Hindcast and historical assessment of Cyclone Tomas and climate change impact analysis on tropical cyclones in the South Pacific

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Introduction

- Islands in South Pacific are extremely sensitive and vulnerable against coastal climate change. Sea level rise will cause significant impacts on these small southern islands.
  - For example, in Fiji the inundation by the swell and coastal disaster has occurred at the south coast.
- Moreover climate change also may affect tropical cyclone (TC) intensity in the future climate.

Purpose

- In this study, we have investigated the impact of TC locally and historically. We have selected TC Tomas in Fiji as a case study,
  1. Conducting the hindcast simulation
  2. Examining how large Tomas intensity was historically
  3. Investigating whether TC intensity in South Pacific will vary due to the climate change

Outline

TC Tomas

1. Hindcast TC Tomas

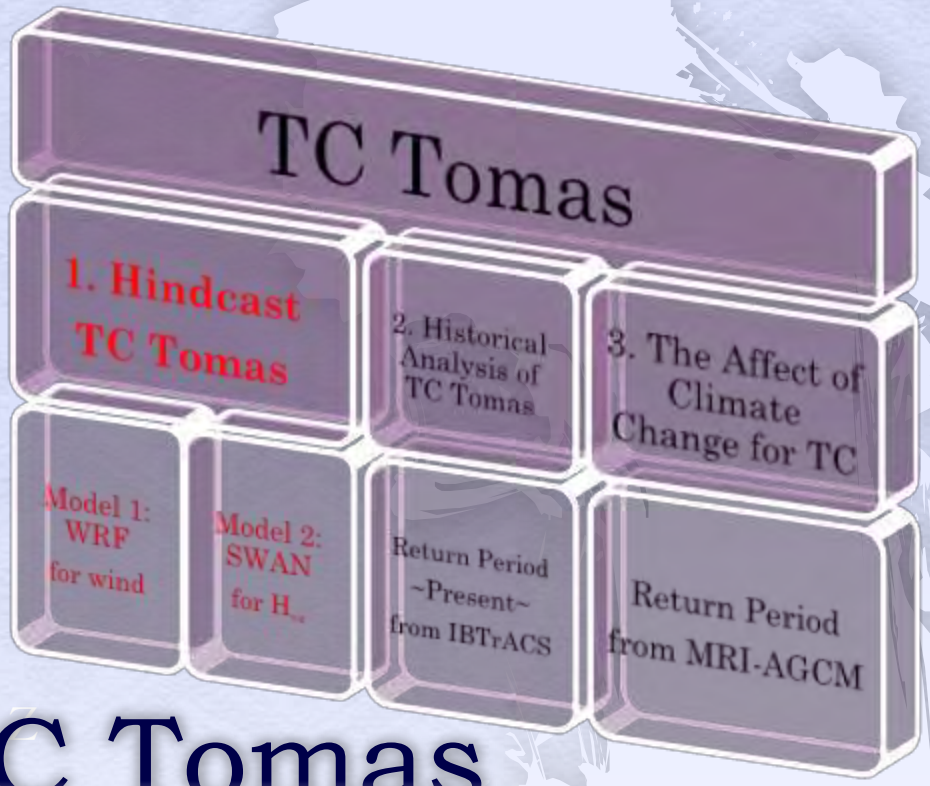
- Model 1: WRF for wind
- Model 2: SWAN for H_{sig}

2. Historical Analysis of TC Tomas

- Return Period from IBTrACS

3. The Affect of Climate Change for TC

- Return Period from MRI-AGCM

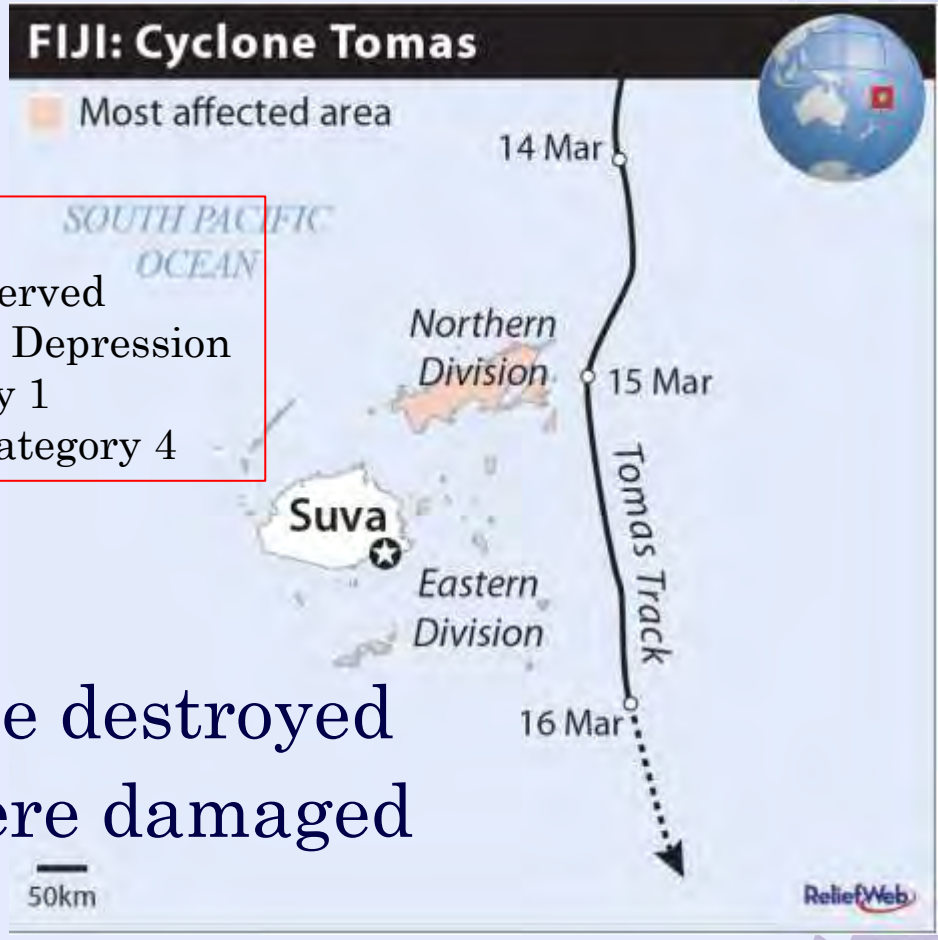


1. Hindcast TC Tomas

About TC Tomas

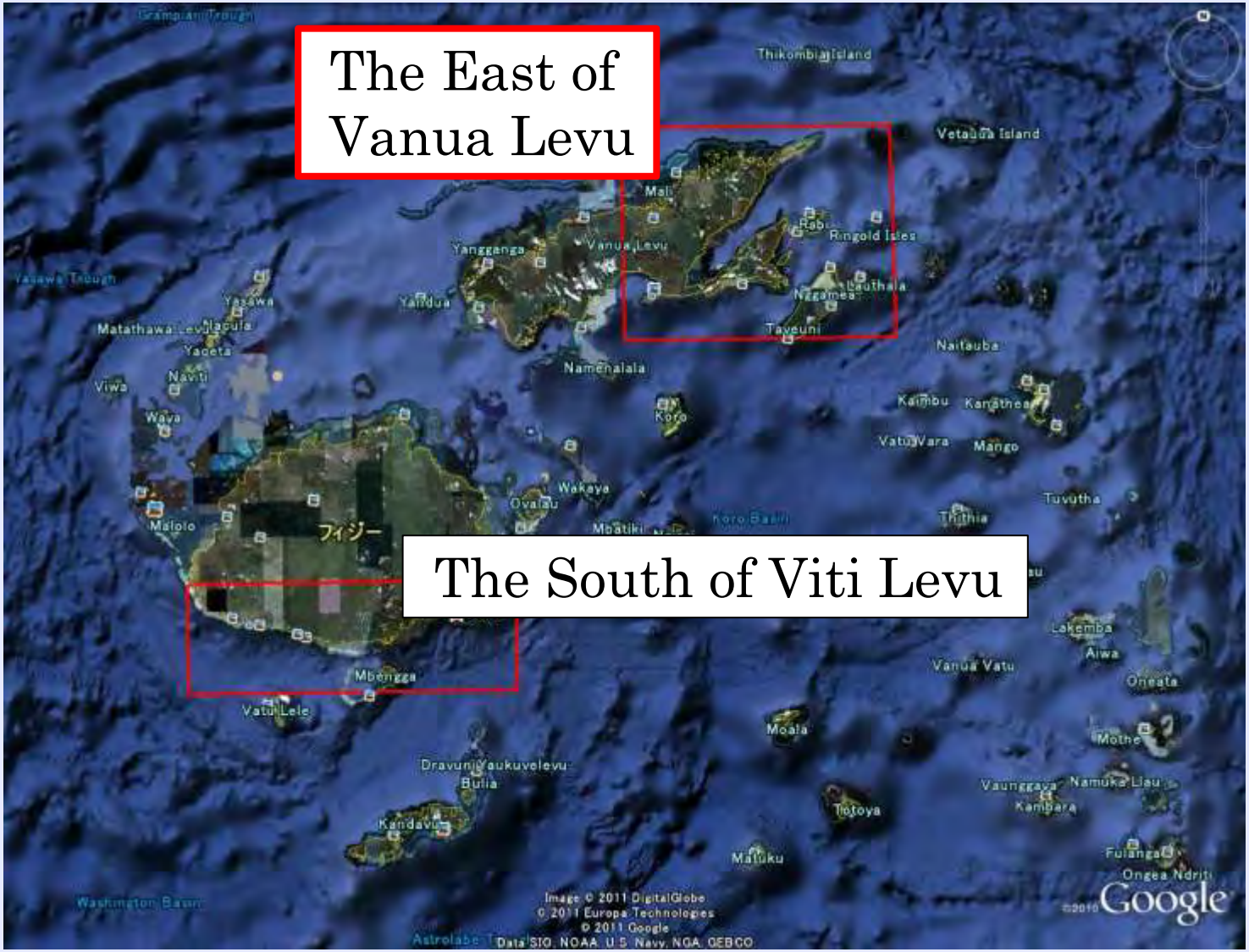
- The Minimum Pressure : 944 hPa
- The Average Sustained Winds :
  51 m/s (= 100 knots)
  - Momentary Winds :
    72 m/s (= 140 knots)

