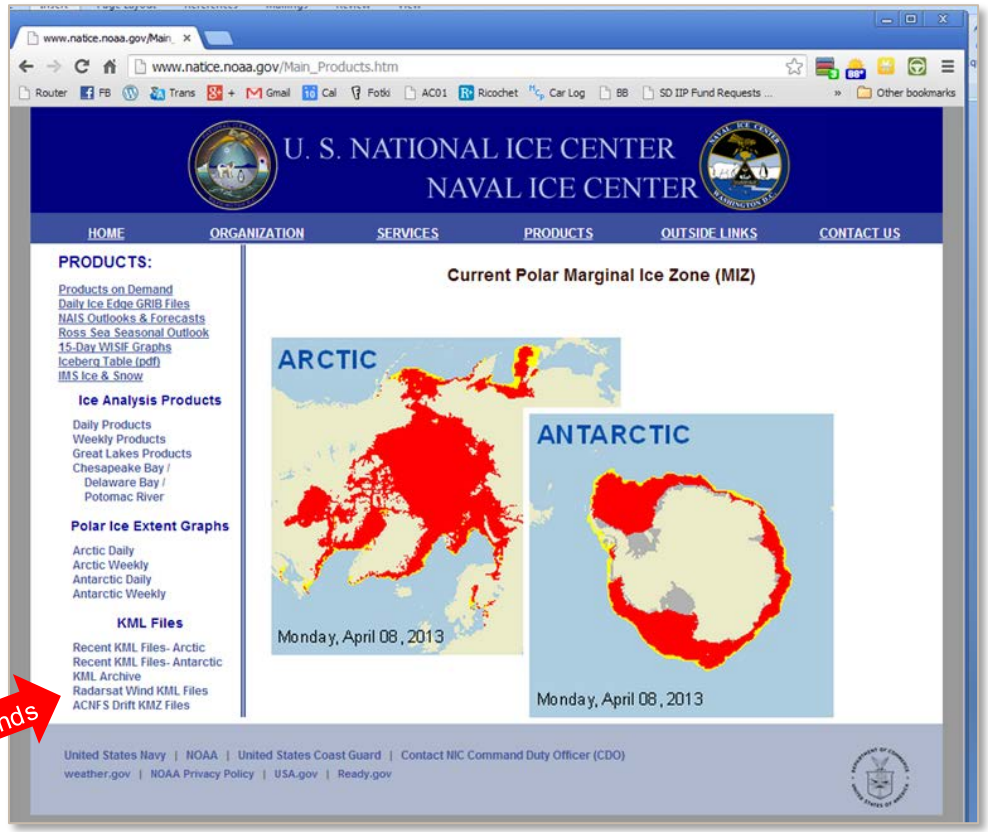
If you want access to the actual wind speeds saved in netCDF format (CF compliant), please let me know:

