Applications of OVW-Derived Surface Pressures in Tropical Cyclones

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SAR TC Working Group:

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Five Working Group Meetings:

1. **10 & 11 February 2009 – Miami, Florida**
2. **31 May & 1 June 2009 – LaSpezia, Italy**
3. **28 & 29 October 2009 – Ypsilanti, Michigan**
4. **March, 2010 – CSTARS Miami**
5. **14-17 May, 2010, Barcelona**

Goal: km-scale Surface winds & Sea-surface Pressure; km → O(200 m) scale ocean surface waves from SAR imagery of TCs

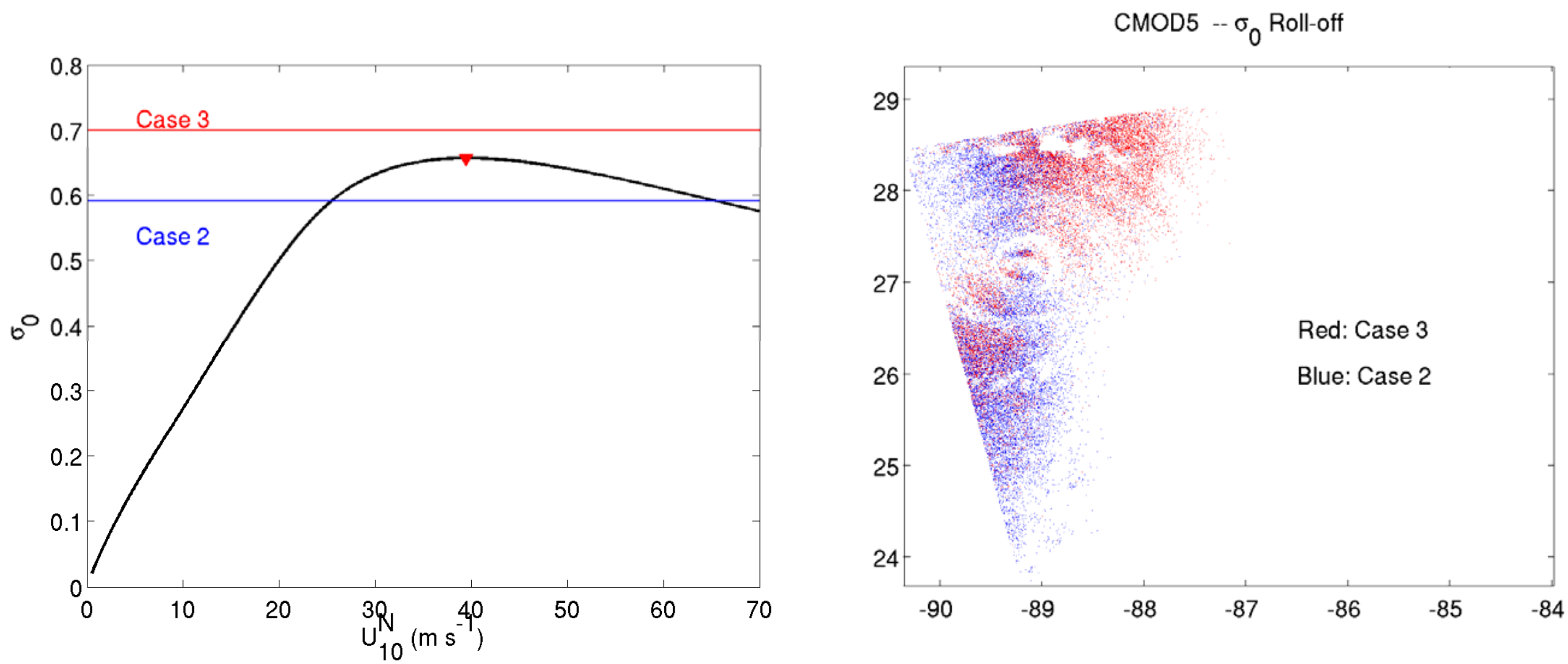
CSA/CSTARS/NOAA AO: ~160 RadarSAT-1 SAR images WPAC/ATL

Objectives

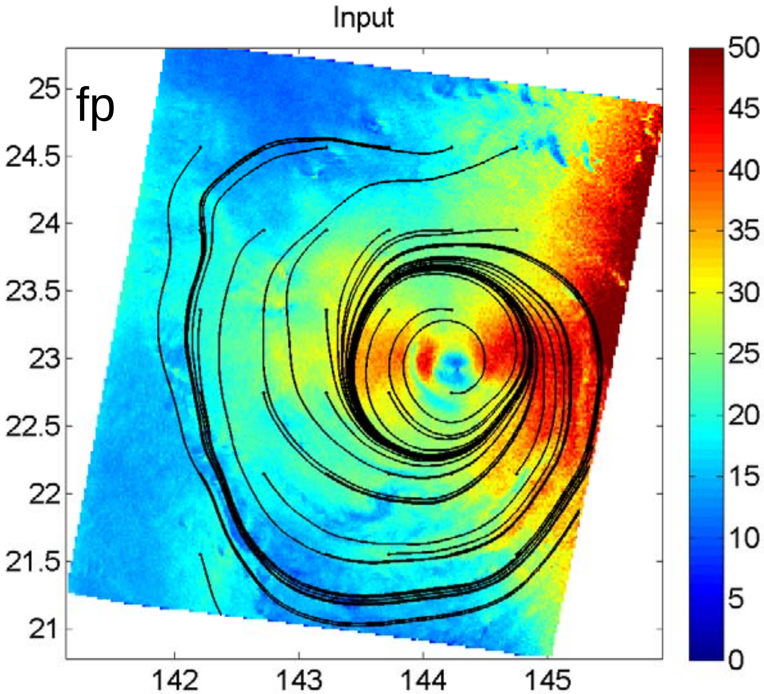
- SAR TC surface winds above 30 m s^{-1} limited by
  - In situ cal/val data
  - Geophysical model functions

$$\sigma_0 = \sigma_0\left(U_{10}^N, \theta, \phi\right)$$

- Wind directions from rolls/streaks
  - Selection of directions
  - Interpolation between identifiable features
    - GD: Power Law vs. parameterized Spiral
    - NURC: dir. from O(100 m) to O(multi-km) (mainly 400 m)
      - No fill-in between WVC
  - Eye location
- Assume barometers more reliable than anemometers in TCs
  - Alternate source of surface wind Cal/Val data?
  - Can we use SLP to extrapolate surface winds into core?



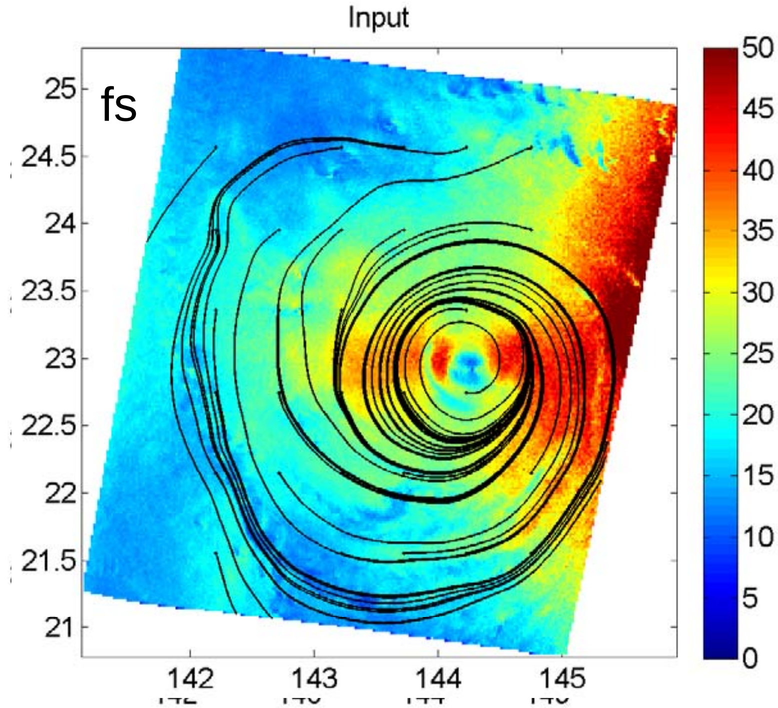
Case 3
Case 2
σ_0
U_{10}^N (m s^{-1})
CMOD5 -- σ_0 Roll-off
Red: Case 3
Blue: Case 2

