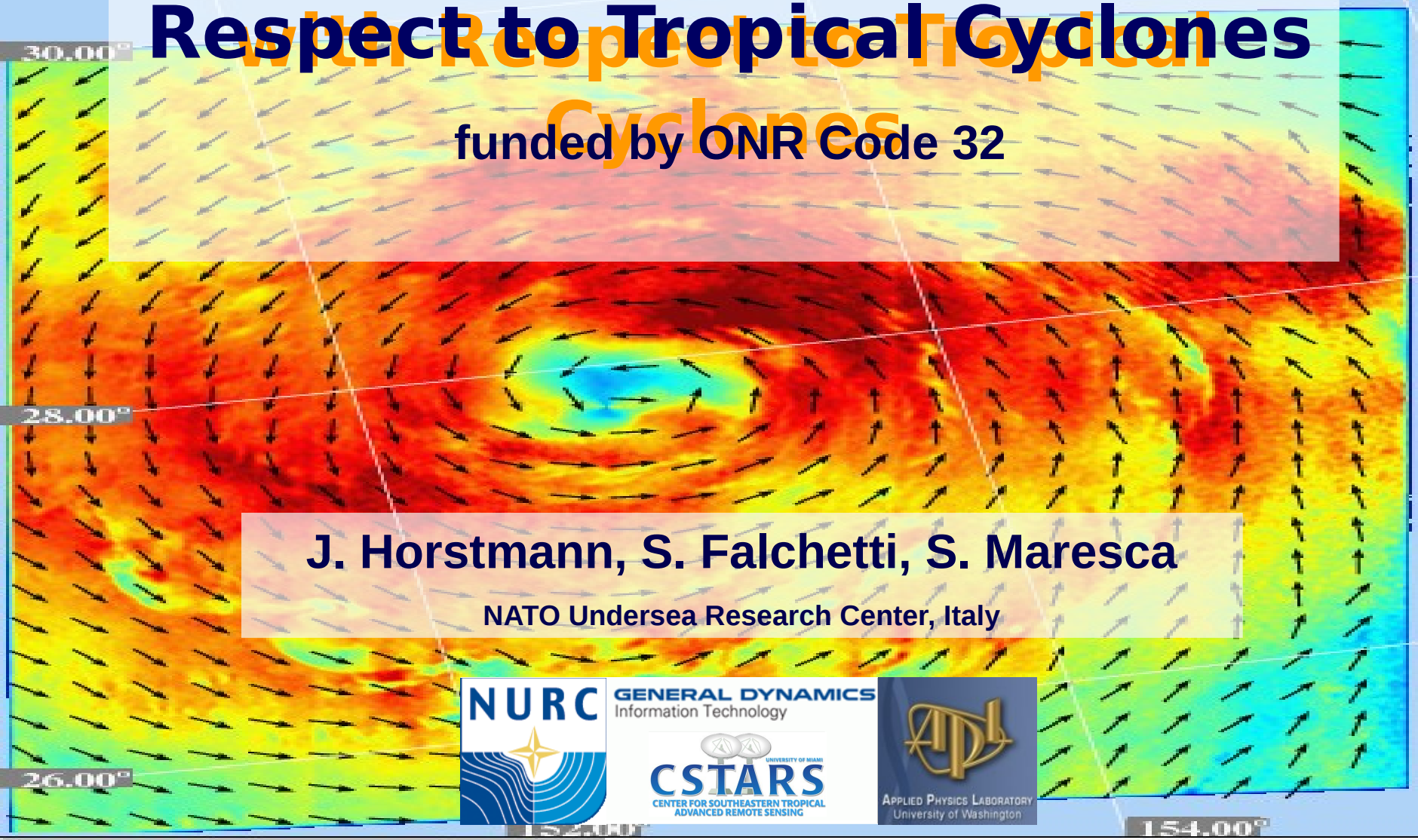
SAR Wind Field Retrieval with Respect to Tropical Cyclones