Time Series
1. 10th, Mar. : first observed
2. 11th,Mar. : Tropical Depression
3. 12th, Mar. : Category 1
4. Within 84 hours : Category 4

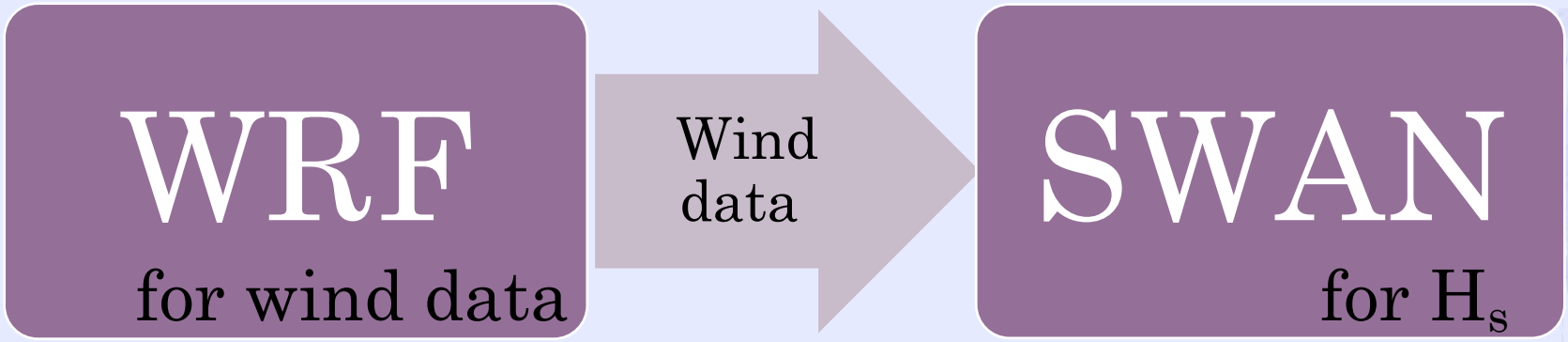


- The Damage
  - Two lives dead
  - Over 500 houses were destroyed
  - Over 1150 houses were damaged

The research fields

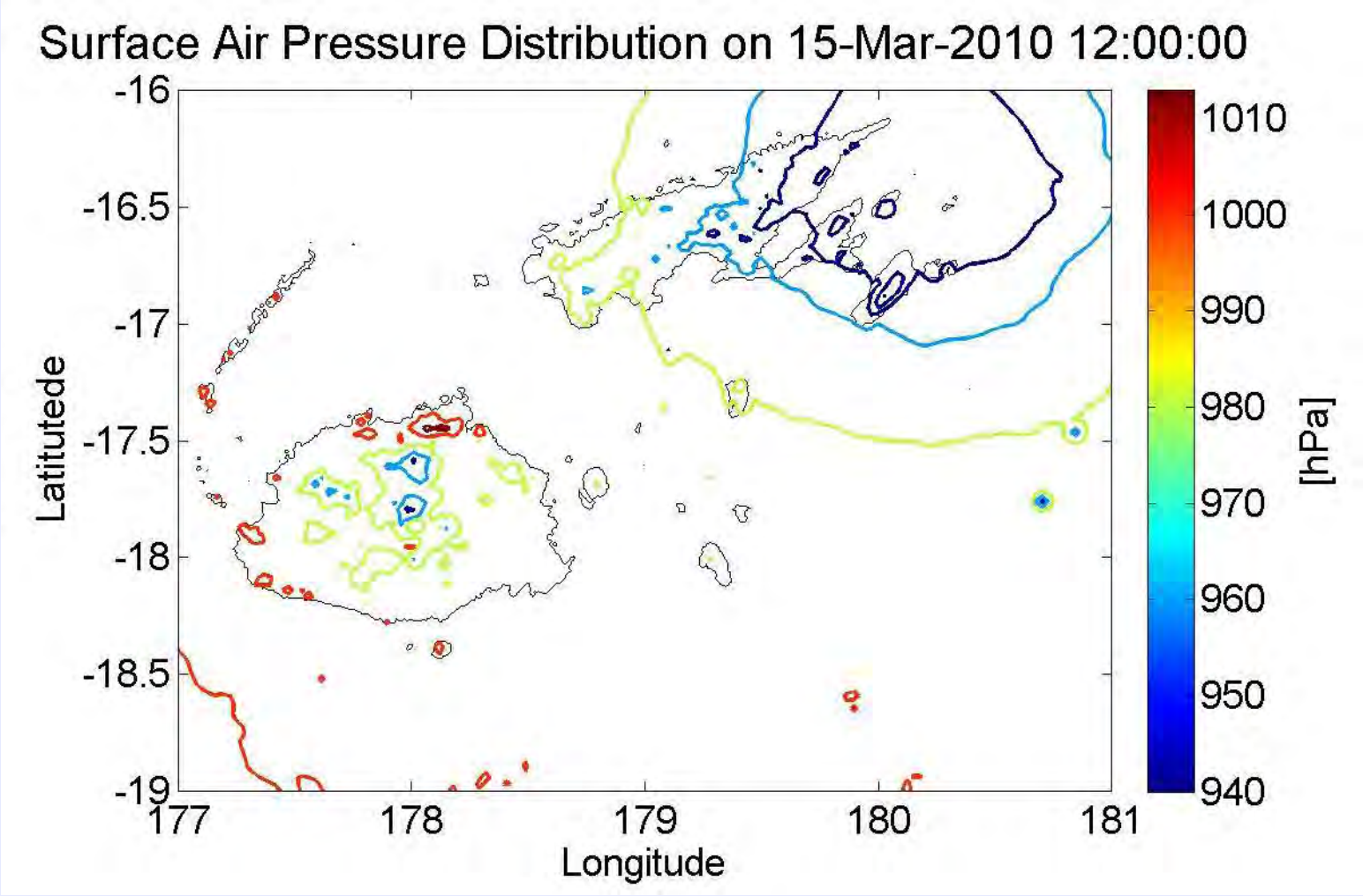


Numerical Information of WRF and SWAN



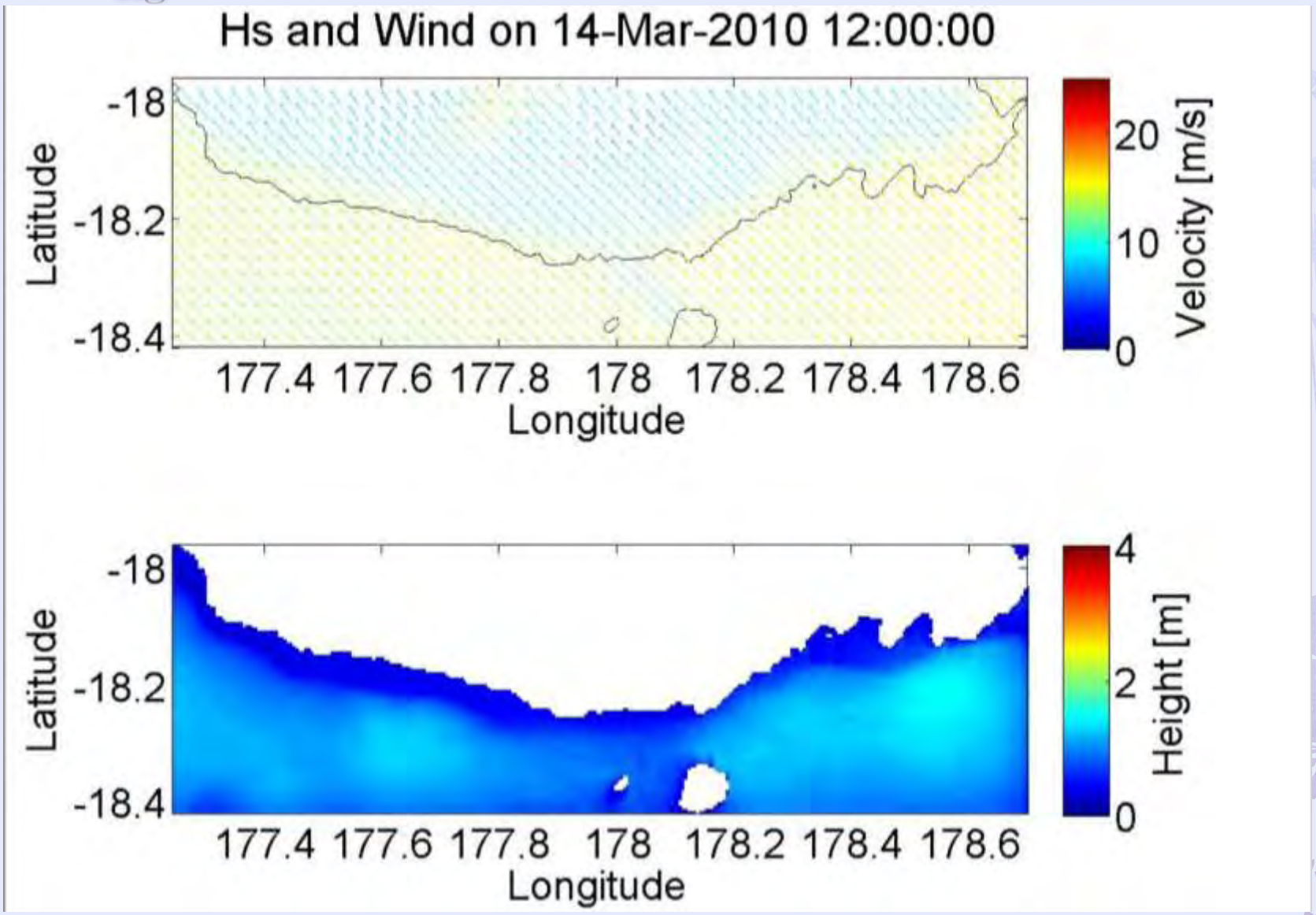
	WRF	**SWAN ver. 40.81**
Simulation Period	12th, Mar, '11 0:00 – 17th,Mar 0:00 (UTC)	13th, Mar, '11 12:00 – 16th,Mar 11:50 (UTC)
Resolution	3 km mesh size	500 m mesh size
Time step	6 sec	10 min
Initial & Boundary Condition	NCEP FNL Operational Global Analysis data	Cold Start
Topology data	GTOPP30	GEBCO (30 sec mesh data)

