



AOMSUC-15 2025 FYSUC

THE 15TH ASIA-OCEANIA METEOROLOGICAL SATELLITE USERS' CONFERENCE (AOMSUC-15)
2025 FENGYUN SATELLITE USER CONFERENCE (2025 FYSUC)



A study on wind field retrieval using hybrid tracking regions based on microwave water vapor channel data from polar-orbiting satellites

Gang Ma¹ Zongru Yang^{1,2} Weihong Tian¹ Xuezhi Bai² Peng Zhang³

magang@cma.gov.cn



1.CMA Earth System Modeling and Prediction Centre (CEMC)

2.College of Oceanography, Hohai University

3Atmospheric Observation Center, CMA

30 Oct., 2025 Qingdao



Outline

01 BackGround

02 Introduction of algorithm

03 Evaluation of retrieved AMV

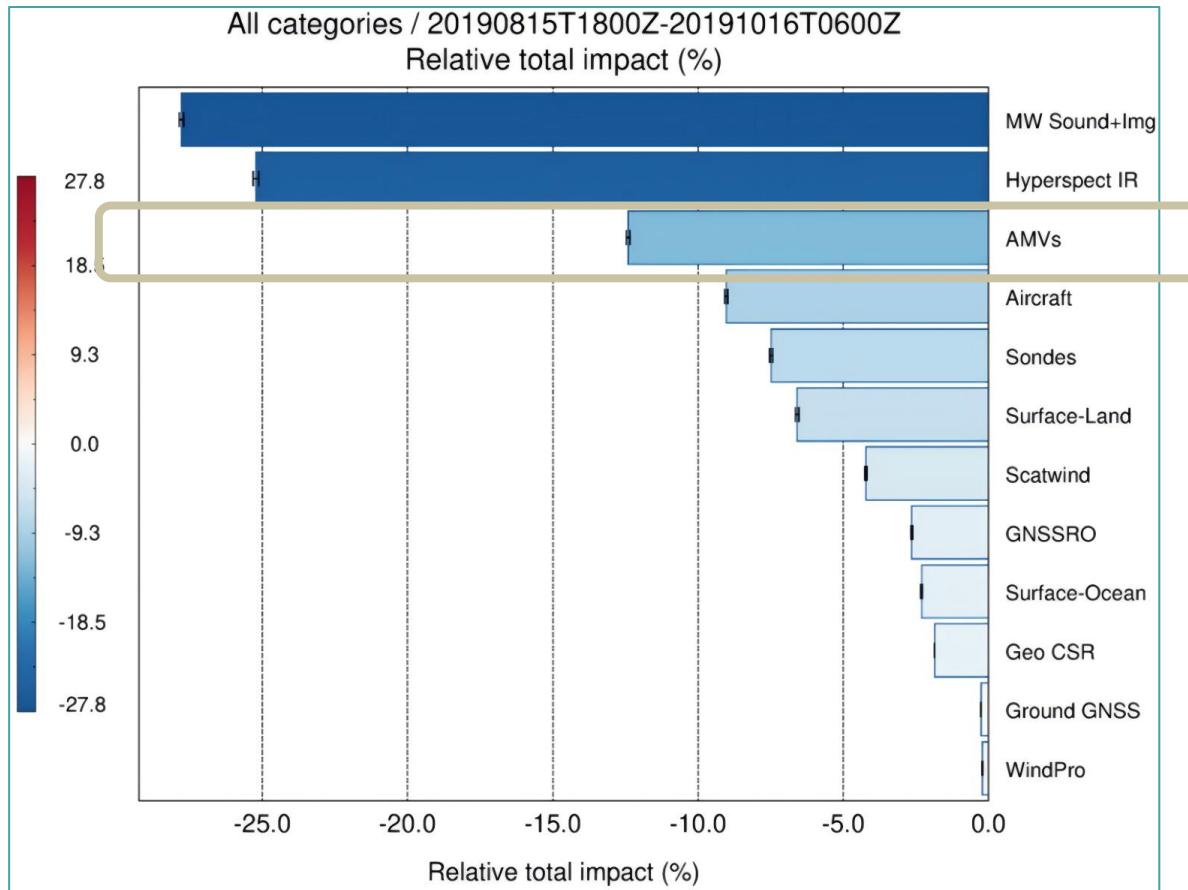
04 Impact to data assimilation

05 Summary ¹

Background

- Key factors to drive atmospheric motion
- Key factor to NWP
- Key factor to affect accuracy of NWP by undifferentiated satellite observations
- Great positive impact of AMV in application of NWP

The wind field is one of the most influential assimilation data sources currently.

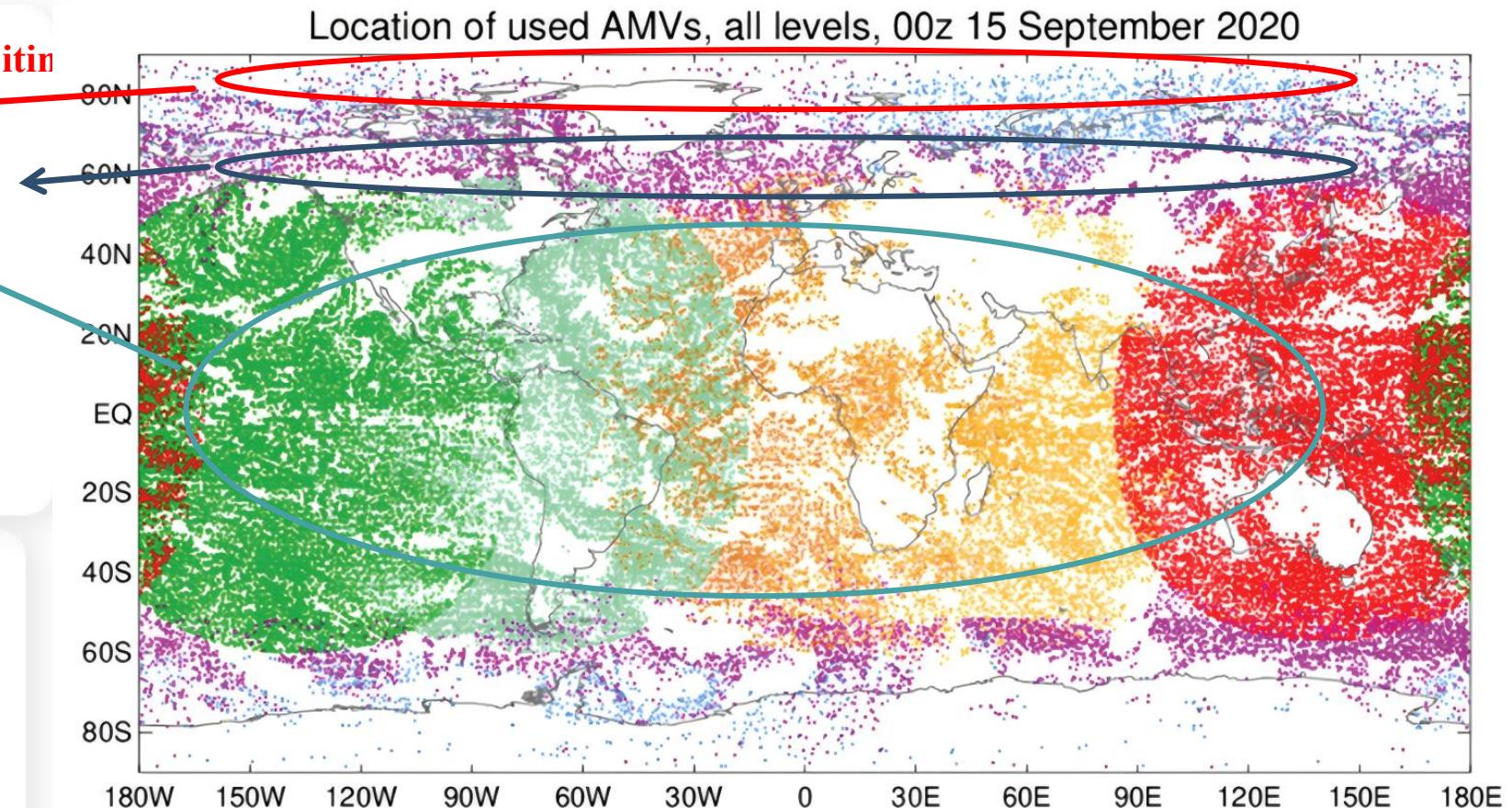


From August to October 2019, all relative FSOI (Forecast Sensitivity to Observation Impact) observed by the UK Met Office Global Numerical Weather Prediction System. (Eyre et al., 2022)

Background (continued)

- High-latitude: Polar AMV of Polar-orbiting Satellite
- Global: AMV of Metop
- Low-latitude: AMV of Geo-Satellite
- All AMV are retrieved by Infrared observation

