12月28日(木)
神戸大学

神戸大学CPSセミナー

T-PARCII航空機を用いた台風LANの観測
Aircraft observation of typhoon Lan (2017)

ーT-PARCII projectー

Kazuhisa Tsuboki[1]

研究参画者・協力者
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高橋暢宏[1], 民田晴也[1], 久島萌人[1],山口宗彦[4], 中澤哲夫[4]

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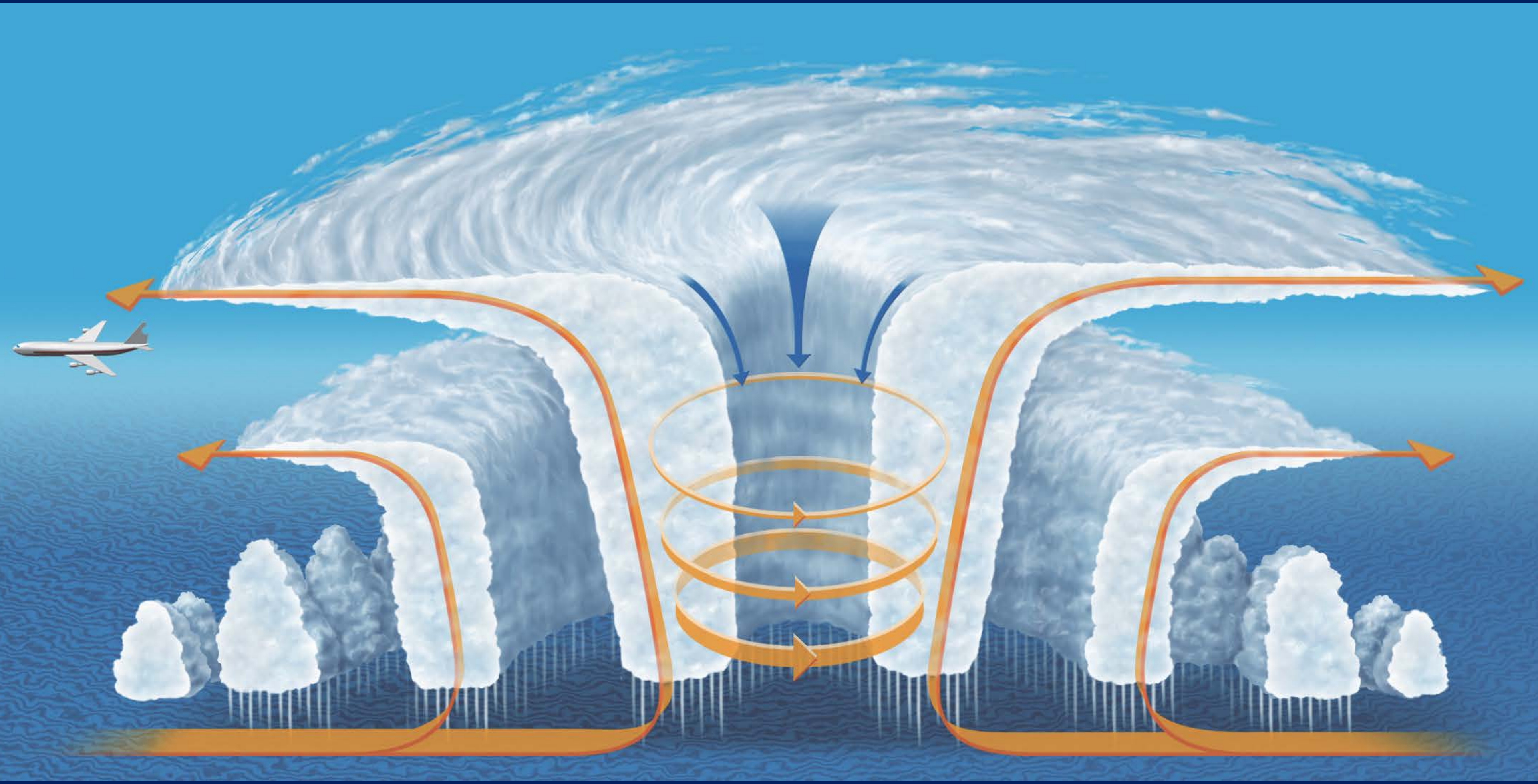
4気象研究所・5京都大学防災研究所

Schematic representation of tropical cyclone



出典:わかる！取り組む！　災害と防災4,豪雨・台風,帝国書院,2017年

The momentum equations of horizontal motion in the cylindrical coordinates are

$$\frac{dv_r}{dt} - fv_\theta - \frac{v_\theta^2}{r} = -\frac{1}{\rho}\frac{\partial p}{\partial r} \tag{1}$$

$$\frac{dv_\theta}{dt} + fv_r + \frac{v_r v_\theta}{r} = -\frac{1}{\rho}\frac{\partial p}{r\partial \theta} \tag{2}$$

where θ is the tangential direction and r is the radial direction. The Lagrange differential is

$$\frac{d}{dt} = \frac{\partial}{\partial t} + v_r\frac{\partial}{\partial r} + v_\theta\frac{\partial}{r\partial \theta} \tag{3}$$

If tropical cyclone is in steady state, Eq. (1) will become

$$f v_\theta + \frac{v_\theta^2}{r} = \frac{1}{\rho}\frac{\partial p}{\partial r} \tag{1}$$

コリオリ力 遠心力 気圧傾度力

This balance equation is referred to as the “gradient wind balance”. Basic state of a tropical cyclone is approximated by the gradient wind balance as well as the “hydrostatic balance” as

$$g\frac{\partial z}{\partial p} = -\frac{R_d T_v}{p} \tag{2}$$

Using the gradient balance equation, Eq. (1) and the hydrostatic balance equation, Eq. (2), the thermal wind balance equation is obtained as,

$$\xi \frac{\partial v_g}{\partial \ln p} = -R_d \frac{\partial T_v}{\partial r} \tag{1}$$

where

$$\xi = \left(\frac{2v_g}{r} + f \right) \tag{2}$$

is inertia parameter.

The inner core structure of tropical cyclone

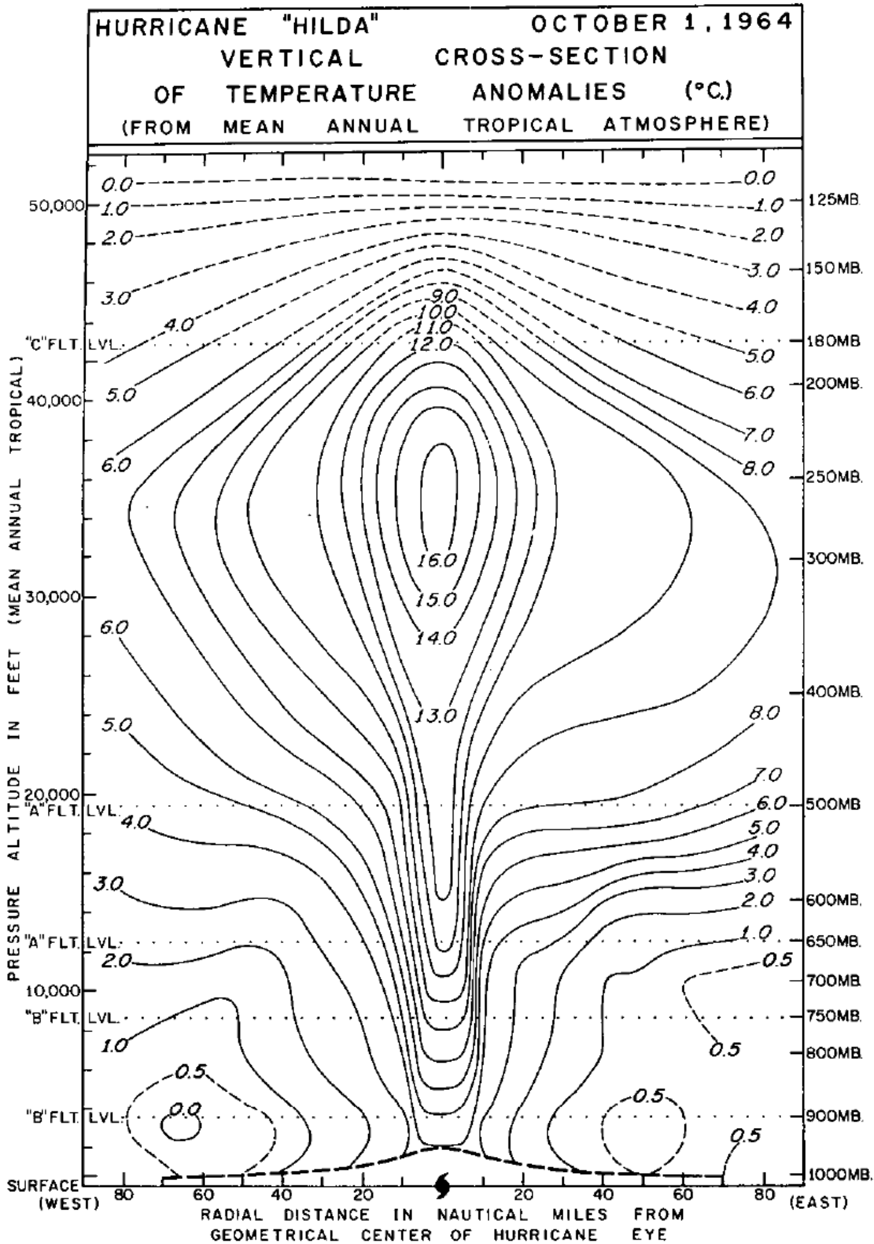


FIGURE 9.—Vertical cross section of temperature anomaly prepared from the soundings presented in figure 8.

Hawkins and Rubsam (1968)

Warm core structure above the tropical cyclone center.

Jordan (1961)

The lower part of the center is moist and the relative humidity decreases with height.

Shea and Gray (1973)

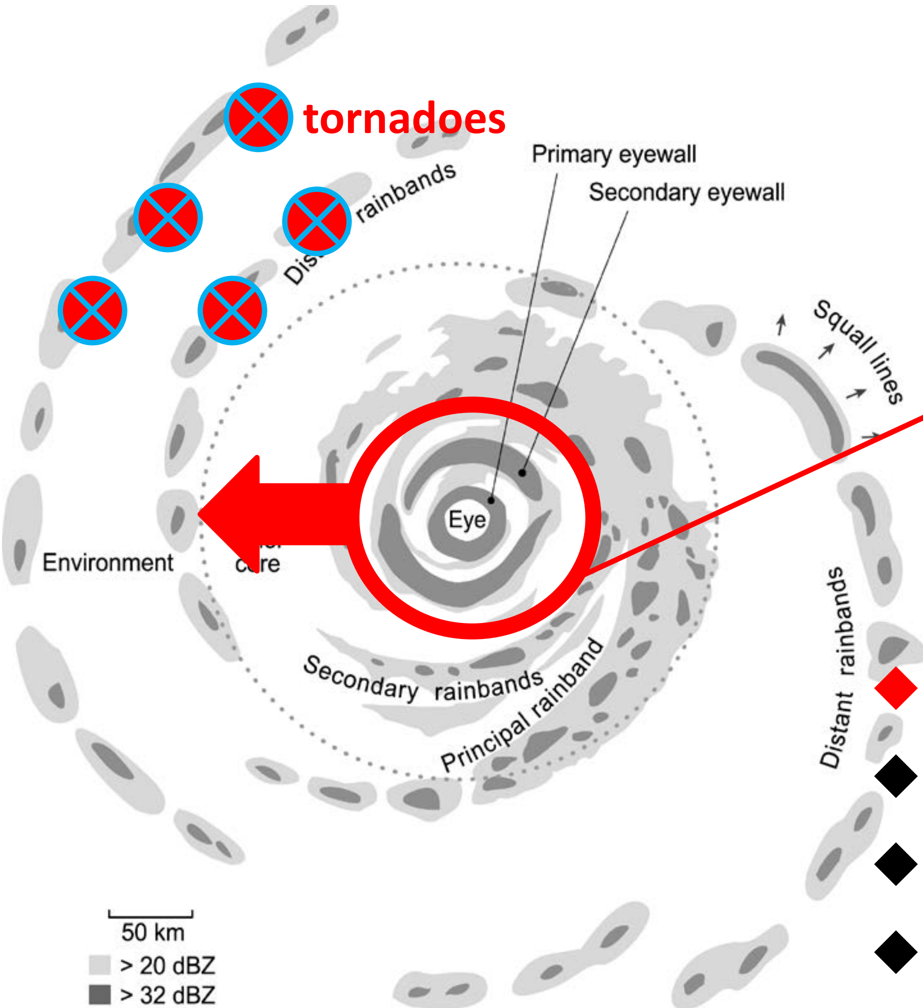
Gray and Shea (1973)