Frank.Monaldo@noaa.gov

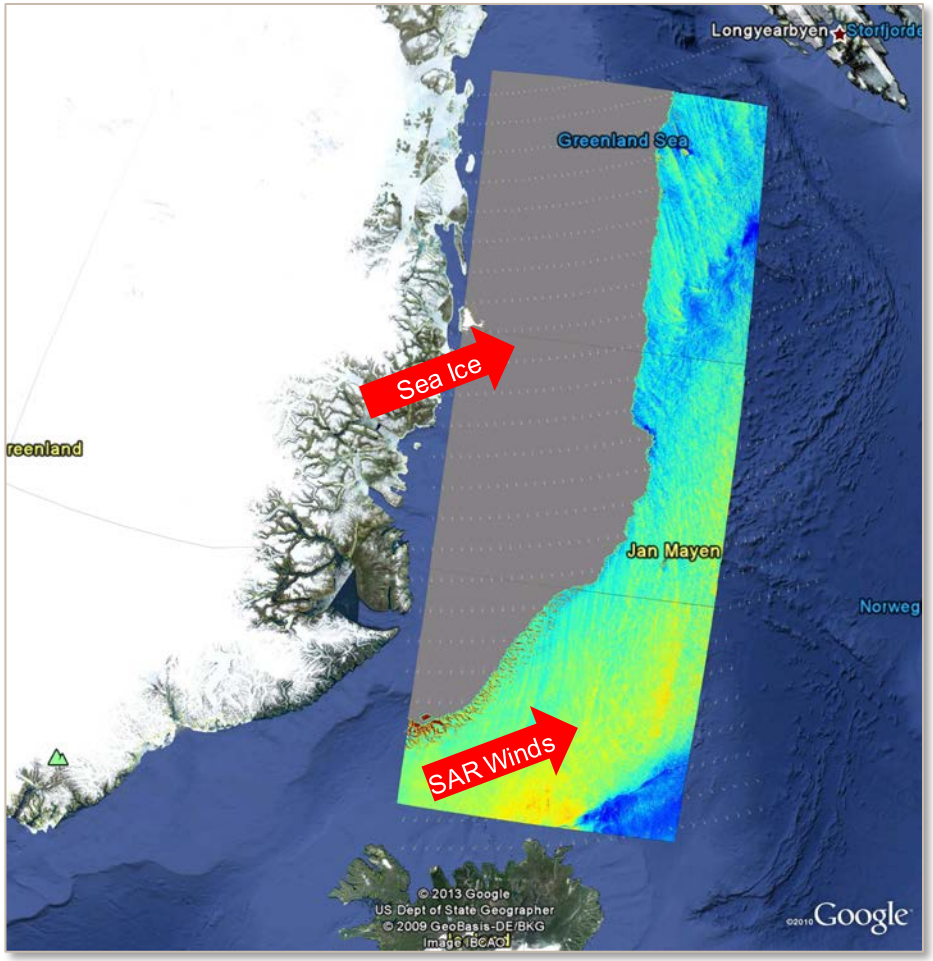
http://www.ospo.noaa.gov/Products/ocean/sar/index.html

