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High-resolution simulations and aircraft observations of typhoons for future typhoon disaster prevention

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- Violent wind and heavy rainfall associated with a typhoon cause huge disaster in East Asia including Japan.
- Previous researches indicate that tropical cyclones are intensifying with the climate change.
- This raised great concern regarding the following two problems. One is how intense tropical cyclones will become in the future warming climate. The other is how far to the north intense typhoons will reach in the future.
- For future typhoon disaster prevention, accurate estimation and prediction of typhoon intensity are very important.
- However, intensity data of the intense typhoon category such as supertyphoon have large error after the US aircraft reconnaissance was terminated in 1987.
- Intensity prediction of typhoon also has not been improved sufficiently for the last few decades.
- To improve these problems, in situ observations of typhoon using an aircraft are indispensable.
- The main objective of the **T-PARCII** (Tropical cyclone-Pacific Asian Research Campaign for Improvement of Intensity estimations/forecasts) project is improvements of typhoon intensity estimations and forecasts.

Typhoons are the most devastating weather system.
Violent wind and heavy rainfall associated with a typhoon cause huge disaster in East Asia including Japan.

Payment of insurance due to disasters in Japan

No.	Disaster	Region	Year/Month	10^8\
1	**TY #19**	All Japan	Sept. 1991	5,680
2	**TY #18**	All Japan	Sept. 2004	3,874
3	snowstorm	Kanto	Feb. 2014	3,224
4	**TY #18**	Kyushu, W. J.	Sept. 1999	3,147
5	**TY #7**	Kinki	Sept. 1998	1,599
6	**TY #15**	Kyushu	Aug. 2015	1,410
7	**TY #23**	Western Japan	Oct. 2004	1,380
8	**TY #13**	N. Kyushu	Sept. 2006	1,320
9	**TY #16**	All Japan	Aug. 2004	1,210
10	**TY #15**	Shizuoka	Sept. 2011	1,123

From The General Insurance Association of Japan
http://www.sonpo.or.jp/archive/statistics/disaster/

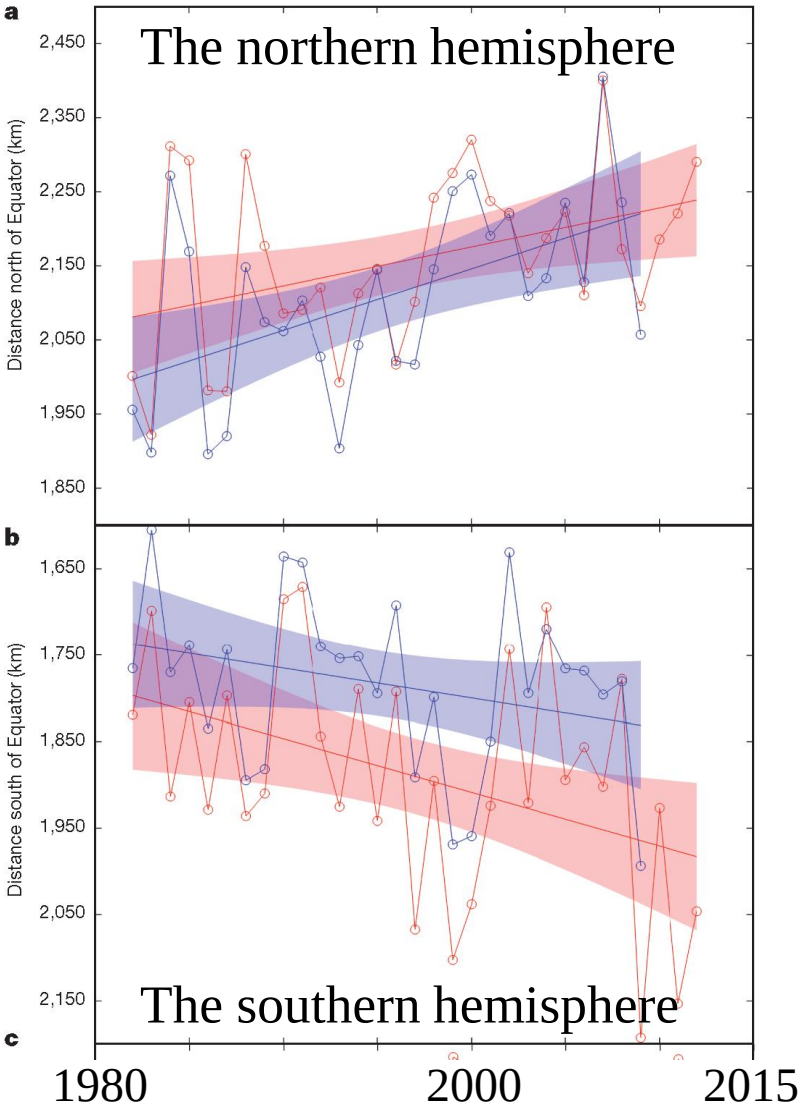
Typhoons are still the largest cause of natural disaster in Japan.

Flooding Kinu River on Sept. 20, 2015

A disaster of Japan in the present climate

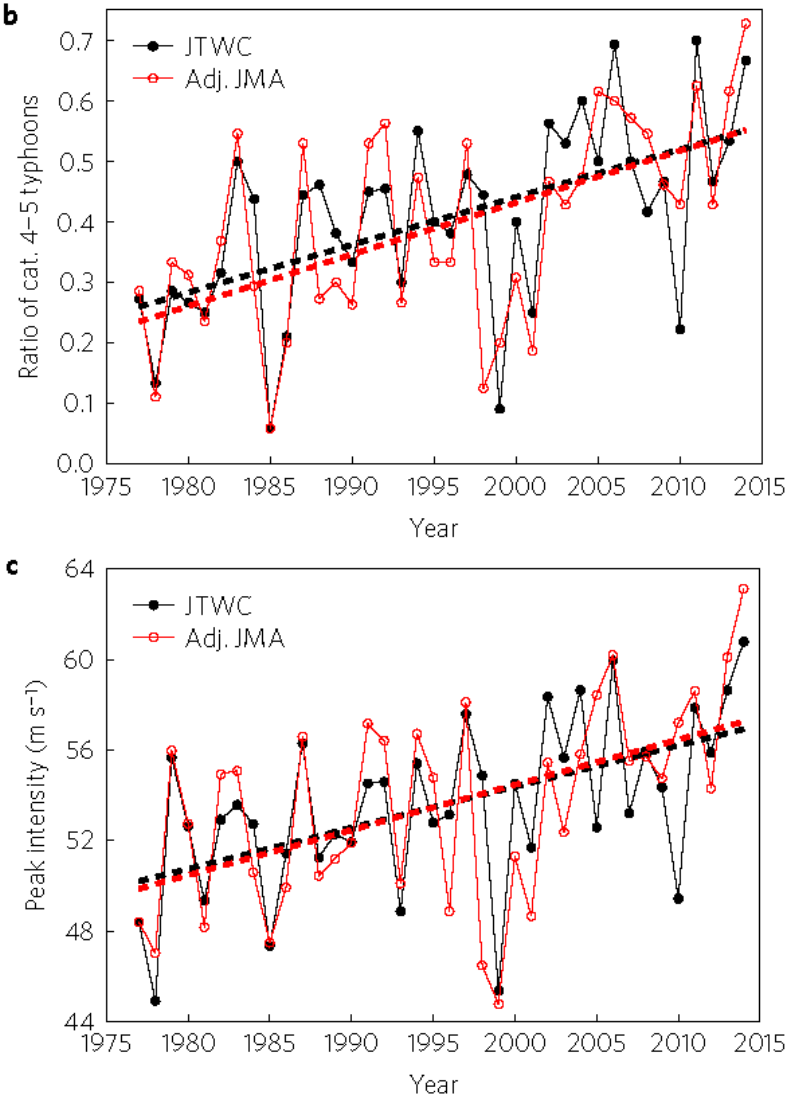
Increase of typhoon risk in mid-latitude regions

The location of typhoon maximum intensity is migrating northward with time.



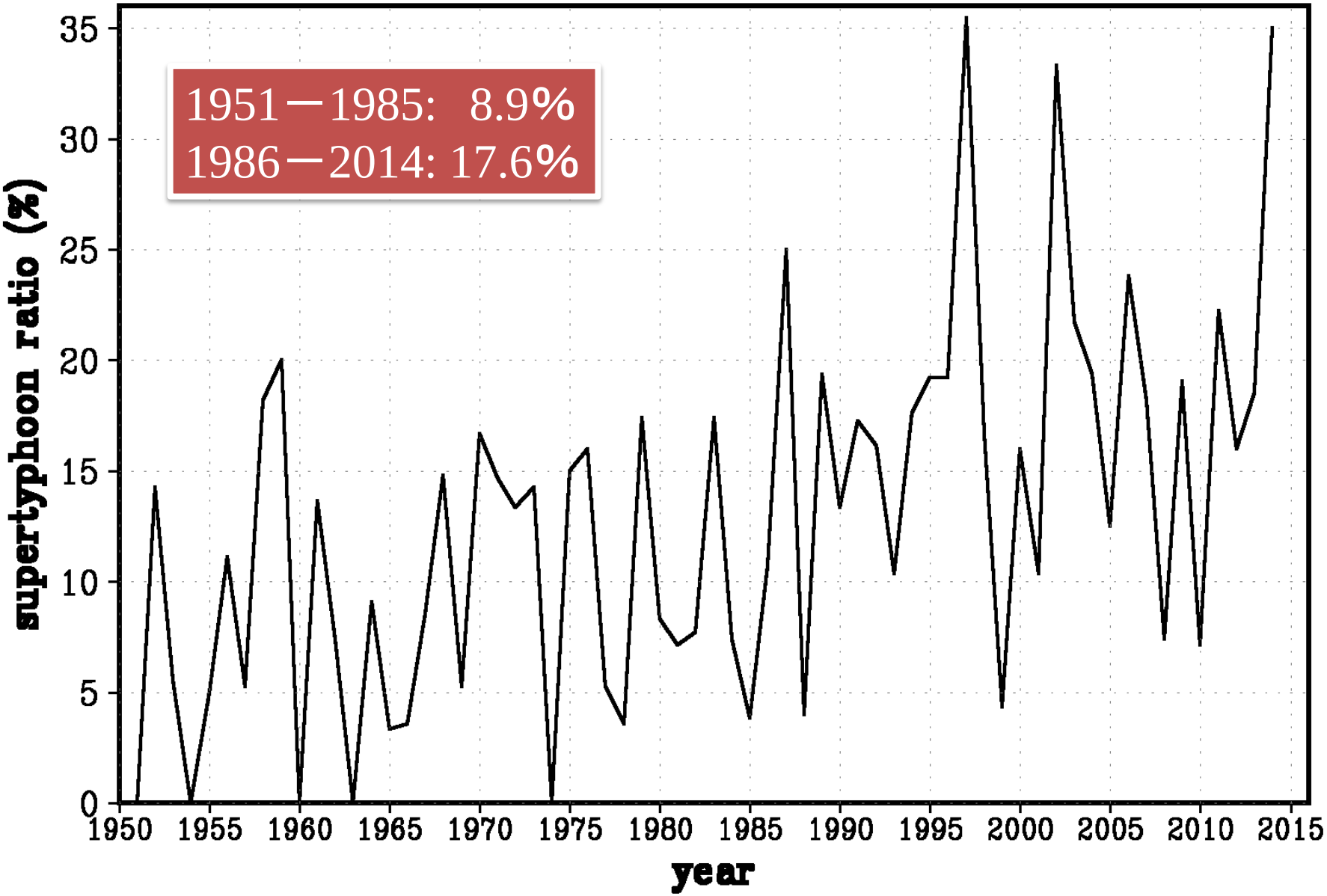
Kossin et al. (2014), *Nature*

Increasing intense typhoons.



