Status Update for Triton GNSS-R Mission

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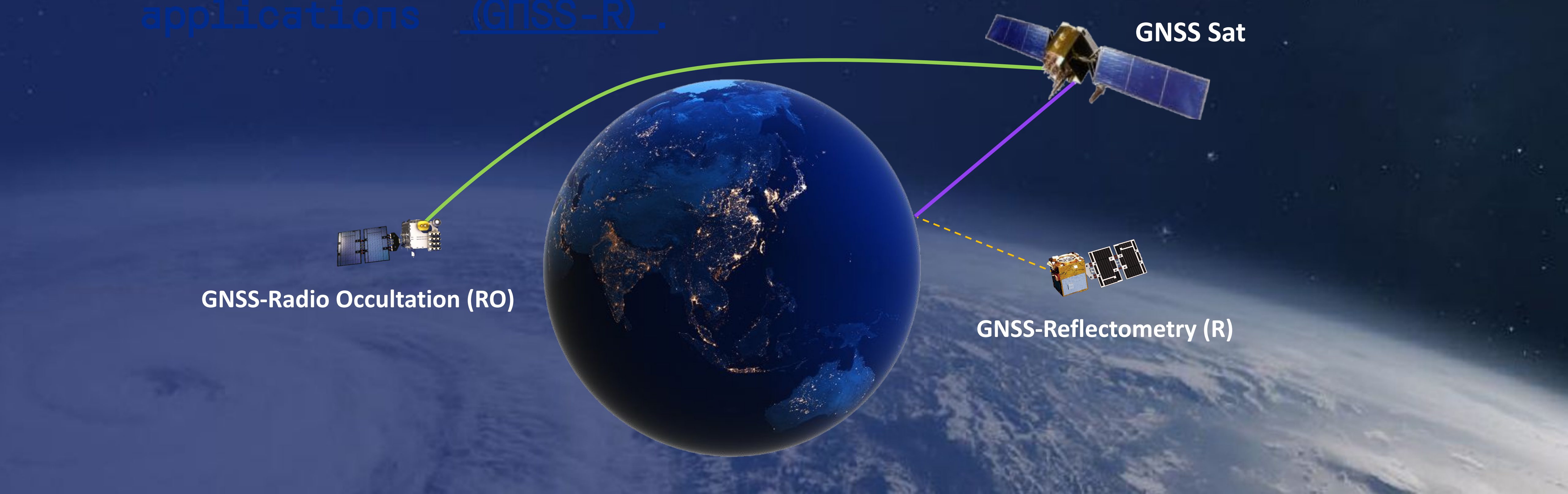
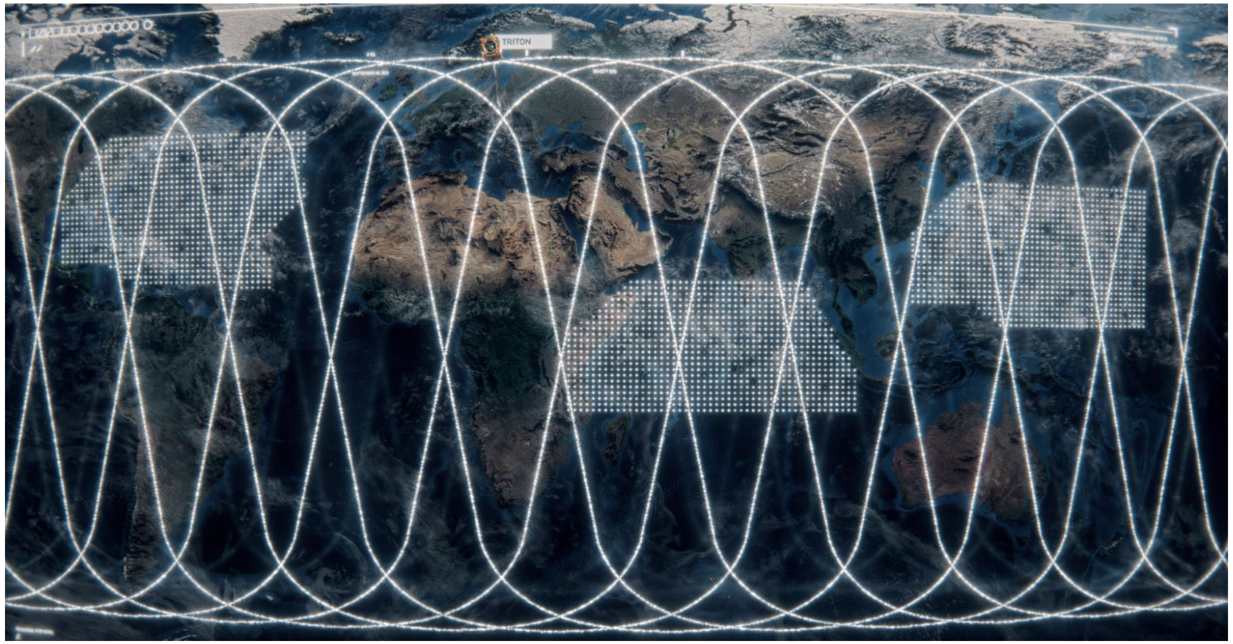
Taiwan Space Agency

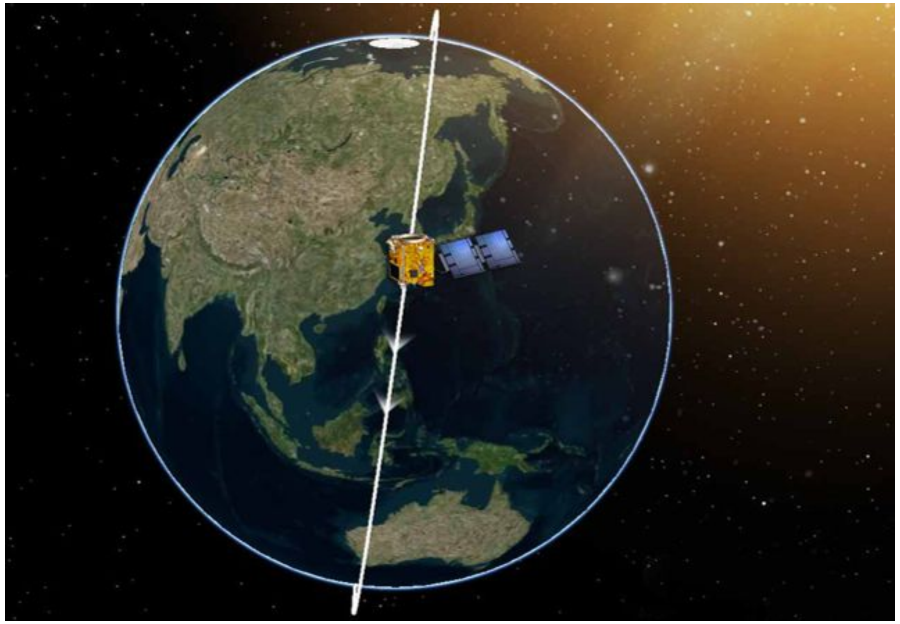
- FORMOSAT-7 constellation demonstrated the promising application of GNSS-RO for weather prediction.
- Triton was once one of FORMOSAT-7/COSMIC -2 constellation satellites.
- Triton is now providing Earth surface reflected signals from GNSS satellites for remote sensing applications (GNSS-R) .



Triton Mission

- Triton processes GNSS reflected signals and retrieve them to be wind speed for weather prediction (GNSS-R).
- To flight demonstrate Taiwan built components and technologies. If proven viable, could boost Taiwan's