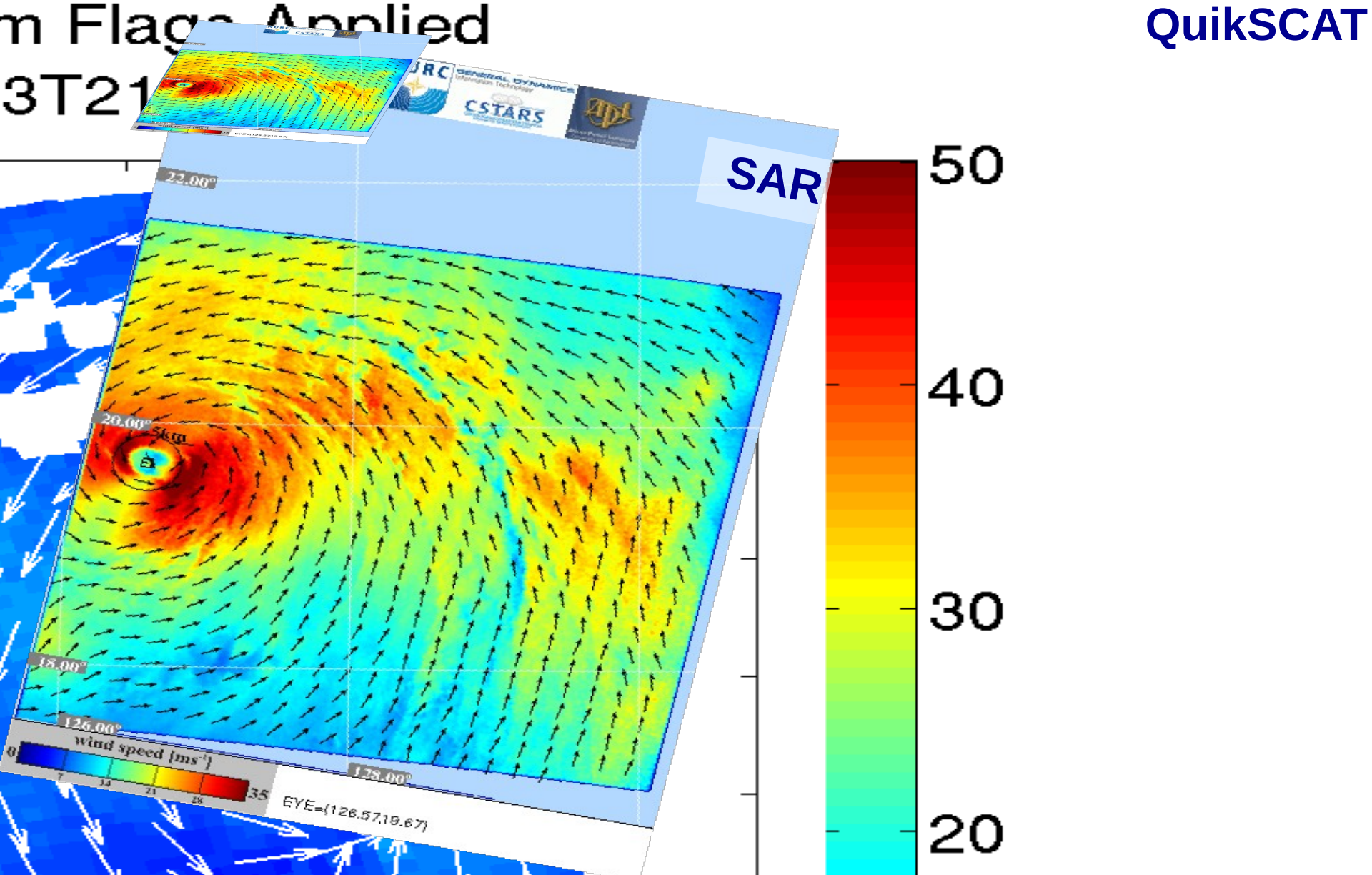
funded by ONR Code 32

J. Horstmann, S. Falchetti, S. Maresca

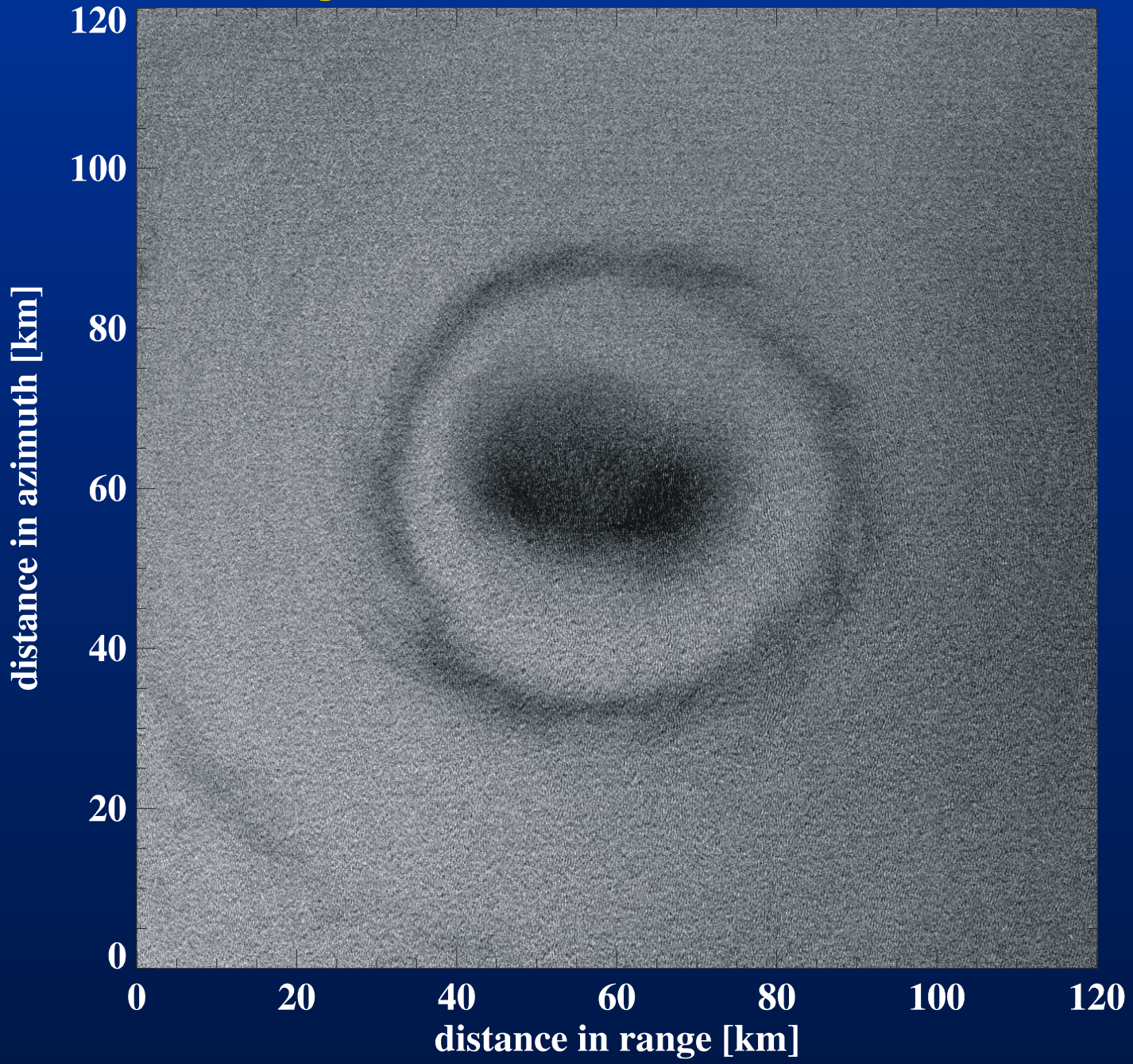
NATO Undersea Research Center, Italy



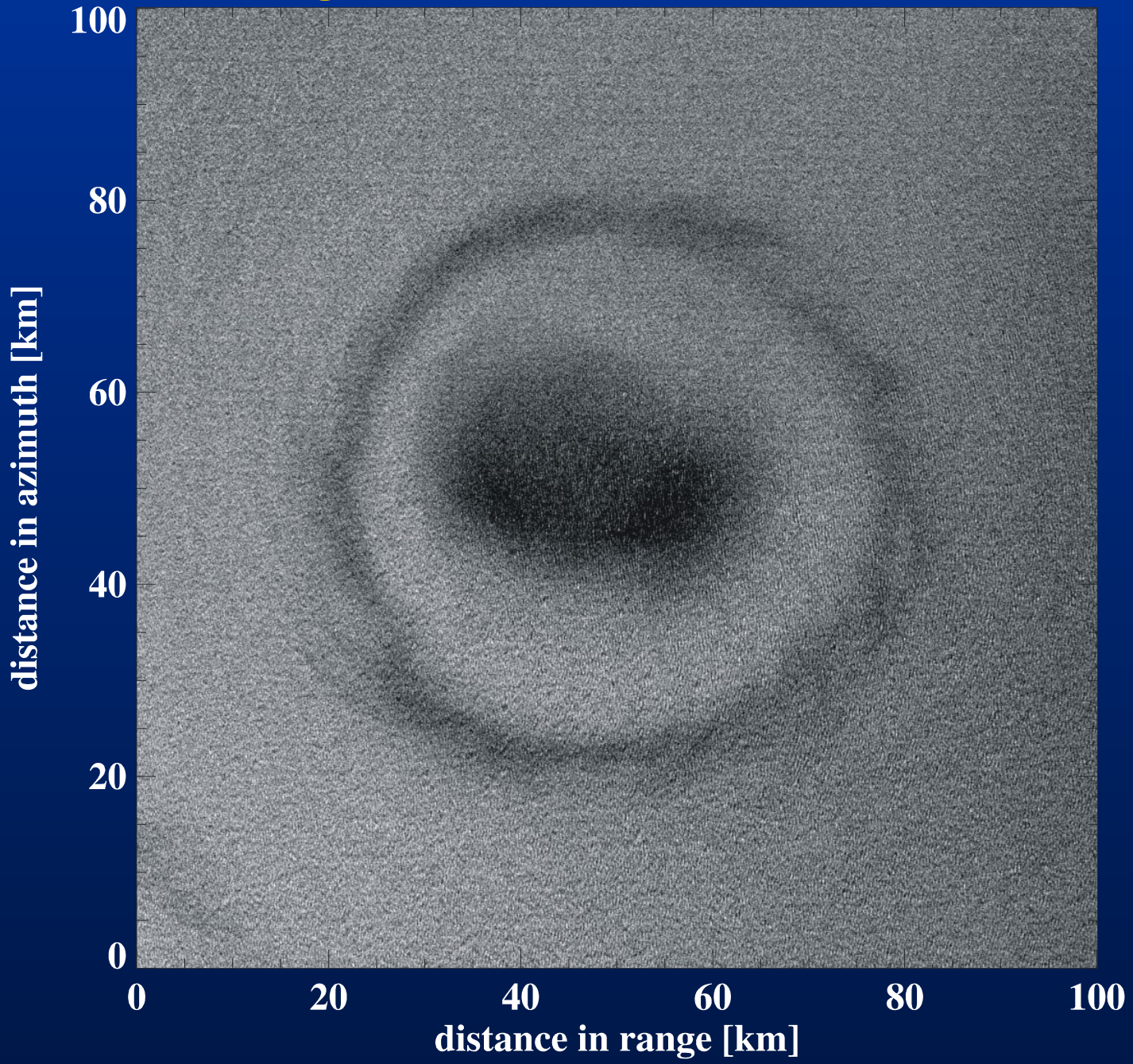
Why SAR for Tropical Cyclones



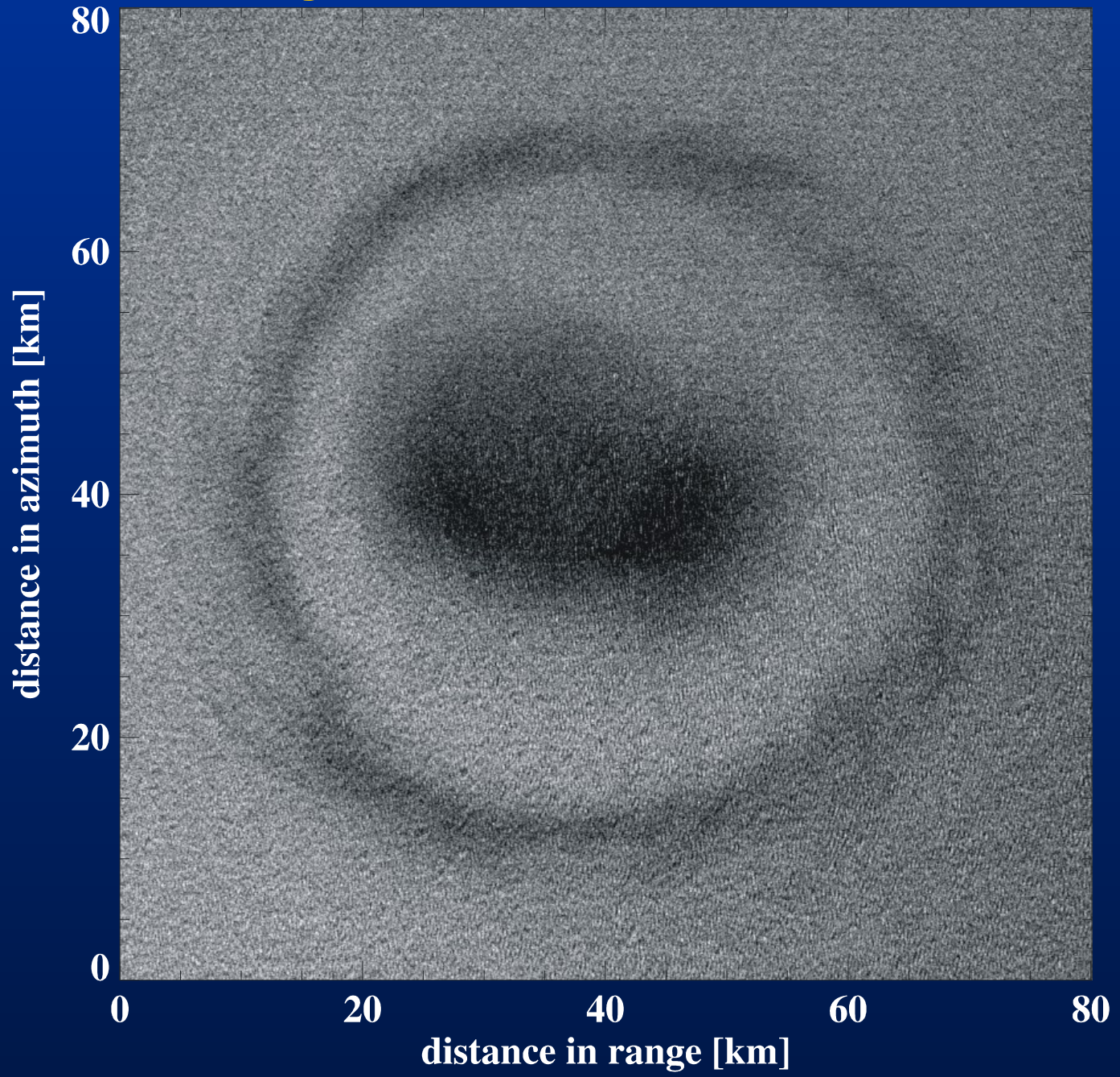
Hurricane eye of Katrina



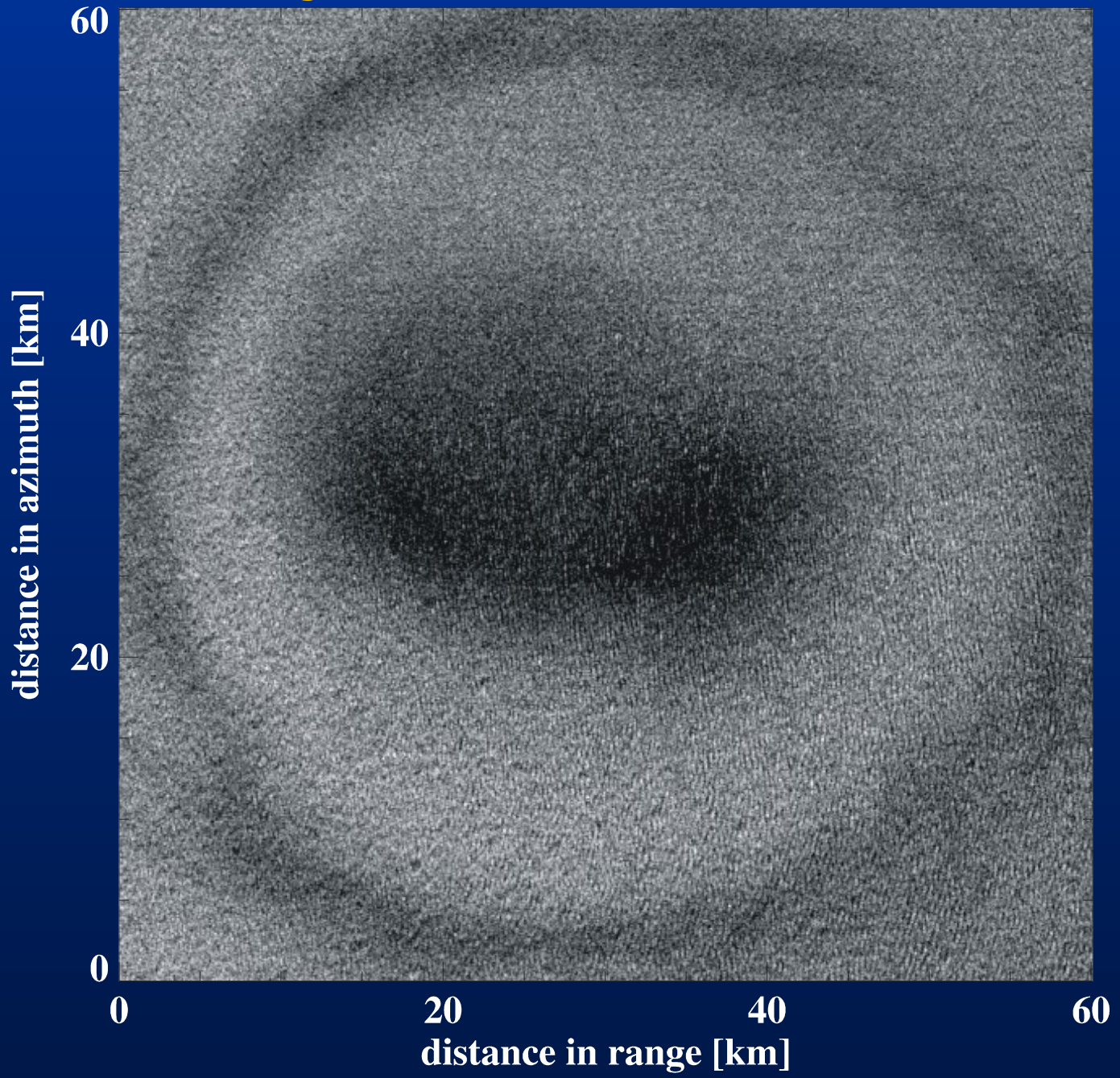
Hurricane eye of Katrina



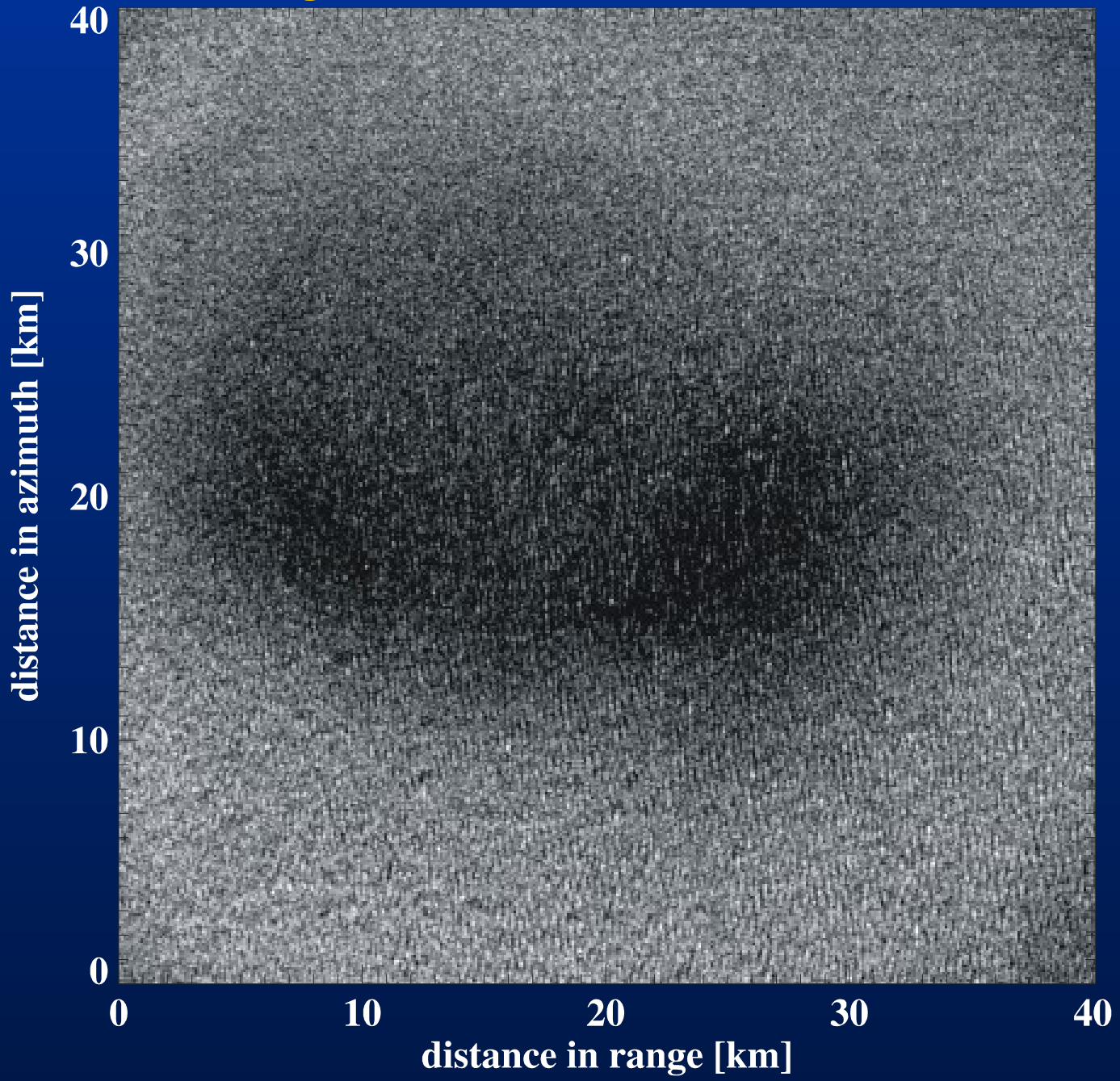
Hurricane eye of Katrina



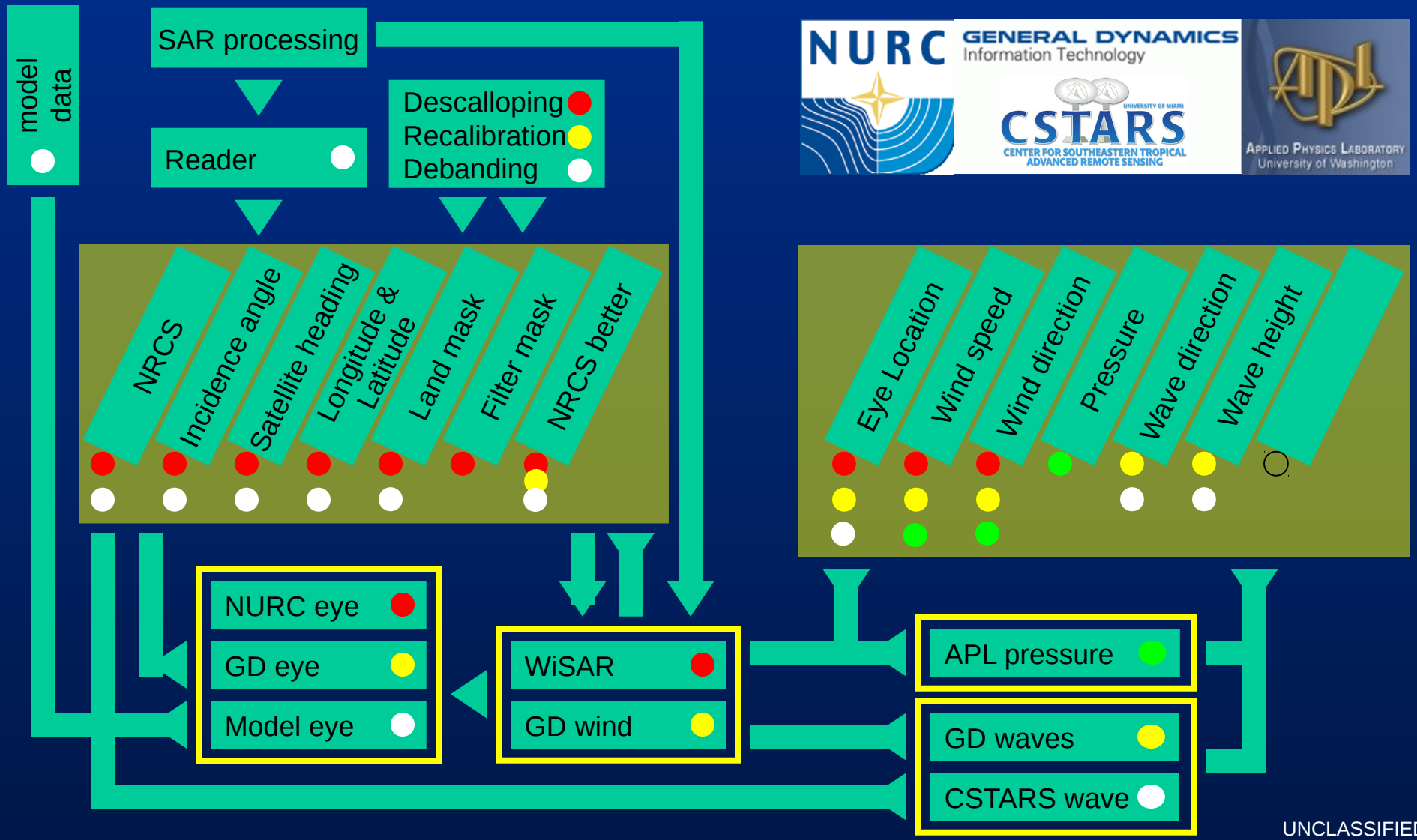
Hurricane eye of Katrina



Hurricane eye of Katrina



SAR Typhoon Processing System within the ITOP Project of ONR



NURC

GENERAL DYNAMICS Information Technology

CSTARS CENTER FOR SOUTHEASTERN TROPICAL ADVANCED REMOTE SENSING

APPLIED PHYSICS LABORATORY University of Washington

UNCLASSIFIED

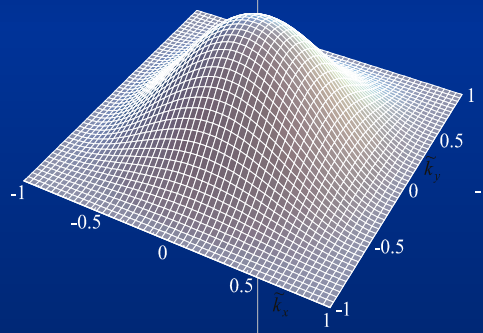
General Approach for Ocean SAR Wind Field Retrieval (WiSAR)

Local Gradient Method

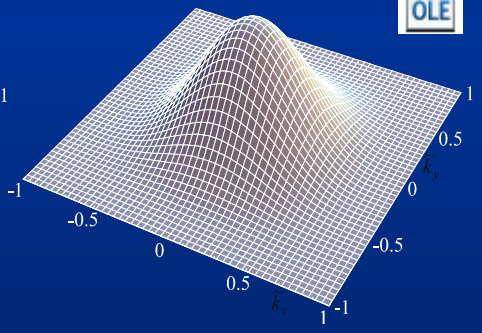
$(B^2B^4_{xy})^3$ → Sobel → $(B^2B^4_{xy})$ → Φ

Binomial filter

2 dim. B2 Filter



2 dim. B4 Filter



Optimized Sobel-Filter

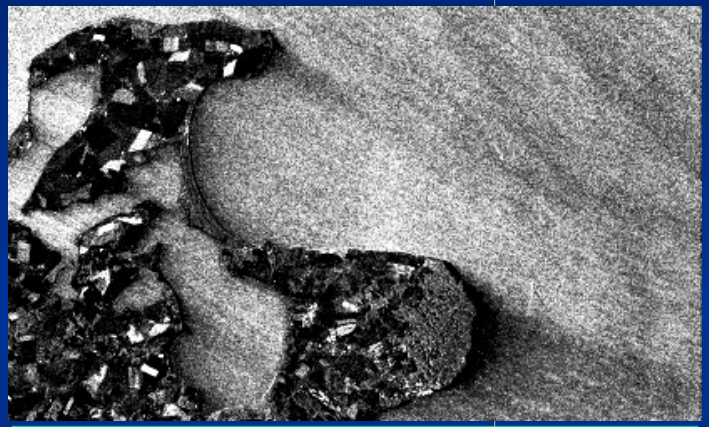
3	0	–3
10	0	–10
3	0	–3

→

3	10	3
0	0	0
–3	–10	–3

→

Geophysical Model Function



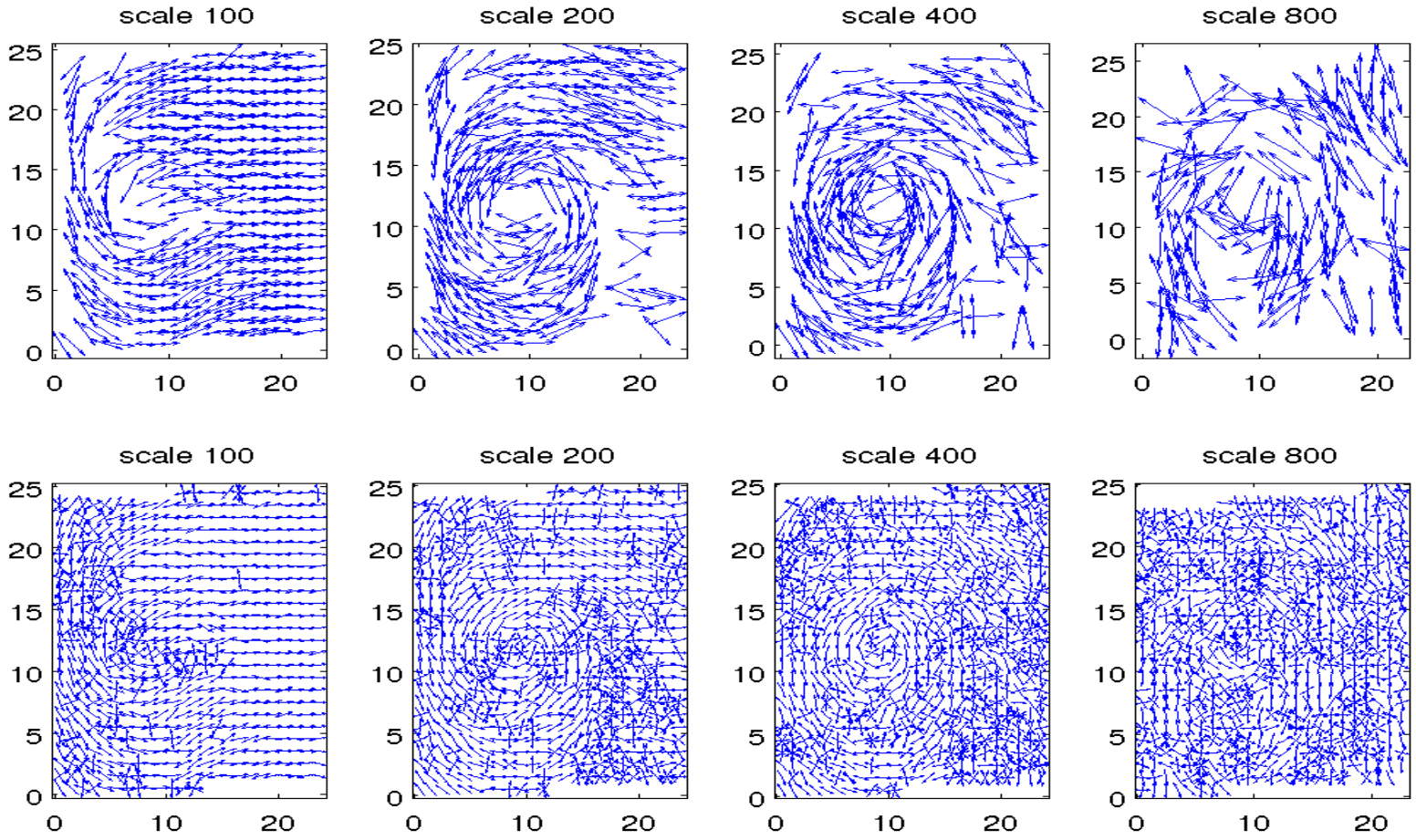
$$\sigma_0^{pol} = a(\theta)u^{\gamma(\theta)}[1 + b(\theta)\cos\phi + c(\theta)\cos(2\phi)]$$