Mei and Xie (2016), *Nature Geoscience*

Ratio of supertyphoon to total number in each year (JTWC best track data)

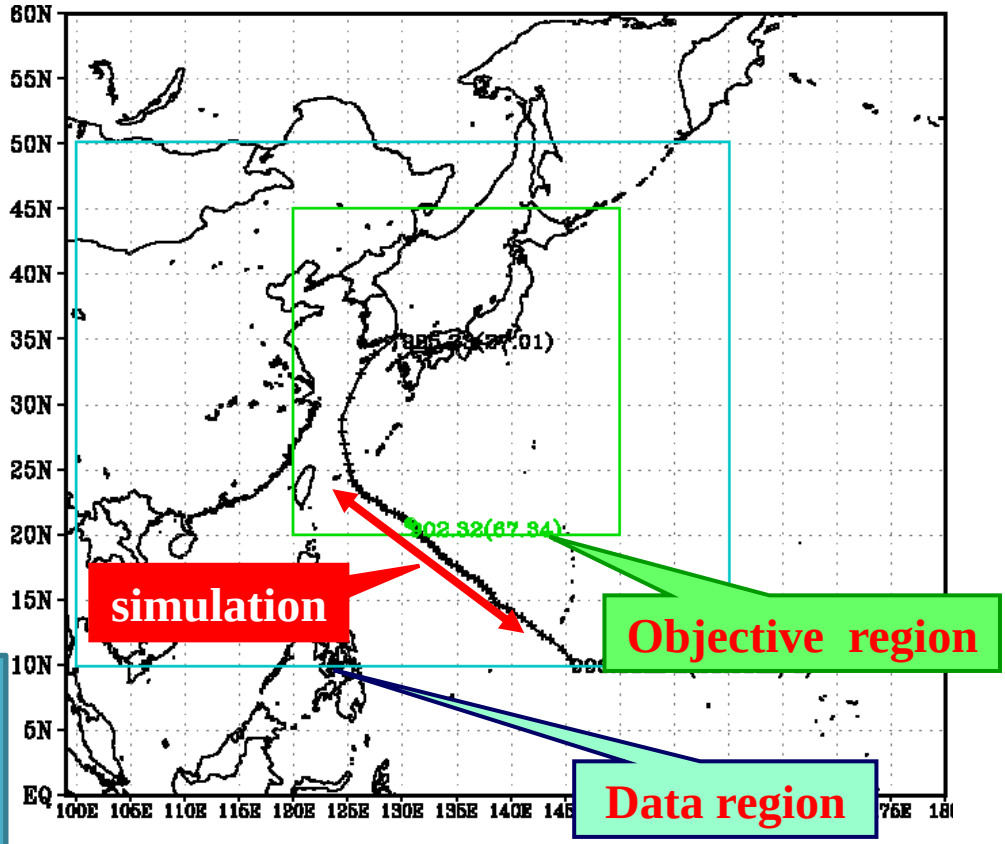


Downscale simulation of the most intense typhoons simulated in the MRI JMA AGCM (GSM) 20 km resolution experiments

Downscale simulations were performed using the cloud-resolving model **(CReSS)** for the AGCM simulated typhoons which fit the following conditions for the present and future climate conditions.

1. **The life-time minimum sea level pressure is below 970hPa in the AGCM simulation.**
2. **The position of the life-time maximum intensity is located in the area of 120－150 E and 20－45 N.**

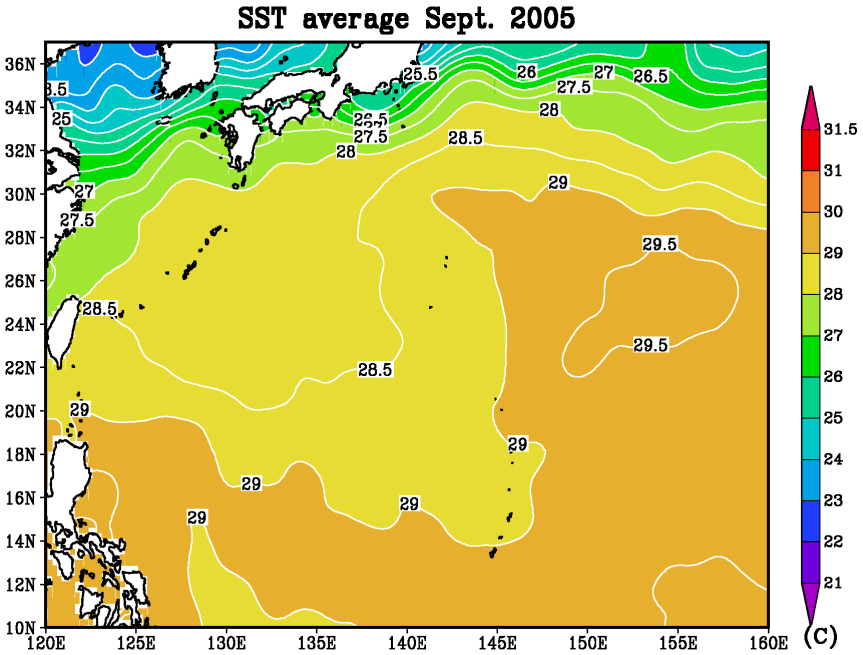
(Green square in the figure)



Present climate : 30 typhoons
Future climate : 30 typhoons

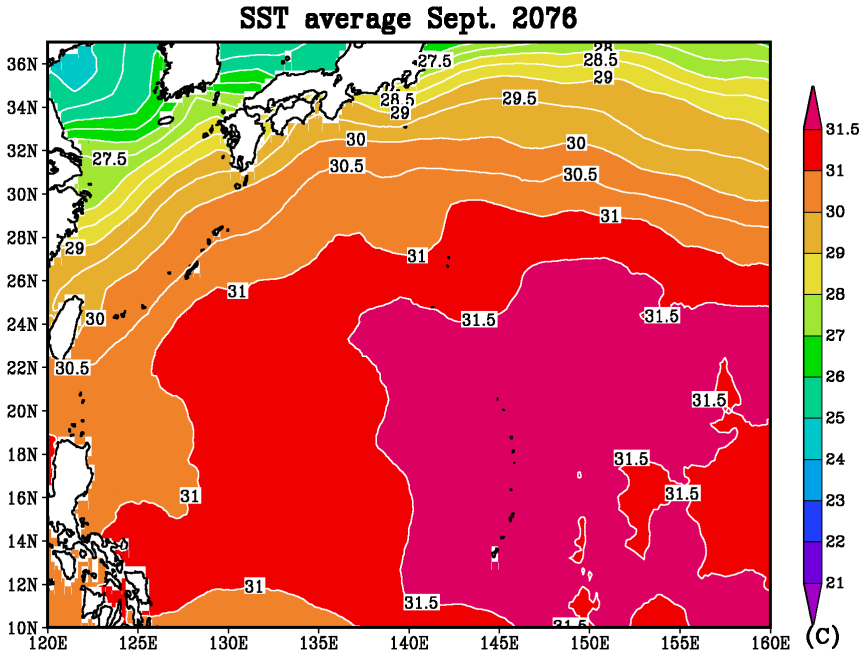
Sea surface temperature (September) in the present climate (2005) and future climate (2076)