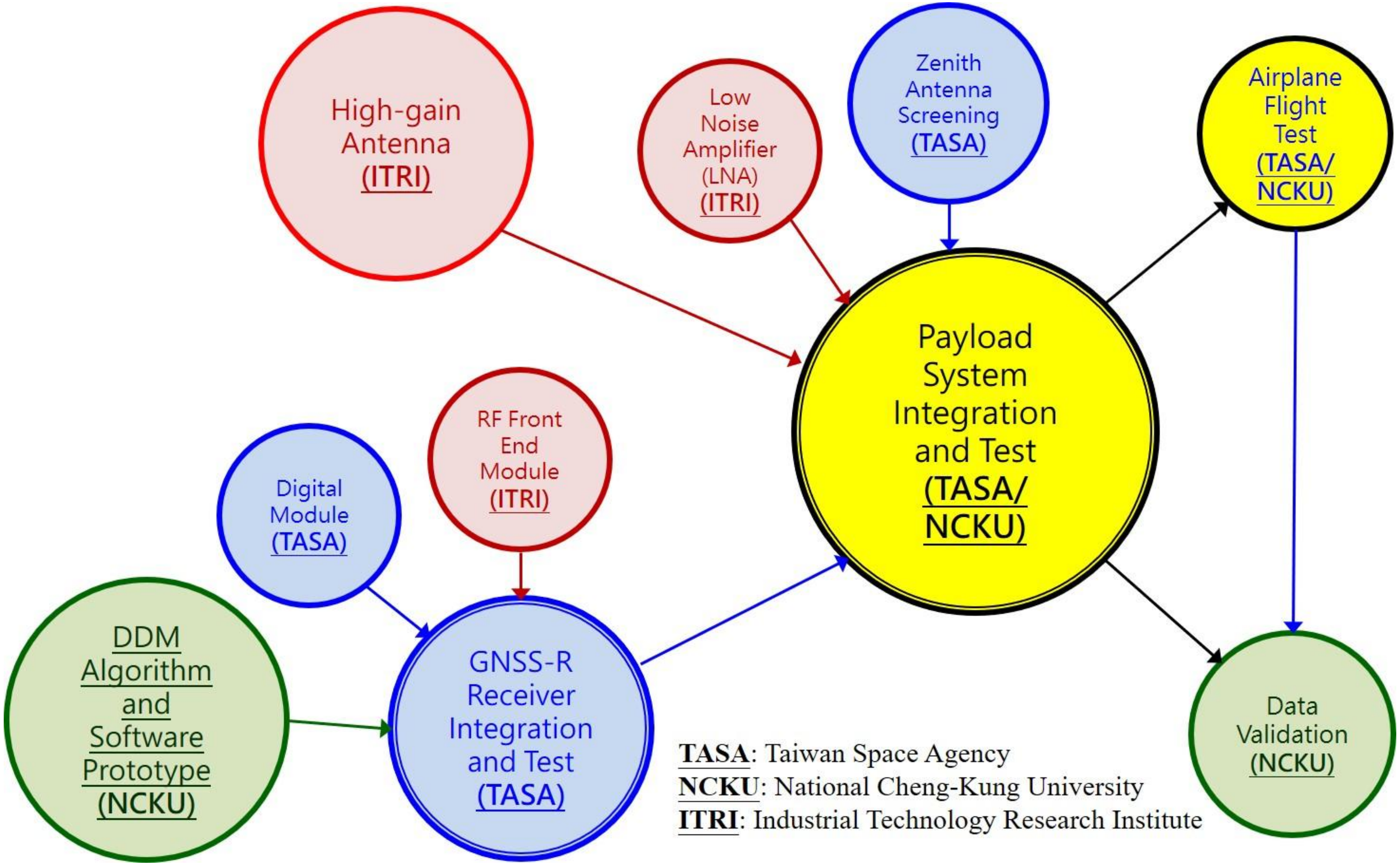
Taiwan Built Components and Technologies

- GNSS reflectometry science payload (GNSS-R)
- Second generation of On Board Computer (OBC) and Power Control Unit (PCU)
- Fiber Optical Gyro (FOG) and GPS receiver (GPSR)
- Solar array peak-power tracking (PPT) controller and micro-stepping solar array driver
- Gyro/Stellar and gyroless tude determination algori
- Data

Key Component	Validation Result
On Board Computer	Passed
Power Control Unit	Passed
Fiber Optic Gyro	Passed
GPS Receiver	Passed
Propulsion Demonstration Module (H2O2)	Passed

Key Technology	Validation Results
Micro-stepping solar array controller	Passed
Solar array peak power tracking controller	Passed
Gyro-less attitude determination system	Passed
Gyro/Stellar Attitude Determination System	Passed
Data Relay System	Passed

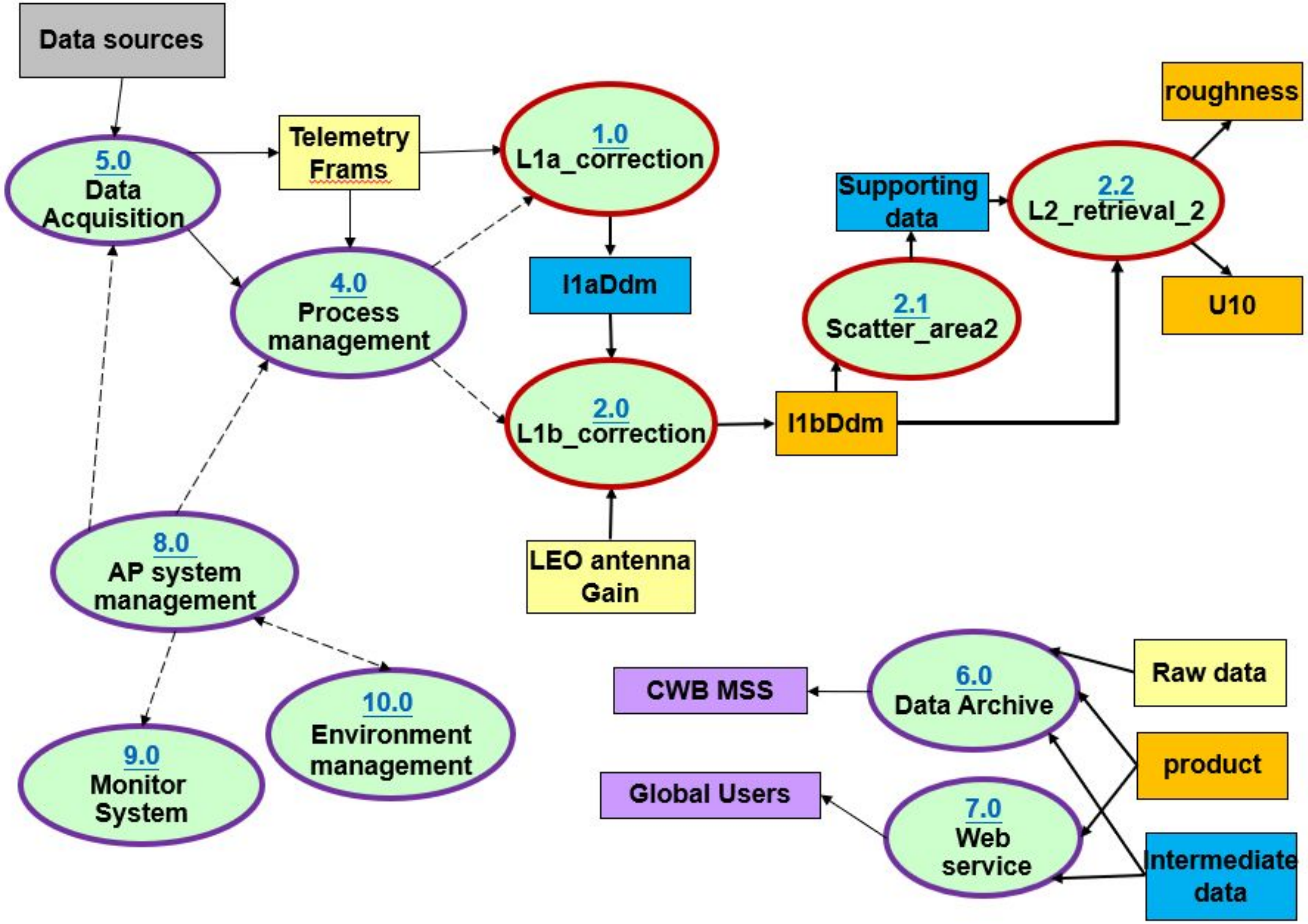
GNSS-R Payload Development Approach



Satellite Status @ LEOP

- Sun pointing was achieved less than 2 orbit, very soon.
- Satellite enter to Normal Mode (NM) in 2 days, then provides full performance.
- GNSS-R payload was switched on 3 rd day after launch.
- Calibration burn was performed in the 2 nd week after launch, using N2H4 propulsion module.
- One Automatic Reconfiguration Order (ARO) was occurred due to single event upset of On-Board-Computer.
- Few auto switch off of GPSR and GNSS-R were occurred due to single event upset. After power on, the functionalities were recovered.
- GNSS-R payload data calibration plan:
  - ✔ Payload parameter decision:1 month after launch.