Φ θ u10

GMF for C-, X- and L-band

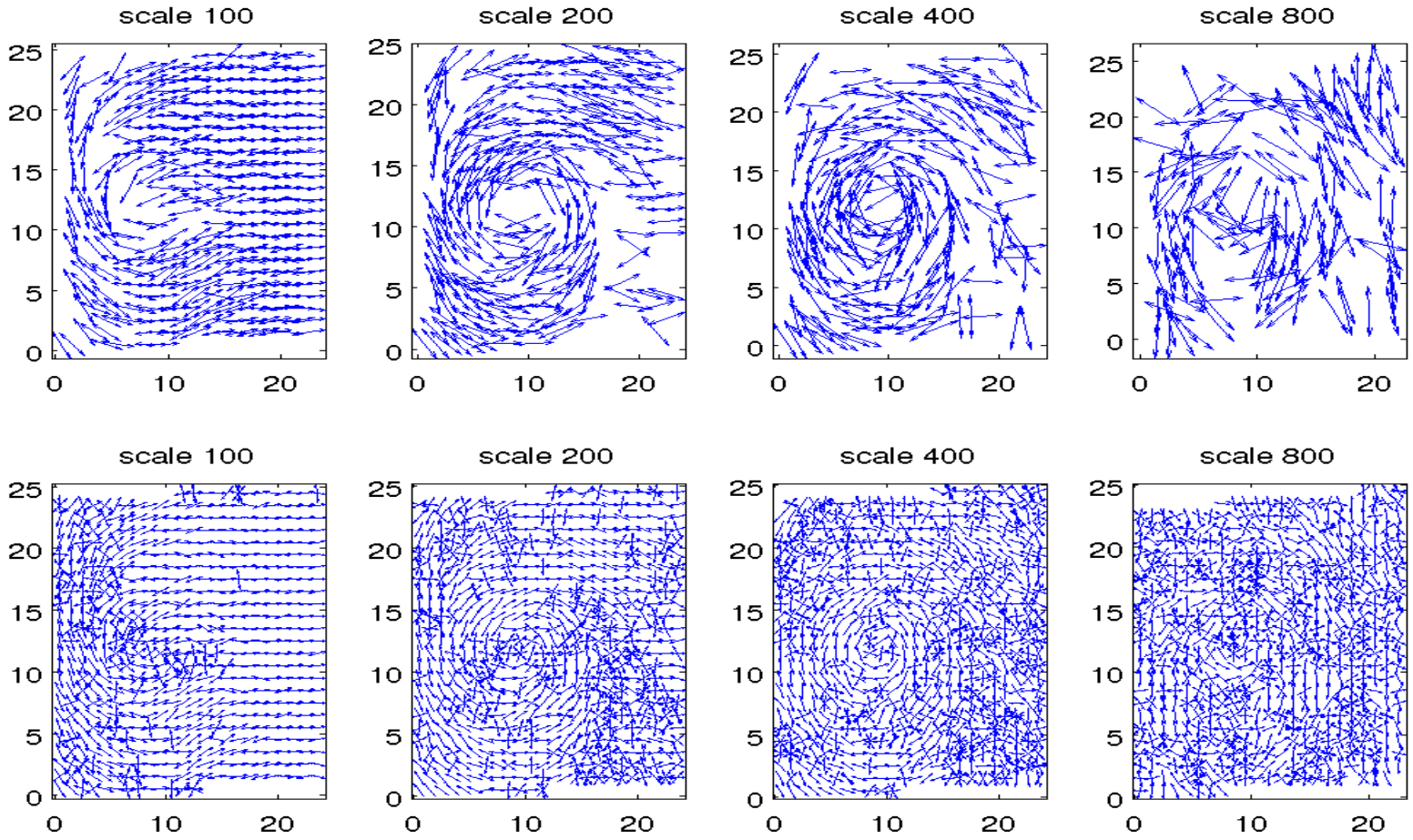
σo

Wind Direction Ambiguity Removal



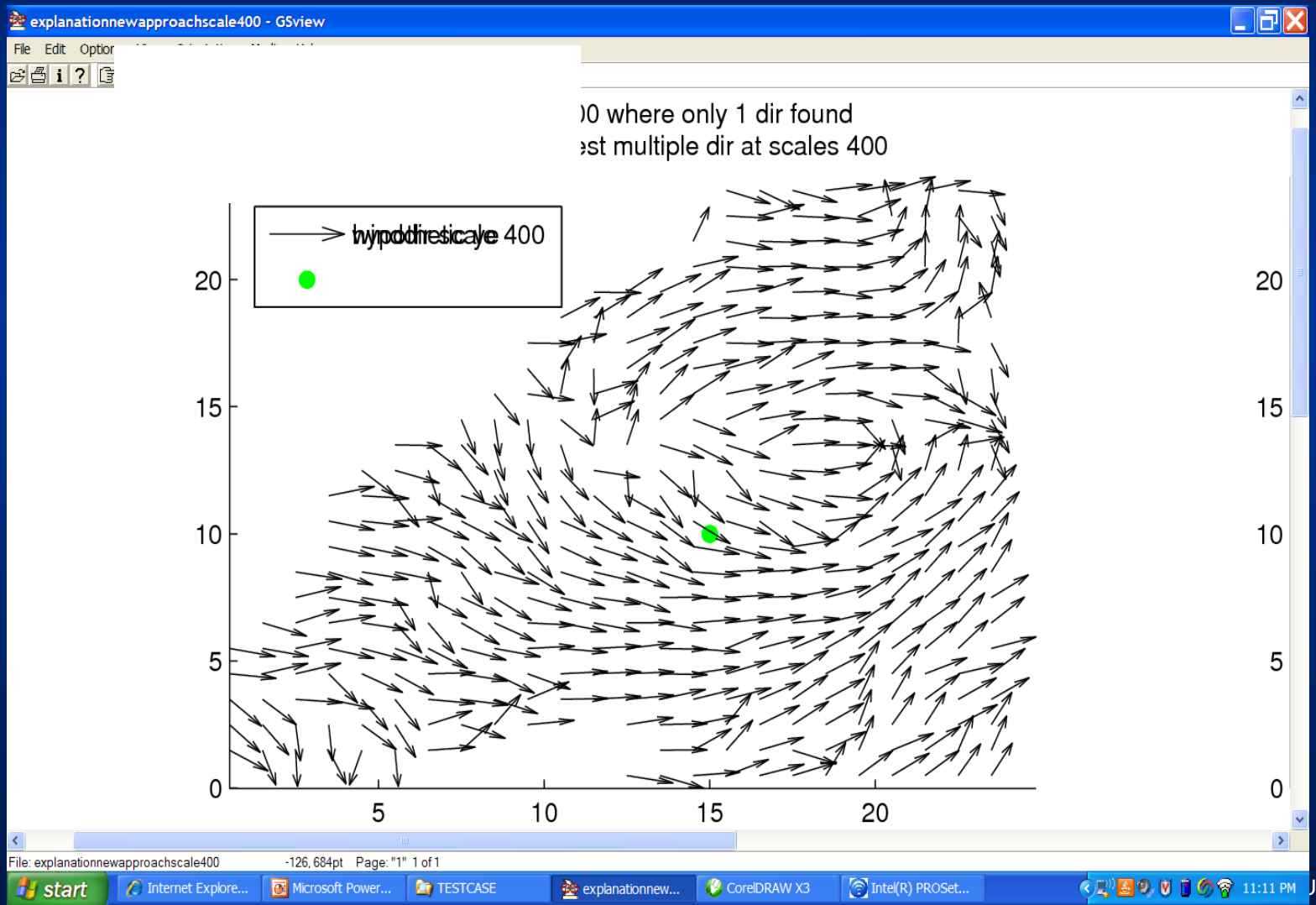
Wind Direction Ambiguity Removal

1. **Select grids with only one wind direction (400m)**



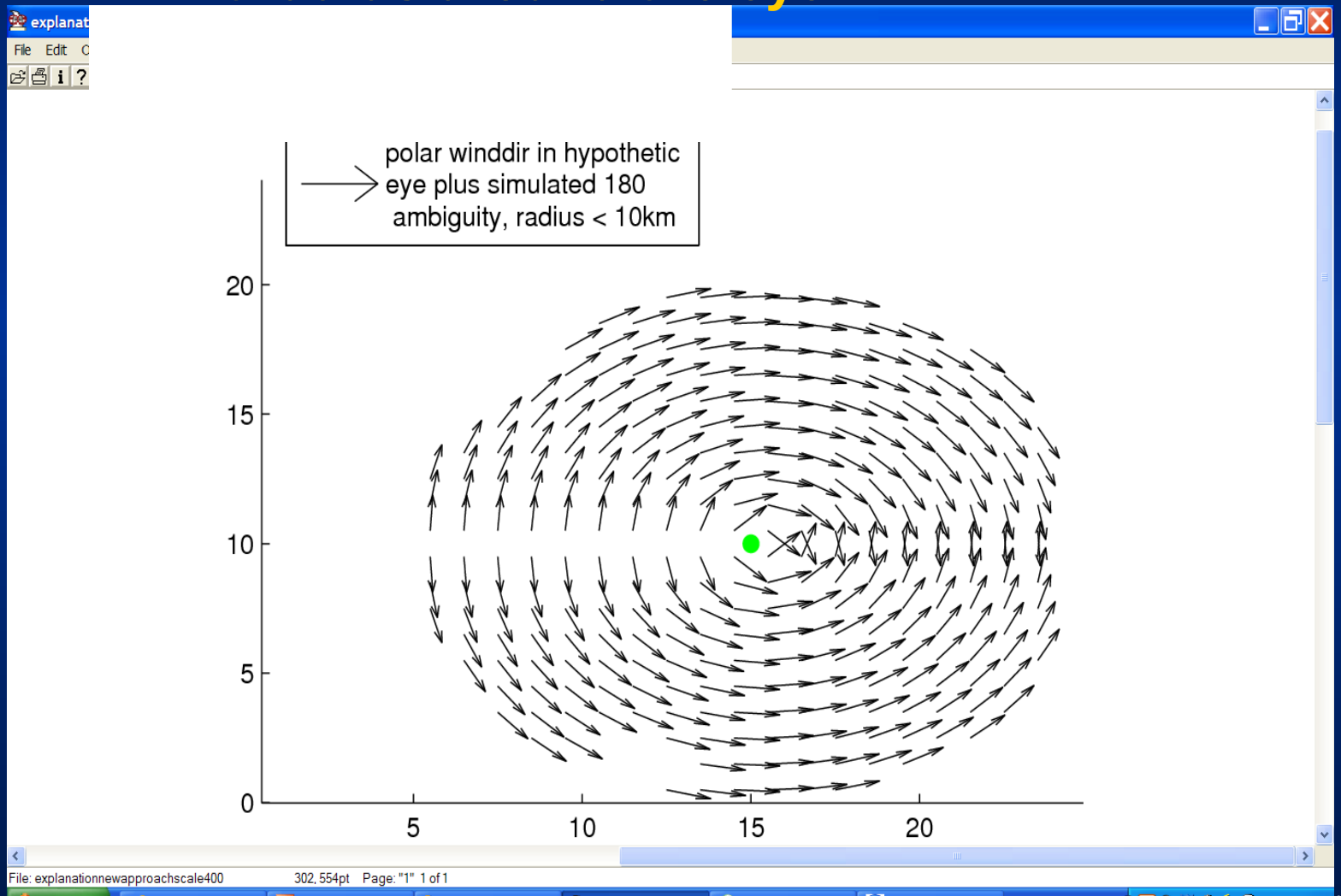
Wind Direction Ambiguity Removal

2. **Select nearest neighbor for the other wind directions**



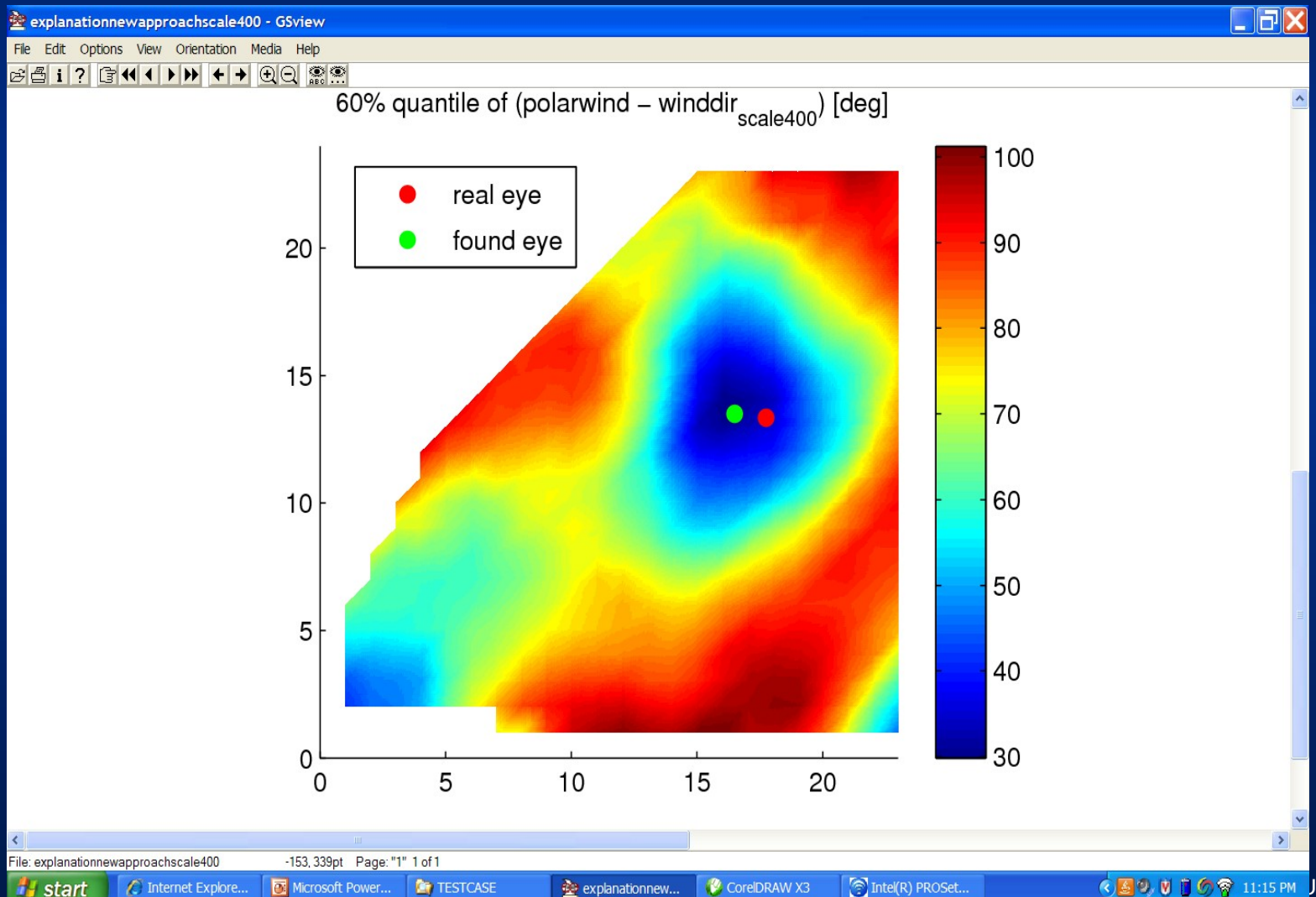
Wind Direction Ambiguity Removal

3. Polar wind directions around hypothetic eye with 180 deg ambiguity
4. Limit radius around the eye



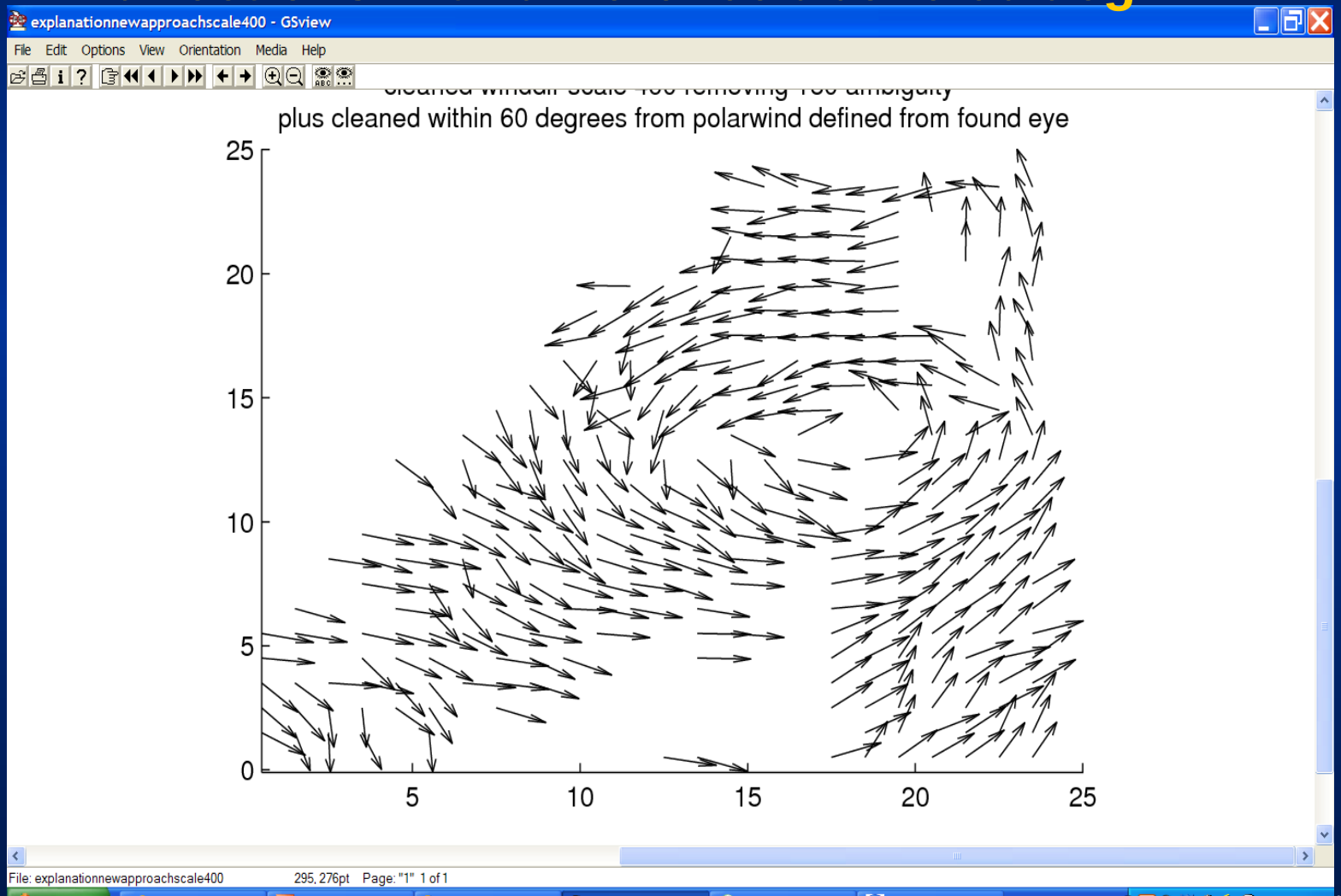
Wind Direction Ambiguity Removal

5. **Retrieve 60% quantile of simulated polar wind at 400 m grid wind**



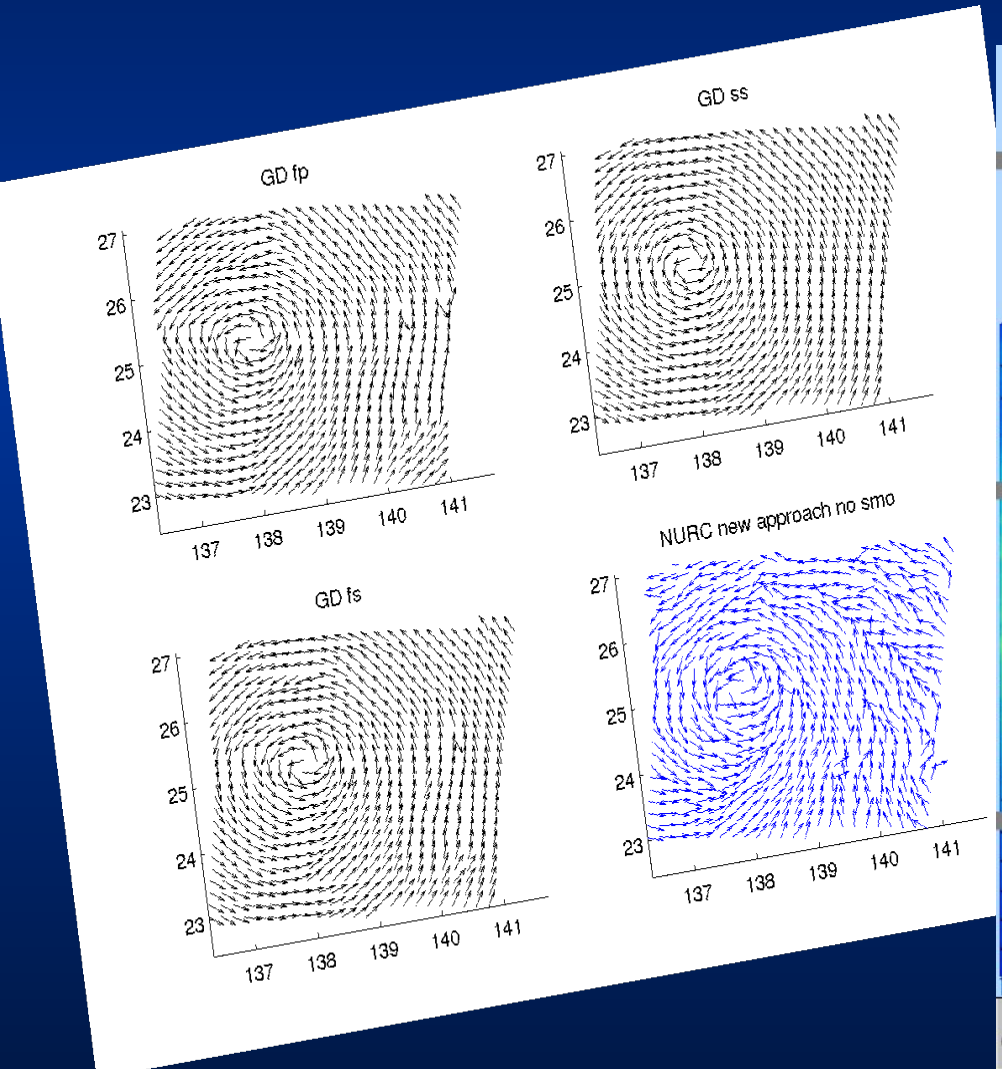
Wind Direction Ambiguity Removal

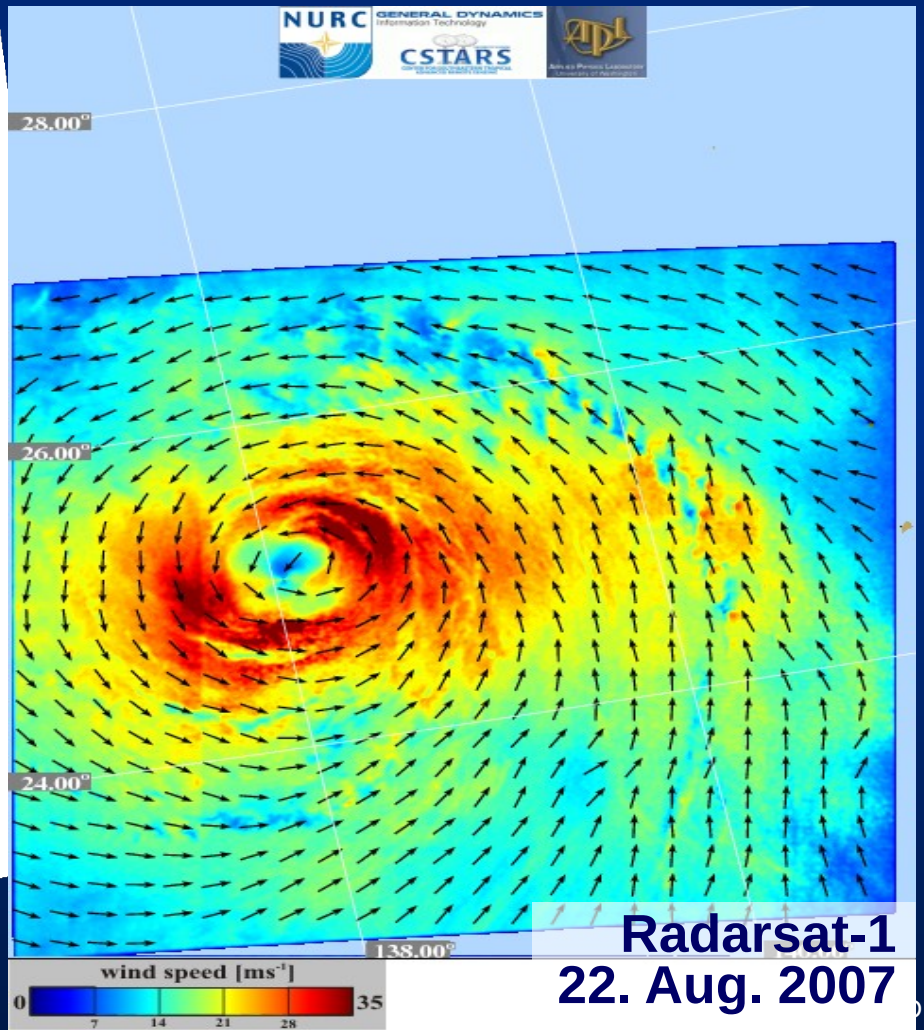
6. **Use eye location and polar wind to remove 180 deg ambiguity and wind directions with difference above 60 deg**



Wind Direction Ambiguity Removal

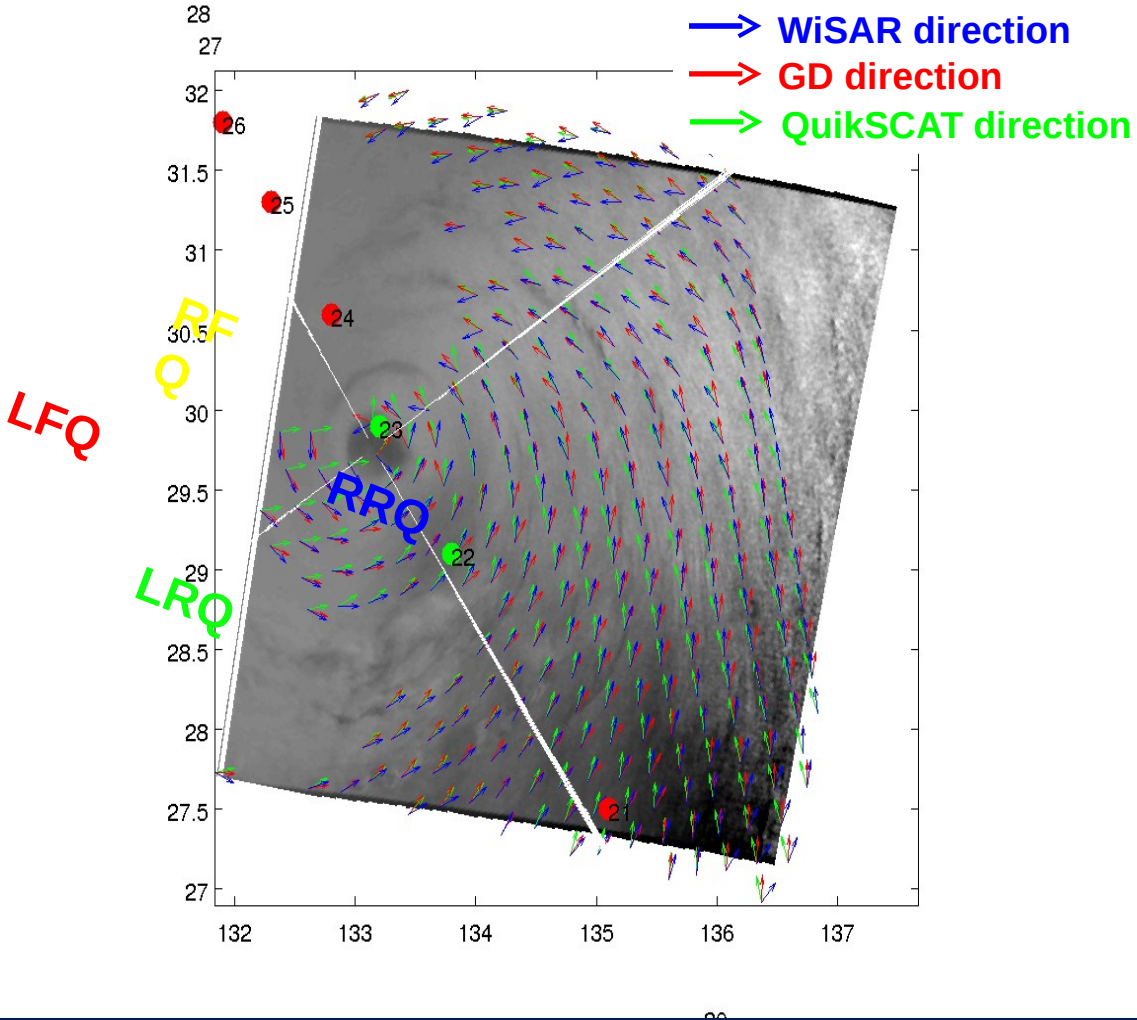
7. **Select nearest neighbor of all scales to previously selected wind directions**
8. **Smooth wind directions**

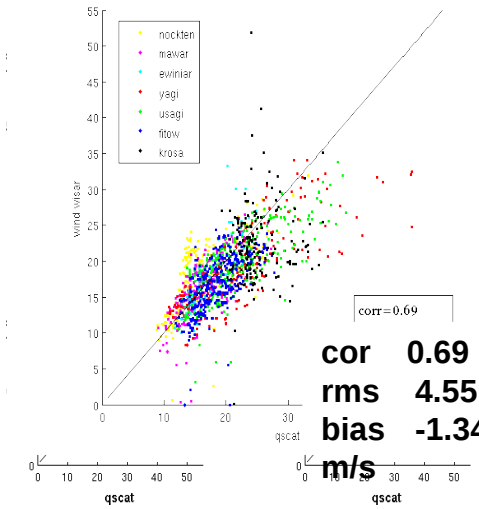




Radarsat-1
22. Aug. 2007

Comparison of SAR to Quikscat winds

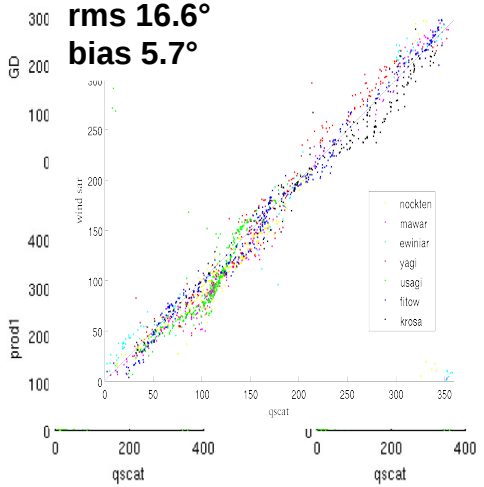




cor 0.69
rms 4.55m/s
bias -1.34 m/s

QuikSCAT wind speed [m/s]

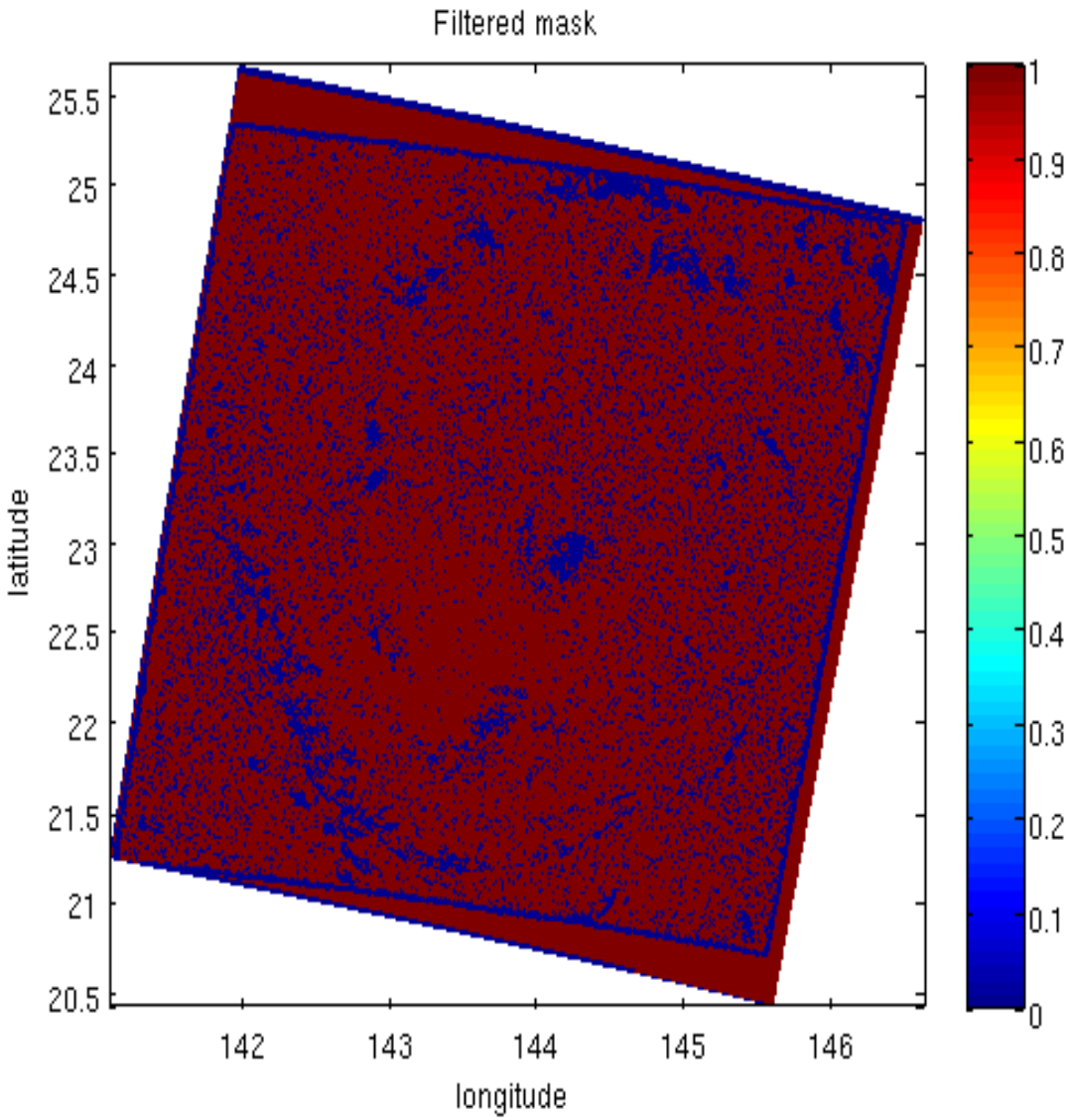
cor 0.97
rms 16.6°
bias 5.7°



QuikSCAT wind direction [°]

