11/20/2024

Ocean Surface Wind Retrieval from ALOS-2/PALSAR-2 and Application Studies Using Synthetic Aperture Radar (SAR) Winds

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Spaceborne Ocean Surface Wind Observations

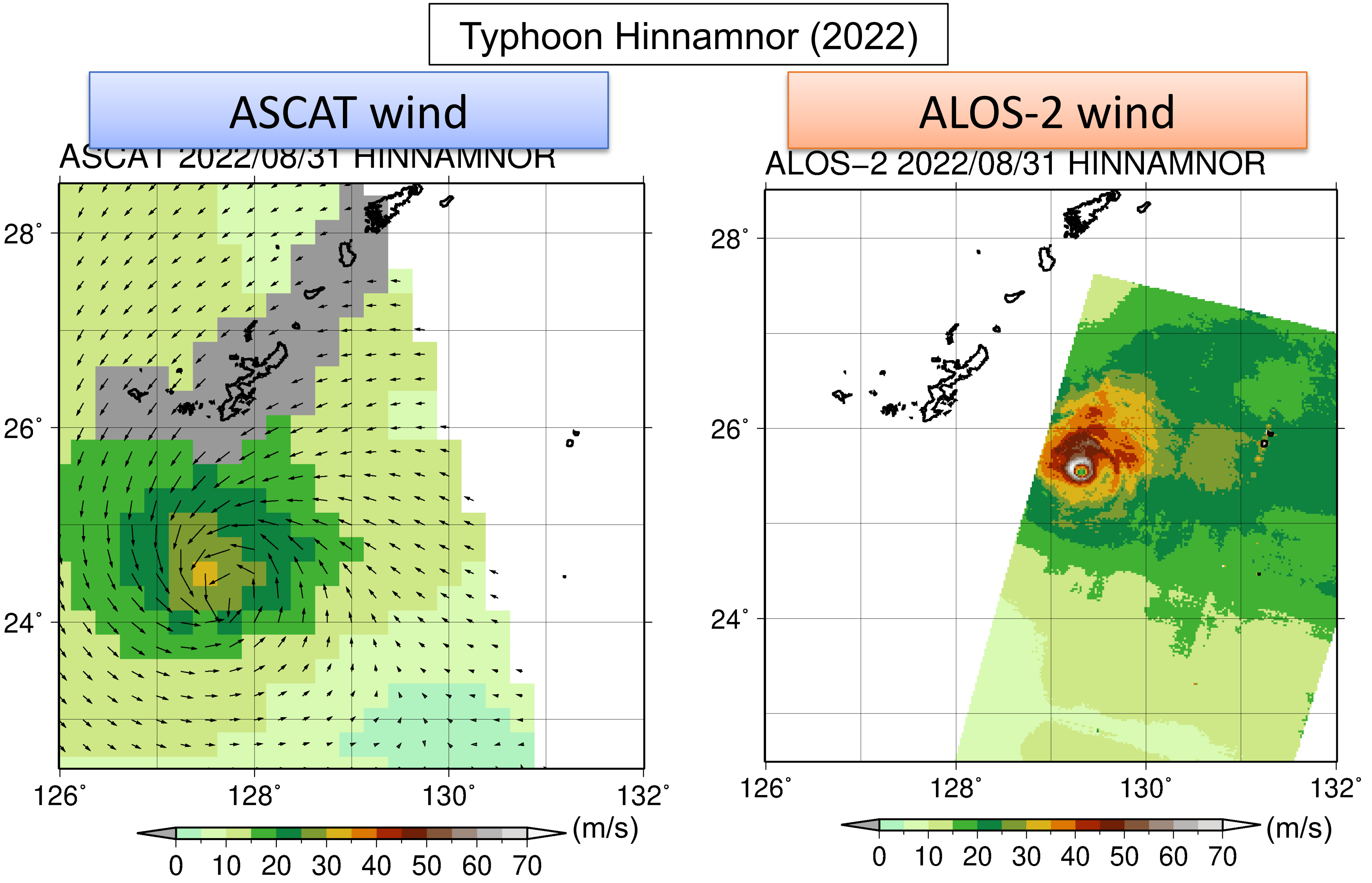
No high-resolution observations of high wind speeds from space before the advent of SAR.
A serious issue of TC-related disaster prevention

Conventional satellite observations:

- Microwave Scatterometer (ASCAT etc.)
  - ✓Saturation above ~20m/s
- Microwave Imager (AMSR2, etc.)
  - ✓Low resolution (50km)
- Microwave Sounder (AMSU, Estimate from a warm core)
  - ✓Low resolution (~20km)
- SMAP, SMOS (L-band Radiometer)
  - ✓Low resolution (40~45km)
- IR Atmospheric Motion Vector (AMV)
  - ✓Poor coverage in the inner core of TCs

Comparison b/w ASCAT and ALOS winds

- Scatterometer (ASCAT) cannot observe high wind speeds (>30m/s) and detailed inner core structure
- ALOS-2 observes a small eye and high wind speeds > 50m/s



ALOS-2/PALSAR-2

- ✓ L-band SAR

- ✓ Orbit (~0300 and 1500 UTC in WNP)

(Local sun time: 12:00±15min in descending pass)

- ✓ Less chance to observe the ocean than C-band SAR satellites because of other main purposes such as monitoring terrestrial areas for landslides, floods, earthquakes, forests, agriculture, etc.

https://www.eorc.jaxa.jp/ALOS/jp/alos-2/a2_about_j.htm

JAXA RESTEC

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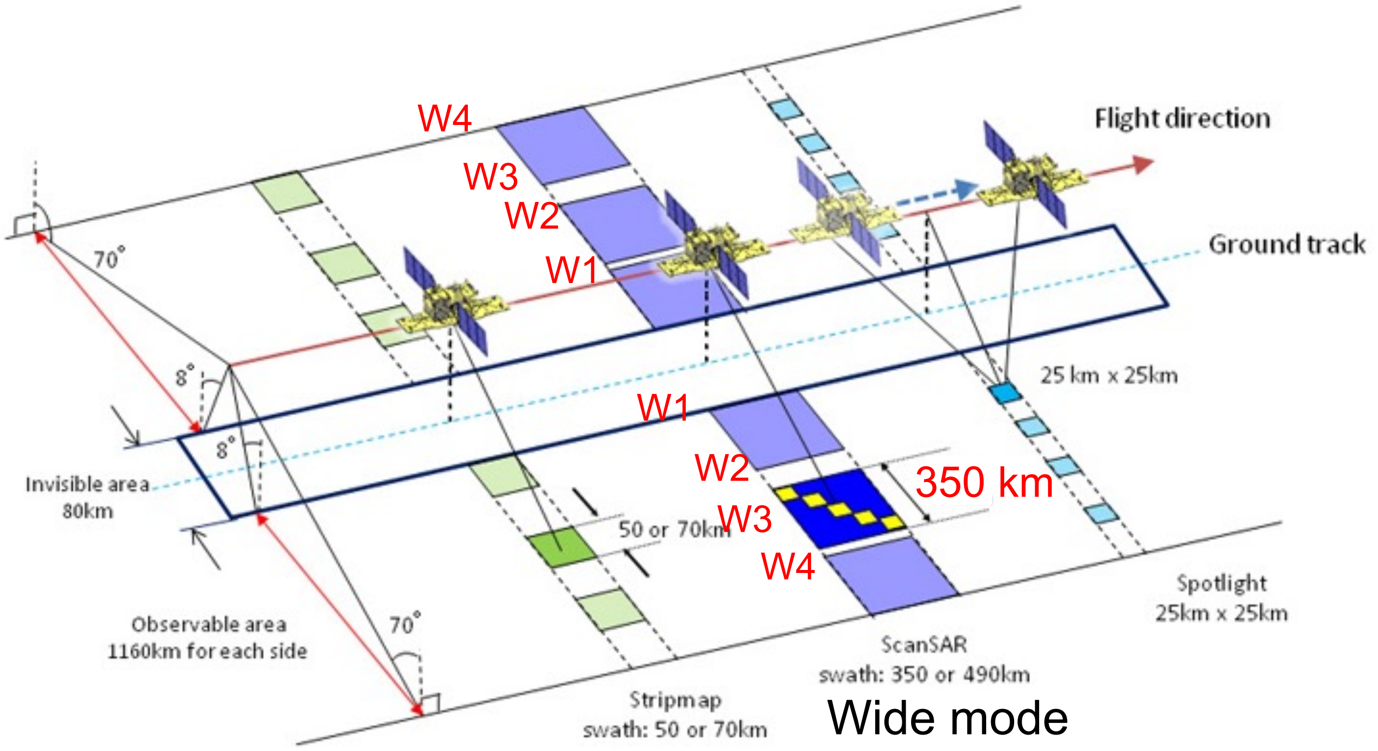