GNSS-R Retrieval Process



DDM Calibration

C ： the DDM values in counts
G ： the total instrument gain applied to the incoming signal and noise in counts per watt

P_g ：the scattered signal power received by the instrument in watts
P_n ：the noise power generated by the received signal with wrong PRN
P_a ：the thermal noise power received by the antenna in watts
P_a=k*T_a*B_w
P_r ：the thermal noise power generated by the instrument in watts
P_r=k*T_r*B_w
k ：Boltzmann's constant=1.380649e-23
T_a & T_r ：antenna and receiver temperature
B_w： signal bandwidth

The value of each bin in DDM can be described by

$$C = G(P_g + P_n + P_a + P_r)$$

The noise floor C_n of DDM can be described by

$$C_n = G(P_n + P_a + P_r)$$

due to the P_n of each DDM is different, it needs to be removed to calculate G by

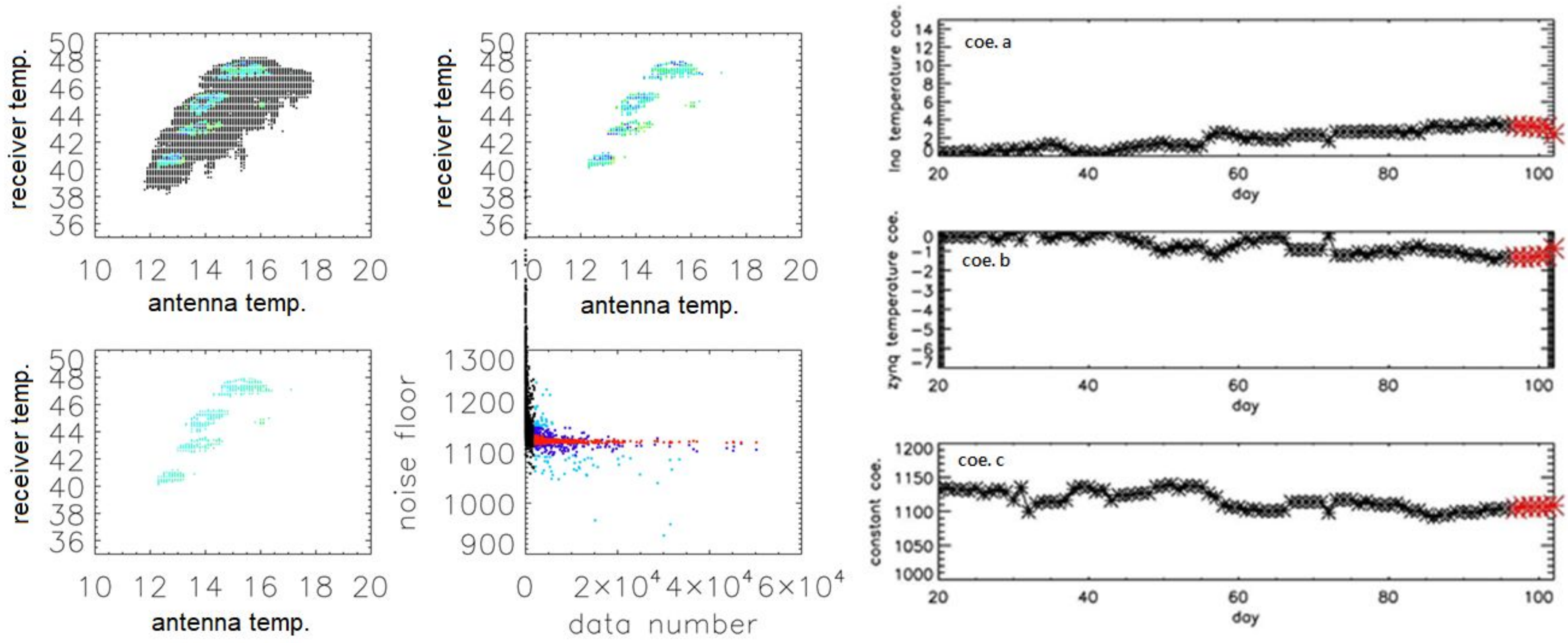
$$C_{min} = G(P_a + P_r)$$

then P_g can be derived by

$$P_g = (C - C_n)\frac{(P_a + P_r)}{C_{min}}$$

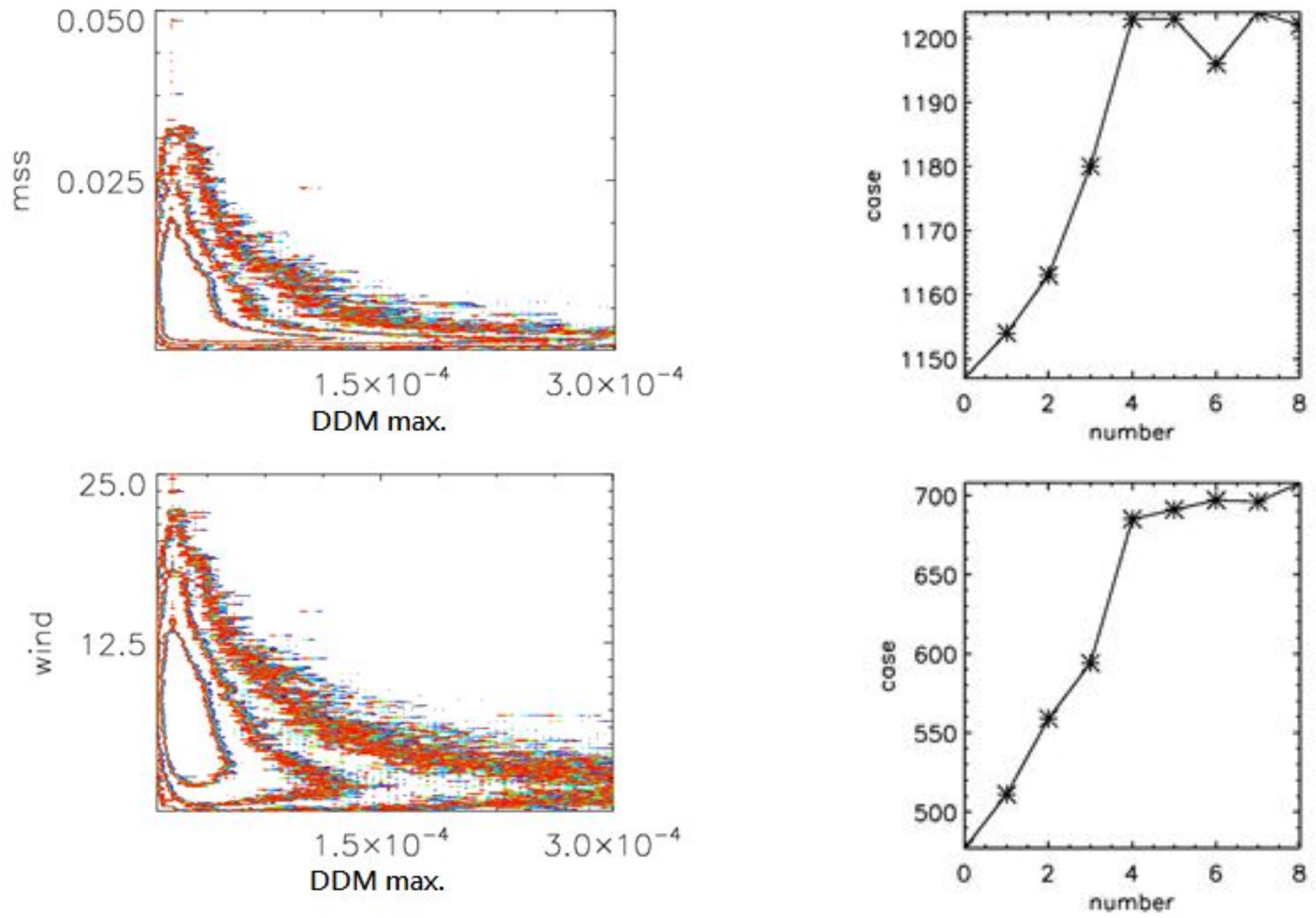
$$(noise\ floor, C_{min}) = a \times (antenna\ temperature) + b \times (receiver\ temperature) + c$$

DDM Calibration



$$(noise\ floor, C_{min}) = a \times (antenna\ temperature) + b \times (receiver\ temperature) + c$$

