# Precipitation top heights estimation in convective systems

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JPL Jet Propulsion Laboratory

**NASA Precipitation Measurement Missions (PMM)**
**2018 PMM Science Team Meeting**
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# Outline

- Introduction
- Correlation analysis
- Precipitation detection
- Precipitation estimation
- Conclusions

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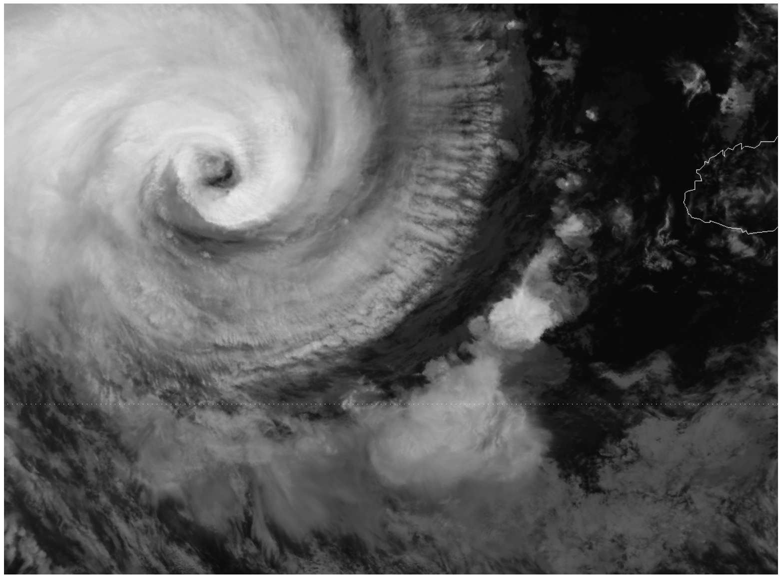
# Introduction

## Convective storms

- Deep convective storms are one of the main causes of uncertainties in weather
- Difficult to measure



*IR image of Tropical Cyclone Winston obtained from http://eumetsat.int*

# Introduction

Data sources for convective storms

- IR images
  - A lot of data is available
  - Poor sensitivity below convections
- Radar measurements
  - High sensitivity to convections
  - Limited number of coincidences
- Radiometers
  - Huge amounts of data
  - Measurements are not directly applicable (or are they?)

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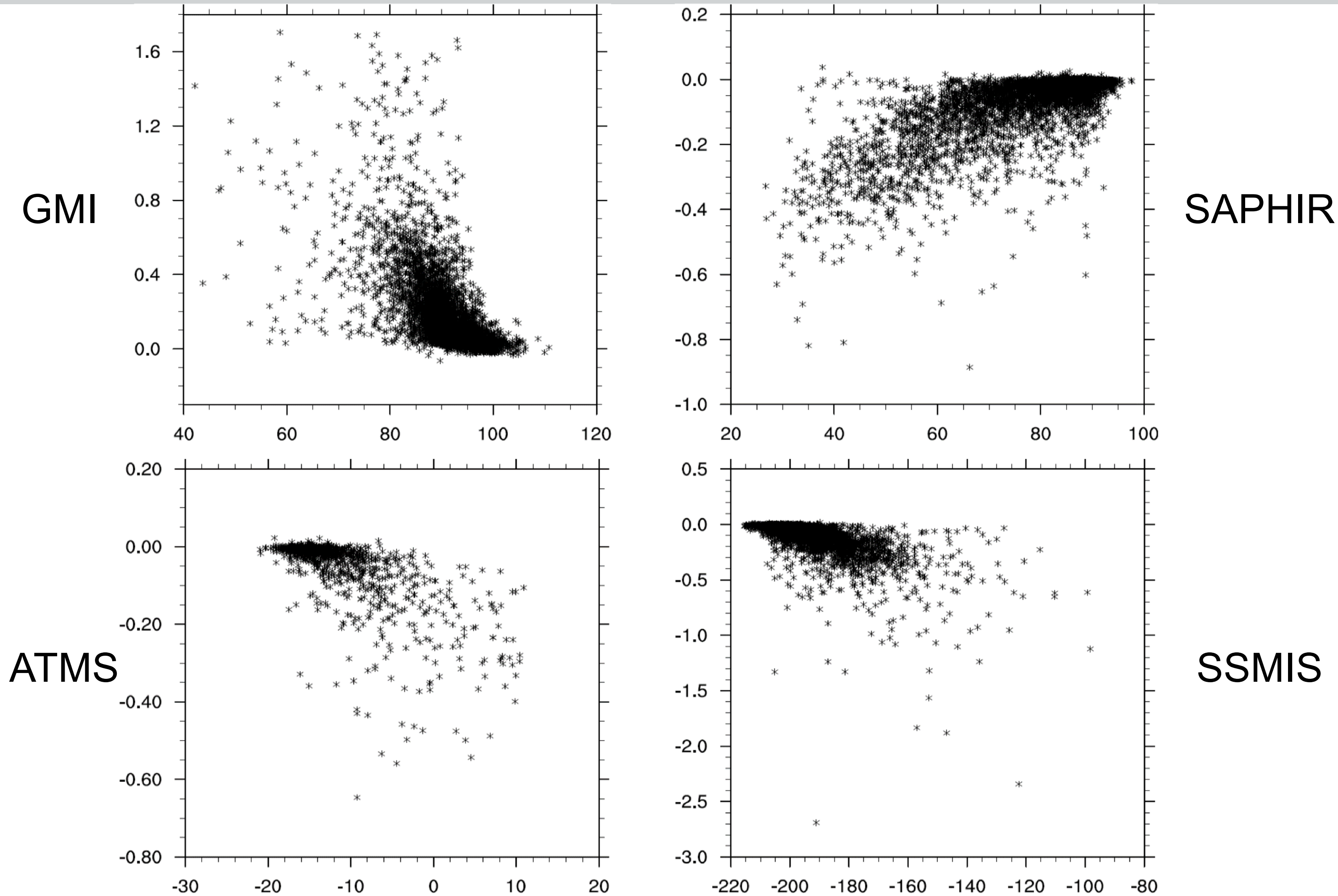
## Correlation analysis

- Is it possible to infer water content $W^{52}$ features from brightness temperatures $T^{6}$?
- Difficult to explain 52 dimension of $W$ with only 6 of $T$
- We reduced the dimensionality using Principal Components Analysis (PCA) and conserved the most significant Principal Components (PC)
  - Linearly compared them in the next slide