The Results of Simulation ~ Air Pressure Gradient ~



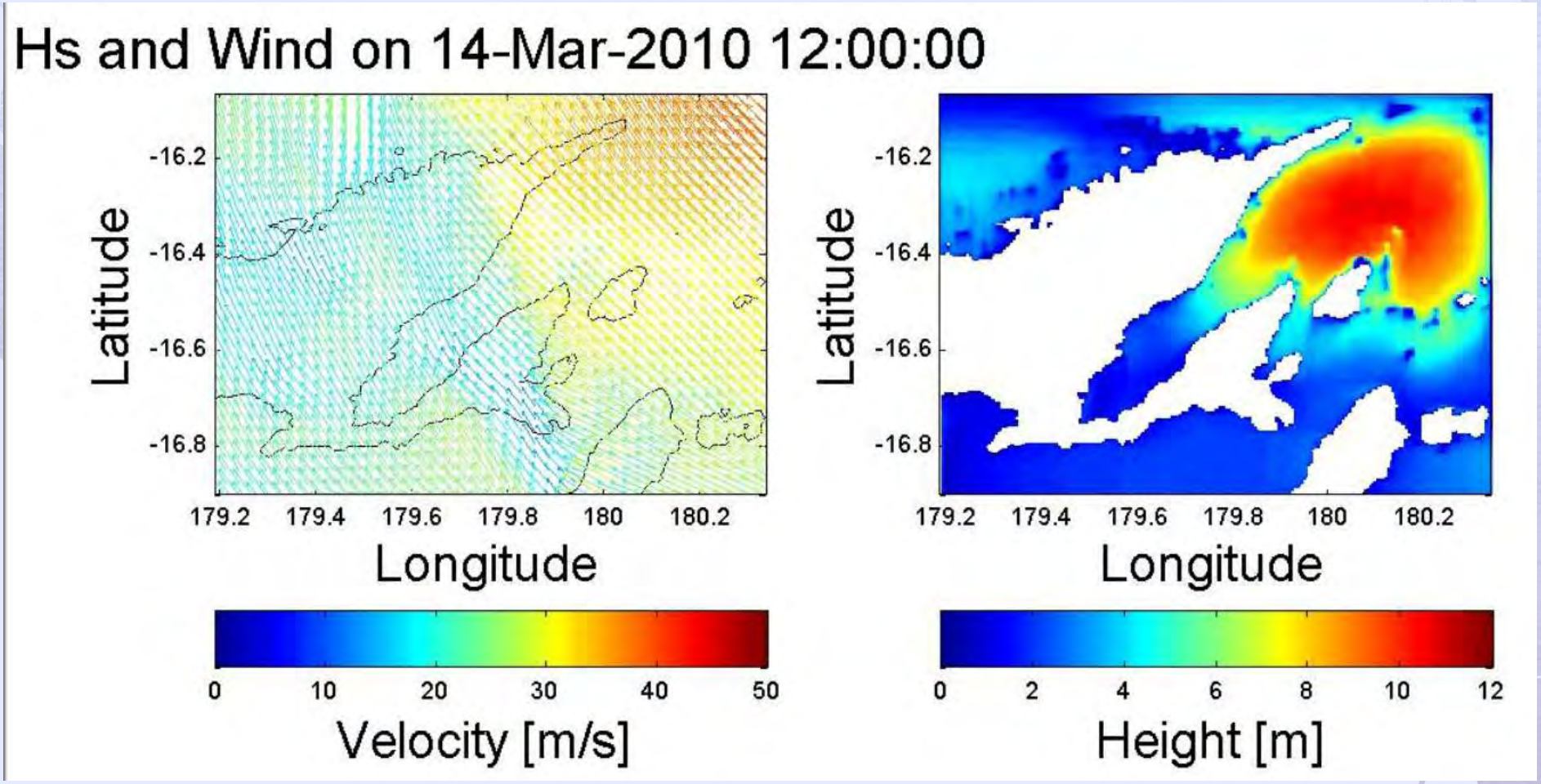
The Results of Simulation

~ H_{sig} and Wind in the South of Viti Levu ~



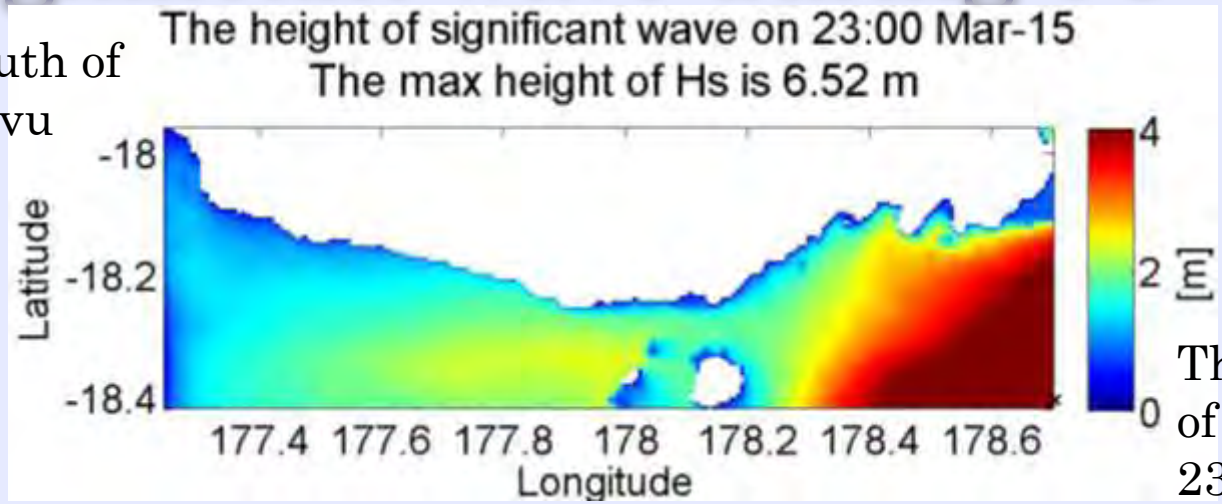
The Results of Simulation

~ H_{sig} and Wind in the East of Vanua Levu



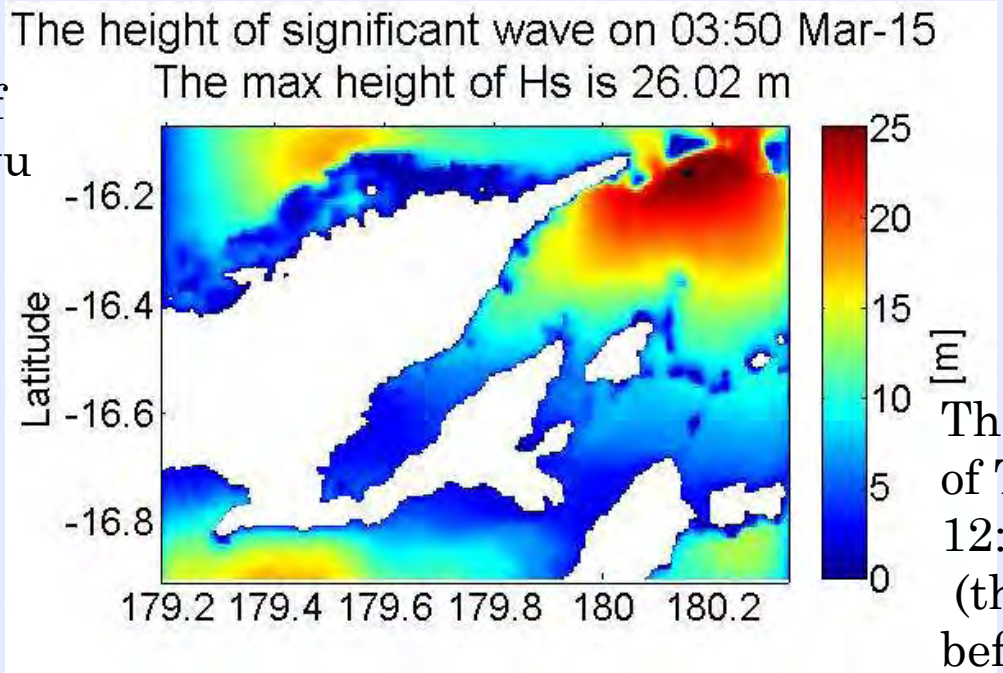
The maximum height of significant wave during TC Tomas