Monthly SST in Sept., 2005



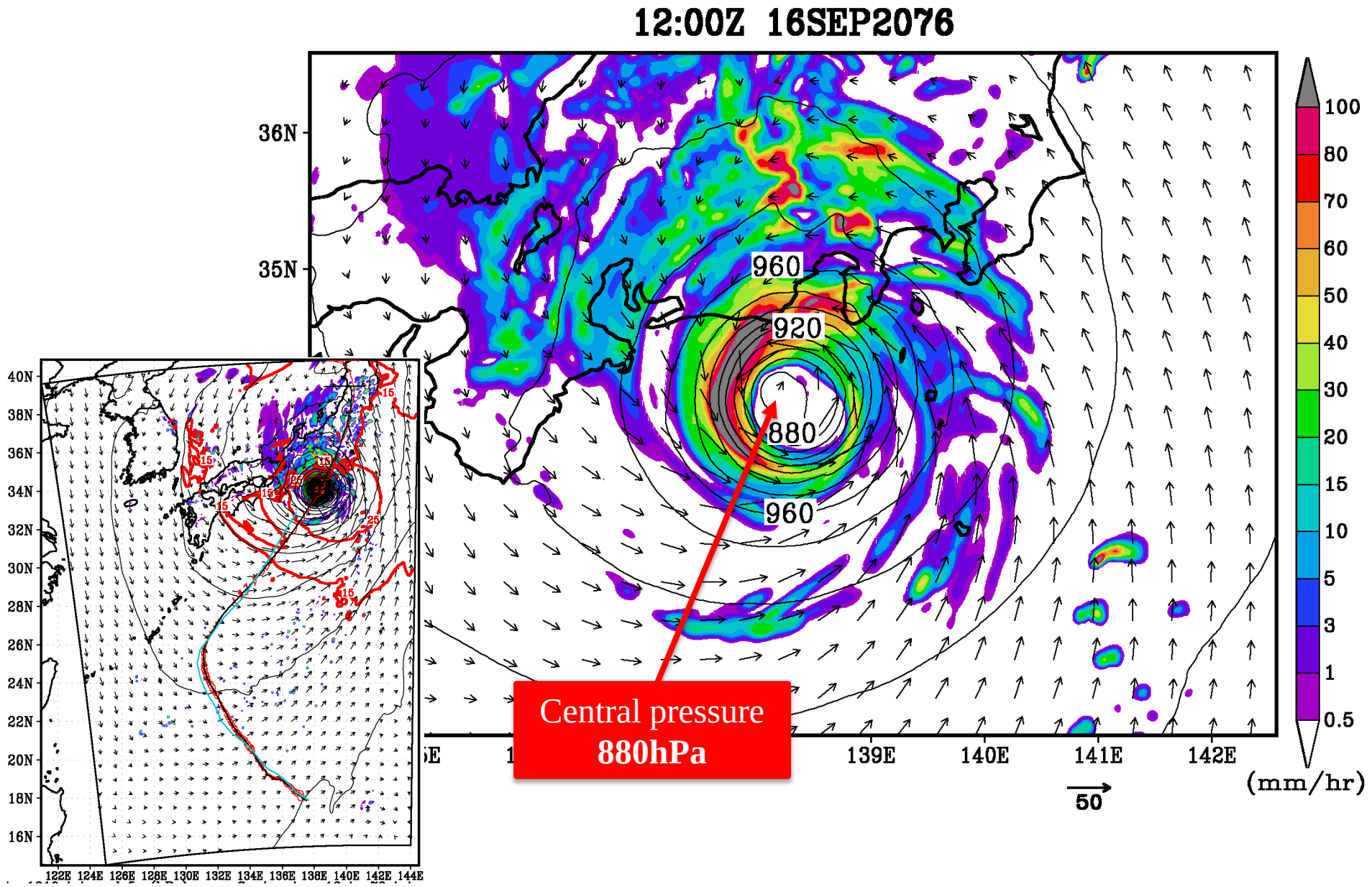
Observed present climate

Monthly SST in Sept., 2076

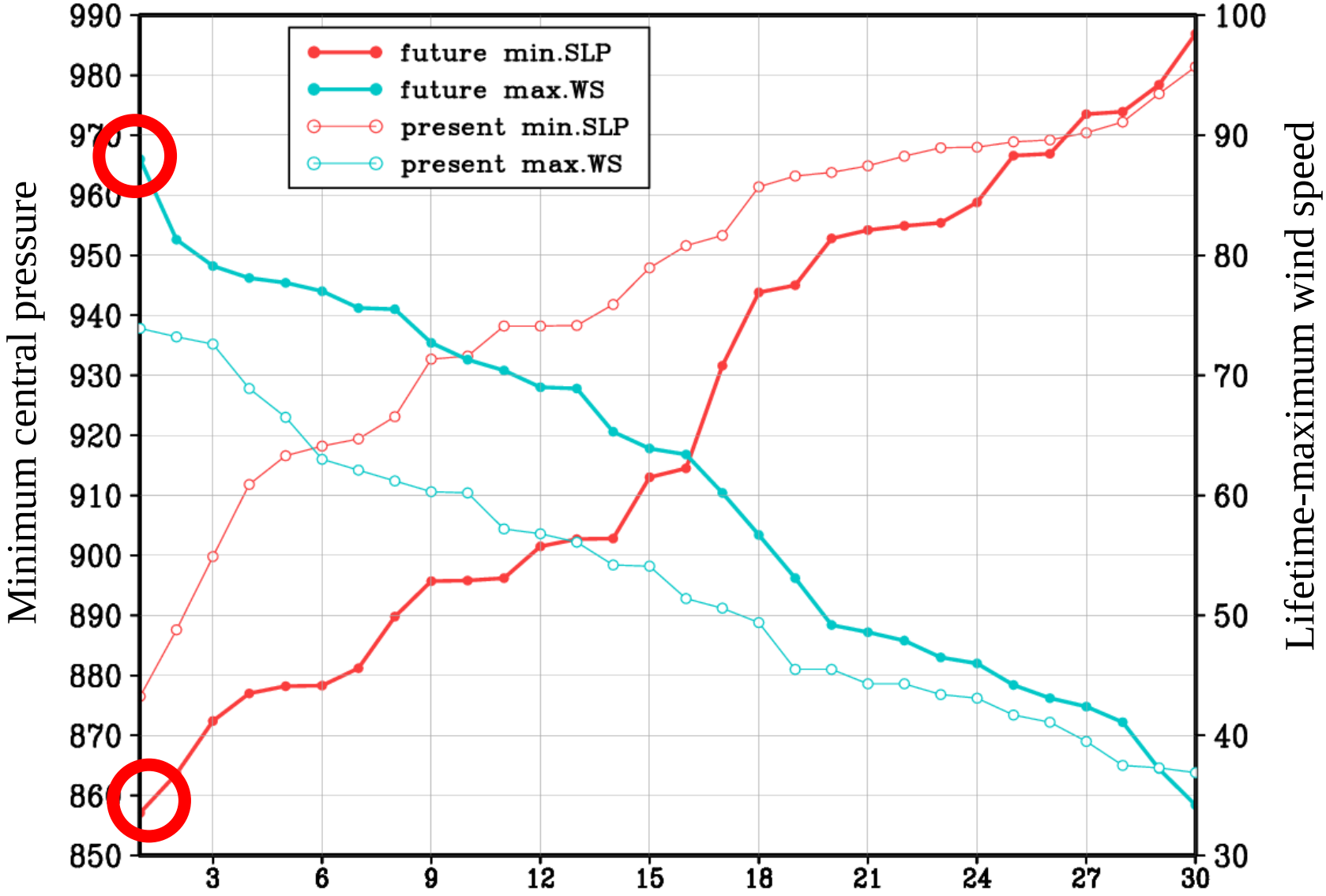


Projected future climate

A supertyphoon landing over Japan in the future climate

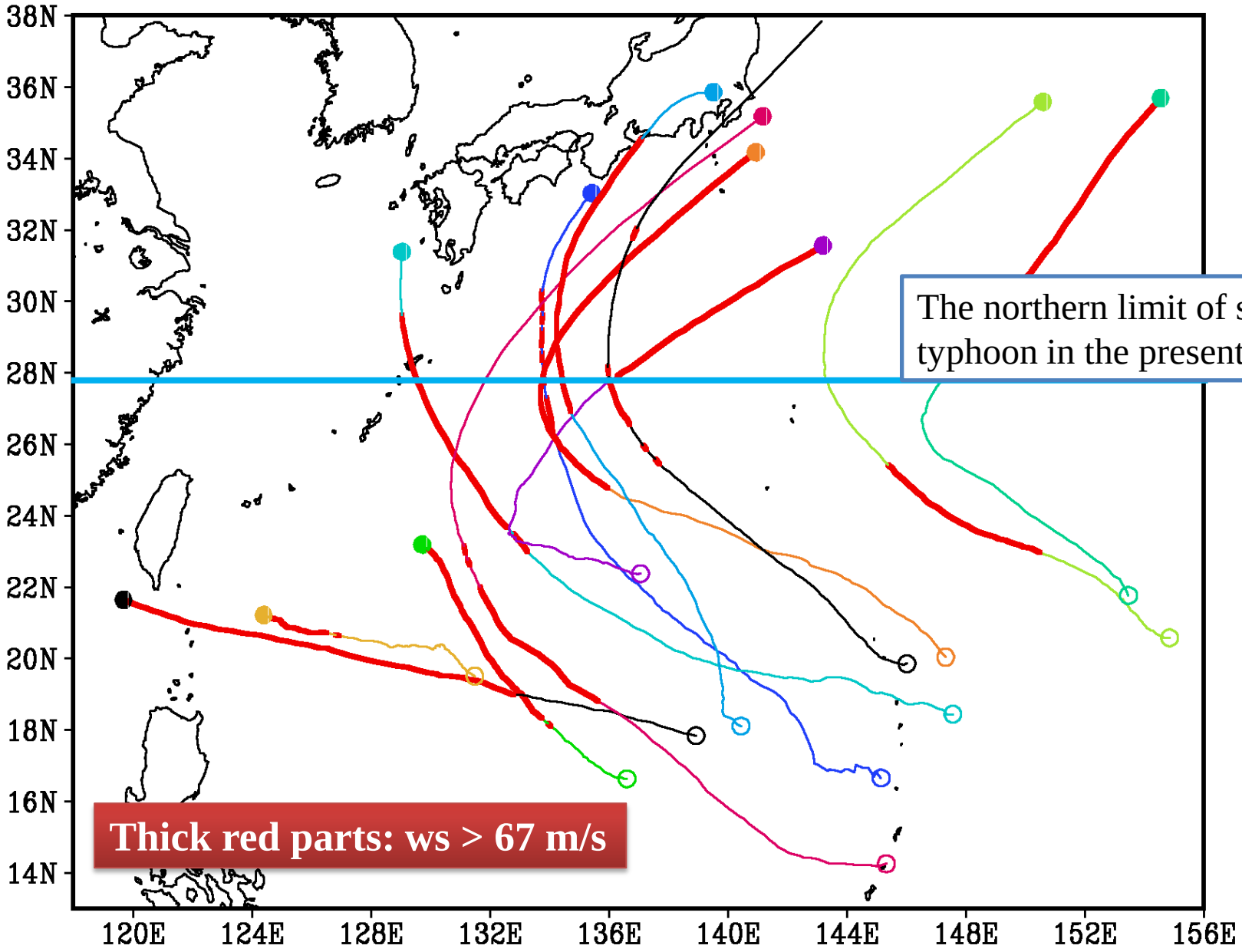


Intensity distributions of the 30 typhoons arranged in order of intensity in the present and future climates