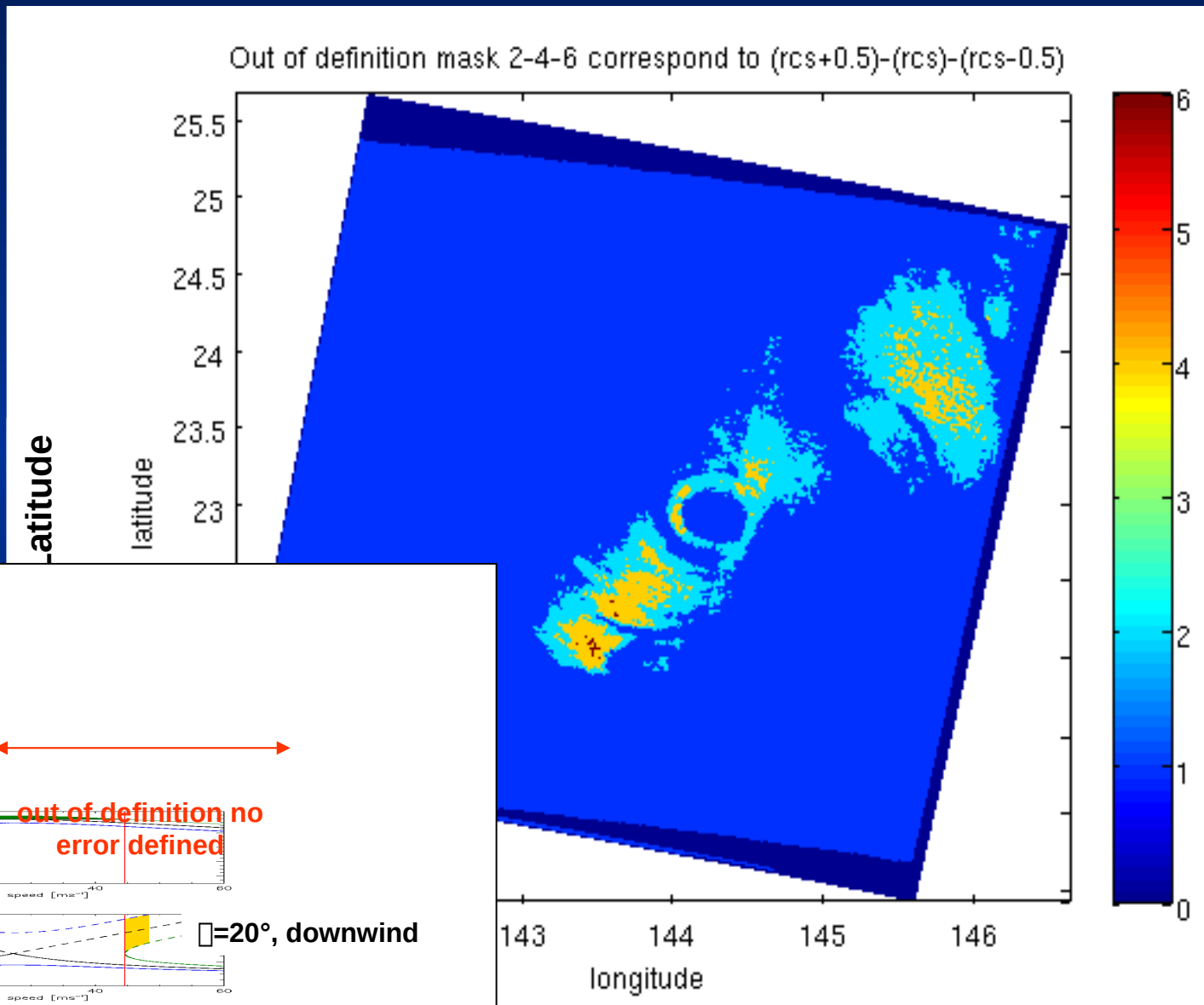
SAR Wind Speed Error Masks

Non wind phenomenon mask



SAR Wind Speed Error Masks

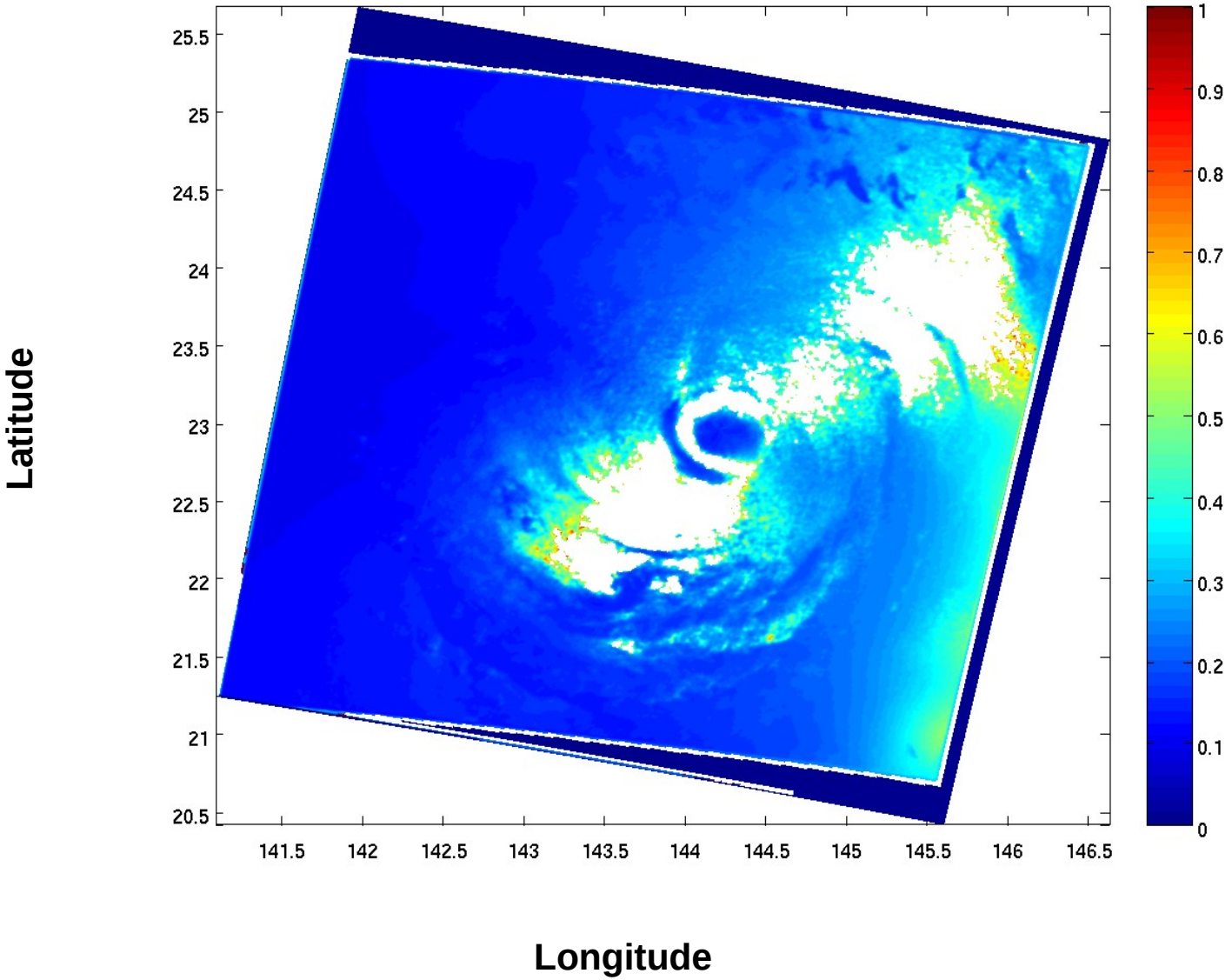
Out of Definition Mask



Longitude

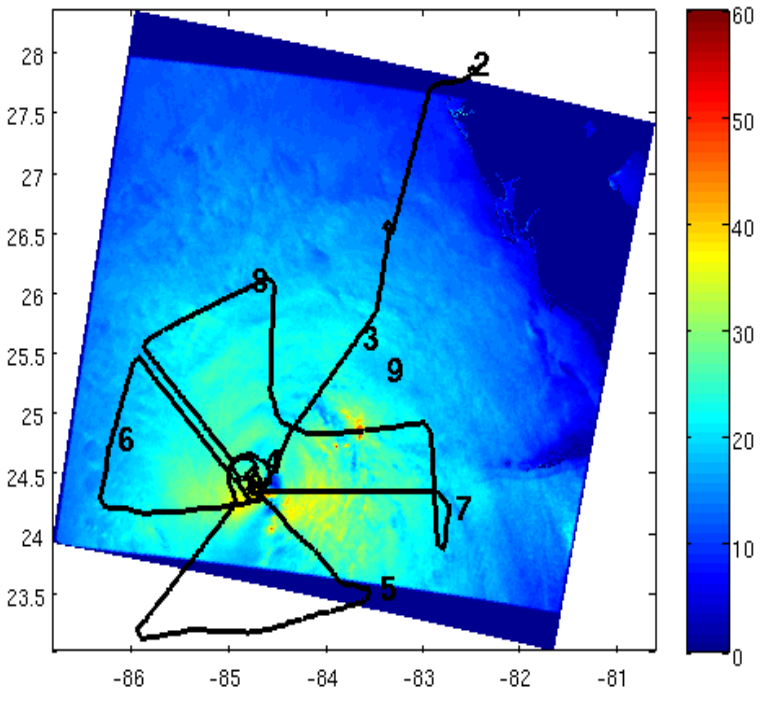
SAR Wind Speed Error Masks

Uncertainty Mask

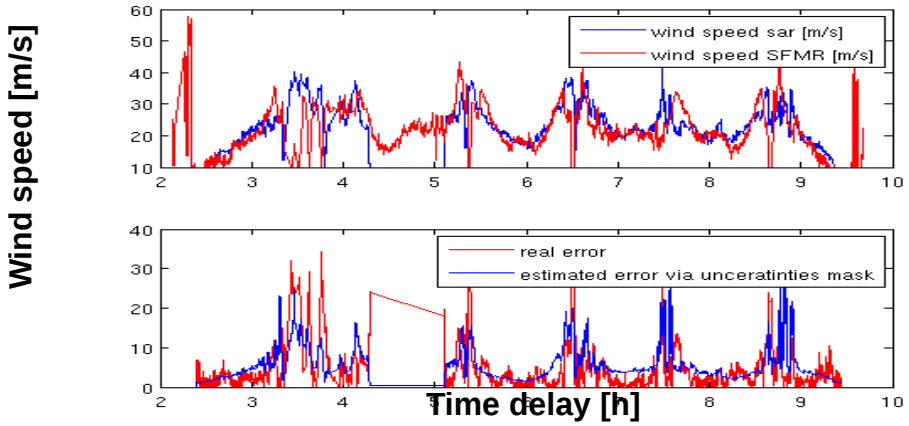


Comparison of SAR and SFMR Wind Speeds

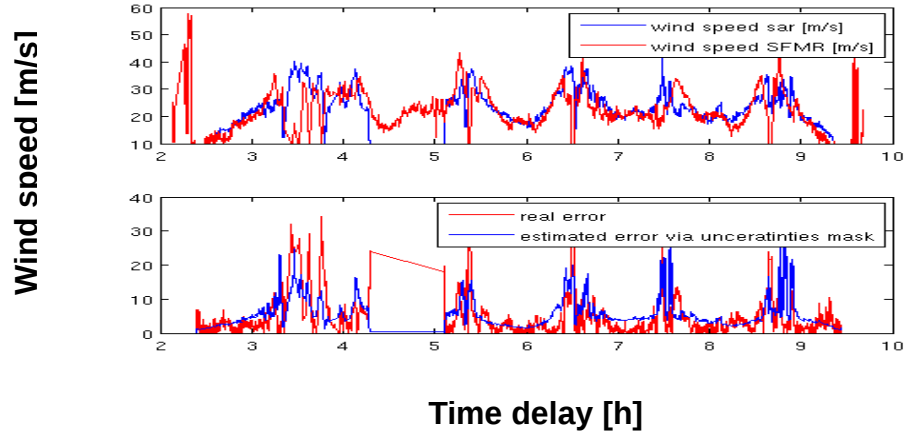
SAR wind speeds with superimposed adjusted SFMR flight track