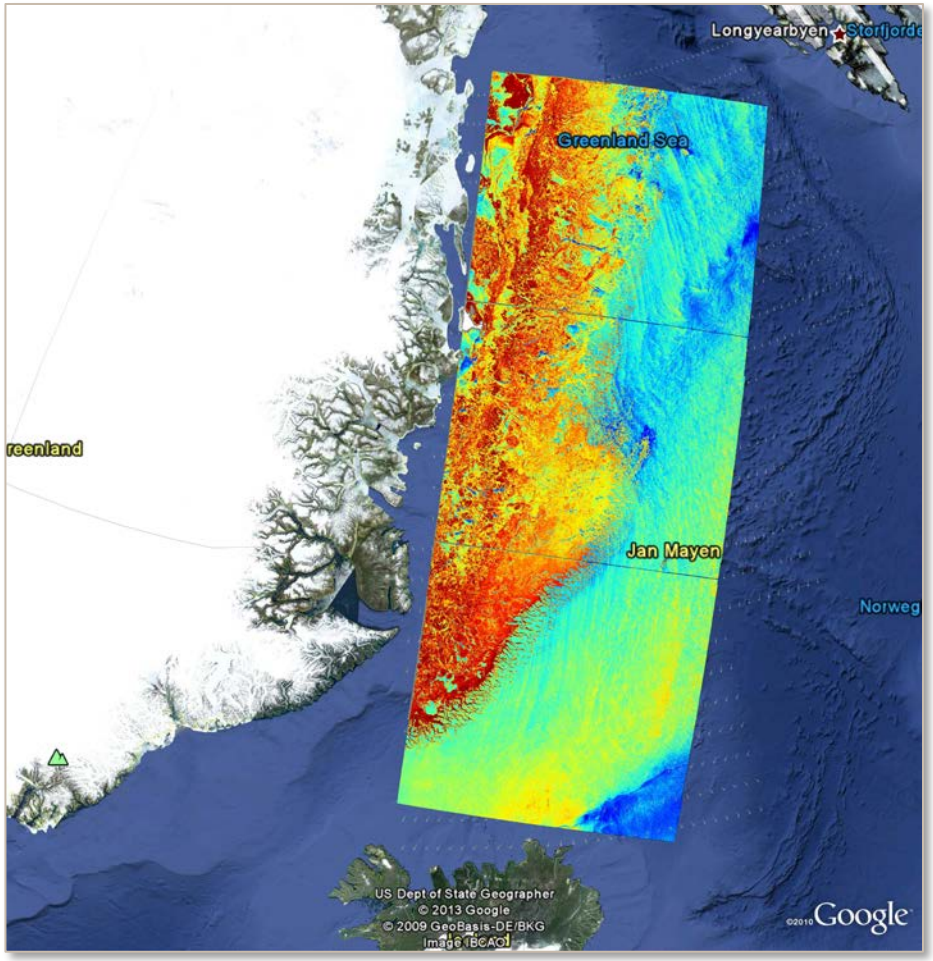
http://www.natice.noaa.gov/

SAR Winds



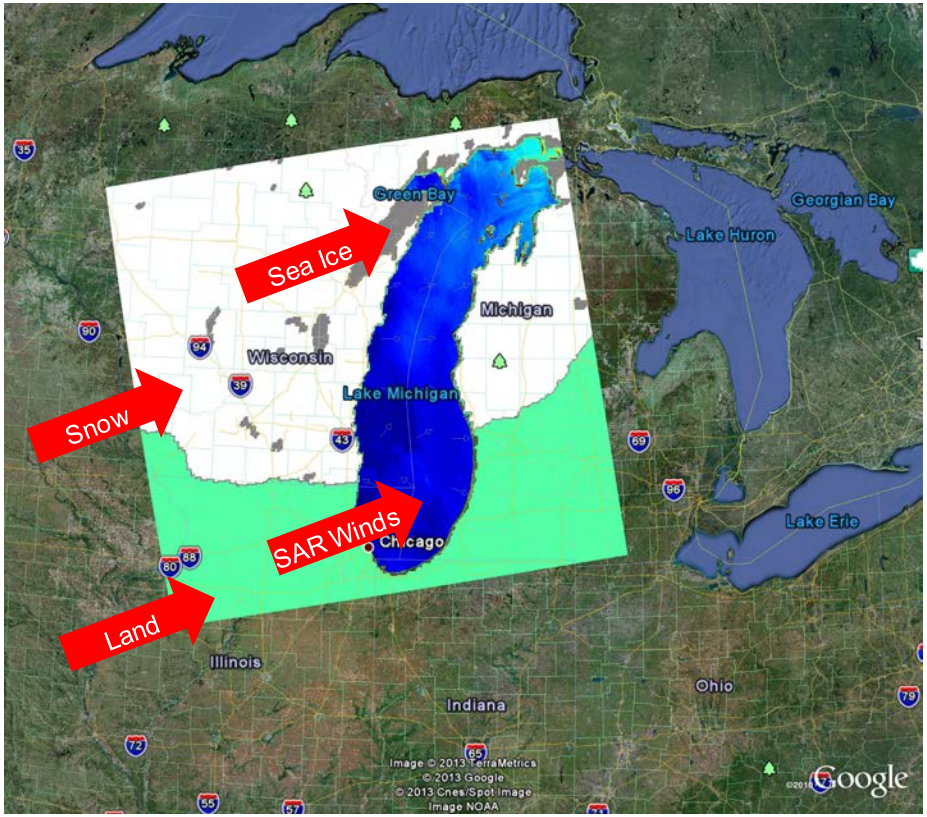
Application of IMS (Interactive Multisensor Snow and Ice Mapping System) (KMZ)