ALOS-2 Wind Retrieval Project Since 2019

■Members

- Researchers from MRI/JMA, JAXA/EORC, and RESTEC
- In collaboration with researchers from IFREMER

■Action items

Product development (JAXA, JMA)

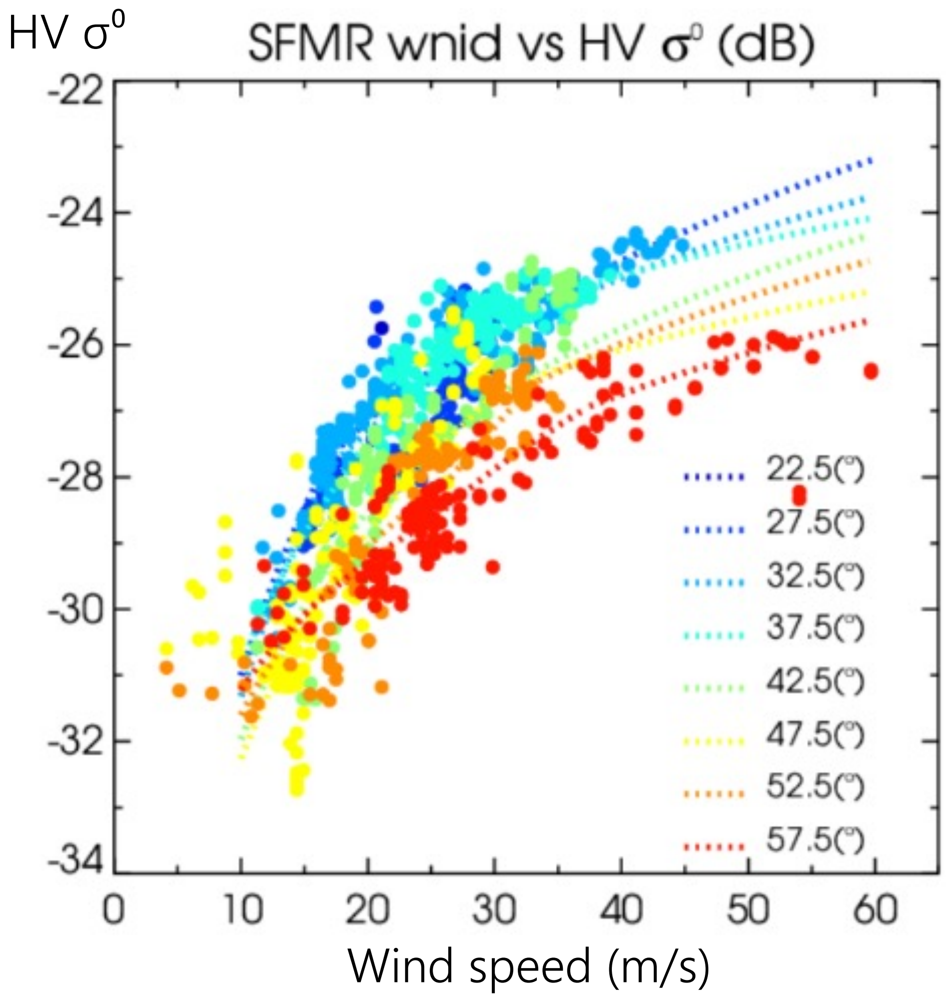
- Collect match-ups between ALOS and aircraft observations
- Develop an ALOS wind product

Application studies (JMA, JAXA)

- Compare between ALOS winds and AMVs, best track Vmax, etc.
- Develop a method for wind structure estimation using SAR winds as a training dataset
- Validate numerical model winds
- Develop a correction method for numerical model winds
- Data assimilation

Product Development (by JAXA & RESTEC)

- Make match-ups between PALSAR-2 HV σ⁰ and SFMR surface winds
- Develop Geophysical Model Functions (GMFs)
- Retrieve ocean surface winds using the GMFs
- Validate retrieved ALOS winds



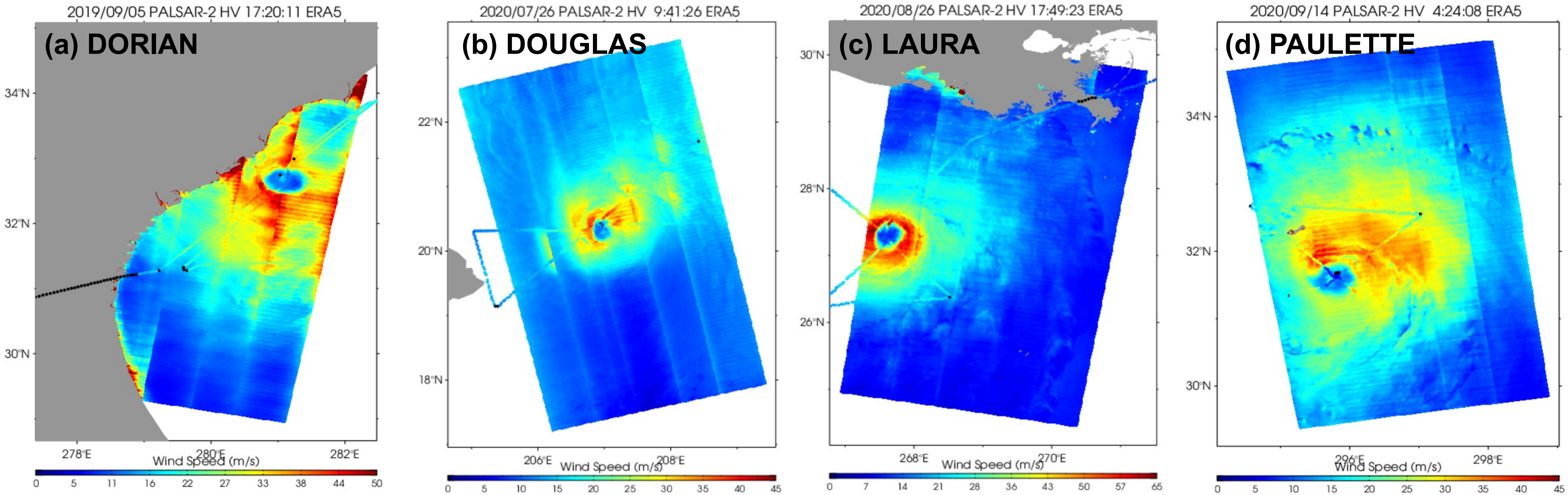
For more detail, refer to Isoguchi et al. 2021:

Isoguchi. O., T. Tadono, M. Ohki, U. Shimada, M. Yamaguchi, M. Hayashi, and W. Yanase, 2021: Hurricane ocean surface winds retrieval from ALOS-2 PALSAR-2 cross-polarized measurements. IEEE International Geoscience and Remote Sensing Symposium IGARSS, Brussels, Belgium, 7291-7294, doi:10.1109/IGARSS47720.2021.9554411.

ALOS-2 Winds (by JAXA & RESTEC)

✓ Confirm the capability of high wind speed retrieval up to 55 m/s

Colors: Ocean wind speed estimations by HV σ⁰ of ALOS-2/PALSAR-2
Colored lines: SFMR measurements.



50m/s 45m/s 65m/s 45m/s

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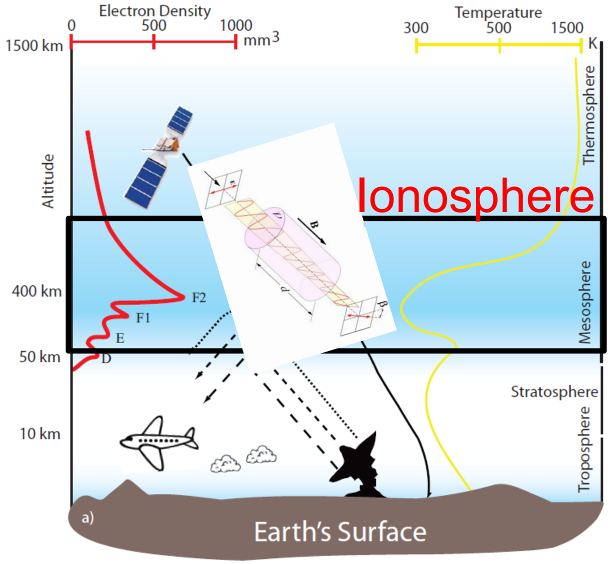
Plans for Product Development (by JAXA & RESTEC)

ALOS-2 wind retrieval

- Radiometric correction
  - ✓ More match-up data are needed for a radiometric correction for W1~W3 modes
  - ✓ Corrections for RFI (Radio Frequency Interference), NESZ (Noise Equivalent Sigma Zero), Faraday rotation in the ionosphere, and rain attenuation

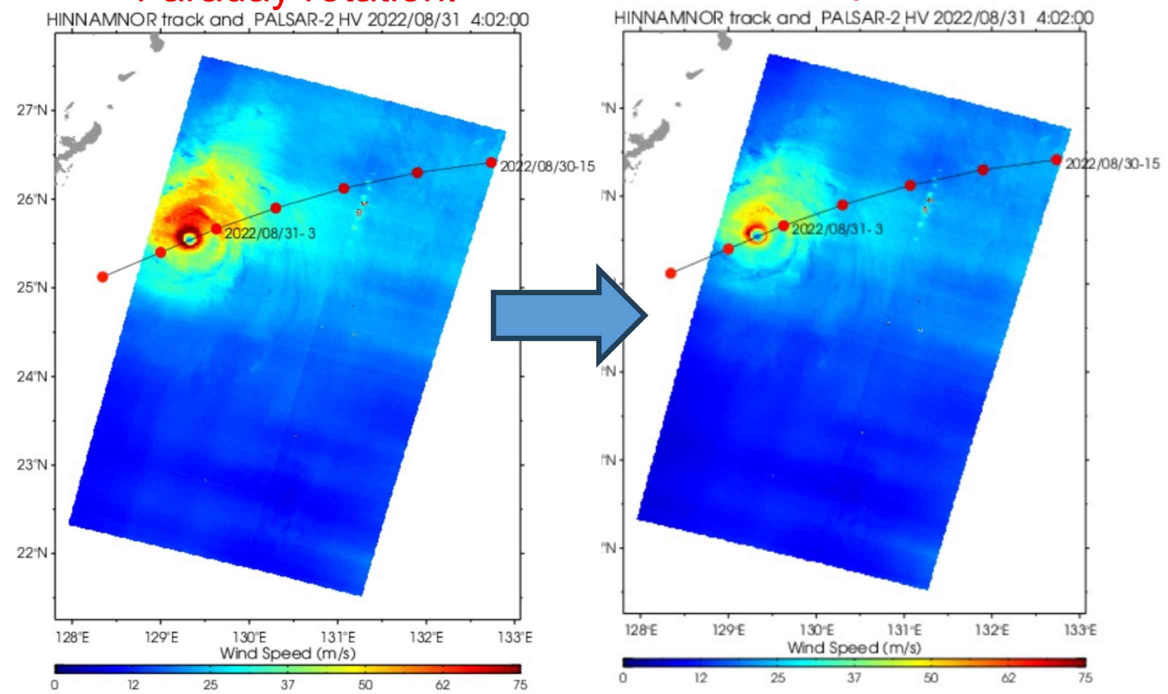
- Use of HH and HV data (dual-pol data)
  - ✓ Wind vector retrieval