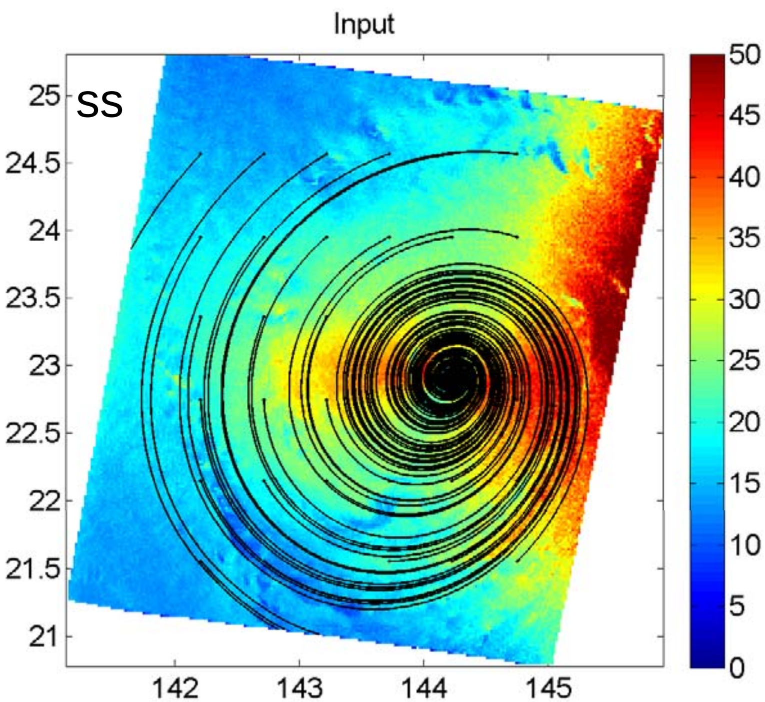


WPAC: Yagi

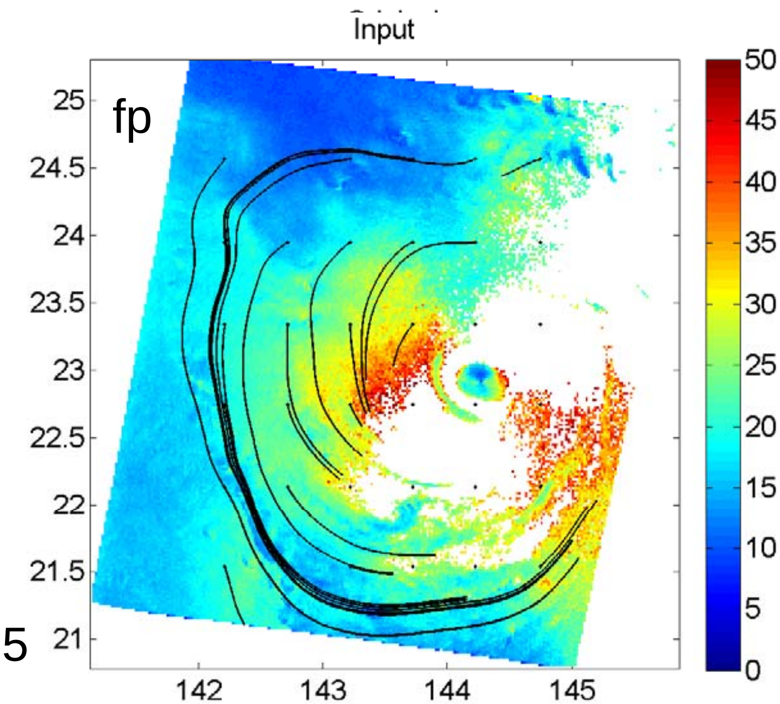
21Sep06
20:16

GD Proc.
CWaR GMF





CMOD5



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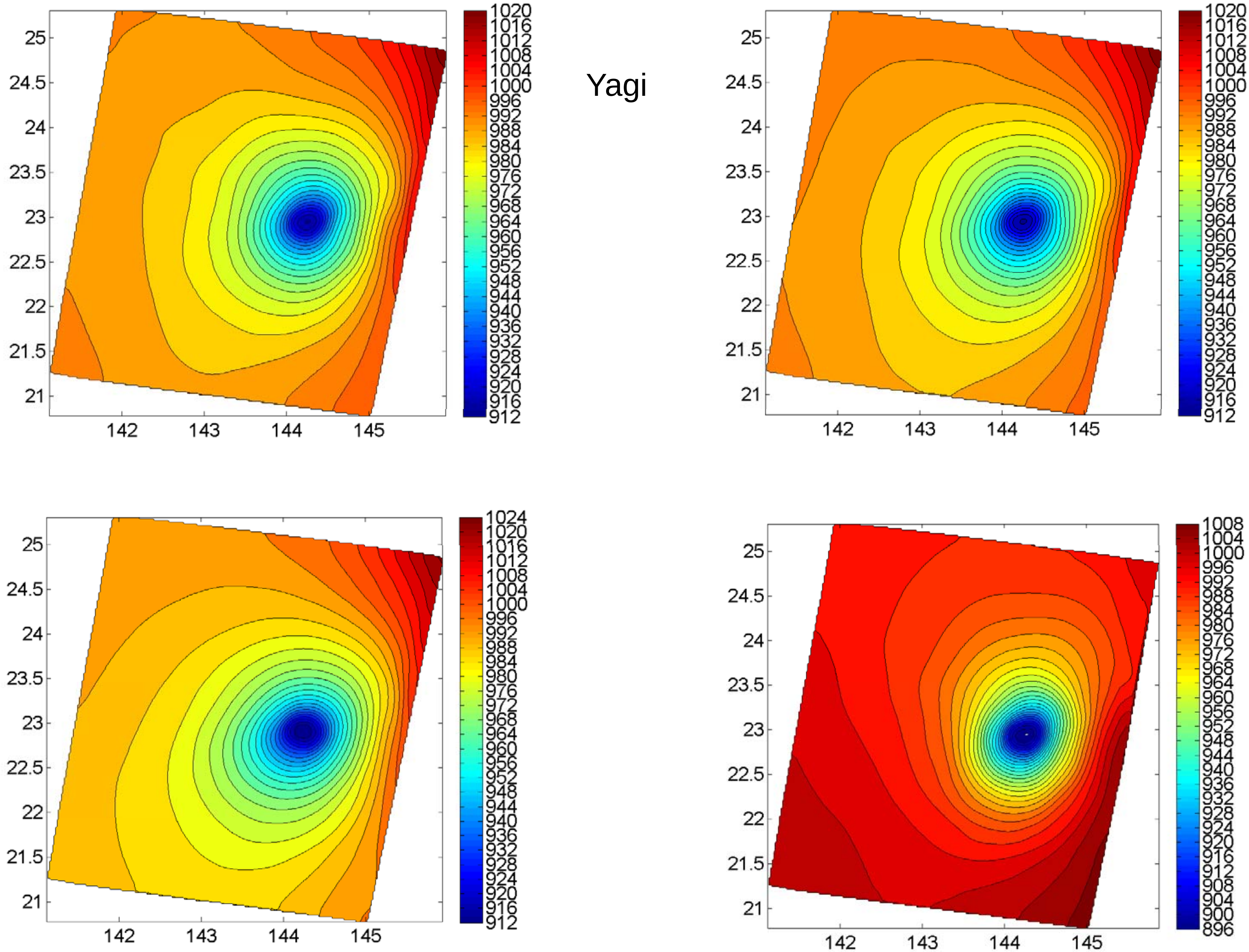

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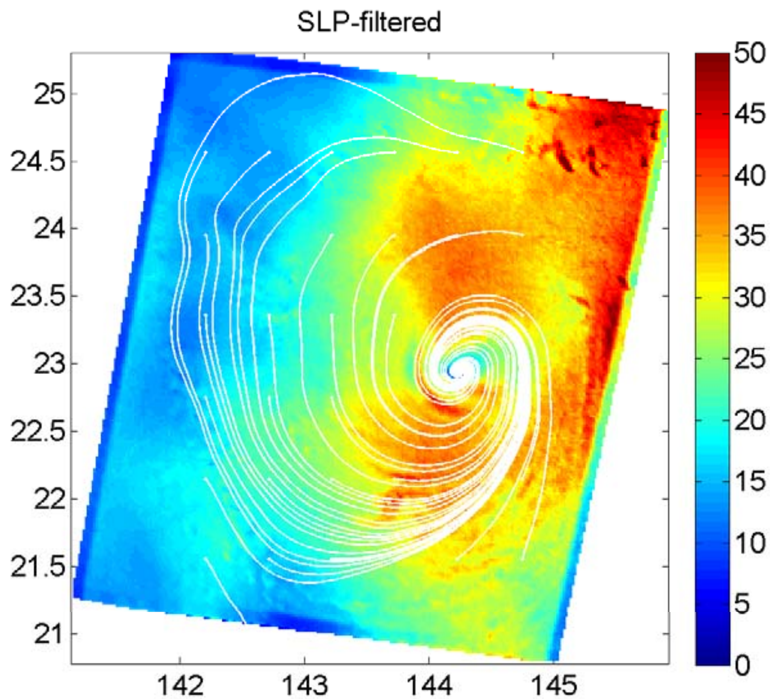
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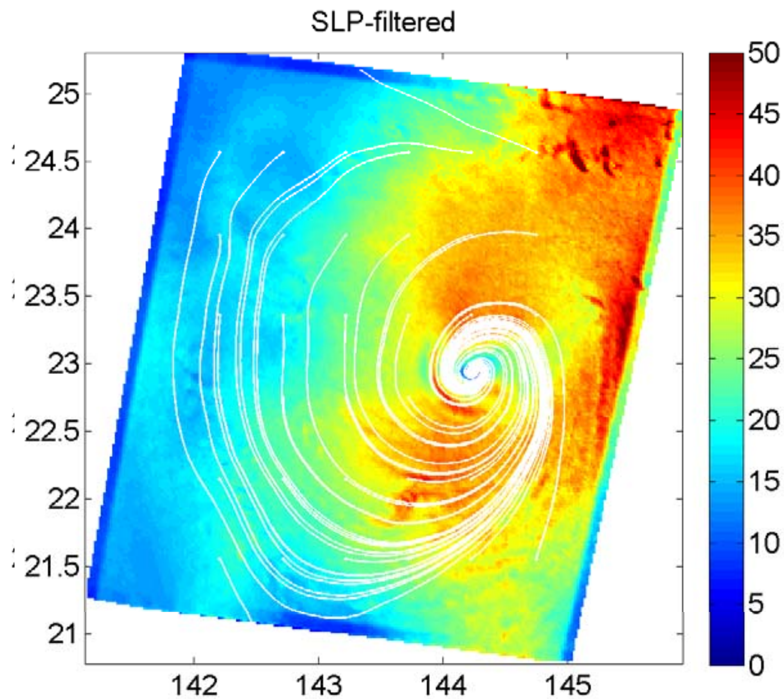
Yagi