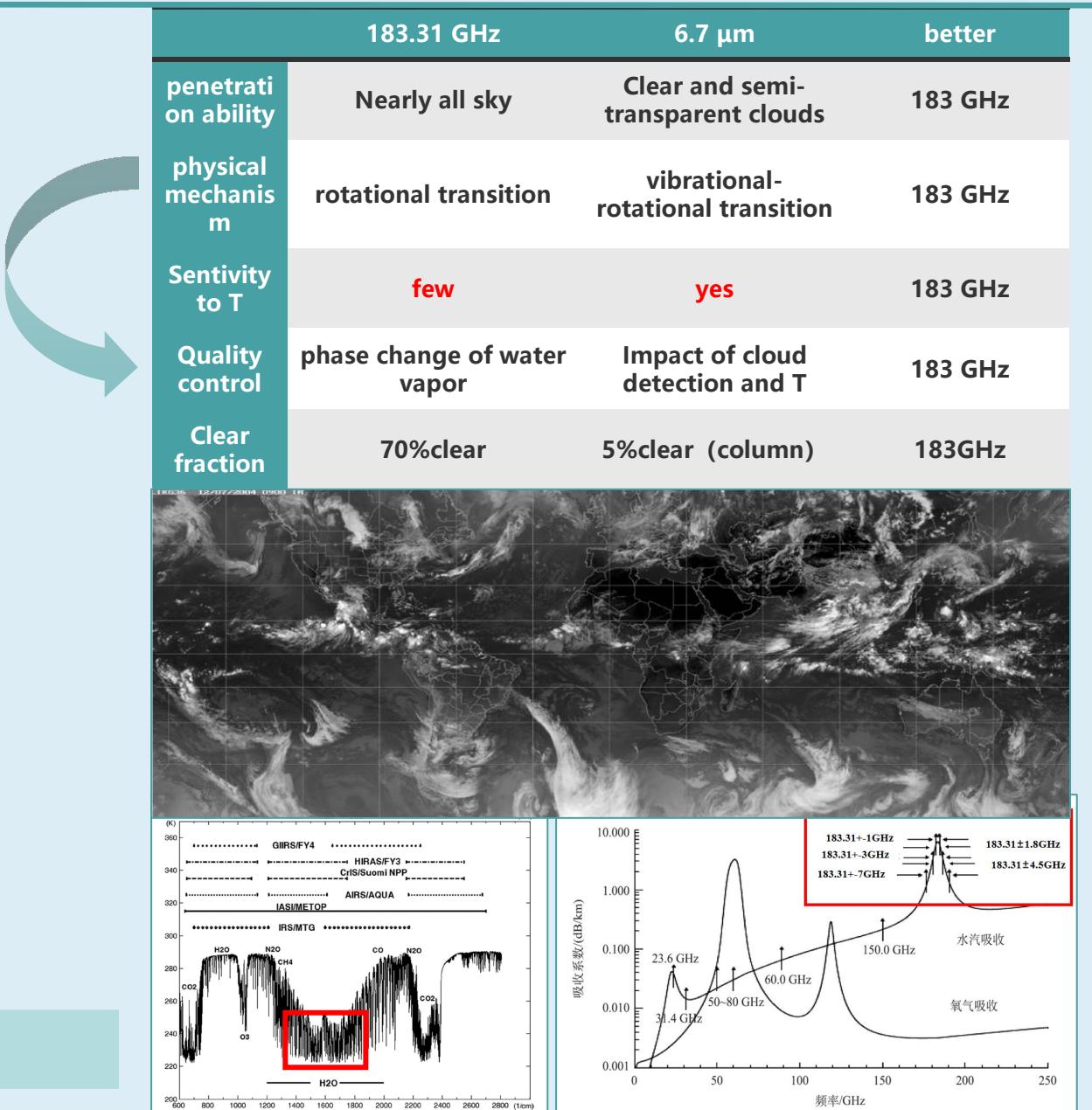
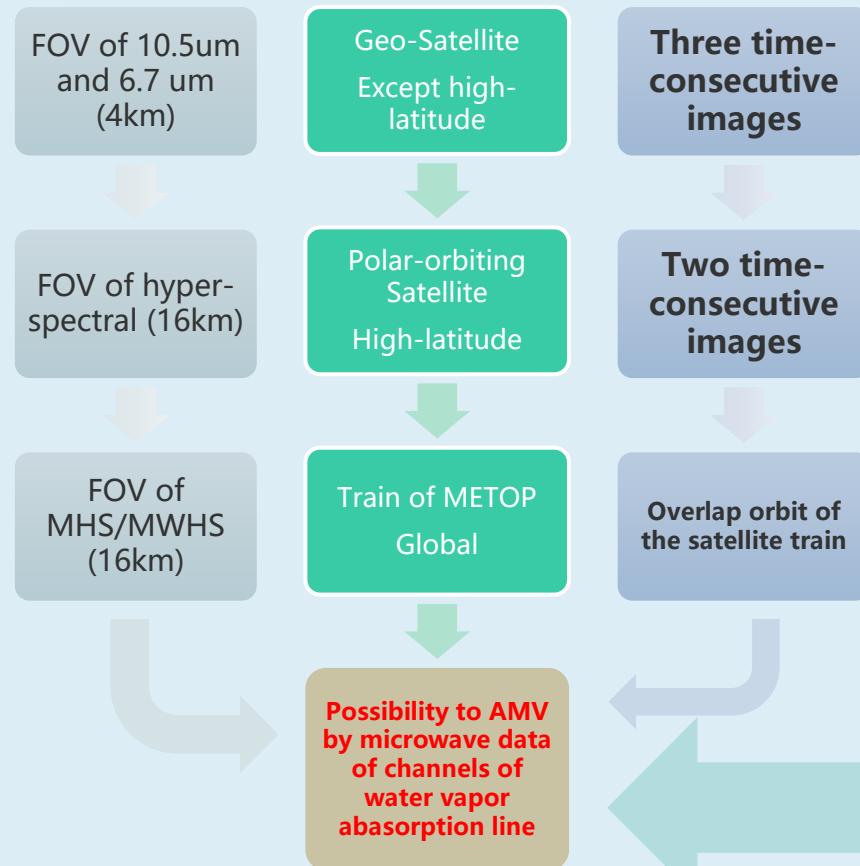
- Analysis to AMV by infrared radiance:
 - Restricted by cloud fraction
- Analysis to possible AMV by microwave data:
 - Few impact of cloud
 - More accurate calibration



Could AMV retrieved by
Microwave radiance???

Background(continued II)

- AMV by sounding channel
 - AMV by overlap orbit of METOP
 - Both absorption line of water vapor at 183GHz and 6.7um



Method——Dense optical flow retrieval pixel by pixel

➤ Farneback Dense Optical Flow Method

- Wind vector is calculated by gradient of brightness temperature of FOV

$$I_x u + I_y v + I_t = 0$$

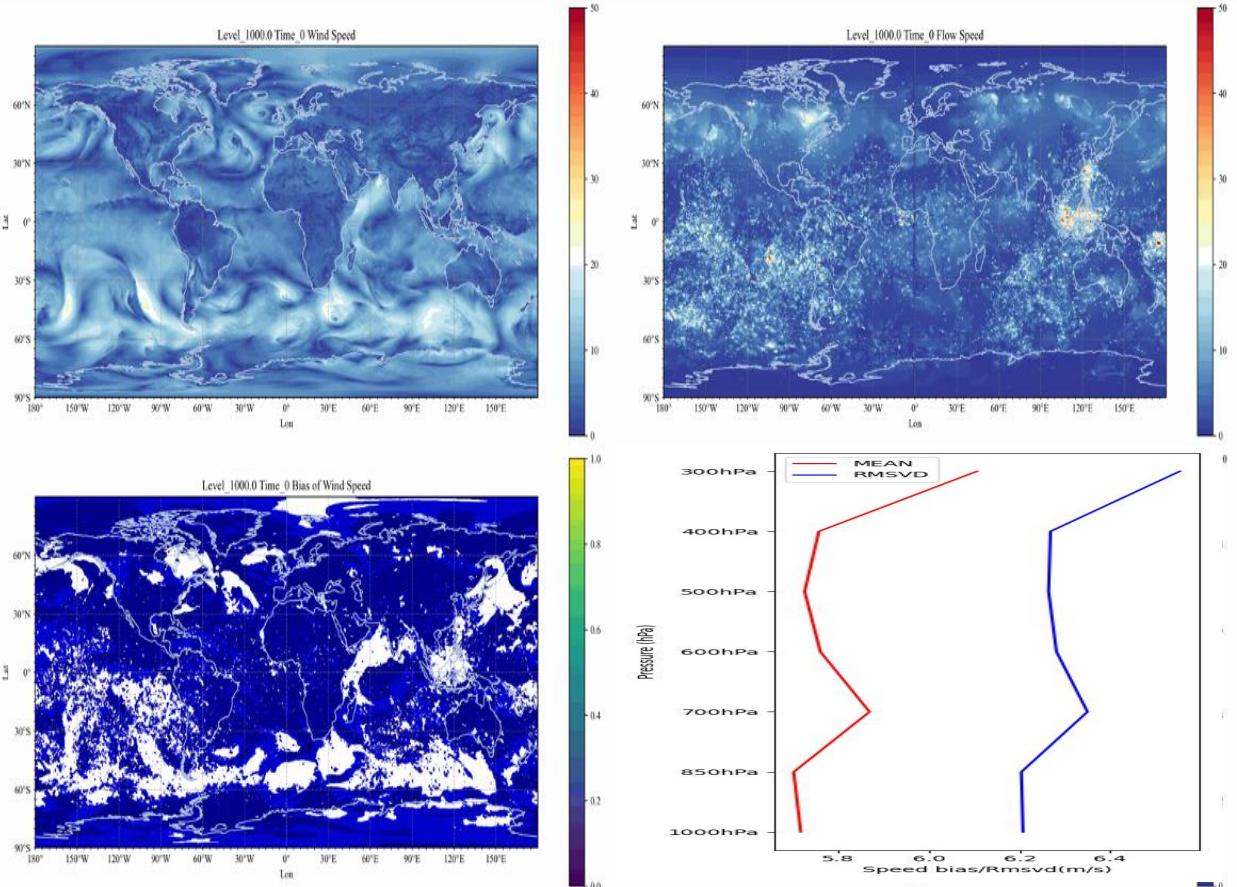
- Local Polynomial-Based Displacement Calculation

$$f(x) = x^T a x + b^T x + c$$

$$f(x) = g(x + d)$$

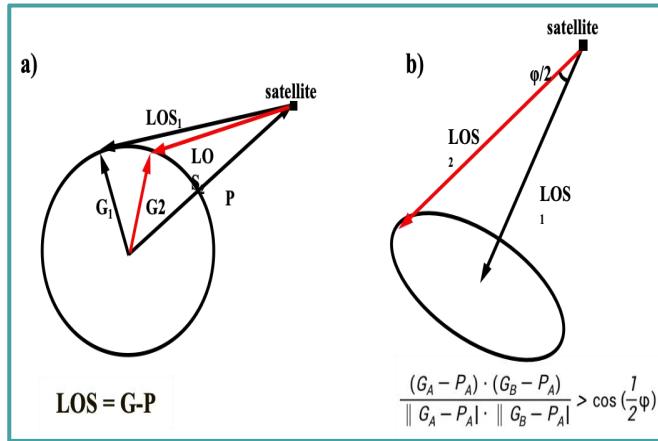
$$E(d) = \sum_x (f(x) - g(x + d))^2$$

- Multi-Scale Pyramid Iterative Optimization of Optical Flow Field
- Local Neighborhood Weighting to Improve Robustness