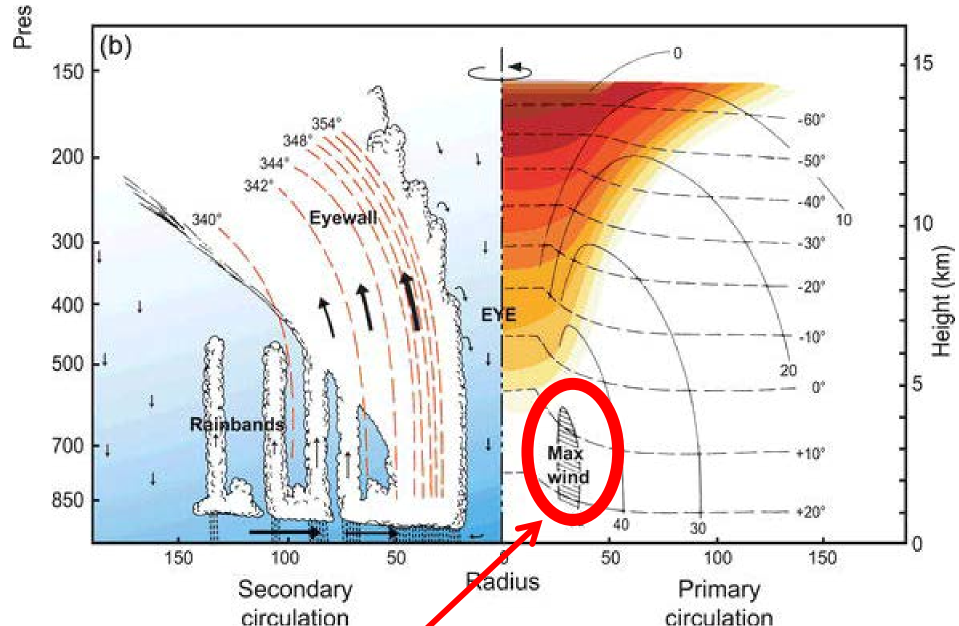
They hypothesized that the warm core is caused by diabatic heating of the descending motion in the eye.

By Hawkins and Rubsam (1968)

Structure of tropical cyclone

Eye wall and spiral rainbands





Maximum wind speed

Property of tropical cyclones

- ◆Intensity: central pressure / max. wind speed
- ◆Size：radius of 15m/s wind area
- ◆Track
- ◆Movement speed
- ◆Number (genesis, approach, landing)

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/

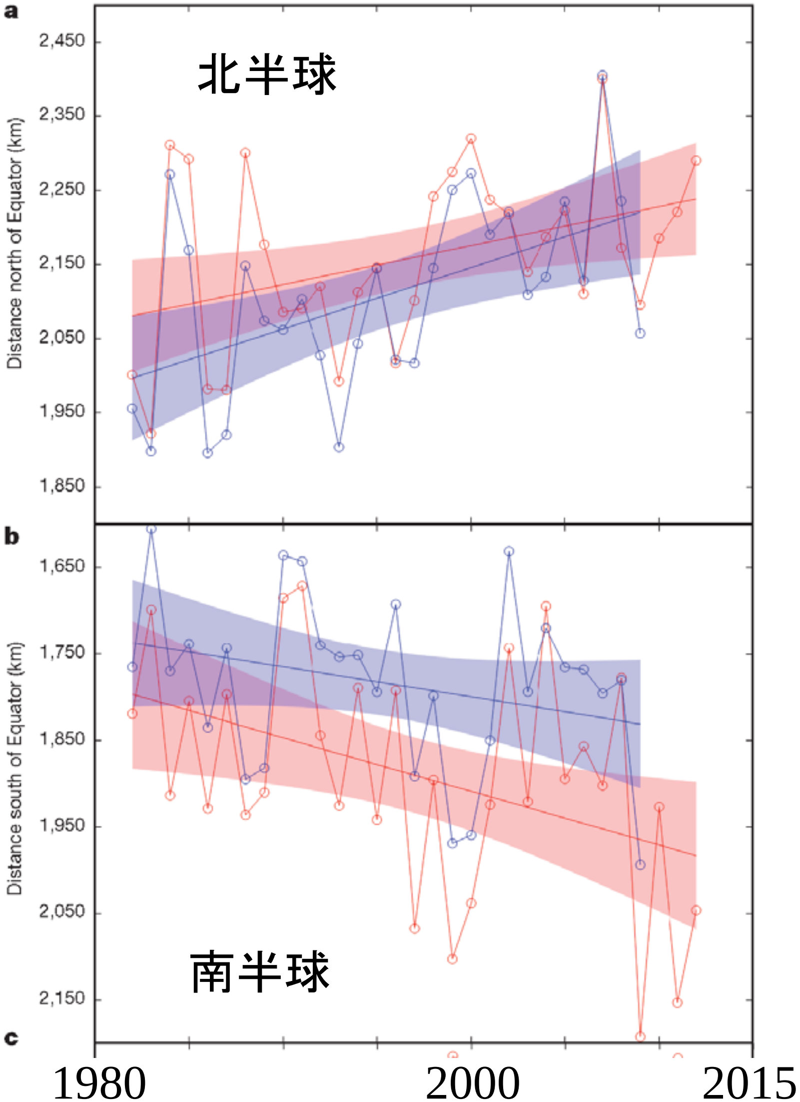
Typhoons are still the largest cause of natural disaster in Japan.

Flooding Kinu River on Sept. 20, 2015

After supertyphoon Haiyan in Nov. 2013

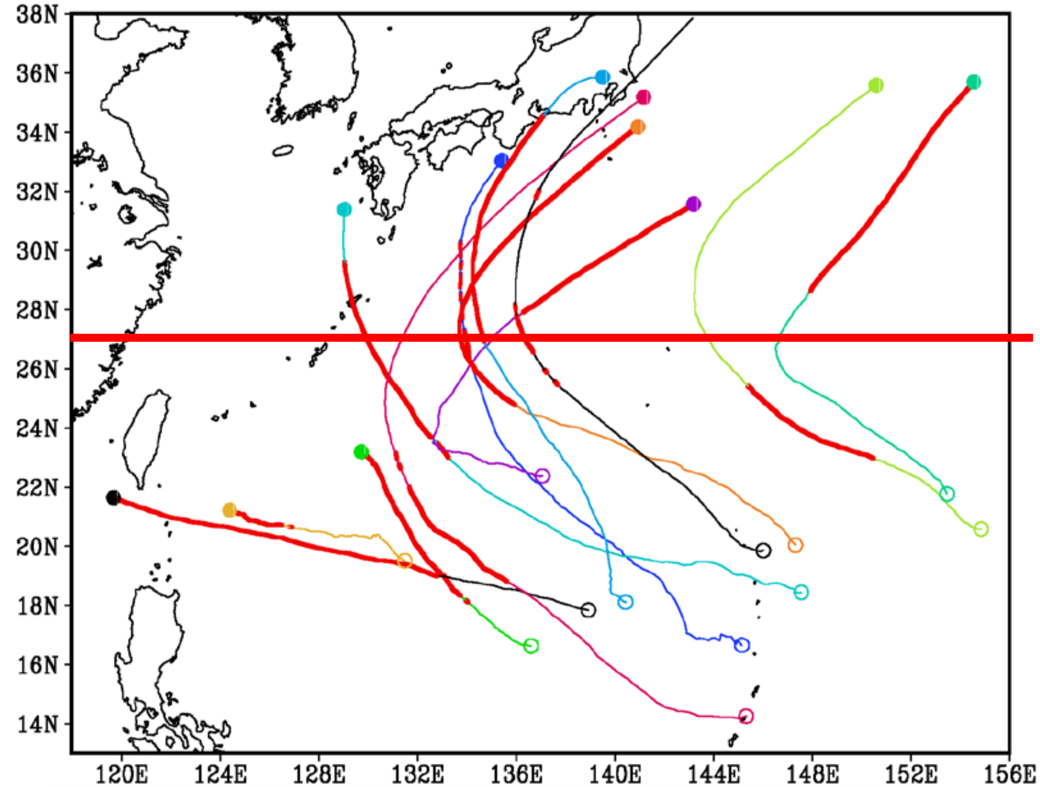
Increase of typhoon risk in mid-latitude regions

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



Kossin et al. (2014), *Nature*

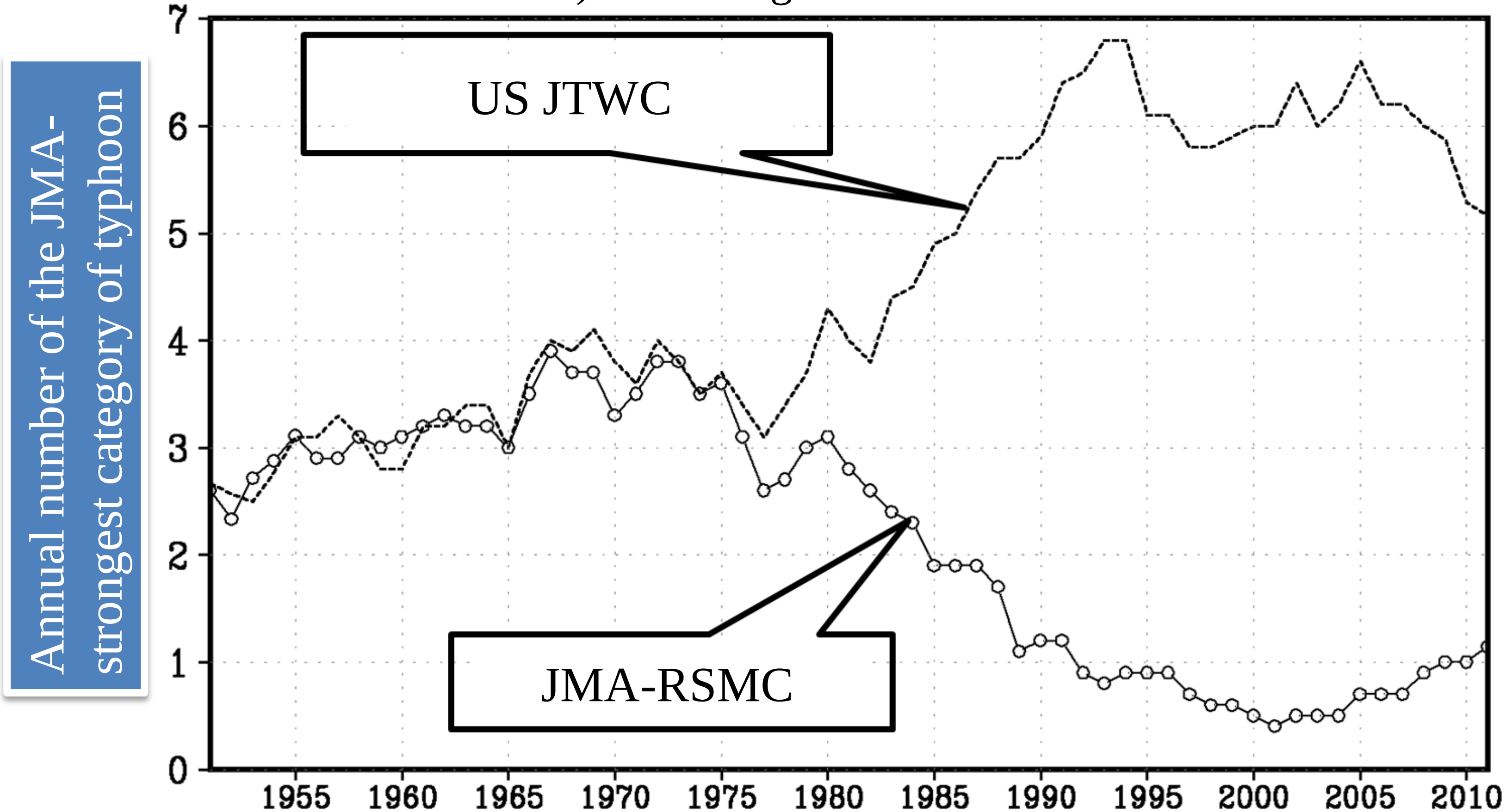
Owing to the climate change, a supertyphoon is projected to reach the main islands of Japan with keeping supertyphoon intensity



The thick and red lines indicate that wind speed is larger than 67m/s.