# Correlation analysis

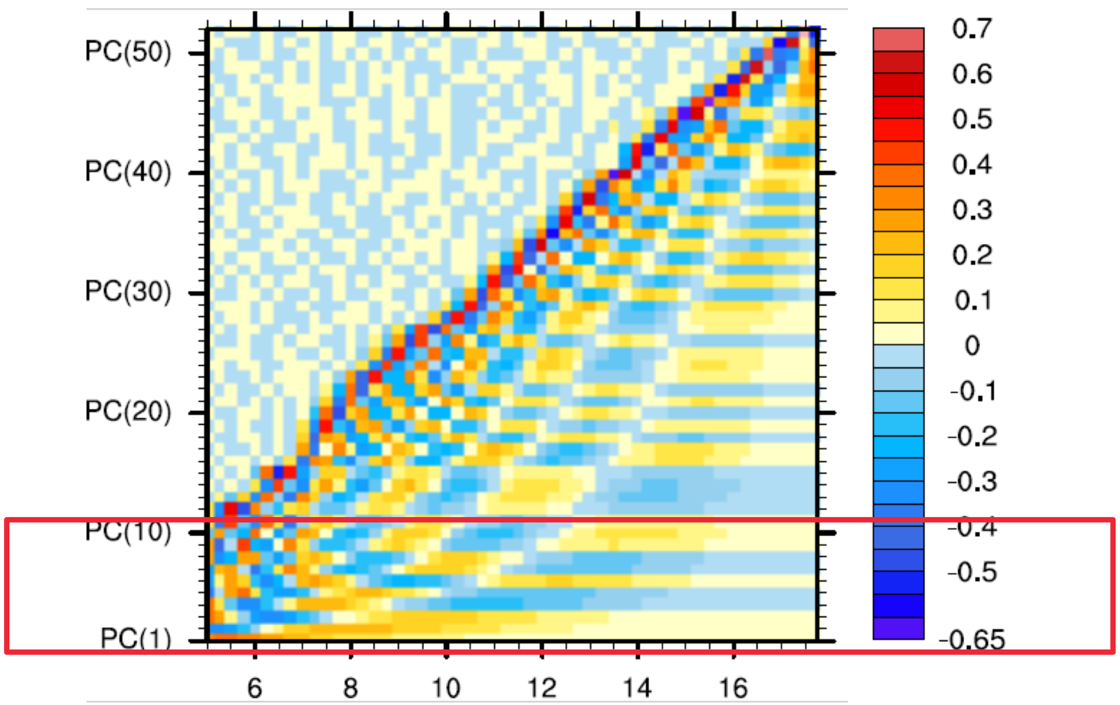
Correlation coefficients



# Correlation analysis

## Water content eigenvectors

- In the first 10 eigenvectors $PC(W)$ the weights for high precipitation is near zero
- High precipitation information is **lost** in the process



# Correlation analysis

Top height correlation

- There is a weak correlation between $\mathrm{PC}(T)$ and $\mathrm{PC}(W)$.
- What about the top precipitation height $H$?

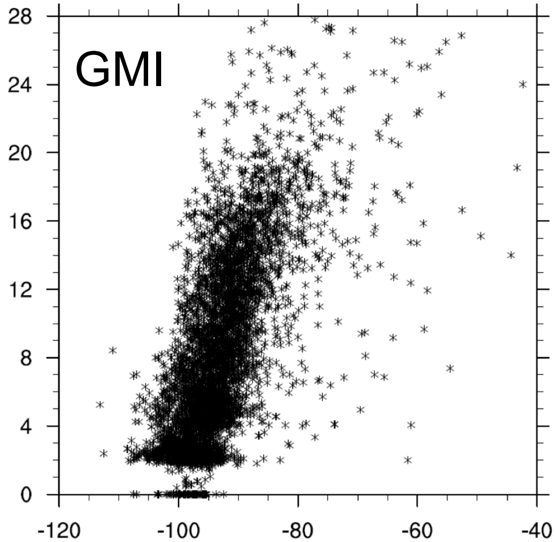
$$[h_{0.05}, h_{0.1}, h_{0.2}, h_{0.3}, h_{0.5},] \in H$$

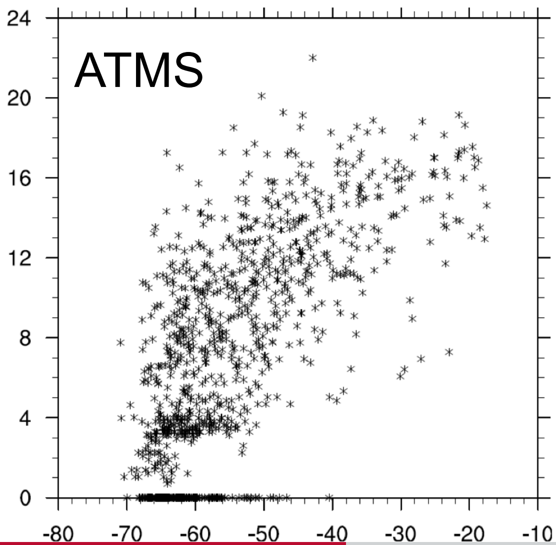
- $h_{threshold}$ is the maximum height at which the water content is greater than the threshold $(g/m^3)$

- $H$ is obtained from $W$
  - Can we use $T$ to estimate $H$?

# Correlation analysis

Top height correlation

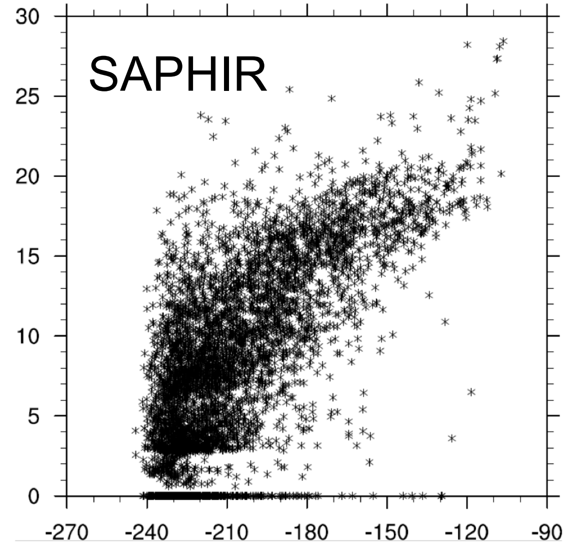


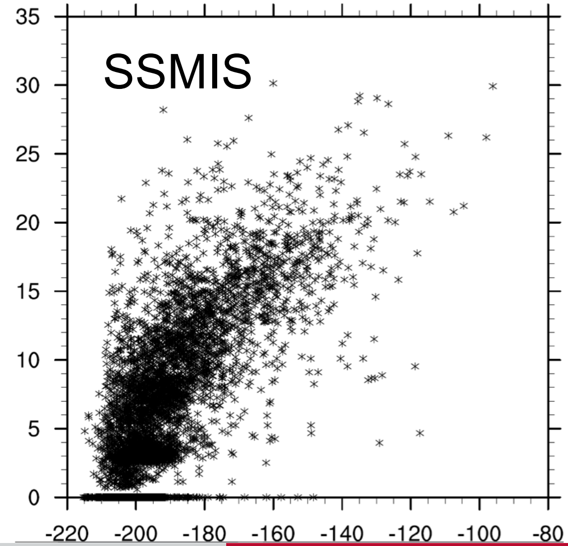




- A strong correlation exists in this case

- *Conclusion:*

We can use brightness temperatures to estimate the top height of condensed water



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- **Precipitation detection**
- Precipitation estimation
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# Precipitation detection

- We developed a **systematic** method for obtaining the maximum height of precipitation from radiometer measurements
- The method produces a precipitation classifier based on two steps:
  - Precipitation detection using Linear Discriminant Analysis or LDA. This method classifies any $t$ into precipitation (*P*) or dry (*D*)
  - Precipitation height estimation using lookup tables based on Principal Components Analysis or PCA. This step gets the estimated height from $t$ measurements

# Precipitation detection

## Source datasets

- We created intersection databases (radar – radiometer) from the following instruments:
  - Dual-frecuency Precipitation Radar (**DPR**)
  - GPM Microwave Imager (**GMI**)
  - **SAPHIR** humidity sounder
  - Advanced Technology Microwave Sounder (**ATMS**)
  - Special Sensor Microwave Image/Sounder (**SSMIS**)

- Millions of records were processed.
- All HDF5 instrument files were downloaded from NASA’s PPS-STORM system

# Precipitation detection

## LDA detector training

- We divided the intersection database into a training database and a testing database

- Every record in both databases was classified as precipitation (P) or dry (D) record depending on two thresholds:
  - $h_{thr}$ defines the minimum height to consider precipitation
  - $w_{thr}$ defines the minimum water content to consider precipitation