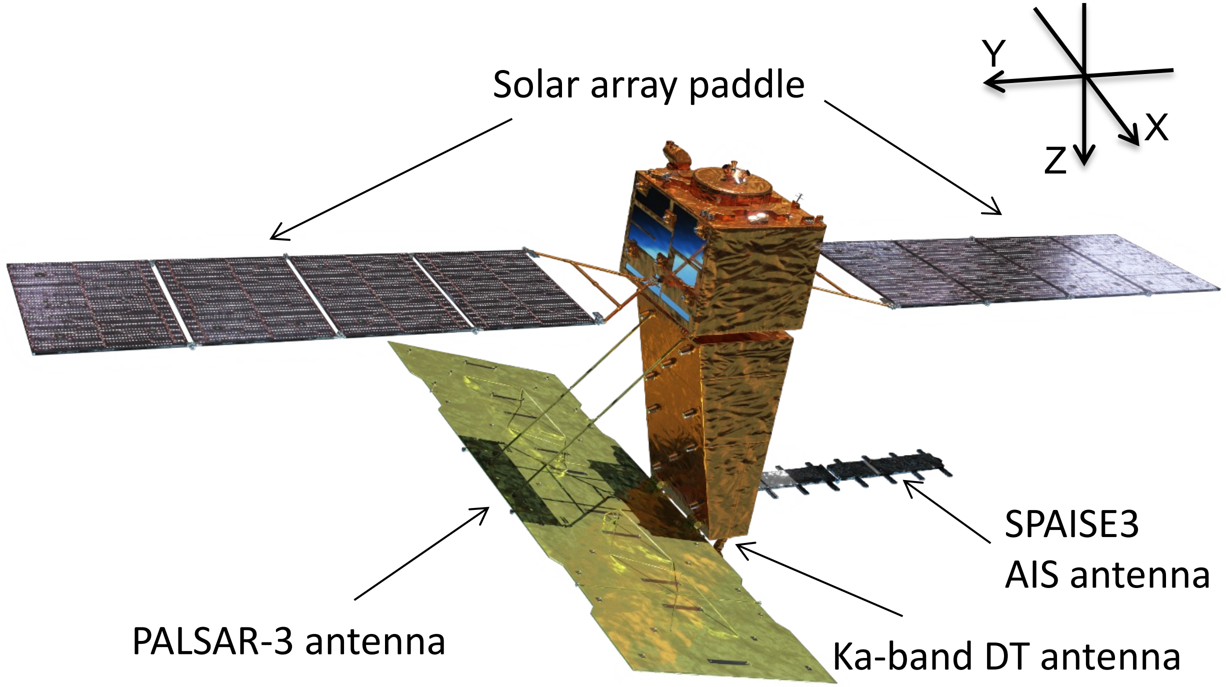
Michael Jehle (2009),'Estimation of Path Delays, TEC and Faraday Rotation from SAR Data'

No correction of Faraday rotation.

Correction of Faraday rotation.



ALOS-4 Overview



Swath width of PALSAR-3/-2

Modes	PALSAR-3	PALSAR-2
Stripmap (res. 3 / 6 / 10 m)	100-200 km	30-70 km
ScanSAR (res. 25m*)	700 km	350-490 km
Spotlight (res. 1 x 3 m)	35km × 35km	25km × 25km

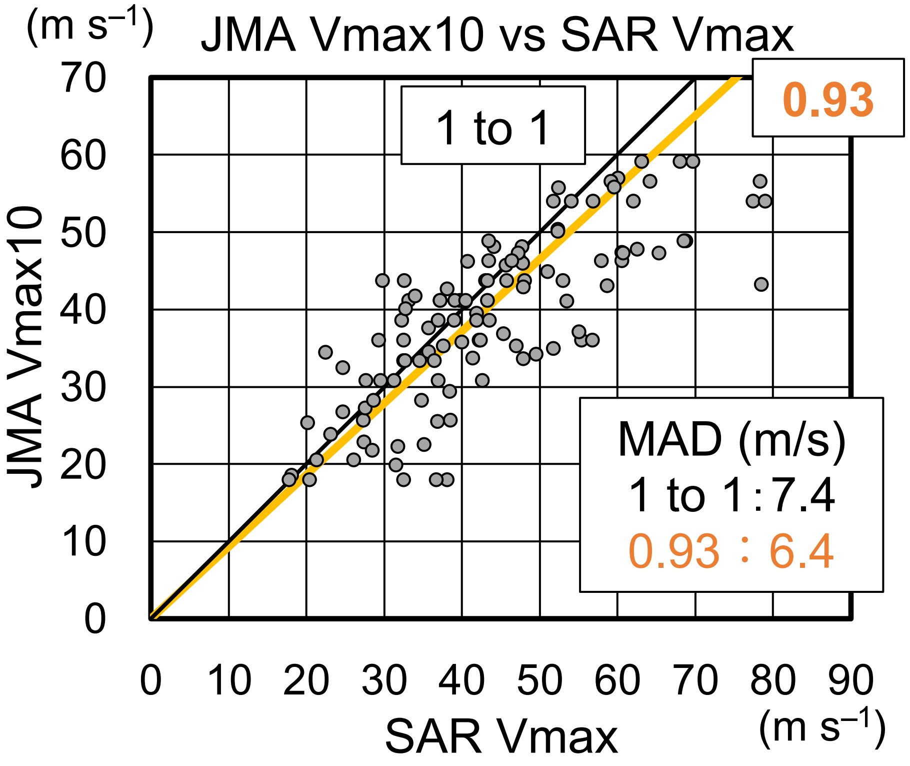
Launch	**July 1, 2024 at 12:06 JST**
Orbit	**Same orbit as ALOS-2** ✓ Sun-synchronous sub-recurrent orbit ✓ Altitude: 628 km ✓ Inclination angle: 97.9 degree ✓ Local sun time at descending: 12:00 ± 15 min. ✓ Revisit time: **14 days** (15-3/14 rev/day)
Lifetime	**7 years**
Size	X 10.0 m x Y 20.0 m x Z 6.4 m
Satellite Mass	~2,990 kg
Downlink	**1.8 / 3.6 Gbps (Ka-band)**
Mission Instruments	- **PALSAR-3** (Phased Array type L-band Synthetic Aperture Radar-3) - **SPAISE3** (SPace based AIS Experiment 3)

Application Studies (by JMA)

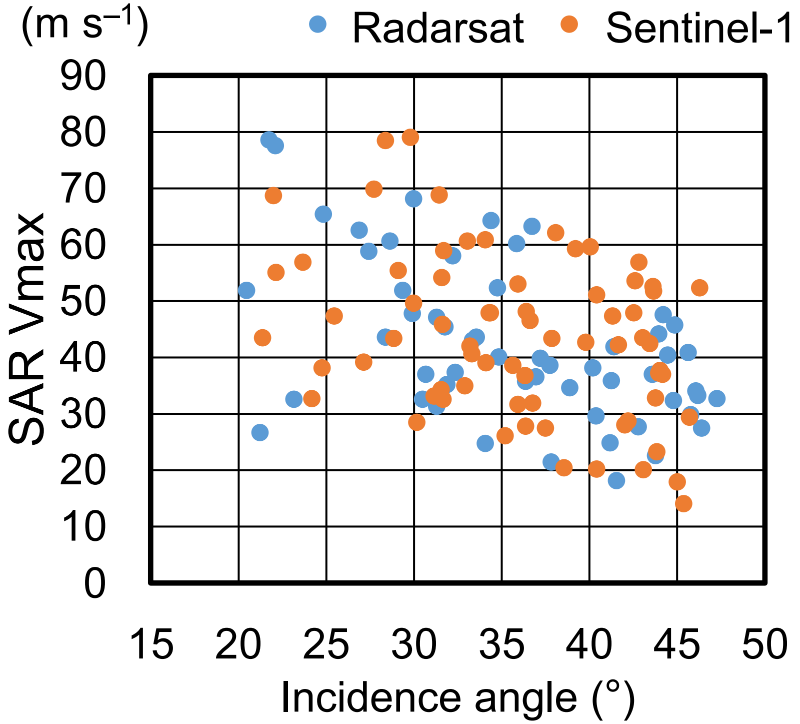
- Examine how to convert SAR Vmax to 10-min Vmax consistent with JMA's Vmax
- Develop an estimation method for the RMW
  - ✓ Use C-band SAR wind data (from Cyclobs or NOAA STAR)
  - ✓ Horizontal resolution: 3 km
  - ✓ Assume SAR winds as 1-min sustained wind speed
- Experiment of SAR wind assimilation