SLP → U10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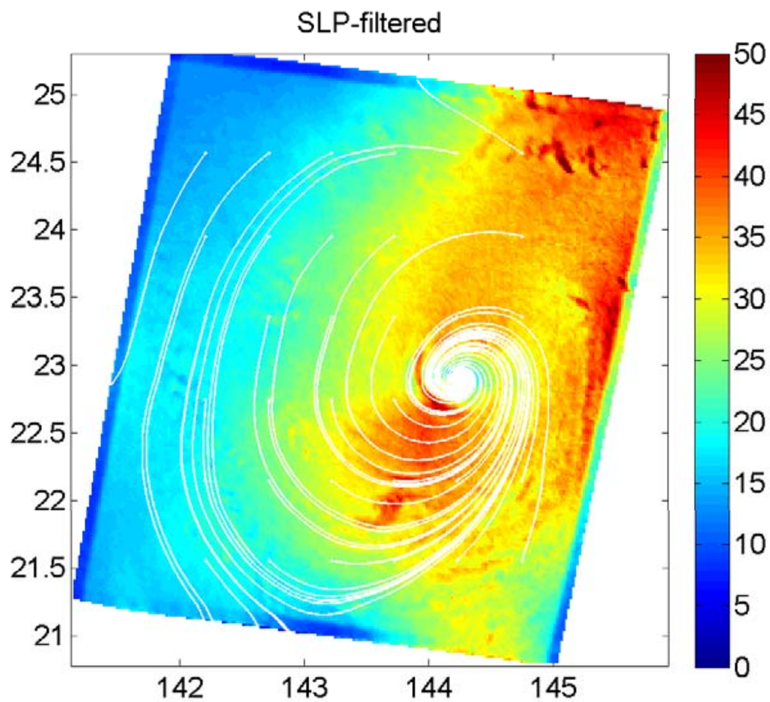
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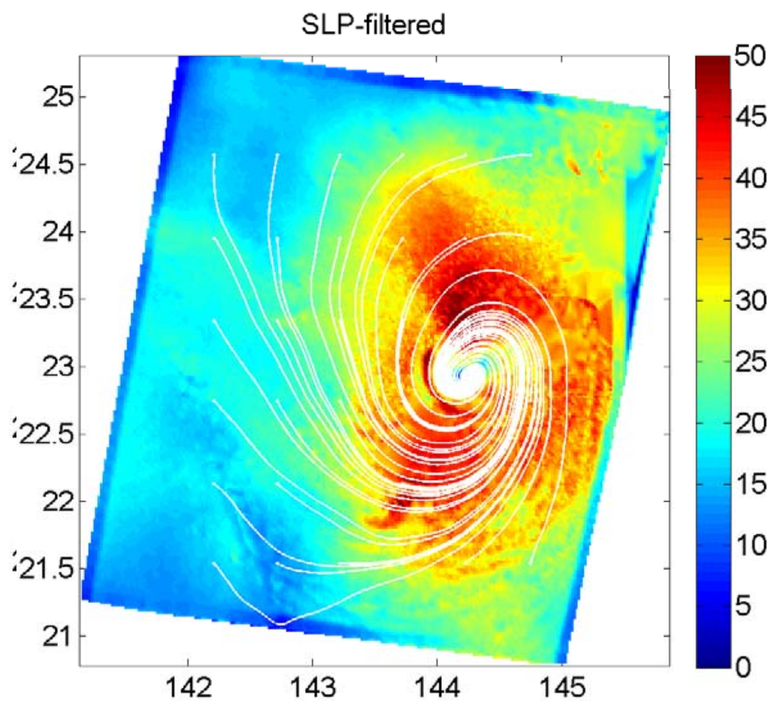
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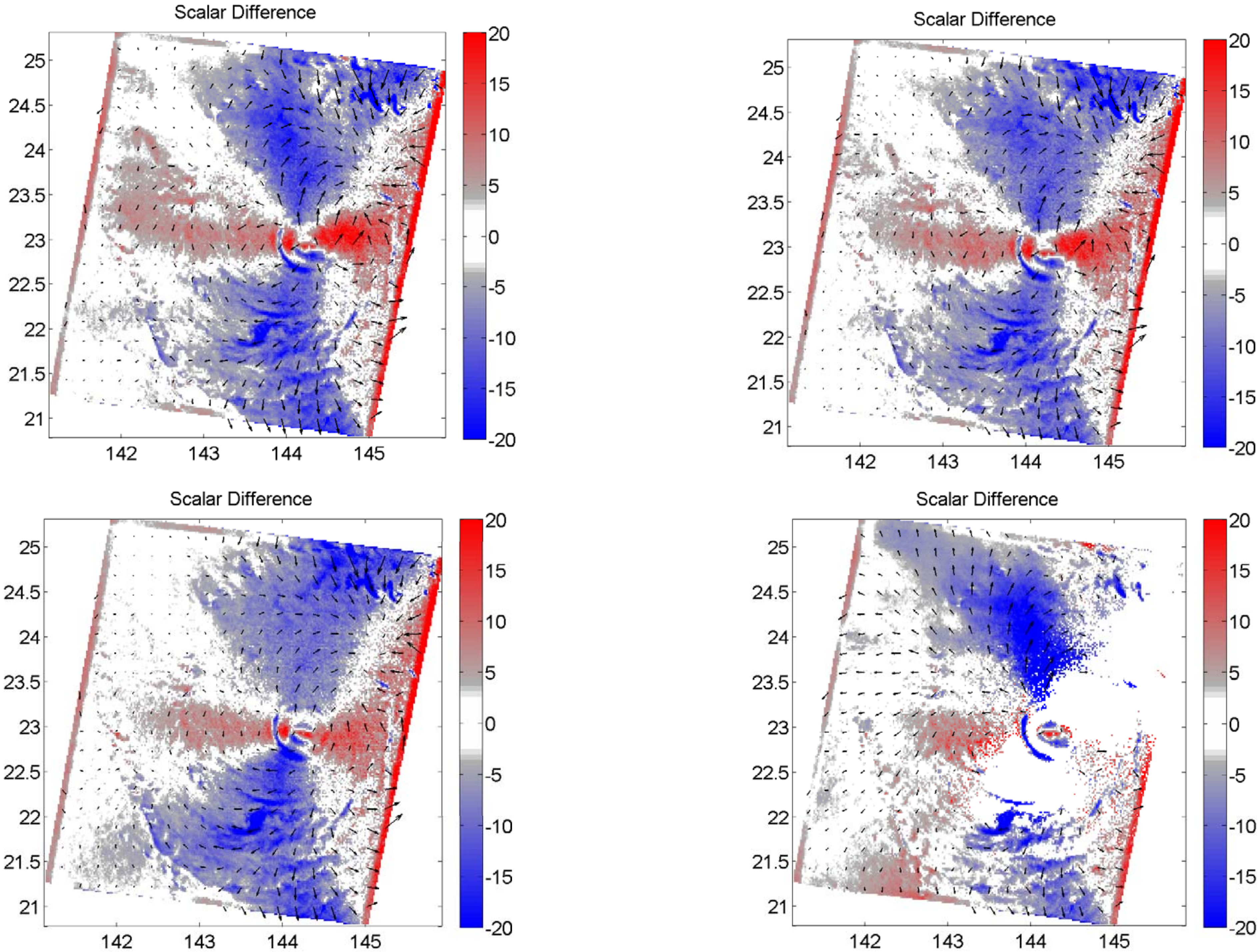
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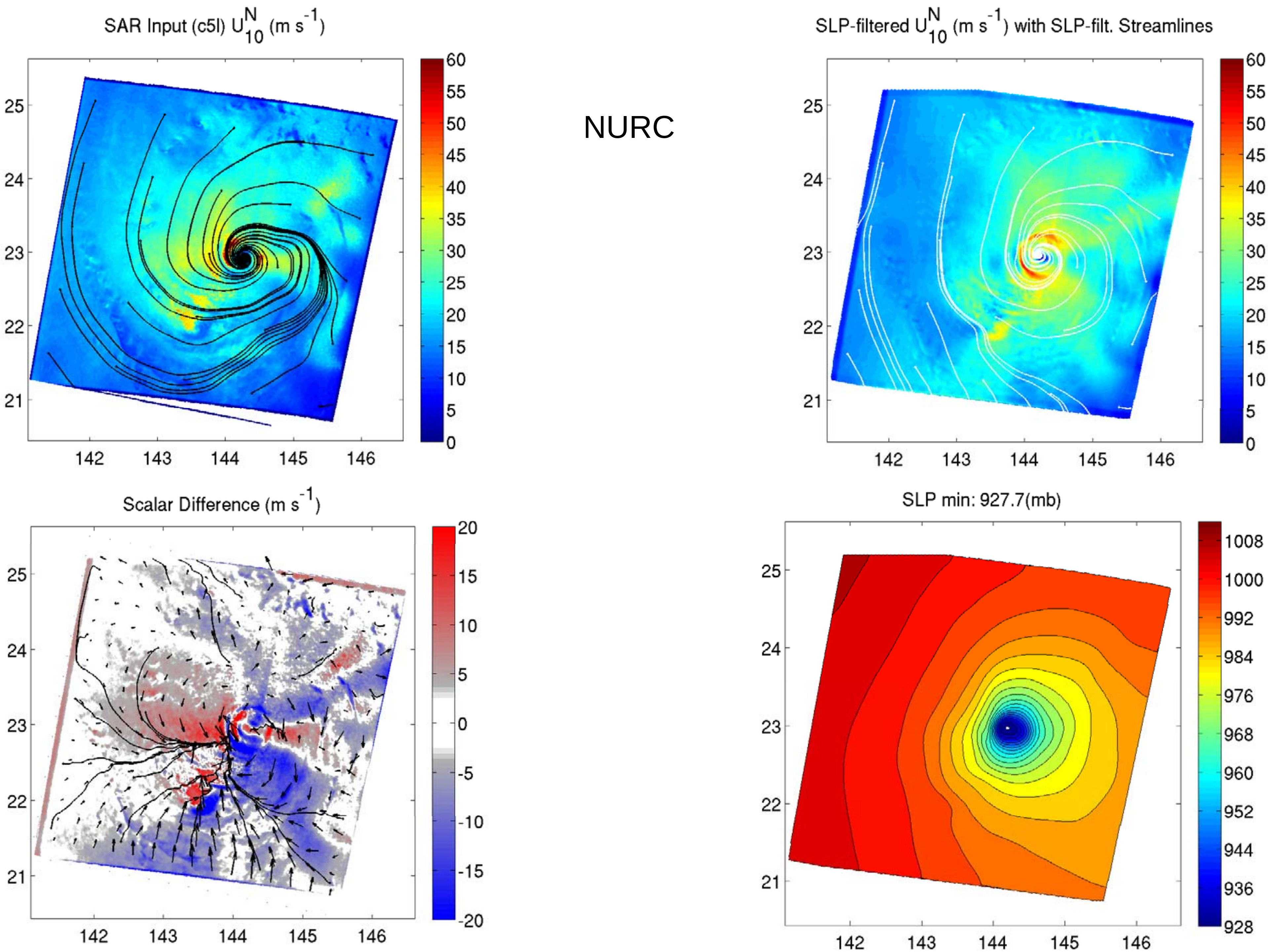
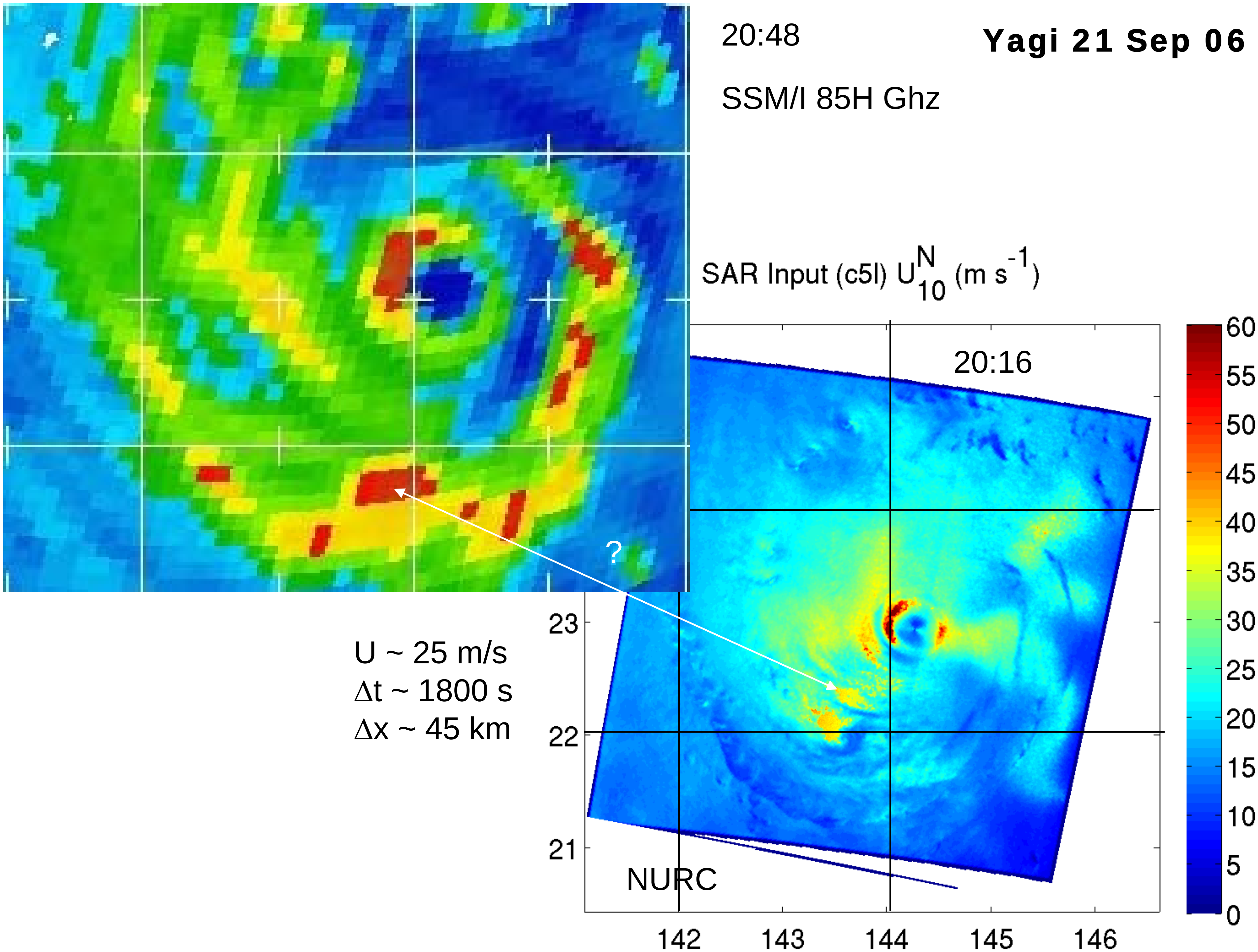


SAR Input (c5l) U^N_{10} (m s^{-1})
NURC
SLP-filtered U^N_{10} (m s^{-1}) with SLP-filt. Streamlines
Scalar Difference (m s^{-1})
SLP min: 927.7(mb)