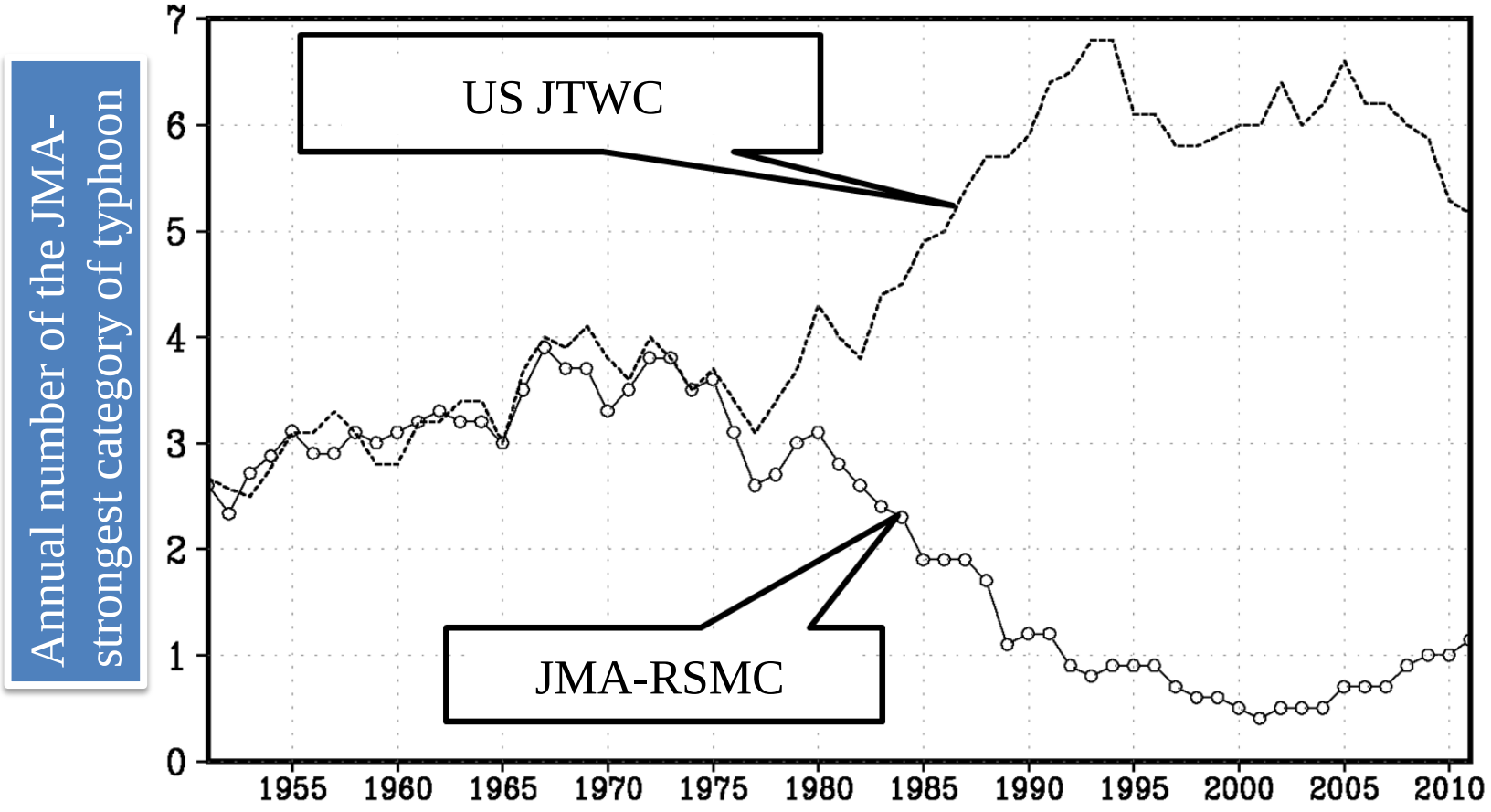
Tsuboki et al. (2015), GRL

Super-typhoon tracks in the future climate simulations



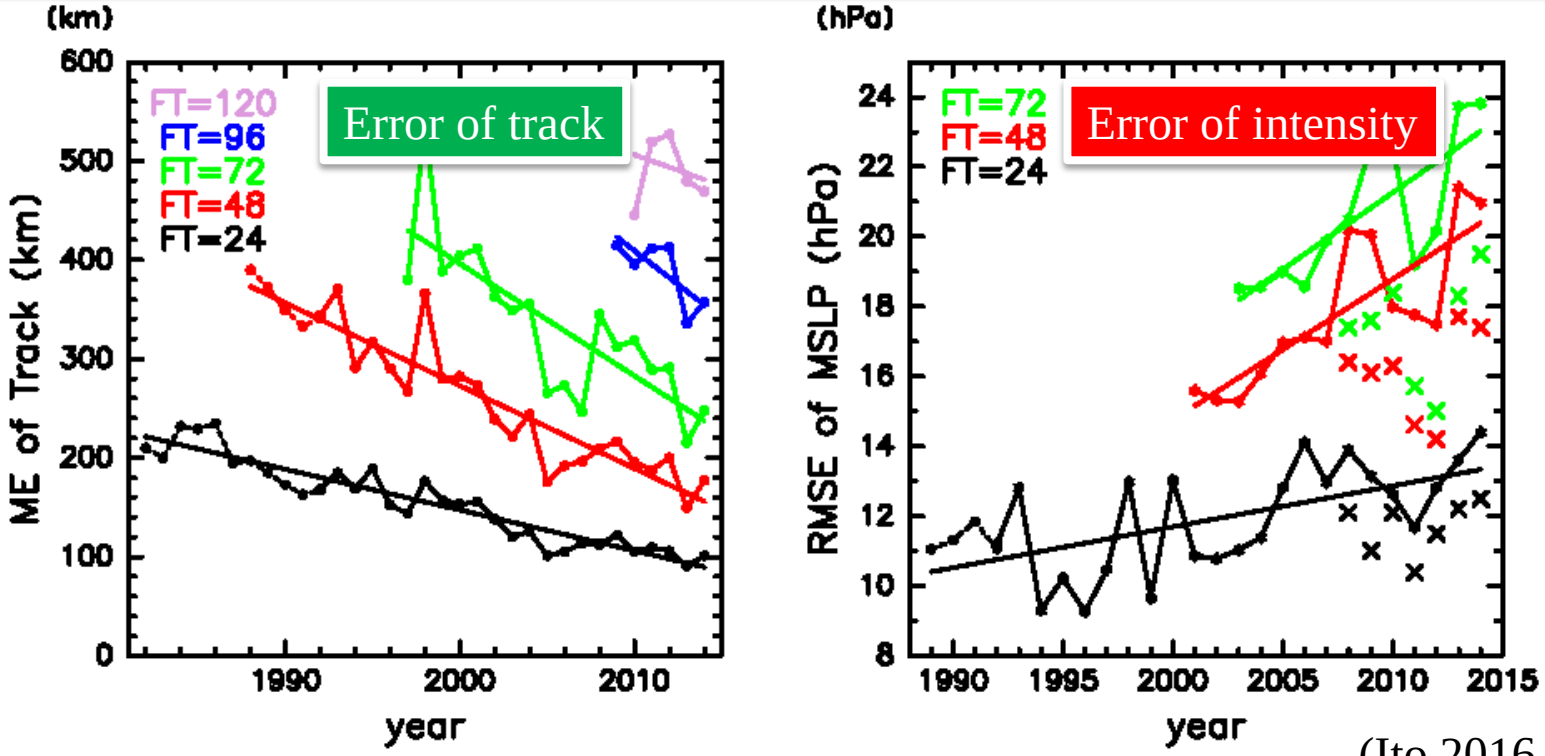
Tsuboki et al. (2015), *Geophysical Research Letters*

- The historical data of typhoon include large uncertainty.
- In particular, intensity of intense typhoons includes large error after the termination of the typhoon reconnaissance by the US aircraft in 1987.
- In fact, the annual number of the JMA-strongest category of typhoon (10 min. averaged sustained wind is 54 m/s or more) shows large difference between JMA and JTWC.



No in-situ observation by an aircraft makes it unknown which is better estimation of intensity; JMA or JTWC.

Problem in typhoon intensity prediction



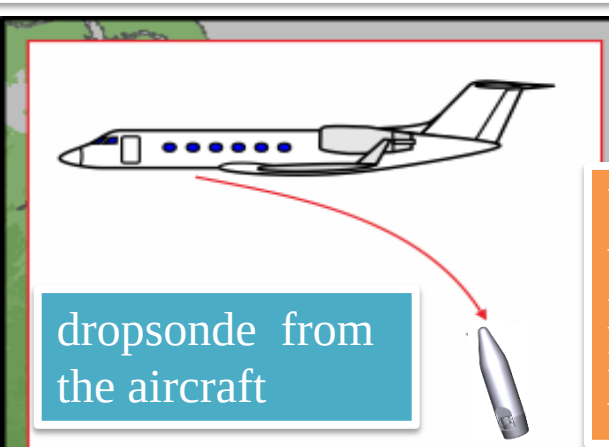
(Ito 2016, *SOLA*)

In the last 25 years, track prediction has been improved while intensity not improved.

For accurate and quantitative prediction of typhoon intensity;

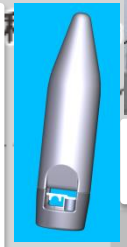
- **High resolution: 2km at least to resolve inner core process of tropical cyclones (e.g. Hill and Lackmann 2011).**
- **Non-hydrostatic, cloud-resolving model**
- **And in-situ observation data.**

T-PARCII (Tropical cyclone-Pacific Asian Research Campaign for Improvement of Intensity estimations/forecasts) is aiming to improve estimations and forecasts

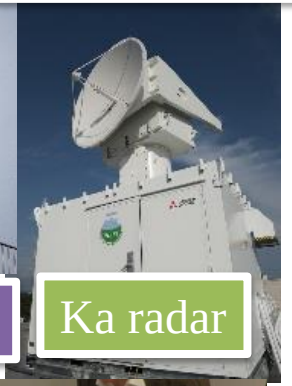


dropsonde from the aircraft

Using dropsondes dropped from the aircraft, temperature, humidity, pressure, and wind are measured in the surrounding region of the typhoon eyewall.



X band radar

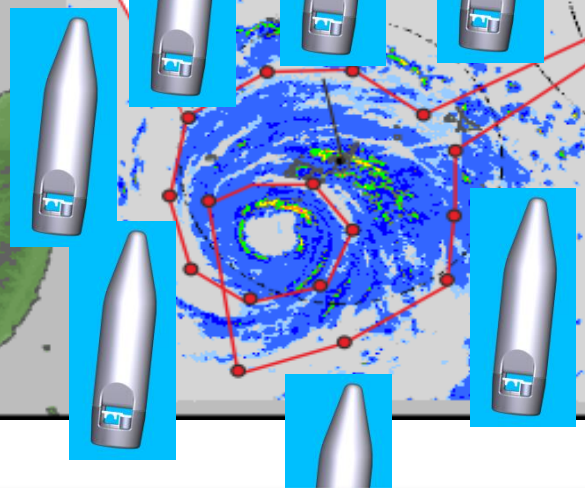


Ka radar

drone

COBRA

沖縄



The dropsonde data are assimilated to the numerical models

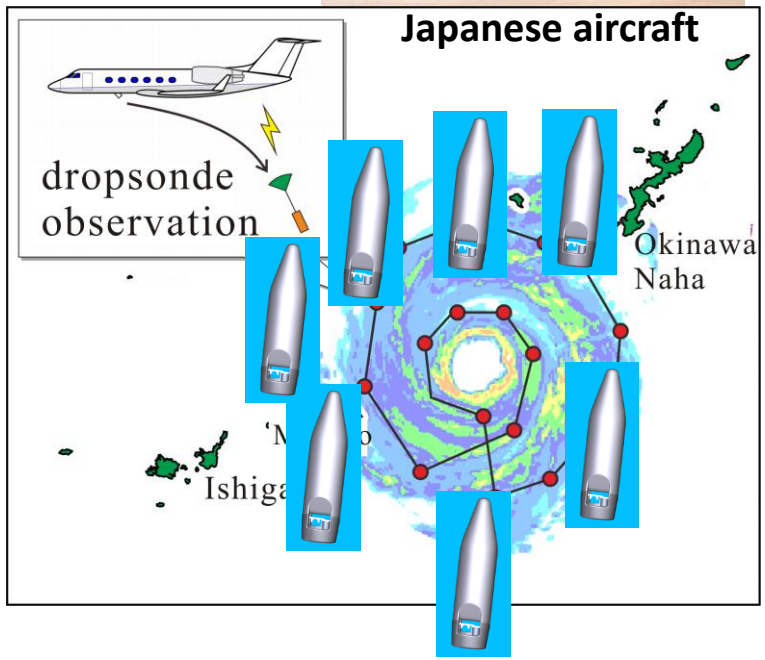
Typhoon prediction using numerical model

- The period of the research is 5 years; from 2016-2020.
- The Gulf Stream II aircraft will be used for dropsonde observation surrounding a typhoon (similar to DOTSTAR in Taiwan).
- A test flight was made on July 27, 2017 to the north of the Noto Peninsula .
- Typhoon observations will be made for the 4 years; 2017-2020. Once or twice flights a year because the budget is limited.
- The main target area of observation is the south of Okinawa.
- Dropsonde data is planned to transmit to GTS in real-time.
- We hope that T-PARCII cooperates with Taiwan CWB observation.