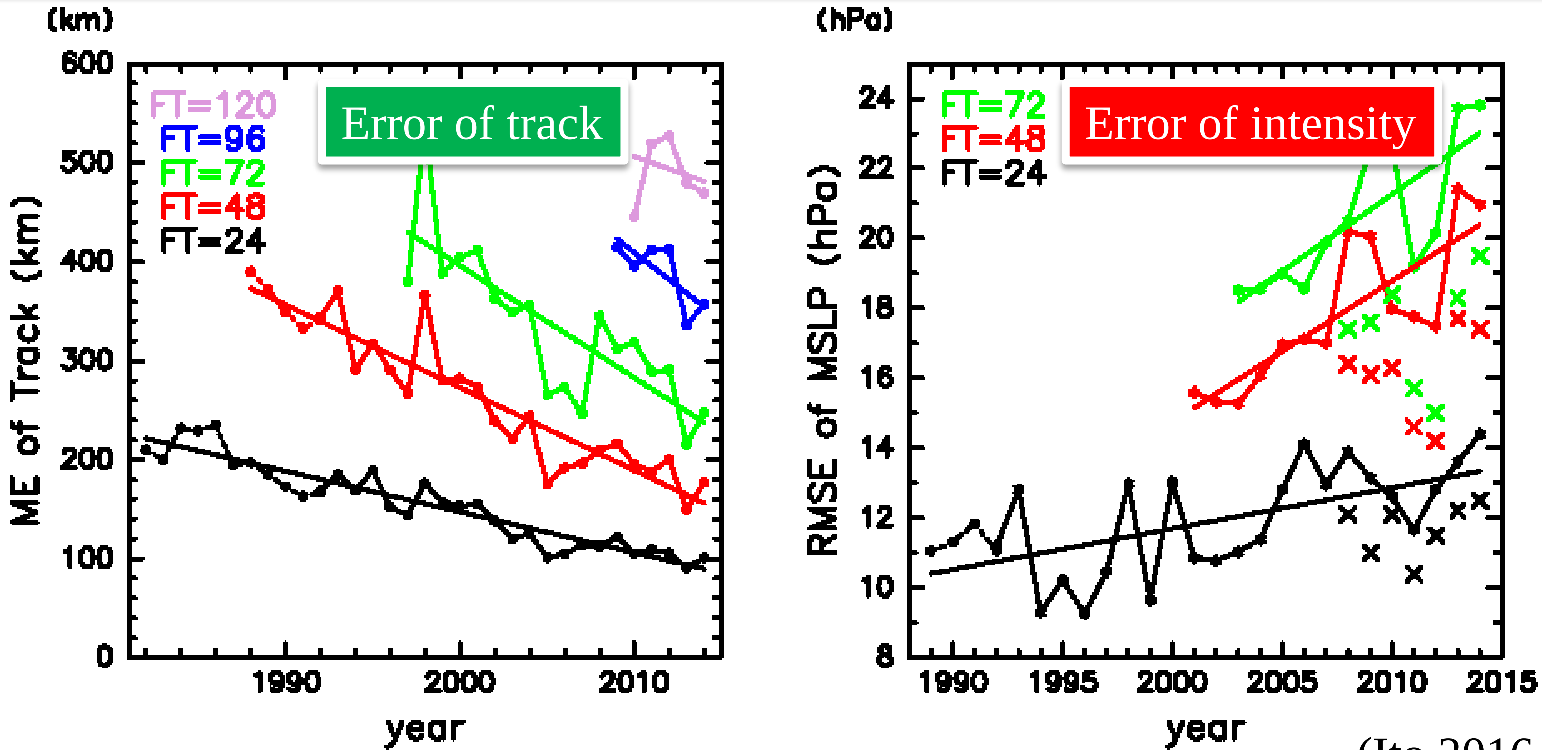
Tsuboki et al. (2015), *Geophysical Research Letters*

- These results raise great concern regarding future change in typhoon intensity in the western North Pacific.
- However, 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 without convective parameterization.**
- **Cloud microphysics, PBL model, Ocean model.**
- **And in-situ observation data.**

科研費基盤研究S:

研究課題名:「豪雨と暴風をもたらす台風の力学的・熱力学的・雲物理学的構造の量的解析」

科研費基盤研究Sによる台風の航空機観測計画:T-PARCII
(Tropical cyclones-Pacific Asian Research Campaign for Improvement of Intensity estimations/forecasts)

目標:

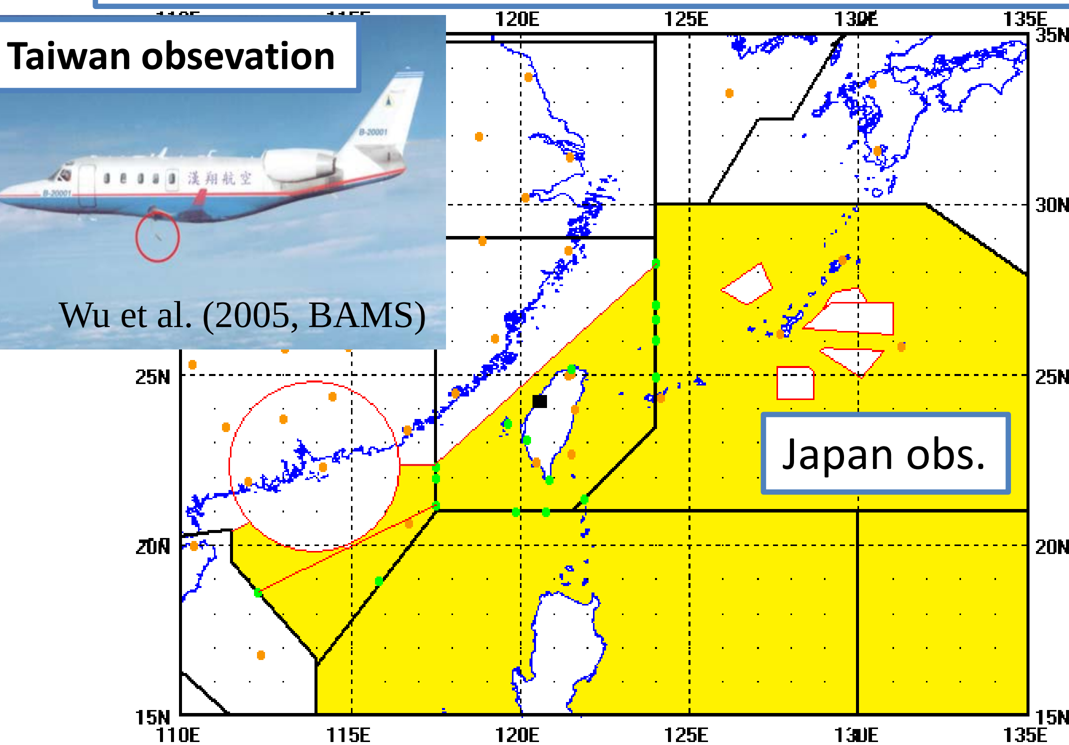
●　非常に強い台風、可能であればsupertyphoon（スーパー台風）の眼の壁雲の周辺にドロップゾンデを投下する観測を実施したい。
＝＞そのような強い台風が観測域に都合よく来るのか？来たとしてもそのような強い台風を航空機で観測できるだろうか？

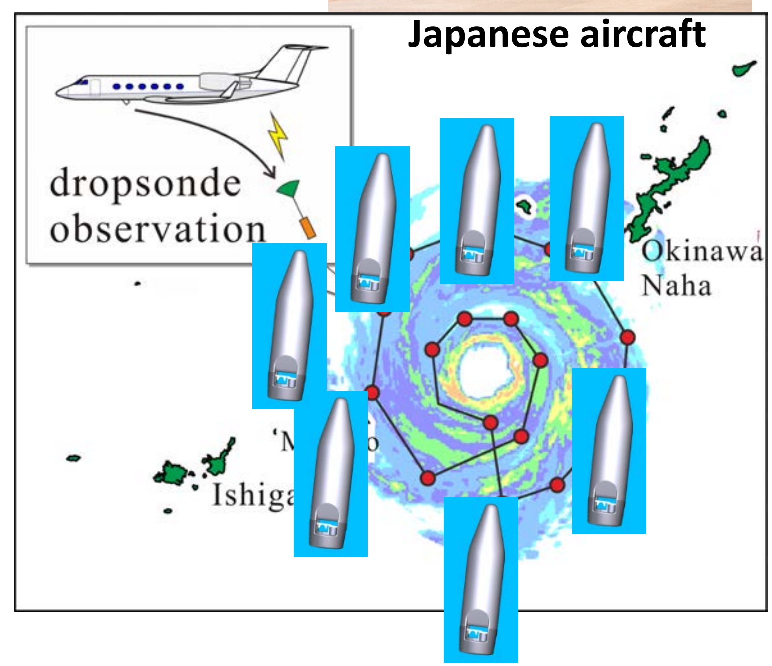
●　台風の航空機観測の先進国である台湾と共同観測を実施したい。
＝＞単独観測さえ難しいのに、国際協調観測が可能か？

●　台風の東側の水蒸気フラックス観測を実施したい（研究所リーダーシップ経費による）
＝＞そのような都合のよい場所に台風が来るだろうか？来たとしても、本州の近くでドロップゾンデが投下できるだろうか？

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.

- 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.

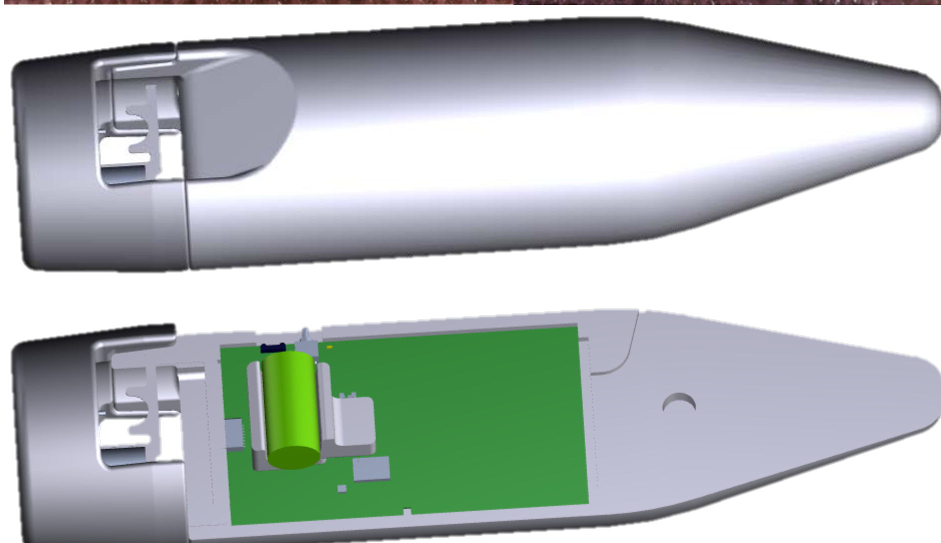




Newly developed dual two-channel receiver of dropsonde in GII
(Meisei electric Co and Nagoya University)