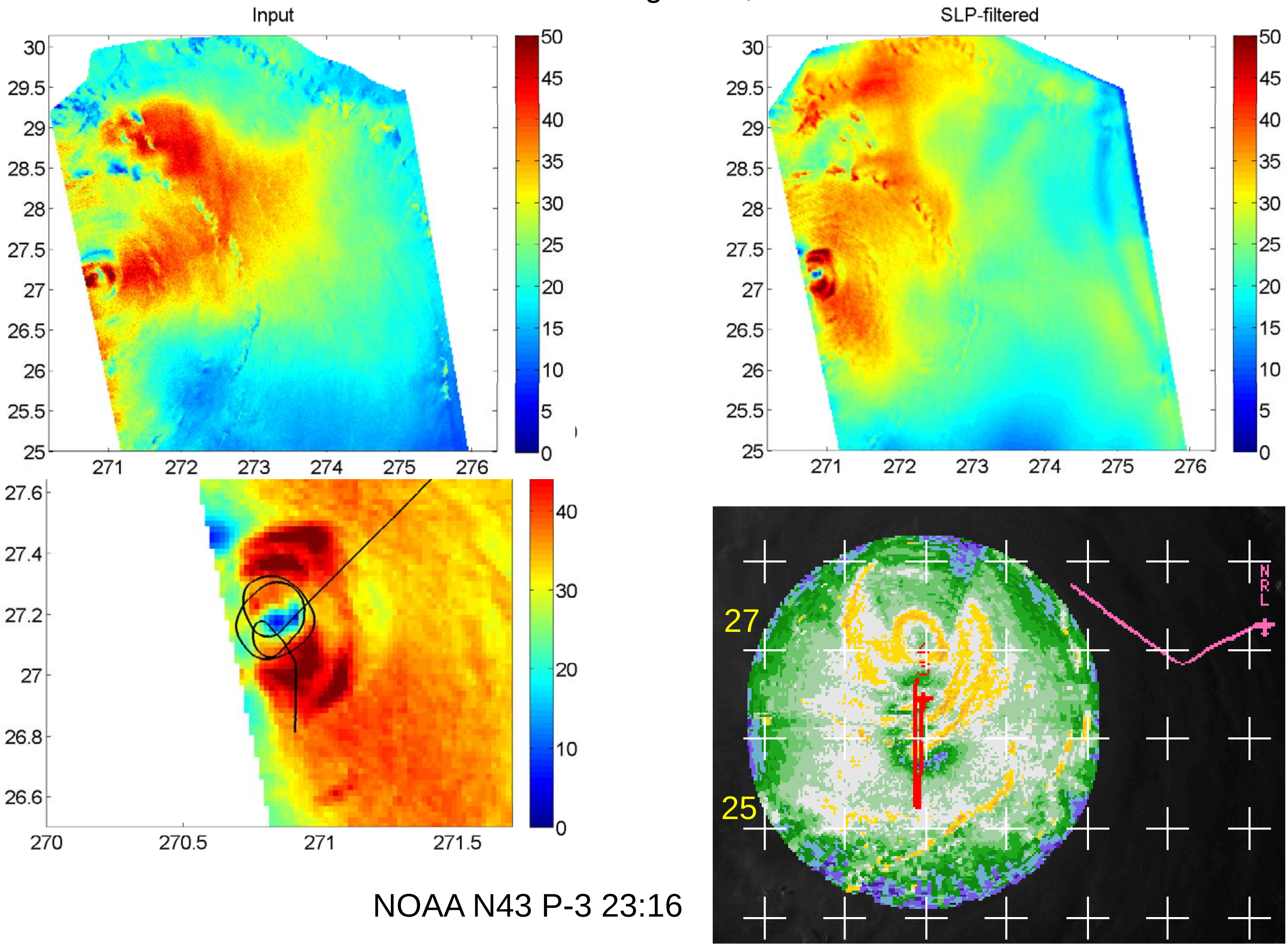
Yagi 21 Sep 06

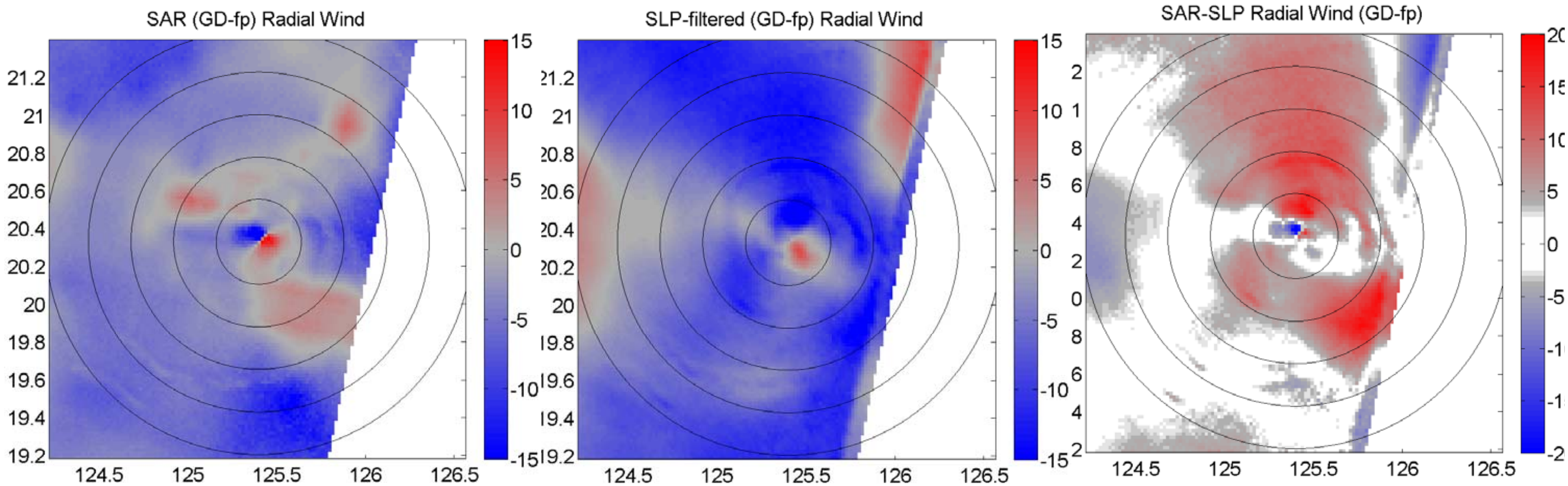


Min SLP (mb)

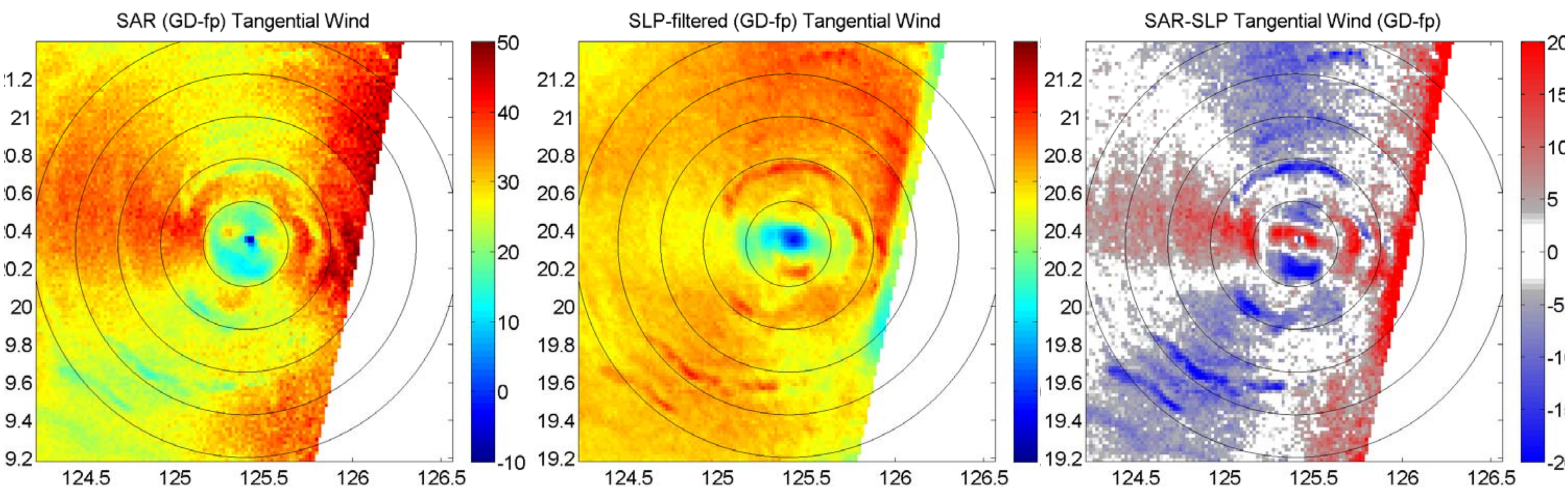
	GD Case1 (fp)	GD Case 2 (fs)	GD Case 3 (ss)	GD Case 4 (fp5a)	Best Track JTWC (~+/-6 mb)	Best Track JMA (~+/- 6mb)	NURC (c5l)
Ewiniar	947.4	947.9	945.1	941.5	944	950	--
Fitow	963.4	963.1	960.5	961.2	970	970	--
Kajiki	940.7	940.7	937.6	921.1	937	945	--
Krosa	907.5	906.3	899.7	902.1	927	927	--
Manyi	932.5	931.1	928.8	919.6	931	932	--
Matsa	954.8	953.2	952.0	942.1	--	--	--
Mawar	957.7	957.8	954.9	952.2	944	950	--
Meari	926.2	925.6	922.3	912.4	--	--	--
Nockten	945.7	943.6	948.4	940.6	933	945	--
Usagi	941.4	939.5	937.8	932.5	939	945	--
Yagi	915.7	915.4	912.3	895.8	898	912	928