The south of Viti Levu

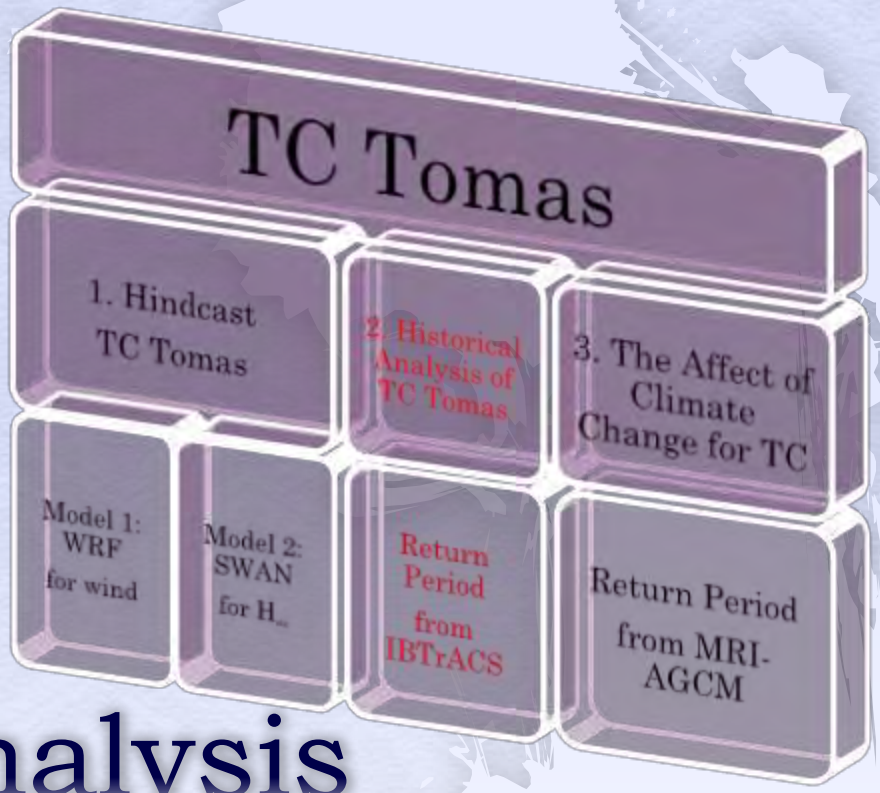


The closet time of TC Tomas : 23:00 15th (the same time)

The east of Vanua Levu



The closet time of TC Tomas : 12:00 15th (the difference is 8 hrs before that time of sig.max)

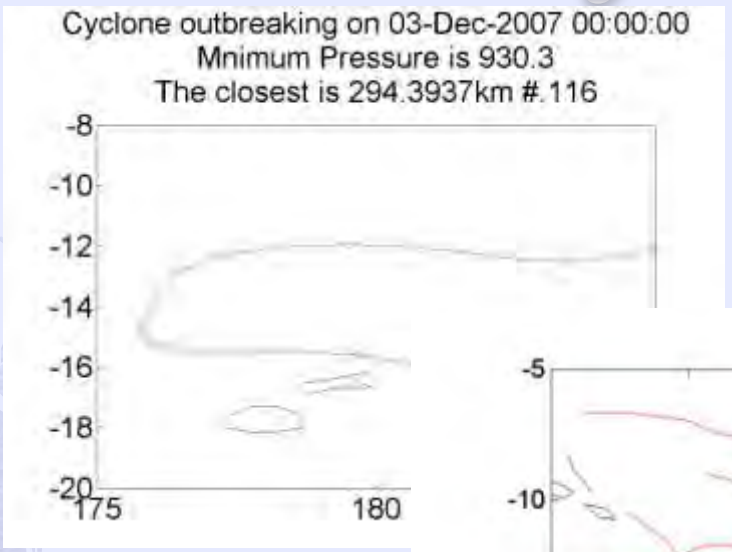


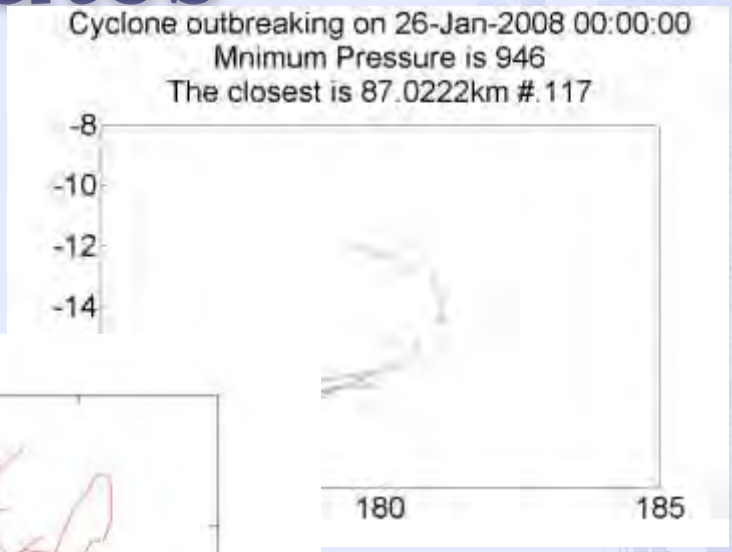
2. Historical Analysis

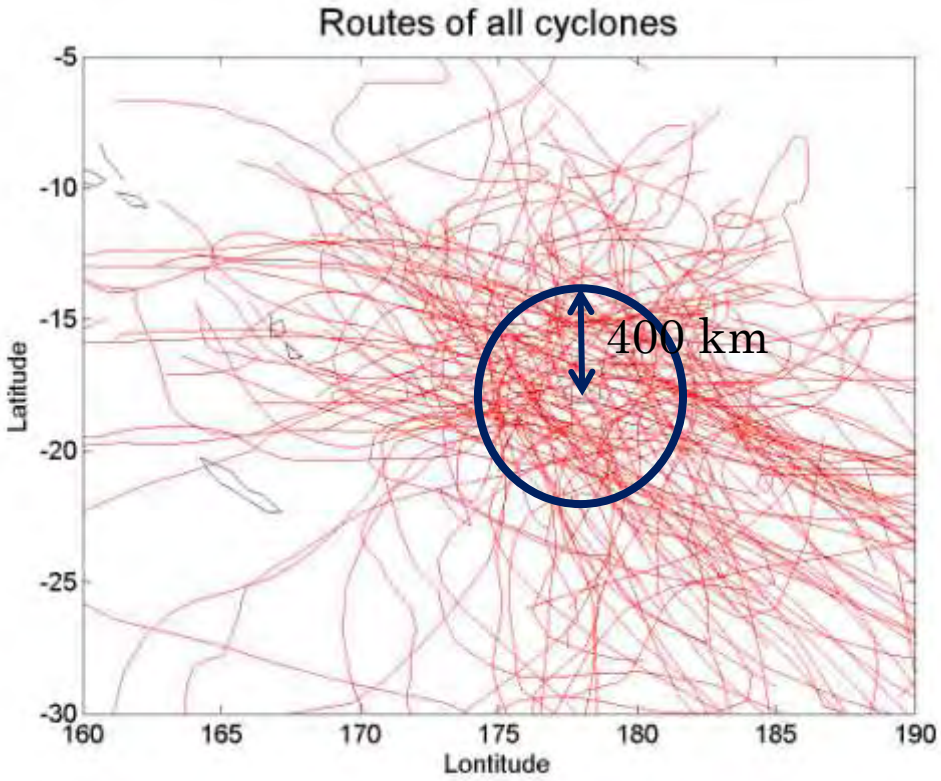
Statistics Analysis ~IBTrACS~

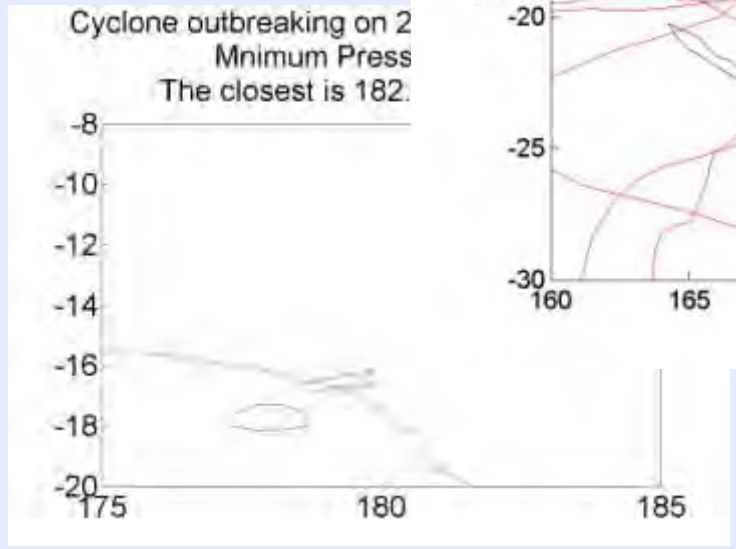
- Sample data
  - IBTrACS (1955 ～ 2008) : 63 samples
- The data extraction condition
  - Using the cyclones which are closer than 400km from Suva
  - Using the strongest cyclone in each years
- The number of sample data picking up is 33 samples