- We used the training database to obtain a LDA discriminant $x$ and its evaluation threshold $v_{thr}$

$$x \cdot t > v_{thr} \text{ implies } P\text{, otherwise } D$$

# Precipitation detection

LDA detector testing

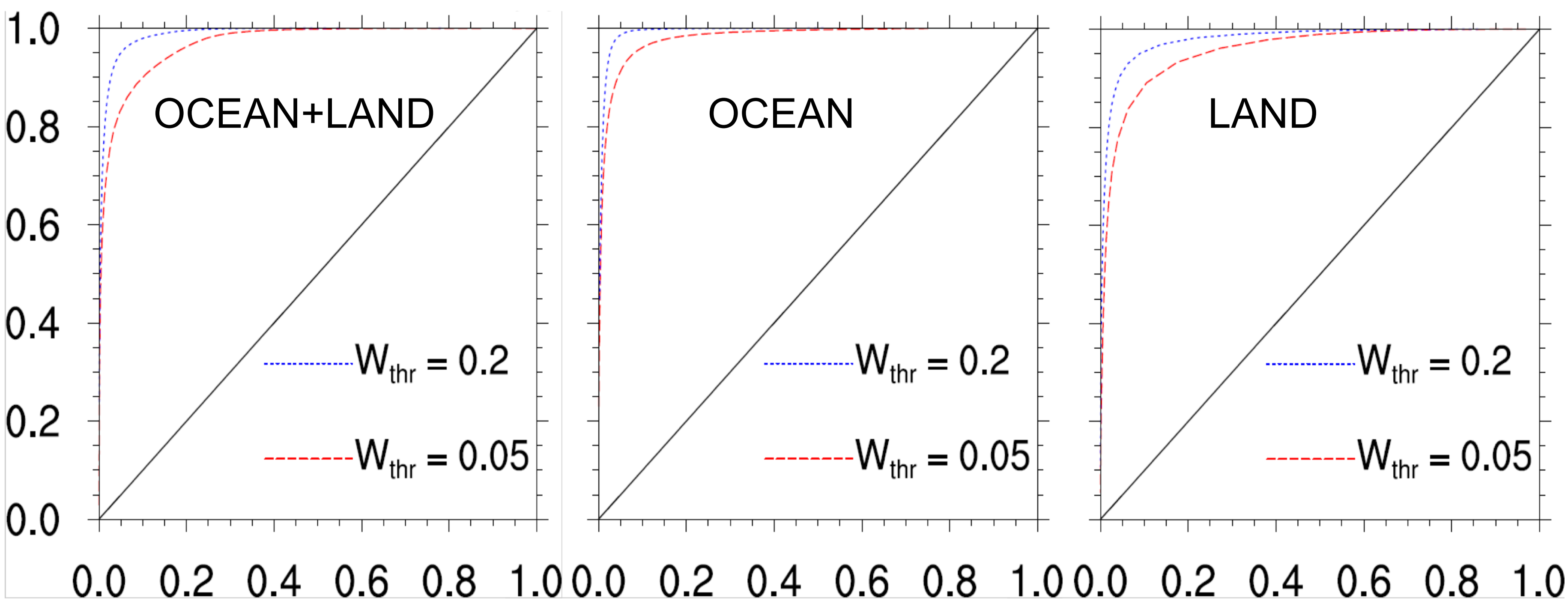
- The testing database was then used to obtain a *score* about how good the detection was

- *Receiver Operating Characteristic* (ROC) curves were obtained from the hits
  - Using different $w_{thr}$
  - Over land, ocean and both

# Precipitation detection

Detector ROC GMI Ocean and Land

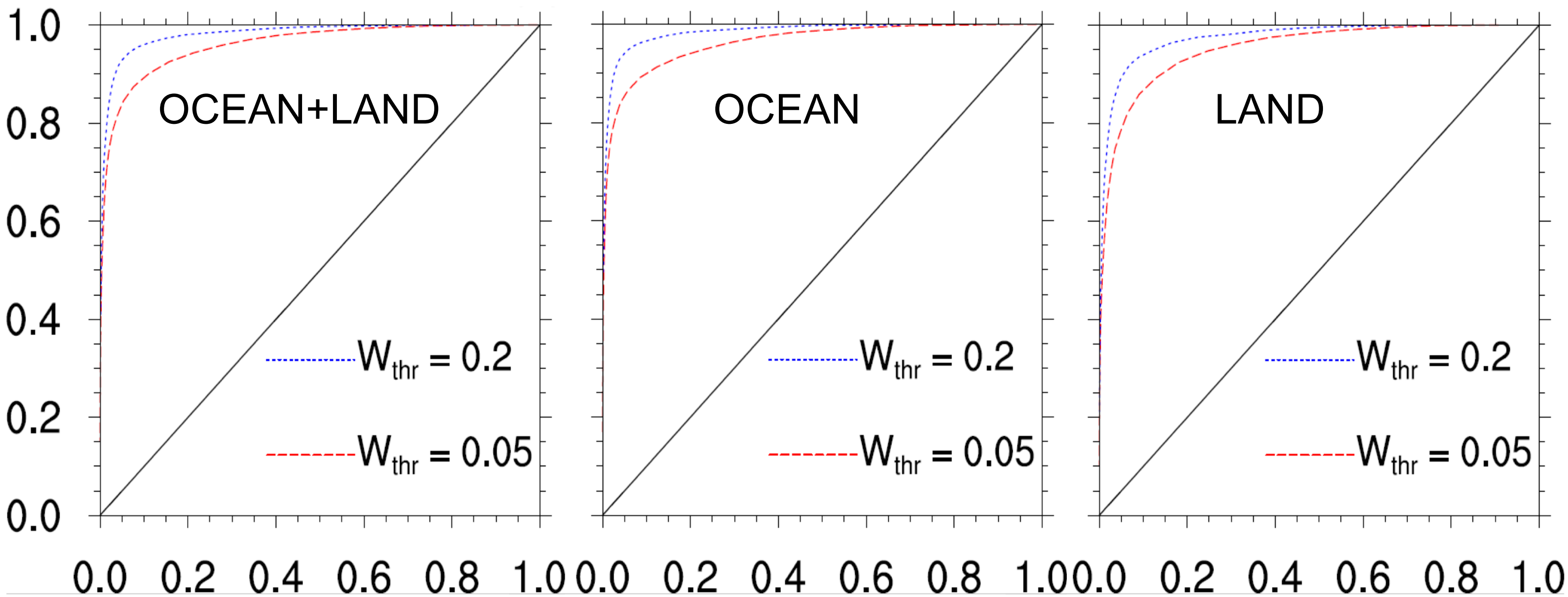
- OCEAN measurements were more accurate
- **Decreased** accuracy in LAND cases
- **Better detection** with higher $w_{thr}$



# Precipitation classifier

Detector ROC SAPHIR Ocean and Land

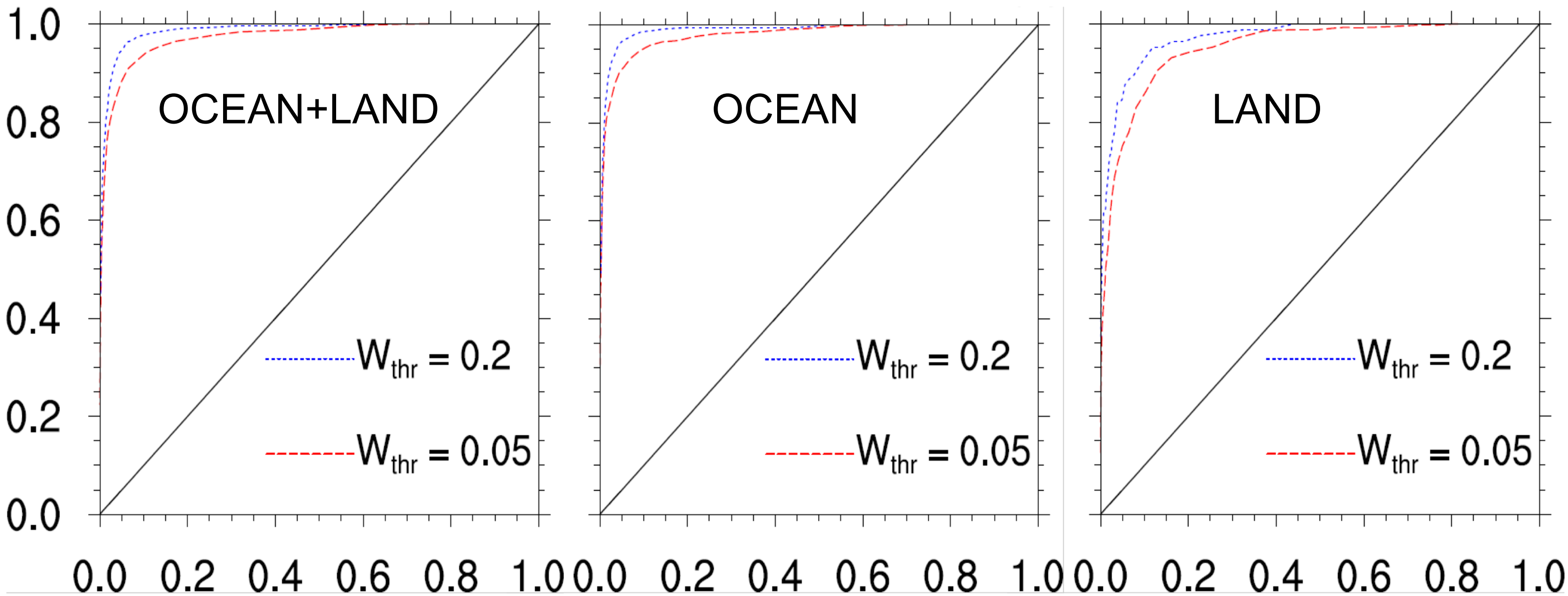
- Not much difference between OCEAN and LAND
- **Better detection** with higher $w_{thr}$