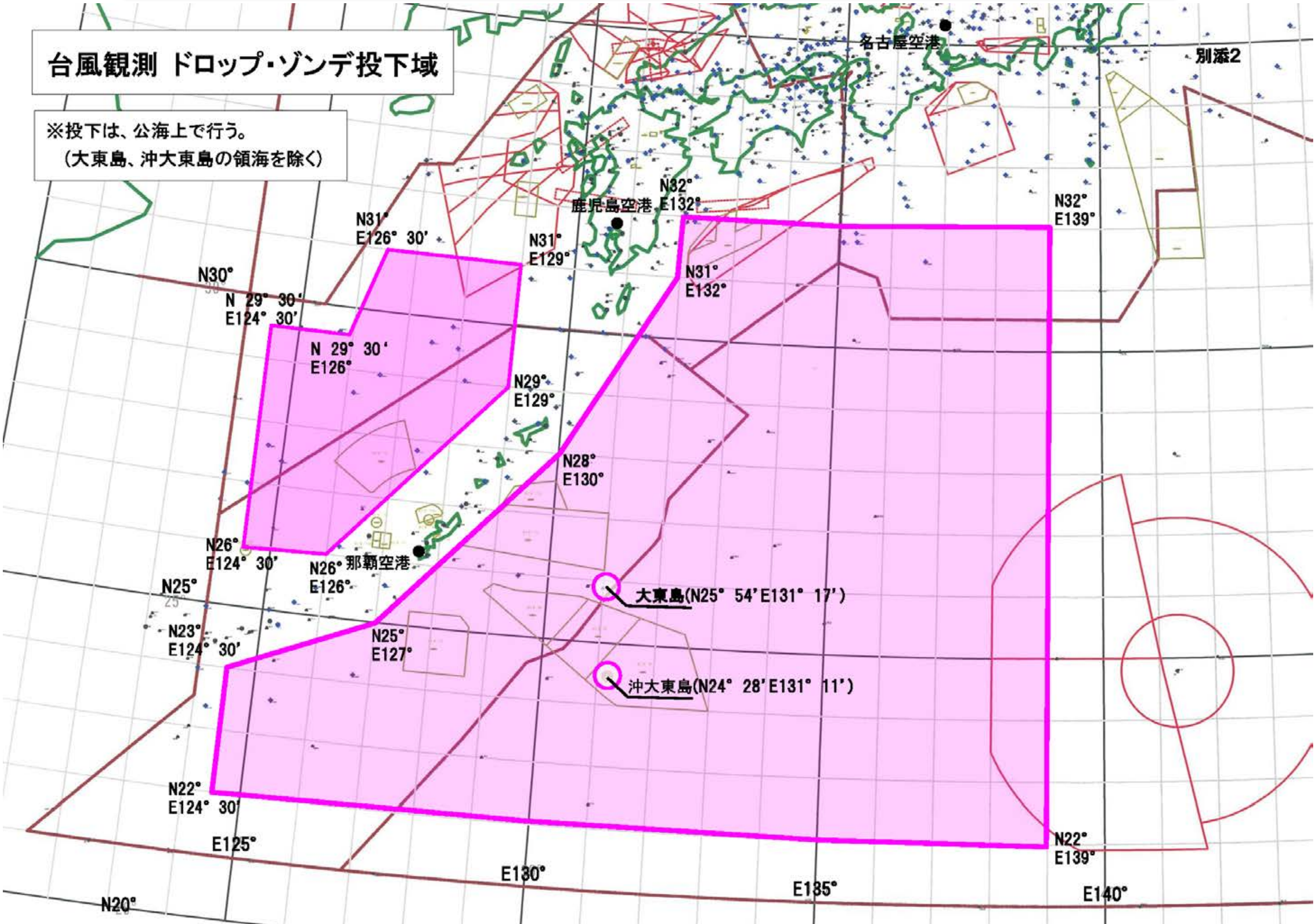
Newly developed dropsonde
(Meisei electric Co and Nagoya University)

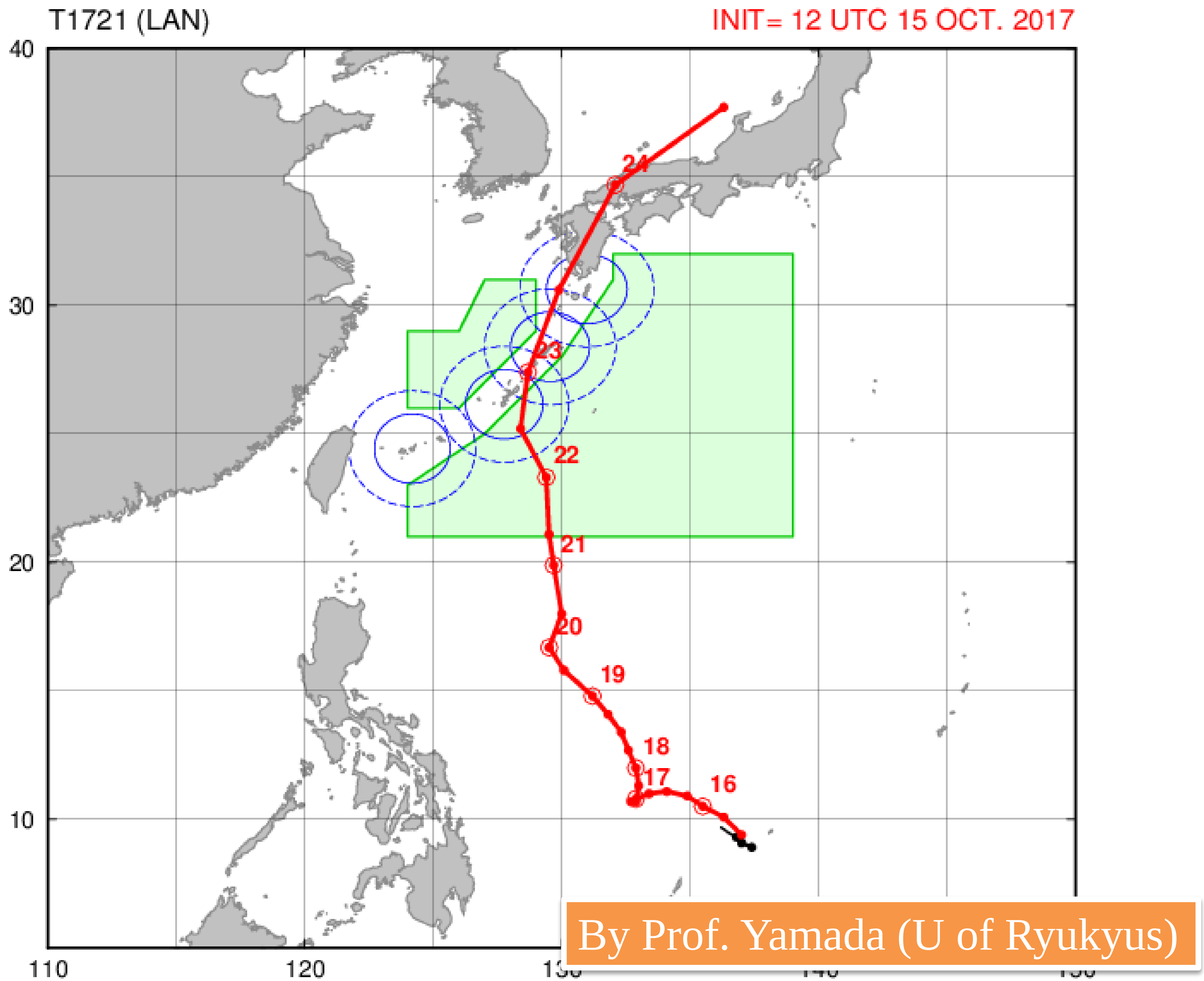
Dropsonde newly developed by Meisei Electric Co.



Specification		
Type name		iMDS-17
Accuracy in Lab.	Temperature	± 0.5 deg C
	Humidity	± 5% RH
	Pressure	±1 hPa
	Wind Speed	± 0.2 m/s
	Wind Dir.	± 5 degree
Sensor Type	Temperature	Thermistor
	Humidity	Capacitive
	Pressure	Silicon
	Wind	GPS
Weight		**110 g**
Dimension		**7cm φ x 28 cm**
Battery		CR123 x 1
Terminal spd		Approximately 13 m/s
Transmitter	Modulation	1200 BPS FSK
	Power	100 mW
	Freq. Step	100 kHz
	Freq. Band	400.1- 406.0

Observation areas of dropsonde





T1721 (LAN)
INIT= 12 UTC 15 OCT. 2017
40
30
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120
130
140
150
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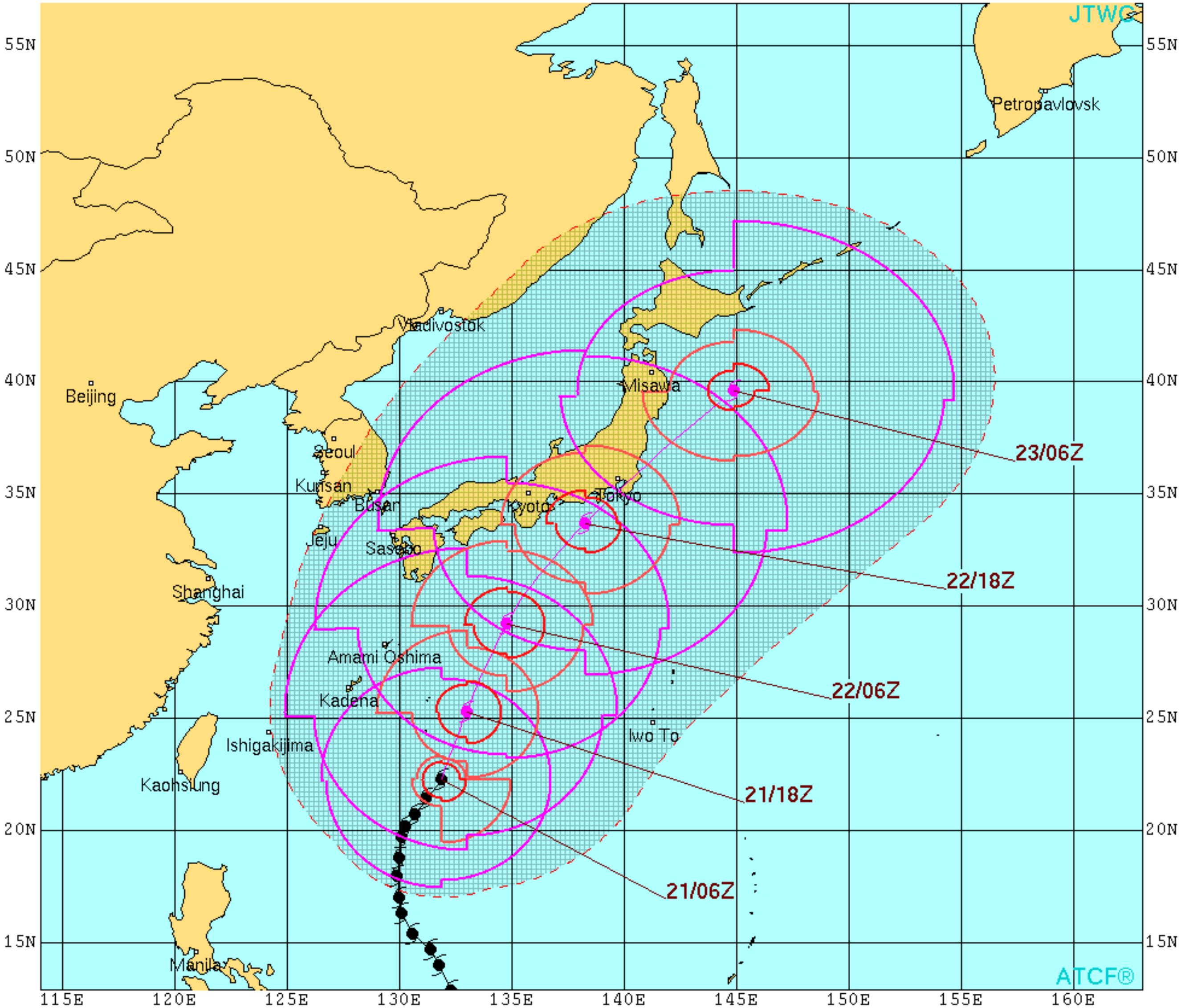
16
By Prof. Yamada (U of Ryukyus)

JTWC 20171021 06UTC: Supertyphoon LAN (2017)