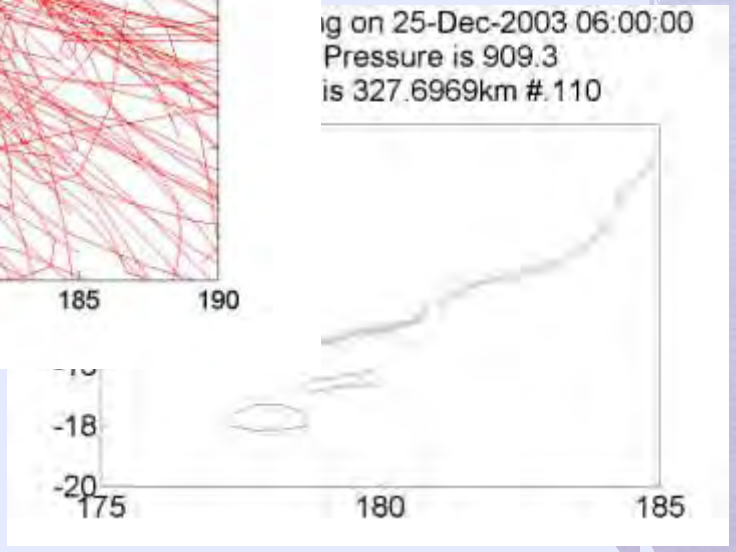
Cyclone Routes





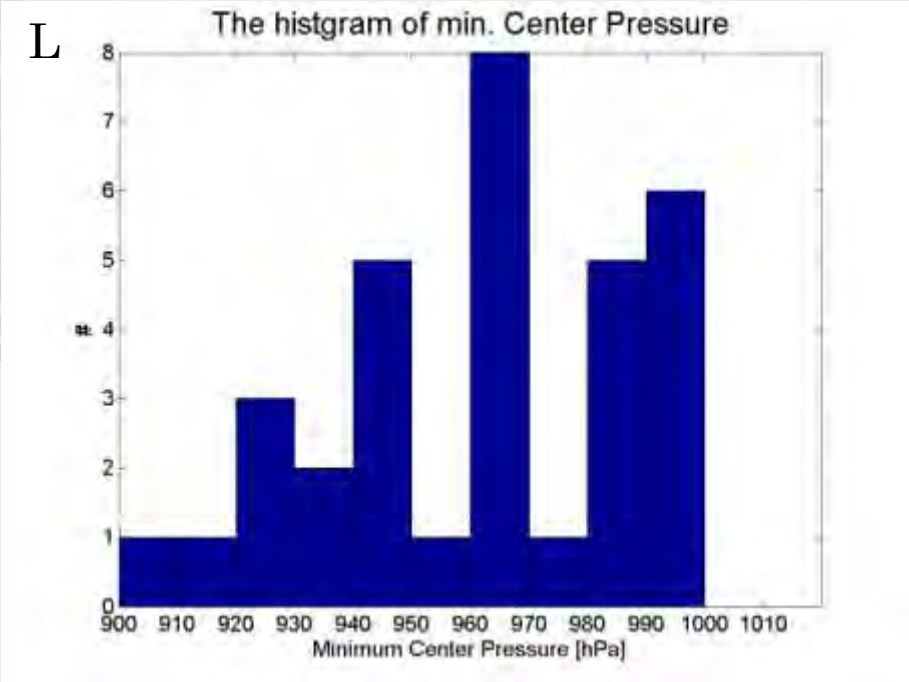




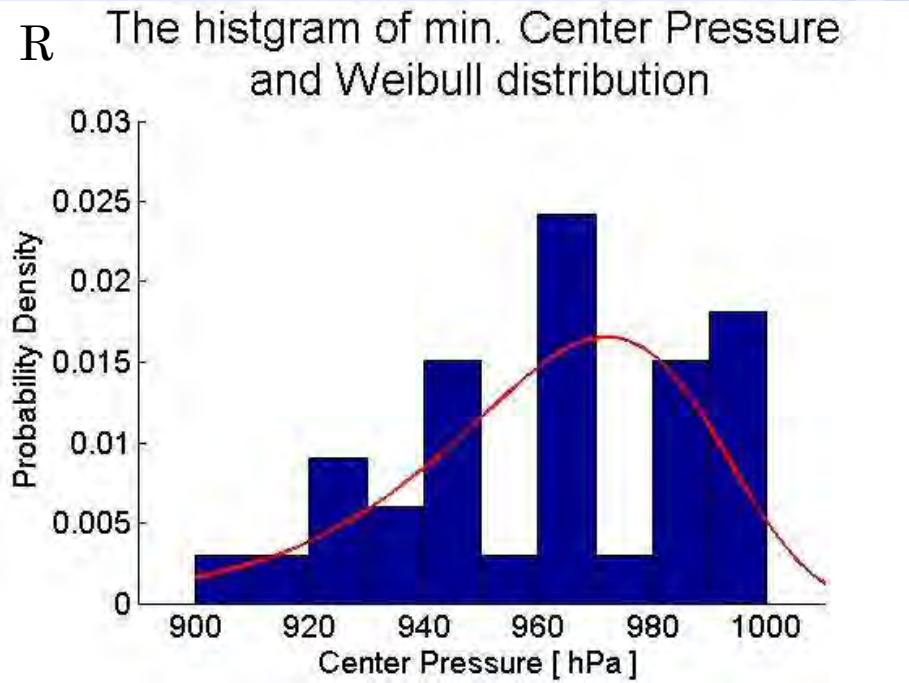


The histogram of Minimum Central Pressure (IBTrACS)