Comparison of SAR Vmax with JMA's 10-min Vmax (by SHIMADA)

- ✓ SAR Vmax: 99th percentile of SAR wind speeds within 200 km of the center.
- ✓ SAR Vmax is not consistent with JMA's 10-min Vmax (Vmax10)
- ✓ Need to correct an incidence-angle-dependent bias
- ✓ Use Dvorak tables to convert 1-min to 10-min Vmax



Incidence-angle-dependent bias

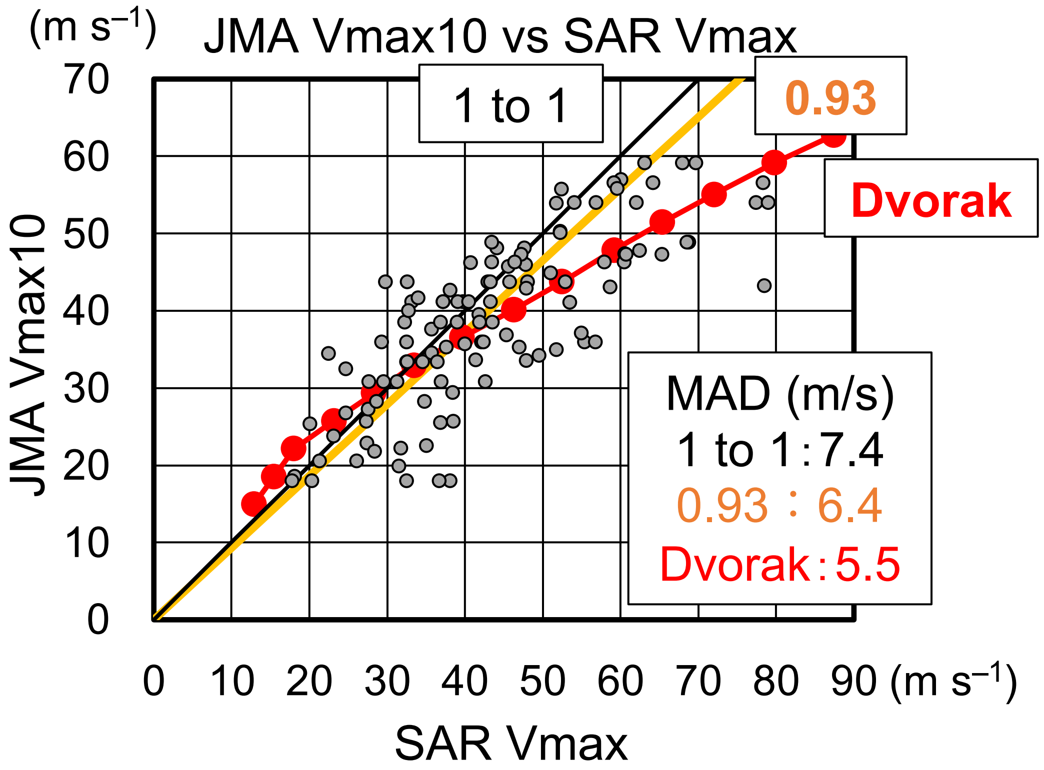


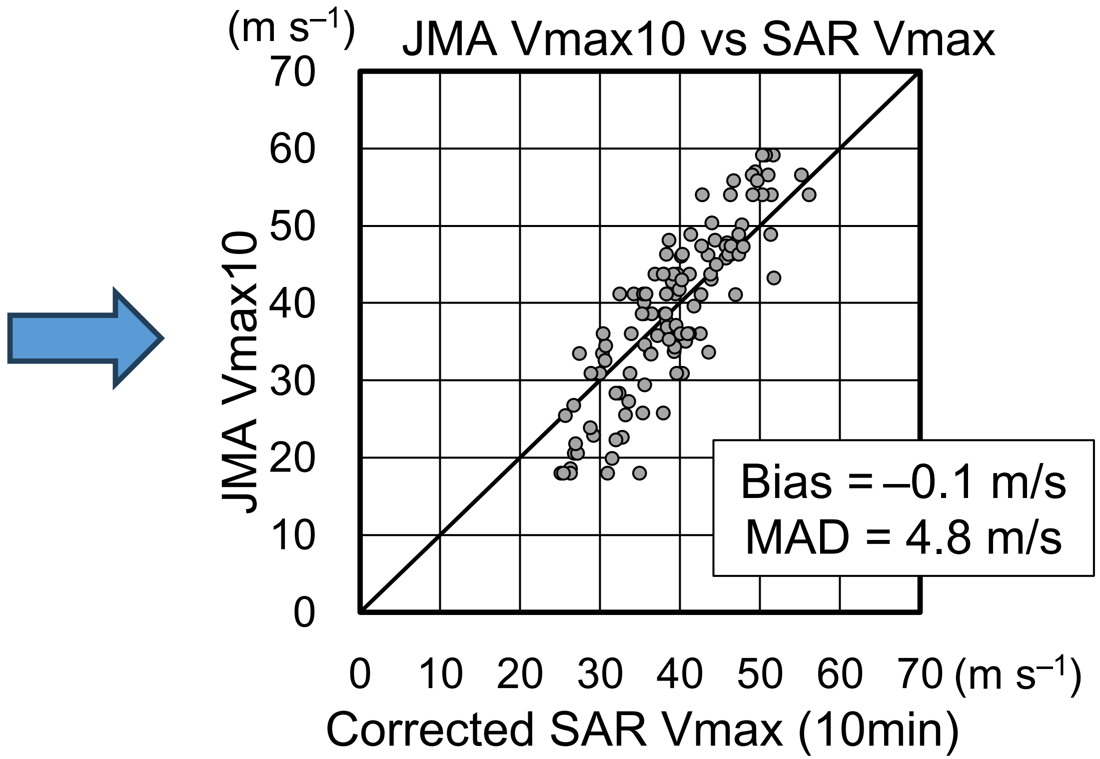
Dvorak conversion table

CI num.	Vmax10 (kt) (JMA)	Vmax (kt) (JTWC)
2.0	36	30
2.5	43	35
3.0	50	45
3.5	57	55
4.0	64	65
4.5	71	77
5.0	78	90
5.5	85	102
6.0	93	115
6.5	100	127
7.0	107	140
7.5	115	155
8.0	122	170

Comparison of SAR Vmax with JMA's 10-min Vmax (by SHIMADA)

- ✓ SAR Vmax: 99th percentile of SAR wind speeds within 200 km of the center.
- ✓ Use Dvorak tables to convert 1-min to 10-min wind speed and correct an incidence-angle-dependent bias using a first order term.
- ✓ Negative biases for intensifying weak TCs and positive biases for mature TCs.