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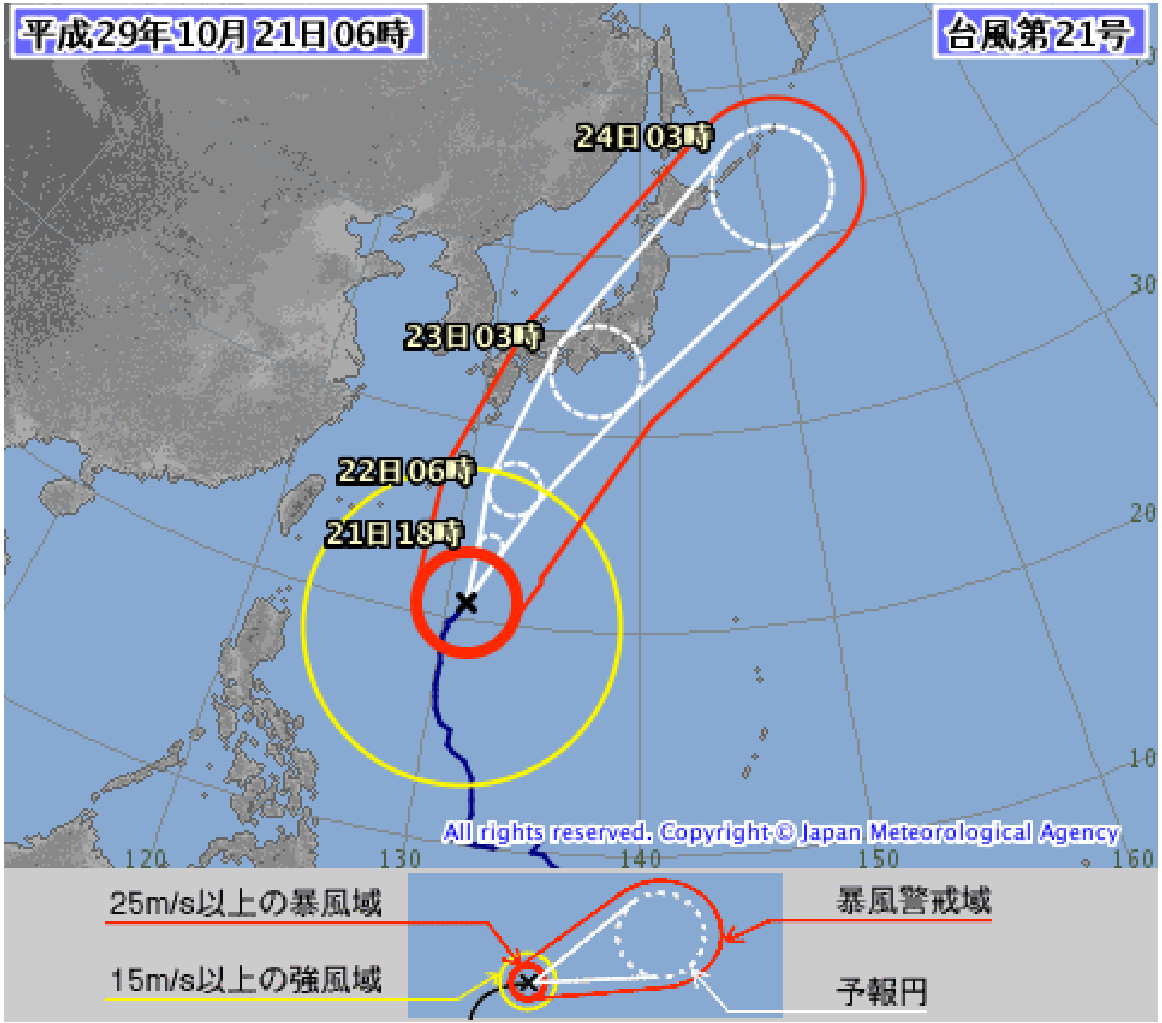
SUPER TYPHOON 25W (LAN) WARNING #24
WTPN32 PGTW 210900
210600Z POSIT: NEAR 22.3N 131.9E
MOVING 035 DEGREES TRUE AT 11 KNOTS
MAXIMUM SIGNIFICANT WAVE HEIGHT: 41 FEET
21/06Z, WINDS 130 KTS, GUSTS TO 160 KTS
21/18Z, WINDS 125 KTS, GUSTS TO 150 KTS
22/06Z, WINDS 115 KTS, GUSTS TO 140 KTS
22/18Z, WINDS 095 KTS, GUSTS TO 115 KTS
23/06Z, WINDS 070 KTS, GUSTS TO 085 KTS
```

CPA TO:	NM	DTG
KADENA_AB	290	21/18Z
SASEBO	339	22/09Z
IWAKUNI	264	22/13Z
R2RS	198	22/18Z
ATSUGI	31	22/21Z
CAMP_FUJI	38	22/21Z
CAMP_ZAMA	31	22/21Z
YOKOSUKA	18	22/21Z
YOKOTA_AB	36	22/22Z
NARITA_AIRPORT	18	22/23Z
SHARIKI	205	23/04Z
MISAWA	163	23/05Z

BEARING AND DISTANCE	DIR	DIST (NM)	TAU (HRS)
KADENA_AB	137	337	0

O LESS THAN 34 KNOTS
34-63 KNOTS
MORE THAN 63 KNOTS
PAST 6 HOURLY CYCLONE POSITS IN BLACK
FORECAST CYCLONE POSITS IN COLOR

Typhoon LAN（T1721) JMA forecast at 06 JST 21 Oct., 2017



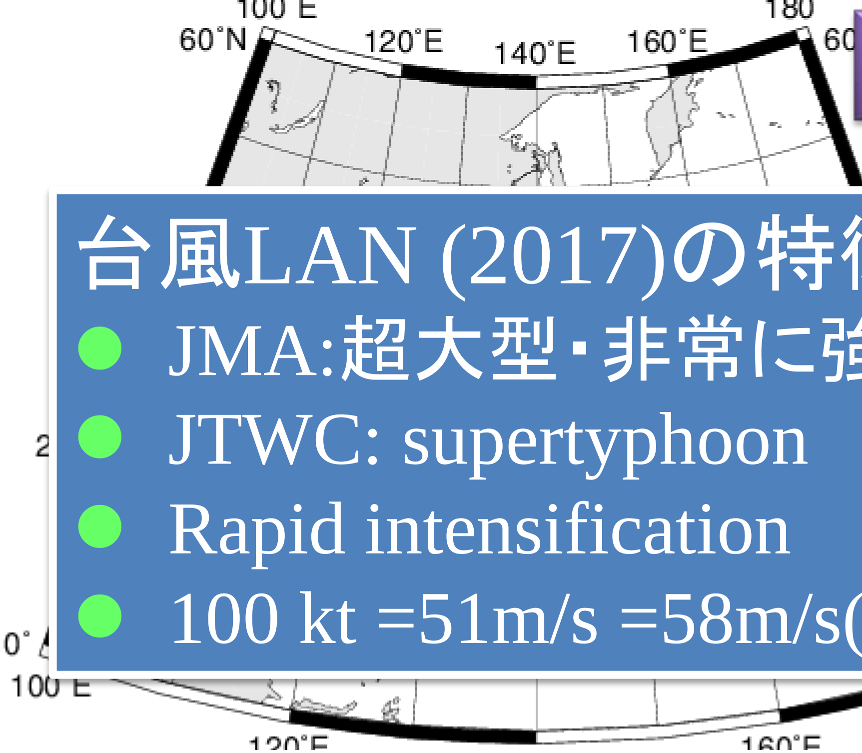
台風の 中心が予報円に入る確率は70%です。

非表示

台風第21号 (ラン)
平成29年10月21日06時45分 発表

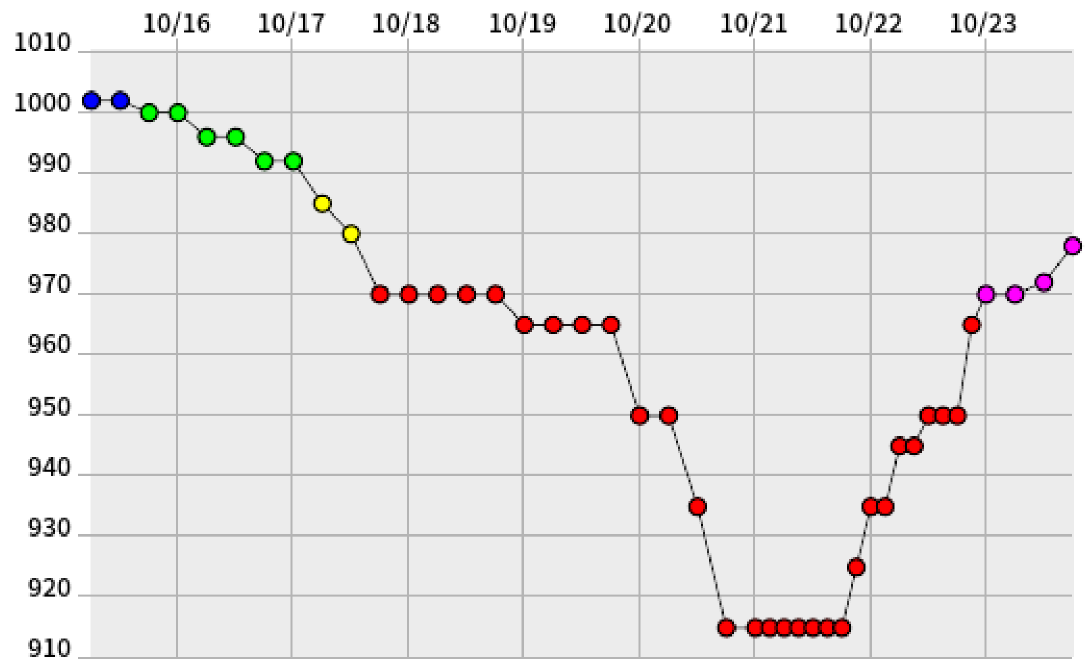
<21日06時の実況>	
大きさ	超大型
強さ	非常に強い
存在地域	日本の南