L

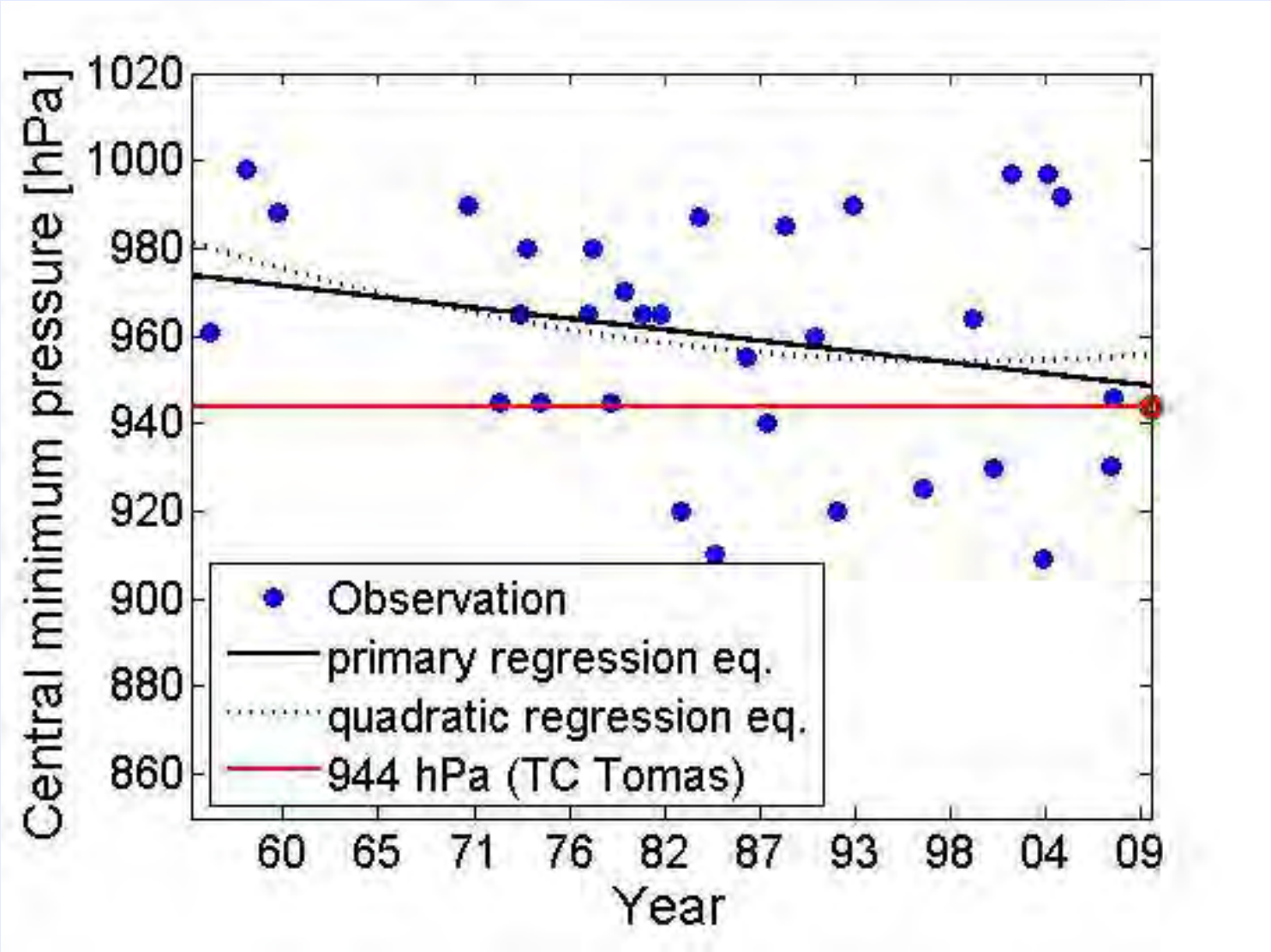


R

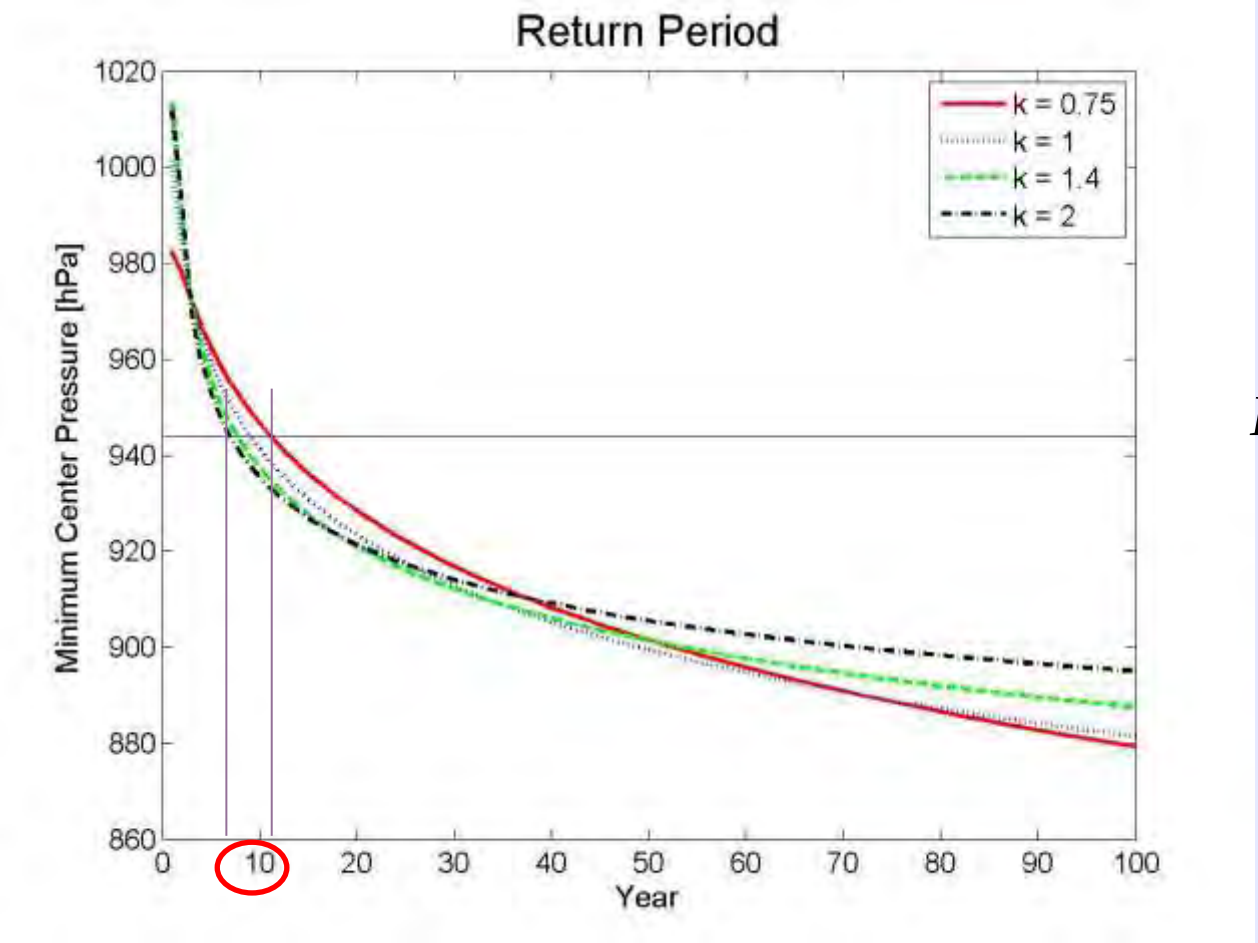


Weibull PDF

The Trend of TC around Fiji sea



The Return Period of TC Tomas from IBTrACS

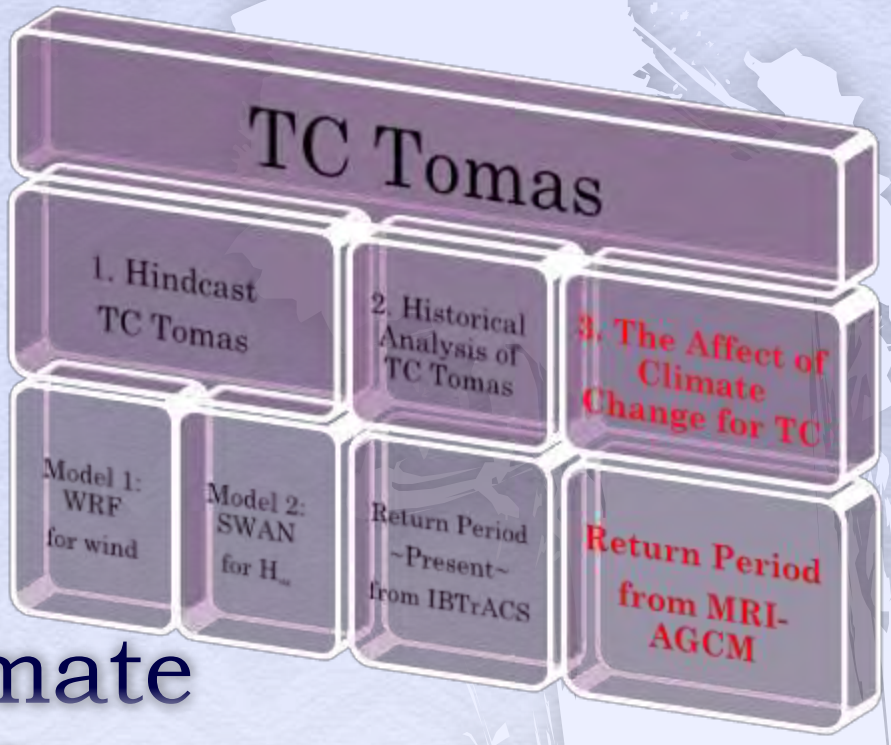


$$R = \frac{1}{\lambda[1 - F(x)]}$$

$$F(x) = 1 - \exp\left[-\left(\frac{x - B}{A}\right)^{k}\right]$$

$$B \le x \le \infty$$

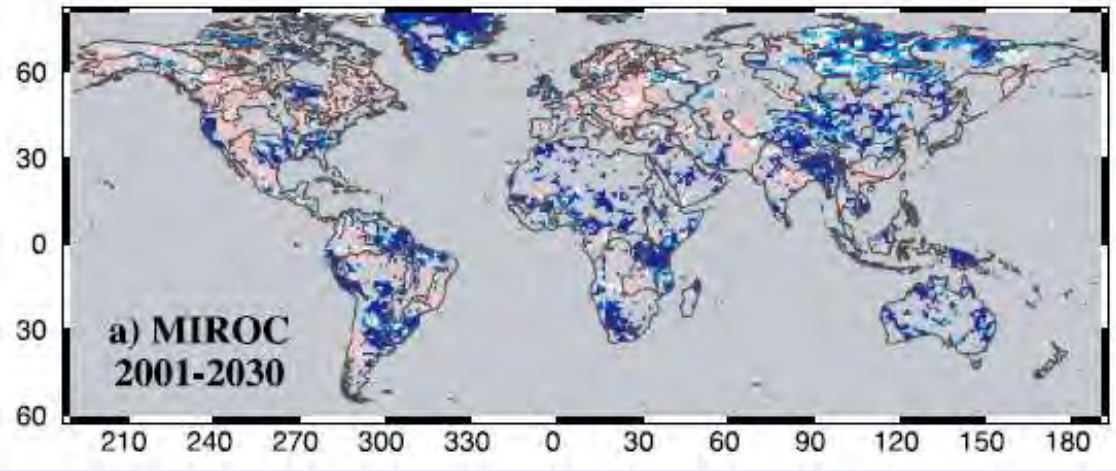
R : return period
λ : mean rate of genesis
F(x) : CDF
A, B : constant
x pressure

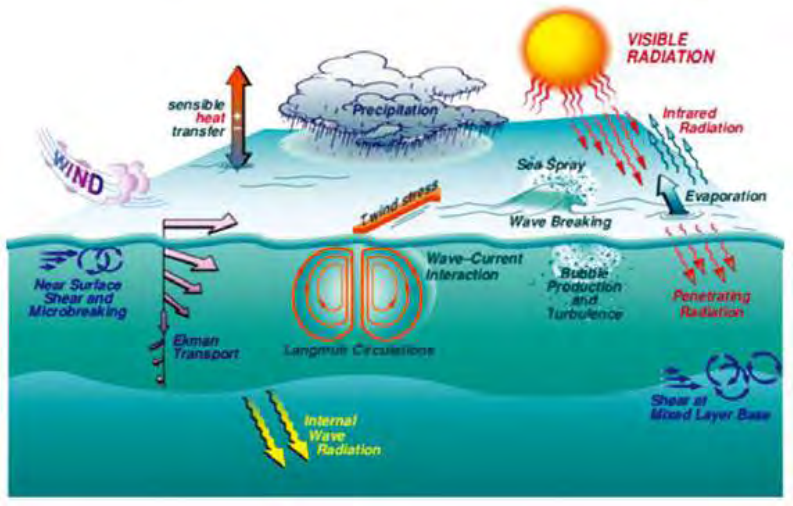


3. The Affect of Climate Change for TC

KAKUSHIN Program

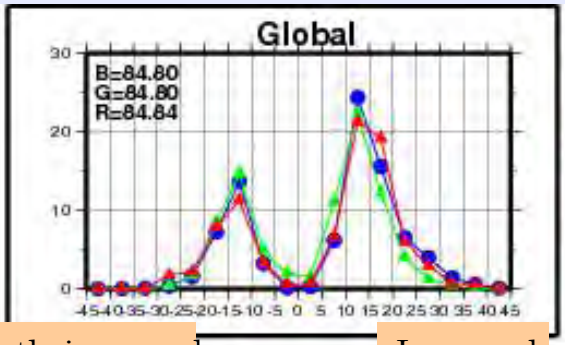
- In Japan, Innovative Program of Climate Change Projection for the 21st Century (abbreviated as KAKUSIN Program) has been carried out to contribute to IPCC AR5 concerning with climate projections for near future and for the end of the 21st century since 2007.
- Long-Term Global Change Projection
- Near-Term Climate Prediction - Climate 2030 -
- Extreme Event Projection





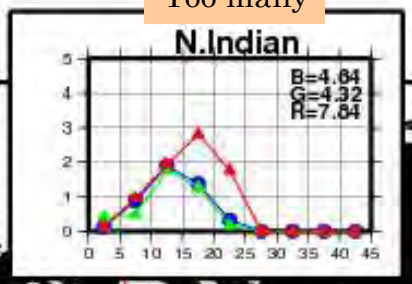
TC genesis distribution of Present climate experiment

TC detection condition is optimized that global annual mean numbers are suitable with the observation.