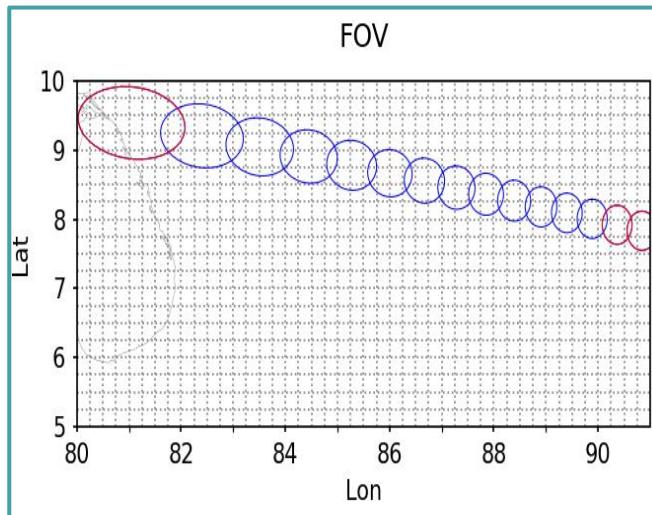


(a) wv of ERA at 1000hPa (b) wv ampped onto optical flow grid
(c) bias of retrieval by optical flow (d) vertical distribution of bias

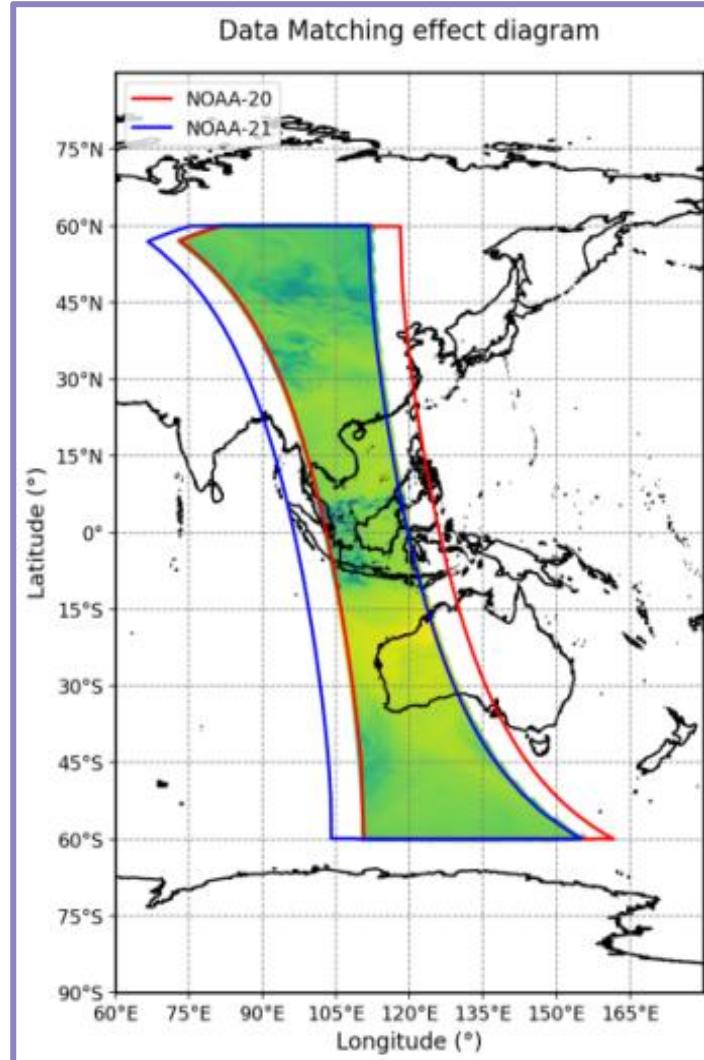
Preprocess I —— Fusion to observation of sequent satellites



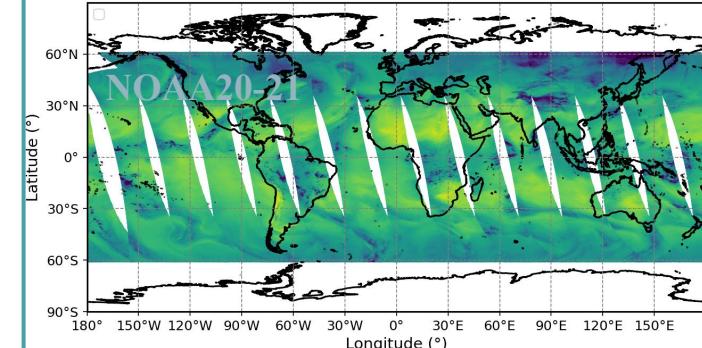
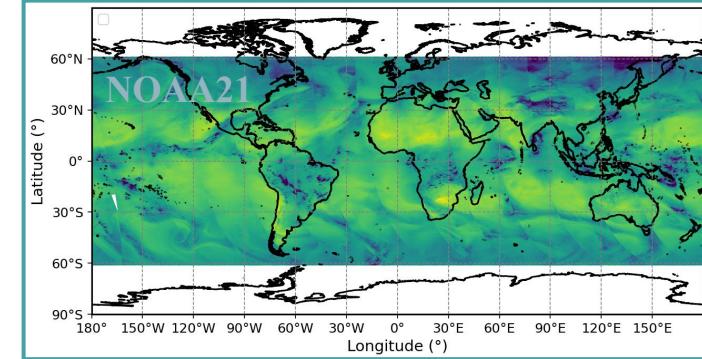
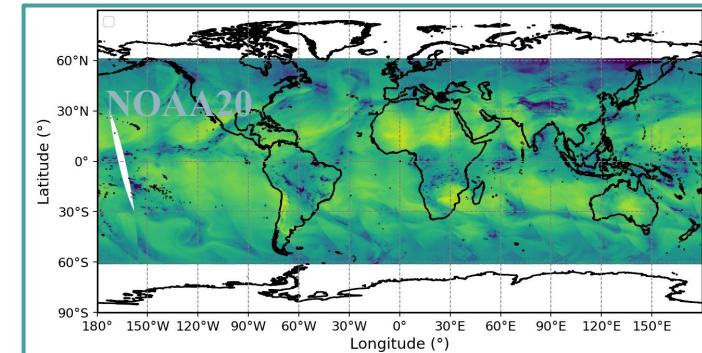
Matching of Sequential Satellite FOVs



Matching of Optical Flow Grids (0.25°) and FOV of 183Ghz channel within a Scanline



Matching the nearest pixels using the KD-tree nearest neighbor algorithm



brightness temperature of channels at 1833.31 ± 1 od ascending orbits within a day

NOAA20

NOAA21

Overlap of
NOAA20 &
NOAA21

Proprocess II——Quality control

➤ Routine QC

- 8 FOV removed at the edge of a orbit
- Remov Outliers with Large Deviations

Cloud detection

➤ Scatter index

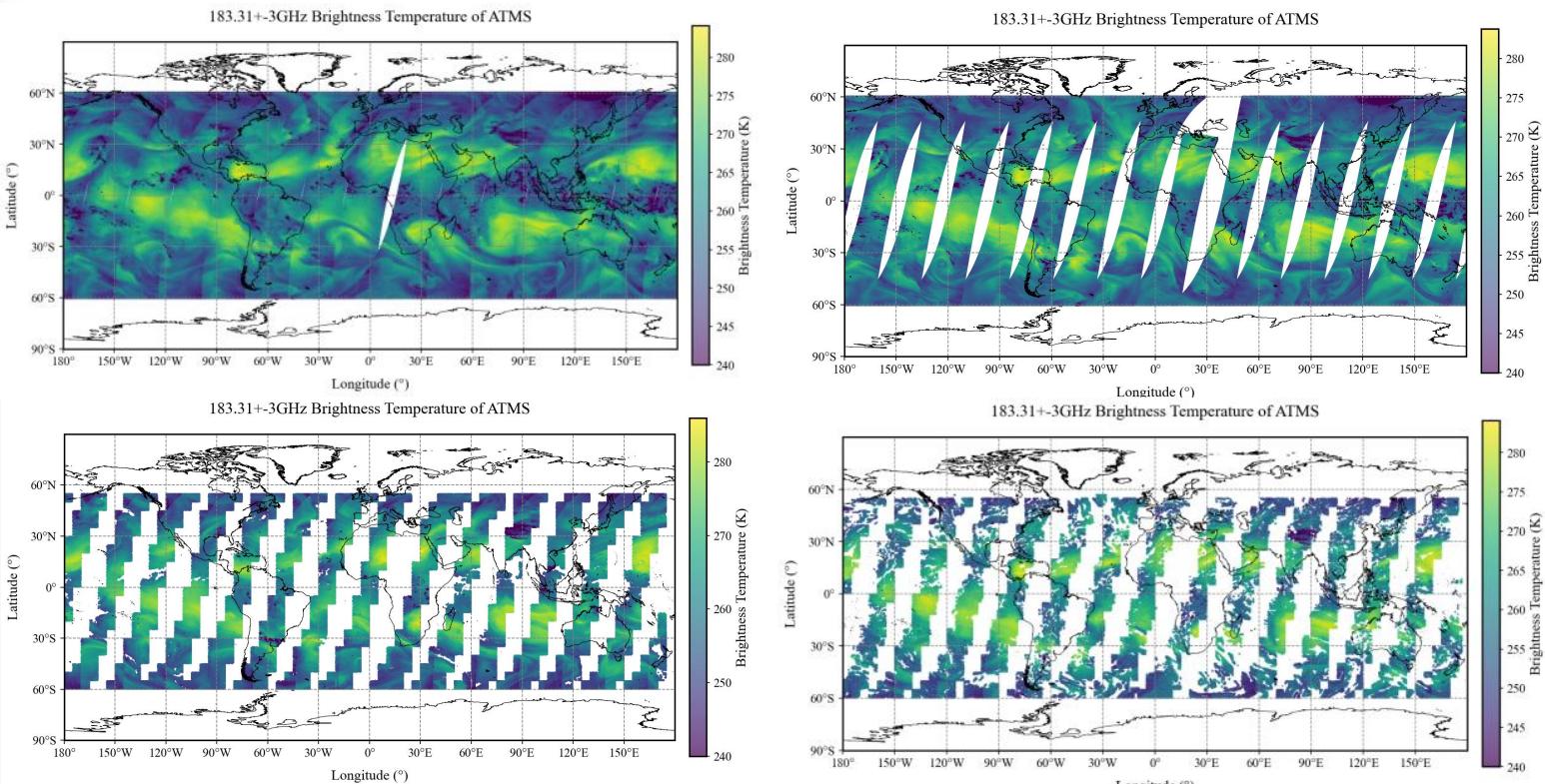
$$SI = (TB_{88.2\text{GHz}} - TB_{165.5\text{GHz}}) - (-39.2010 + 0.1104\theta)$$

$TB_{88.2\text{GHz}}$ and $TB_{165.5\text{GHz}}$: brightness temperature of channels 16 and 17 of ATMS, θ :Zenith Angle