# Precipitation detection

Detector ROC ATMS Ocean and Land

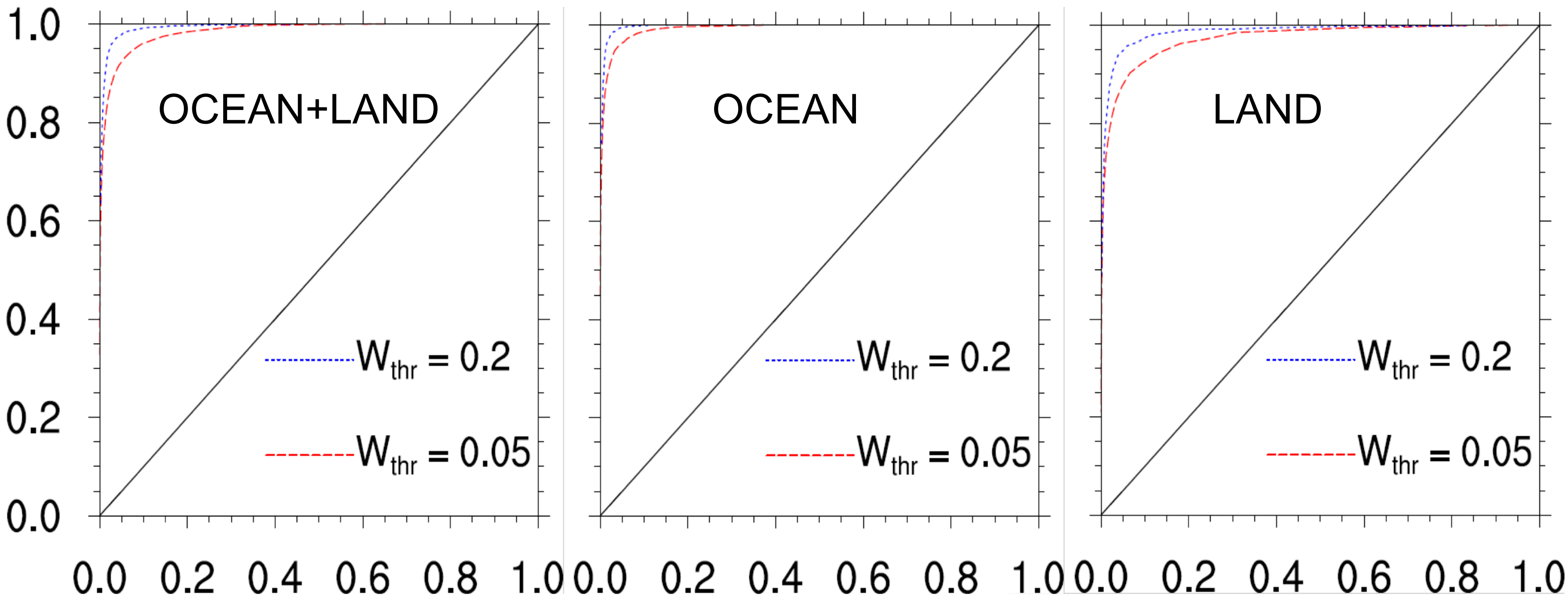
- LAND is performing **worse**
- **Better detection** with higher $w_{thr}$



# Precipitation detection

Detector ROC SSMIS Ocean and Land

- LAND is performing **worse**
- **Better hit ratio** than other instruments
- **Better detection** with higher $w_{thr}$



# Precipitation detection

## Detection summary

- Over 85% of hit rate for all instruments
- **LAND** is a source of **uncertainty**
- SSMIS channels are very good for high precipitation detection.
- The higher the $w_{thr}$ the better the precipitation detection
  - Caution: lower water content is undetectable

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# Precipitation estimation

PCA classifier training

- We built lookup tables from the top height average values (expectation) in the training database
  - In every lookup table, every cell is addressable by $PC(t)$

$$[t_1, t_2, \dots, t_n,] \Rightarrow [PC_1(t), PC_2(t), PC_3(t)]$$

  - The value of every cell is the expectation top height for the corresponding Principal Components

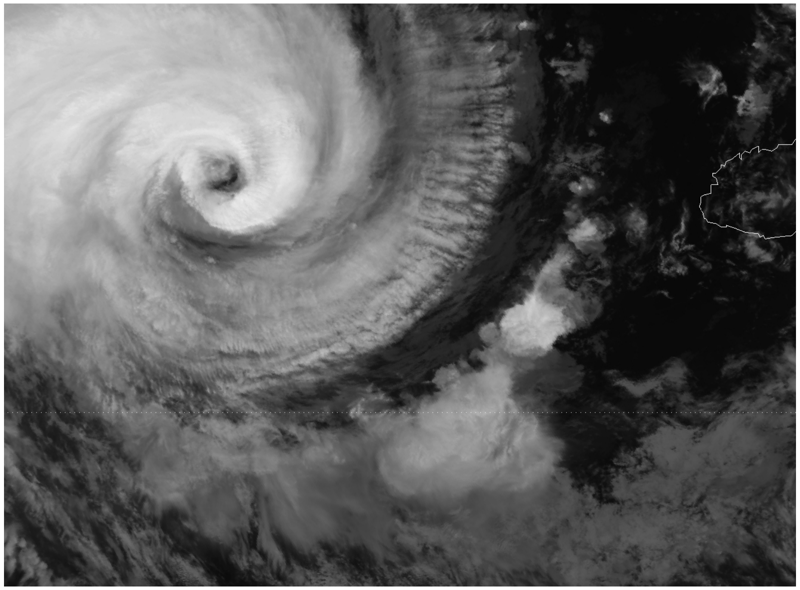
$$L(PC_1(t), PC_2(t), PC_3(t)) = \mathrm{E}\{h(W)\}$$