DDM Calibration

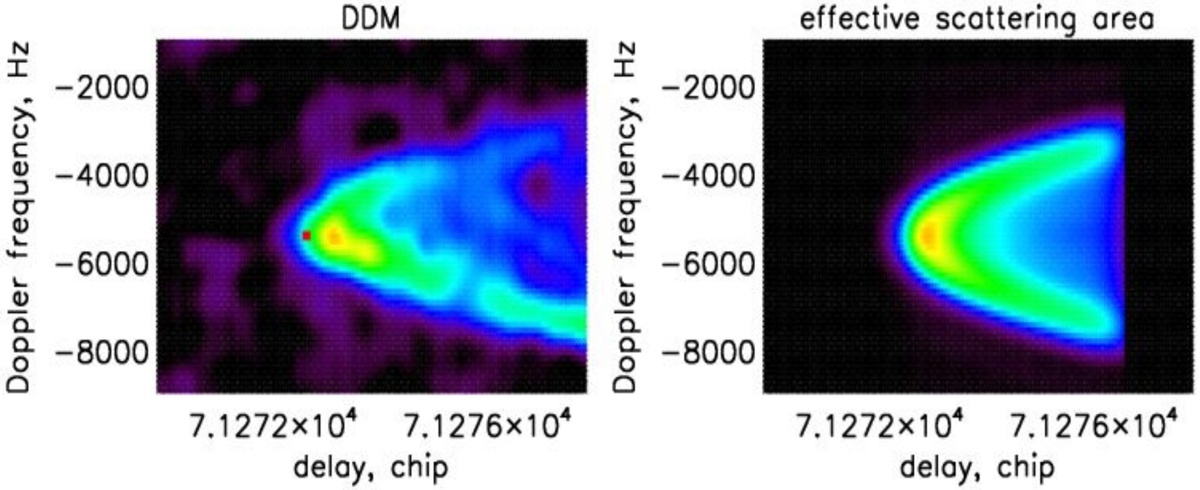


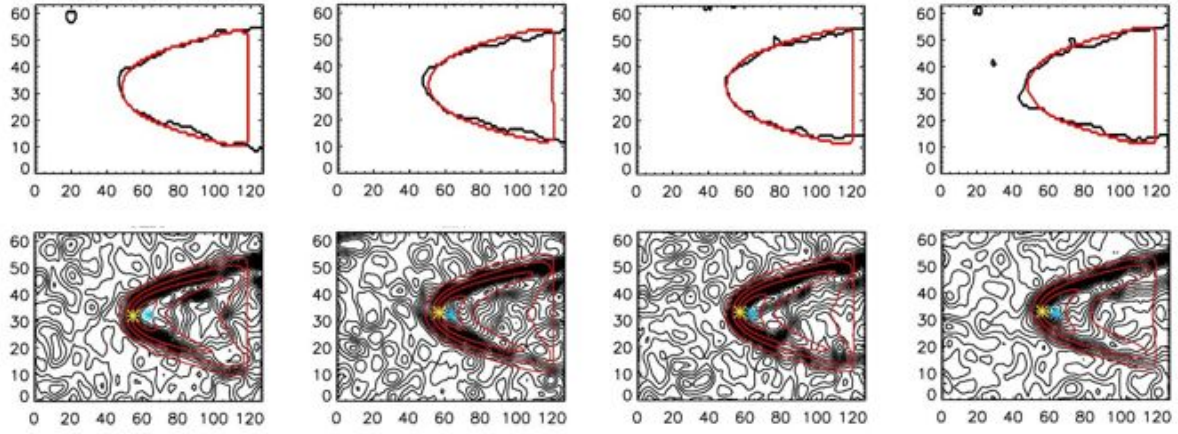
Specular Point Determination

$$\langle P(\hat{\tau},\hat{f}^D)\rangle = \frac{P^T\lambda^2}{(4\pi)^3}\iint_S \frac{G^T G^R}{R_0^2 R^2}\Lambda^2\left(\frac{\delta\tau}{\tau_c}\right)S^2\left(\frac{\delta f^D}{T_i}\right)\sigma_0 d^2 r$$

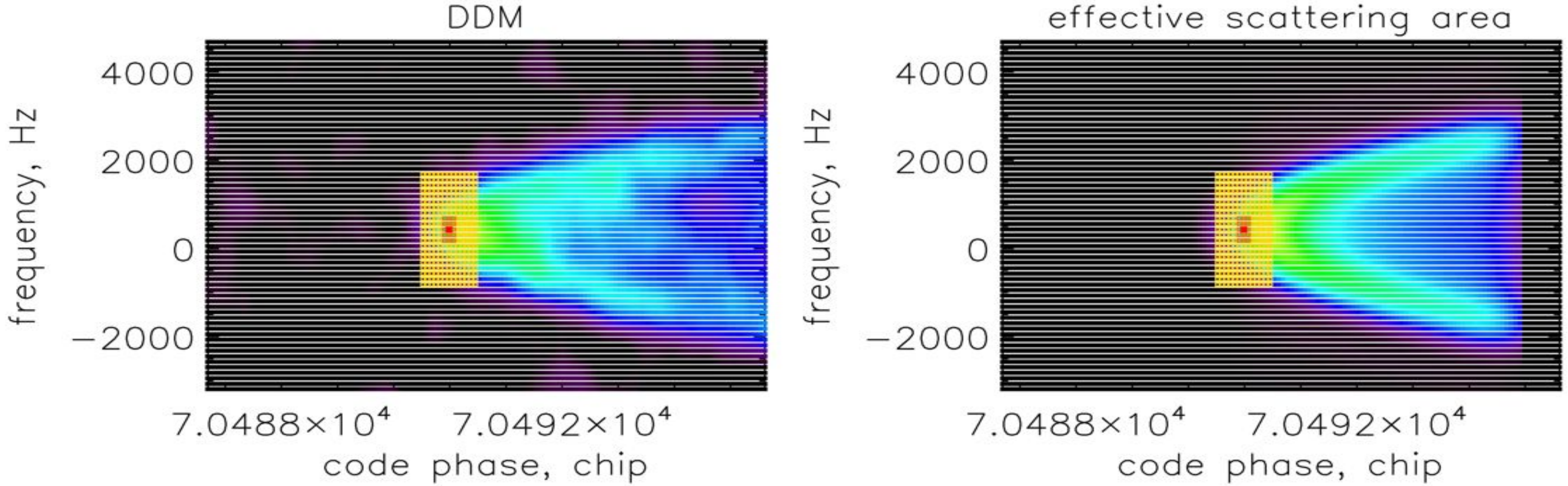
$$\langle P(\hat{\tau},\hat{f}^D)\rangle = \frac{P^T\lambda^2 G^T G^R \sigma_0 \bar{A}_{eff}}{(4\pi)^3 R_0^2 R^2}$$

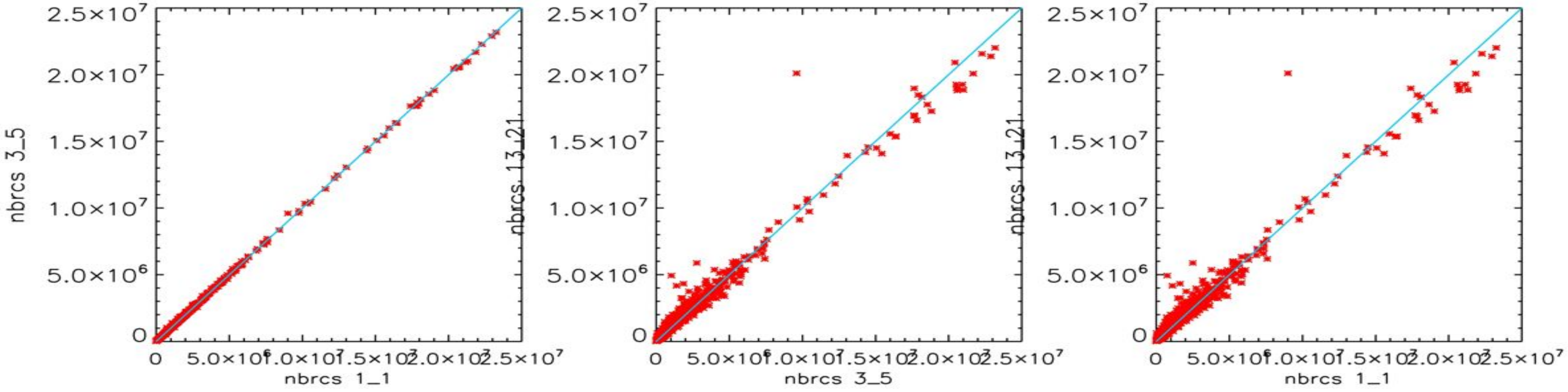
$$P^T G^T \sigma_0 = \langle P(\hat{\tau},\hat{f}^D)\rangle \frac{(4\pi)^3 R_0^2 R^2}{\lambda^2 G^R \bar{A}_{eff}}$$