中心位置	北緯 21度00分(21.0度)
	東経 130度55分(130.9度)
進行方向、速さ	北北東 15km/h(8kt)
中心気圧	925hPa
中心付近の最大風速	50m/s(95kt)
最大瞬間風速	70m/s(135kt)
25m/s以上の暴風域	全域 280km(150NM)
15m/s以上の強風域	南側 950km(500NM)
	北側 750km(400NM)
<21日18時の予報>	
強さ	非常に強い
存在地域	南大東島の南約230km
予報円の中心	北緯 23度50分(23.8度)
	東経 131度40分(131.7度)
進行方向、速さ	北 25km/h(14kt)
中心気圧	925hPa
中心付近の最大風速	50m/s(95kt)
最大瞬間風速	70m/s(135kt)

Typhoon LAN (2017) [best track]



台風LAN (2017)の特徴

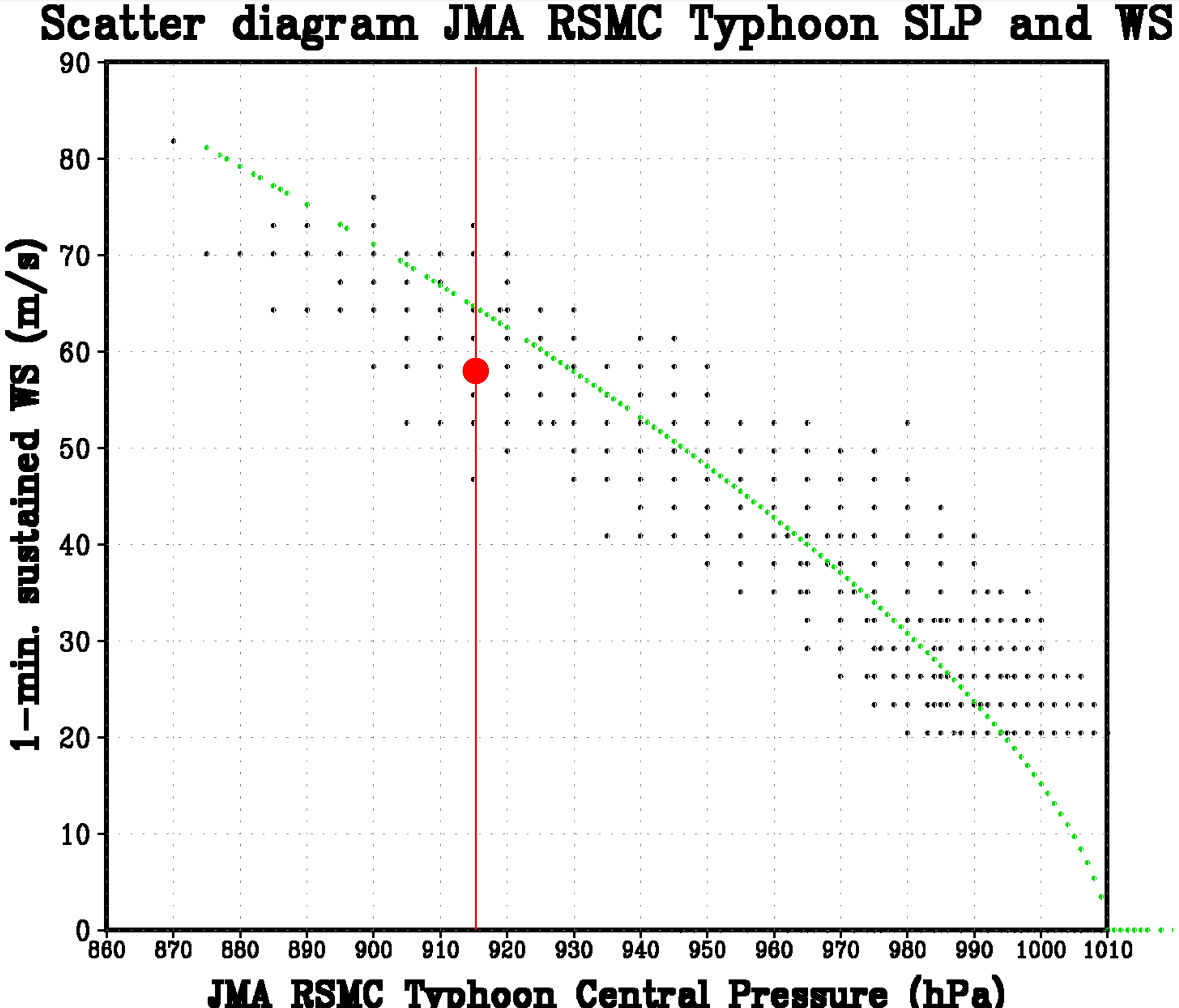
- JMA:超大型･非常に強い
- JTWC: supertyphoon
- Rapid intensification
- 100 kt =51m/s =58m/s(1min)

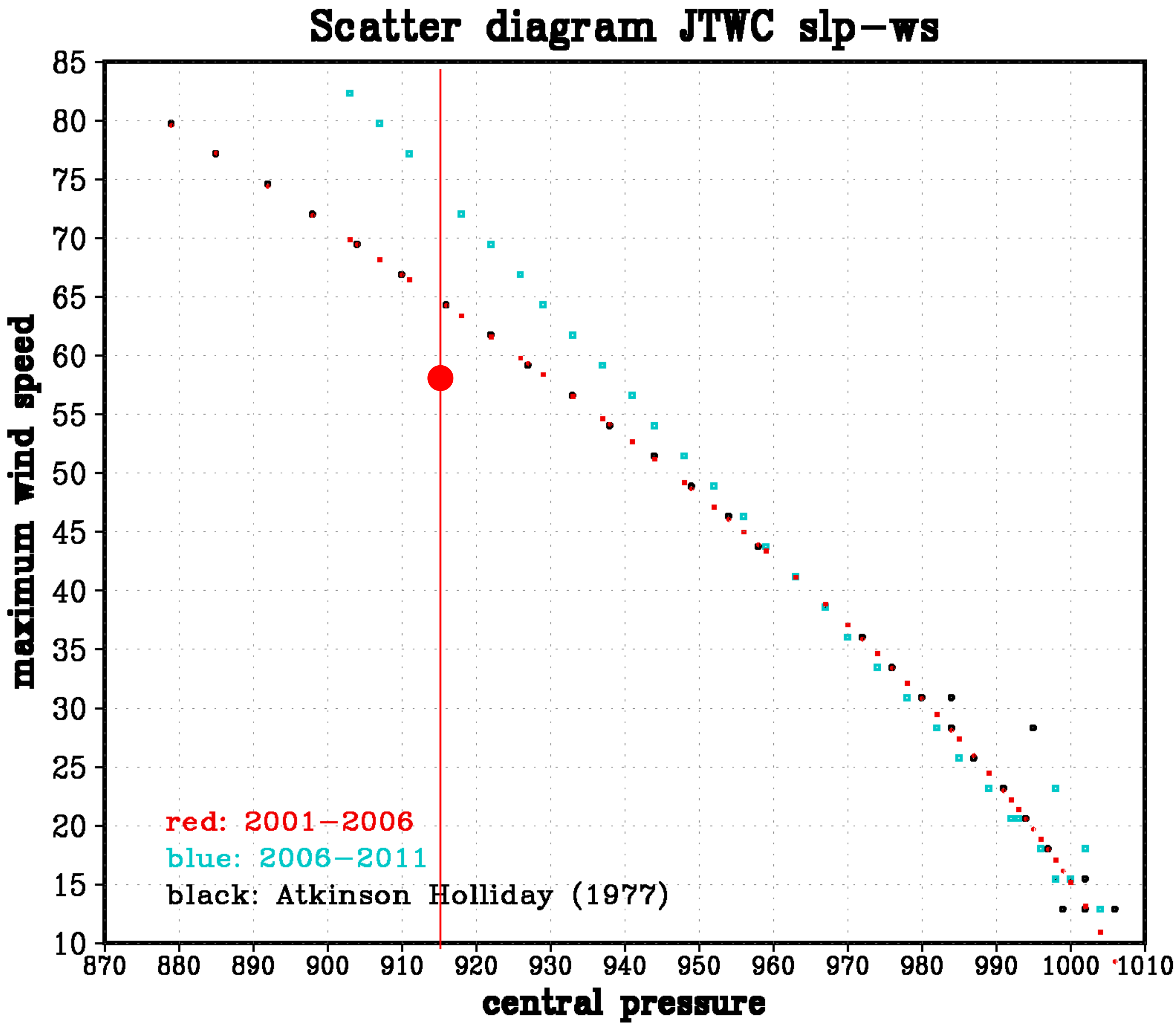


基本情報
発生日時
2017-10-15 18:00:00 UTC
消滅（最新）日時
2017-10-23 00:00:00 UTC
継続期間（寿命）

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

JMAのRSMCのベストトラックの風速と気圧の関係をA-H(1977)と比較したもの




Scatter diagram JTWC slp-ws
maximum wind speed
central pressure
85
80
75
70
65
60
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45
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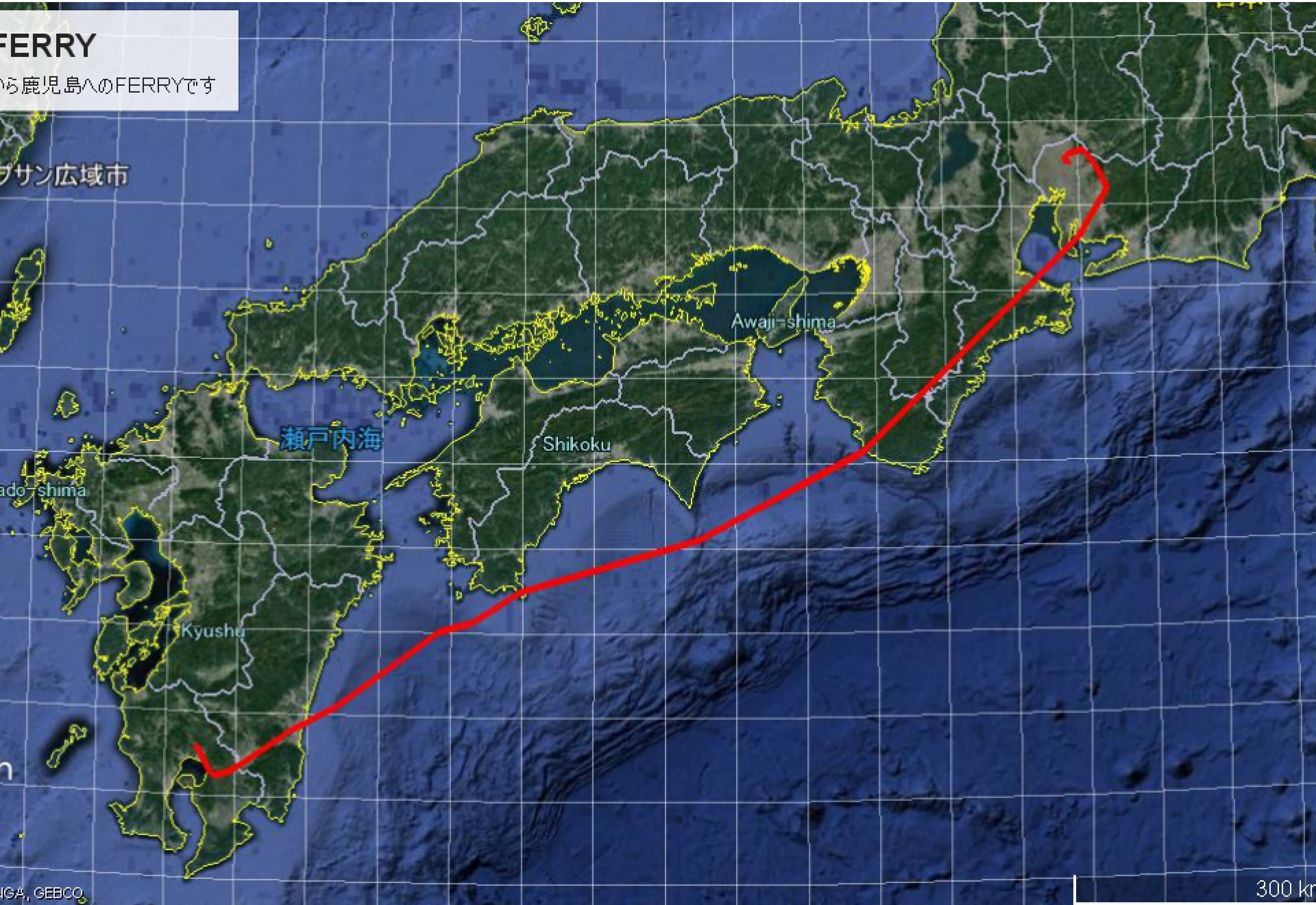
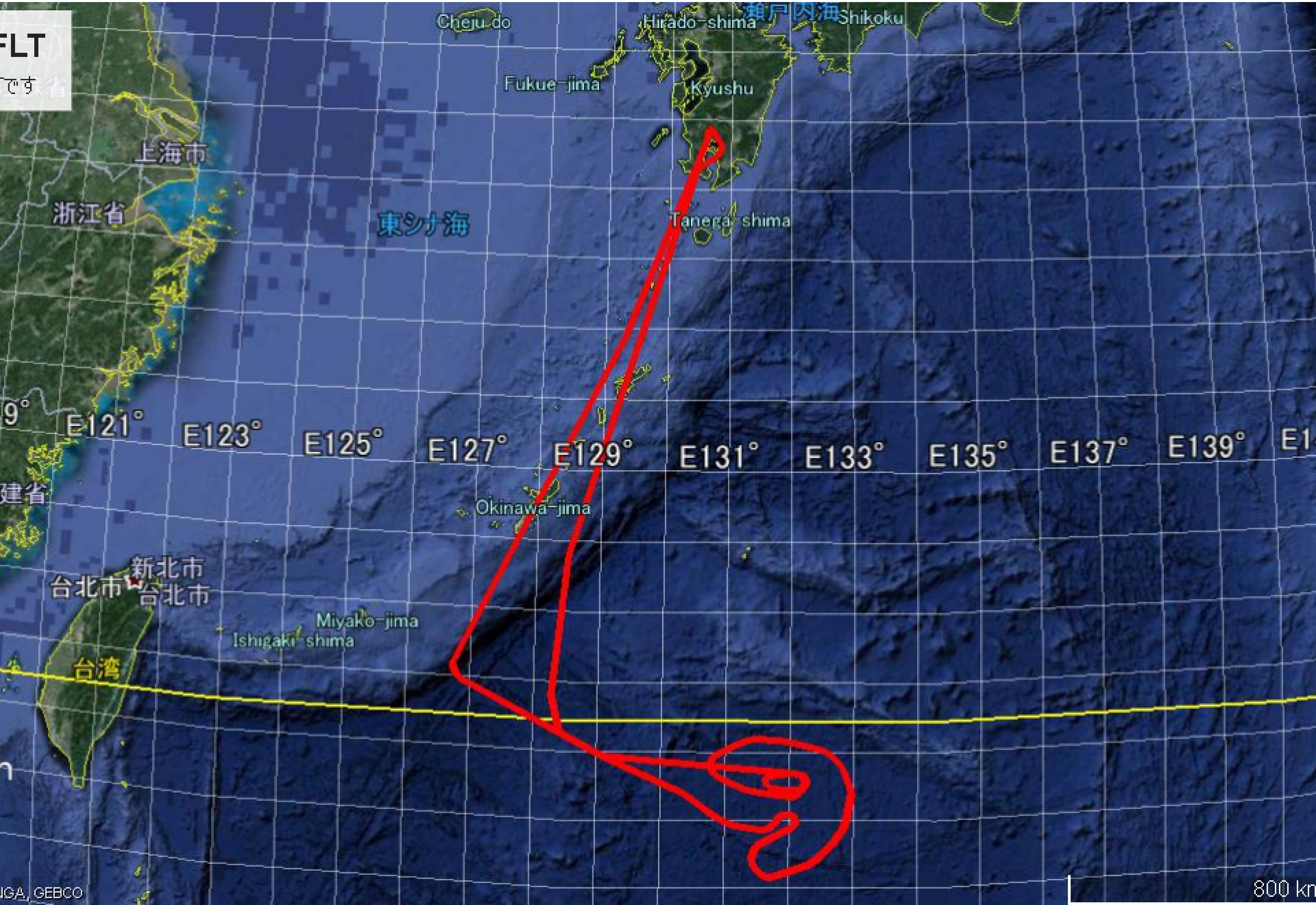
25
20
15
10
870
880
890
900
910
920
930
940
950
960
970
980
990
1000
1010
red: 2001-2006
blue: 2006-2011
black: Atkinson Holliday (1977)