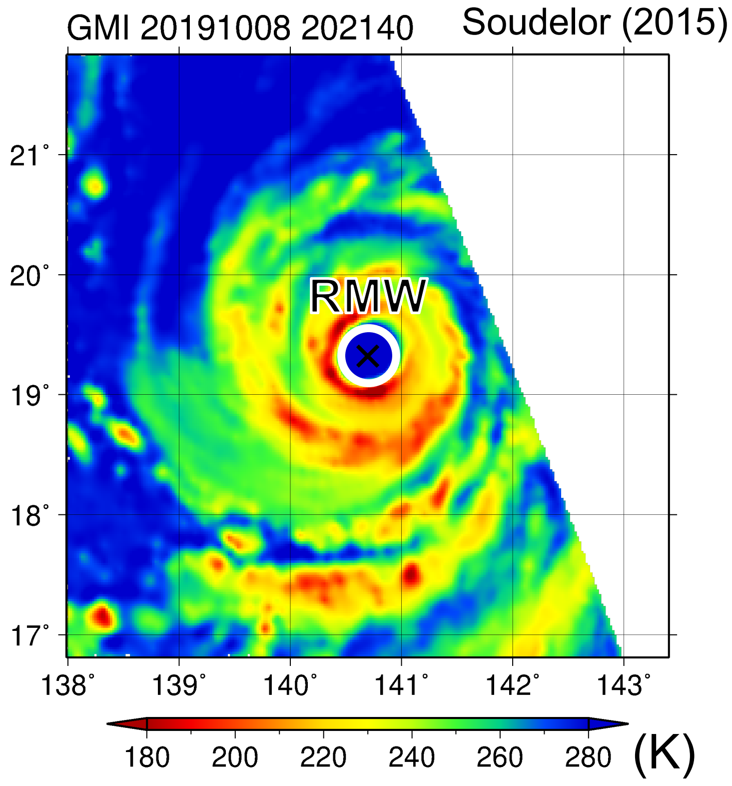
Shimada, U., M. Hayashi, and A. Mouche, 2024: A comparison between SAR wind speeds and western North Pacific tropical cyclone best track estimates. *J. Meteor. Soc. Japan*, **102**, 575-593.

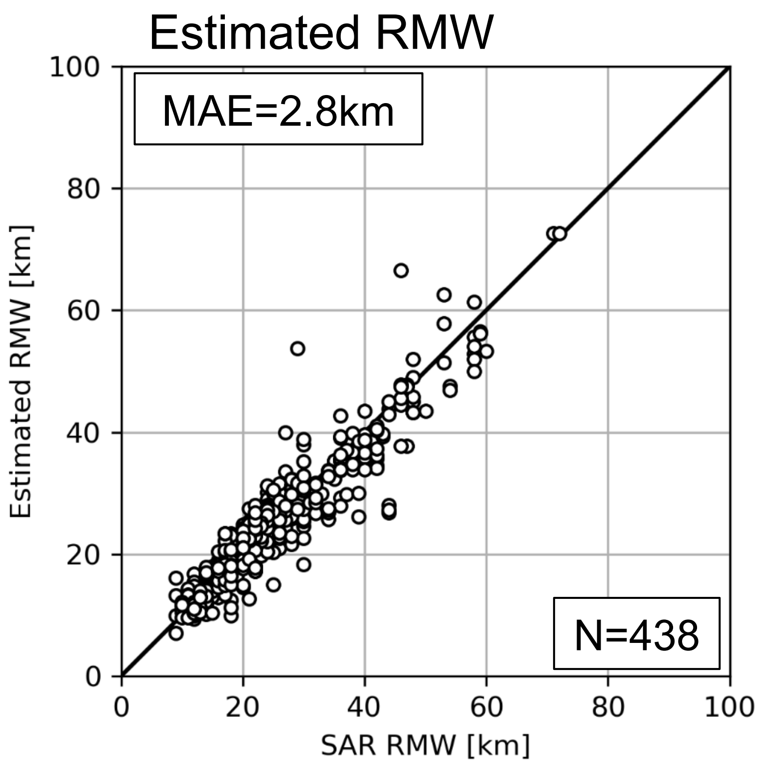
JAXA RESTEC

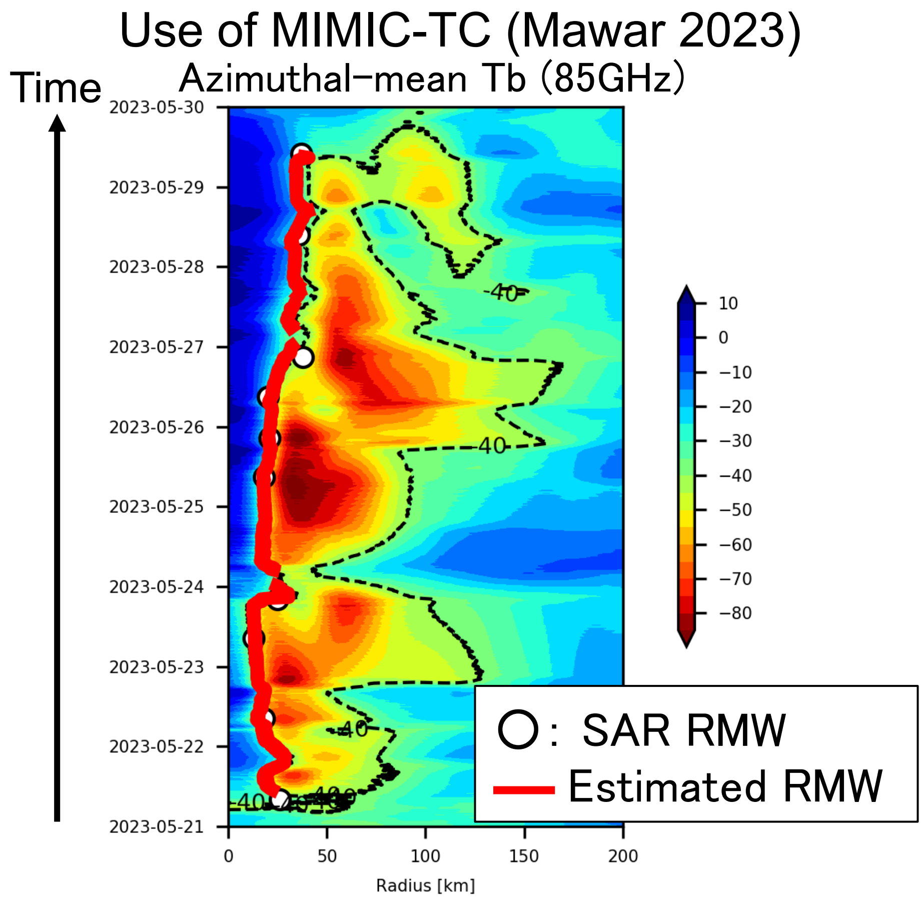
RMW Estimation Using Microwave Satellite Data (by SHIMADA)

Method: Regression between RMW and Reye.
Reye = −40℃ radius of azimuthal mean 89GHz Tb.