Katrina 28 Aug 2005, 23:50





Krosa: GD direction interpolation; CWaR model Function



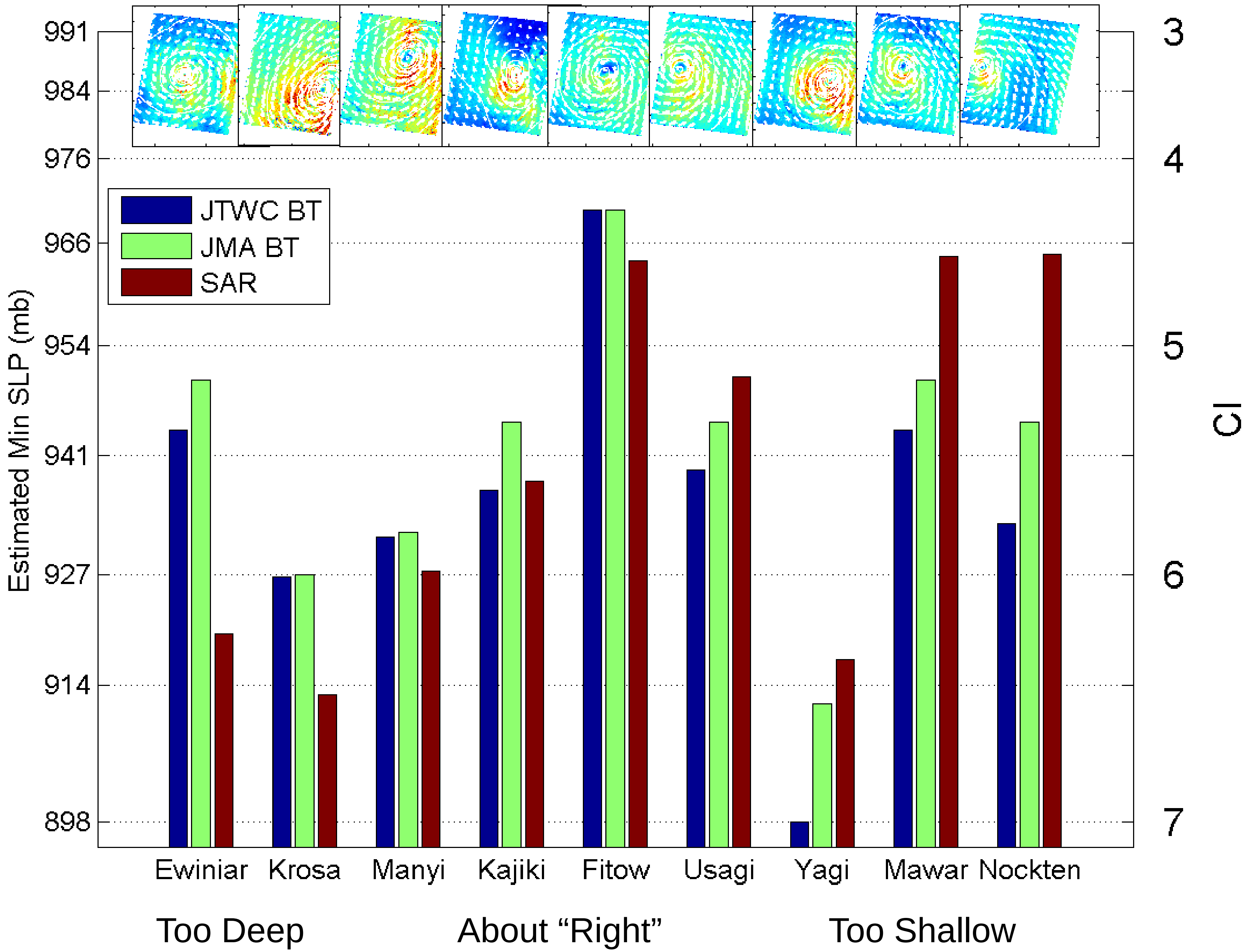
Conclusions

- Final quality of SLP fields is limited by quality of input SAR winds
  - Can SLP retrieval be incorporated into wind retrieval?
  - Methodology for choosing SAR wind direction
- However, if enough of the inner core winds are “good”, first cut application can estimate min(SLP) relatively well compared to Dvorak methods in WPAC

What’s Next

- Investigate incorporating SLP code into wind retrieval methodology at NURC (starting next week)
- Quantitative evaluation of SLP-filter winds
  - ATL cases w/ in situ data
- Incorporate more “TCBL” dynamics into PBL model
- Future: Use SAR surface waves to find Cd?

Extra Slides



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Estimated Min SLP (mb)
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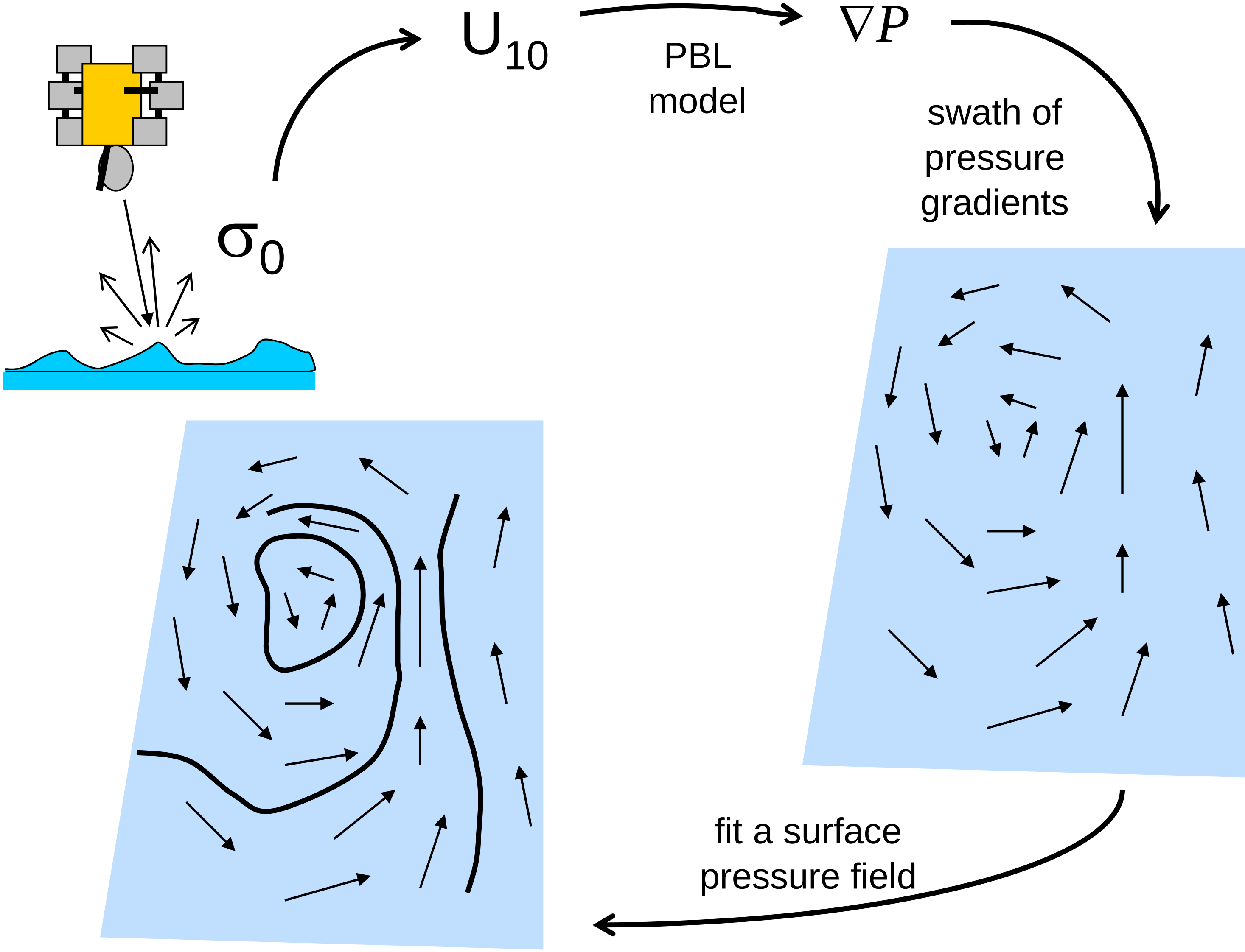
JTWC BT
JMA BT
SAR
Ewiniar
Krosa
Manyi
Kajiki
Fitow
Usagi
Yagi
Mawar
Nockten
Too Deep
About “Right”
Too Shallow


U_{10}
PBL
model
∇P
σ_0
swath of
pressure
gradients
fit a surface
pressure field

UW: Two Goals

- Assess storm intensity from SAR winds provided by General Dynamics (Wackerman) and NURC (Horstmann)
  - Min(SLP) is a useful measure of overall storm intensity
  - Integrated scene-wide evaluation of SAR wind retrievals
  - “Sanity” check on winds
  - Winds → SLP → Pressure Drop
- Research goal: use pressure to correct/improve high wind retrievals
  - Smooth modifications to match SAR bulk pressure gradients (BPG) with observed BPG
  - In progress, currently testing cost function weights

TCBL Core Dominated by Nonlinear Dynamics

- Need simple TCBL models that include nonlinear effects
  - (1) “gradient wind” correction (Seems to work quite well)
  - (2) Nonlinear vortex model (Foster, *BLM*, 2009)
    - Vertical transport of inflow momentum plays a key role in TC BL jet strength
- TCBL roll vortices & streaks
  - Nonlocal fluxes: transports jet momentum into surface
  - Wind directions (relative orientation between SAR linear feature and wind direction is subtle, depends on TCBL mean flow, which depends on TC quadrant)
  - Foster *JAS*, 2005; Foster *JFM, 1997*

Progress

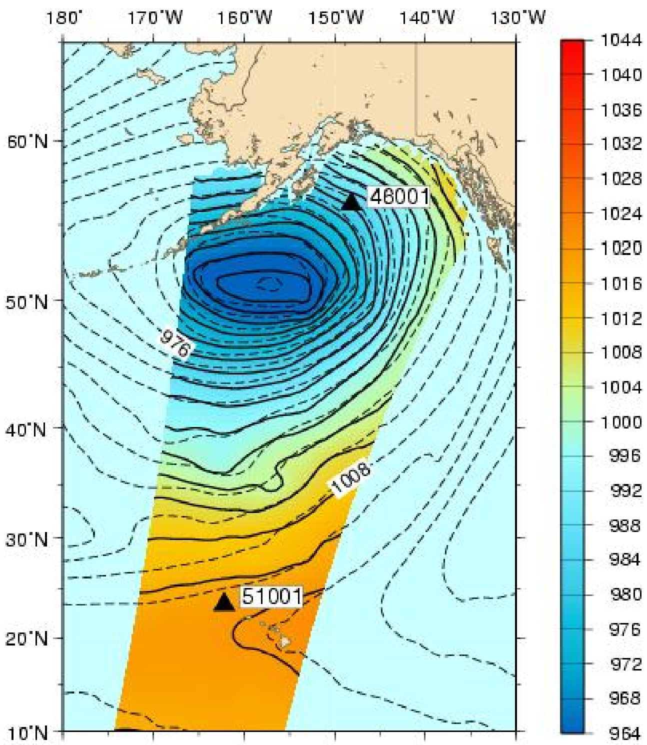
- Amazing computer issues (incompatible compilers, link libraries, OS)
  - Mostly now solved
- Assessing calibration
- Tuning cost function weights & gradient wind parameters

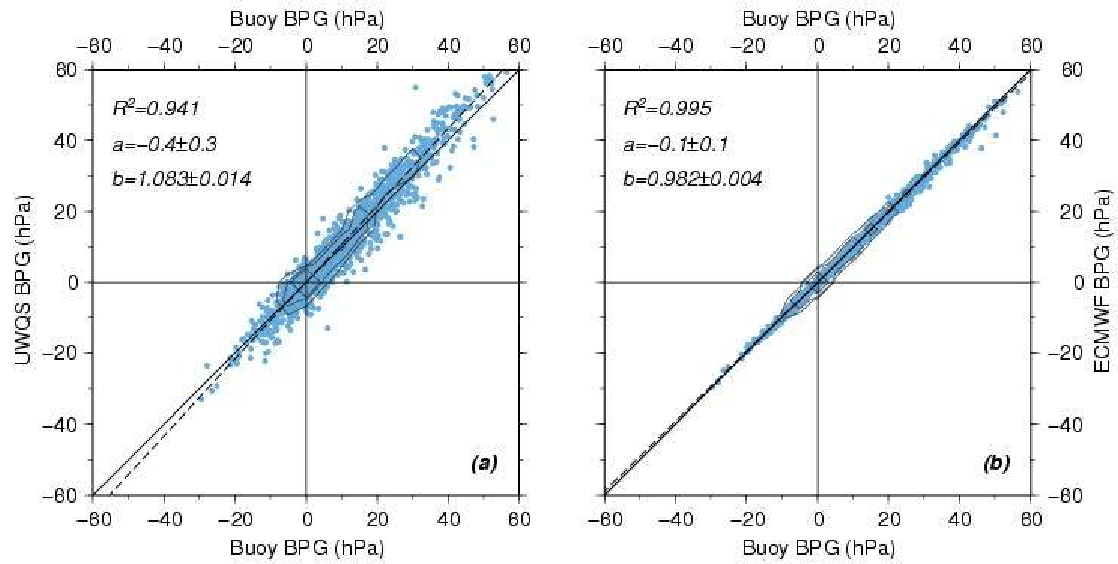
Plans

- Use SLP to aid in wind direction selection
- Parallel effort using TCBL model 2, extrapolate towards center, re-calculate surface winds
- Examine modified surface winds & orientation relative to SAR streaks