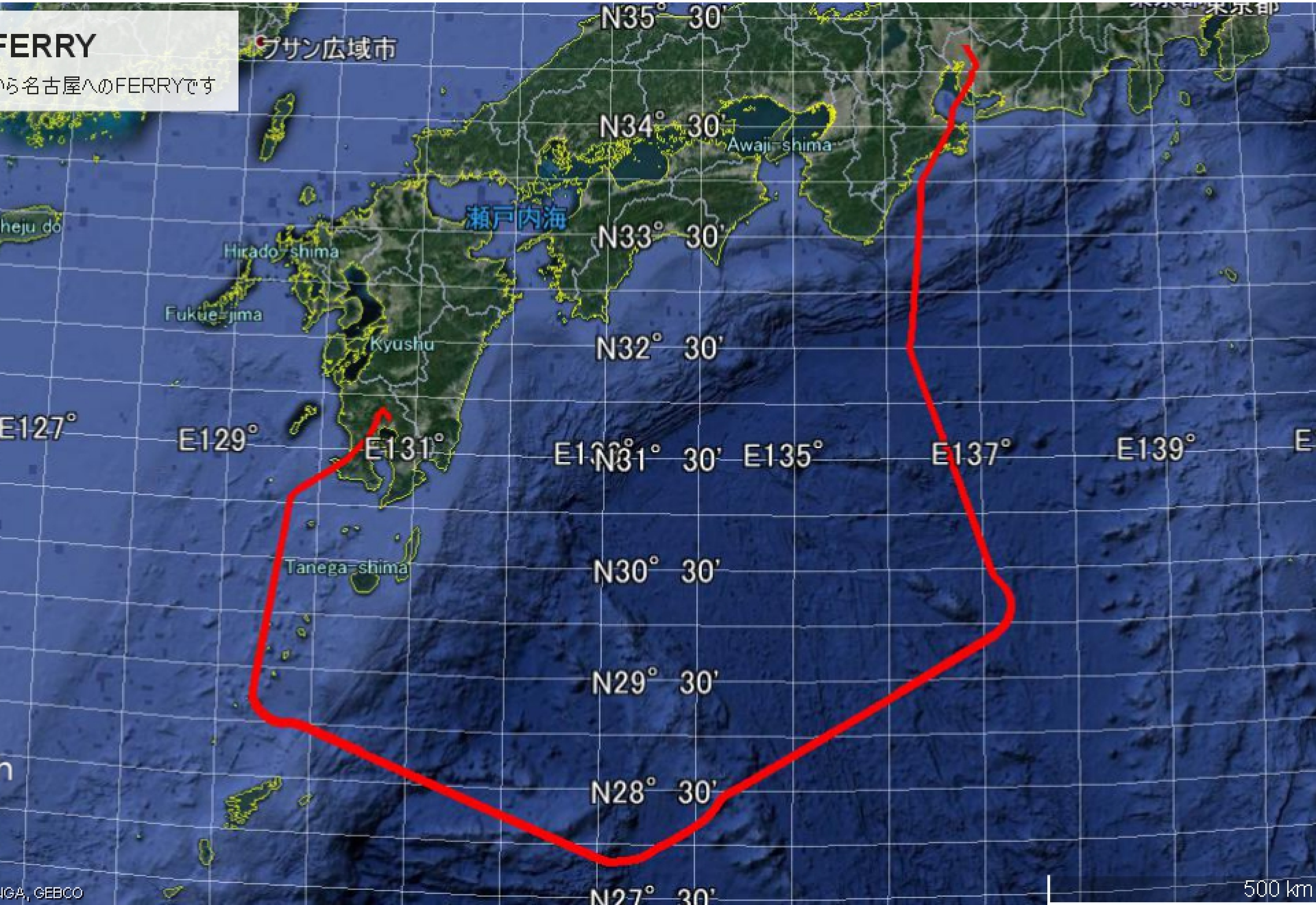
Flight pass of GII ferry from Nagoya-Komaki to Kagoshima

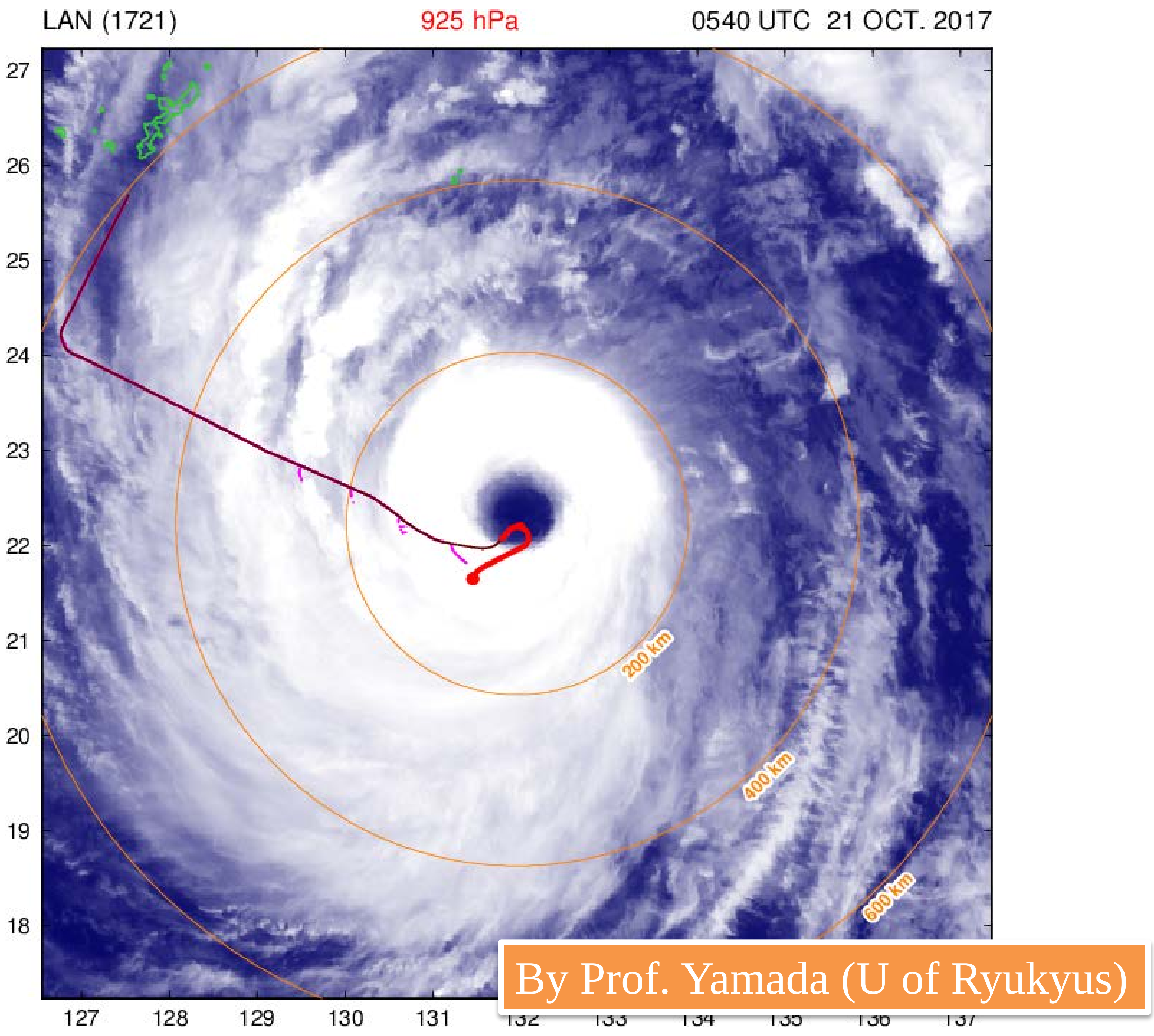


Flight pass of observation from Kagoshima to Kagoshima



Flight pass of observation from Kagoshima to Nagoya-Komaki




LAN (1721)
925 hPa
0540 UTC 21 OCT. 2017
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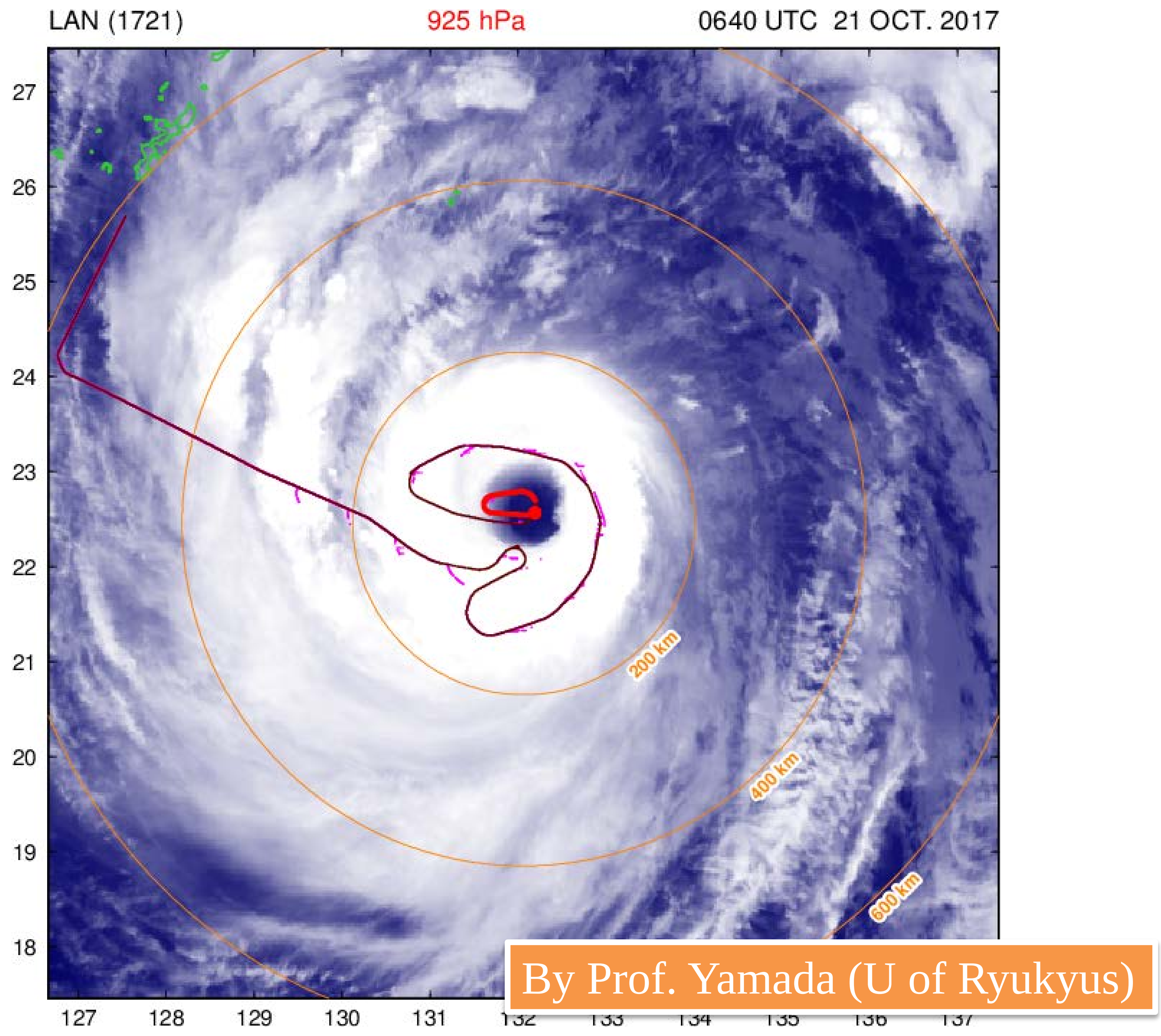
200 km
400 km
600 km
By Prof. Yamada (U of Ryukyus)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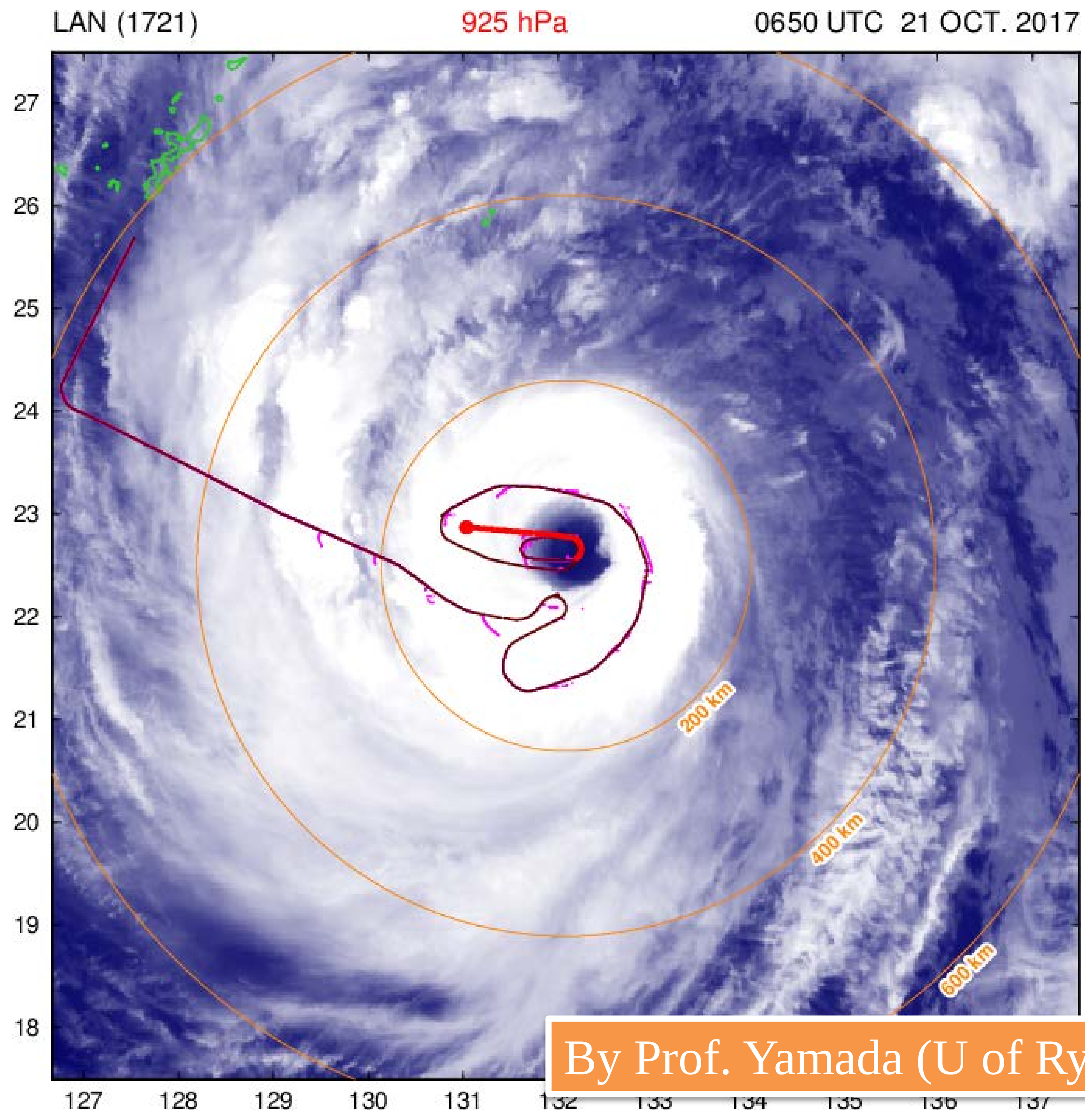


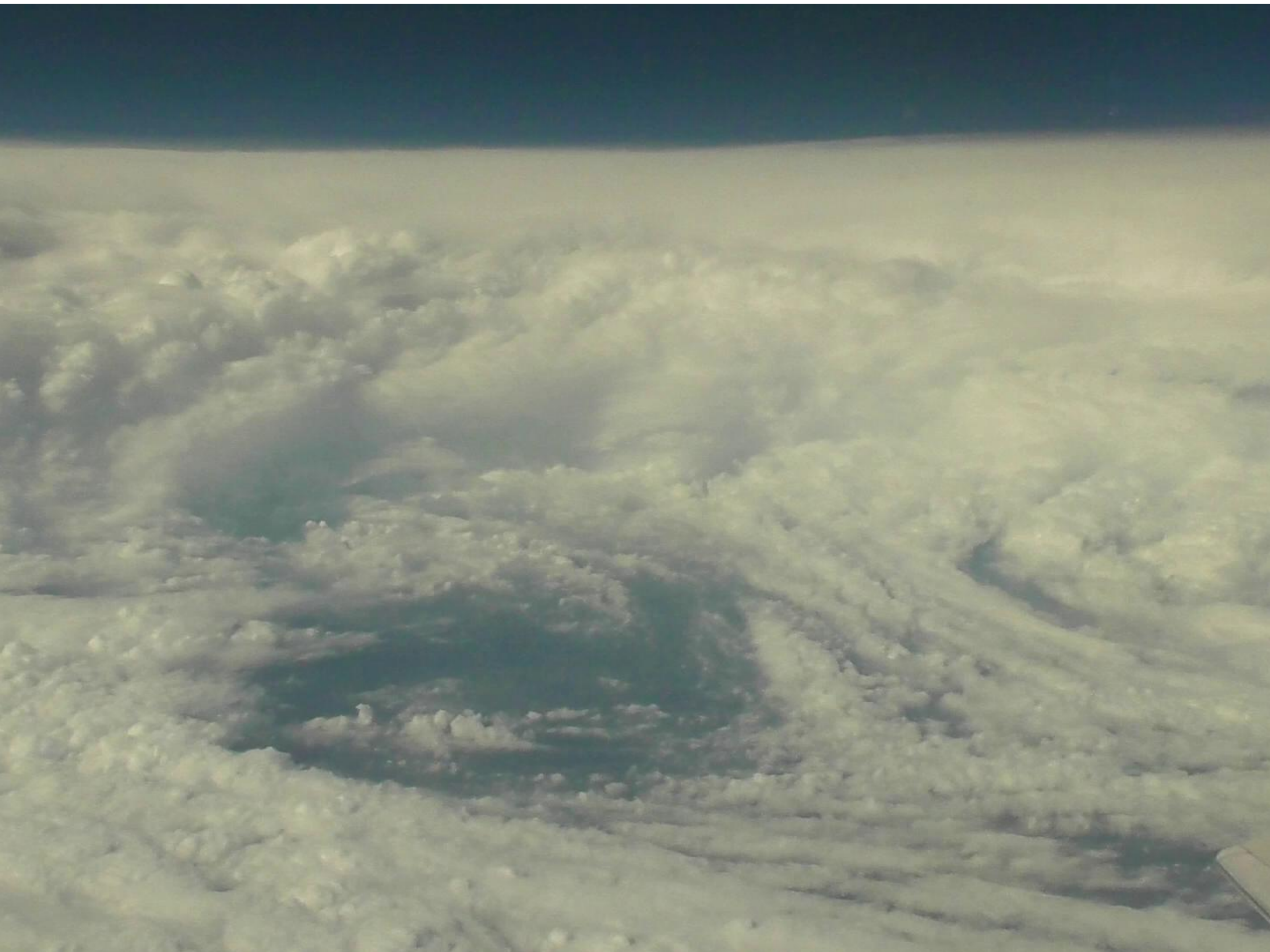
By Prof. Yamada (U of Ryukyus)

From: Peter Black - NOAA Affiliate
Date: Sun, 22 Oct 2017 19:30:50 -0700
Subject: Re: [Tropical-storms] Fwd: [T-PARCII-obs:0218] Re: [T-PARCII-advisory-board:0027] Re: dropsonde observation to typhoon Lan
To: Kazuhisa Tsuboki

Dear Tsuboki-san-

There is nothing so exciting in this world as flying into the eye of a major hurricane. It is another world that opens up as you penetrate from turbulence and darkness into the calm, clear eye like the curtain opening on the stage of a famous play. This is such a spectacular and magical place. ・・・・・