Taiwan obsevation

Wu et al. (2005, BAMS)

Japanese aircraft

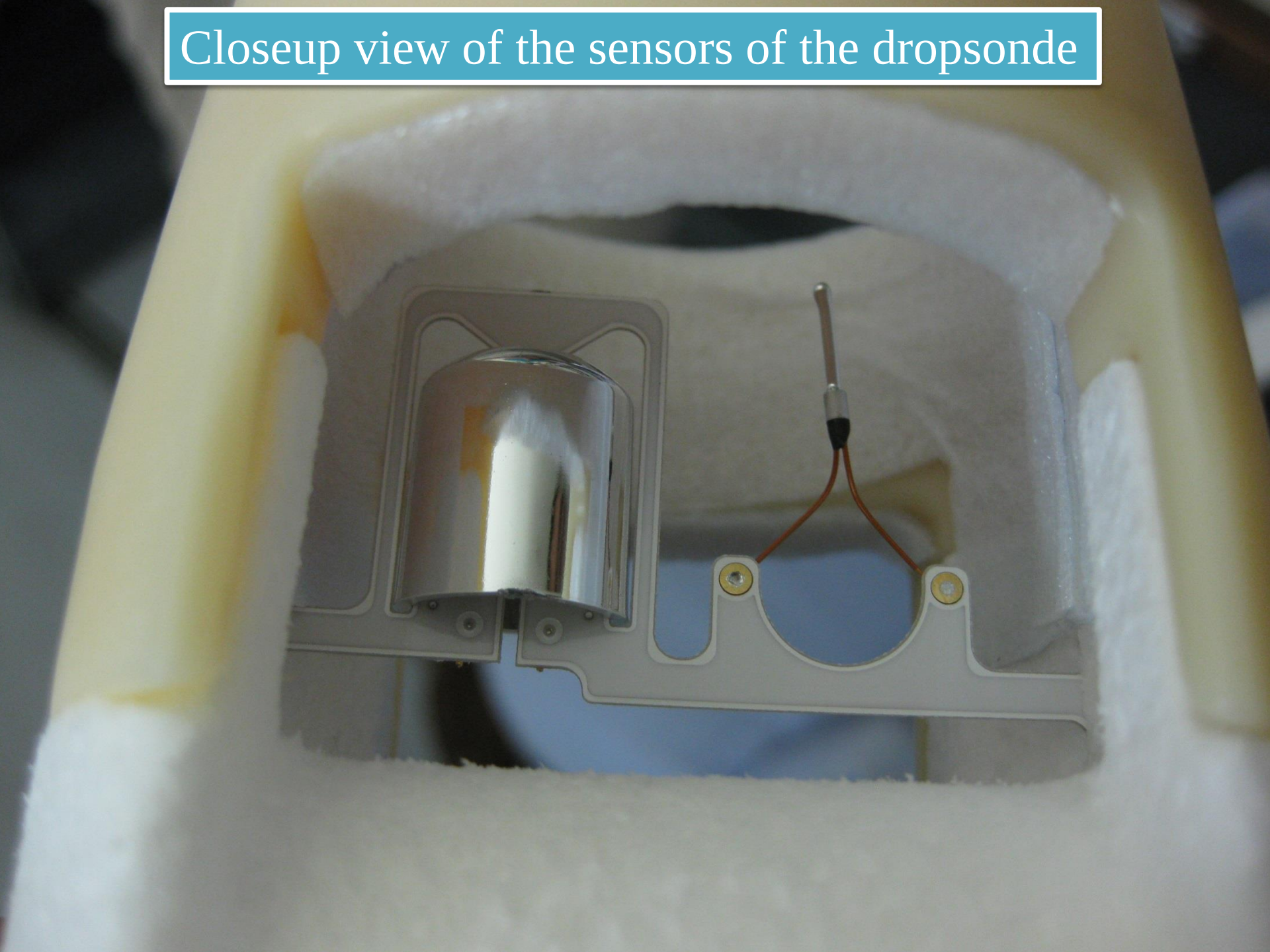


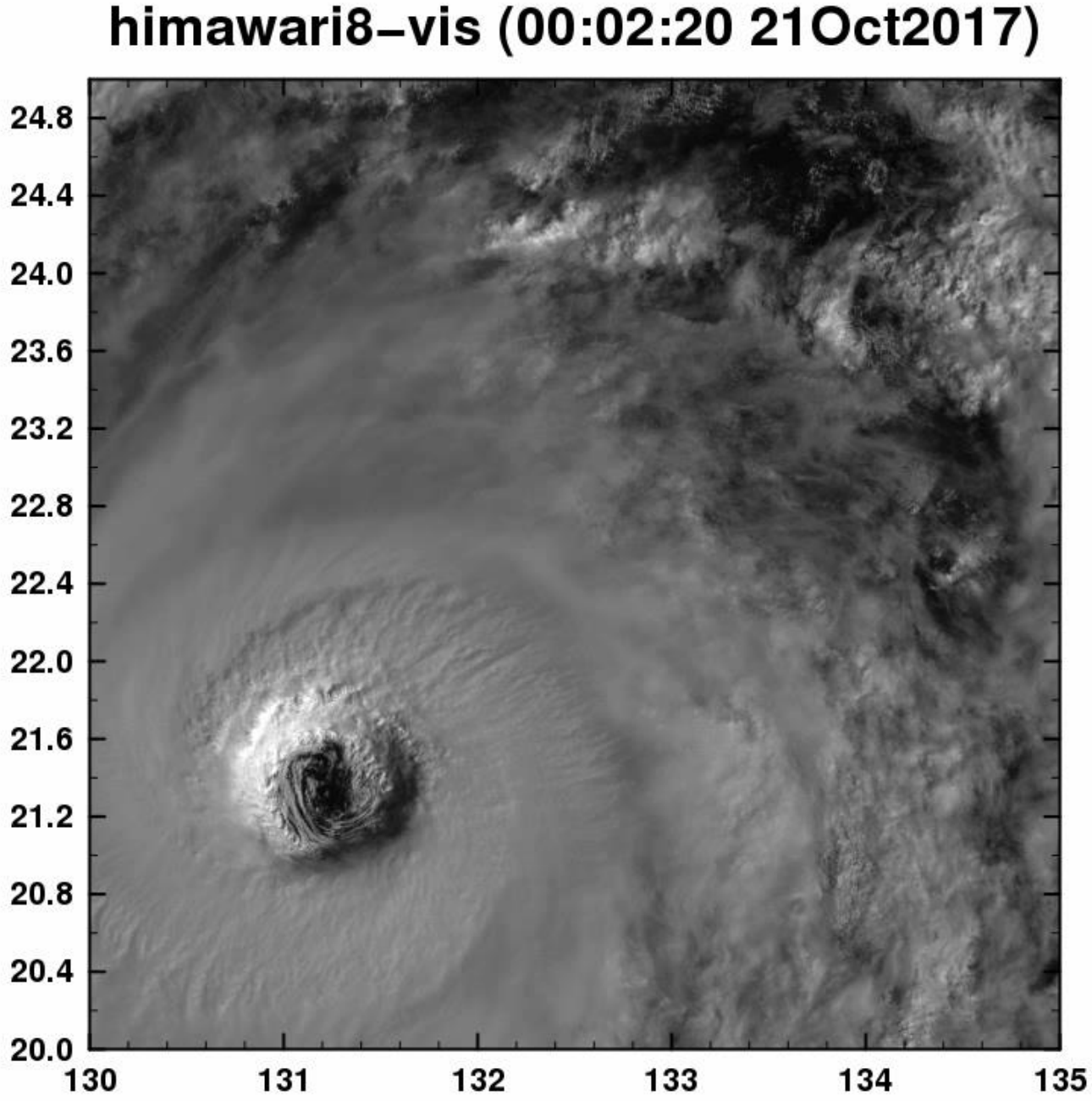
Diamond Air Services (DAS) will operate the Gulfstream II aircraft for the project. DAS is located in the Nagoya City Airport which is close to Nagoya University.

Newly developed dual two-channel receiver of dropsonde in GII
(Meisei electric Co and Nagoya University)

Newly developed dropsonde (Meisei electric Co and Nagoya University)

Closeup view of the sensors of the dropsonde




himawari8–vis (00:02:20 21Oct2017)
24.8
24.4
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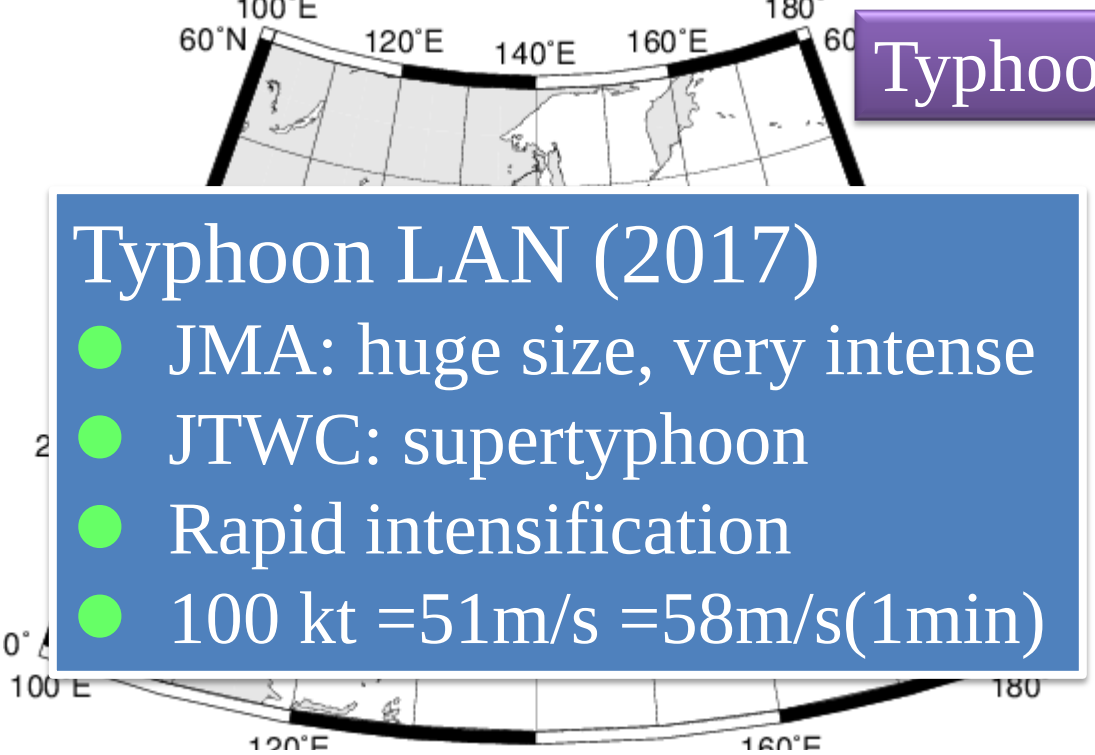
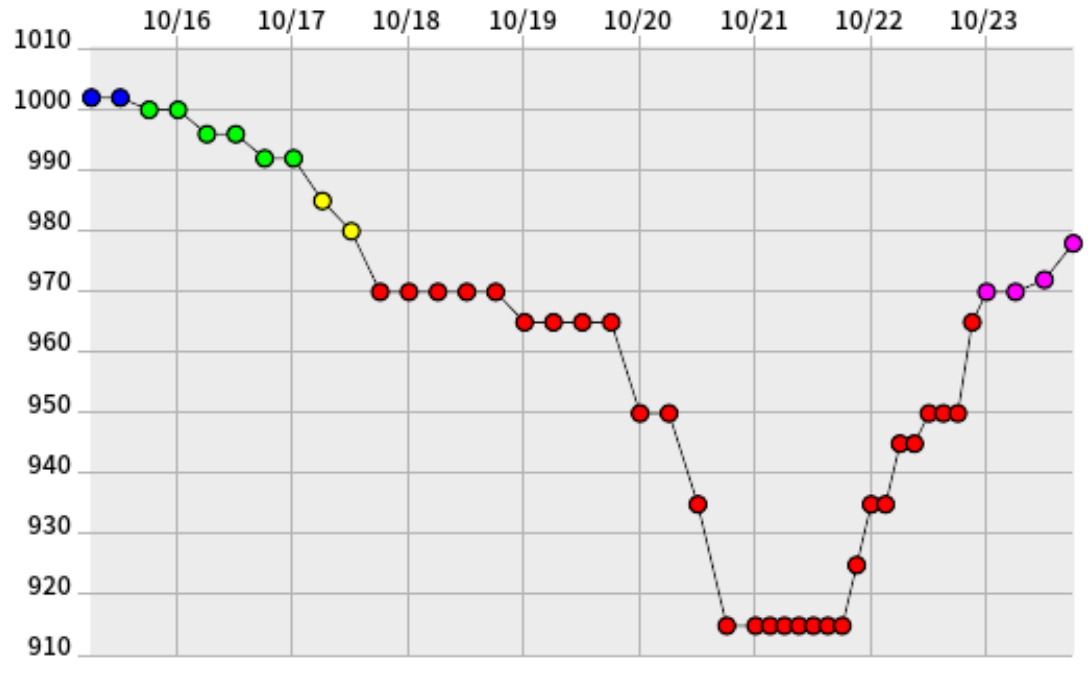
Typhoon LAN (2017) [best track]