- We obtained lookup tables for **every** instrument

# Precipitation estimation

PCA classifier testing

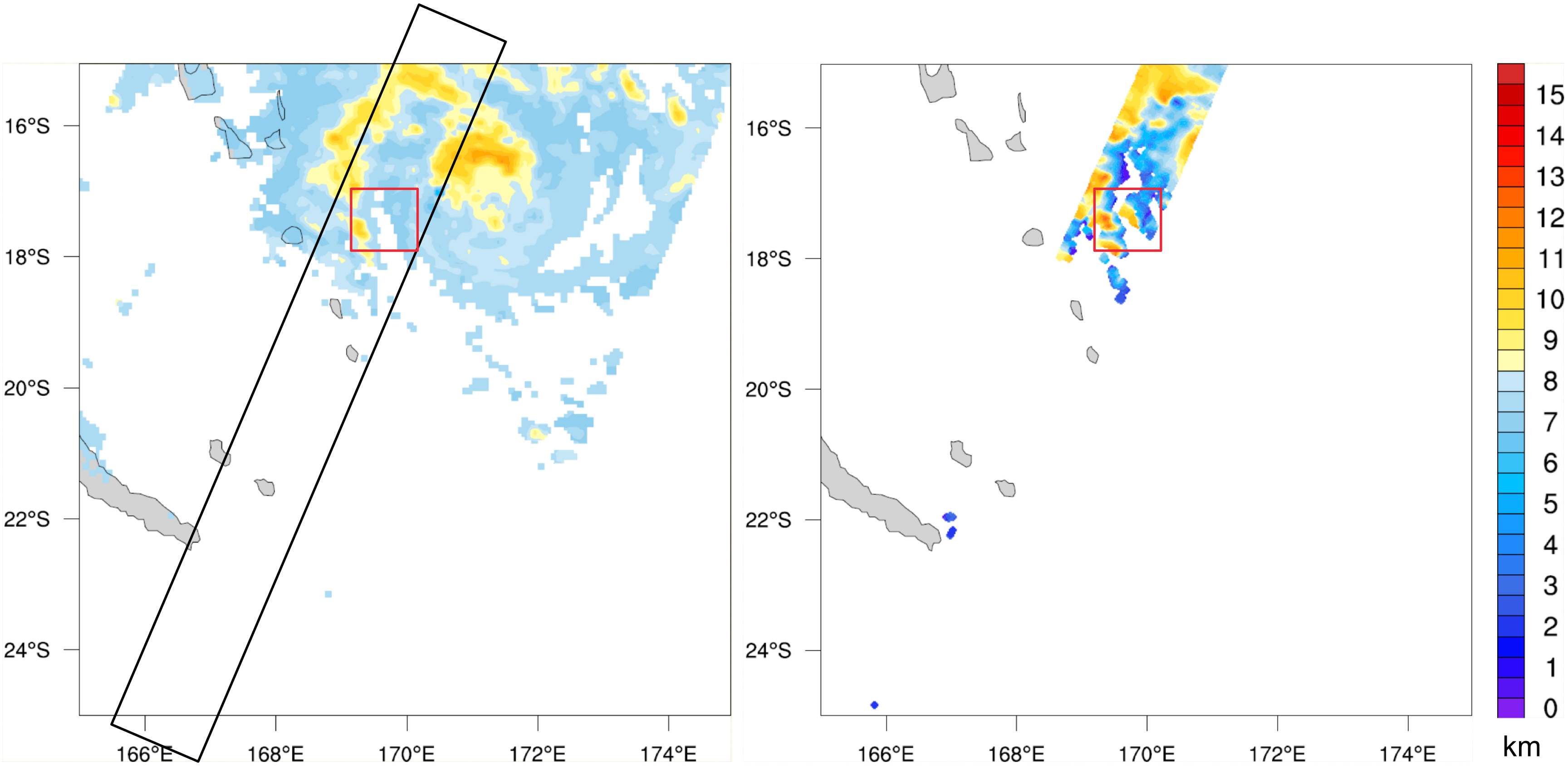
- We used some of the available data from Tropical Cyclone Winston
- Chosen dates:
  - 11 February 2016
  - 22 February 2016
- Chosen region:
  - Lat: -25 to 15 degrees
  - Lon: 165 to 175 degrees
- Parameters
  - $h_{thr} = 5\ \mathrm{km}$
  - $w_{thr} = 0.05\ g/m^3$



