An Improved Asymmetric Hurricane Parametric Model Based on SAR Observations

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Outline

1. Research Background
2. Methodology
3. Experimental Results
4. Discussion and Summary

Background

- ✓ In real-time forecasting, predictions of winds, and thus surges, can be performed using advanced numerical weather forecasting models.
- ✓ Alternatively, parametric hurricane wind models are more frequently used due to their simplicity and efficiency, especially in long- term wind and surge risk assessment and structural design

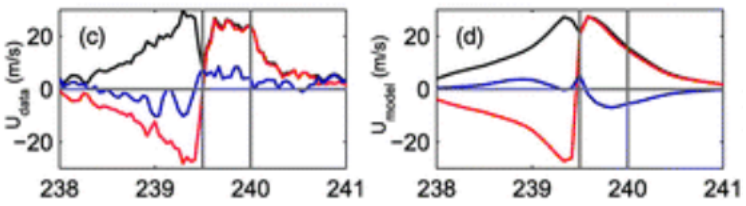
hurricane mechanism studies

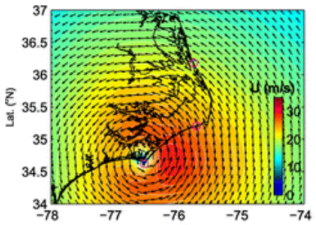
Hurricane Risk Assessment

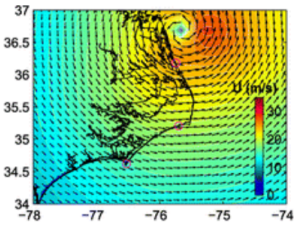
Hurricane Parametric Model

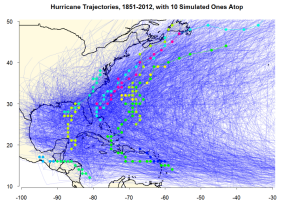
Extreme Wind & Storm surge forecasting

Industries (fisheries, insurance, etc.)









Existing Models

Tangential wind profile model (1-D)

H80 (Holland 1980) / SMRV (Mallen 2003) / H08 (Holland 2008) / W10 (Wood 2010)/ OHMRV (G.S. Zhang 2014) / DMRV (Sitkowski 2011) / λ model (Shuai Wang 2015) / M16 (Murty 2016) and etc.

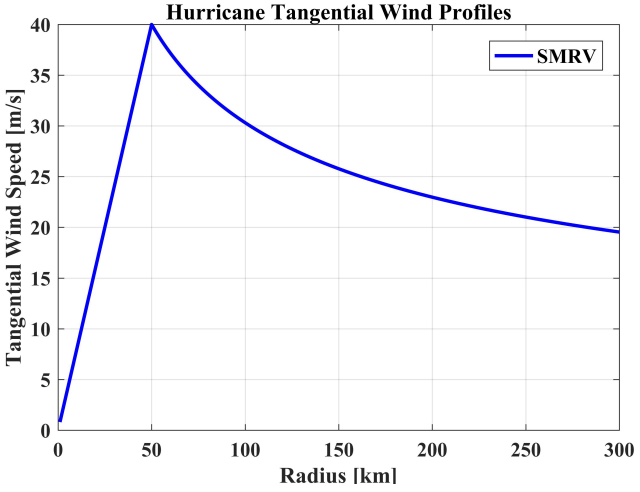
2-D model

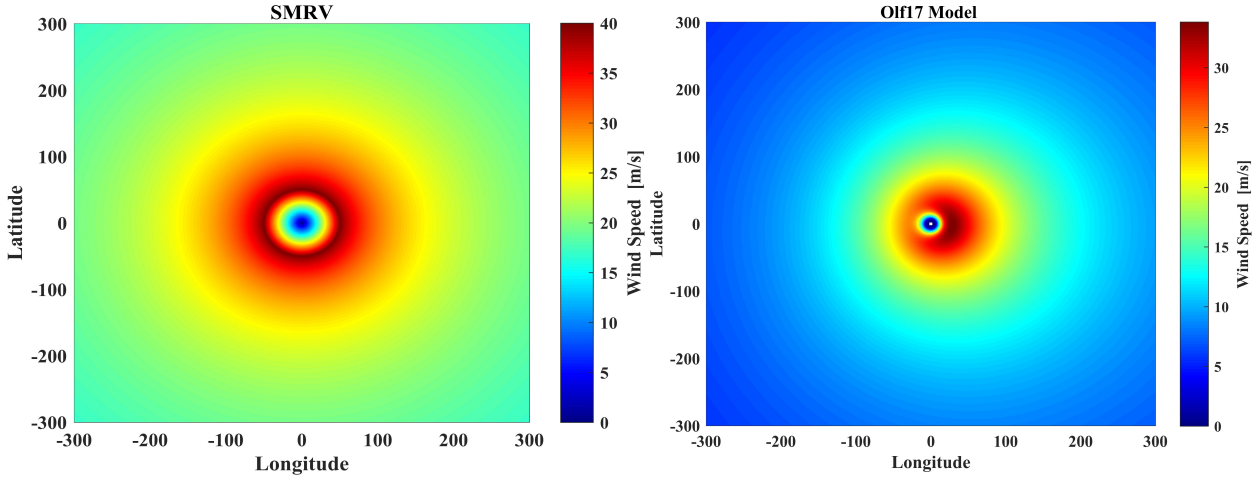
Symmetric model :

Axisymmetric model / Elliptic symmetry model (SHEW, G.S. Zhang 2017)

Asymmetric model :

OHM (Xie 2006) / Olf17 (Olfateh 2017)