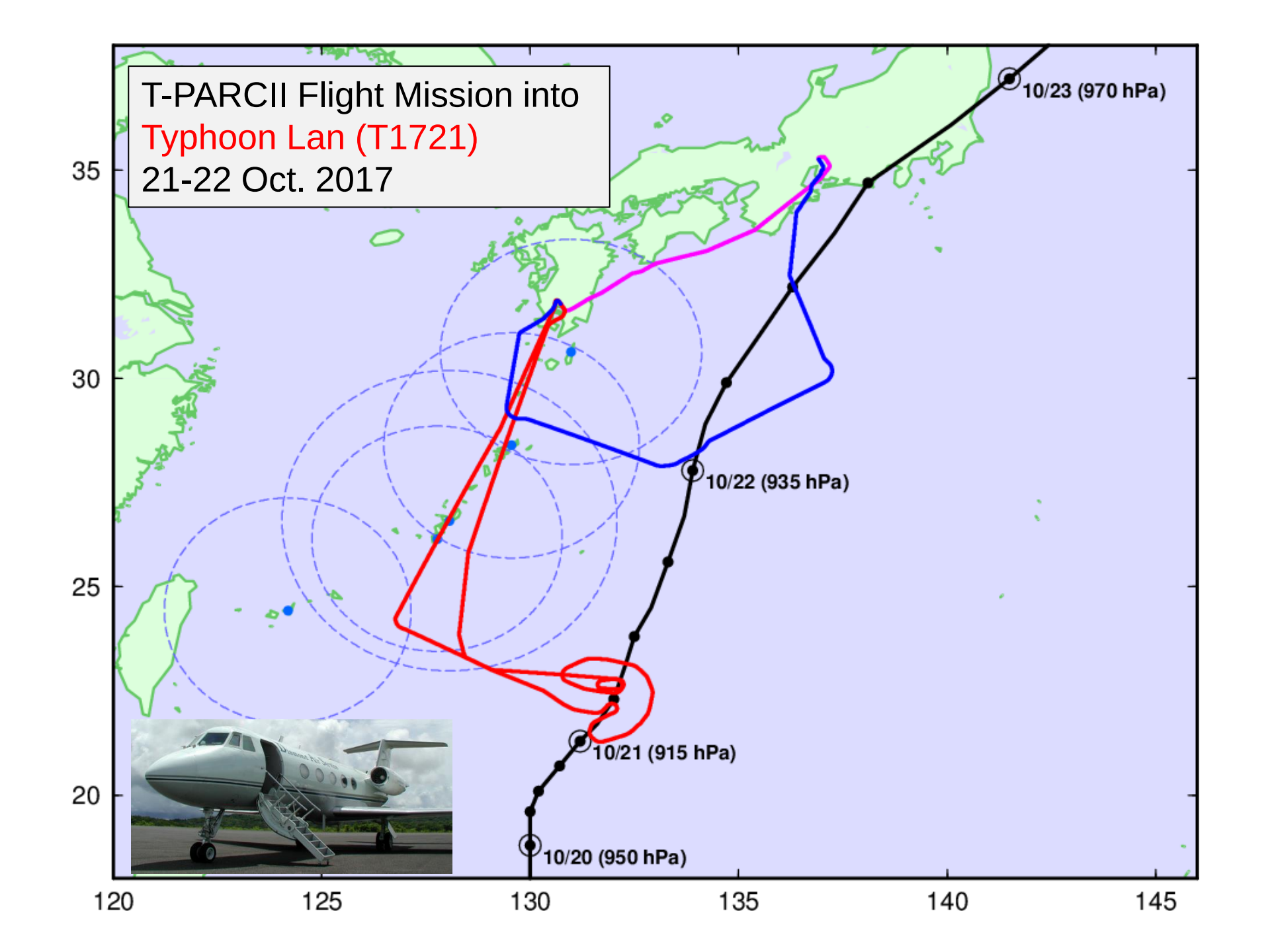
Typhoon LAN (2017)

- JMA: huge size, very intense
- JTWC: supertyphoon
- Rapid intensification
- 100 kt =51m/s =58m/s(1min)





基本情報
発生日時
2017-10-15 18:00:00 UTC
消滅（最新）日時
2017-10-23 00:00:00 UTC
継続期間（寿命）
174 (時間) / 7.250 (日)
移動距離
3912 (km)
平均速度
22.5 (km/h) | 539 (km/d)
移動幅
緯度26.4度： 経度10.1度
Wind Flux
2.0350E+03
Accumulated Cyclone Energy
1.5498E+05
Power Dissipation Index
1.2553E+07
最大気圧低下
-20 hPa / 06時間 -35 hPa / 12時間 -50 hPa / 24時間 -55 hPa / 48時間