IR image showing the Winston the 21 of February 22:00

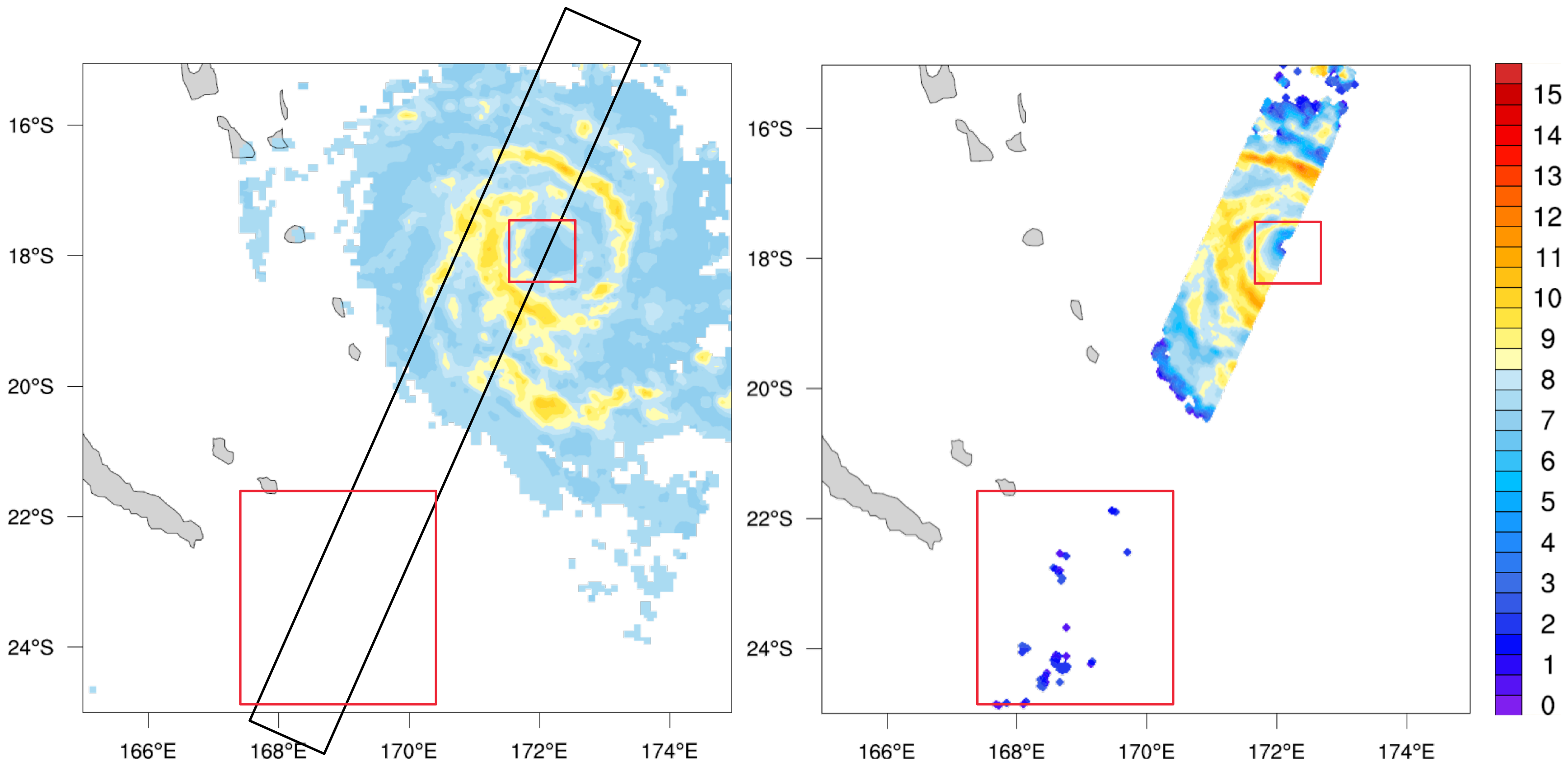
# Precipitation estimation

GMI - 11 February estimation



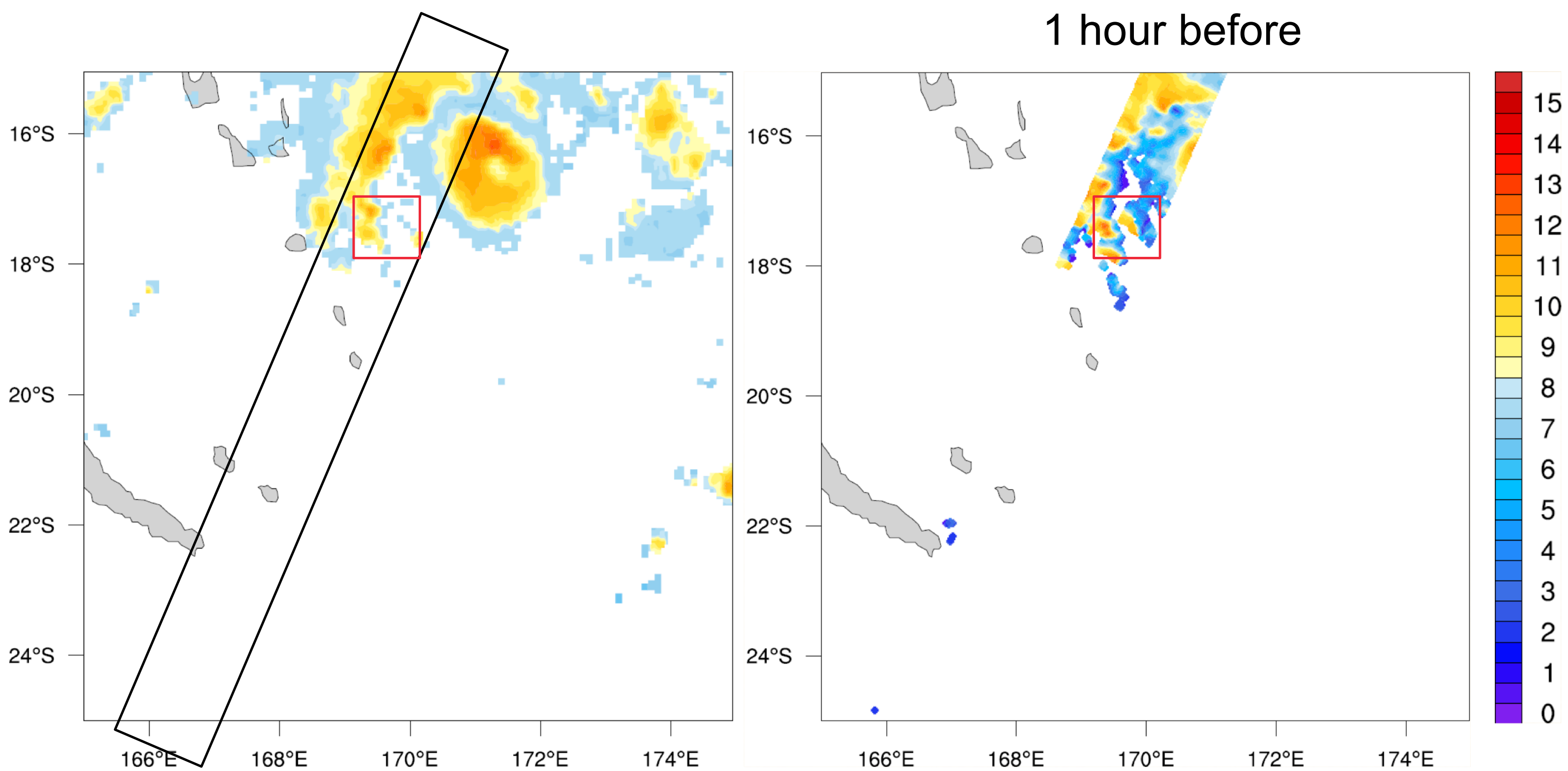
# Precipitation estimation

GMI - 22 February estimation



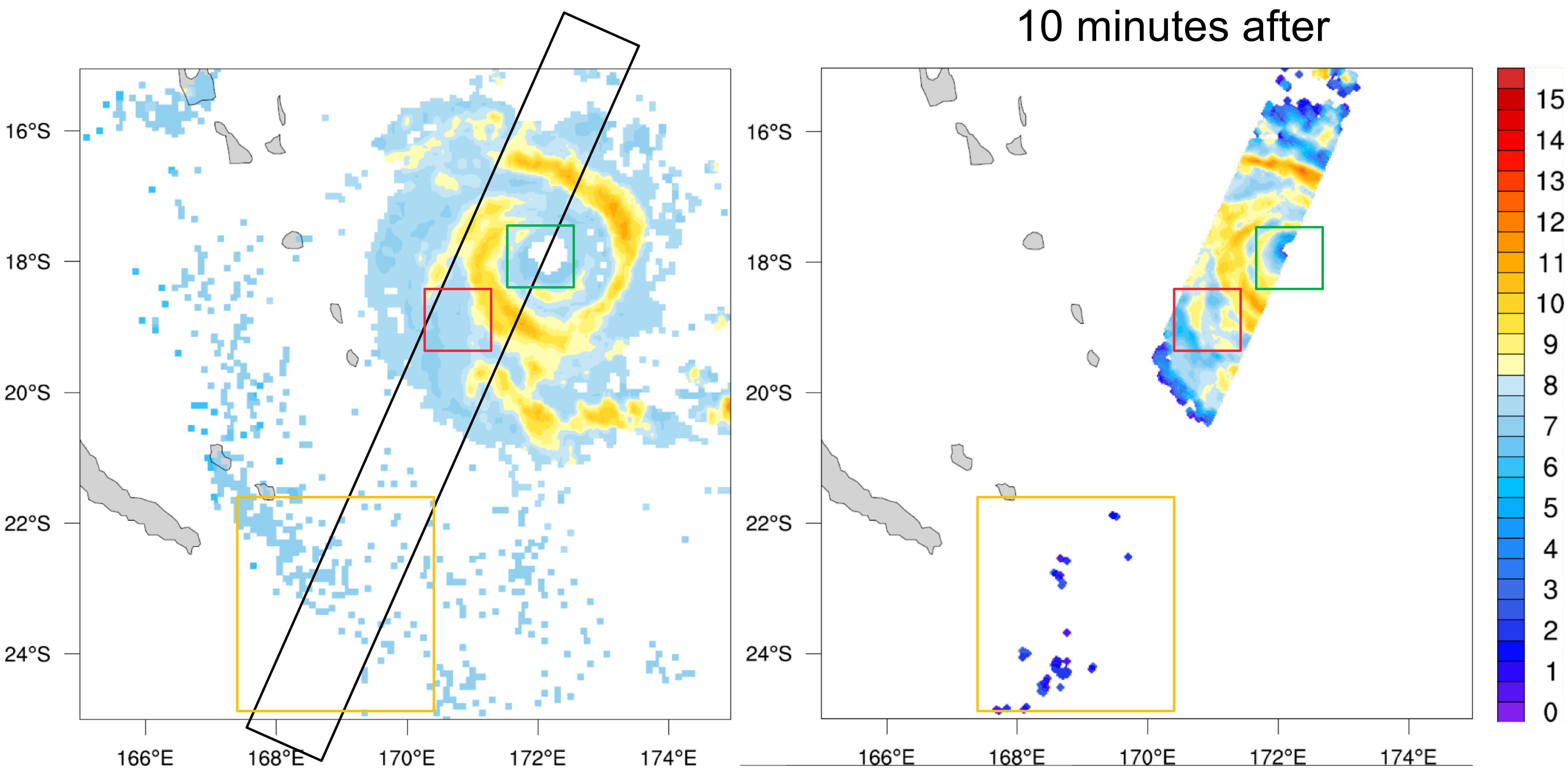
# Precipitation estimation

SAPHIR - 11 February estimation



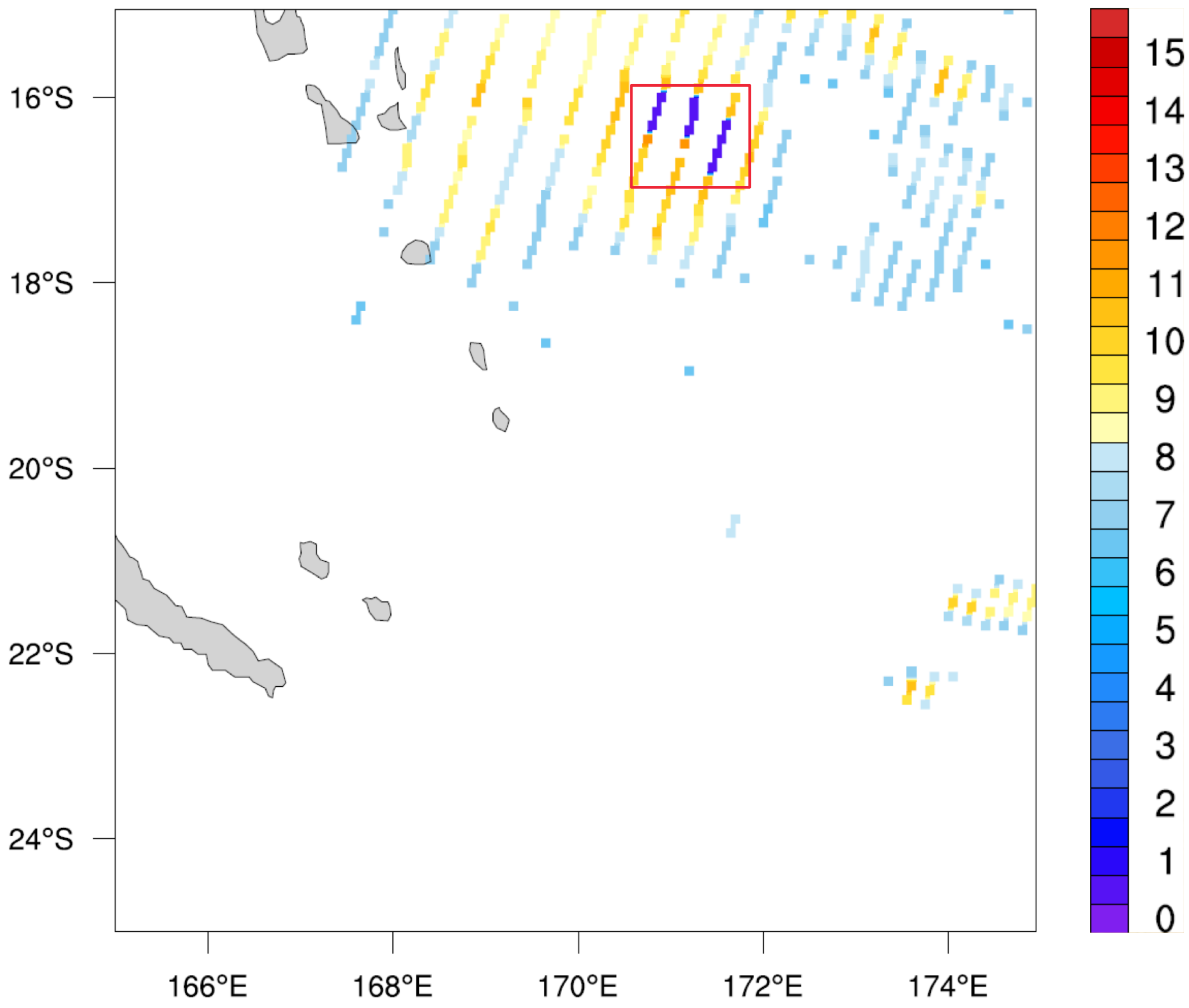
# Precipitation estimation

SAPHIR - 22 February estimation



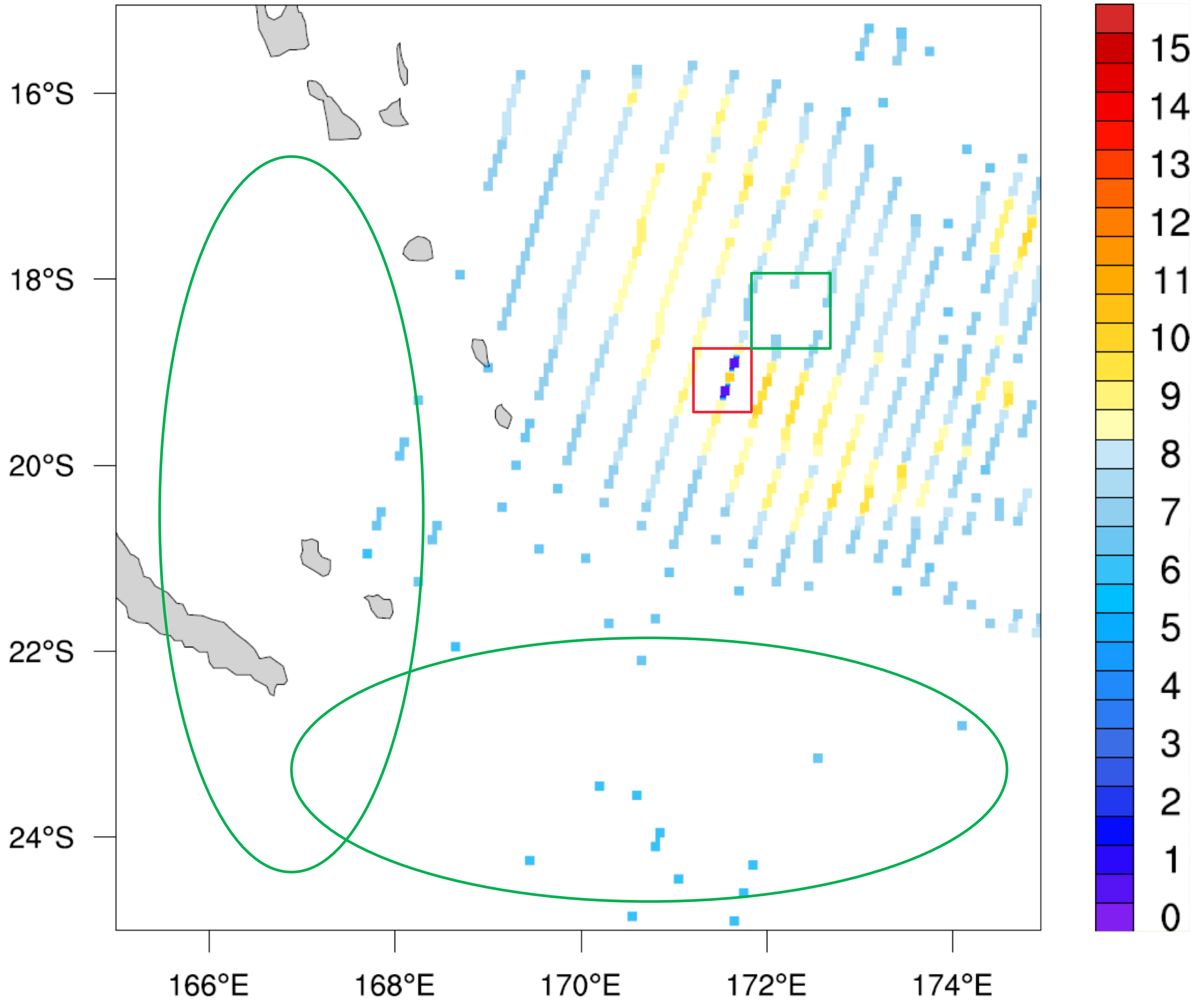
# Precipitation estimation

ATMS - 11 February estimation



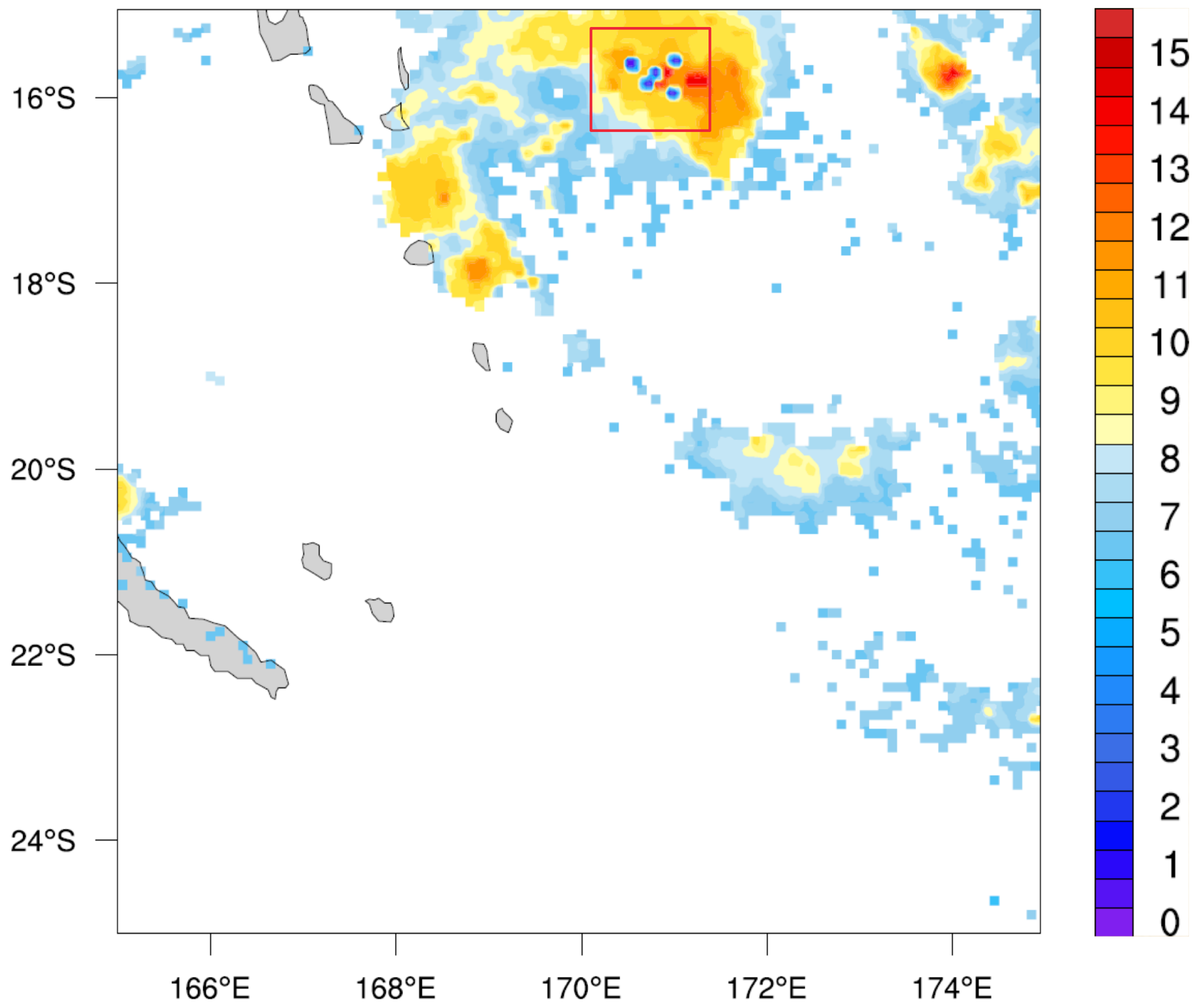