Reject FOV with a $SI > 15$

Possible phase change

Vertical speed(Background): $w < 0.1 \text{ m/s}$



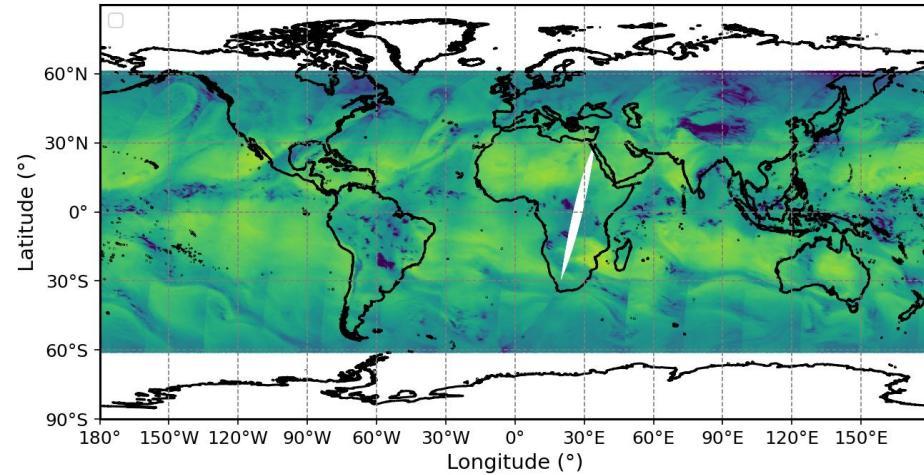
- (a) Brightness temperature of channel 18 of ATMS
- (b) 8 FOV removed at the edge of a orbit
- (c) Detection by scatter index
- (d) Introduce of possible phase change

Experiment Scheme

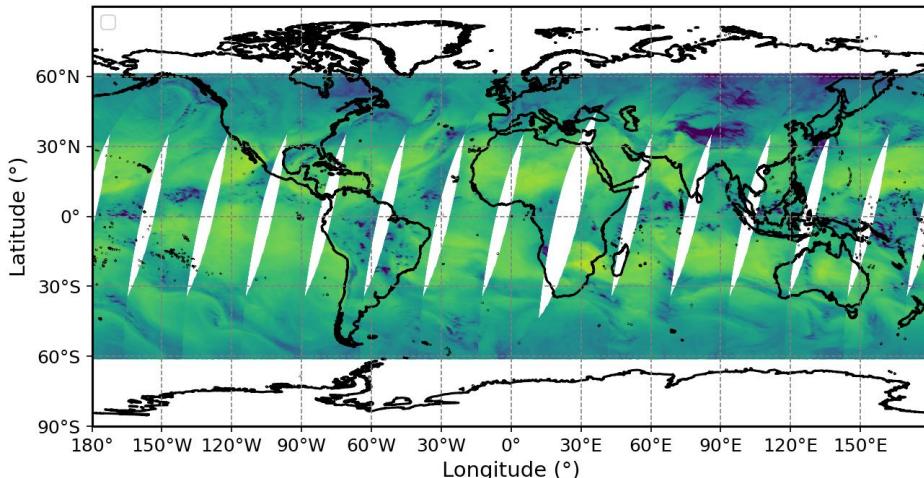
- **Exp.1: Evaluation in fixed tracking area**
- **Exp.2: Evaluation in hybrid tracking area**
- **Exp.3: Evaluation to retrieval with FY -3D involved**
- **Exp.4: Impact to data assimilation**

EXP1.—Tracking area of optical flow retrieval

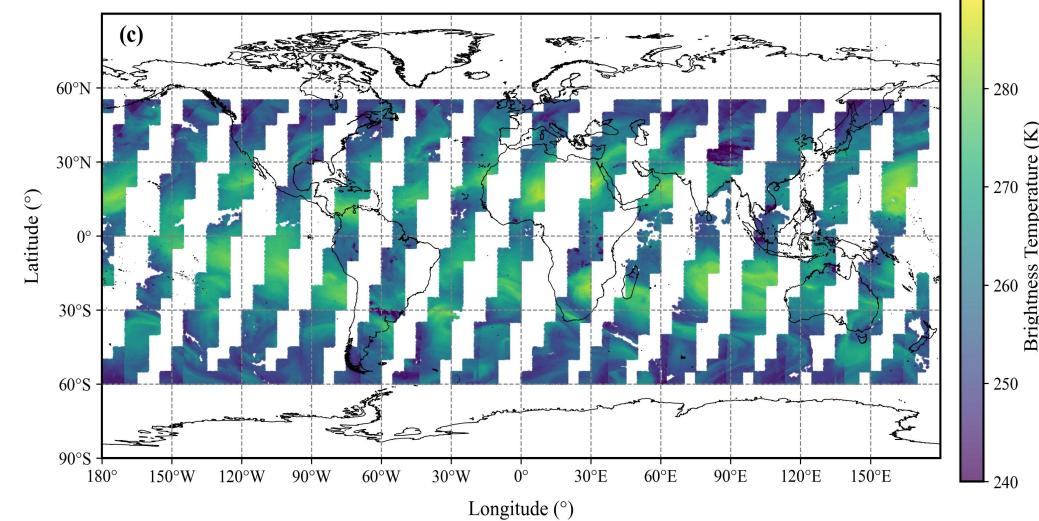
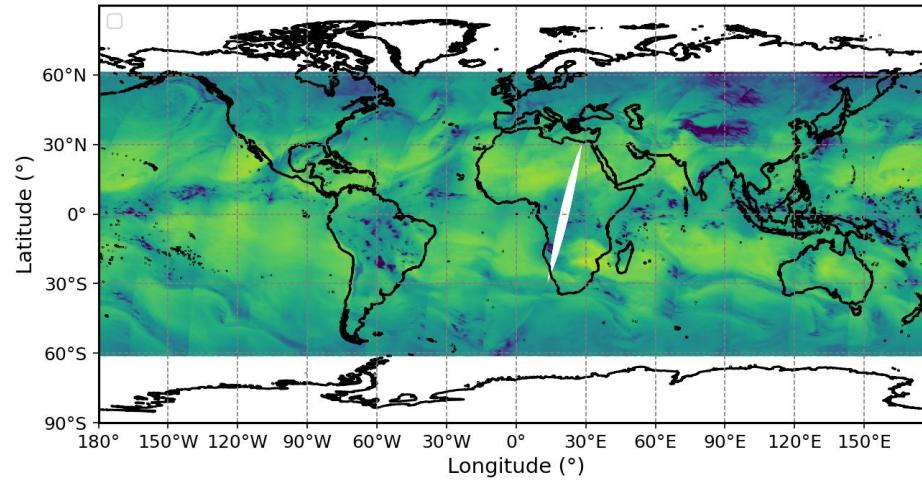
NOAA20



Overlap



NOAA21



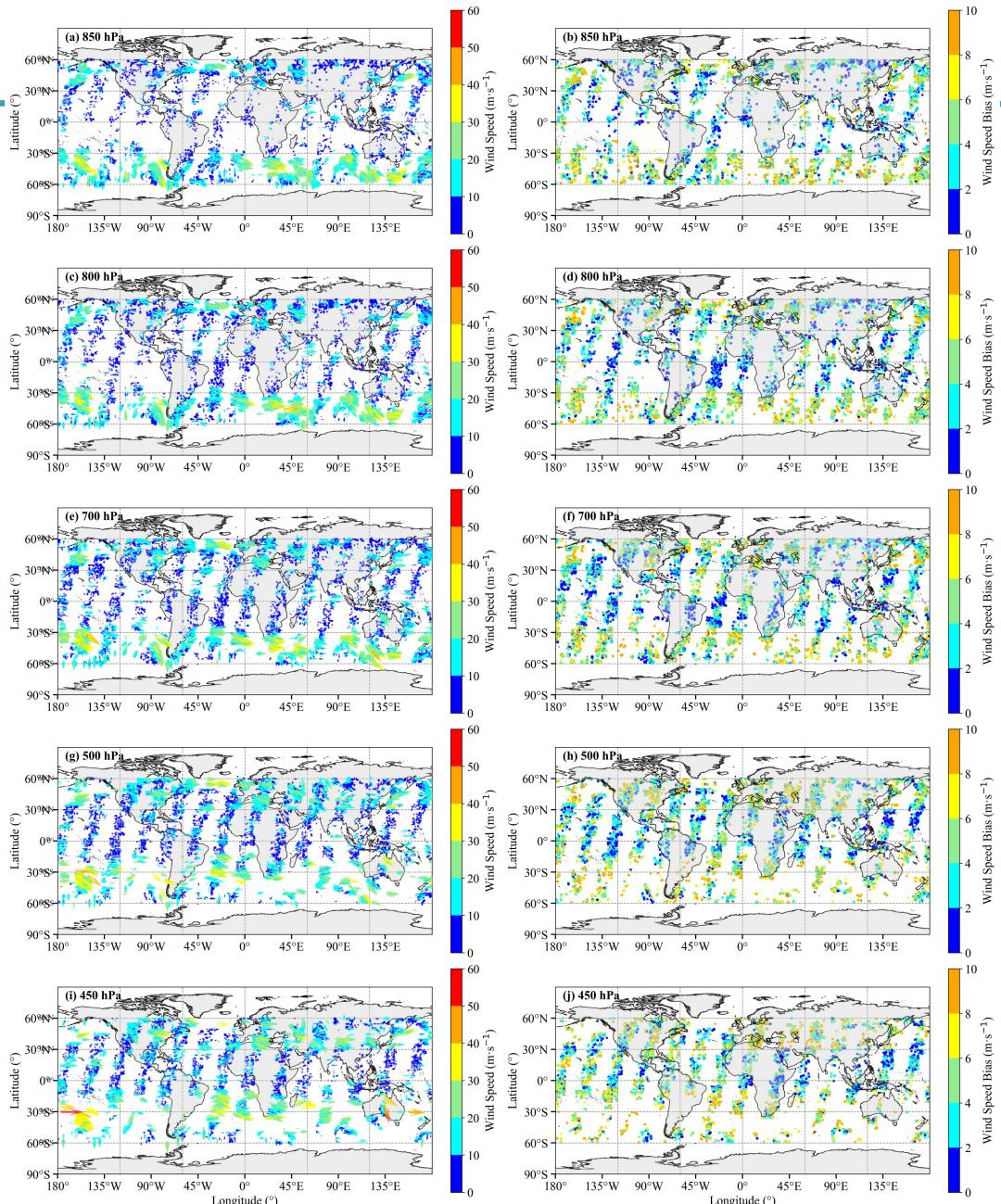
Brightness Temperature of overlapped FOV that
Projected onto the 5° Optical Flow Grid