T-PARCII Flight Mission into
Typhoon Lan (T1721)
21-22 Oct. 2017
10/23 (970 hPa)
10/22 (935 hPa)
10/21 (915 hPa)
10/20 (950 hPa)
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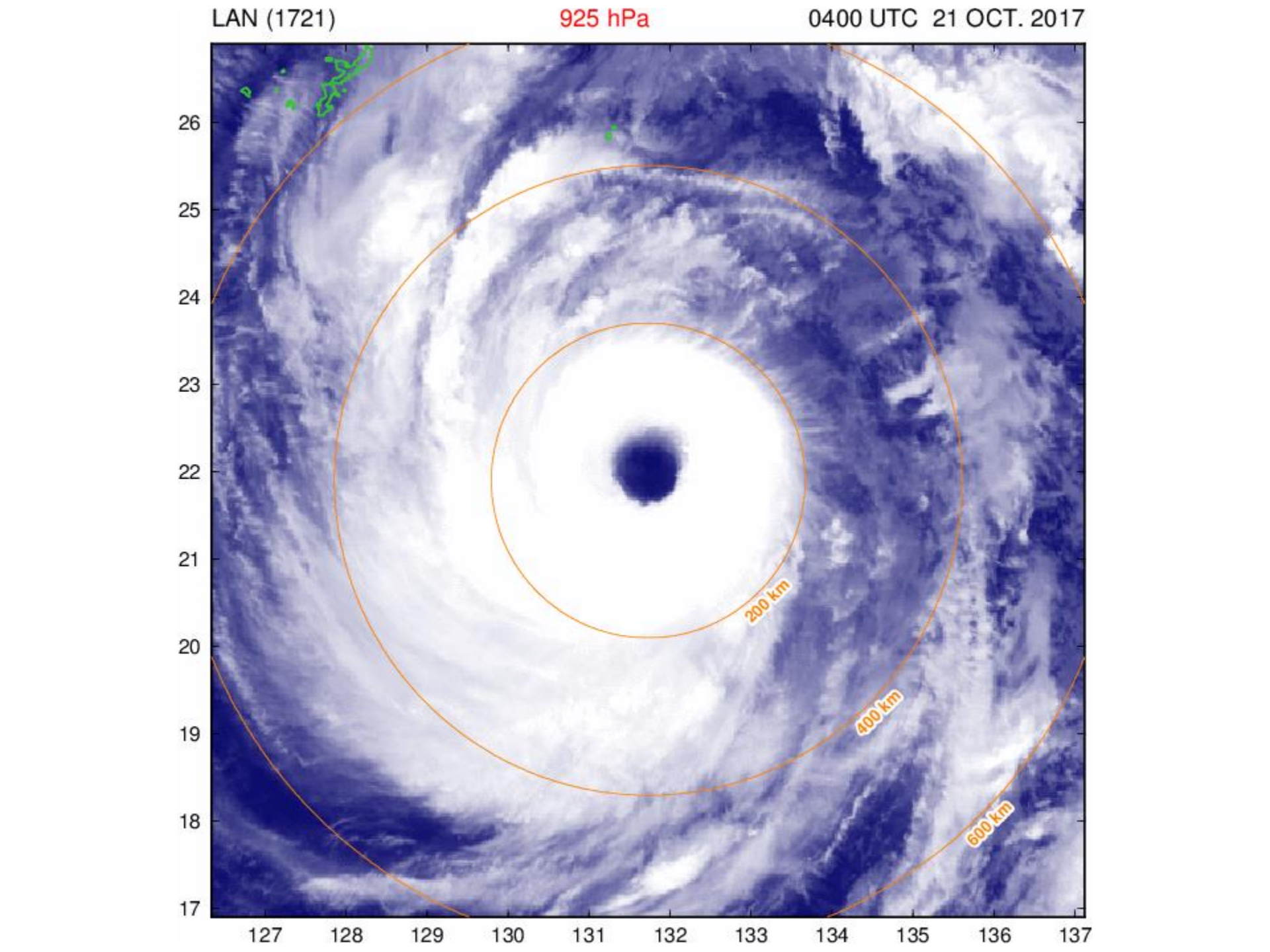
LAN (1721)
925 hPa
0400 UTC 21 OCT. 2017
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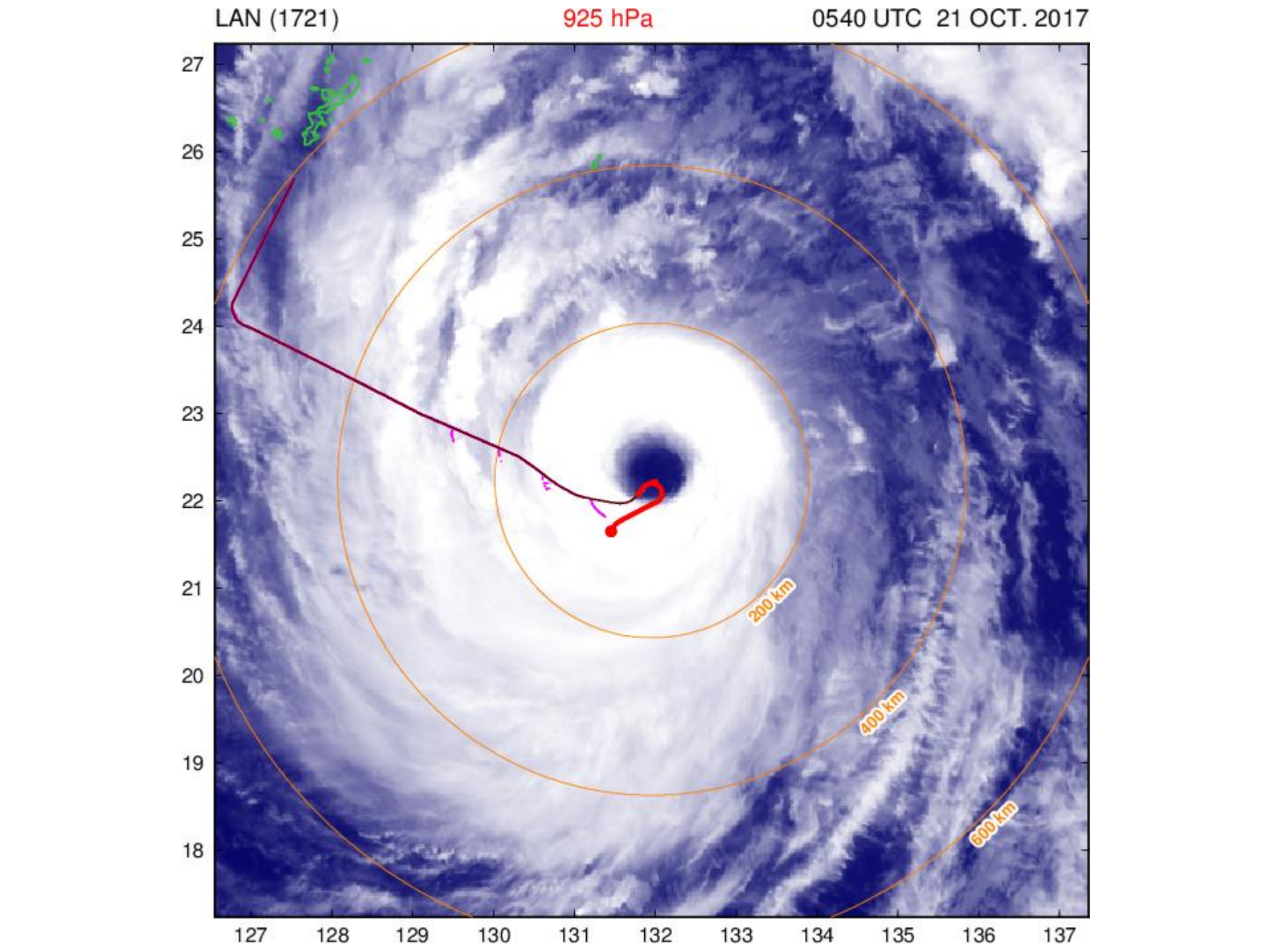
LAN (1721)
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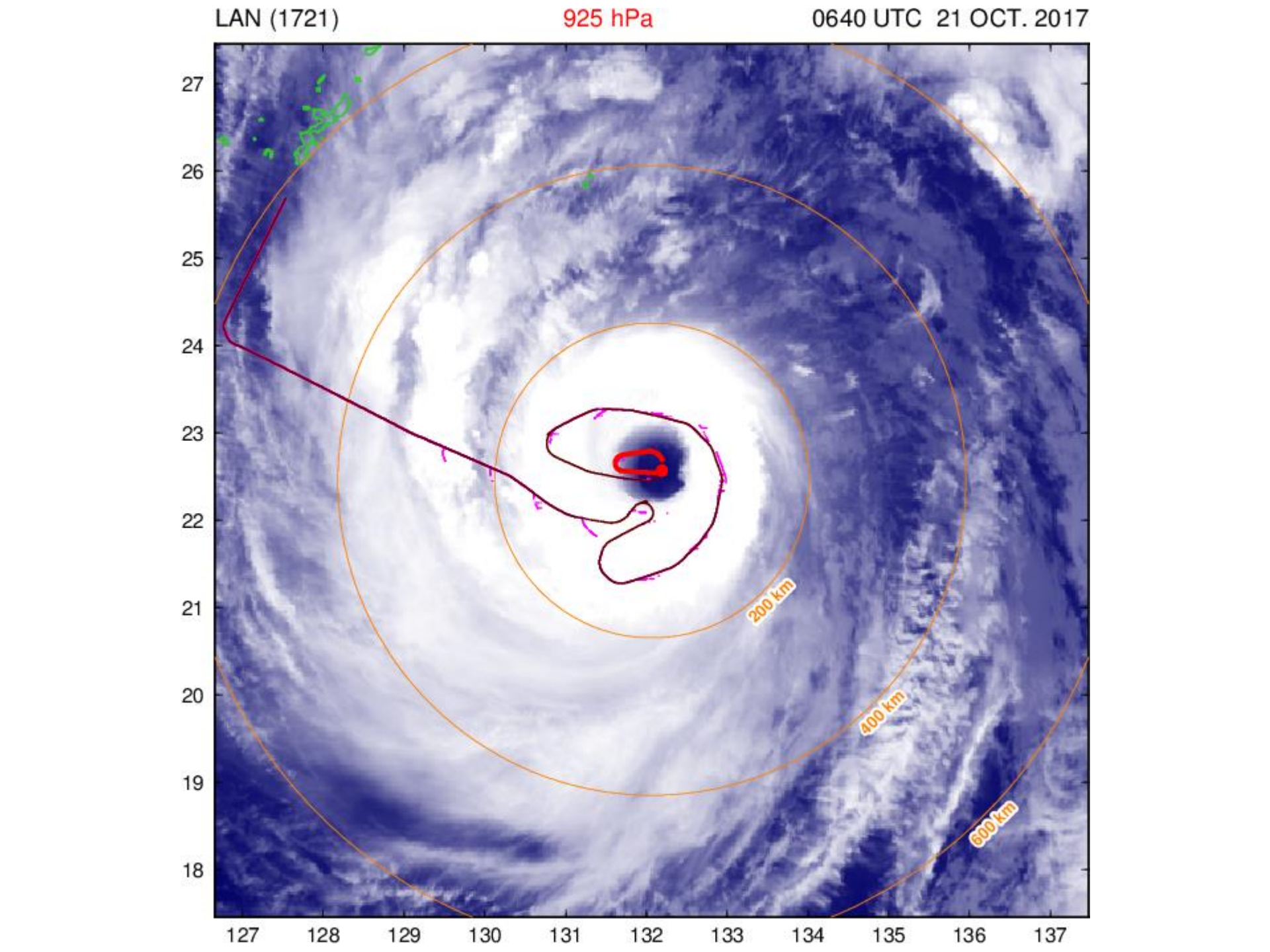
LAN (1721)
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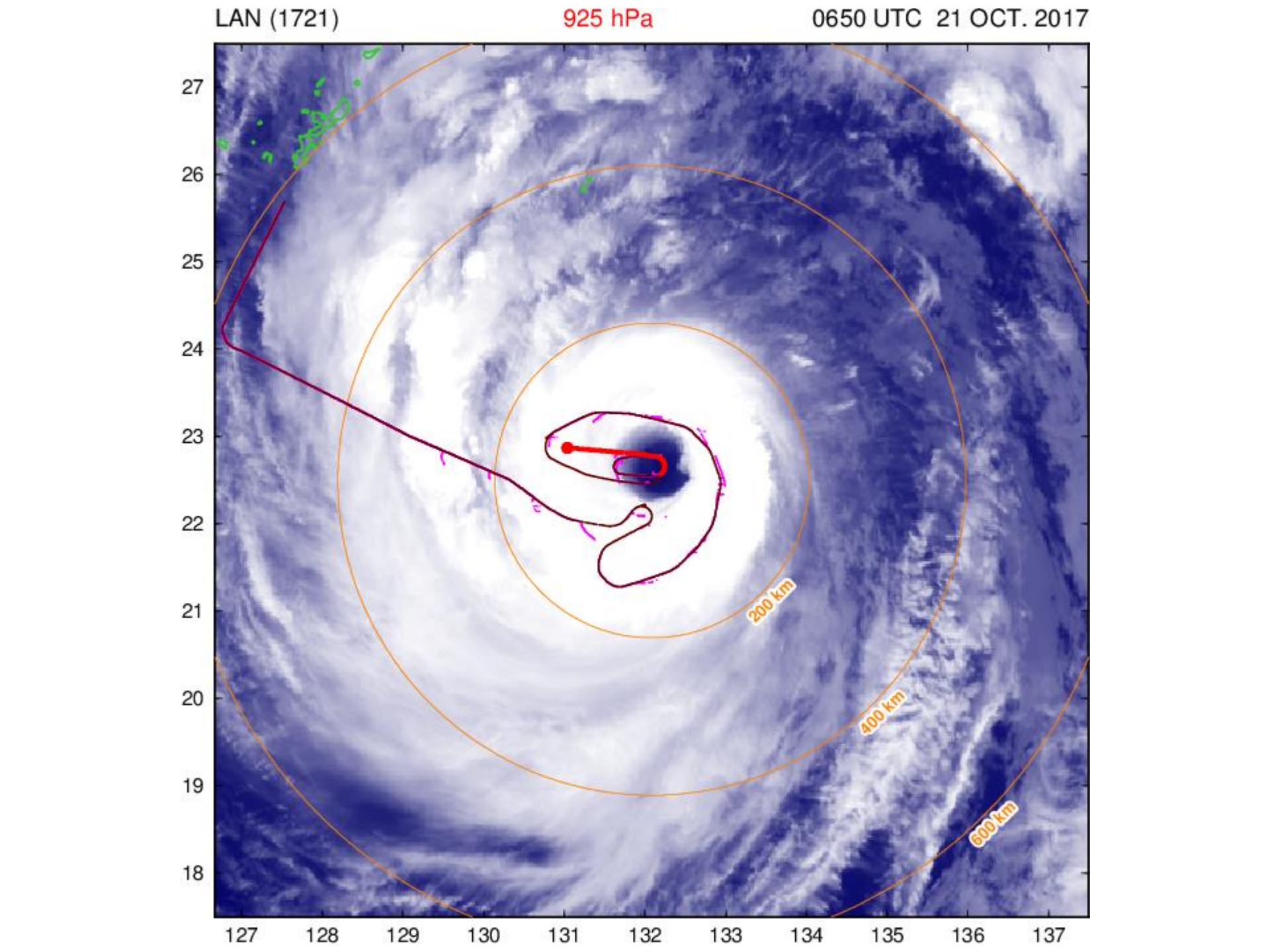
LAN (1721)
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0650 UTC 21 OCT. 2017
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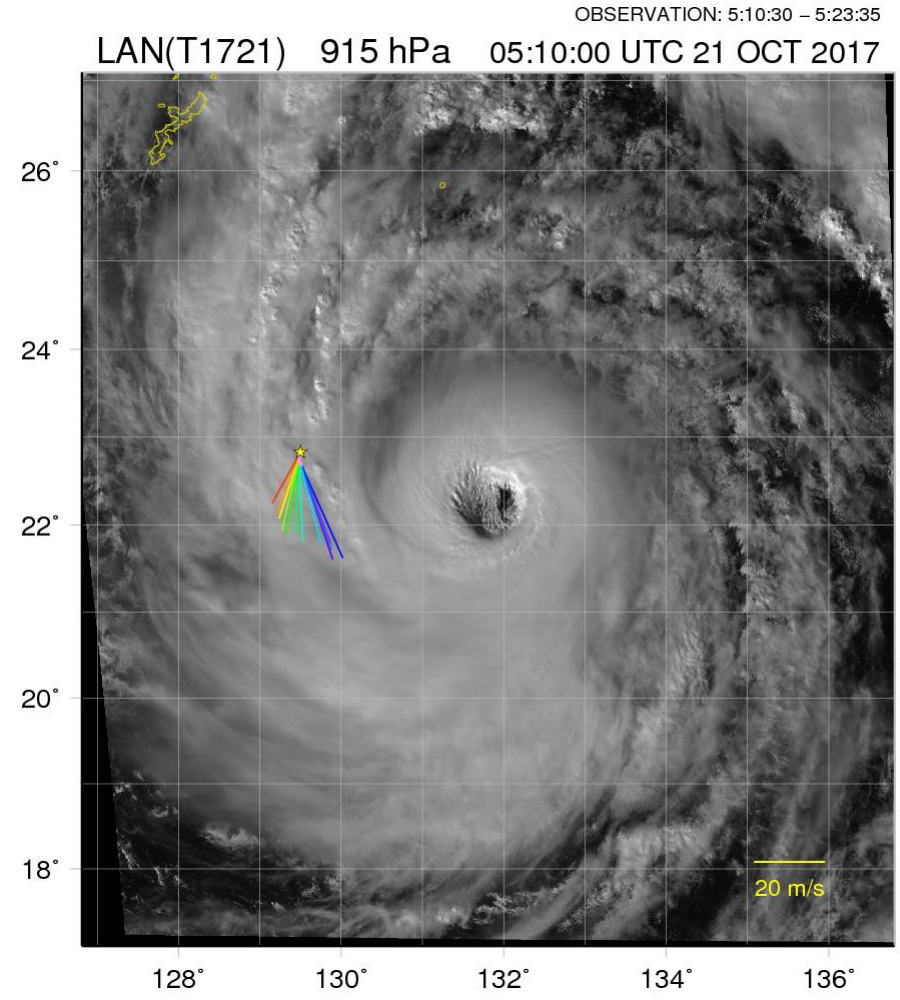
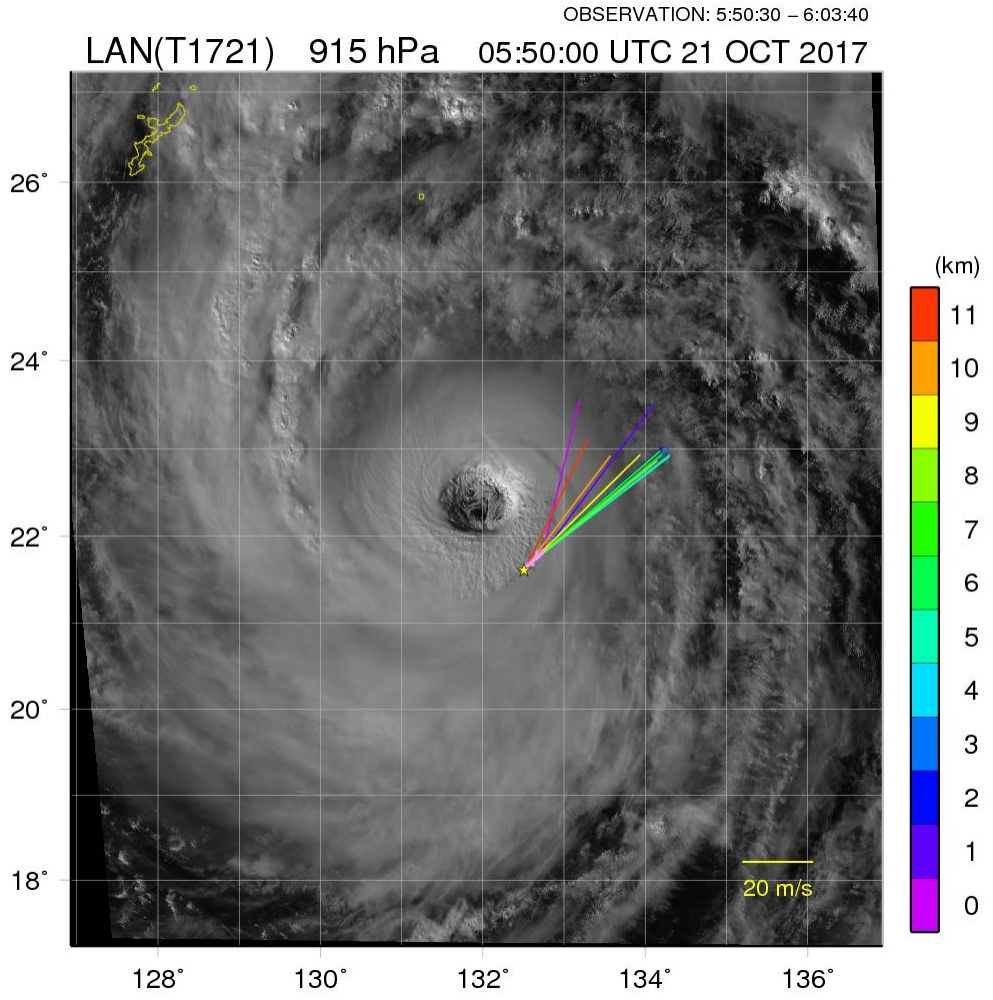
200 km
400 km
600 km