$$RMW=0.70*Reye+4.63$$

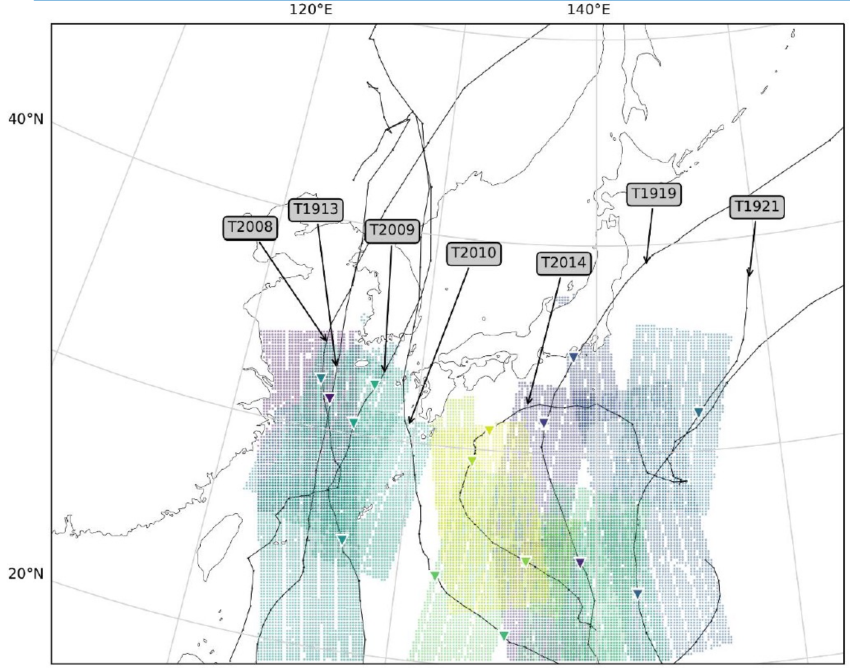






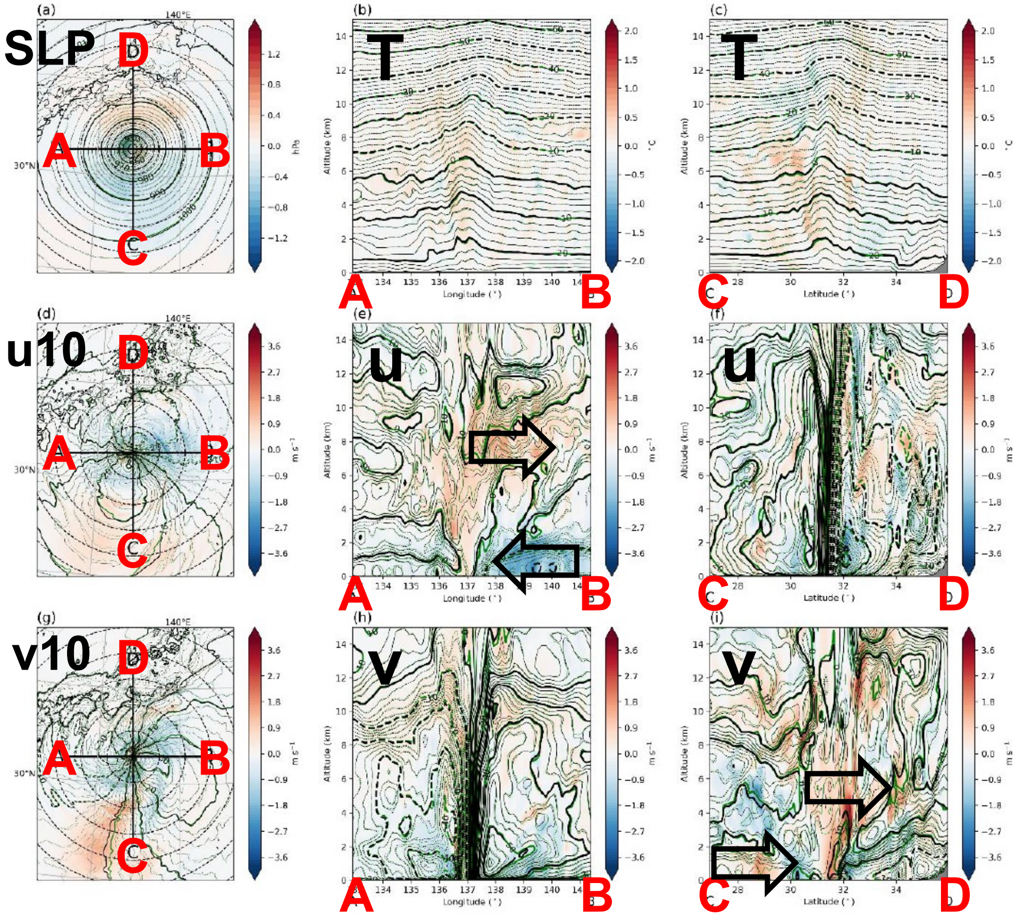
C-band SAR Assimilation (by IKUTA)

✓Examine the impact of C-band SAR assimilation by the JMA's regional 4D-Var system.
✓Confirm positive effects on analyses and forecasts.



Color dots: Assimilated SAR wind speeds

▼ T1913, 1200UTC 06 SEP 2019, 960 hPa, 40 m s^{-1}
▼ T1919, 0900UTC 10 OCT 2019, 915 hPa, 55 m s^{-1}
▼ T1919, 2100UTC 11 OCT 2019, 945 hPa, 45 m s^{-1}
▼ T1919, 0900UTC 12 OCT 2019, 955 hPa, 40 m s^{-1}
▼ T1921, 0900UTC 23 OCT 2019, 940 hPa, 50 m s^{-1}
▼ T1921, 2100UTC 24 OCT 2019, 975 hPa, 35 m s^{-1}
▼ T2008, 0000UTC 26 AUG 2020, 950 hPa, 45 m s^{-1}
▼ T2009, 1200UTC 31 AUG 2020, 950 hPa, 45 m s^{-1}
▼ T2009, 0000UTC 02 SEP 2020, 945 hPa, 45 m s^{-1}
▼ T2009, 0900UTC 02 SEP 2020, 950 hPa, 40 m s^{-1}
▼ T2010, 2100UTC 03 SEP 2020, 925 hPa, 50 m s^{-1}
▼ T2010, 0000UTC 05 SEP 2020, 915 hPa, 50 m s^{-1}
▼ T2014, 2100UTC 06 OCT 2020, 980 hPa, 30 m s^{-1}
▼ T2014, 1200UTC 08 OCT 2020, 965 hPa, 35 m s^{-1}
▼ T2014, 1200UTC 09 OCT 2020, 980 hPa, 30 m s^{-1}



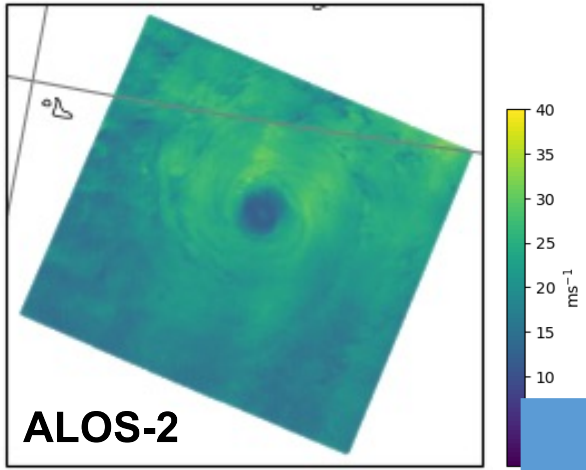
Colors:
Analysis increments

✓The assimilation modified not only the low-level inflow, but also the upper outflow.
✓The SAR assimilation effect propagated from the surface to the upper troposphere.