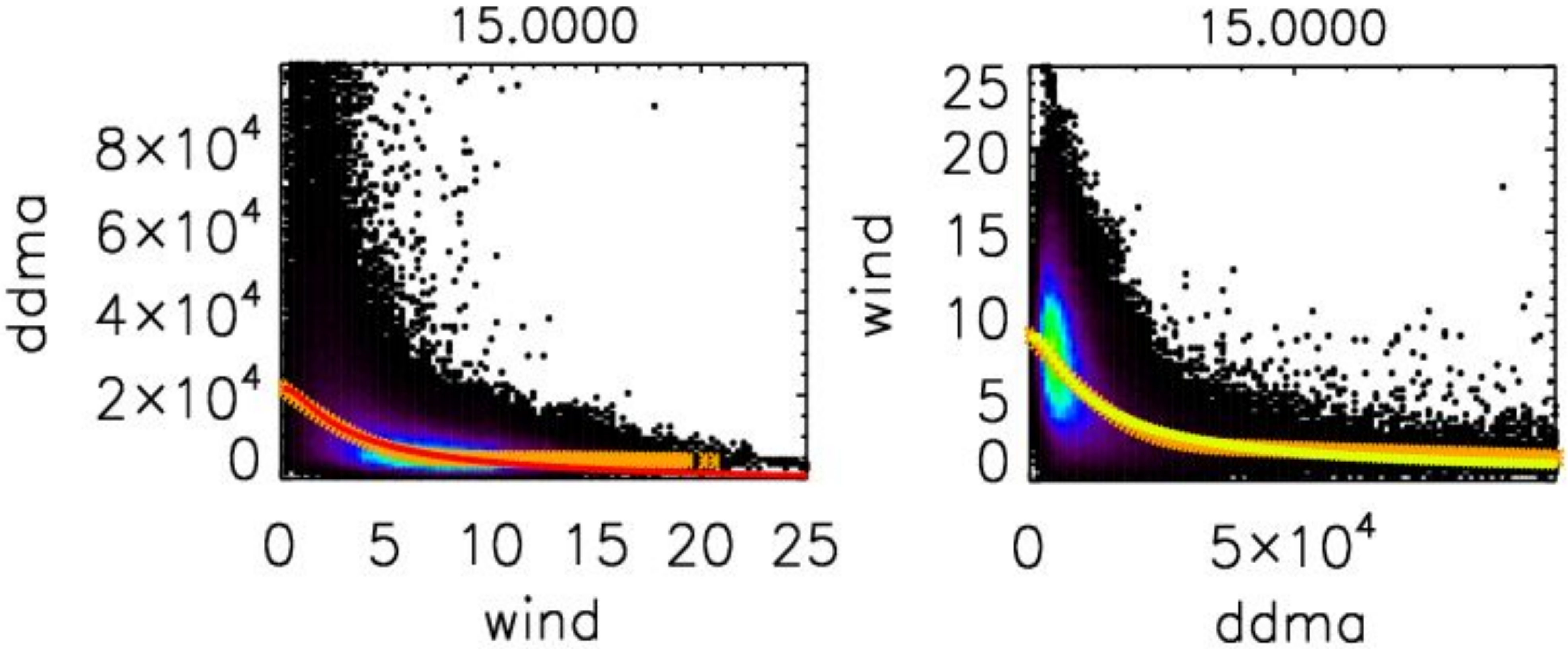


Normalized Bistatic Radar Cross Section (NBRCS)



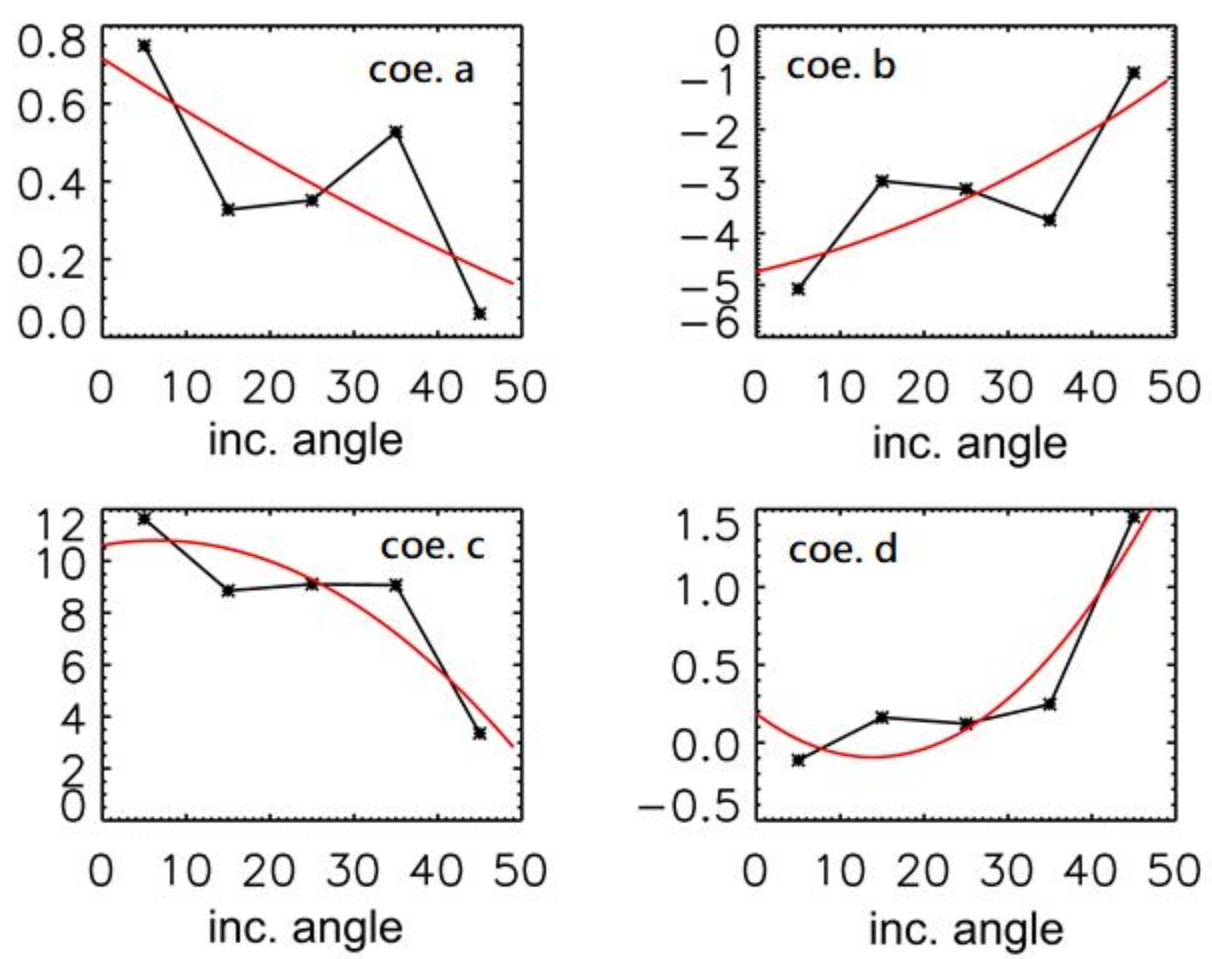


Geophysical Model Function (GMF)