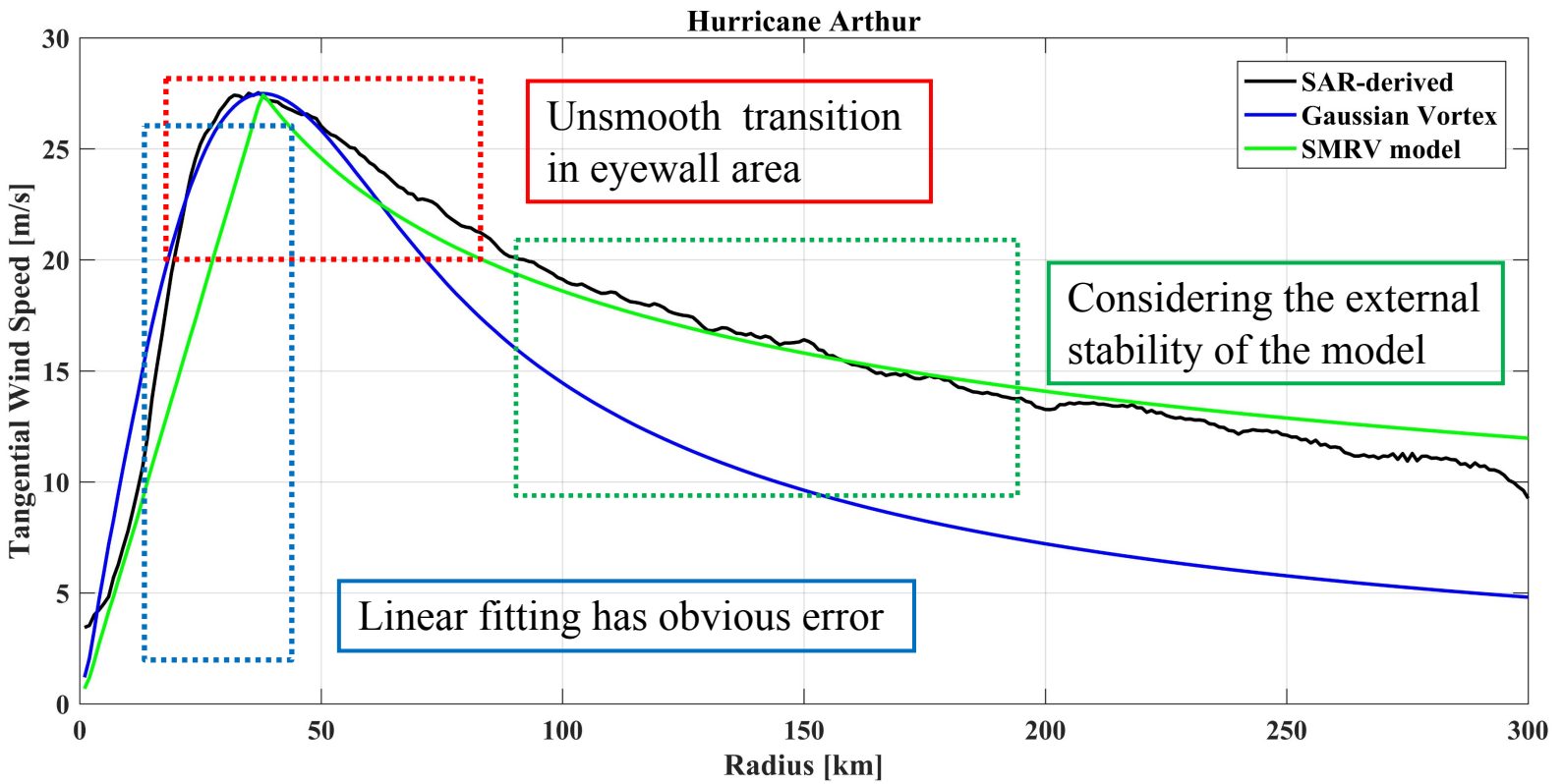




Tangential Profile and distribution of wind speed

Motivations

1-D Tangential wind profile (e.g. Hurricane Arthur)



2-D model e.g. Olf17(Olfateh 2017)

$$V_{H80}(r) = \left[\left(\frac{R_{max}}{r}\right)^{B} \frac{B}{\rho}(P_n - P_c) exp\left[-\left(\frac{R_{max}}{r}\right)^{B}\right] + \frac{r^2 f^2}{4}\right]^{\frac{1}{2}} - \frac{rf}{2}$$

$$V = V_{H80}(1 + \varepsilon \sin(\theta + \alpha)\left[\left(\frac{R_a}{r}\right)^{D}\left(\frac{R_w}{r}\right)^{-B} e^{\left(\frac{R_w}{r}\right)^{B}\left(\frac{R_a}{r}\right)^{D}}\right]^{\frac{1}{2}})$$

Too many parameters

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Methods

$$\bar{V}(r_{nor}) = \frac{1+\sigma^{-2}}{r_{nor}}\left[1 - \exp(-\sigma^2 {r_{nor}}^2/2)\right]$$

e.g. Guass Vortex

Gauss Function

Smooth transition

1-D tangential profile

Piecewise Function

Sectional description

e.g. SMRV(Mallen 2003)

$$V = \begin{cases} v_1\left(\frac{r}{r_1}\right) & (r \le r_1) \\ v_1\left(\frac{r_1}{r}\right)^{\alpha_1} & (r_1 < r \le 150\ km) \end{cases}$$

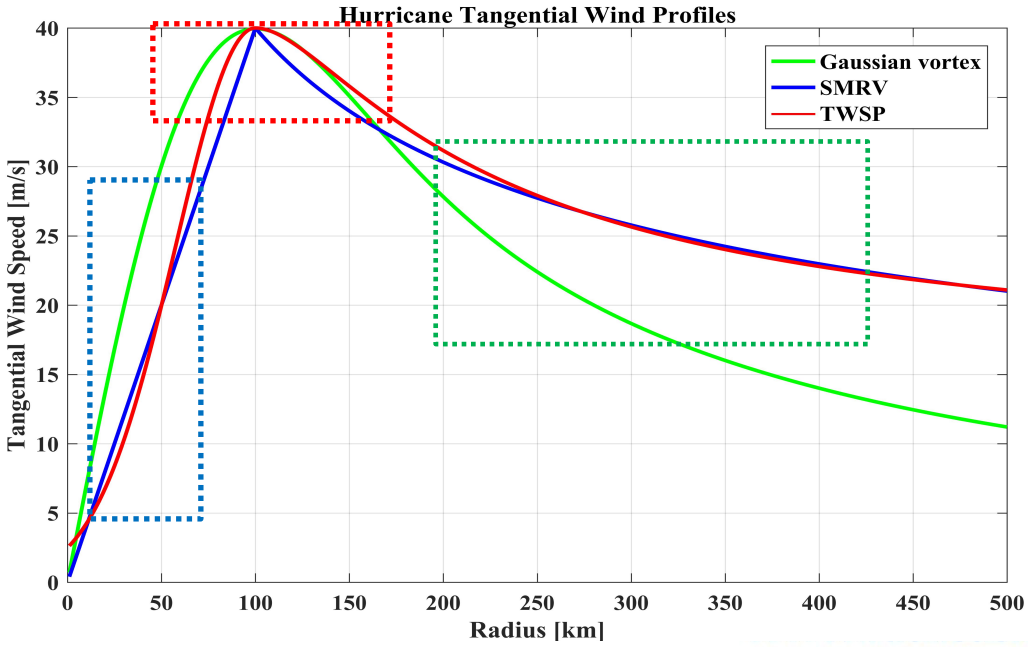
$$V_s = \begin{cases} V_1 \exp\left(-\left(\left(\frac{r}{r_1} - 1\right)/a\right)^2\right) & r \le r_{max} \\ V_1 \exp\left(-\left(\left(\frac{r_1}{r} - 1\right)/b\right)^2\right) & r_1 < r \le 150km \end{cases}$$

growth exponent

decay exponent

New Profile Model: TWSP

Idealized tangential wind profiles for Gaussian vortex(green), SMRV(blue) and TWSP(red) for $v_1 = 40m/s$, $r_1 = 100km$. $\alpha_1 = 0.4, a = 0.6, b = 1$