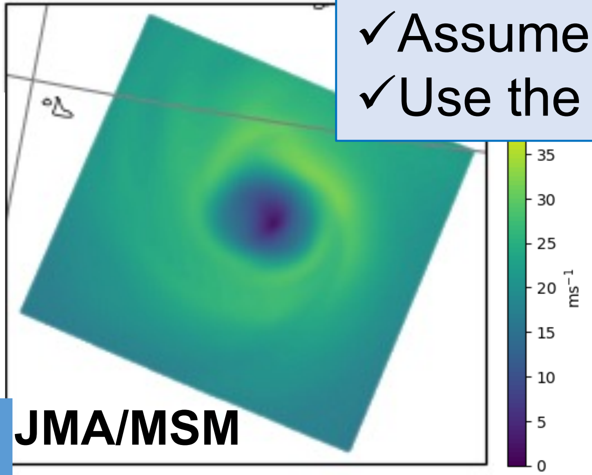
Ikuta, Y., and U. Shimada, 2024: Impact of Assimilation of the Tropical Cyclone Strong Winds Observed by Synthetic Aperture Radar on Analyses and Forecasts. *Mon. Wea. Rev.*, **152**, 1007-1025.

ALOS-2 Wind Assimilation (by IKUTA)

Obs: 07/21/2021 0400UTC



ALOS-2



JMA/MSM

Case study of Typhoon IN-FA (2021)

✓Assume an observation error of 1.8 m/s and no bias correction

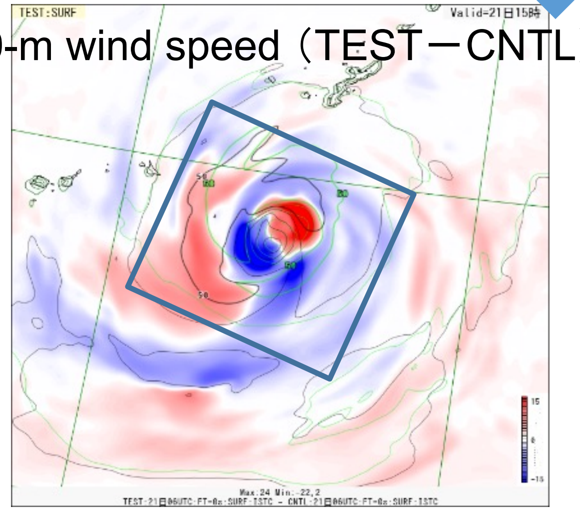
✓Use the JMA's regional data assimilation system (4D-Var)

Data assimilation

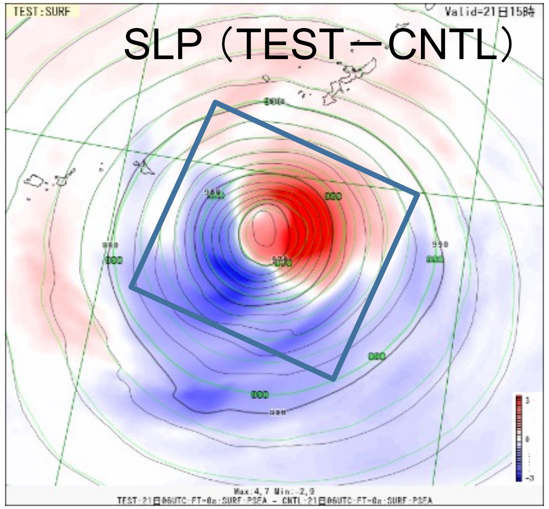
CNTL：no SAR assimilation

TEST：SAR assimilation

10-m wind speed（TEST－CNTL）

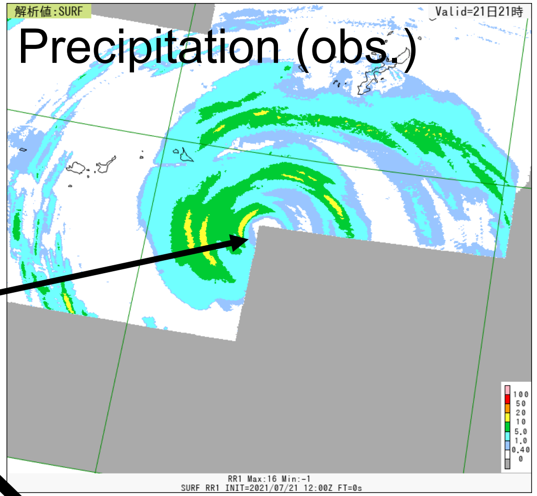


SLP（TEST－CNTL）



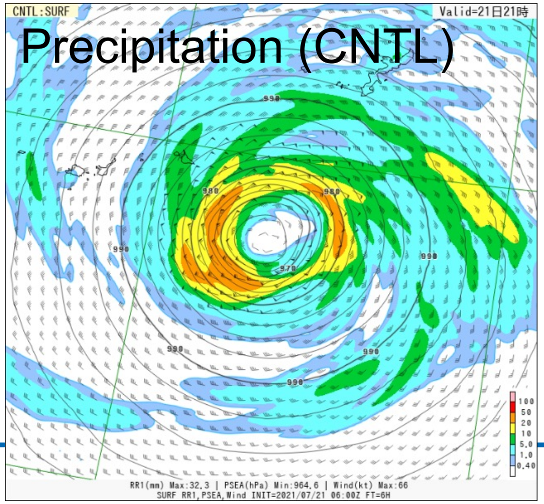
Initial time:
07/21/2021 0600UTC
Forecast time: 6 hour

Precipitation (obs.)

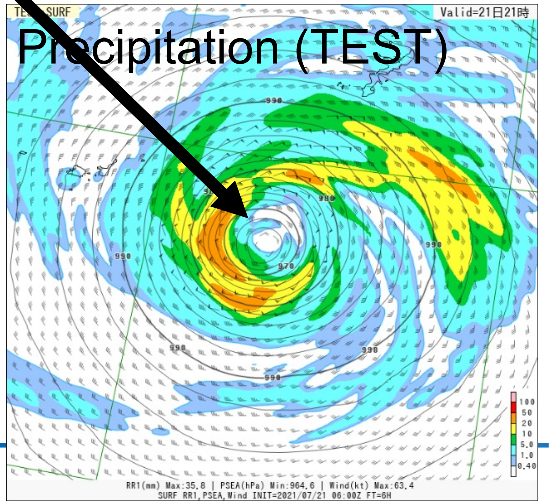


A remnant of an inner eyewall is reproduced.

Precipitation (CNTL)



Precipitation (TEST)



Future Plans

■"ALOS winds" product development

- Improve GMFs by further collecting match-ups between ALOS and SFMR observations
- Improve the quality of ALOS winds
- Distribute ALOS wind products on a public ALOS website in near future
- Observe ocean waves with high spatial resolution
- Collaborate with T-PARCII (PI: Prof. Tsuboki)

■Application studies

- Develop an estimation method for wind structure parameters using SAR wind speeds as a training dataset
- Develop a correction method for numerical model wind speeds
- Data assimilation
- Study the dependence of sea surface roughness on ocean waves

Thank you for your attention.