EXP1.—Distribution of retrieval and their bias

- 5 pressure layers corresponded to peak of weighting function of the 5 channels at 183GHz:
 - Retrieved wind speed: <10m/s(low latitude), 10~20m/s(Mid-latitude), Max value 30m/s(50m/s)
 - Error (contrast to ERA): 2~4m/s(Mean), 4~8m/s(Mid_latitude)

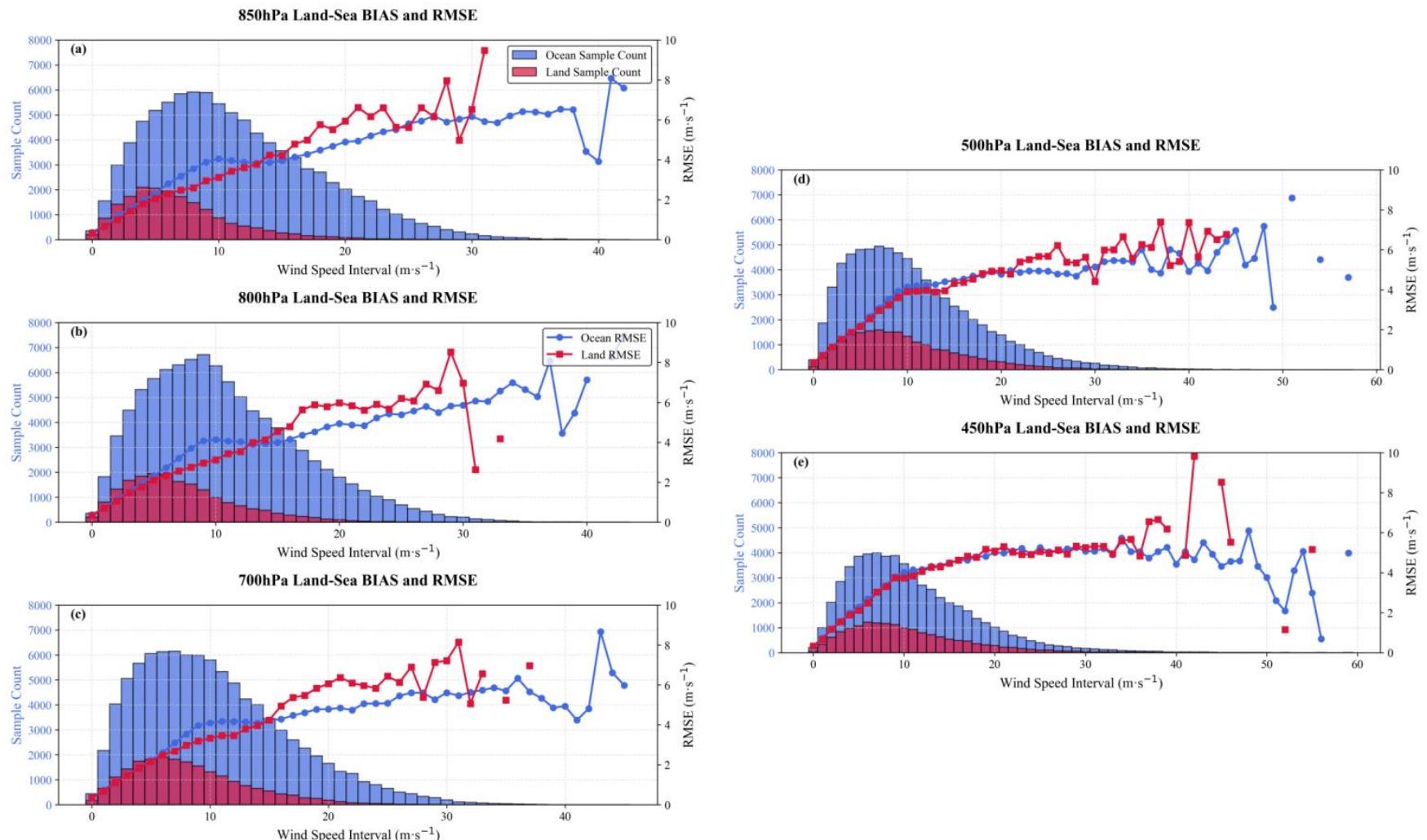


- Global cover of retrieved wind by radiance of channels at 183GHz
- Systematically low wind speed with large error



EXP1.—Distribution and Bias over land and over ocean

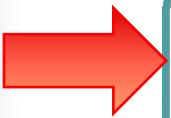
- Max wind speed over ocean $>60\text{m/s}$ (55m/s)
- Samples over ocean are 5 times than the one over land



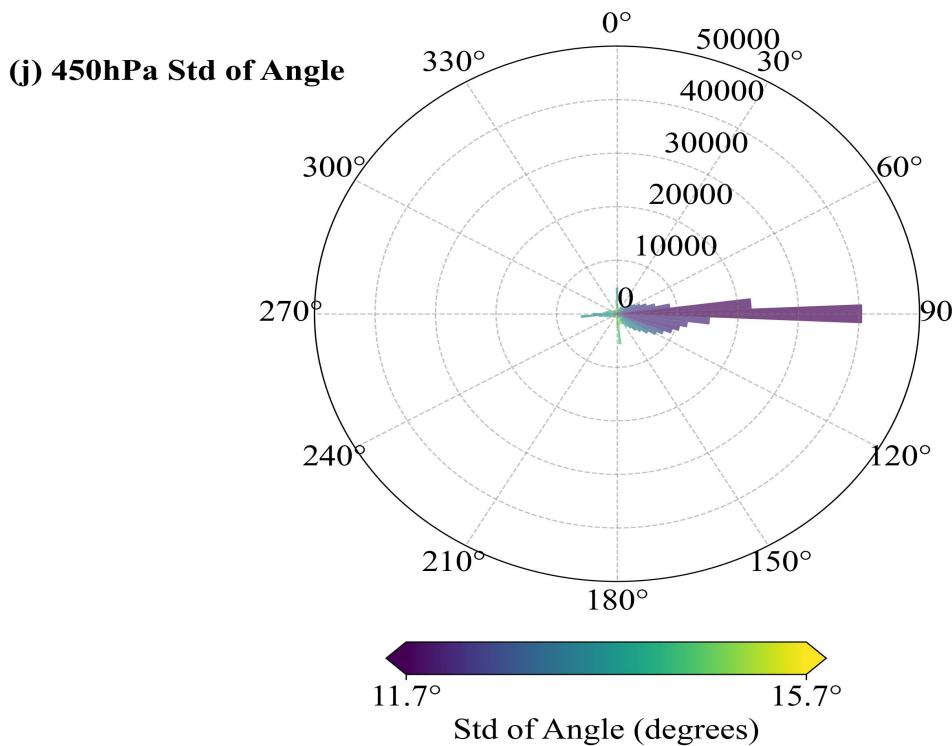
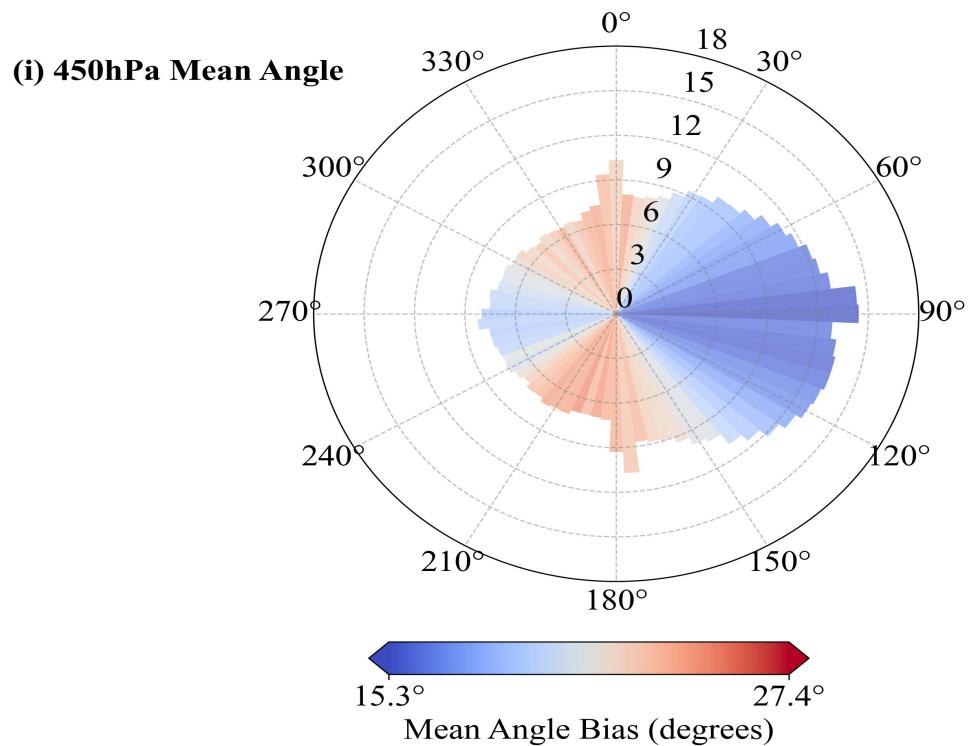
Samples (bar) at 5 pressure layers (850-450 hPa) over ocean(blue) and over land(red) , and their RMSE(line)

EXP1.—Bias to direction of retrieval

- Max bias $<30^\circ$, Max STD $<16^\circ$
- Contrast to AMV $<40^\circ$ of METOP (Yang et al., 2021)



- Smaller bias to zonal wind than to meridional wind
- More retrieved to zonal wind than to meridional wind