Comparison of wind speeds

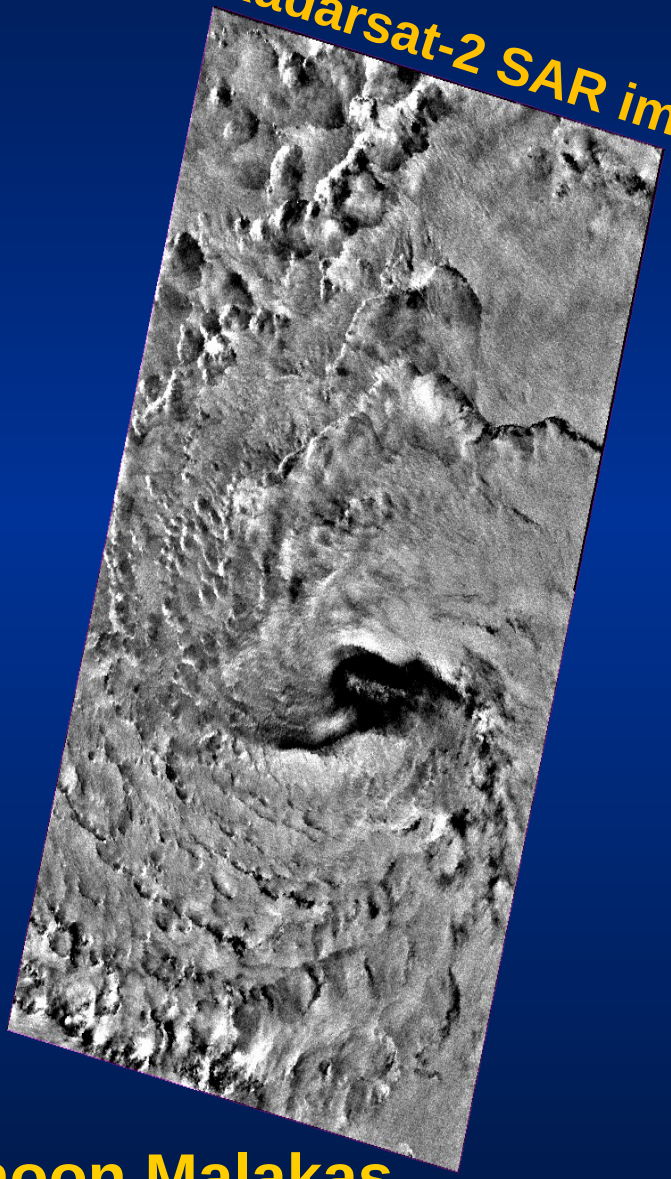


Comparison of wind speed errors

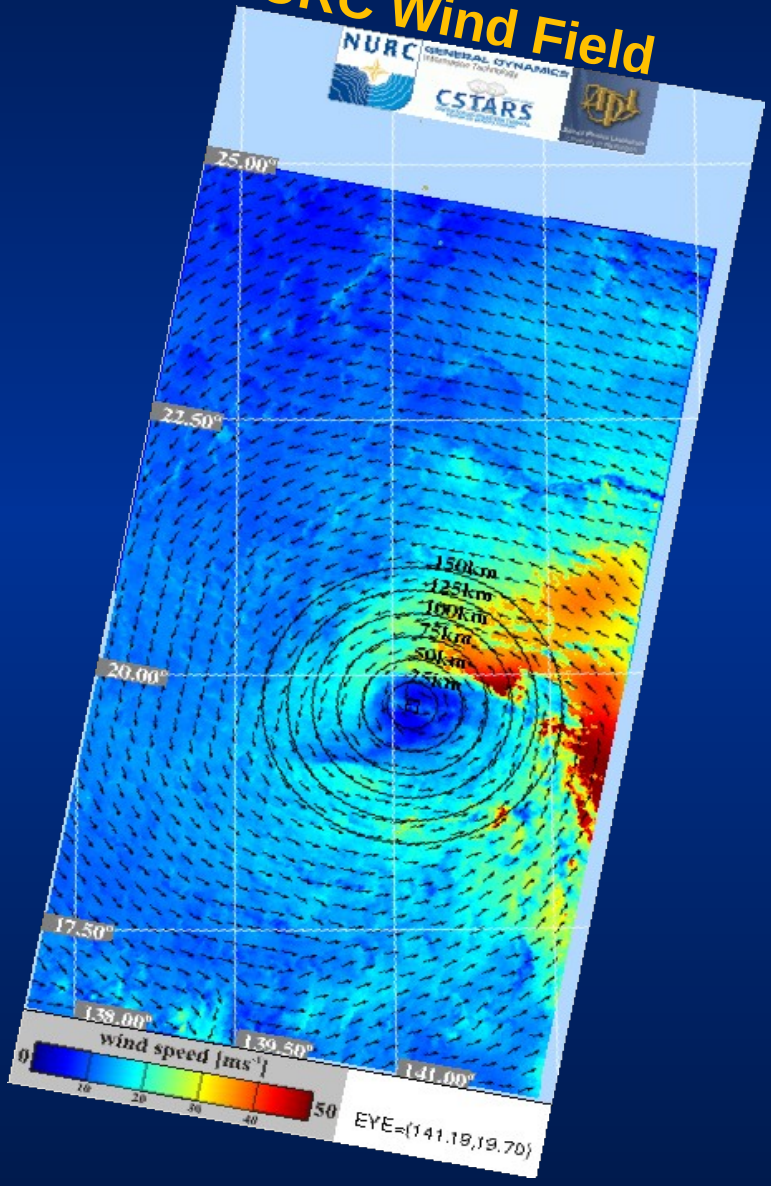


Assimilation SAR Winds into HWIND

Radarsat-2 SAR image

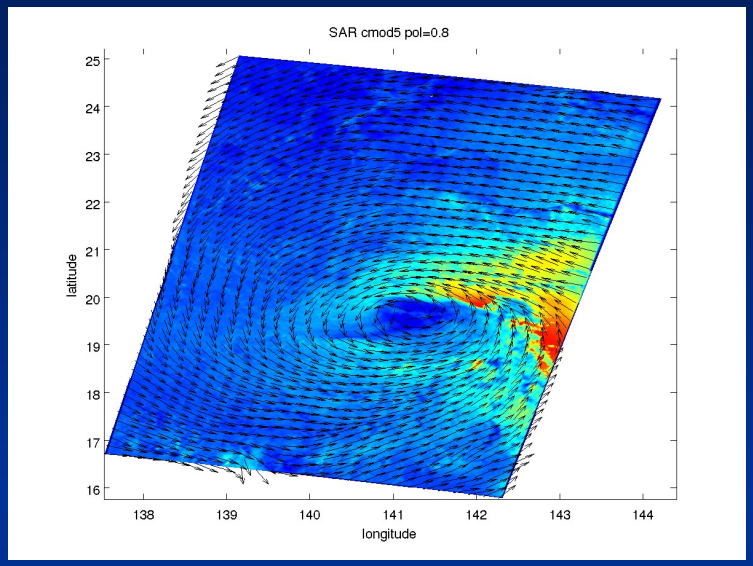


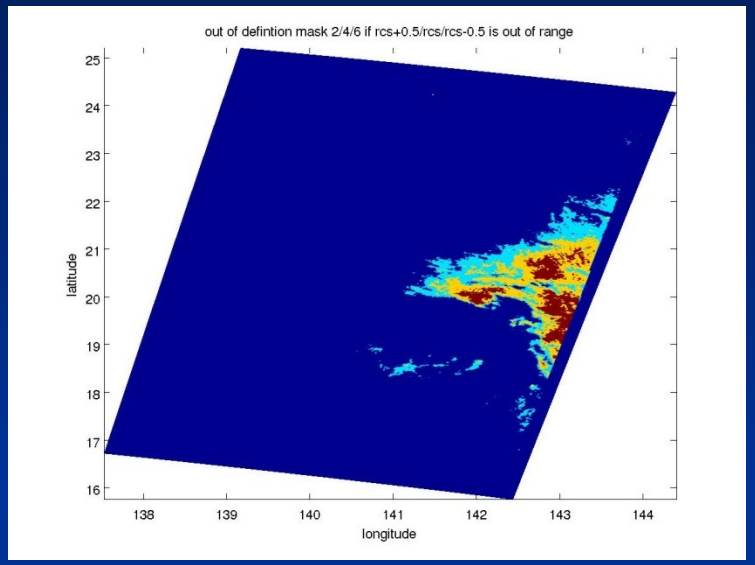
NURC Wind Field

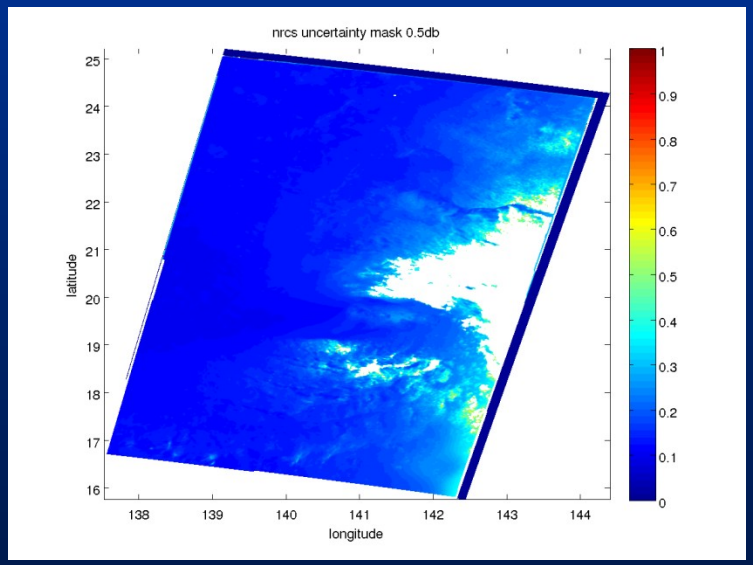


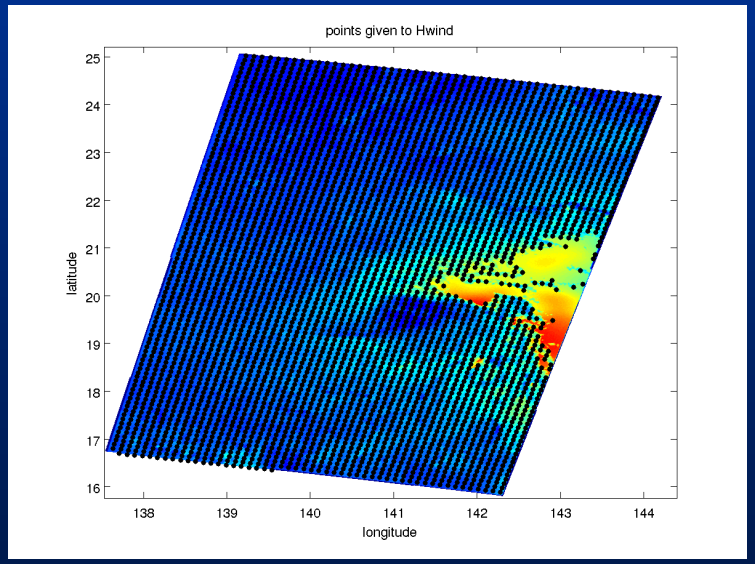
Typhoon Malakas

Wind Speed Error and Certainty Masks



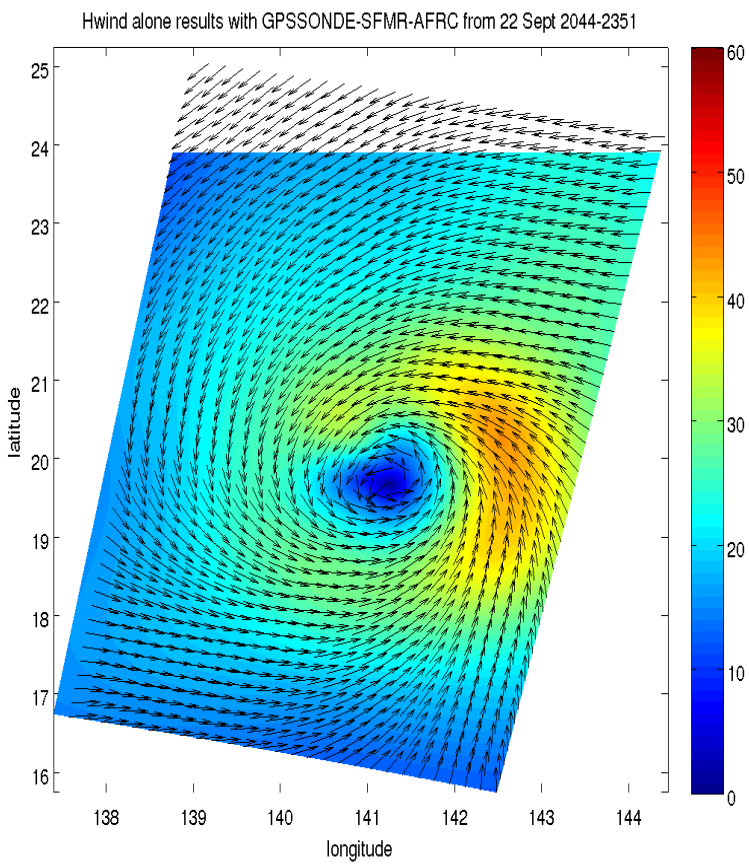




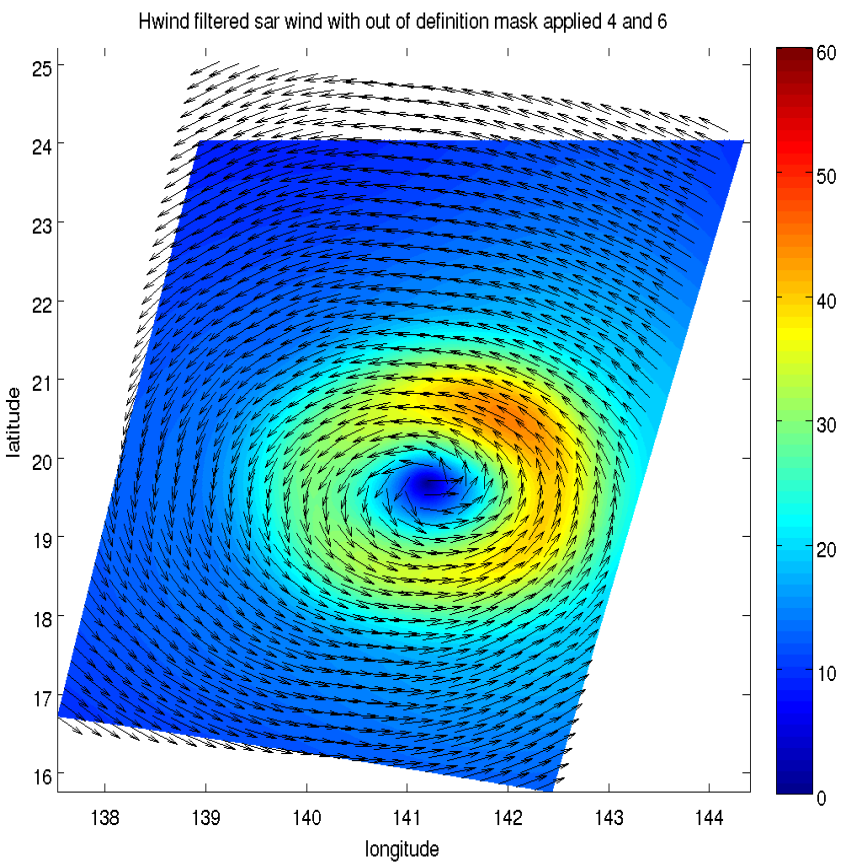


Assimilation into HWIND

HWIND with in situ and SFMR

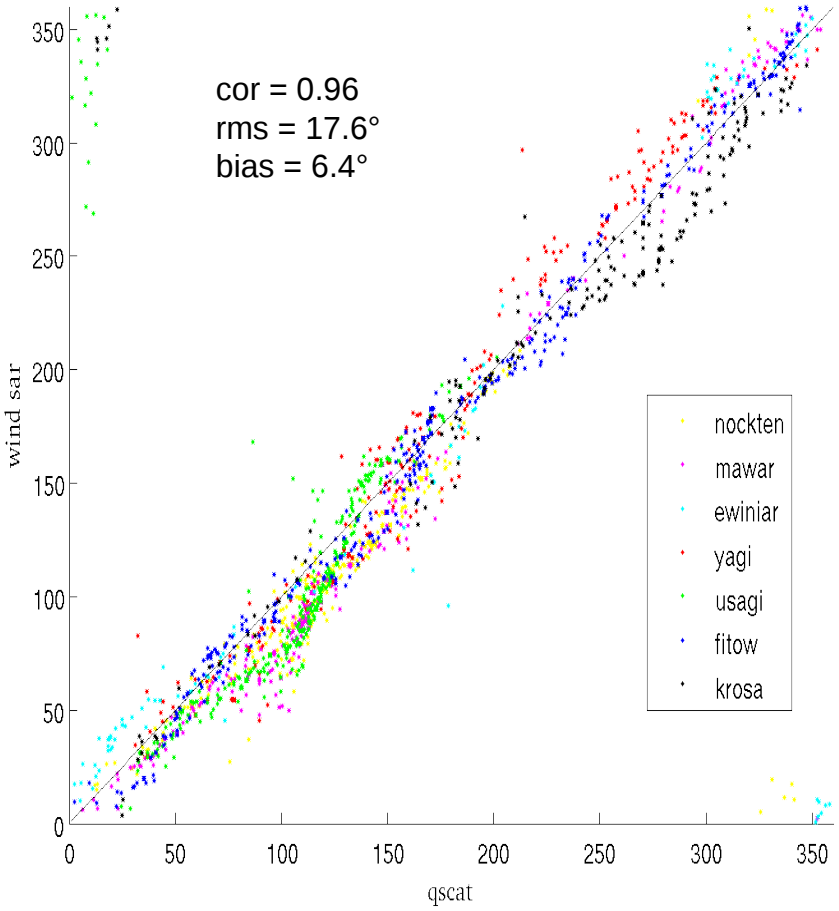


HWIND with SAR wind field solely

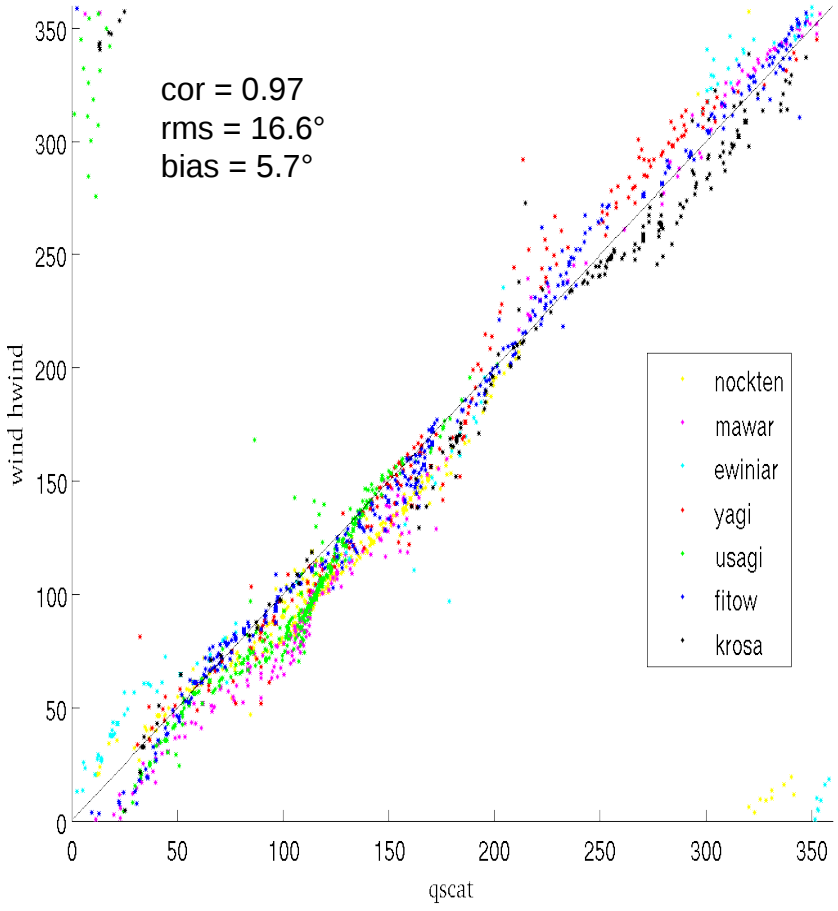


Comparison of SAR to Quikscat winds

SAR wind directions NURC-GD merged

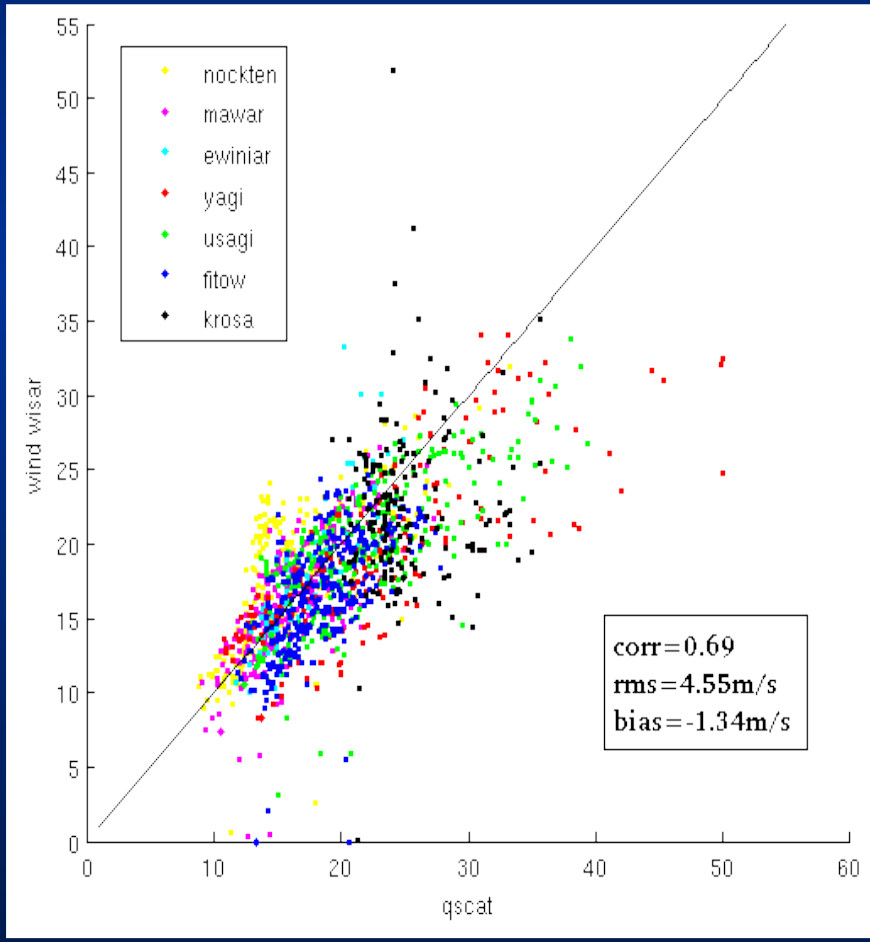


HWIND wind directions assimilation of SAR wind field (solely)

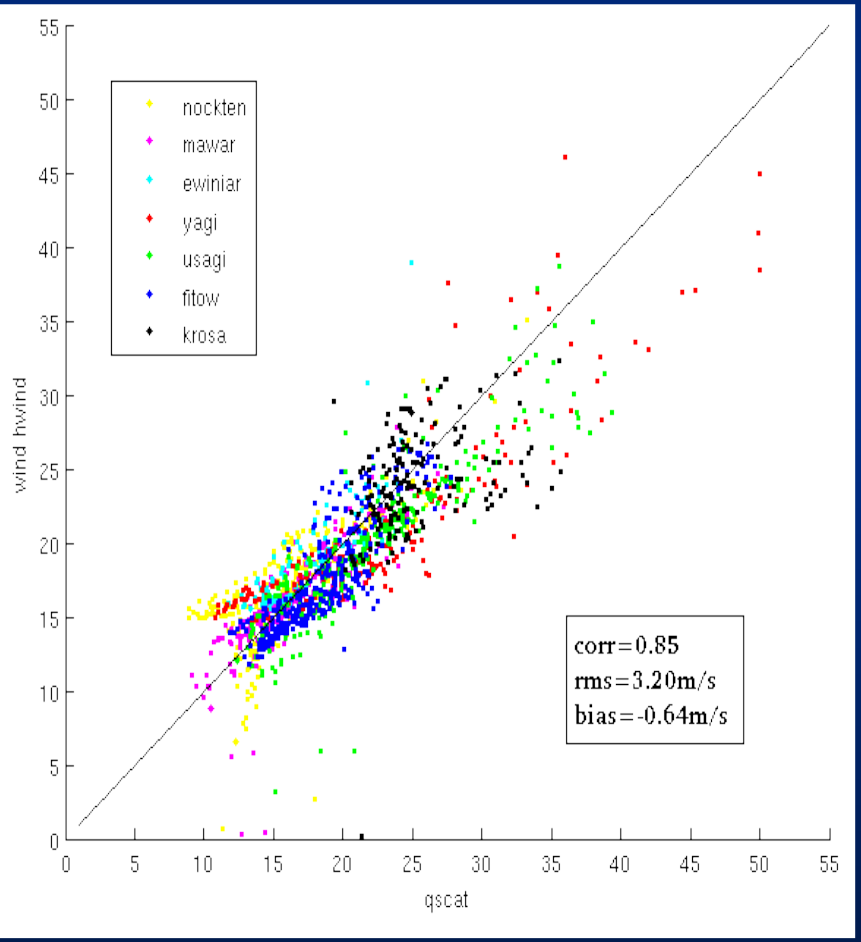


Comparison of SAR to Quikscat winds

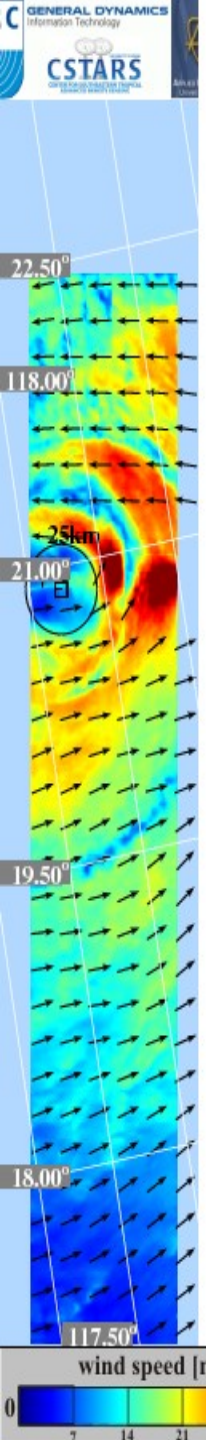
SAR wind speeds NURC-GD merged

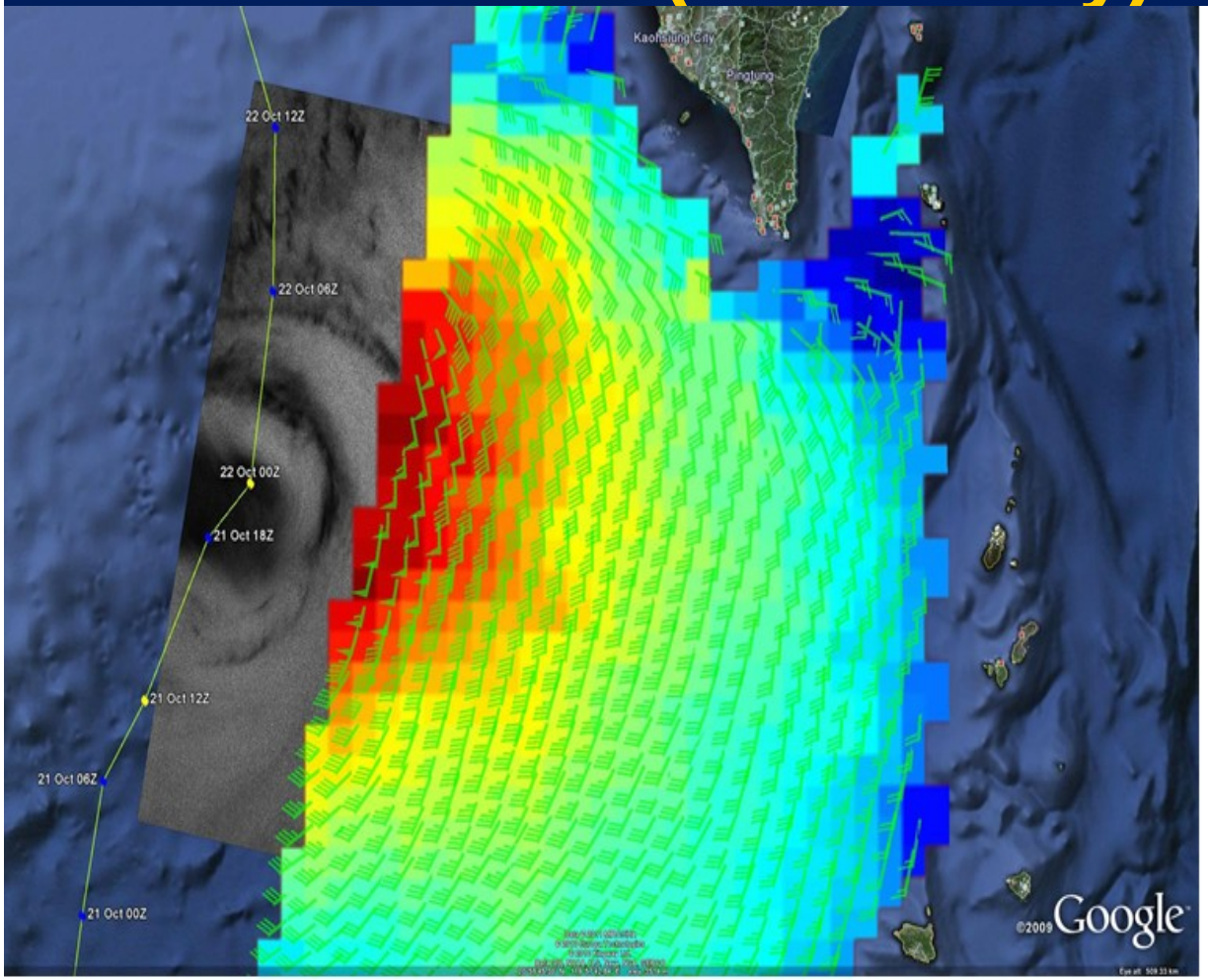


HWIND wind speeds assimilation of SAR wind field (solely)

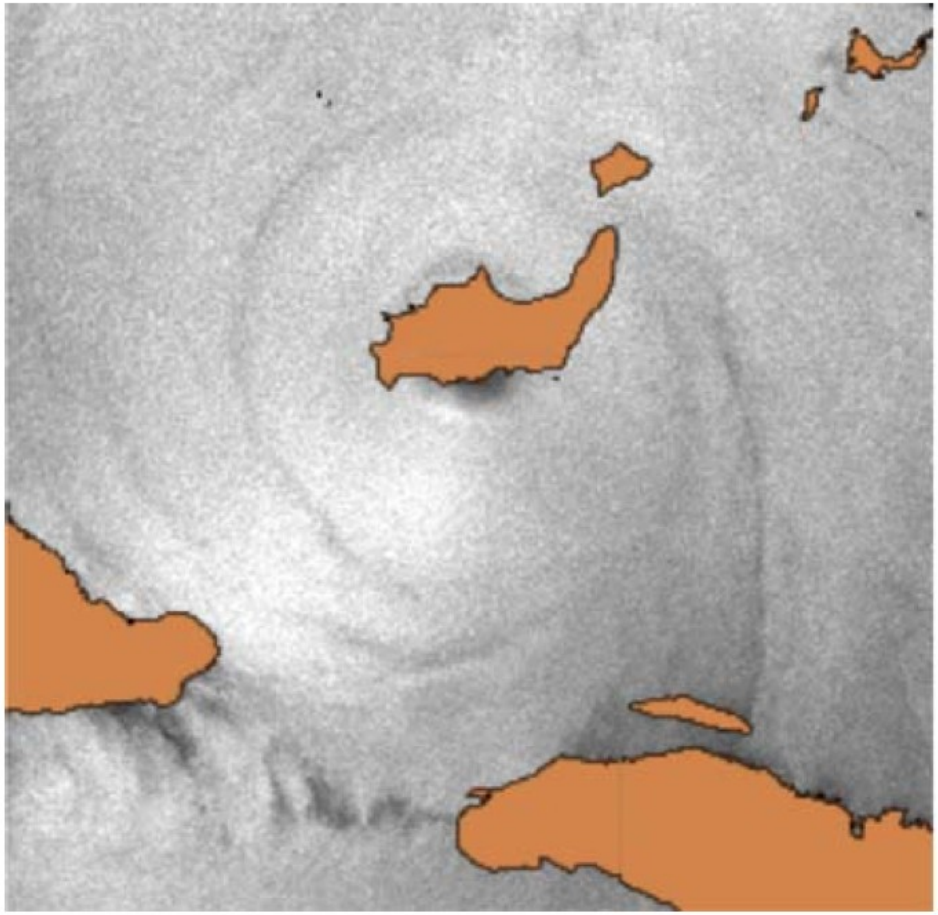


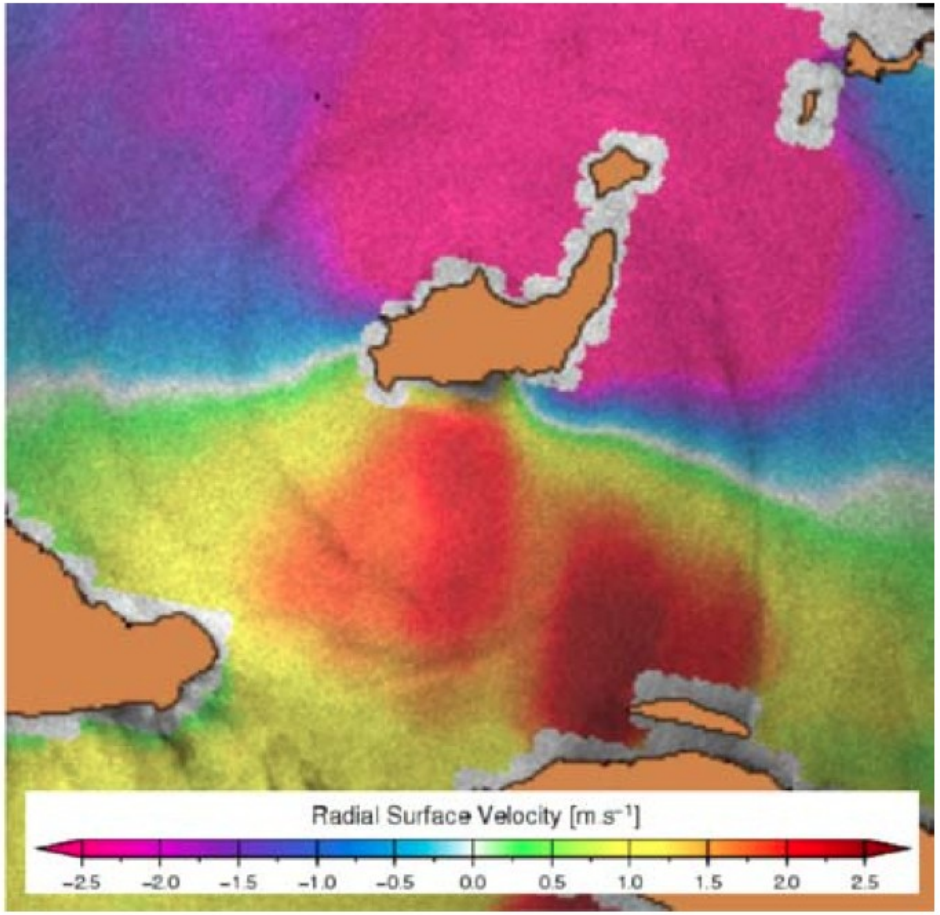
TerraSAR-X Winds Compared to ASCAT Results (Priliminary)