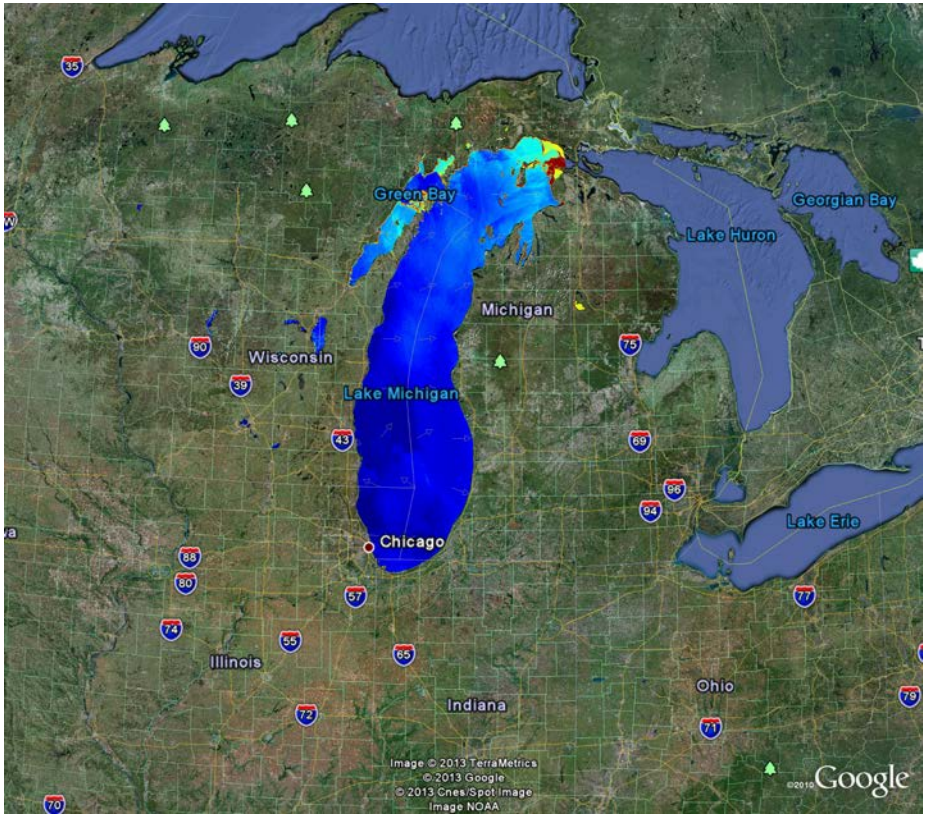




Eastern coast of Greenland, 2013 Apr 10 07:37 UTC

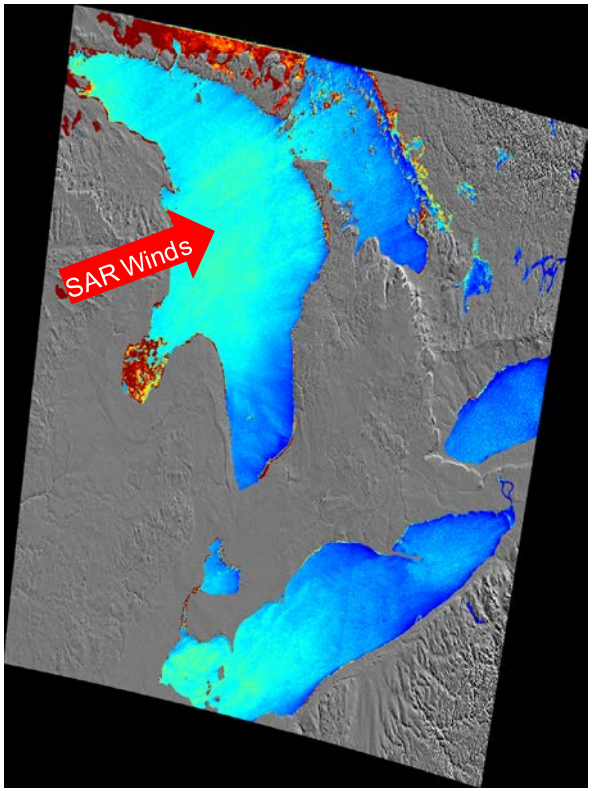
Application of IMS (Interactive Multisensor Snow and Ice Mapping System) (GeoTFF)