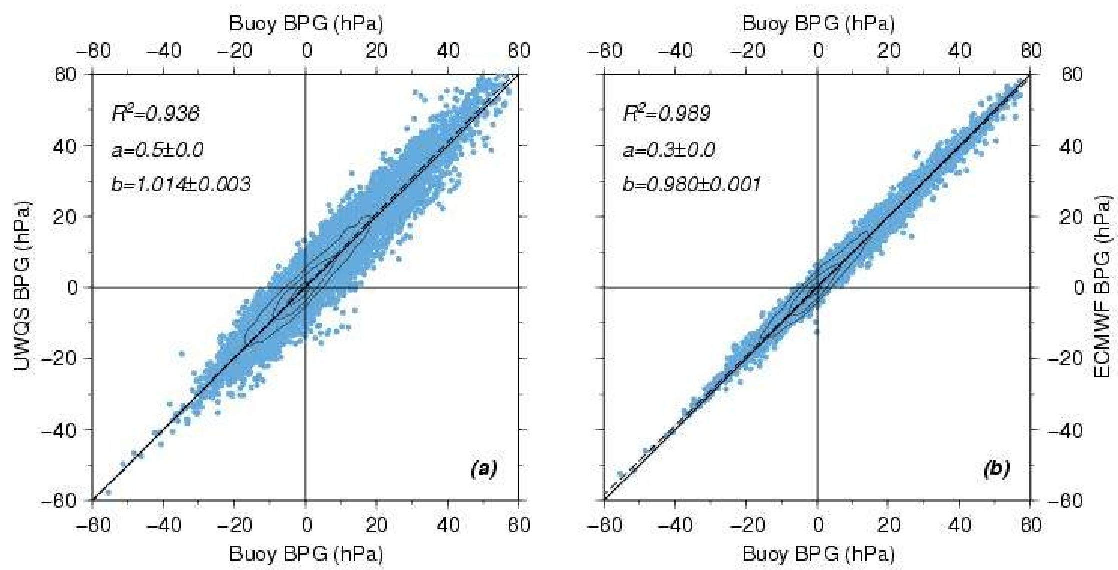
Six-year BPG comparison (51001 & 48001)

Typical remotely-sensed SLP





Patoux, Foster, Brown,
J Appl. Meteor, **47**, 835–852, 2008



QuickSCAT

Six-year comparison all 52 possible NDBC buoy pairs

How Can We Evaluate & Improve SAR High Wind Retrievals?

- Surface pressure is easier to measure than surface wind (buoys, drop sondes)
- Simple, but nonlinear, TCBL model relates SAR surface winds to pressure gradients & hence to bulk pressure differences within SAR image.
- Optimization procedure to find minimum SAR wind corrections to match observed bulk pressure gradients (and surface wind obs.)

$$J = \underbrace{\sum_{n=1}^{N}\left(\Delta P_n^S - \Delta P_n^O\right)^2}_{SLP\ obs} + w_1 \underbrace{\sum_{m=1}^{M}\left(S_m - S_0\right)^2}_{SFMR\ obs} + w_2 \underbrace{\sum_{l=1}^{L}\left|\mathbf{u}_l^i - \mathbf{u}_l^{i-1}\right|^2}_{Smoothness}$$

- SLP is an integrated property, hence local pressure data provides information over wide region of SAR image – NOT point-wise Cal/Val

σ_0

GMF + directions

"$\mathbf{U}_{10}^{N}$"

PBL Model

∇P

SLP Pattern

ΔP, S_{SFMR}

$\mathbf{U}_{10}^{N}$ new

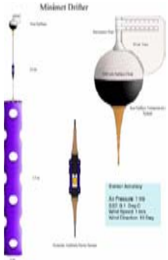
Optimize

Minimize

$\Sigma(\Delta P_{SAR} - \Delta P_{obs})^2 +$

$w_1\Sigma|S_{SAR} - S_{SFMR}|^2$

$w_2\Sigma|\mathbf{U}_{i+1} - \mathbf{U}_i|^2$



TCBL Core Dominated by Nonlinear Dynamics

- Need simple TCBL models that include nonlinear effects
  - (1) “gradient wind” correction
  - (2) Nonlinear vortex model (Foster, *BLM*, 2009)
    - Vertical transport of inflow momentum plays a key role in TC BL jet strength
  - (3) General nonlinear similarity (may be too slow)
- TCBL roll vortices & streaks
  - Nonlocal fluxes: transports jet momentum into surface
  - Wind directions
  - Foster *JAS*, 2005; Foster *JFM, 1997*

Axisymmetric, Balanced Vortex

$$\frac{\partial U}{\partial r}+\frac{U}{r}+\frac{\partial W}{\partial z}=0$$

$$U\frac{\partial U}{\partial r}-\frac{V^2}{r}+W\frac{\partial U}{\partial z}-fV=\frac{-1}{\rho_0}\frac{\partial P}{\partial r}+\frac{\partial}{\partial z}\left(K\frac{\partial U}{\partial z}\right)$$

$$U\frac{\partial V}{\partial r}+\frac{UV}{r}+W\frac{\partial V}{\partial z}+fU=\frac{\partial}{\partial z}\left(K\frac{\partial V}{\partial z}\right)$$

$$\frac{V_g^2}{r}+fV_g=\frac{1}{\rho_0}\frac{\partial P}{\partial r}$$

PBL Dynamics

$$\mathrm{Re}\frac{h}{L}\left[UU_x + VU_y + WU_z\right] - a\left(V - V_g\right) = \frac{\partial}{\partial z}\left(K\frac{\partial U}{\partial z}\right)$$

$$\mathrm{Re} = \frac{U_{10}^N h}{K_m}$$

$$Ro = \frac{U_{10}^N}{fh}$$

$$\delta = \sqrt{2K_M / I}$$

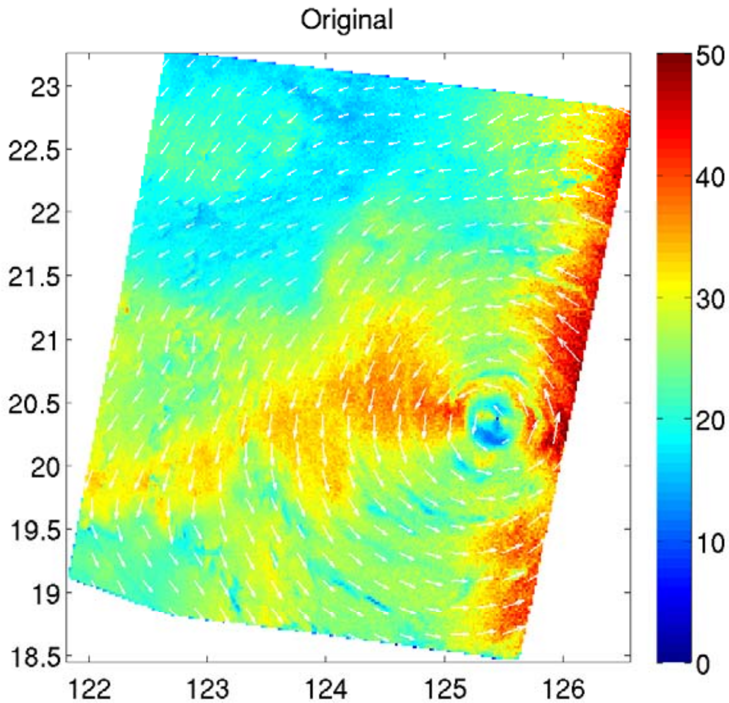
$$I = \sqrt{\left(f + \frac{2V_{grad}}{r}\right)\left(f + \frac{V_{grad}}{r} + \frac{\partial V_{grad}}{\partial r}\right)}$$

$$I \sim f \rightarrow \delta \sim \delta_E$$

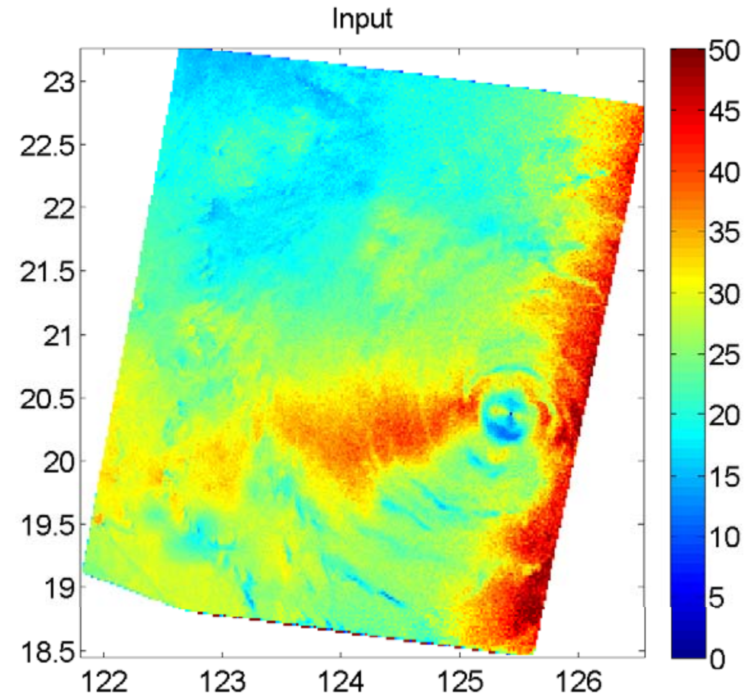
$$a = \frac{\mathrm{Re}}{Ro} = O\left(1\right) \qquad \varepsilon = \mathrm{Re}\frac{h}{L} < 1$$