2-D model

Asymmetrical radial distribution of the wind speed in Olf17 model

Tangential Profile (TWSP V_s)

$$V^t(r) = \varepsilon \bar{V}_{R_w} \sin(\theta + \alpha) \left[e \left(\frac{R_a}{r} \right)^D e^{-\left(\frac{R_a}{r}\right)^D} \right]^{1/2}$$

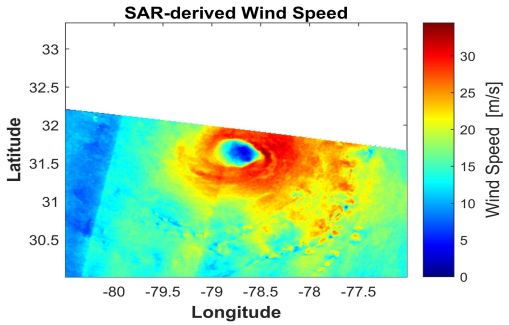
modify by V_s

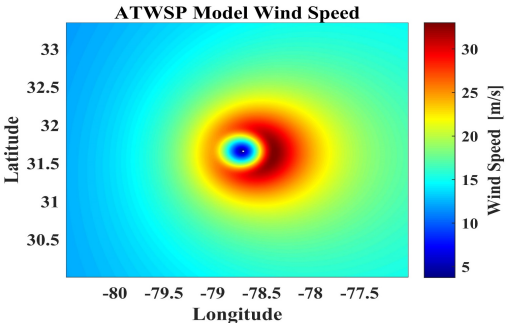
$$V_t = \varepsilon \sin(\alpha + \theta) V_s$$

Asymmetric structural function (ASF)

$$V = V_s(1 + V_t/V_s)$$

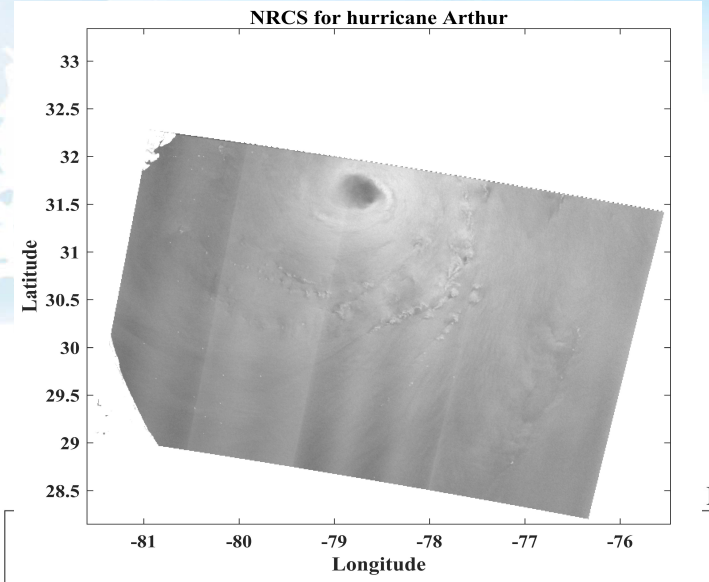
Asymmetric model (ATWSP)





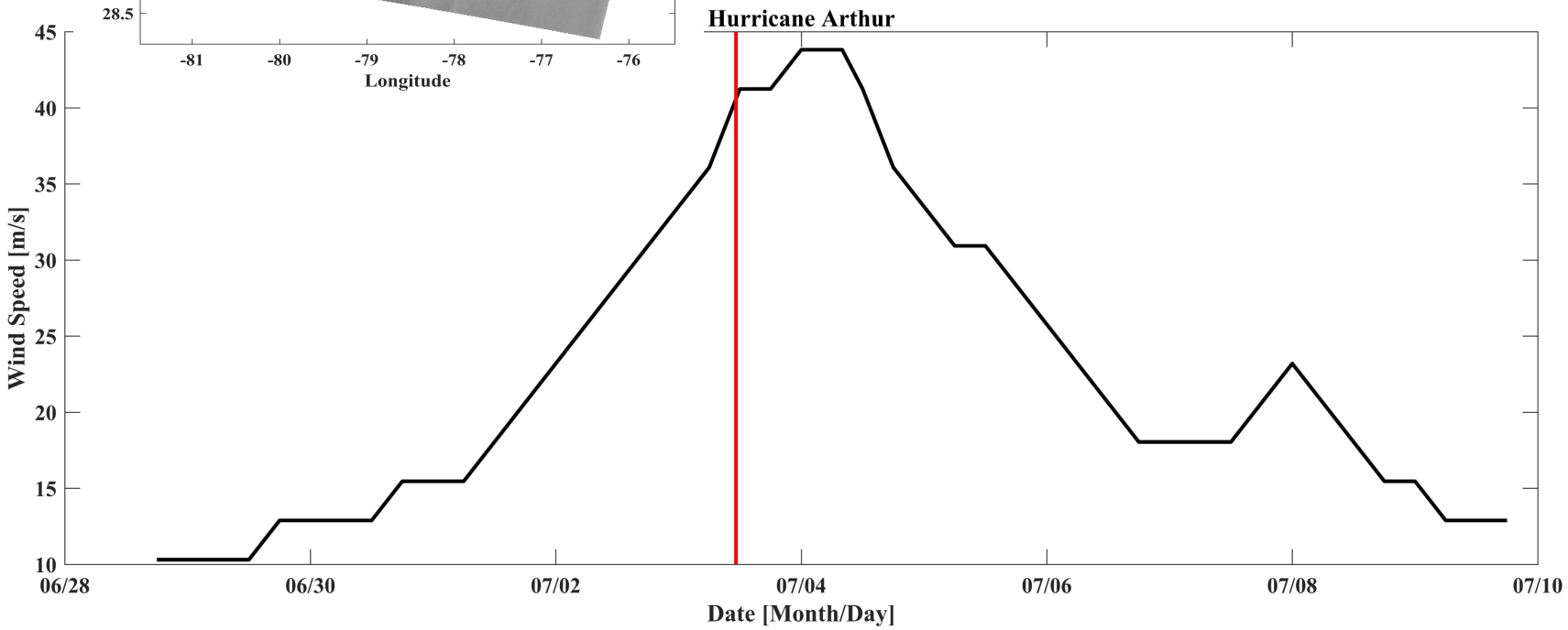
Hurricane Arthur (2014)