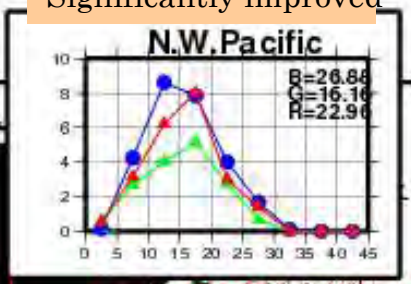


Observation (BT)
MRI-AGCM3.1S
MRI-AGCM3.2S

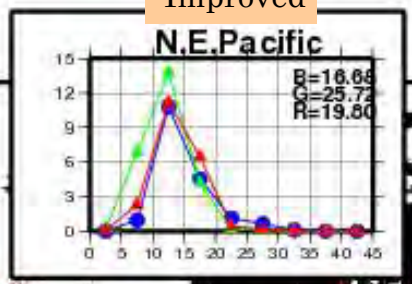
Too many



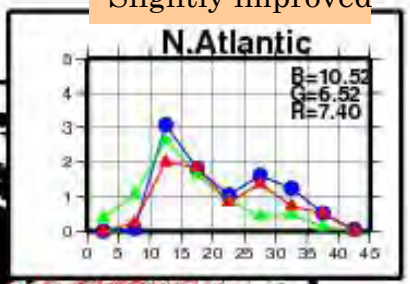
Significantly improved



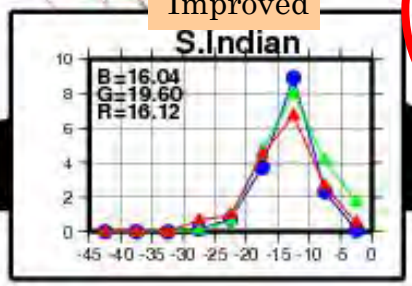
Improved



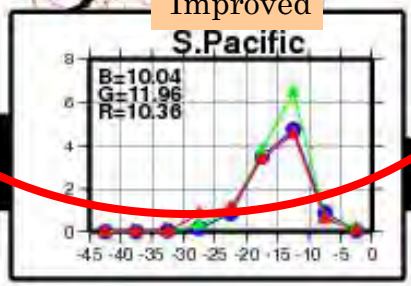
Slightly improved

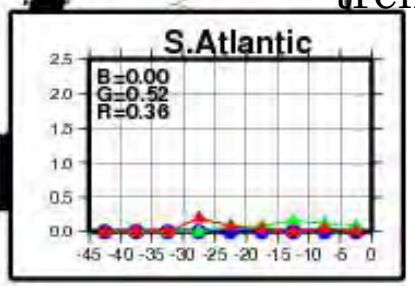


Improved



Improved

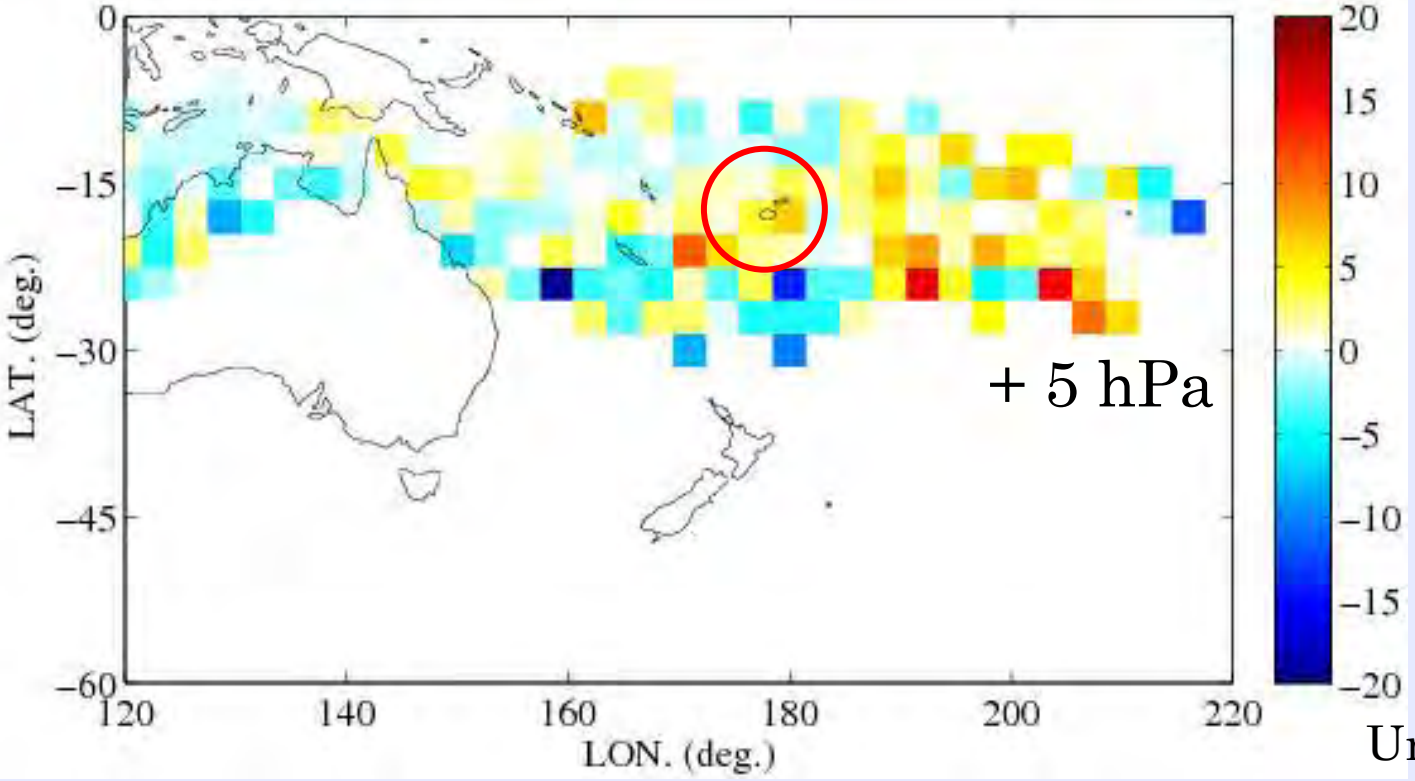




Bias of easterly shift trend

The Future Prediction of TC in South Pacific with Ensemble Mean

Case	Period	Resolution	Cumulus convection model†	Sea surface temp.‡
SF0A	2075-2099	20km	A-S	M
SFA			Yoshi.	
HF0A		60km	A-S	M
HFA			Yoshi.	M,C1,C2,C3
HFA kf			K-F	M,C1,C2,C3
HFA as			M. A-S	M,C1,C2,C3



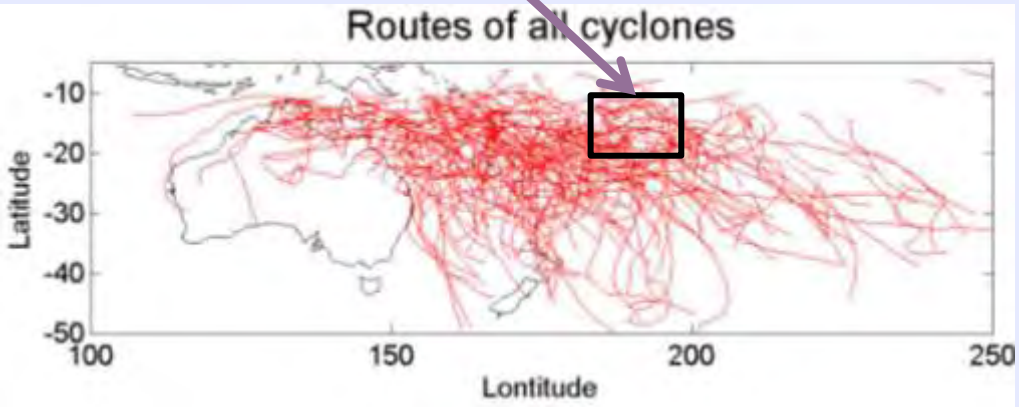
M:
mean of CMIP3

C1, 2, 3:
Principle cluster components of CMIP3

Unit [hPa]