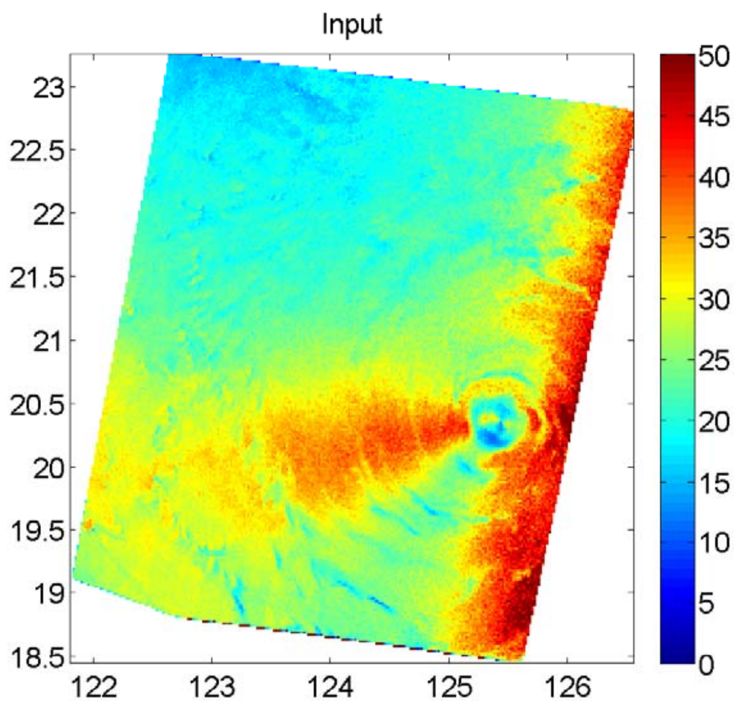
GD Winds

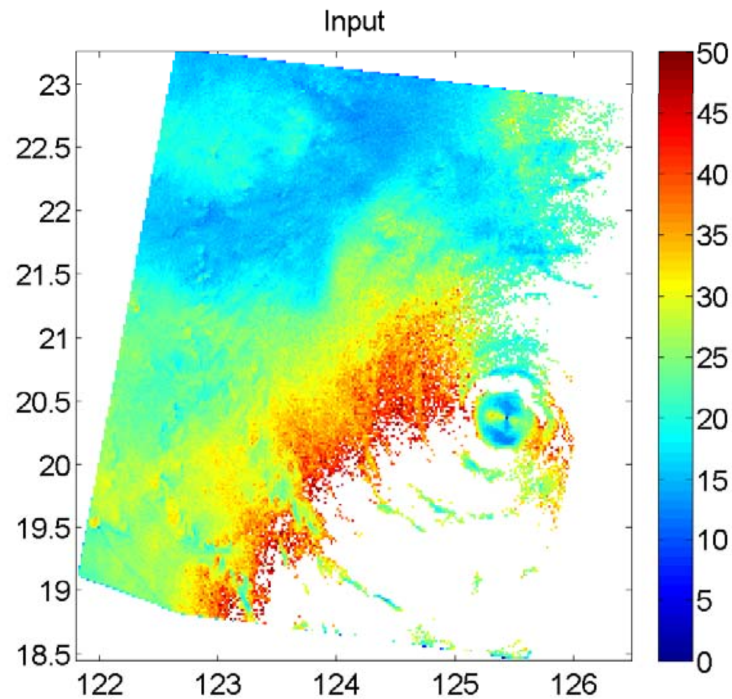
- Case 1 (fp): Linear features for directions, power-law interpolate directions only. CWaR model function.
- Case 2 (fs): Linear features for directions. Interpolate directions only with spiral model. CWaR model function.
- Case 3 (ss): Fit spiral model to linear features, use spiral model as direction. CWaR model function (same as March, 2010 Miami SWG mtg.)
- Case 4 (fp5a): Linear features for direction, power-law interpolation of directions only. CMOD5 (α=0.6). Missing data where SAR σ_0 exceeds CMOD5.



Krosa







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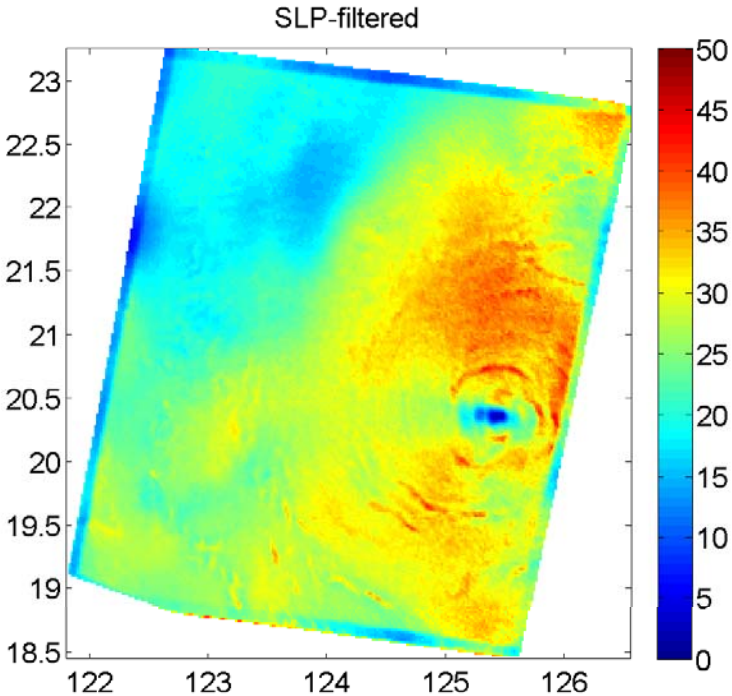
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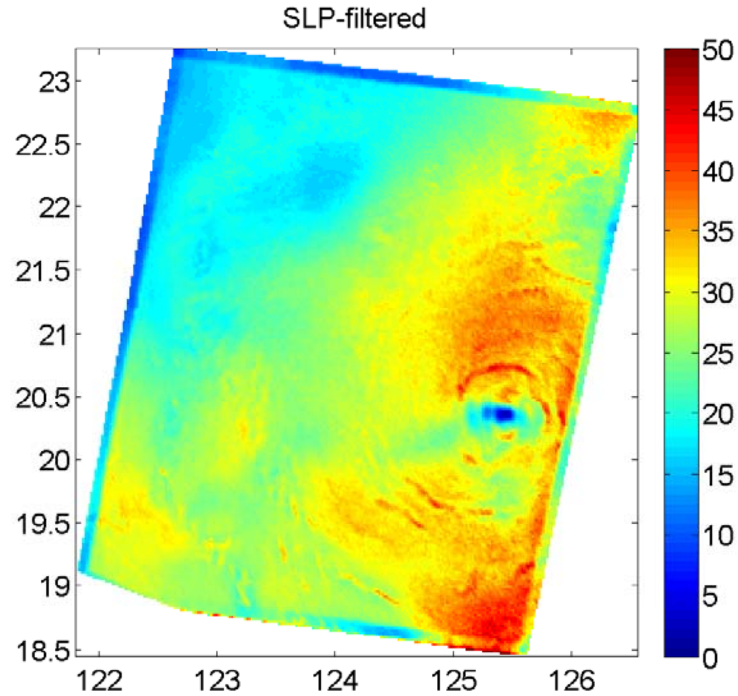
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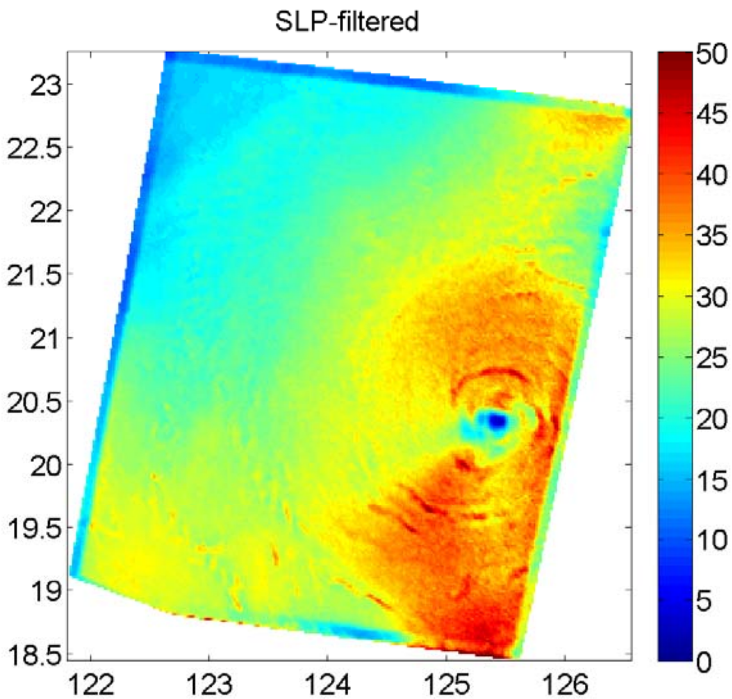
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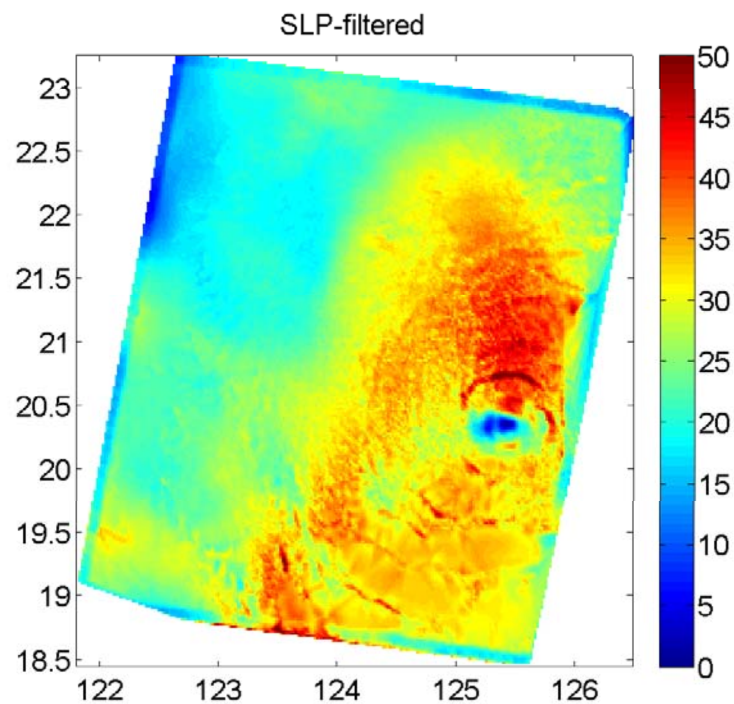
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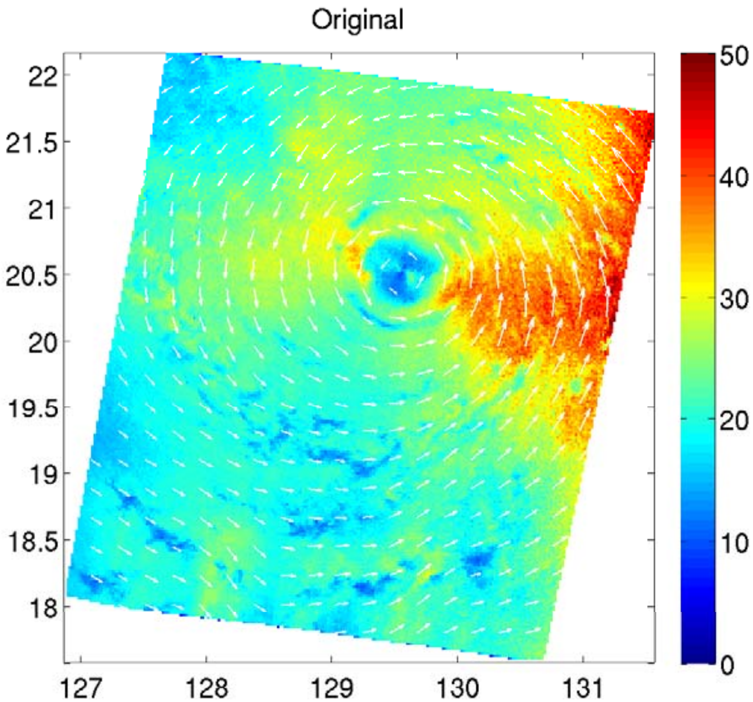
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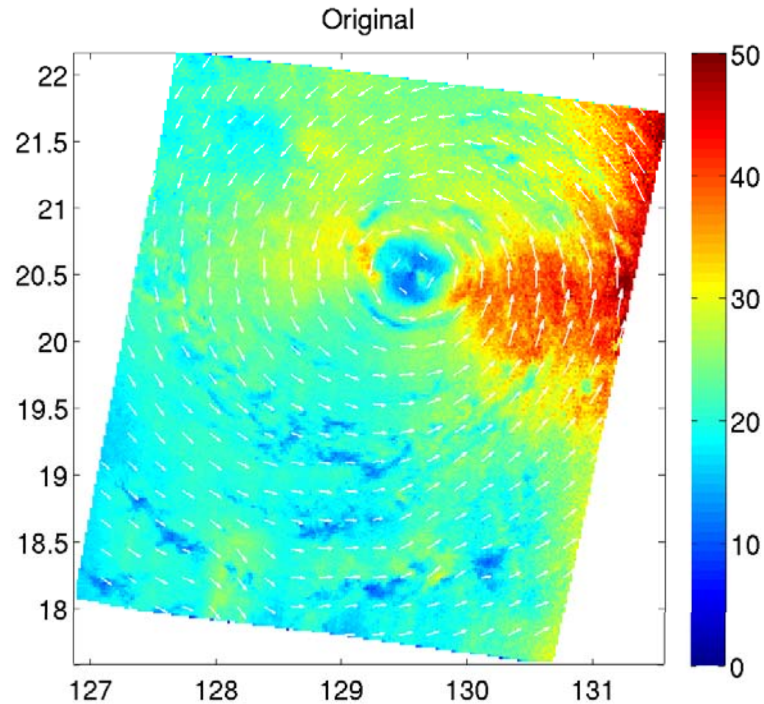
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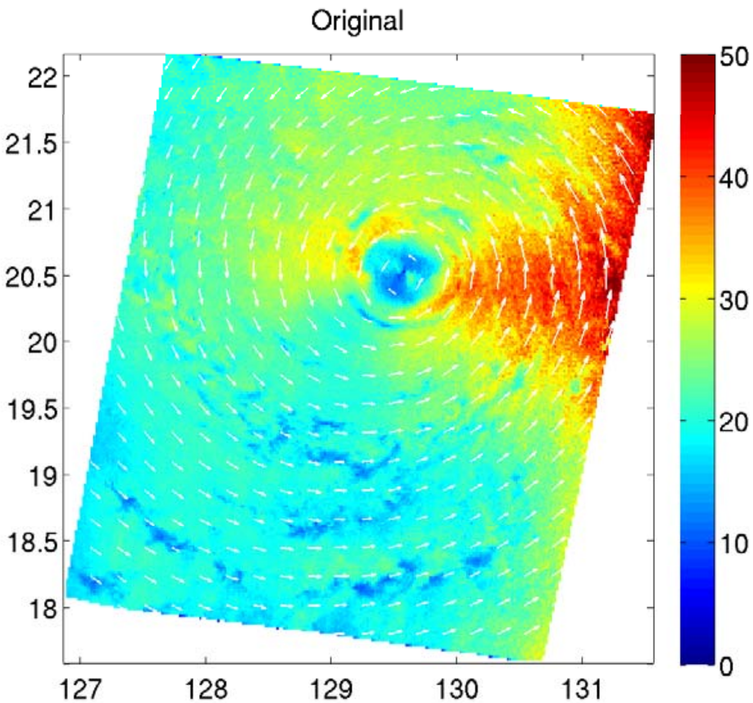
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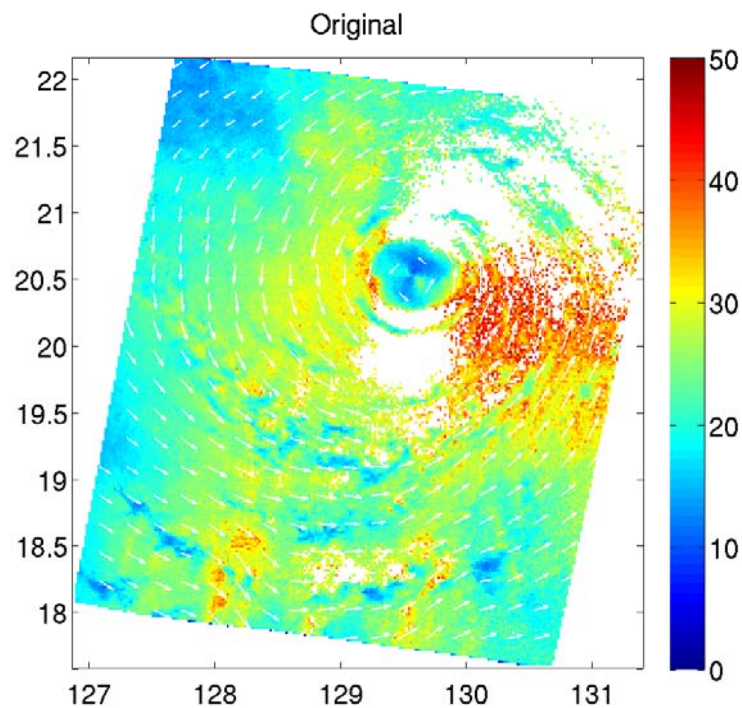
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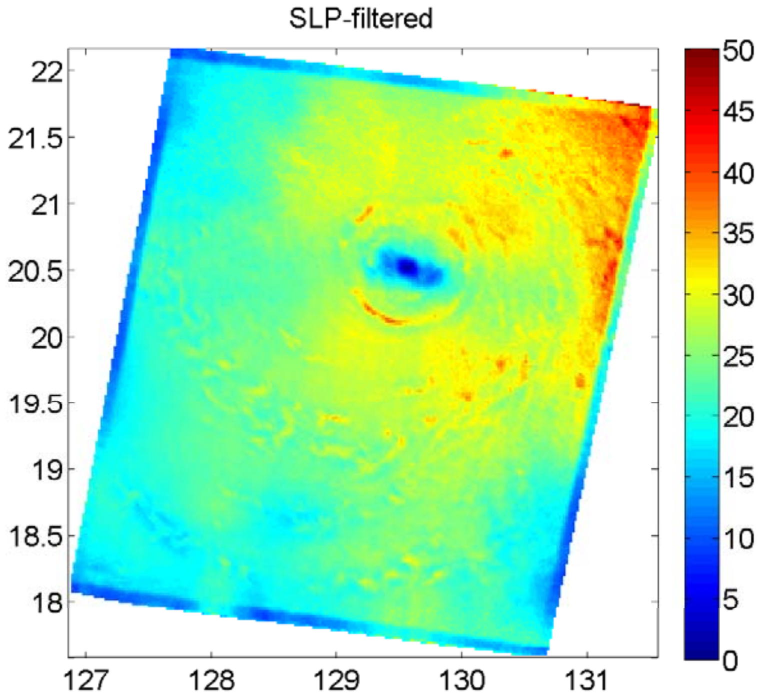