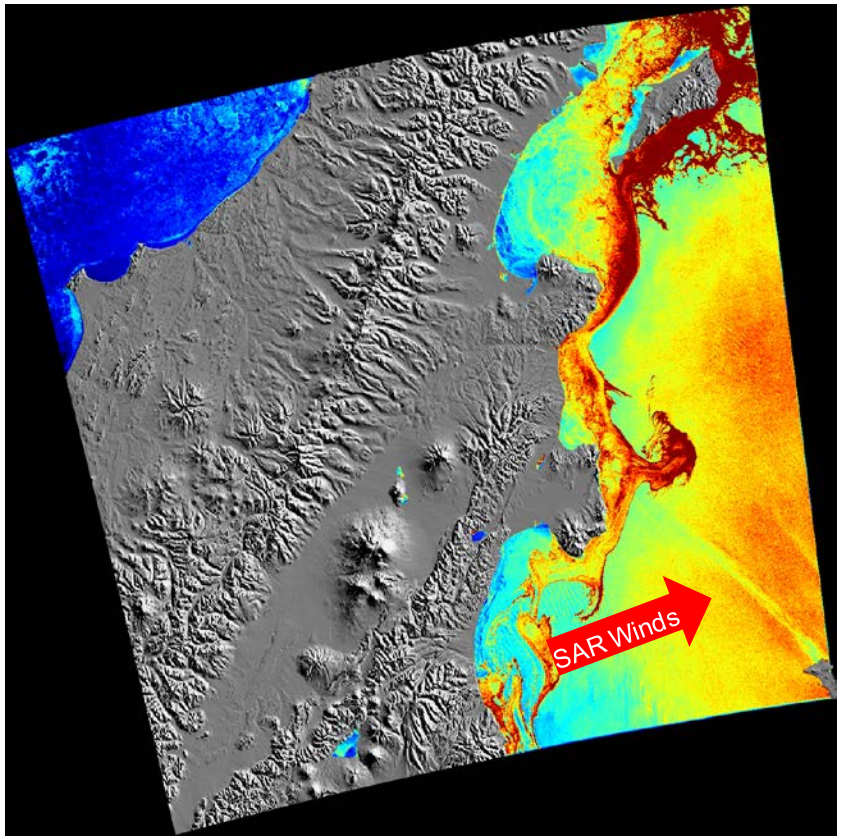
Lake Michigan

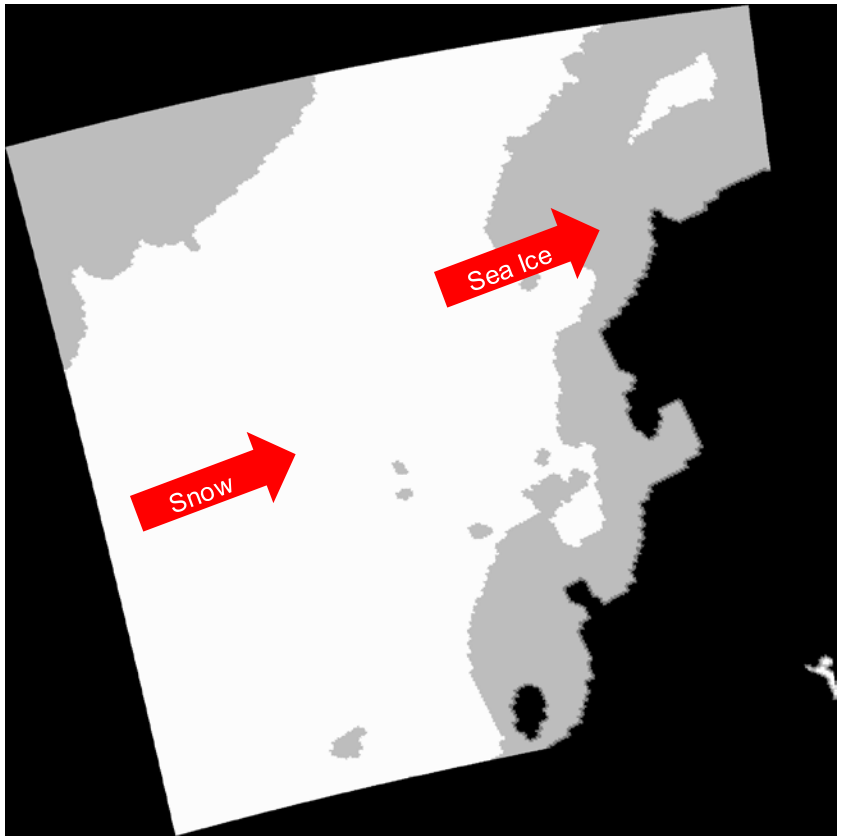
Application of IMS (Interactive Multisensor Snow and Ice Mapping System) (GeoTIFF)



Lake Huron and Lake Erie, 2013 Mar 16 11:35:51 UTC

Application of IMS (Interactive Multisensor Snow and Ice Mapping System) (GeoTIFF)





Kamchatka Peninsula, 2013 Mar 11 06:57:20 UTC

Bottom Line Message

- **NIC/NOAA has long used SAR (synthetic aperture radar) imagery for sea ice location and identification.**
- **SAR imagery can be used to estimate the wind speed field.**
- **SAR wind imagery may help in SAR imagery interpretation at the NIC and coastal area applications.**
- **Data available in PNG, KMZ, GeoTIFF w/ IMS ice mask data. Actual winds are available at netCDF (CF) compliant files.**