Statistics Analysis Near Fiji

- Sample data
  - IBTrACS (1955 ～ 2008) : 33 samples
  - MRI-AGCM 3.2S Present (1980～2003): 41 samples
  - MRI-AGCM 3.2S Future (2076～2099): 47 samples
- The data extraction condition (for MRI-AGCM)
  - The domain is from 175 deg. to 185 deg. (EW)
    from -15 deg. To -20 deg. (NS)



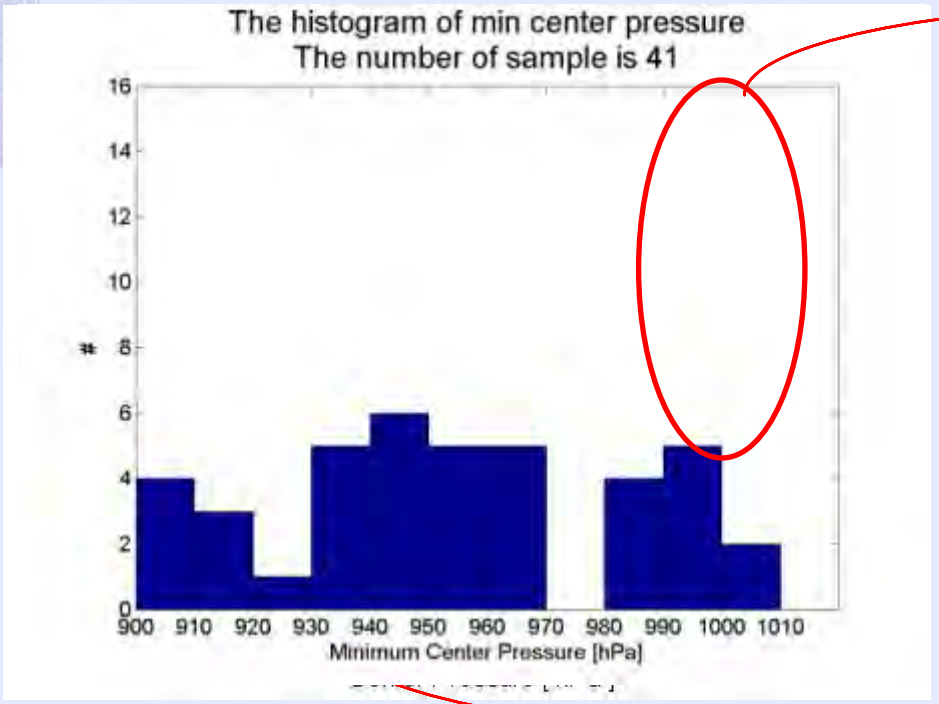
The histogram of Minimum Central Pressure near Fiji

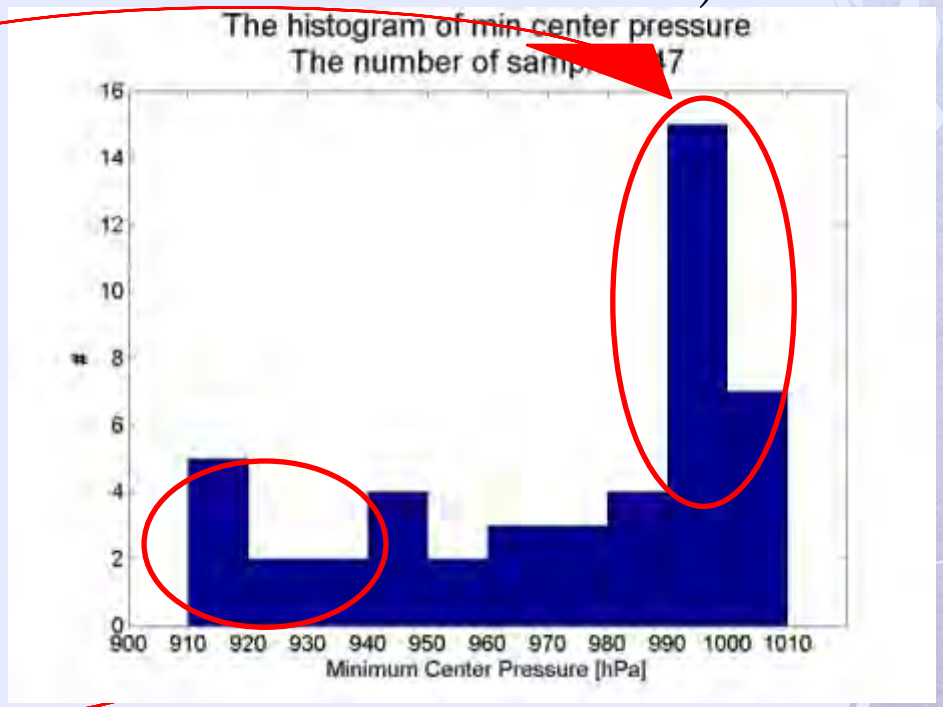
The Extraction Condition

The domain is from 175 deg. to 185 deg. (EW)

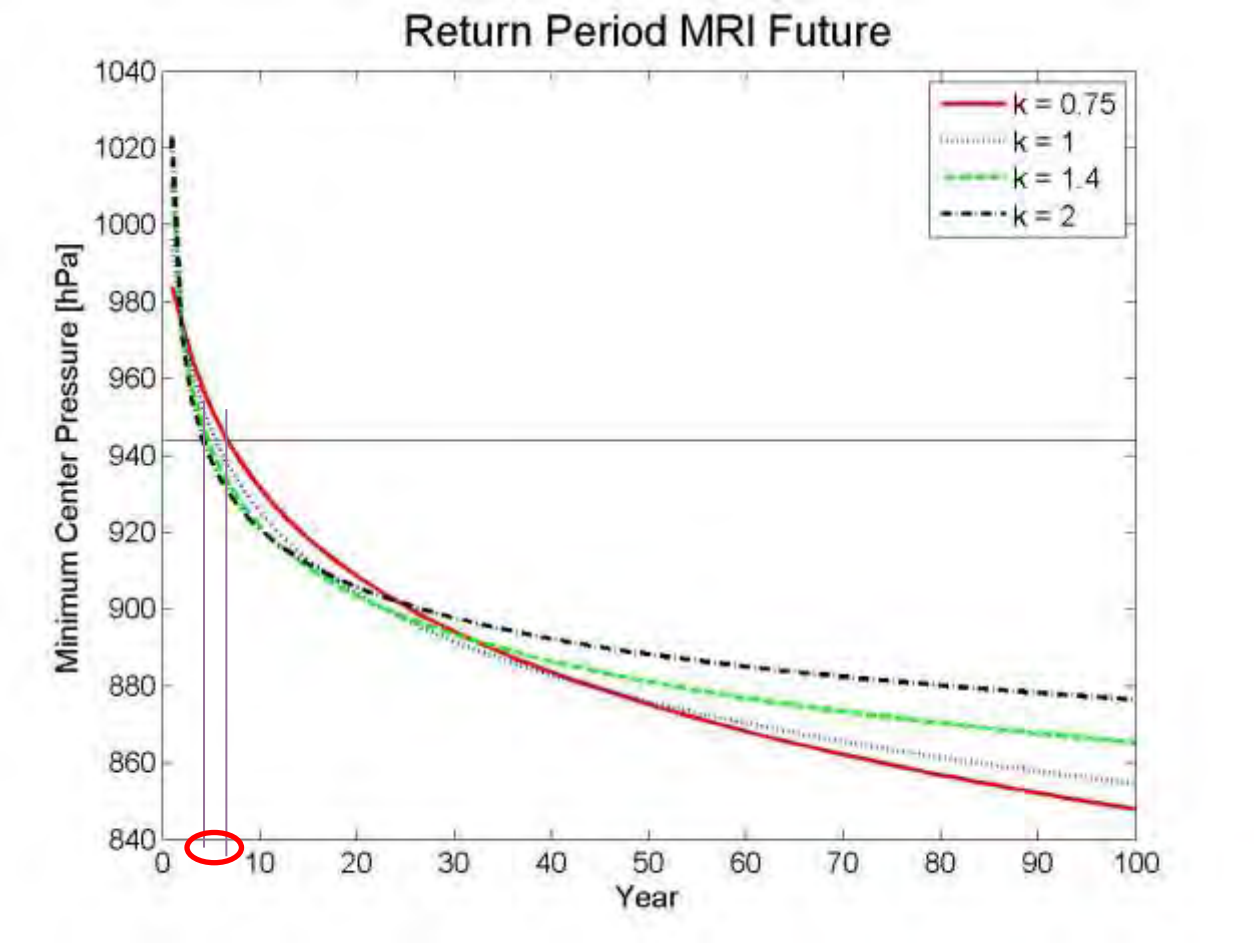
from -15 deg. To -20 deg. (NS)

Future (data: MRI-AGCM 2076～2099)





The Return Period of TC Tomas (944hPa) from MRI-AGCM



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$$F(x) = 1 - \exp\left[-\left(\frac{x - B}{A}\right)^{k}\right]$$

$$B \le x \le \infty$$

R : return period
λ : mean rate of genesis
F(x) : CDF
A, B : constant
x pressure

4. Conclusions

1. The significant wave height is high in the east of Vanua Levu, this is consistent with the disaster report.
2. The return period of TC Tomas is about 10 years.
3. In future climate around Fiji, the intensity of TC will be weaker (about 5hPa) in average.
   On the other hand, the strong TC will be formed more frequently. And the return period of TC same as TC Tomas will be about 5 years.

Thank you for your attention.
And questions?