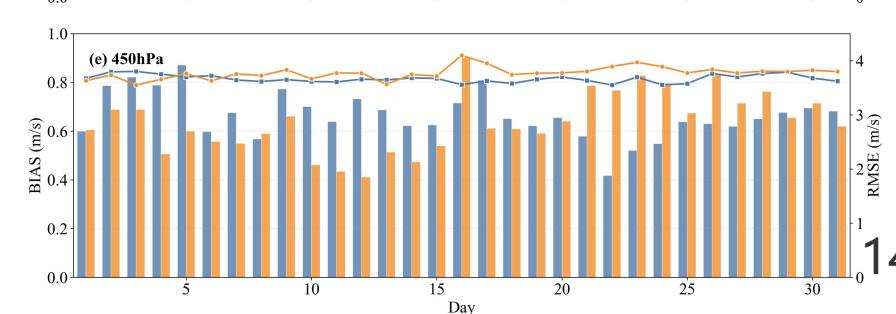
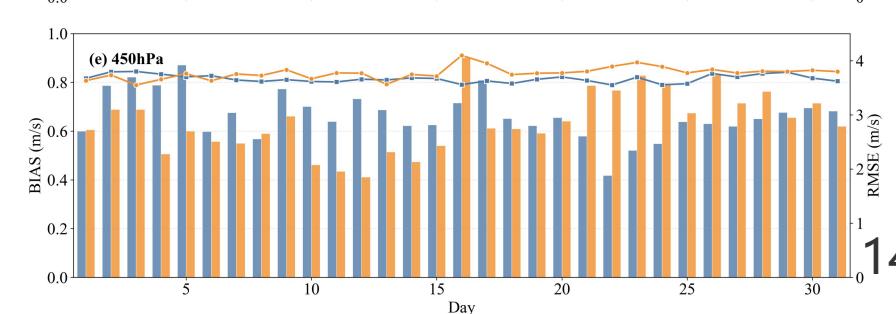
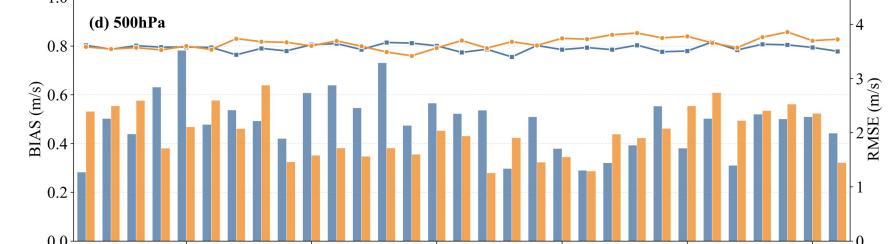
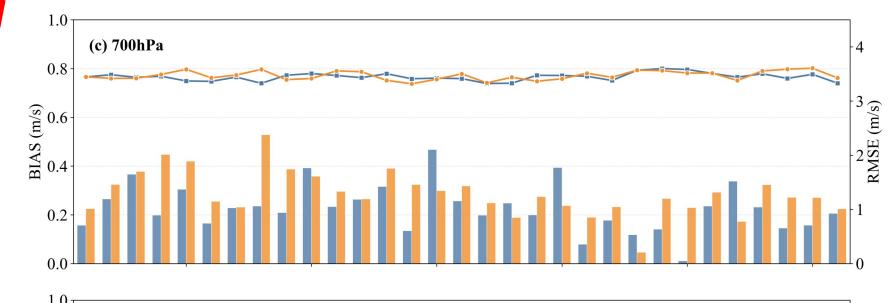
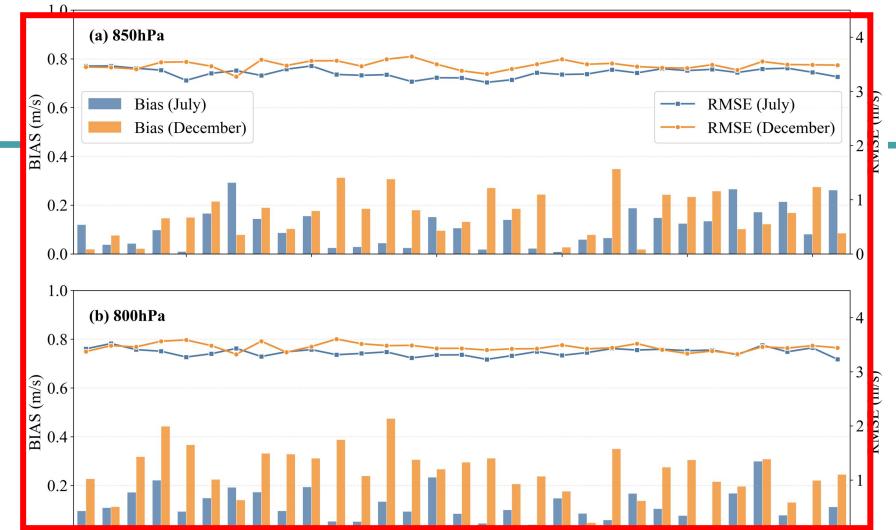
Bias of retrieved wind direction

(Left column = mean speed error[m/s], Left column = number of samples, color bar=Bias/ STD)

EXP1.— Seasonal change of bias

➤ Comparison to retrievals in July 2023(blue) and in December 2023(orange) in 5 pressure layers day by day

- Error increases significantly as the altitude increases
- **Seasonal difference available at low Troposphere**
- Seasonally consistent bias at upper layers

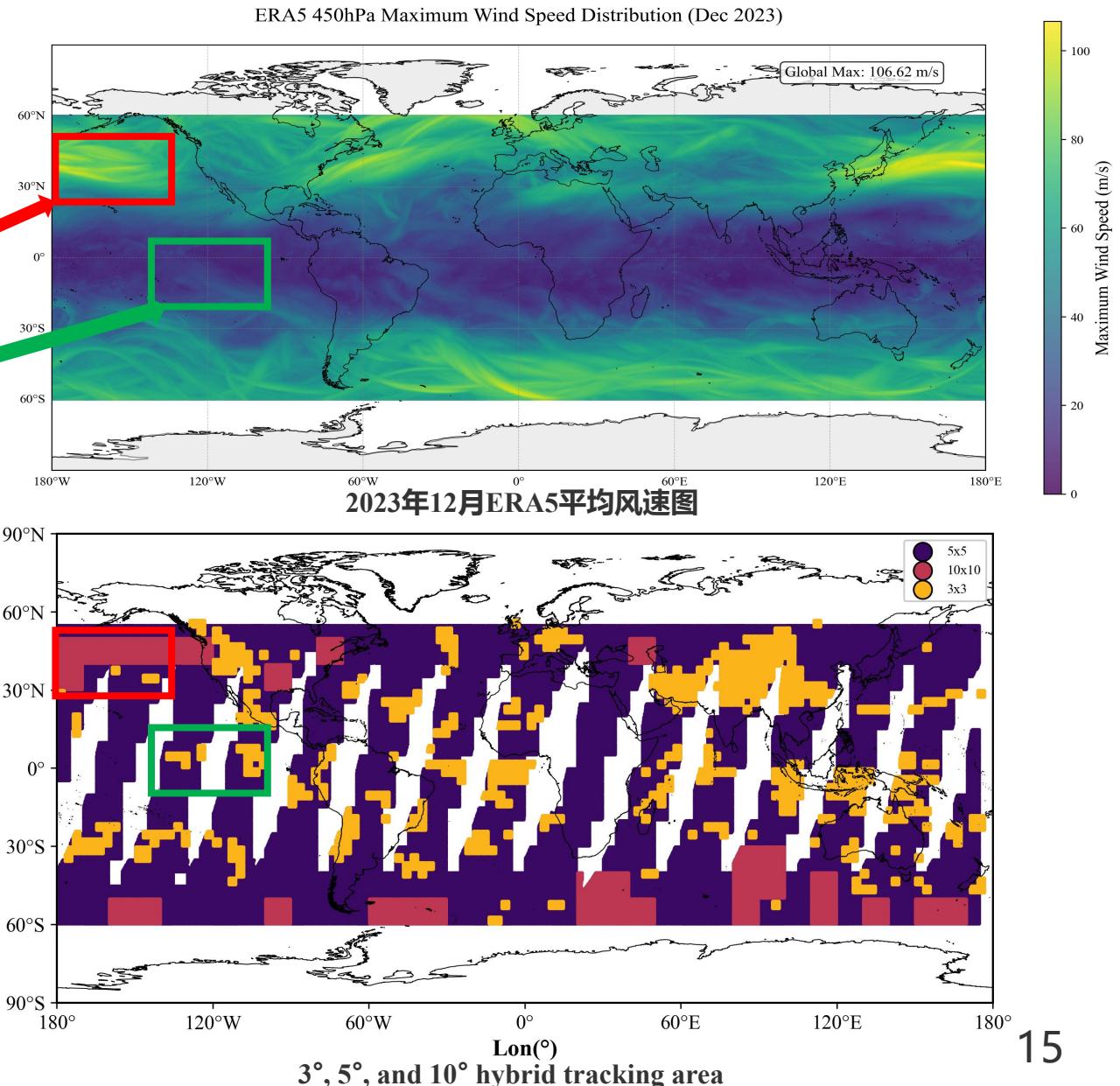


EXP2.—Hybrid tracking area

- Global retrieval in 5° tracking area
- Instead by 10° tracking area in region with high wind speed in background
- Instead by 3° tracking area in region with low wind speed in background