Hurricane Arthur



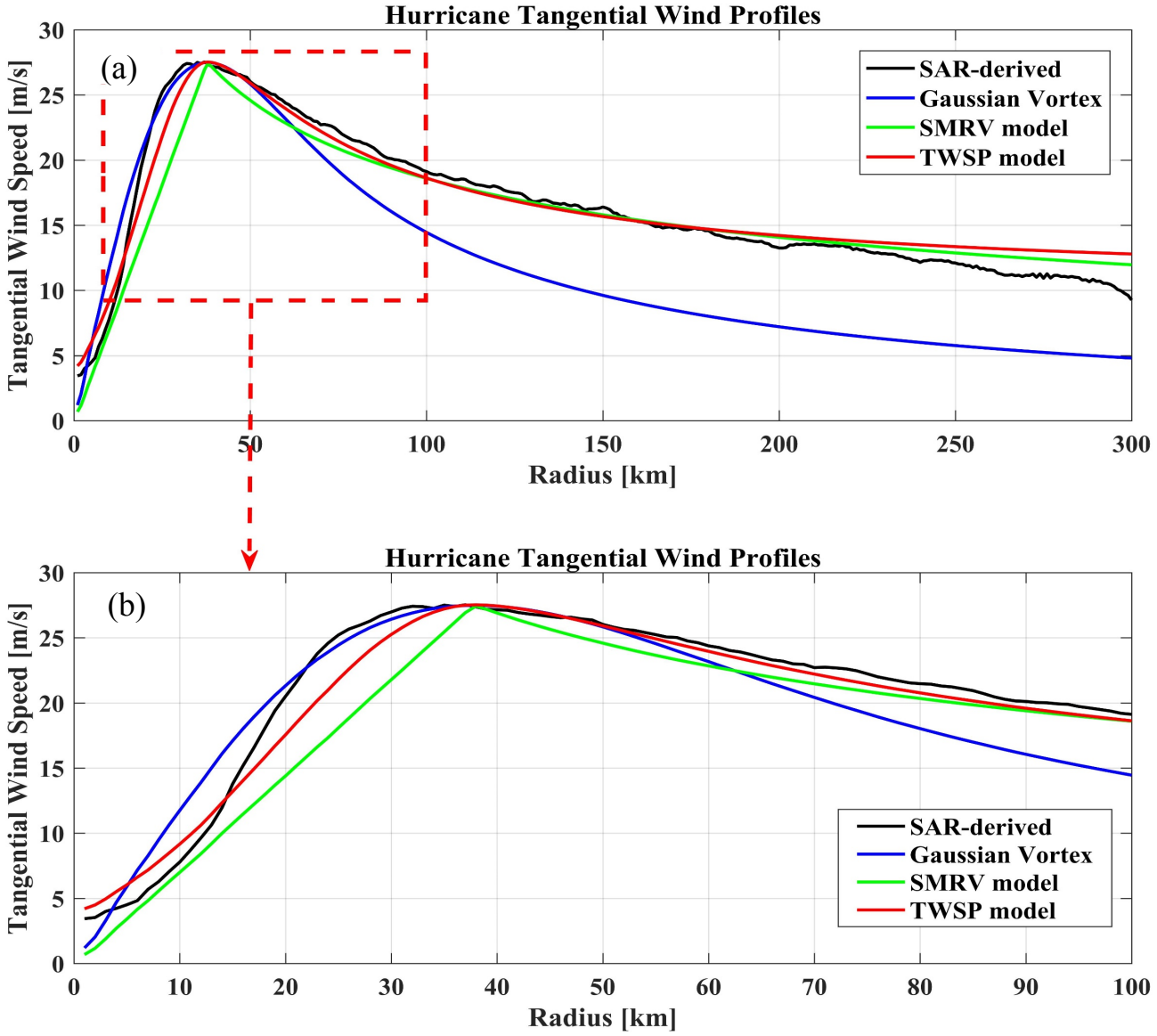
The main information about SAR image

Name	Arthur
Date	2014-07-03
Time(UTC)	11:13
Satellite Platform	Radarsat-2
Polarization Mode	Cross-polarization (VH)