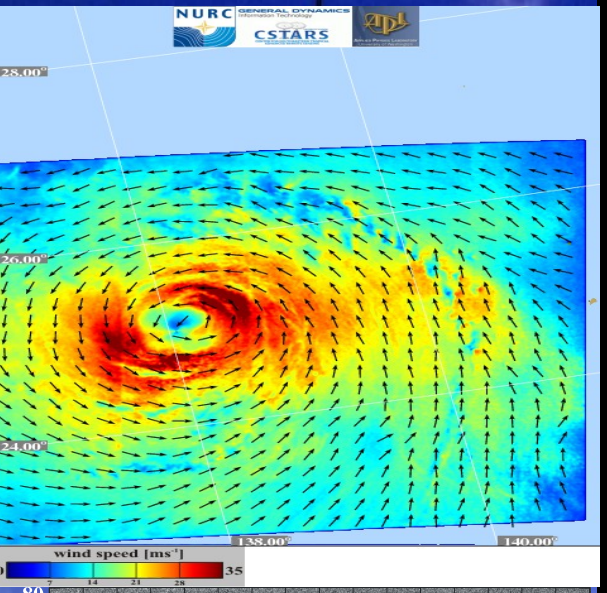


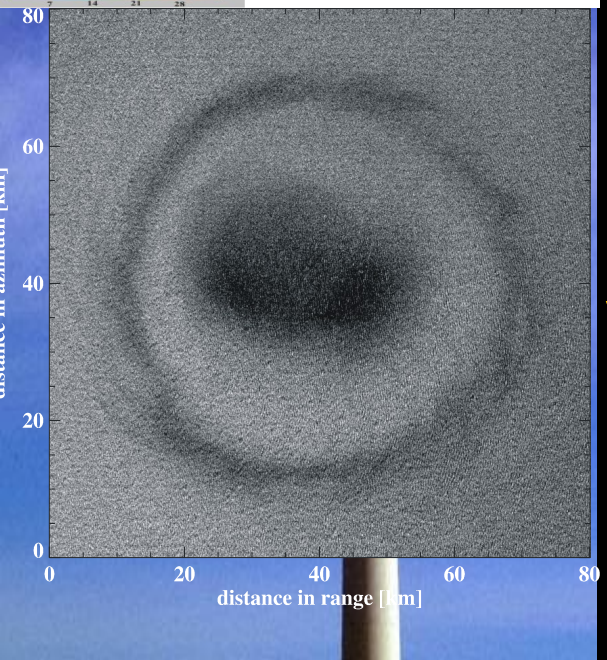
Inclusion of Doppler Shift Information for SAR Wind Retrieval





Summary & Outlook





SAR wind directions are retrieved from wind streaks (rms of 20°) lack of inflow

SAR wind speeds are retrieved from C-band models (rms of ~2 m/s)

For extreme winds the wind speed the rms is significantly larger (~5 m/s)

SAR wind retrieval scheme is fully automated

Validation of X-band model for high winds

Inclusion of Doppler shifts for wind direction retrieval

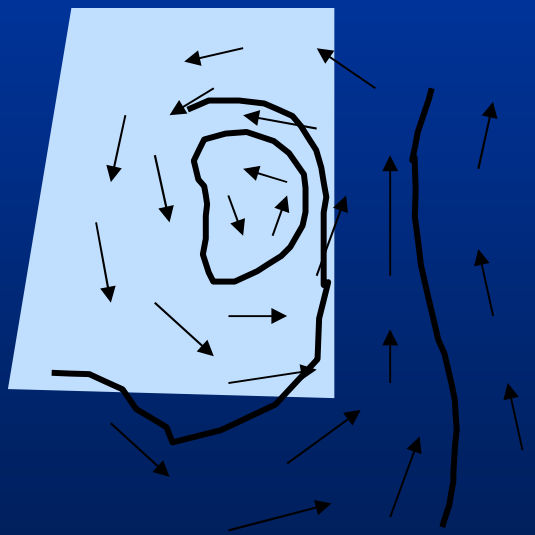
Application of APLs Boundary Layer Model

U10

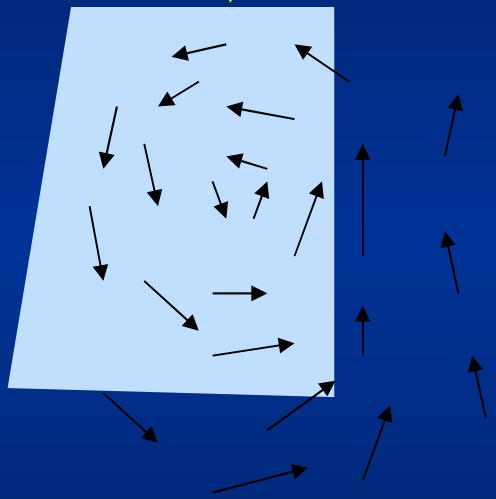
PBL model

$k \cdot \nabla P$

□0



swath of pressure gradient vectors

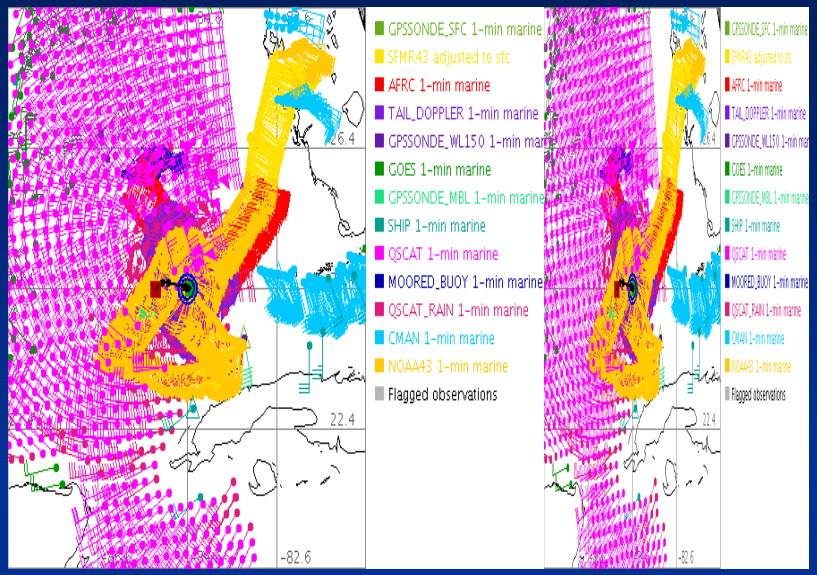


swath of pressure gradient vectors

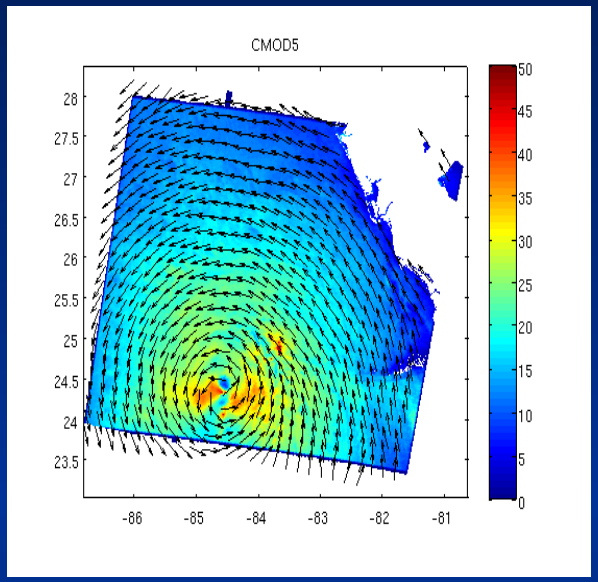
fit a surface pressure field

Assimilation into HWIND

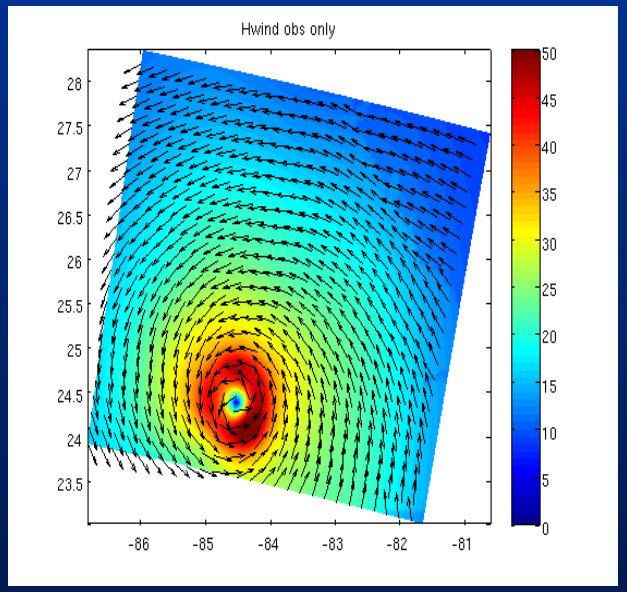
Input

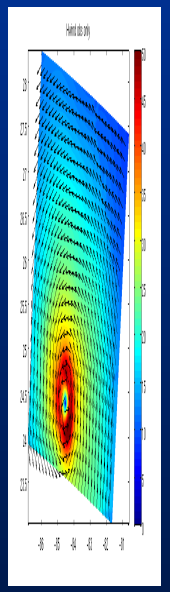


Input

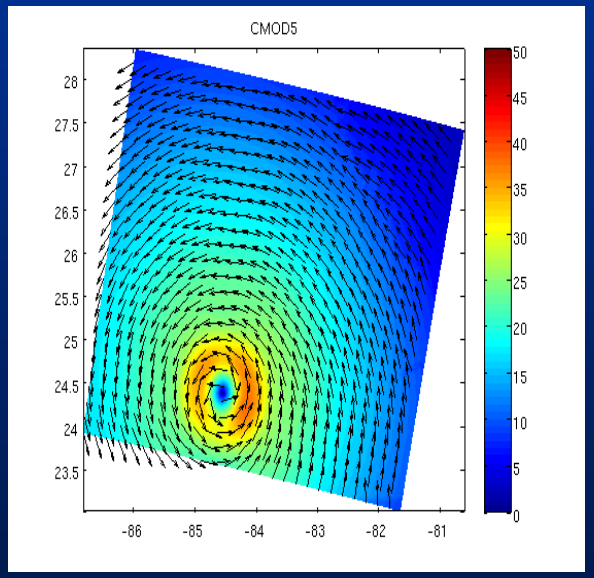


Output



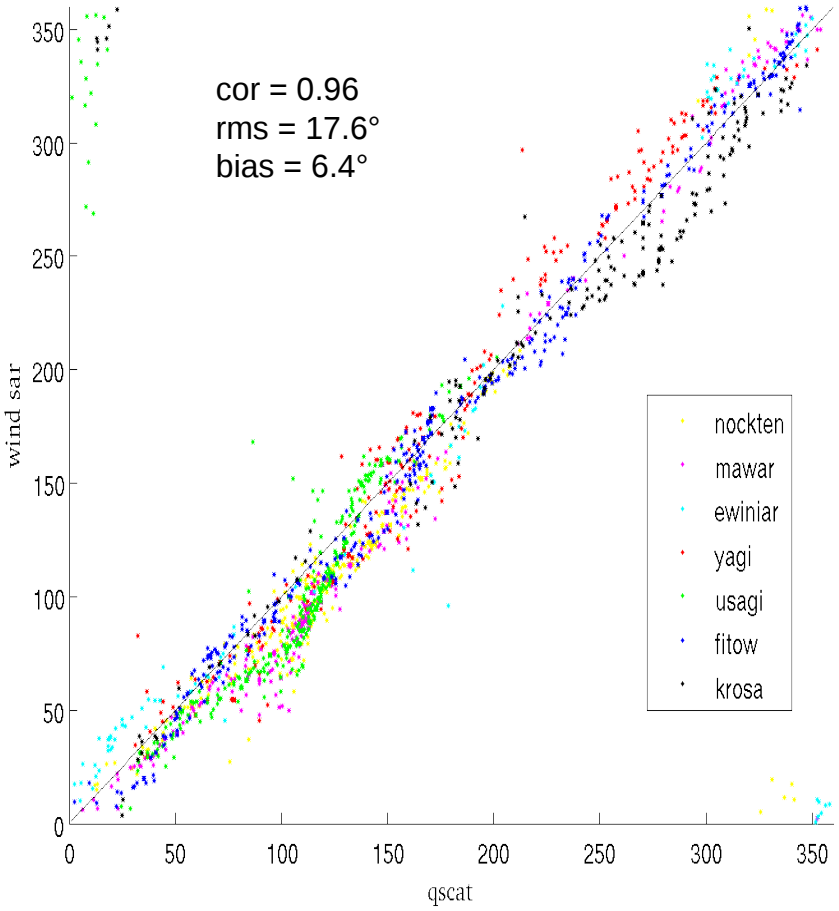


Output

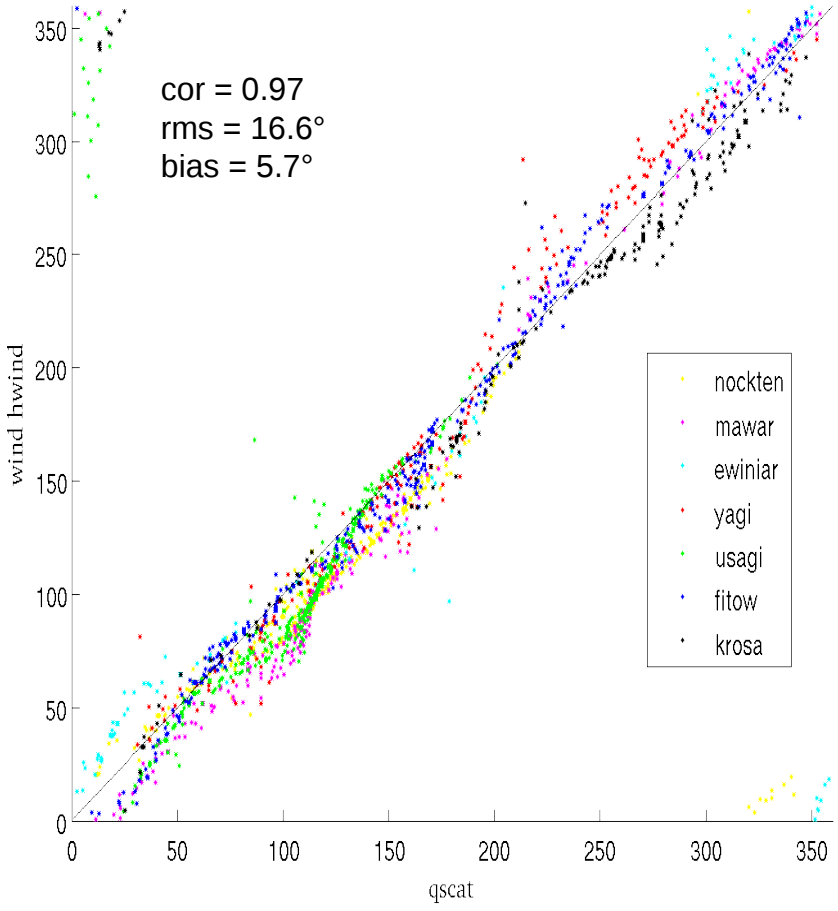


Comparison of SAR to Quikscat winds

SAR wind directions NURC-GD merged

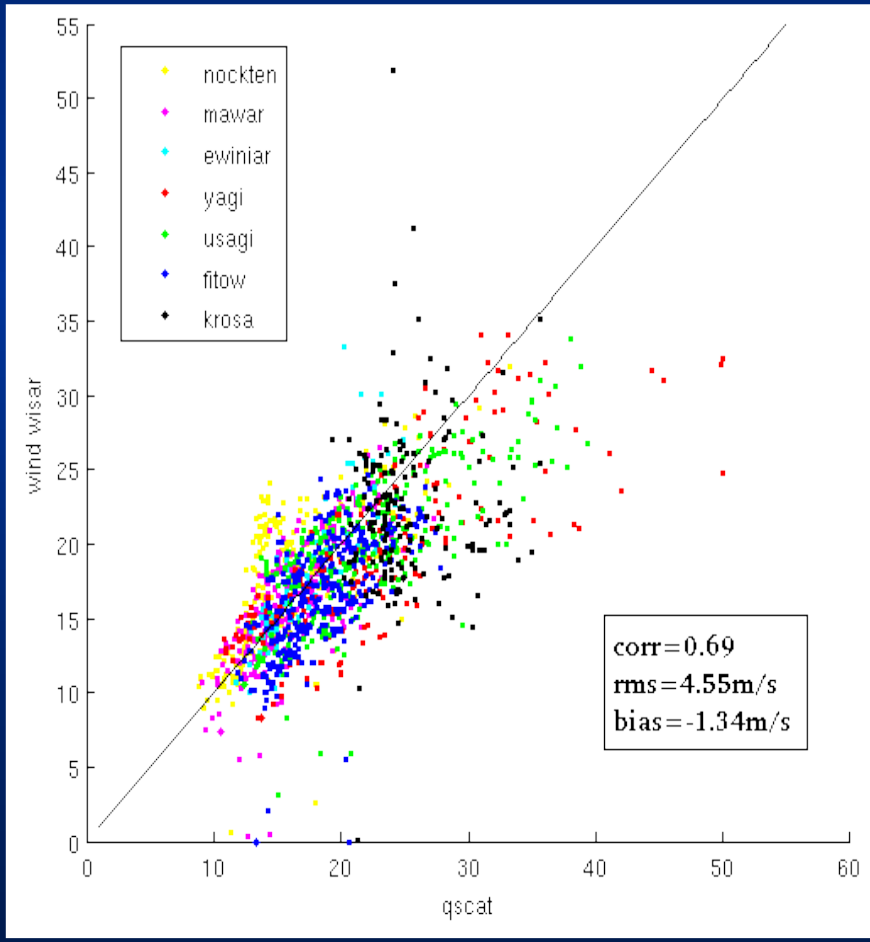


HWIND wind directions assimilation of SAR wind field (solely)

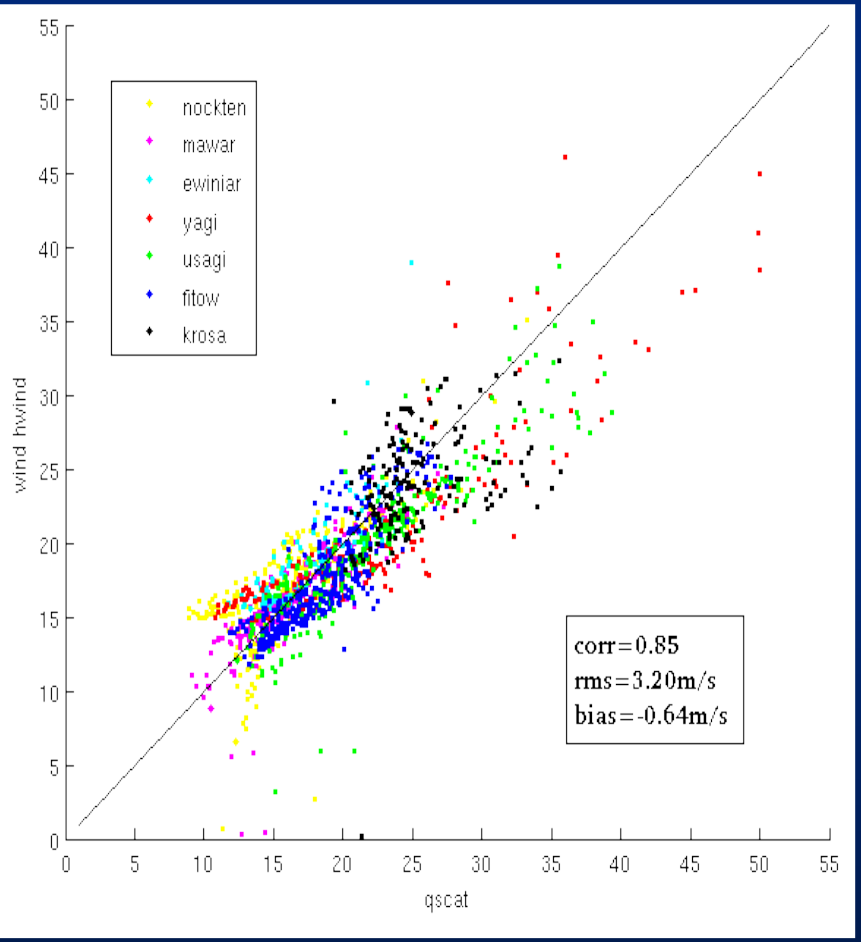


Comparison of SAR to Quikscat winds

SAR wind speeds NURC-GD merged

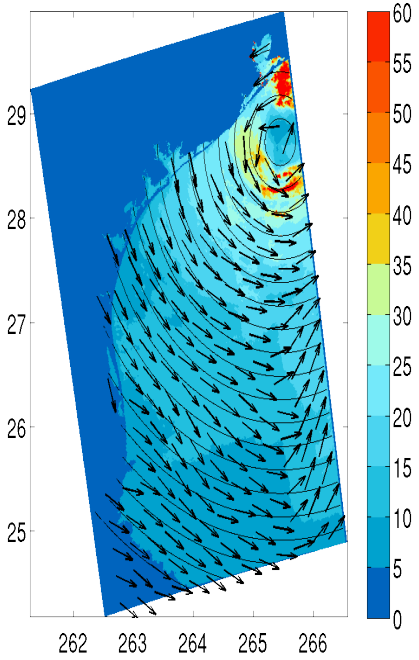


HWIND wind speeds assimilation of SAR wind field (solely)