$$y = ax^{-3} + bx^{-2} + cx^{-1} + d$$

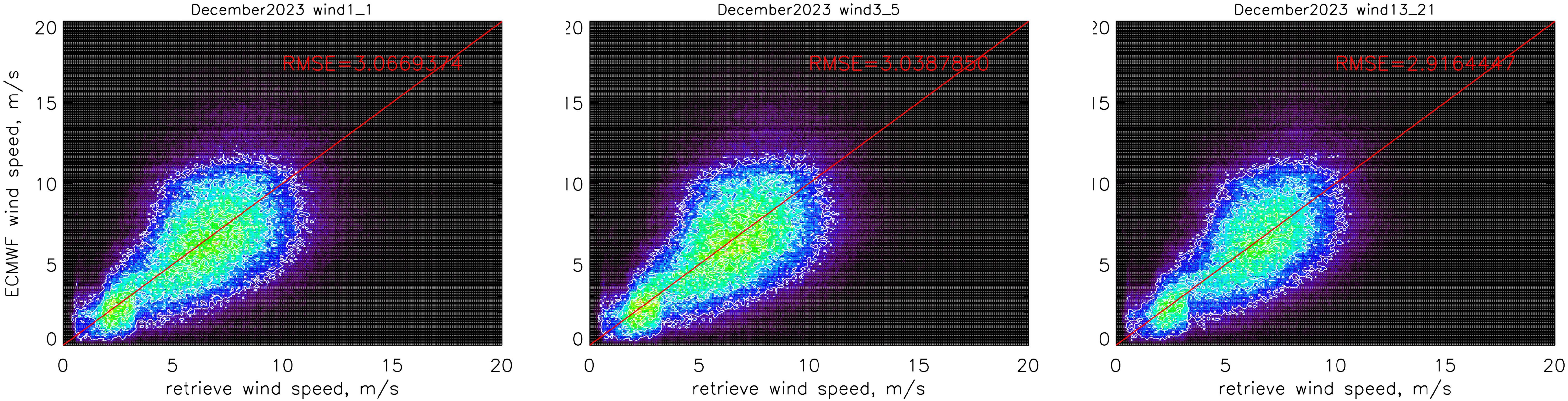
Coefficients of GMF



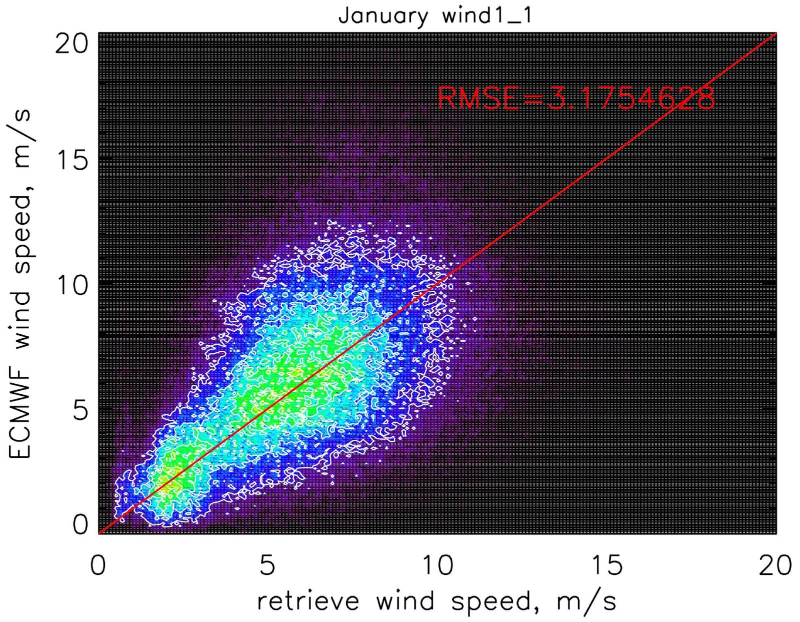
$$y = ax^{-3} + bx^{-2} + cx^{-1} + d$$

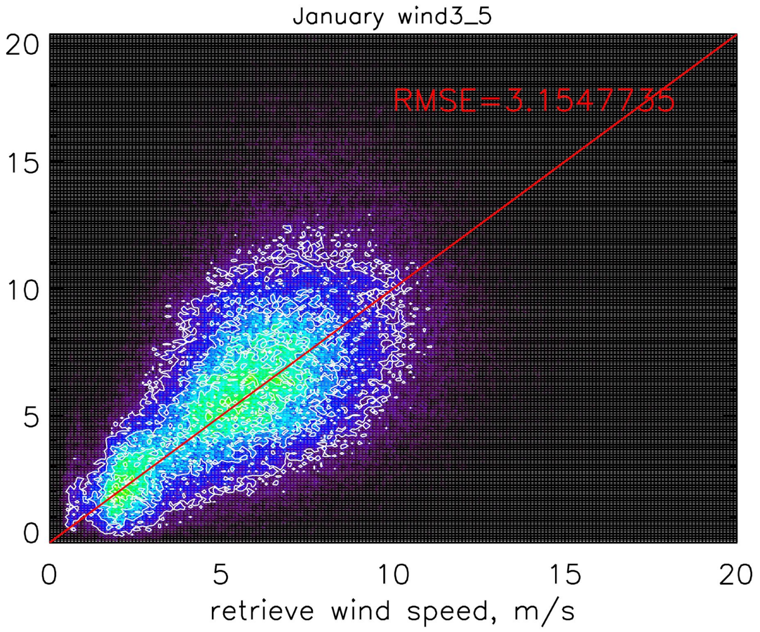
$$coe_{inc} = P_{coe}(inc)^2 + Q_{coe}(inc) + R_{coe}$$

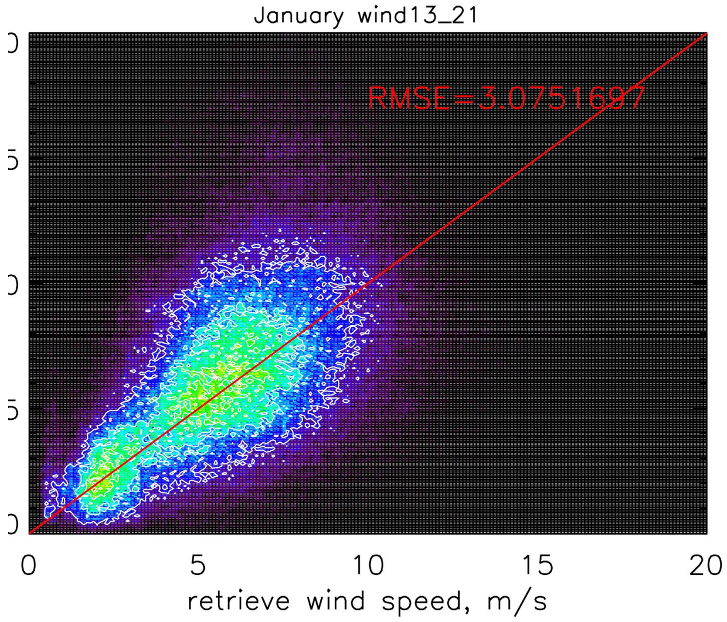
Wind Speed Retrieval Results (Dec. 2023)



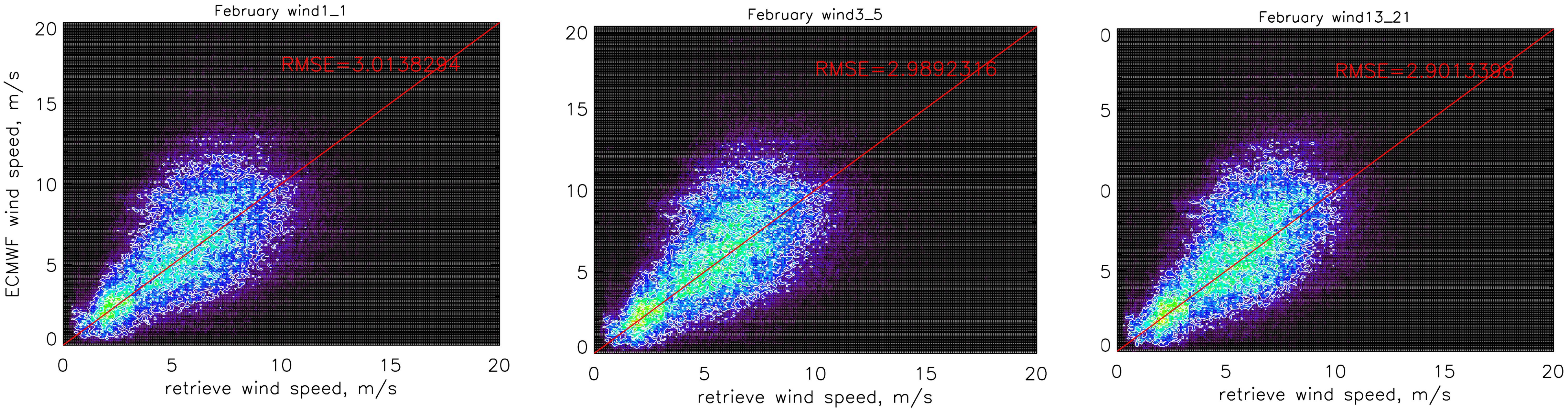
Wind Speed Retrieval Results (Jan. 2024)



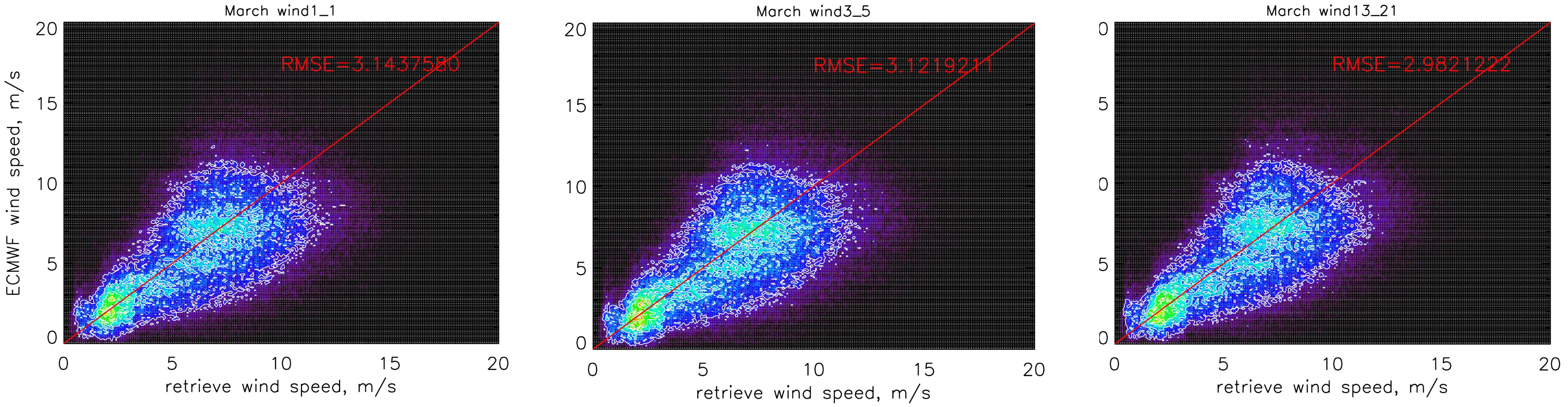




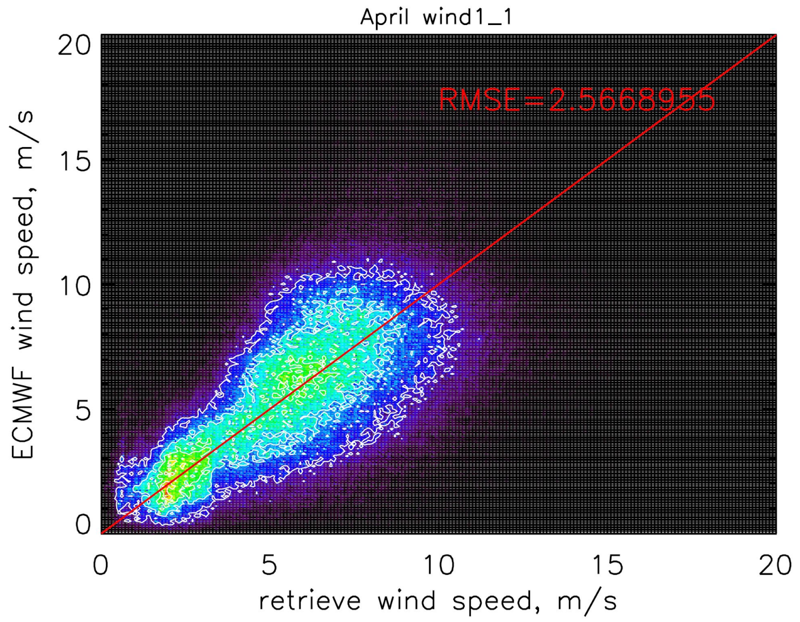
Wind Speed Retrieval Results (Feb. 2024)