Best track Intensity time series and the SAR capture time

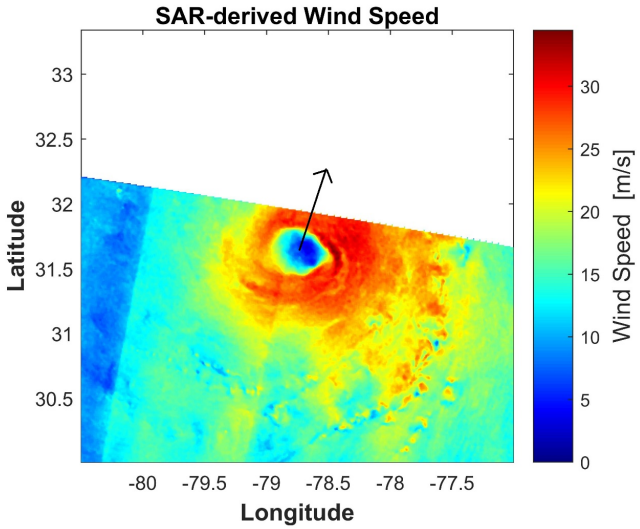
Tangential wind profiles

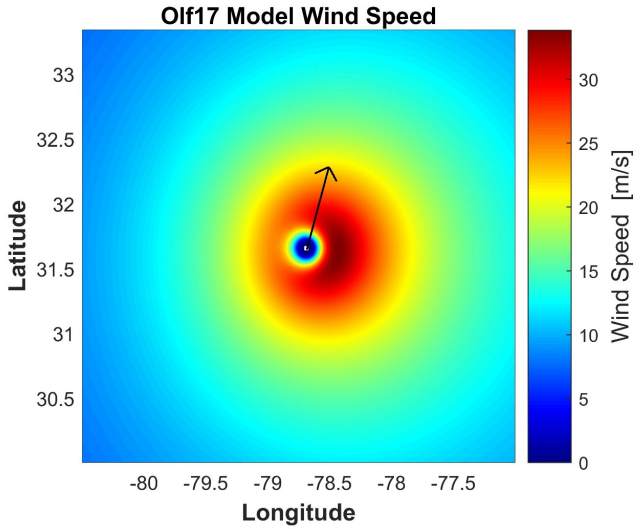


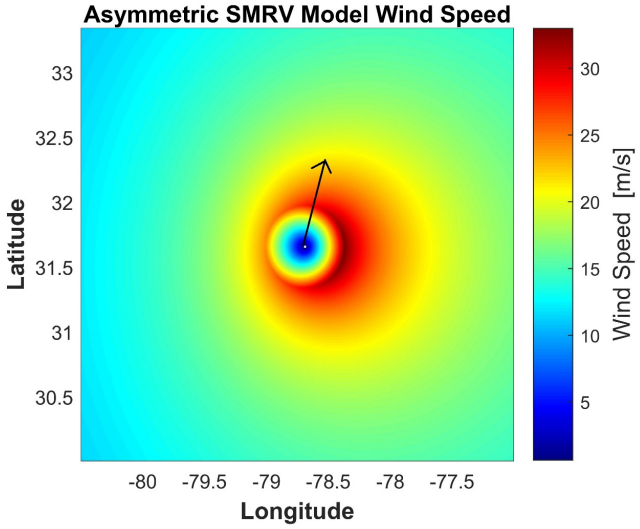
Hurricane Arthur

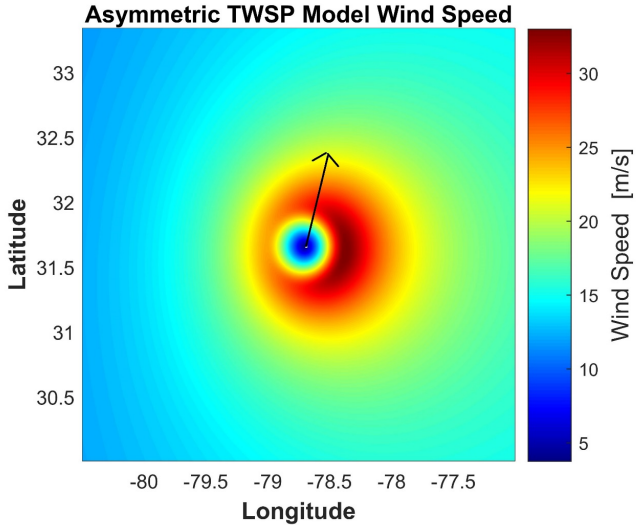
Tangential wind profiles simulated by models and derived by SAR.
(a) Complete profile
(b) Profile of hurricane eye and high wind speed area.

2D Surface wind speed







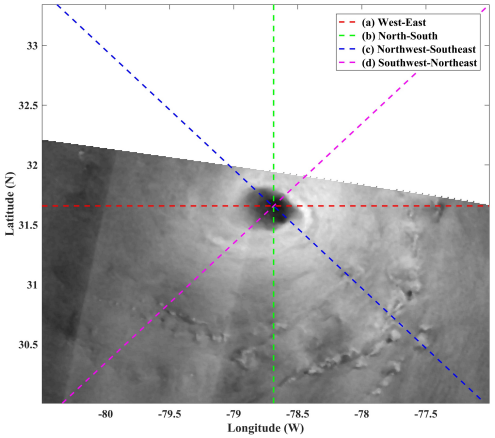


Hurricane Arthur

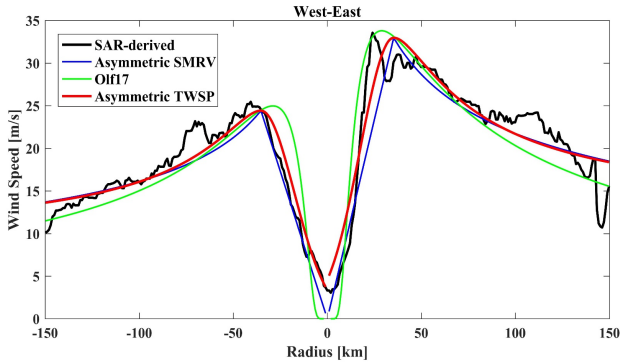
The wind speed derived by SAR and simulated by models. The black arrows represent the direction of movement, which are calculated from the best track data.

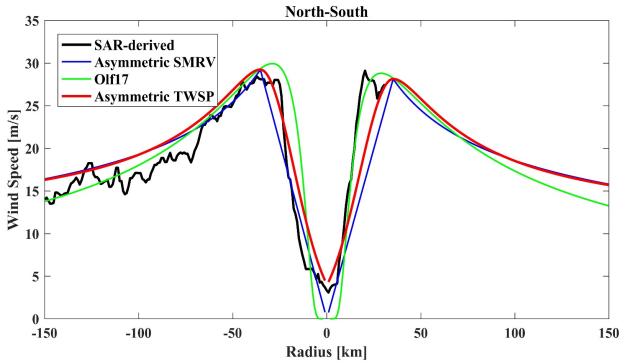
Comparison with SAR

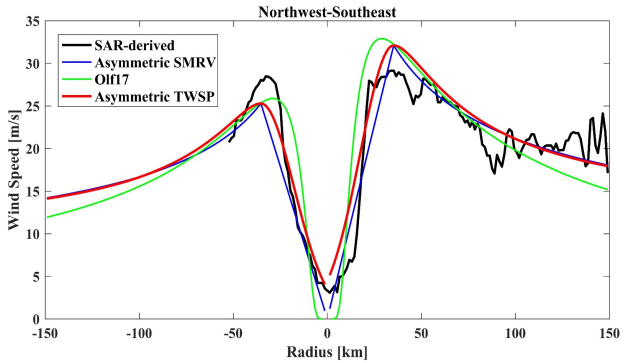
Hurricane Arthur

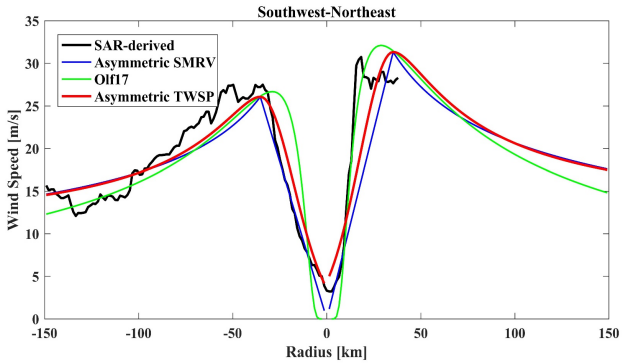


The position of eight main direction profiles on SAR images.