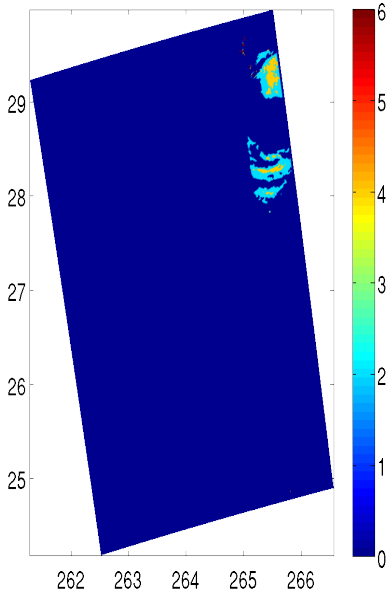


Application of APLs Boundary Layer Model

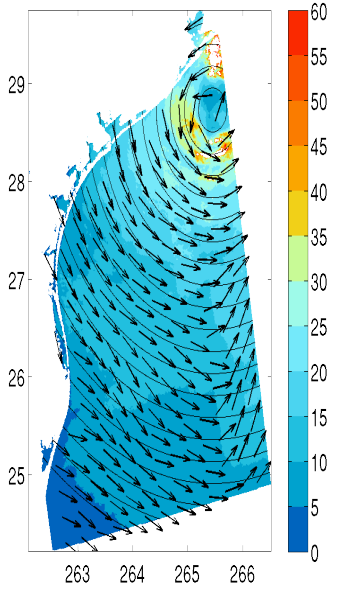
SAR wind field



SAR out of definition mask



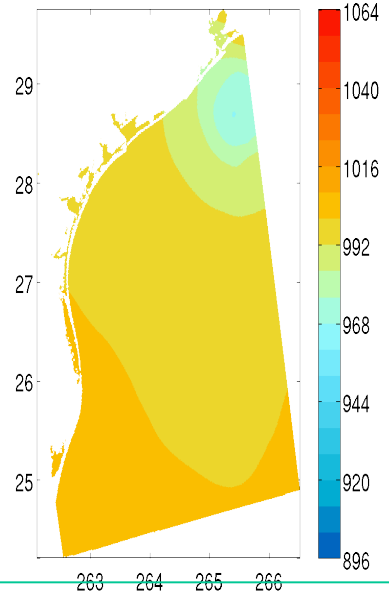
SAR input to SLP model



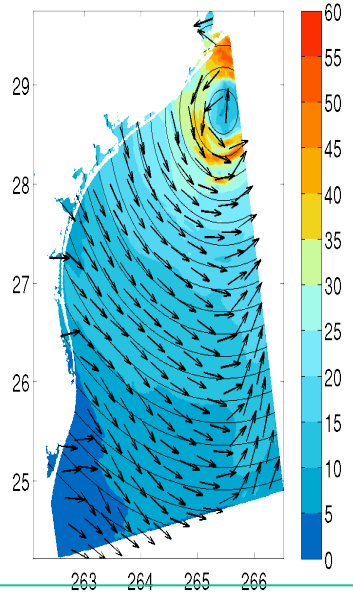
Hurricane Ike

Application of APLs Boundary Layer Model

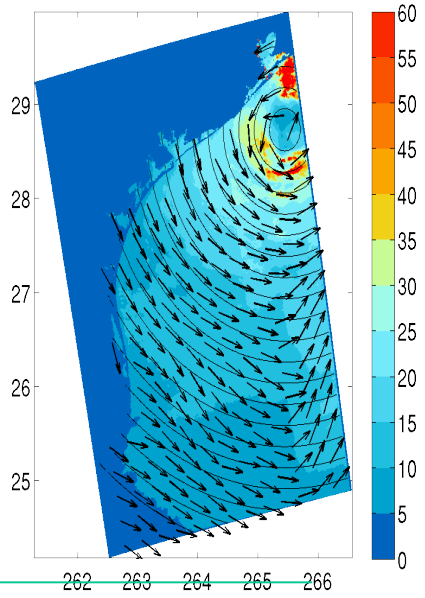
SLP pressure field



SLP retrieved wind field

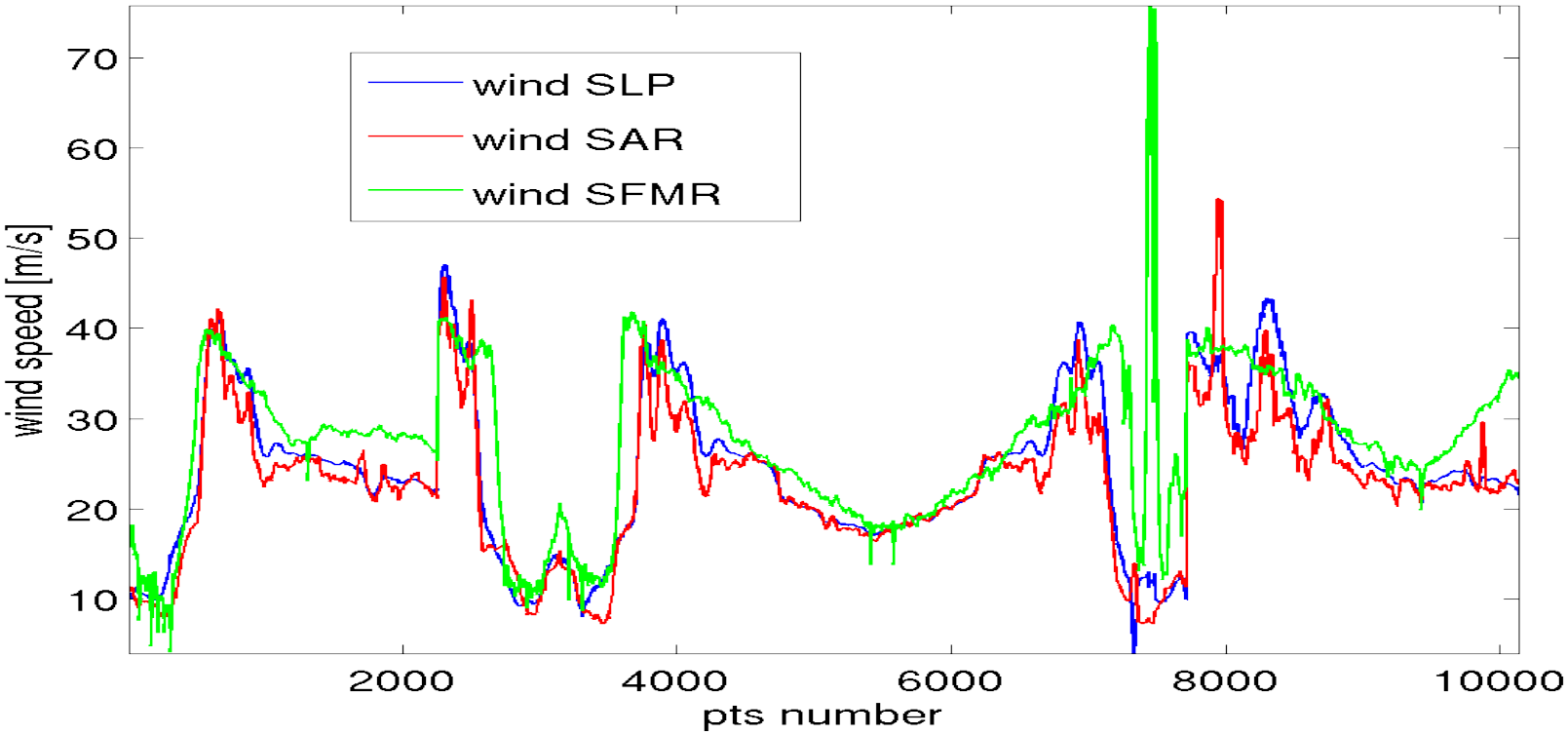


SAR retrieved wind field



Hurricane Ike

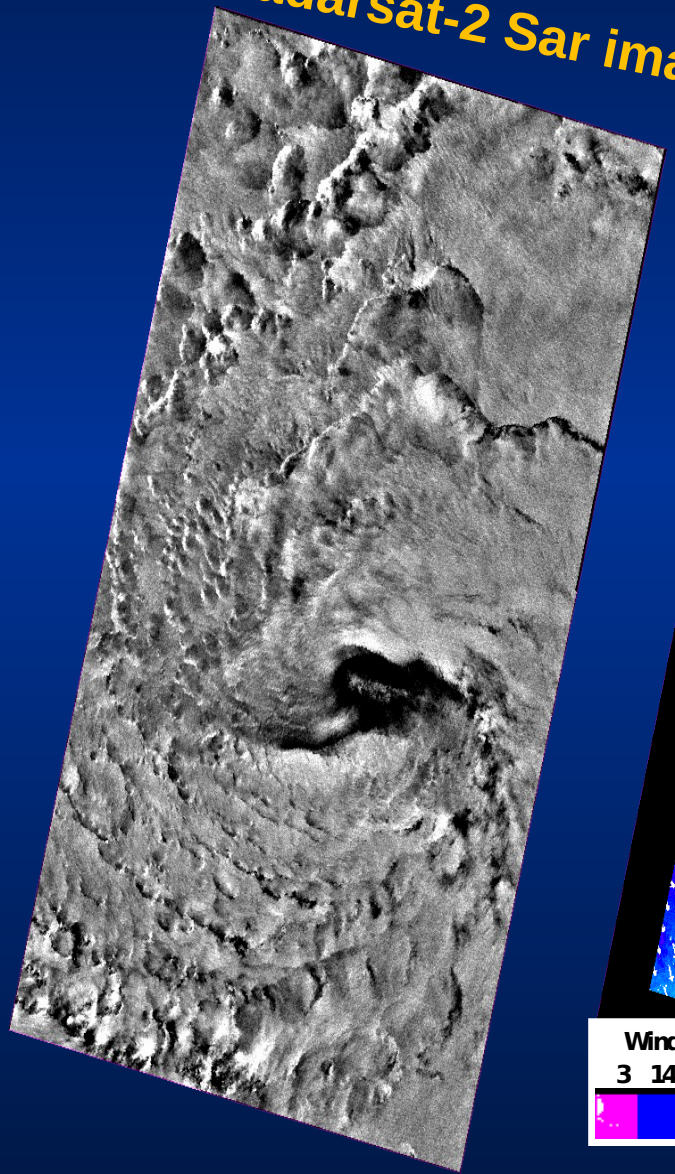
Application of APLs Boundary Layer Model



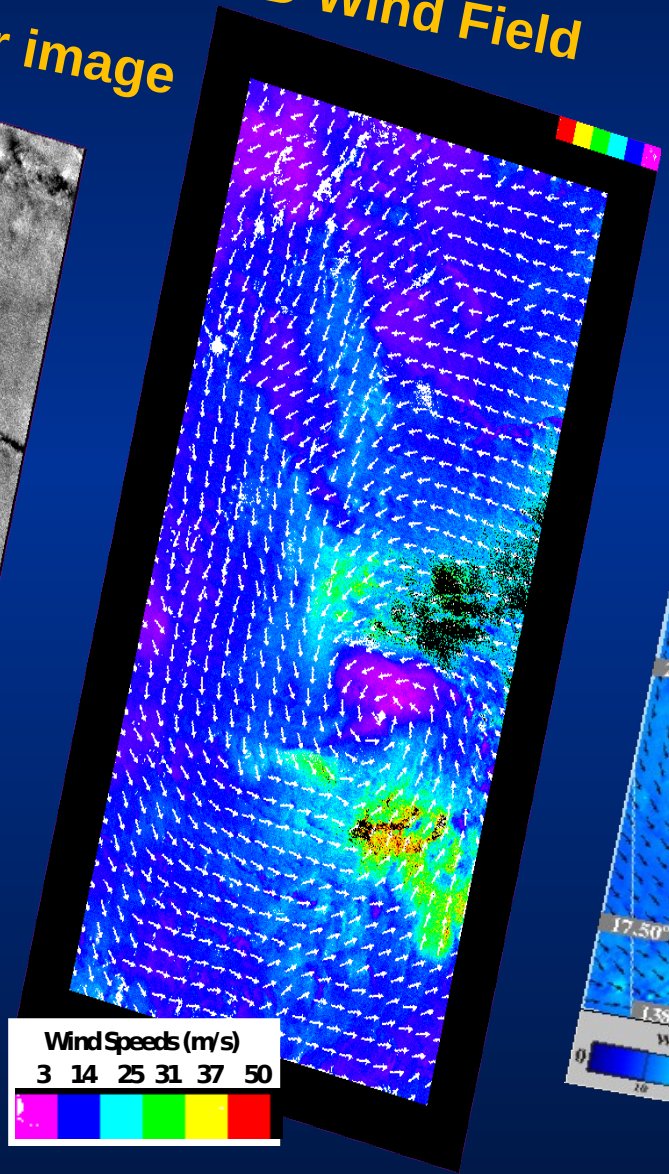
Hurricane Ike

Typhoon Malakas, Radarsat-2 Retrieved Wind Fields

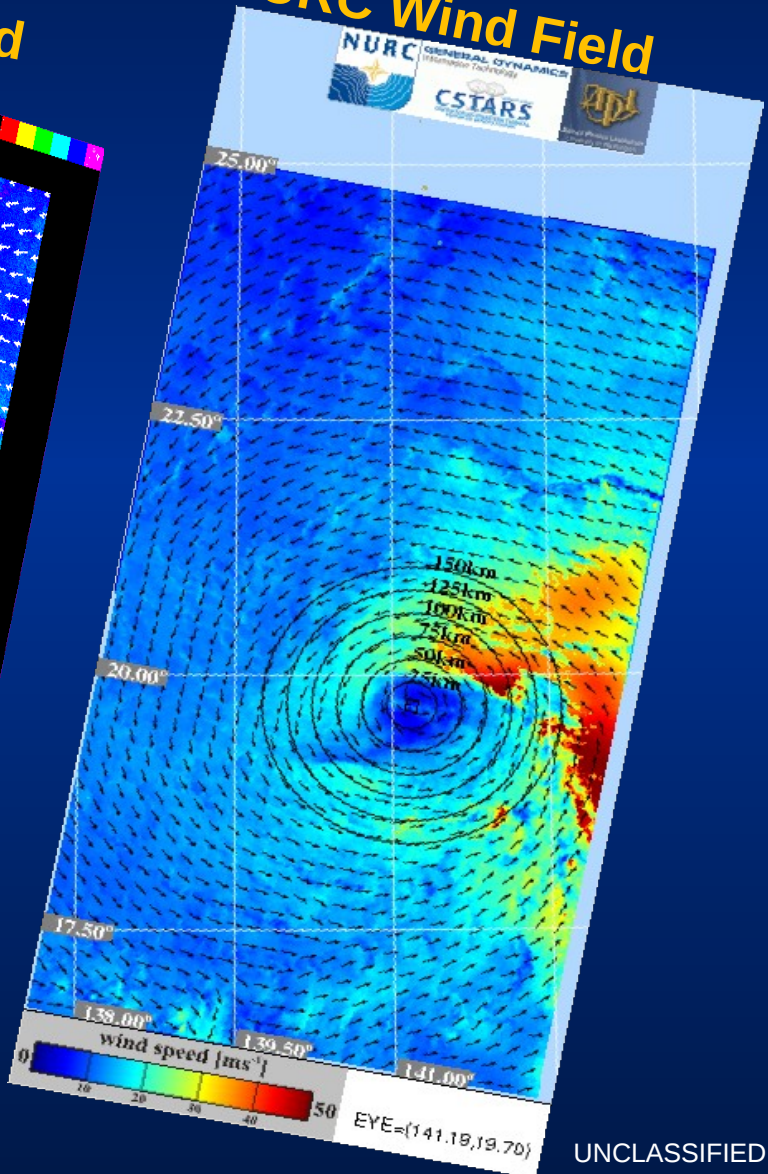
Radarsat-2 Sar image



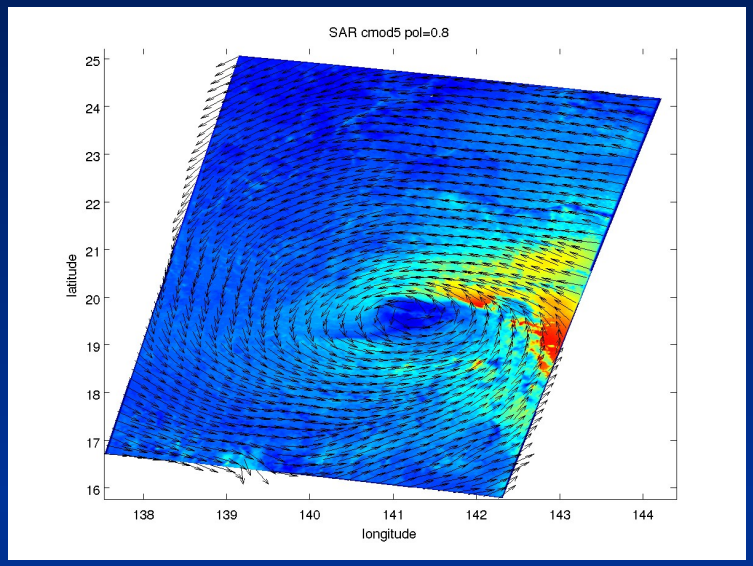
GD Wind Field

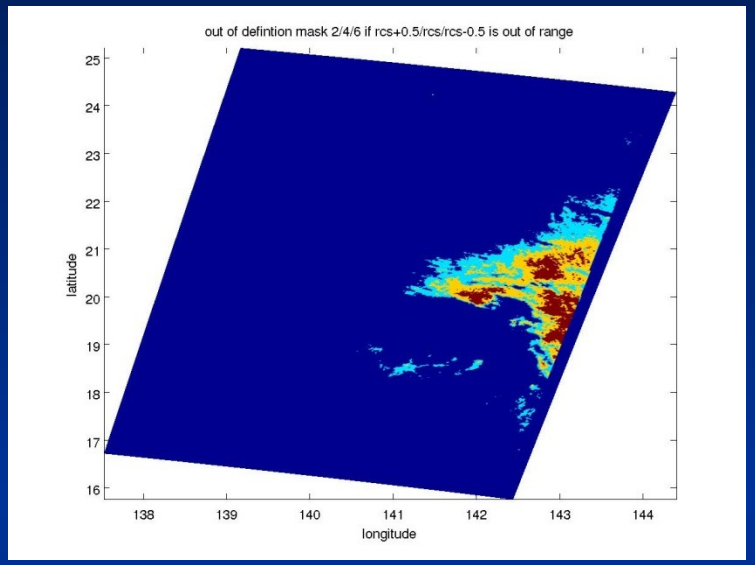


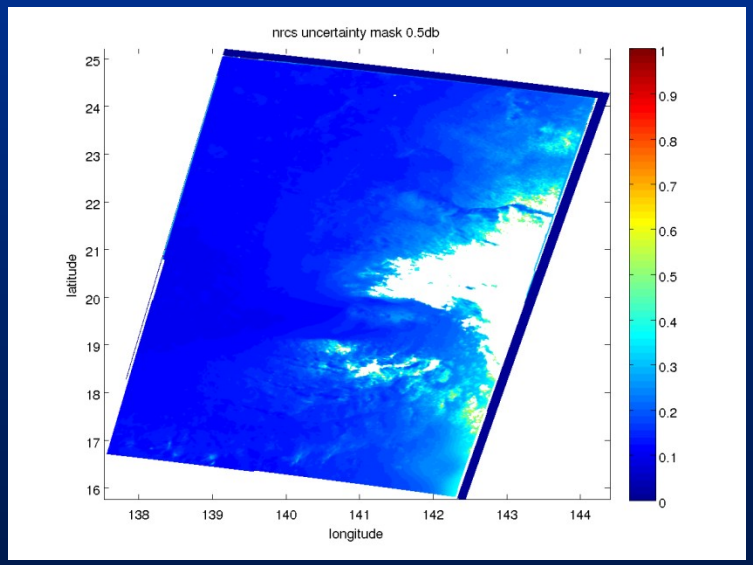
NURC Wind Field

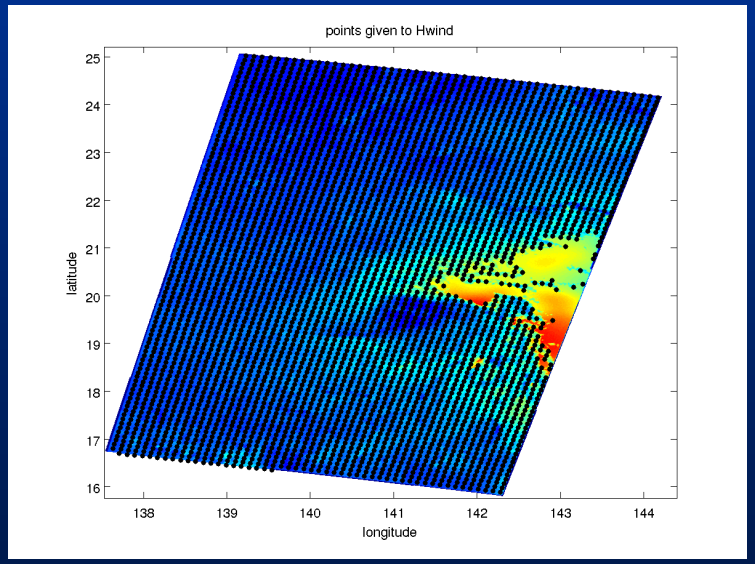


Typhoon Malakas, Wind Speed Error and Certainty Masks



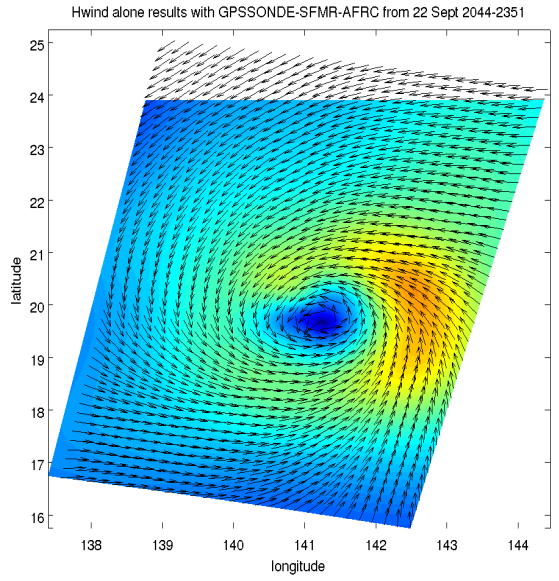




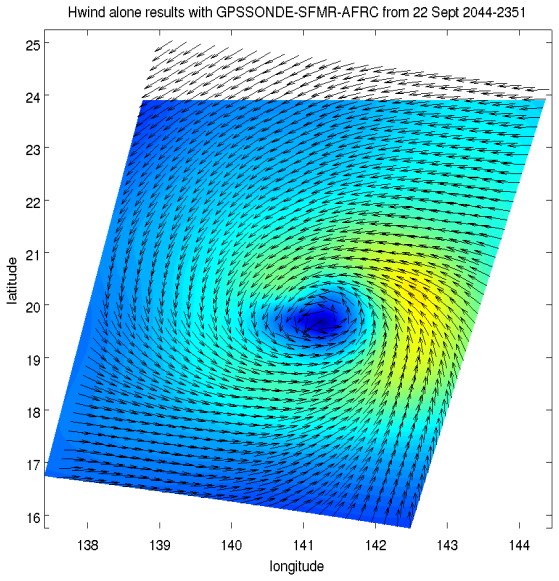


Typhoon Malakas, Assimilation into HWIND

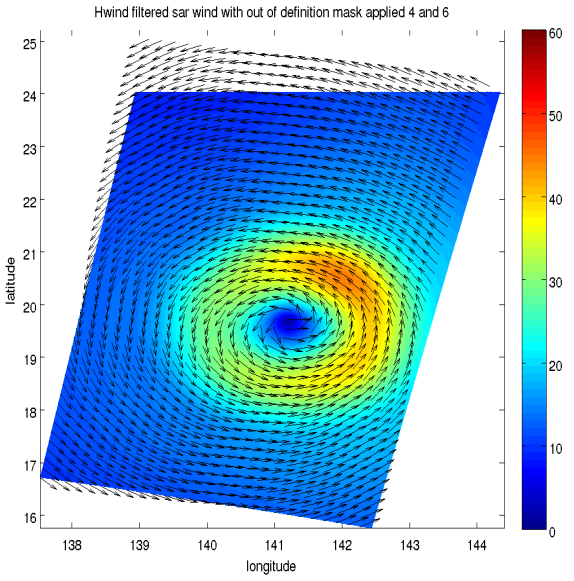
HWIND with in situ and SFMR 1 min



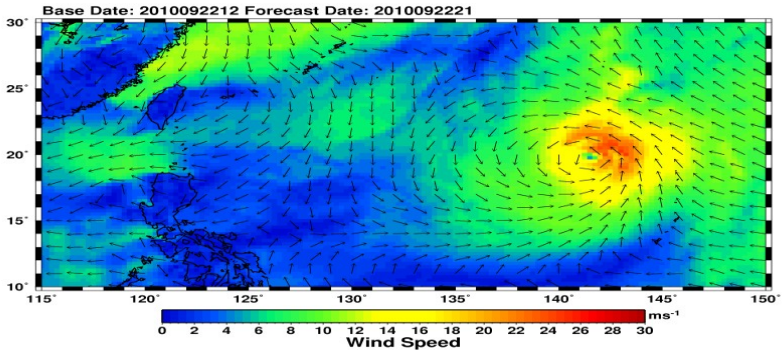
HWIND with in situ and SFMR 10 min.



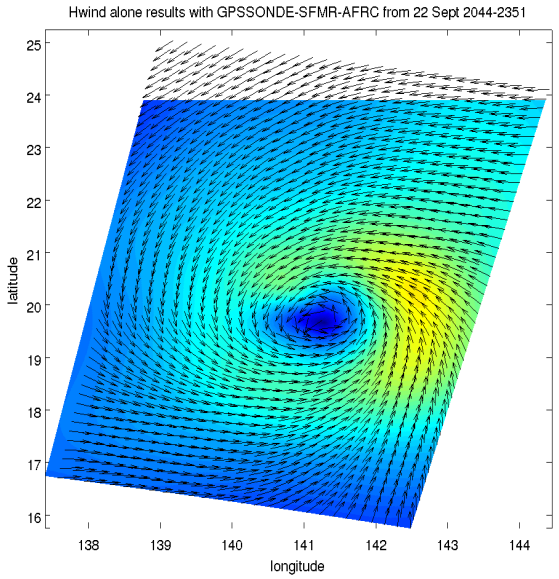
HWIND with SAR wind field 10 min.



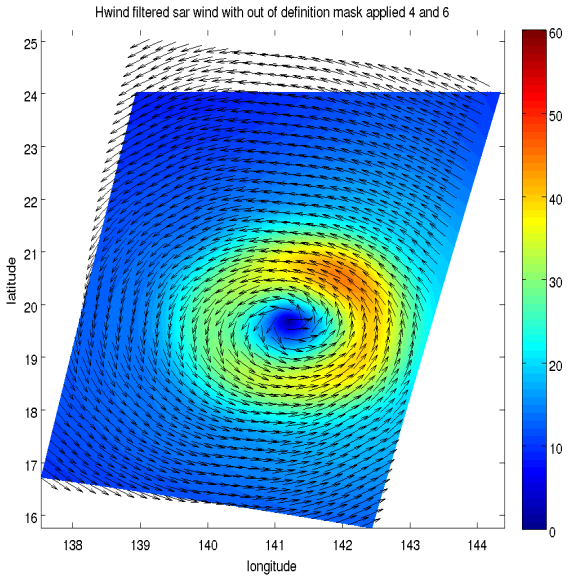
Typhoon Malakas, Comparison to Numerical Model Results



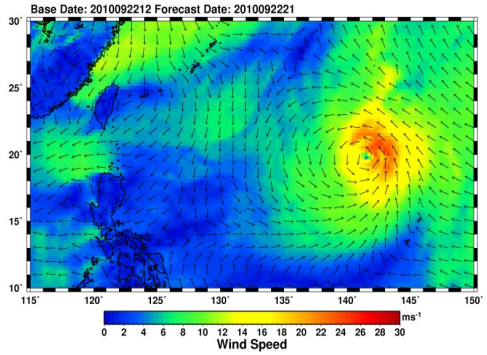
HWIND with in situ and SFMR 10 min.

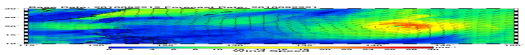


HWIND with SAR wind field 10 min.