Again I congratulate you and your team. ・・・・



科研費基盤研究Sによる台風の航空機観測計画：T-PARCII
(Tropical cyclones-Pacific Asian Research Campaign for Improvement of Intensity estimations/forecasts)：

今年度の達成点：

● 非常に強い台風、可能であればsupertyphoon（スーパー台風）の眼の壁雲の周辺にドロップゾンデを投下する観測を実施したい。
＝＞達成：スーパー台風で超大型の台風（日本に多くの被害）の観測を実施。

● 台風の航空機観測の先進国である台湾と共同観測を実施したい。
＝＞達成：台湾と共同観測を実施。日本は06UTC, 21, 00UTC 22, 台湾12 UTC 21, Sept. 2017の観測を実施。

● さらに眼の中の観測を実施：21日に2回、22日に1回眼に突入。この想定外のプラスアルファの成果が得られた。

● 台風の東側の水蒸気フラックス観測を実施したい（研究所長リーダーシップ経費による）
＝＞達成：22日、鹿児島から小牧空港への帰還飛行において、非常に強い台風で超大型の台風の東側でドロップゾンデ観測を実施。

今後の予定

- ◆航空機GIIからGIVへの機種変更？
- ◆2018年度：SATREPS (研究代表者：高橋幸弘教授（北海道大学）)との協調観測。Philippines領域から沖縄領域にかけての台風観測
- ◆2018年度末：科研費基盤研究S中間評価
- ◆2019年度：未定
- ◆2020年度：PRECIP (PI: M. Bell (CSU))との協調観測。南西諸島・台湾領域での観測

台風研究と航空機観測のロードマップ

	実施中の基盤研究(S)	次申請の基盤研究(S) 気象学会の大型研究	気象学会の大型研究
航空機観測	◆ 台風の航空機観測のパイロット研究 ◆ 台風の航空機観測技術の高度化	台風、豪雨、エアロゾル、温室効果気体の航空機観測技術の確立	台風の現業観測・監視
台風予測	航空機観測の入力による台風予測の改善	航空機観測と数値予報の双方向通信による台風予測	現業的航空機観測による台風の双方向通信による予測
国際協力	台湾との共同観測	台湾・韓国・香港との共同観測	東アジア地域の国々との国際協力による台風の監視と予測
	ガルフストリームII	ガルフストリームIV	MRJ
	2016年	2020年	2025年

名古屋大学宇宙地球環境研究所の飛翔体観測推進センターは国内の航空機観測の中核的役割を担う