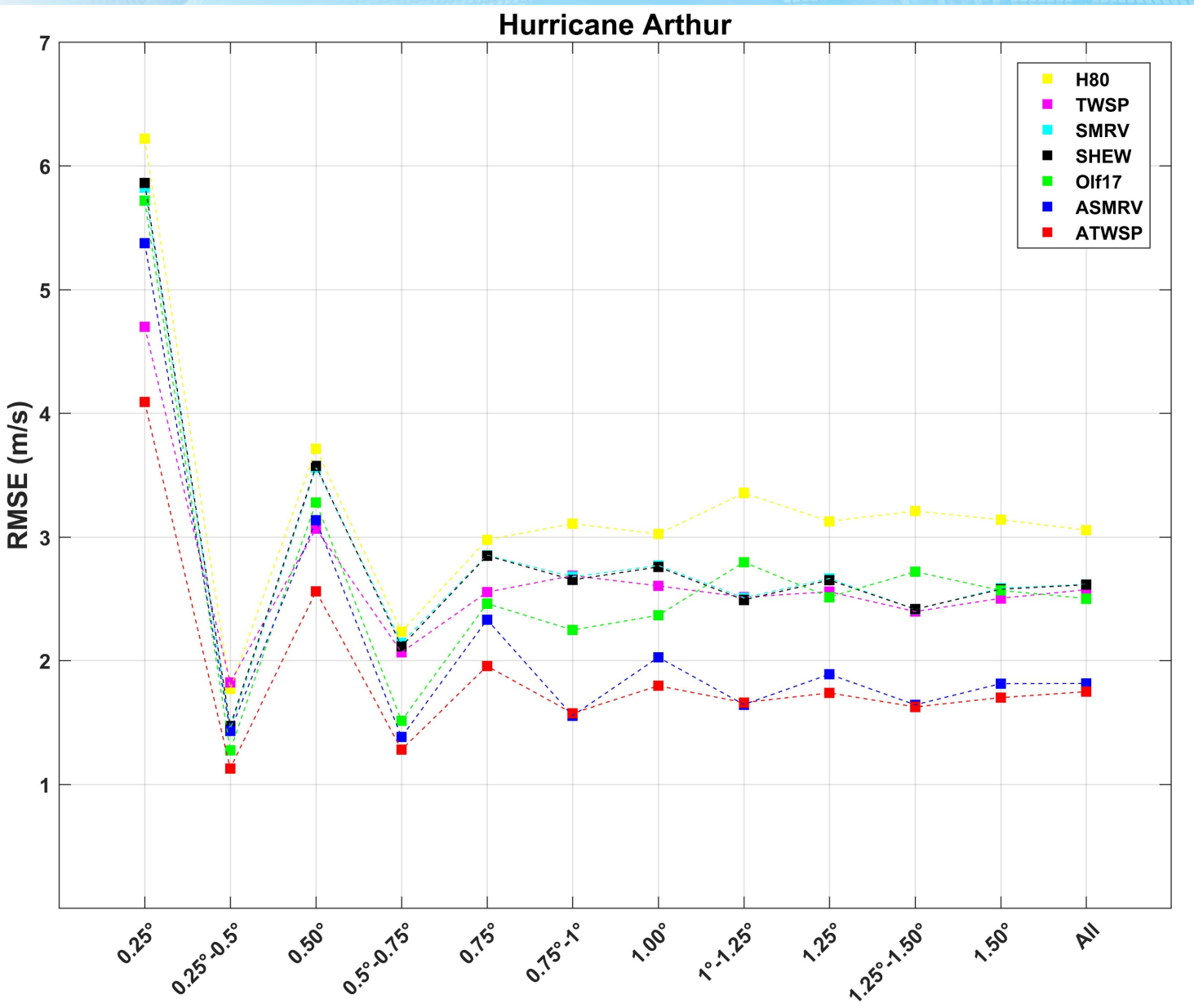








Comparison of wind speed profiles in eight main directions.