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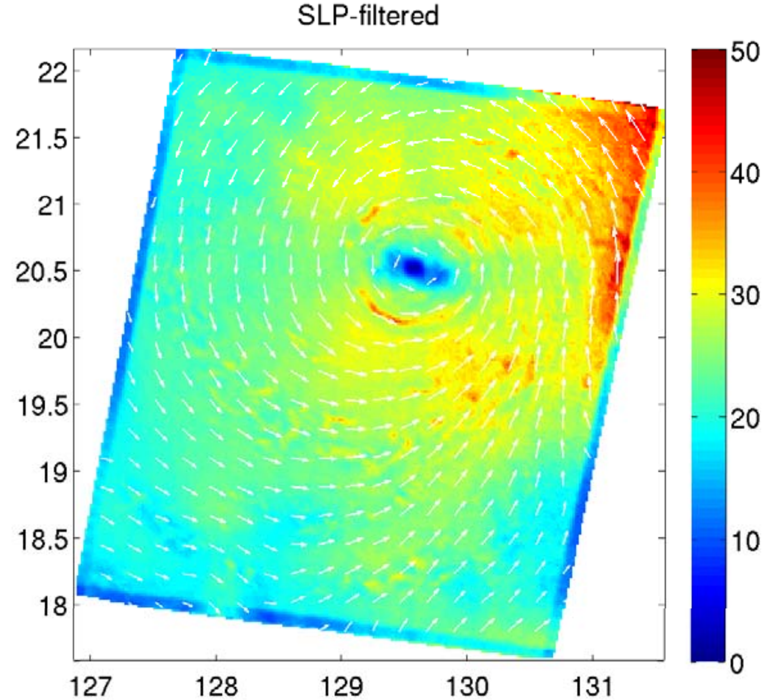

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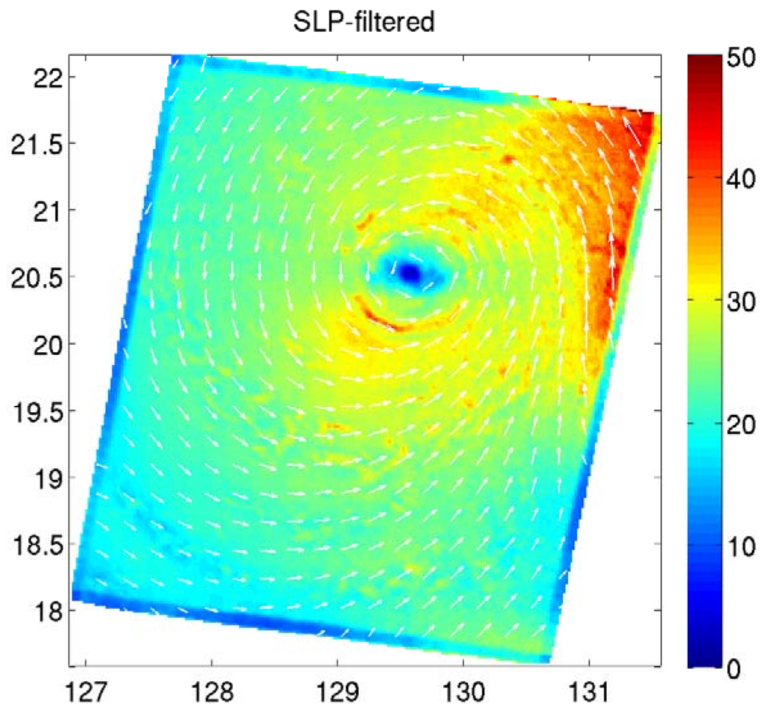

SLP-filtered
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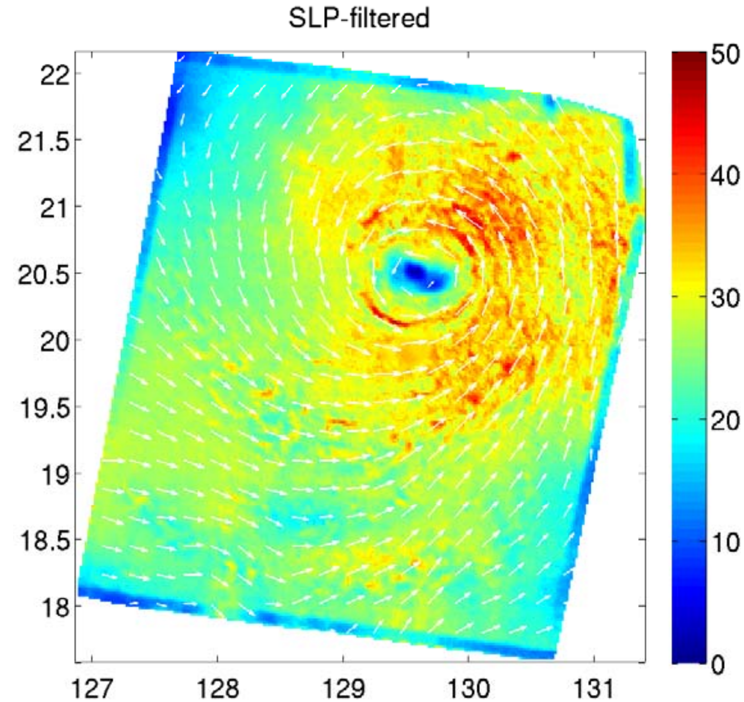

SLP-filtered
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