Hybrid tracking area
used in various screen
of background wind

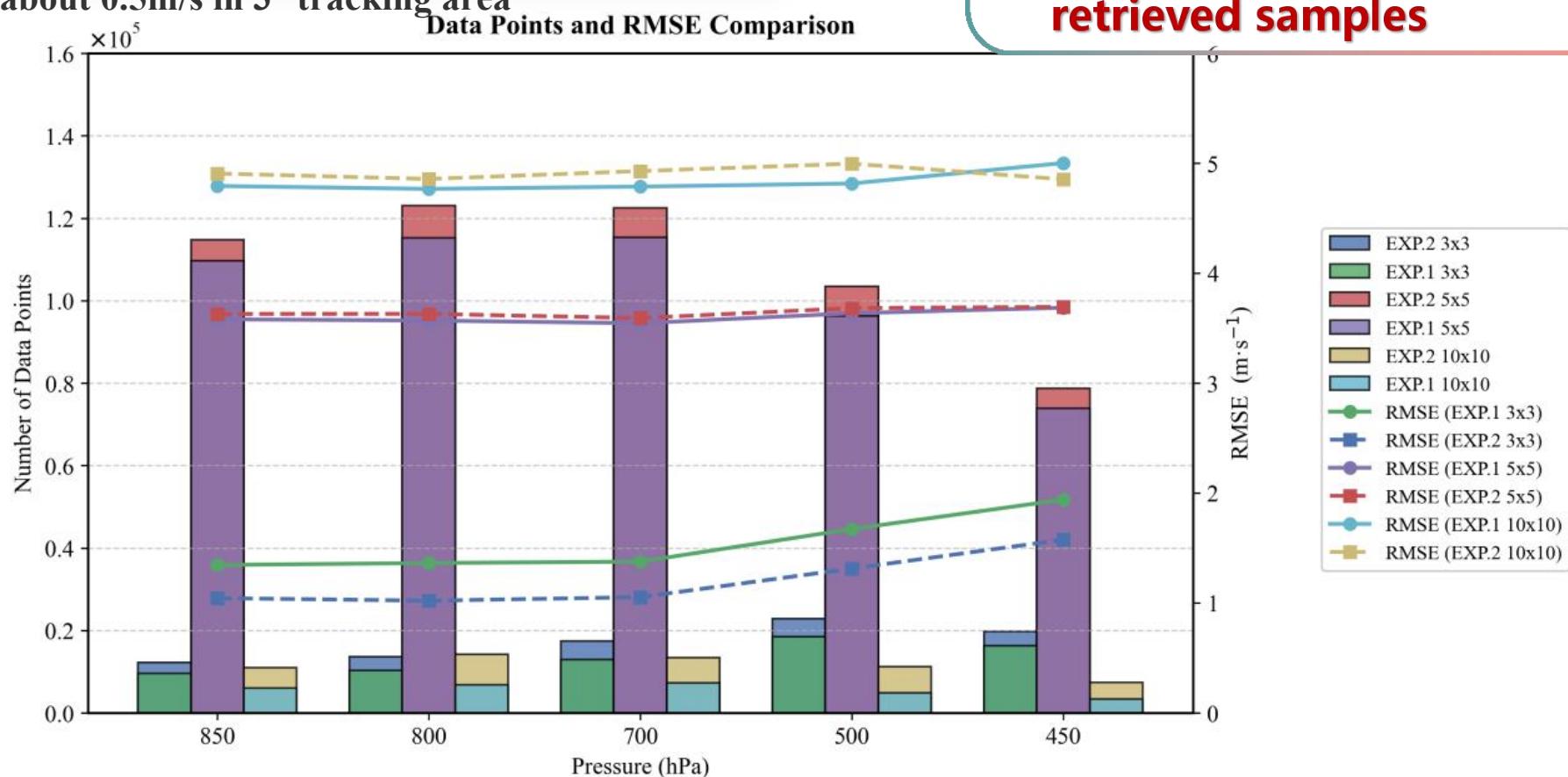


EXP2.—Distribution in various tracking area

- Obviously increase of retrieved samples in hybrid tracking area
- RMSE decrease about 0.5m/s in 3° tracking area



- Few difference to bias, rmse and std
- Obvious increasement to retrieved samples



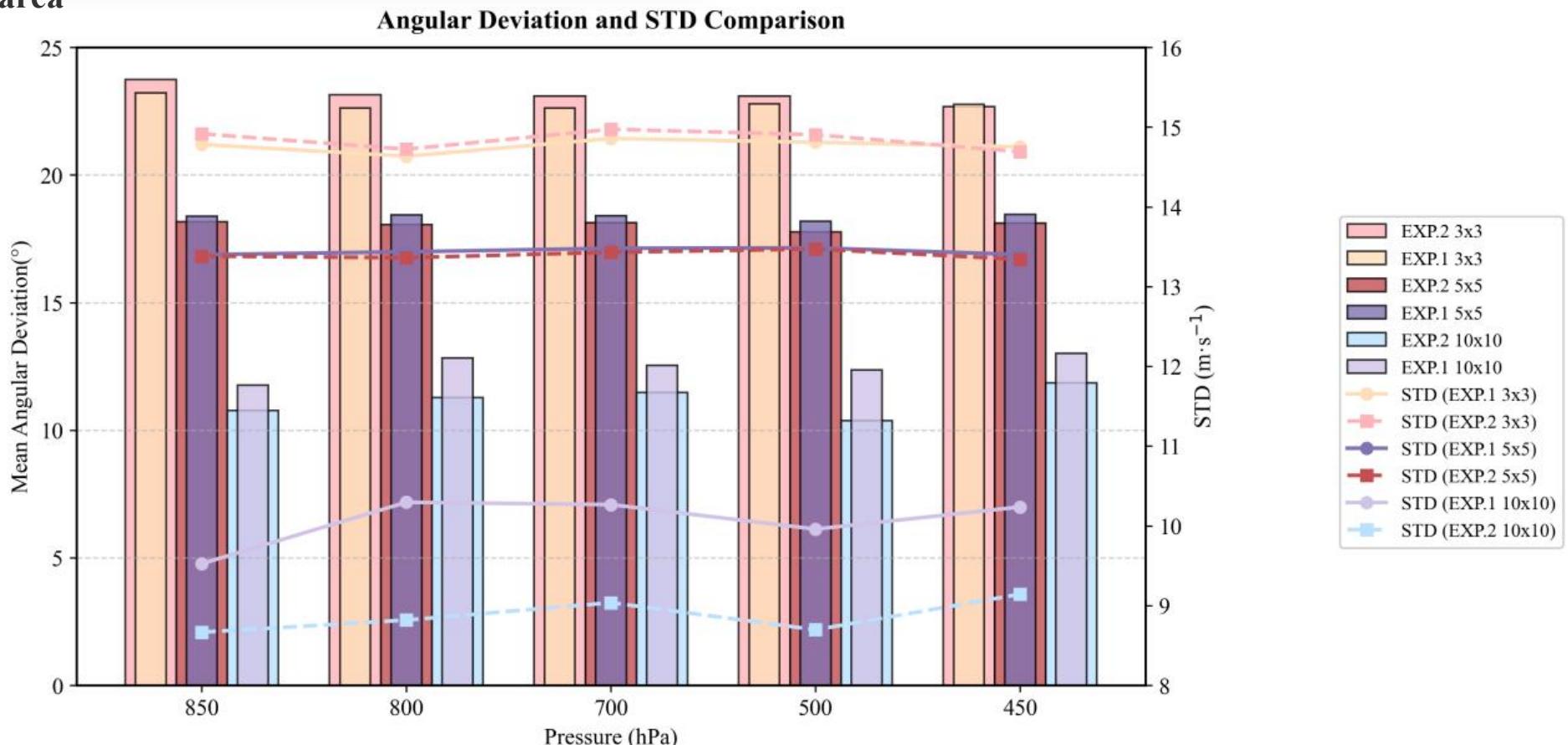
Retrieved sample and corresponded RMSE in various tracking area in Exp.1 and Exp.2

EXP2.—Bias to direction of retrieval

- Largest bias available in 3° tracking area
- Both bias and std decrease more than 1° within 10° tracking area



Decreased retrieved wind direction available



Comparison to bias and std of retrieved wind direction in Exp.1 and Exp.2

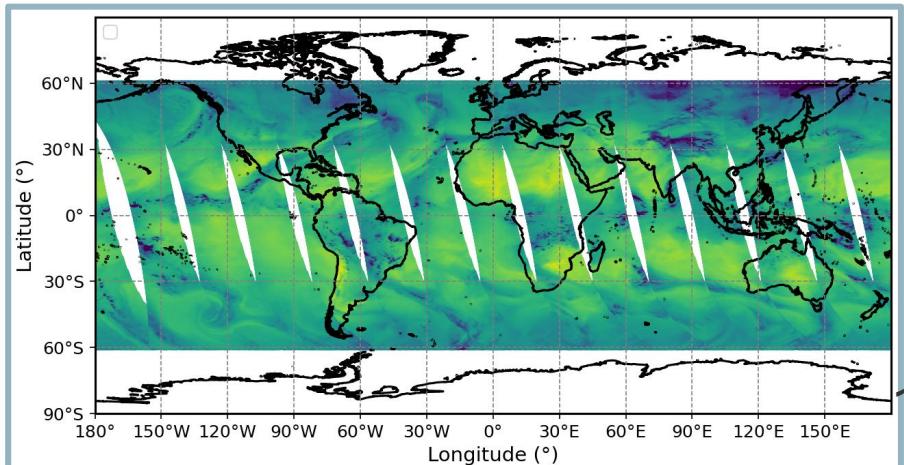
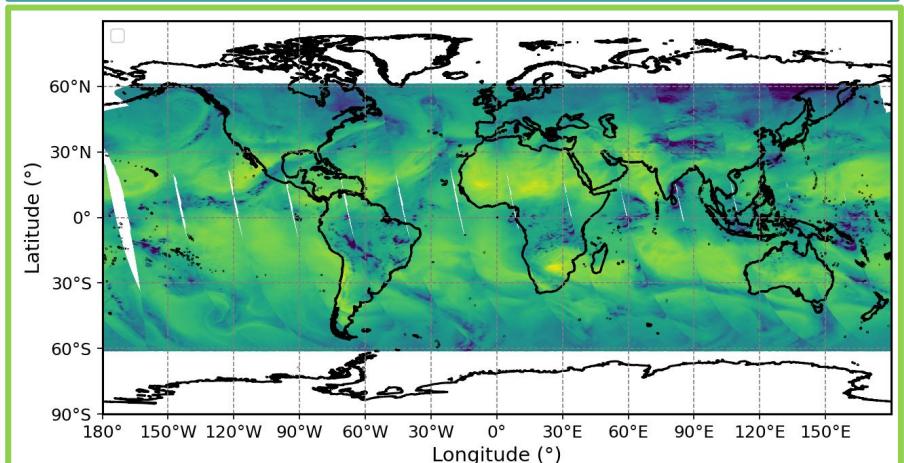
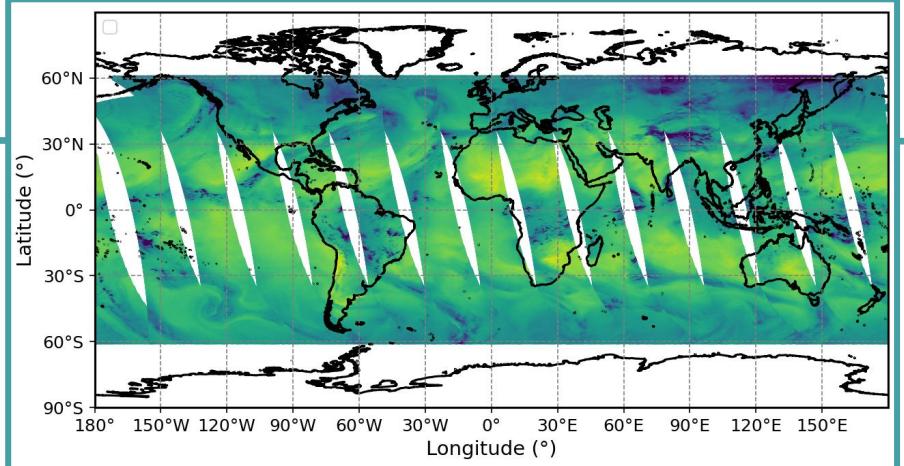
EXP3. - Experimental Design