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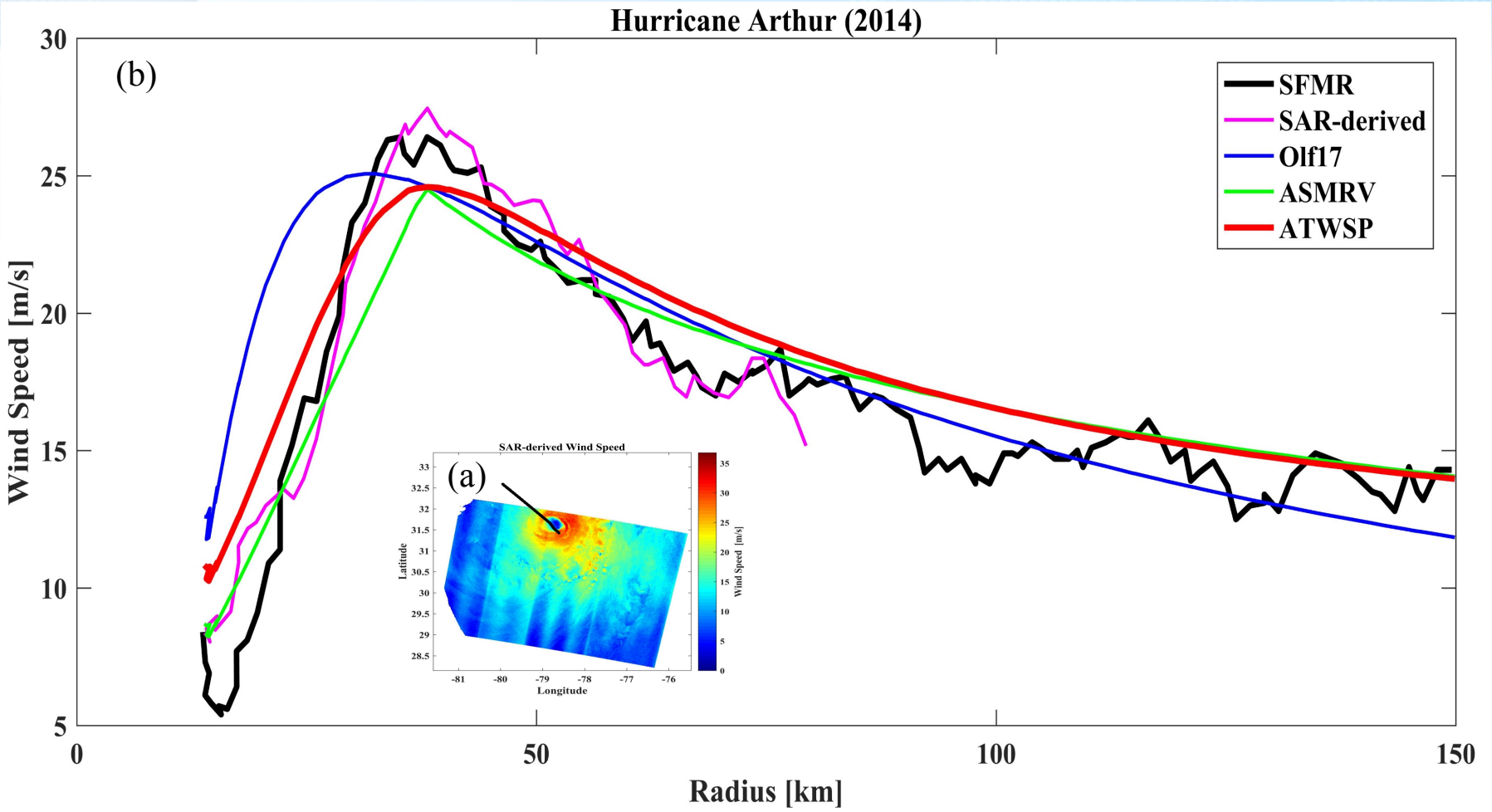
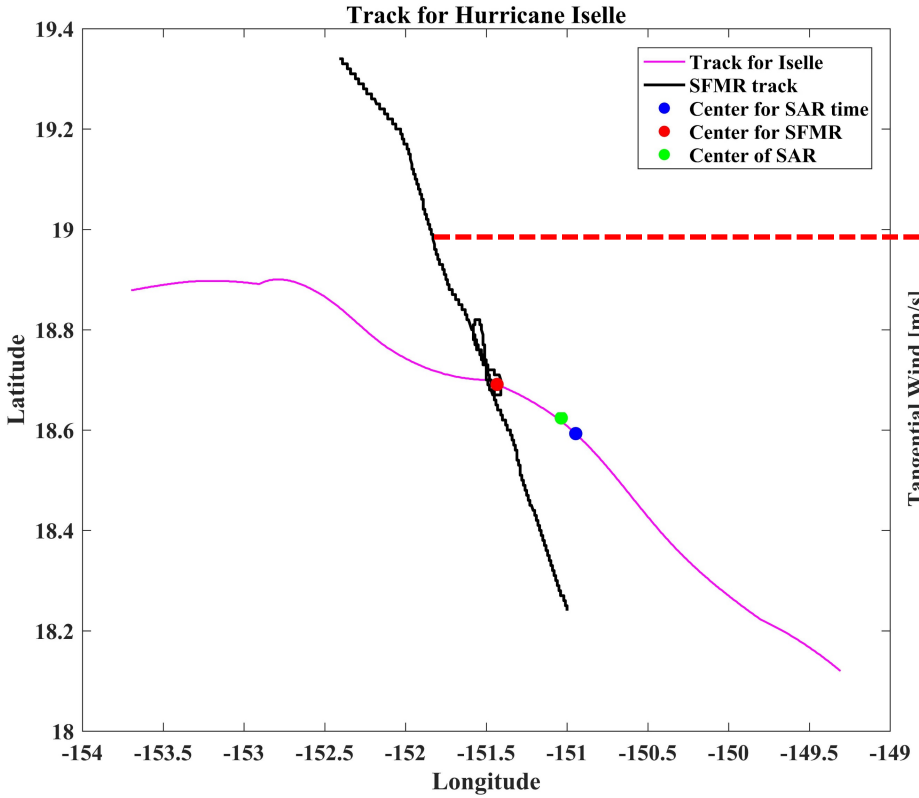
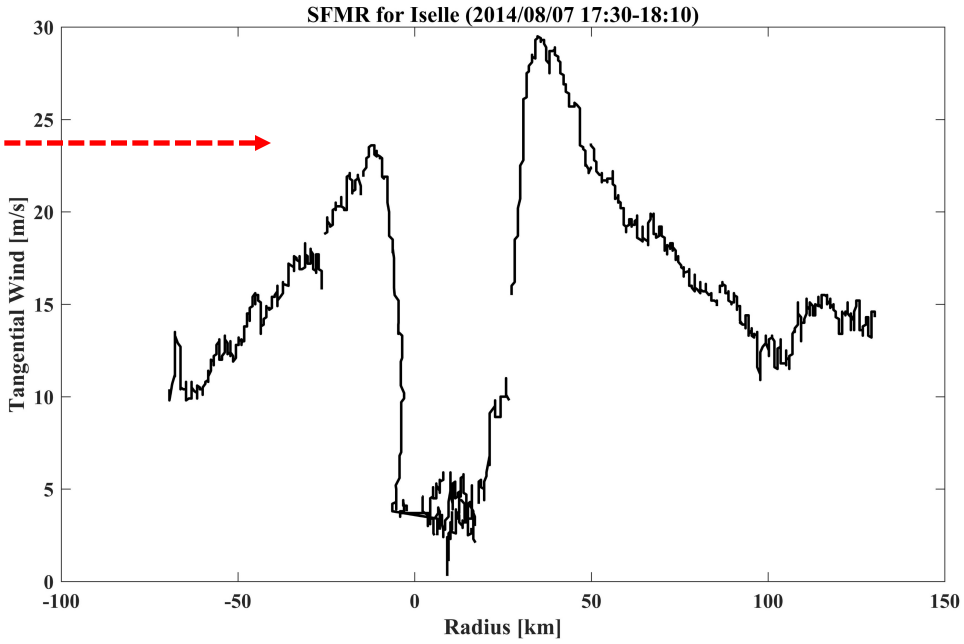
Comparison with SFMR



(a) The flight track of SFMR measurements (11:00 UTC to 11:27 UTC, 3 July 2014).
(b) The comparison of wind speed obtained by SFMR, derived by SAR and simulated by models.