# Precipitation estimation

ATMS - 22 February estimation



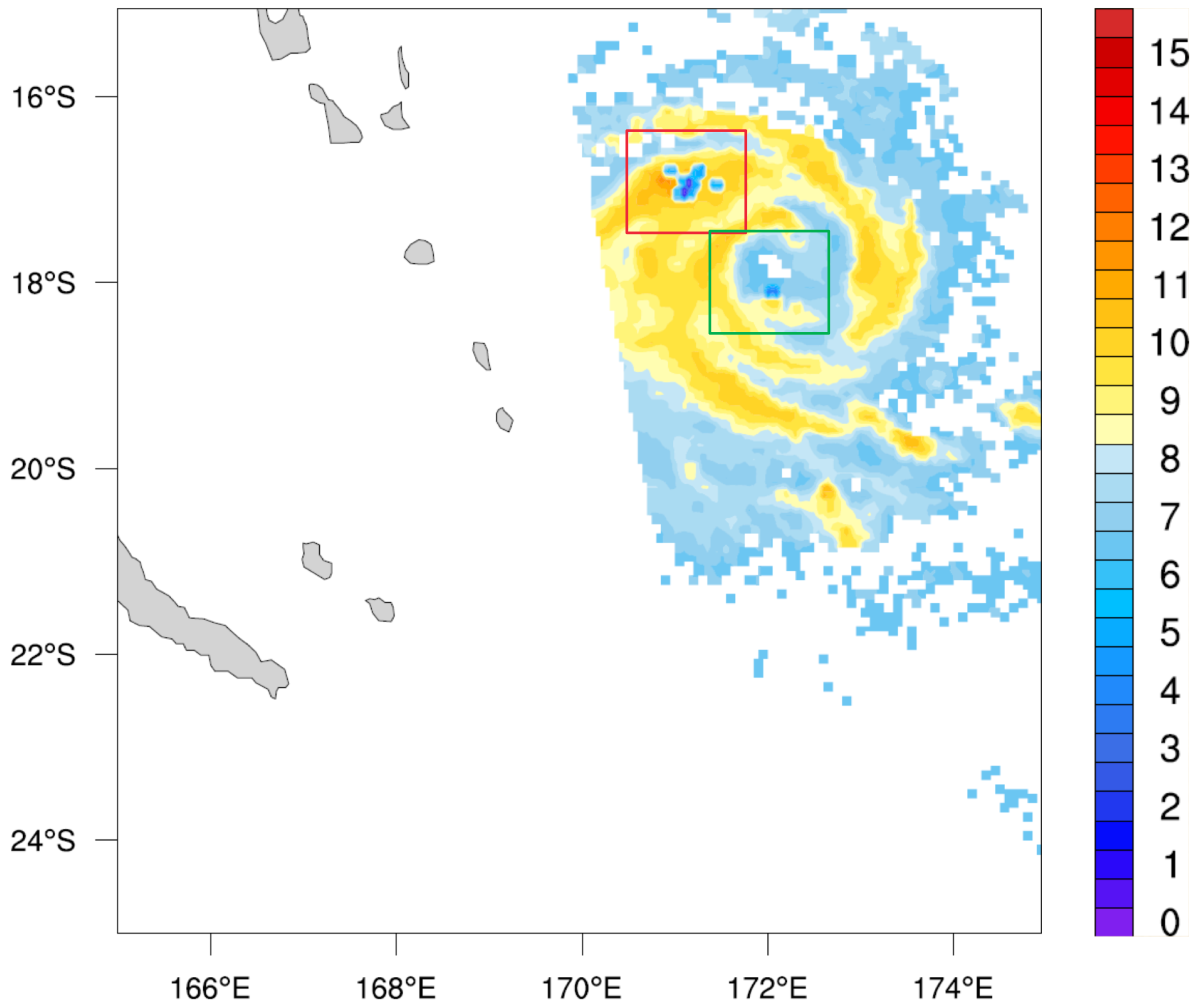
# Precipitation estimation

SSMIS - 11 February estimation



# Precipitation estimation

SSMIS - 22 February estimation



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# Conclusions

Results

- We cannot infer **all** the water content information from brightness temperatures

- Good estimations of the maximum top height of precipitation can be obtained from just brightness temperatures

- The combined use of coincident DPR and the other instruments is critical to train the detection/estimation

# Conclusions

Implications

- It is possible to build a **historical record** of convective precipitation
  - Radiometer information is available since 1998
- **Near-hour worldwide estimations**
- Improvement of convective system models
- Better estimations for **storm evolution**
- **Hazardous precipitation** detection in aviation weather
- Which radiometers channels are better for detecting convective precipitation
  - New generation of instruments

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# Thank you!

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