Penetration in to the eye of typhoon Lan (2017)

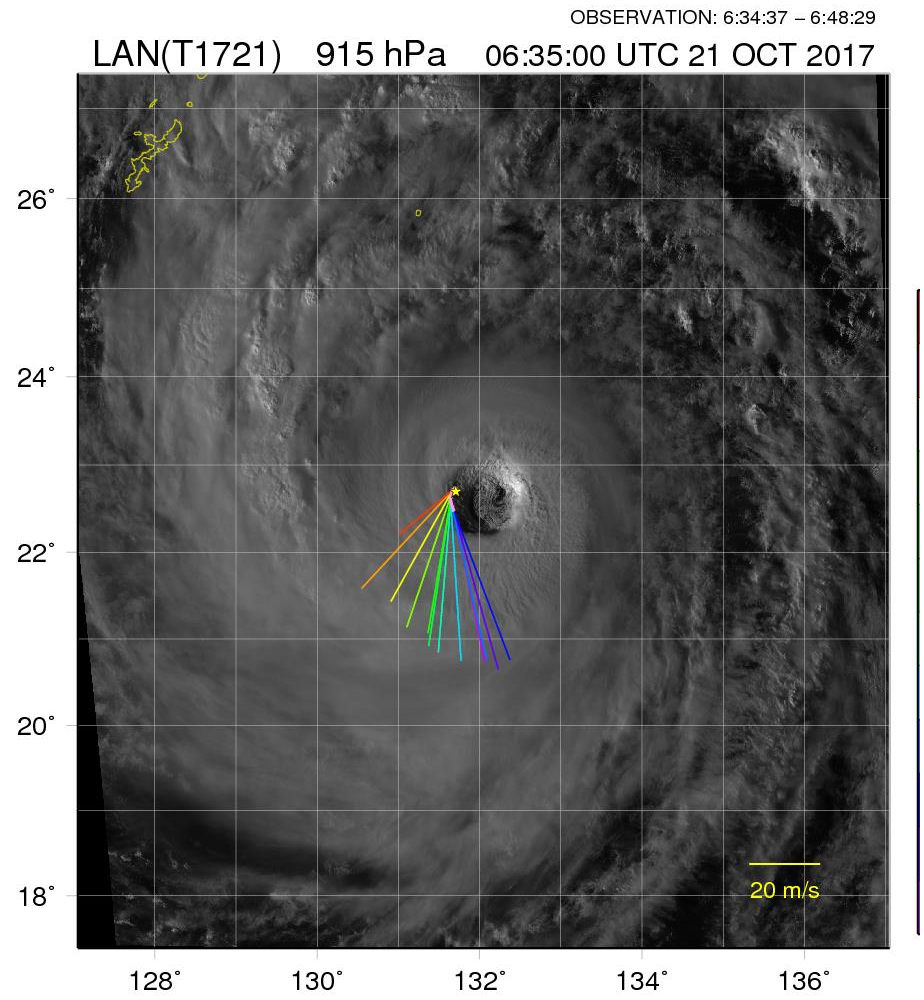
The eye of typhoon Lan (2017) observed by the T-PARCII project on October 21, 2017
The eyewall cloud and mesoscale vortex with open sea are shown in the photo.

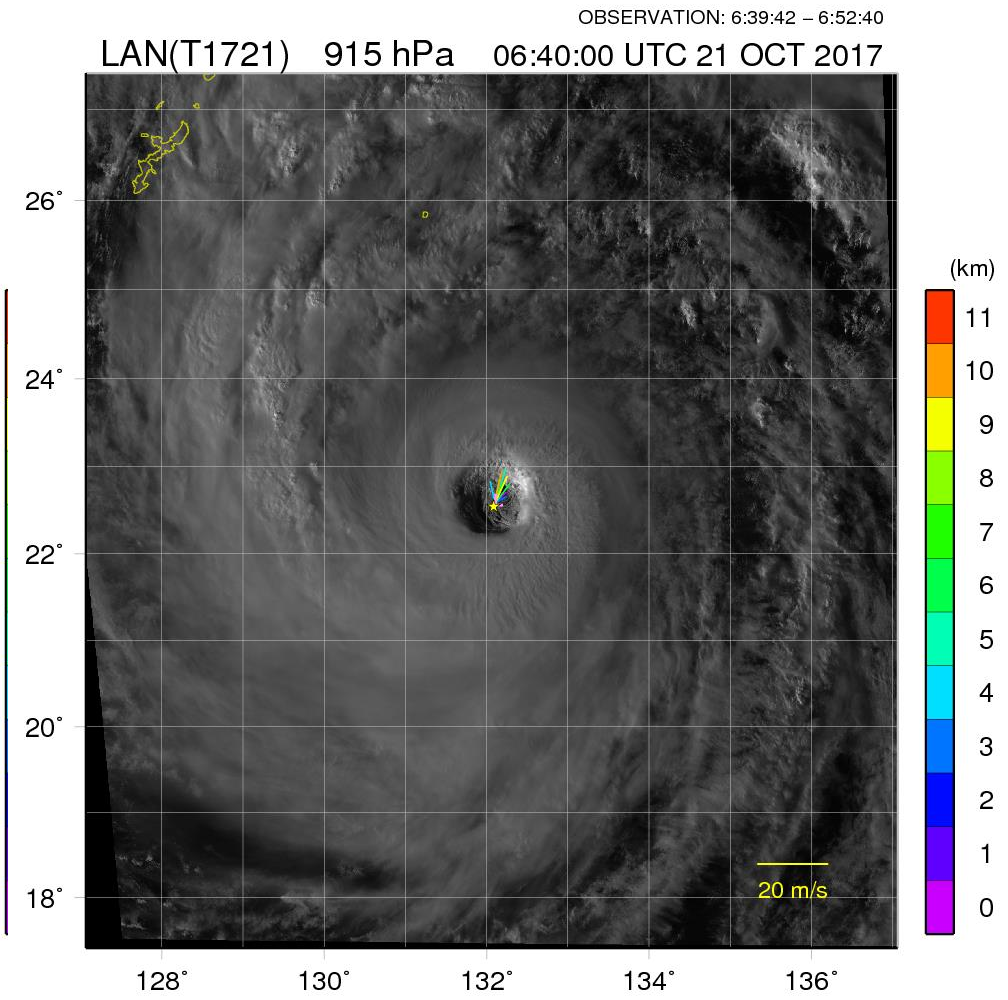
Dropsonde soundings from the aircraft in the surroundings of the eyewall





Dropsonde soundings from the aircraft in the eye of typhoon LAN (2017)





- The most intense supertyphoon could attain wind speeds of 85–90 m s^{-1} and minimum central pressures of 860 hPa in the climate of around the end of twenty-first century.
- Supertyphoons in the future climate could strike the main islands of Japan which are located in the mid-latitude.
- These results suggest that a typhoon risk is increasing in East Asia.
- The T-PARCII is aiming to improve estimations and forecasts of tropical cyclone intensity as well as storm track forecasts.
- Nagoya University and the Meisei Electric Co., Ltd. developed a new dropsonde and four-channel receiver.
- First observation was performed on October 21 and 22, 2017 to observe the very large and intense typhoon LAN (2017) to the southeast of Okinawa.
- This observation was performed as a joint observation with Taiwan group.
- We made dropsonde observations around the eyewall of LAN and in the eye from a height of 43,000 ft.
- Penetration observations into the eye were performed twice on 21 and once on 22 of October.
- The observation provides very important data for the improvements of intensity estimation and forecast as well as for studies of the typhoon.

Thank you !!

The CReSS model is free for scientific researches. If you are interested in CReSS, Please contact me (K. Tsuboki).
(ISEE, Nagoya University)