Hurricane Iselle (2014)

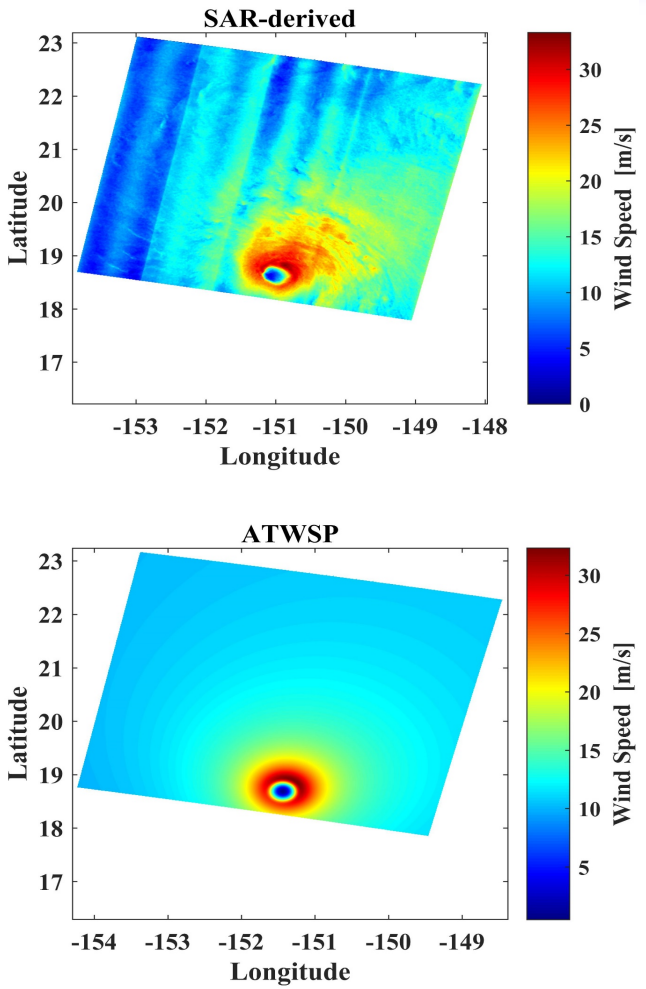




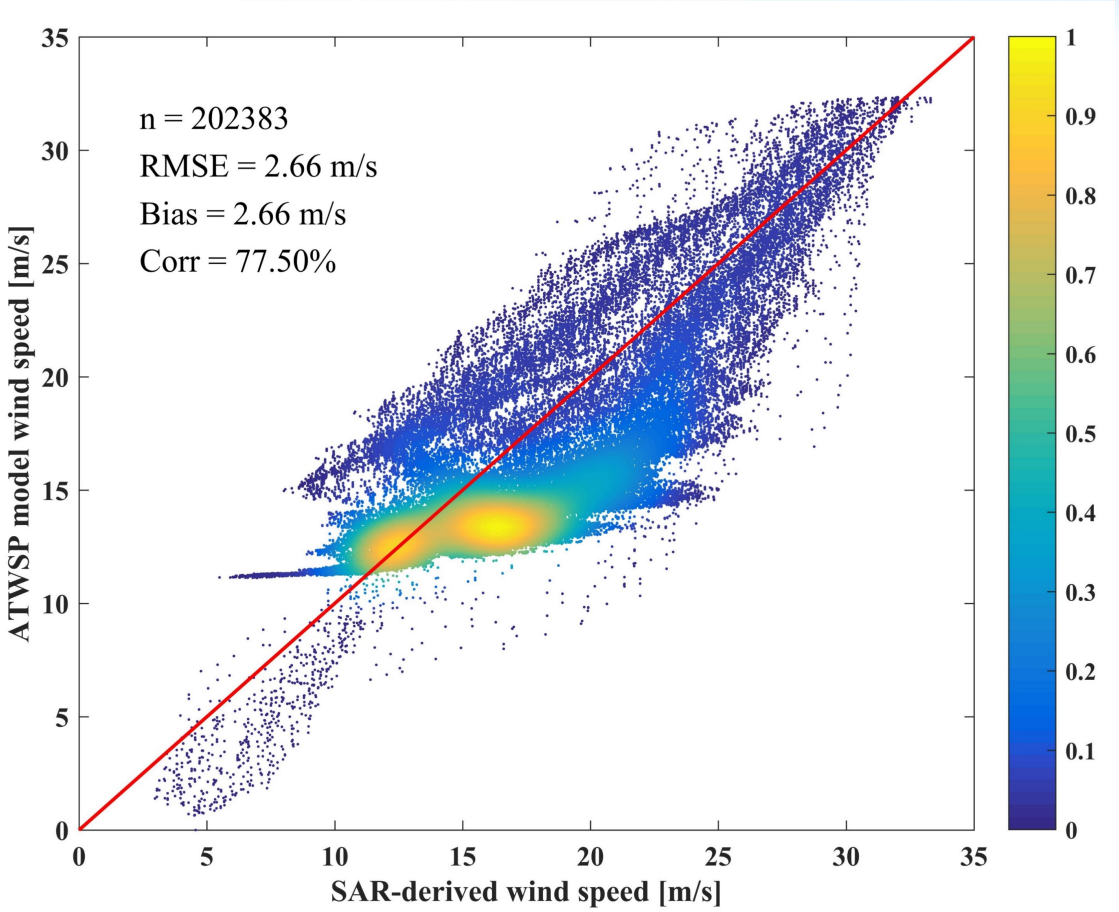
Track of hurricane Iselle (magenta line) and the track for SFMR (multicolor line), the points represent the different center.

Tangential wind profile of SFMR at the closest time to SAR image generation (2014/08/07 UTC 15:58:55)

Hurricane Iselle (2014)



SAR-derived wind speed(top) and the simulated one with ATWSP model(bottom) for hurricane Iselle.



Comparison of wind speed of Iselle derived by SAR and simulated by ATWSP model.

Summary

Preliminary results:

1) 1D TWSP model has good stability and applicability in the area far from the TC center (150-300 km).

2) ATWSP has Less parameters comparing with OHM and Olf17 model, and easy to use. Reconstructing 2-D distribution of wind speed requires only 1-D flight measurements.

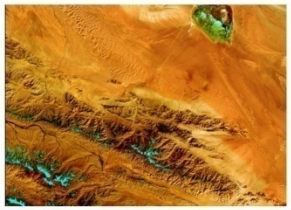
3) For Hurricane Arthur, the RMSE of reconstructed wind speed by ATWSP model is 1.97m/s.

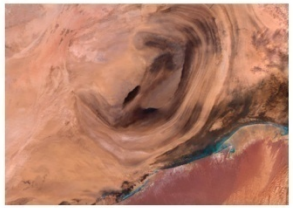
Future work:

1）The effects of parameters (ε and exponent a and b) need to be further investgated.

2）Higher-order Fourier sins in ASF (Asymmetric structure function) requires validation by using more flight measurements.

Thanks!



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