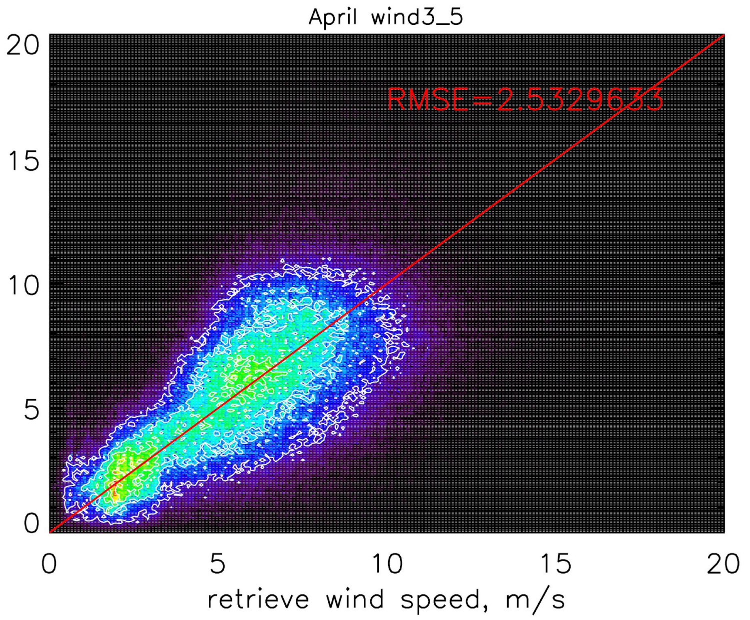


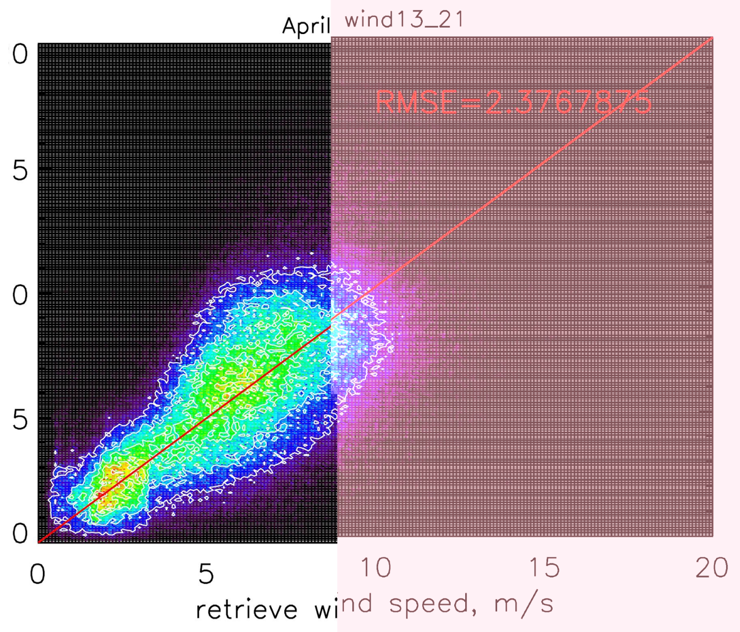
Wind Speed Retrieval Results (Mar. 2024)



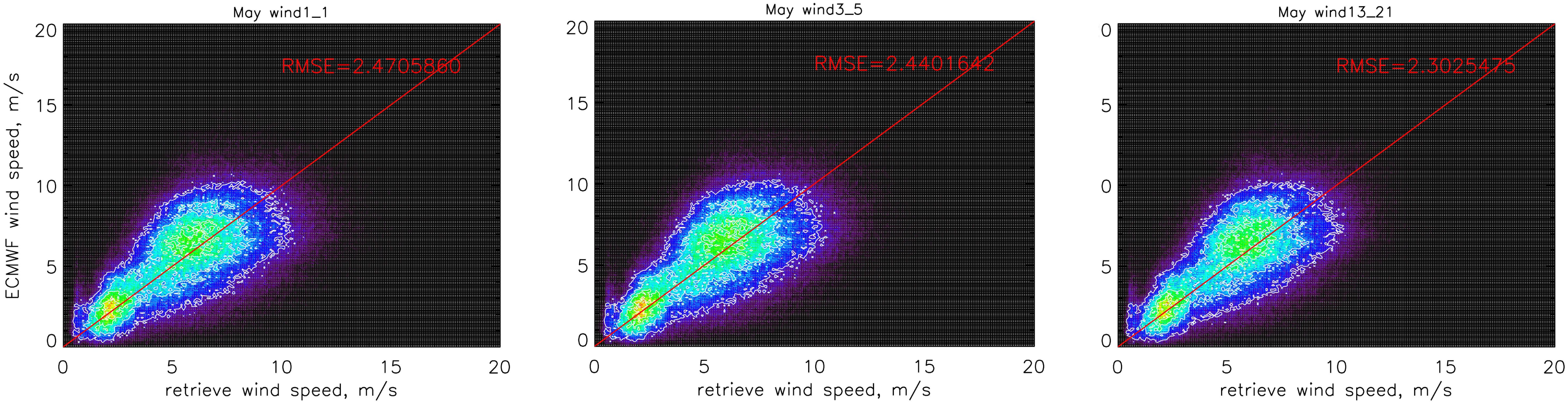
Wind Speed Retrieval Results (Apr. 2024)