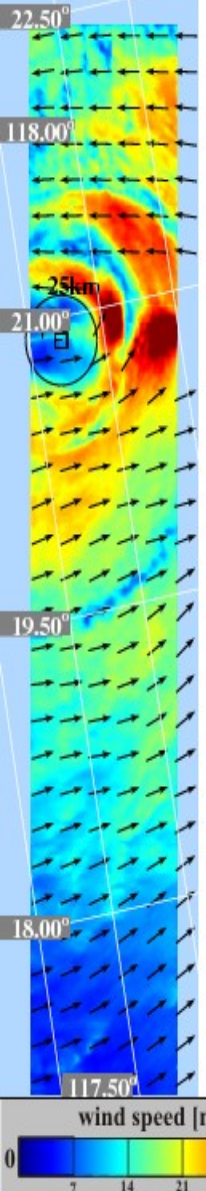


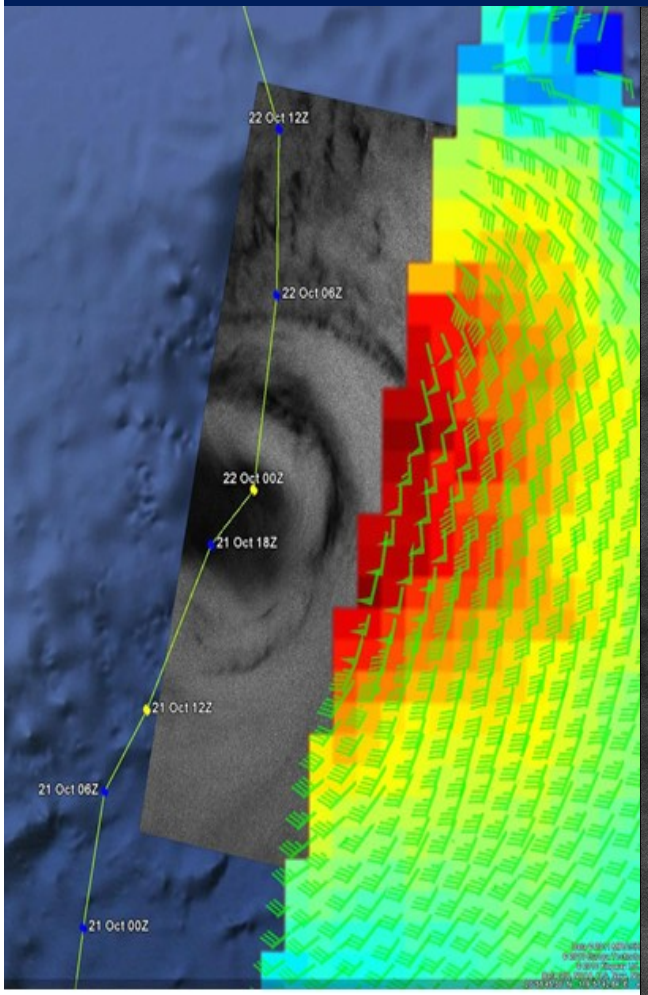
ECMWF winds

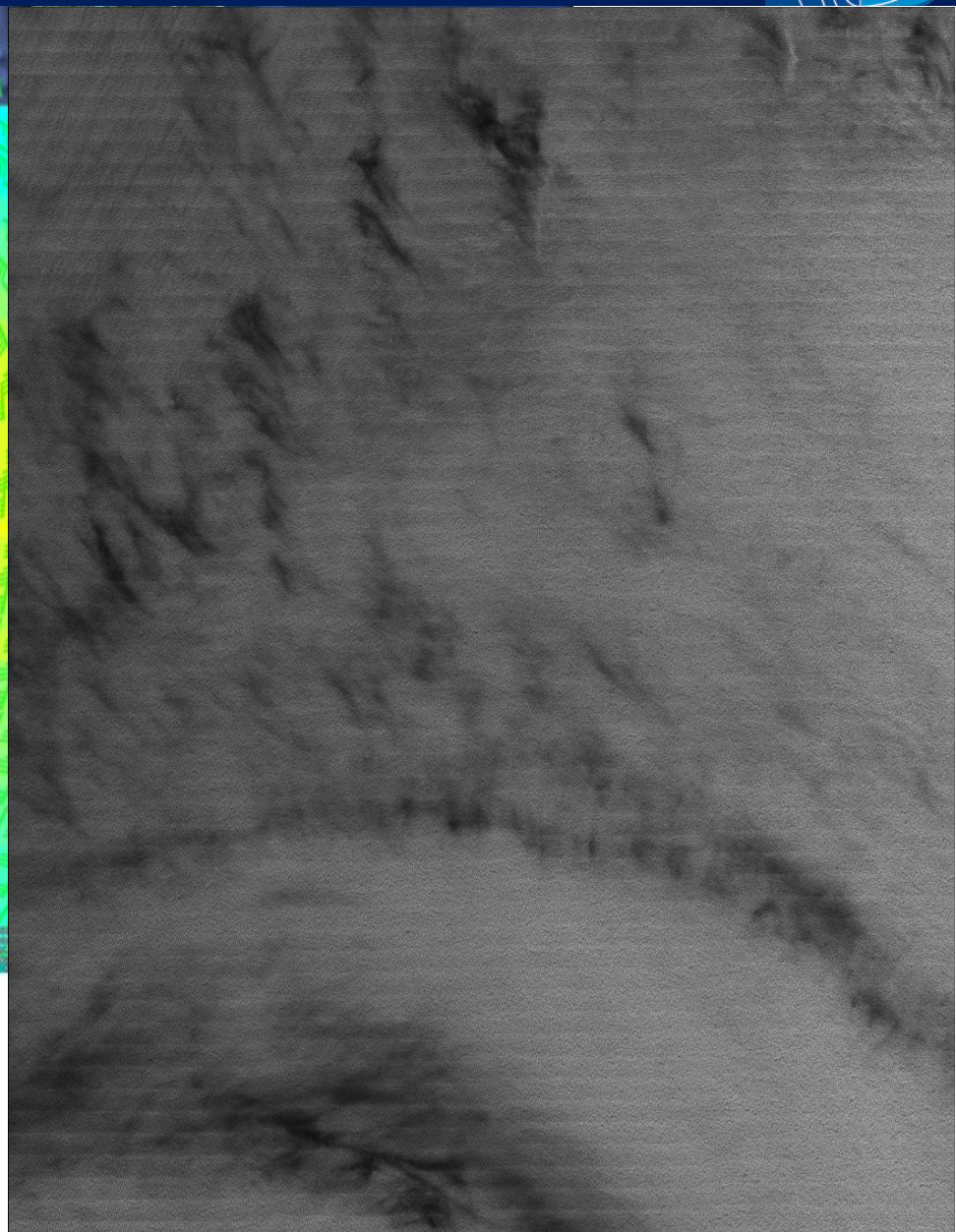




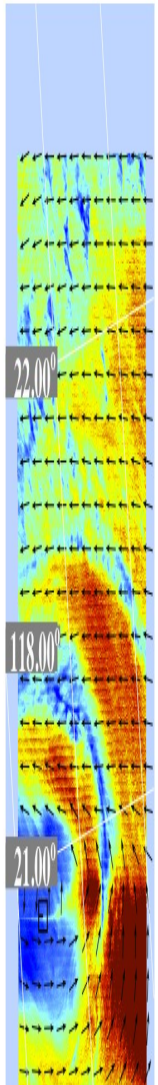
Typhoon Megi, Comparison to ASCAT Results

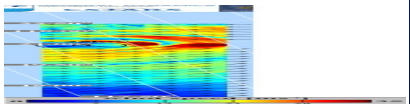


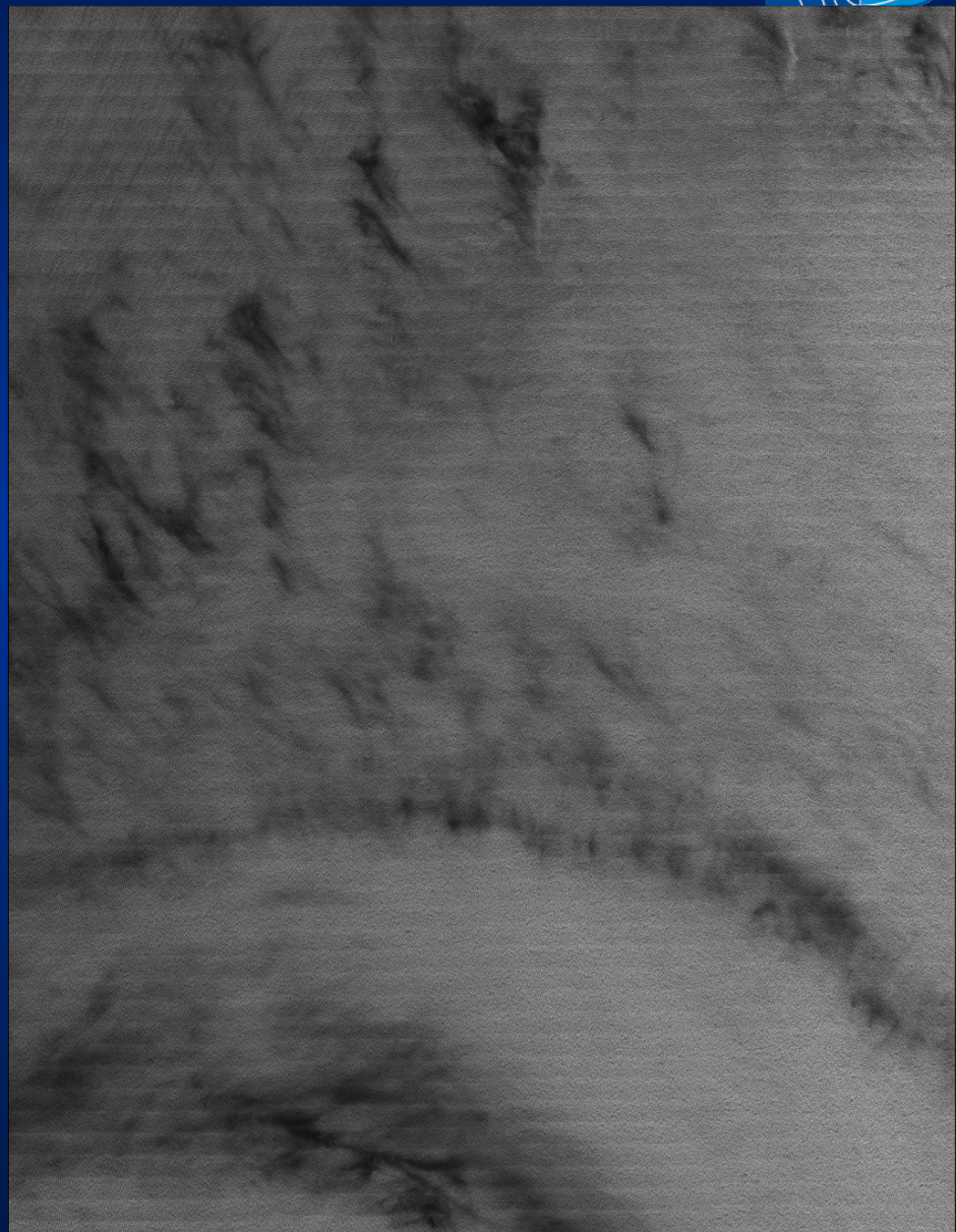




Typhoon Megi, 200m Resolution Wind Field

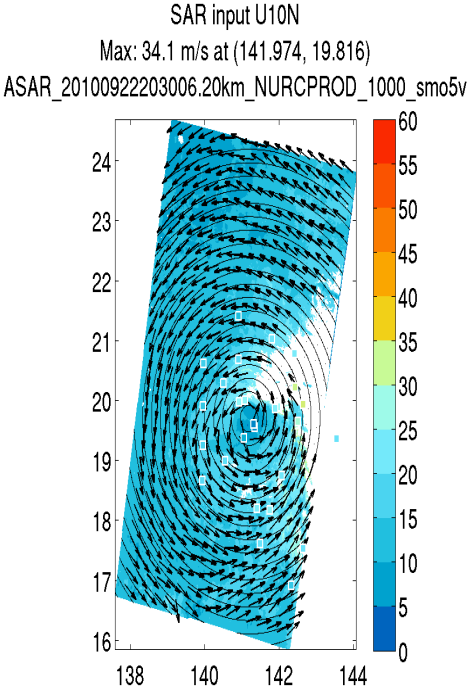




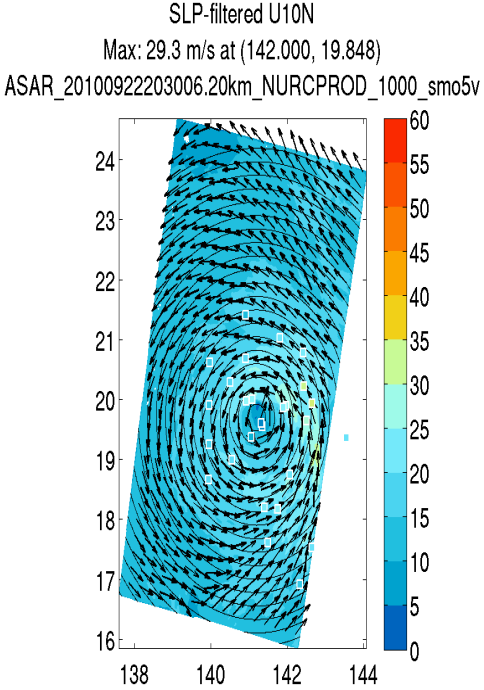


Typhoon Malakas, Assimilation into APLs Boundary Layer Model

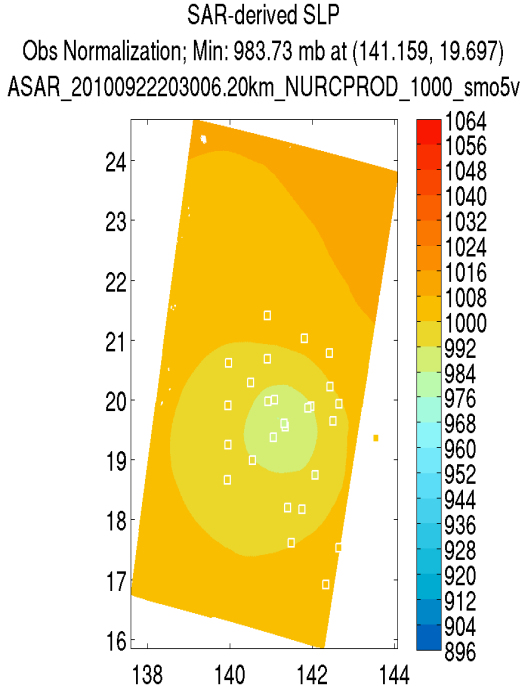
SAR input wind including masks



Boundary Layer Model retrieved wind field



Boundary Layer Model retrieved pressure field



Publications:

1. Synthetic Aperture Radar Retrieved Winds Assimilated into HWIND (SLP-winds)
2. Estimation of Wind Speed Uncertainties in Synthetic Aperture Radar Wind retrieval
3. Automated SAR Eyefinding in SAR images
4. Synthetic Aperture Radar Wind Retrieval of Tropical Cyclones
5. Descalloping of Synthetic Aperture Radar Images
6. SAR Retrieved Pressure Fields
7. SLP iterated SAR winds
8. The Dave's Paper's
9. Empirical Wave Retrieval
10. Physical Wave Retrieval
11. Comparison or merged SAR wave retrieval
12. Duncan Ross Comparison (Waves)
13. SARTYPS group paper?
14.

NURC Summary

Run eye finder on entire CSA Hurricane data set promising results

Uncertainty estimator comparison to SFMR validation with *in situ* ongoing

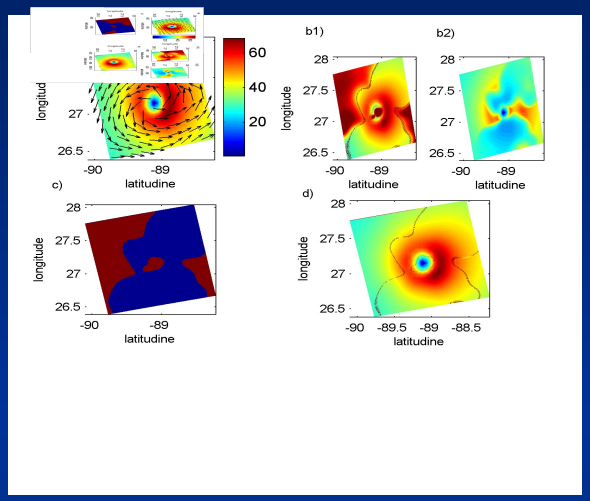
Comparison of SAR retrieved winds in Hurricanes to QuikSCAT show to little inflow

Assimilation of SAR retrieved winds into HWIND shows improvement of wind field compared to QuikSCAT (e.g. no hourglass)

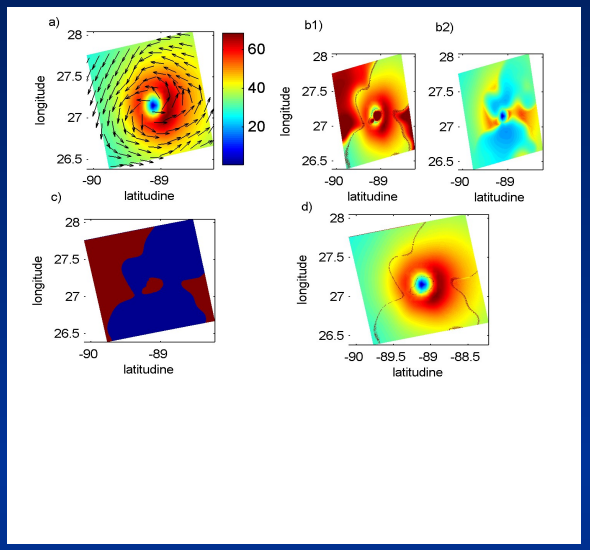
GMF for X-band shows promising results (to be investigated also for moderate winds)

Simulated Effect of Wind Speed Ambiguities

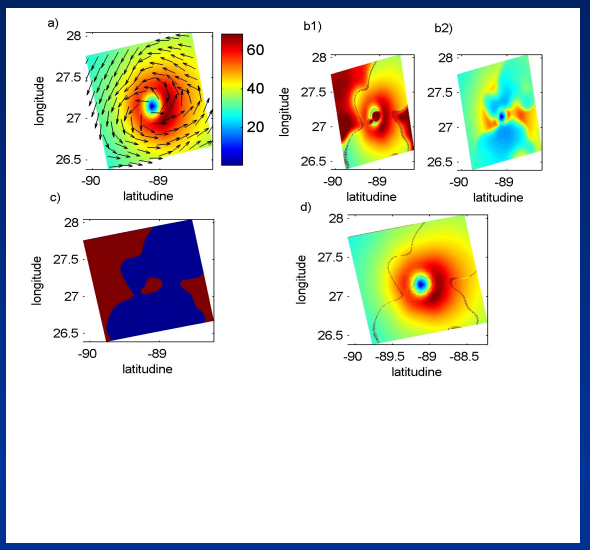
Hwind + SAR



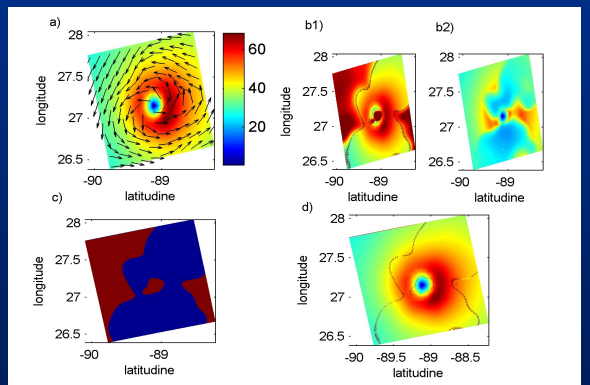
Upper solution



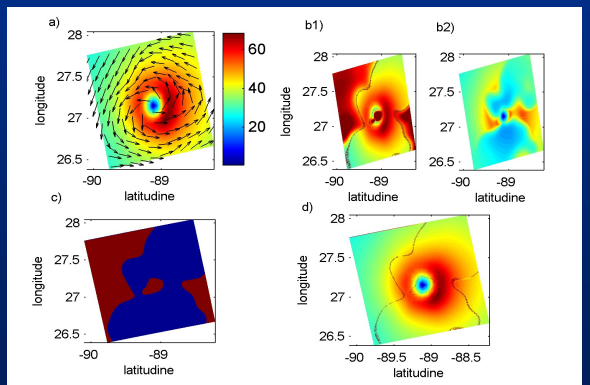
Lower solution



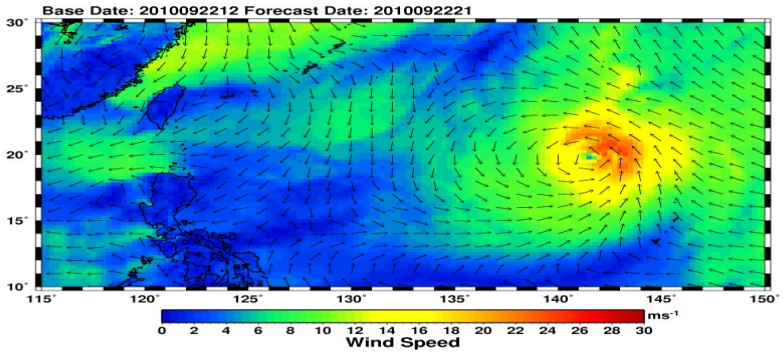
Cluster-Mask



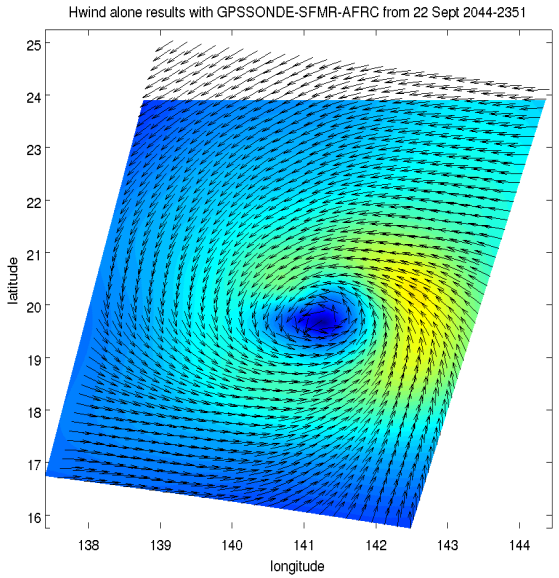
Rebuilt Wind



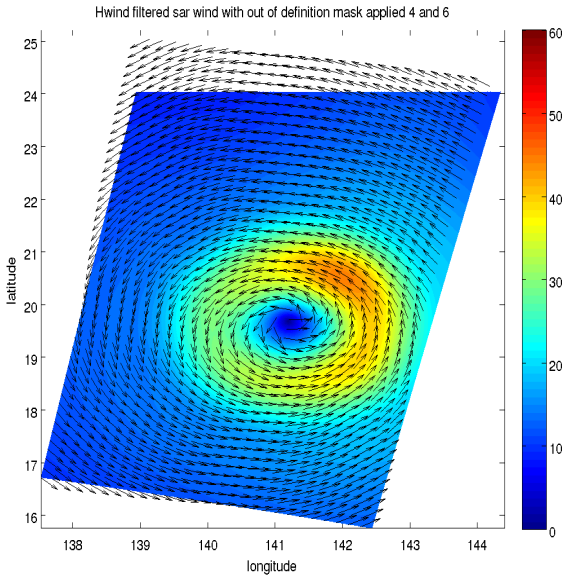
Comparison to Numerical Model Results



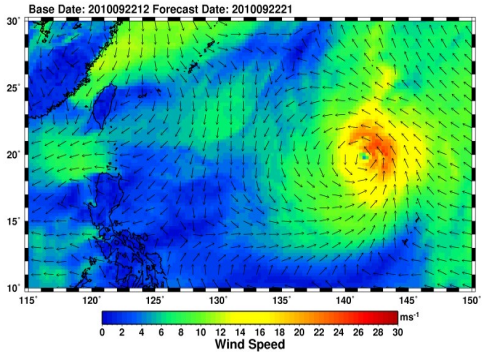
HWIND with in situ and SFMR 10 min.

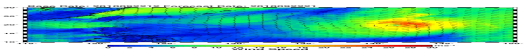


HWIND with SAR wind field 10 min.



ECMWF winds





Comparison of SAR to QuikSCAT winds