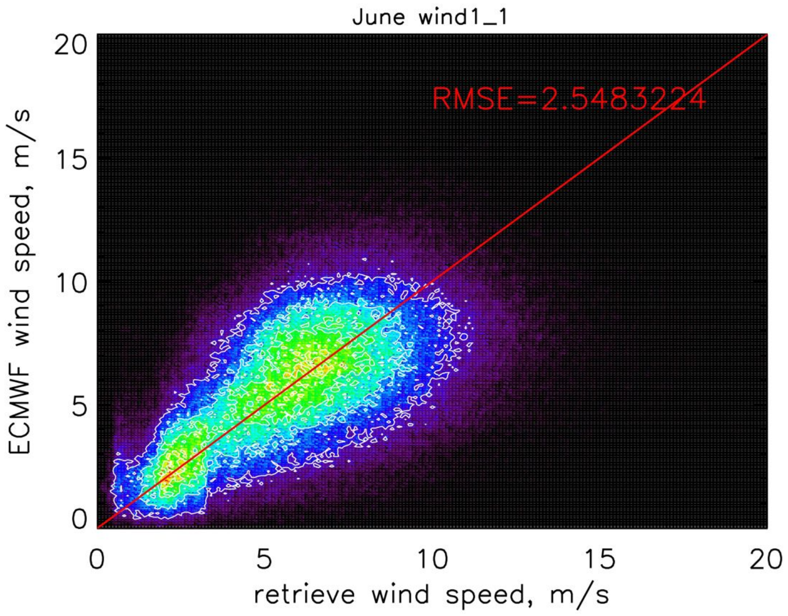


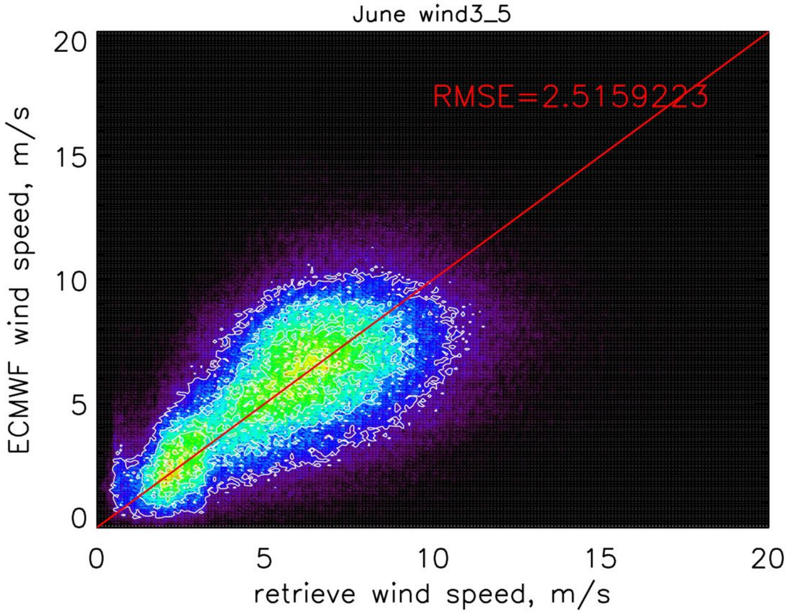


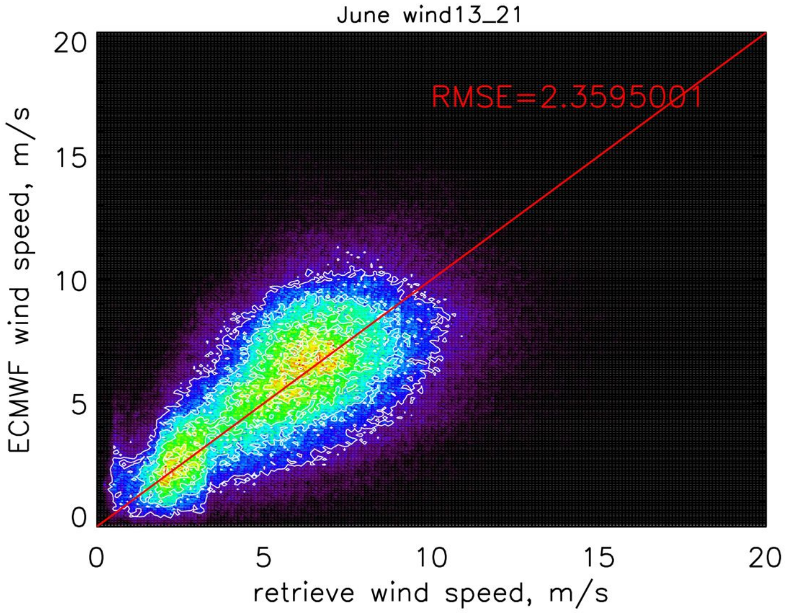
Wind Speed Retrieval Results (May 2024)



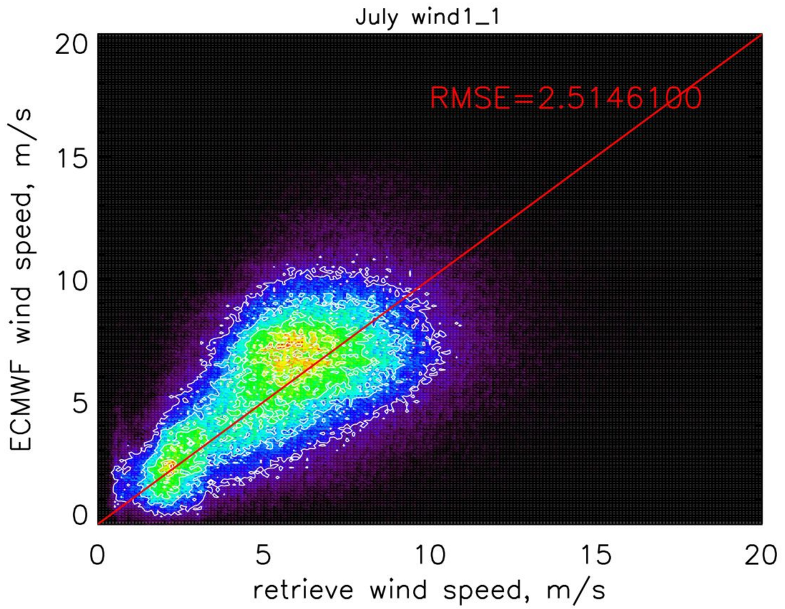
Wind Speed Retrieval Results (Jun. 2024)

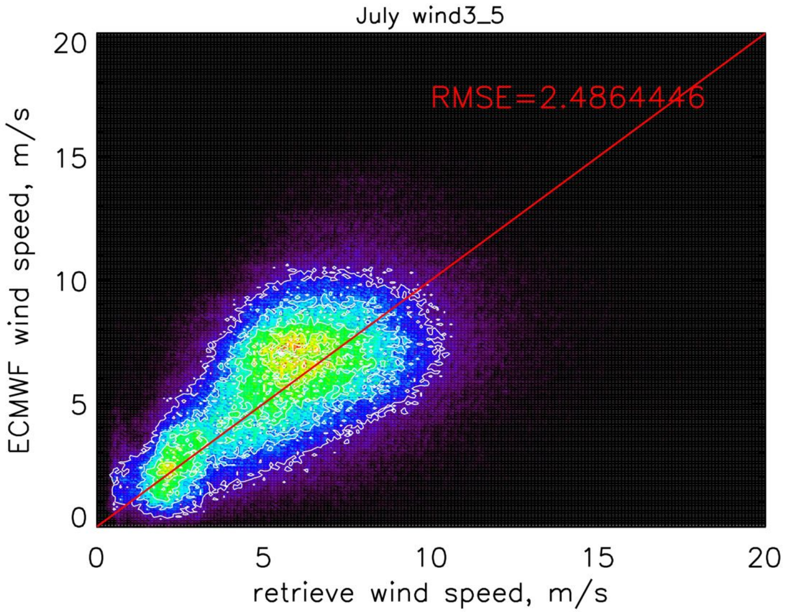


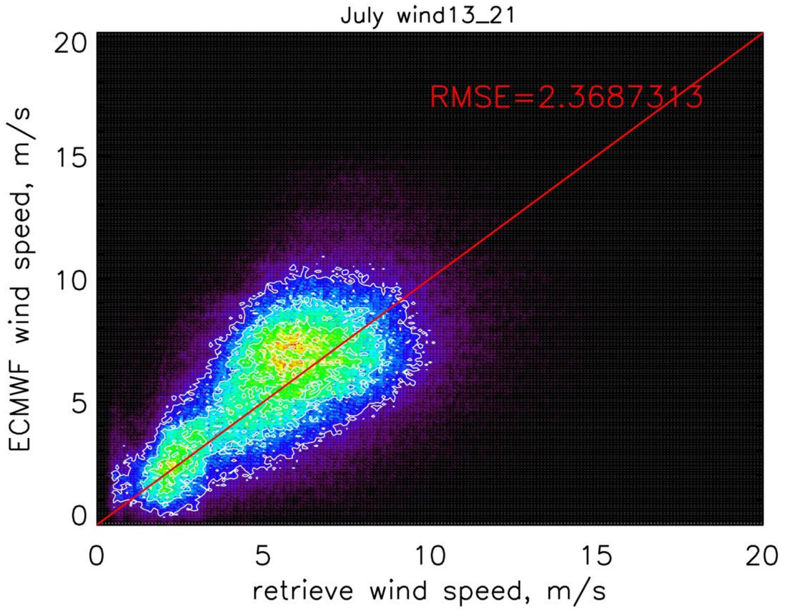




Wind Speed Retrieval Results (Jul. 2024)

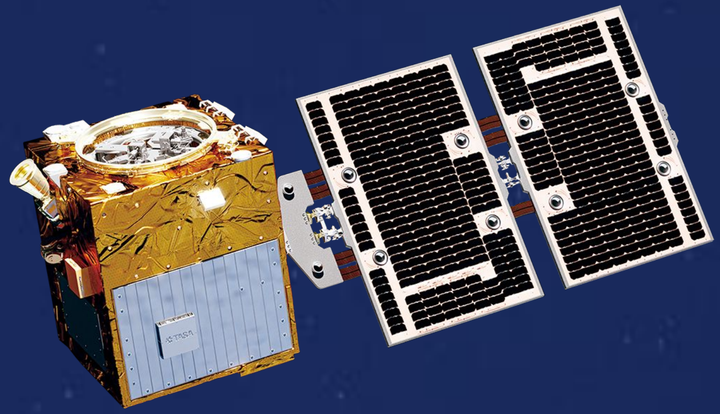






Conclusions

- The RMSE of retrieval ocean surface wind speed compared with ECMWF is around 2.7 m/s.
- The RMSE of retrieval ocean surface wind speed before Mar. 2024 is around 3 m/s and around 2.4 m/s after Mar. 2024.
- Prepare TRITON products v2.0 (not later than mid-2025)
  - DDM calibration with NBRCS then rebuild GMF
  - Minimum variance method to combine two GMF wind speed
  -



Thanks for Your Attention