➤ Data

- **NOAA20-21 (Dec. 2023)**
- **NOAA20-FY3D (Dec. 2023 & July 2024)**
- **NOAA21-FY3D (Dec. 2023 & July 2024)**

➤ Content:

- Correction of brightness temperature between satellites
- Altitude assignment to retrievals
- Time interval between satellites
- Hybrid optical flow grid
- Result of retrieved Wind by three consecutive satellite



EXP3.—Correction to brightness temperature of FY -3D

➤ Simulation of brightness temperature

DD = OTD-STD

$$= (T_{ATMS\text{-obs}} - T_{MWHS\text{-II}\text{-obs}}) - (T_{ATMS\text{-obs}} - T_{MWHS\text{-II}\text{-obs}})$$

➤ Correction by a regressed value

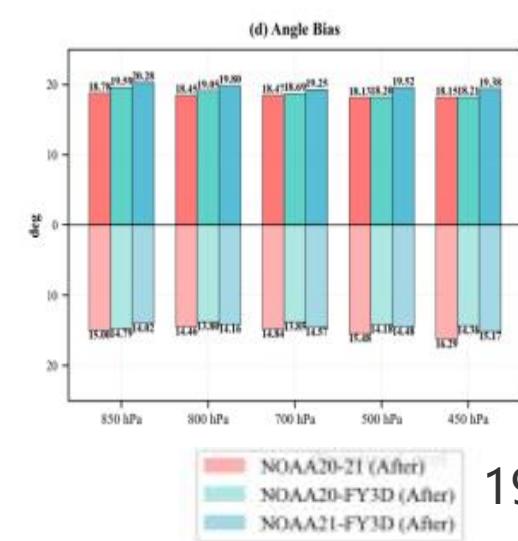
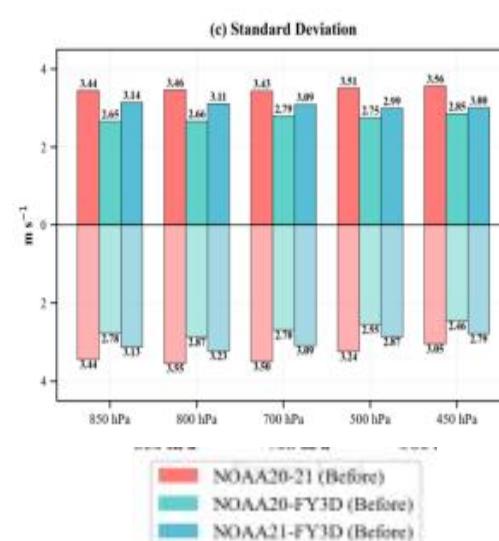
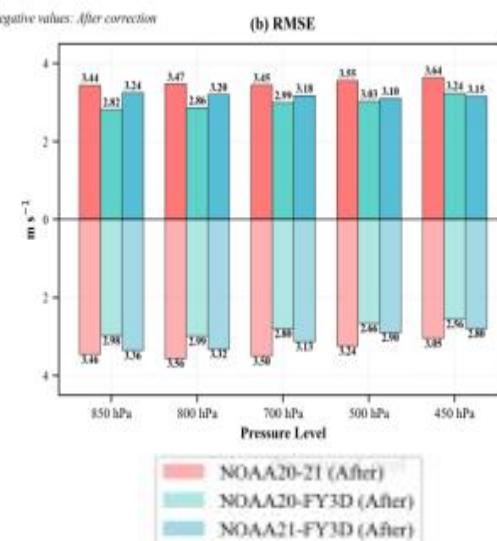
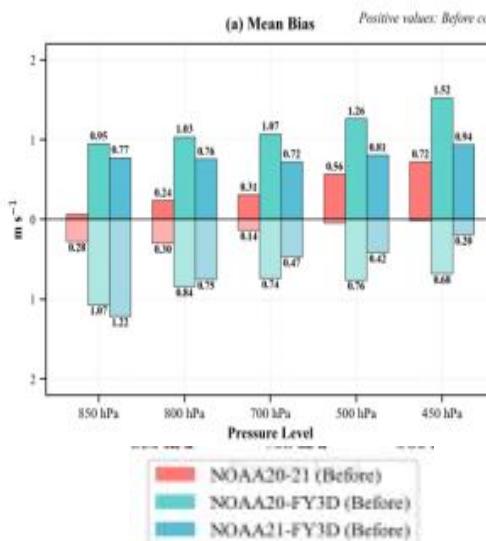
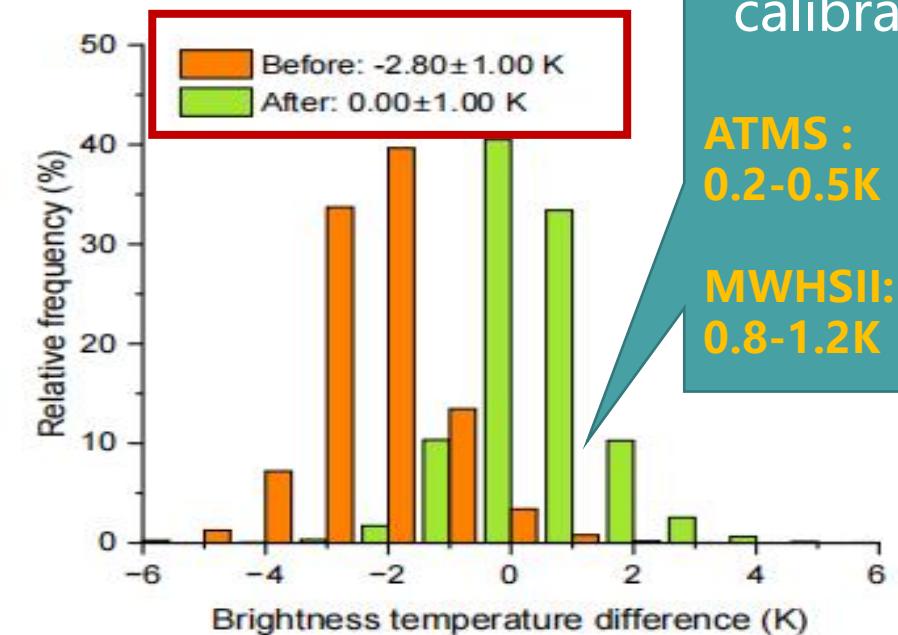
$$BT_{MWHS\text{theo}} = BT_{MWHS\text{obs}} - DD$$

$$BT_{MWHS\text{theo}} = BT_{MWHS\text{obs}} \times A + B$$

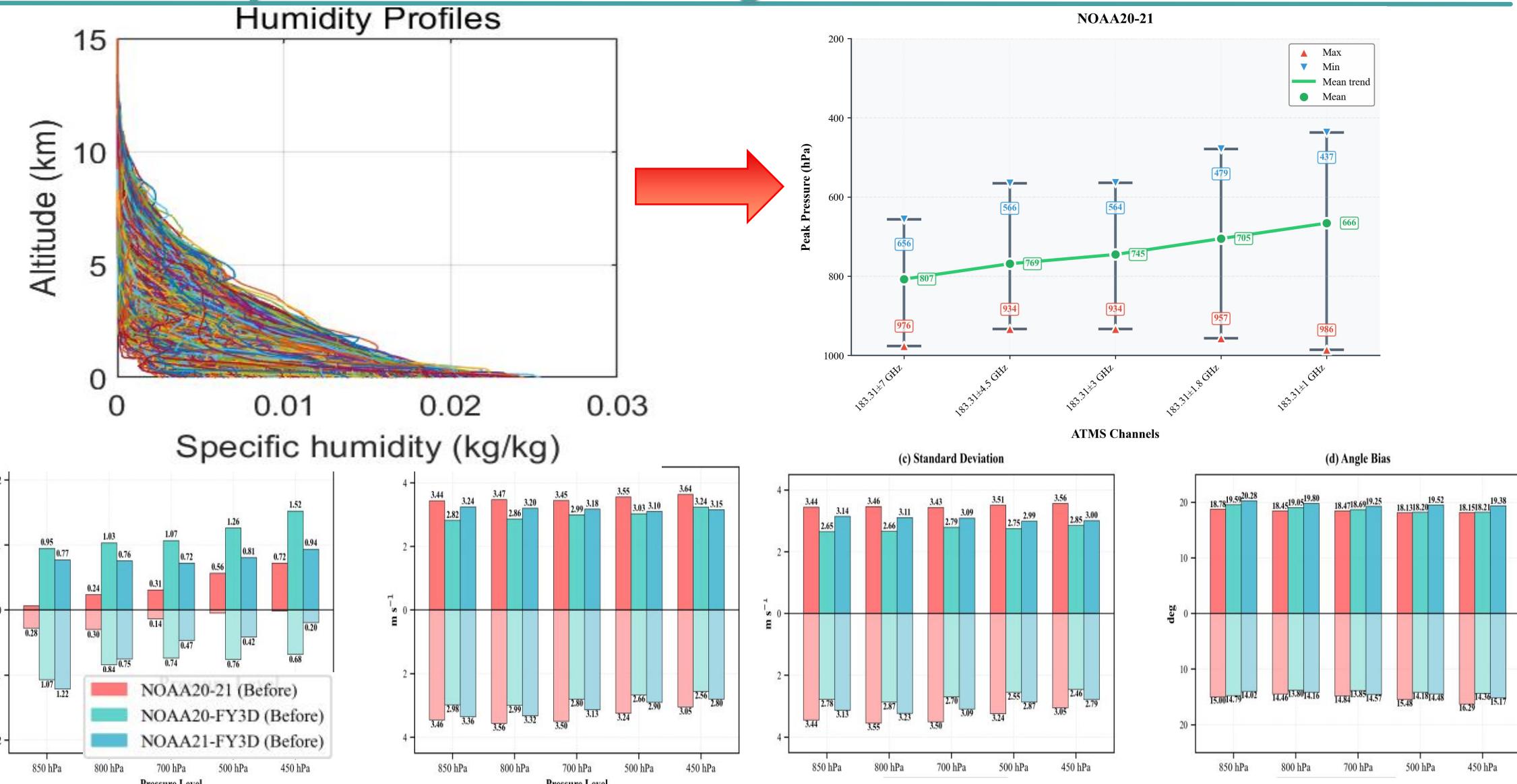
Accuracy of calibration

ATMS :
0.2-0.5K

MWHSII:
0.8-1.2K



EXP3.—— Dynamic Altitude Assignment of retrieval



NOAA20-21 (December 1 - 7, 2023)

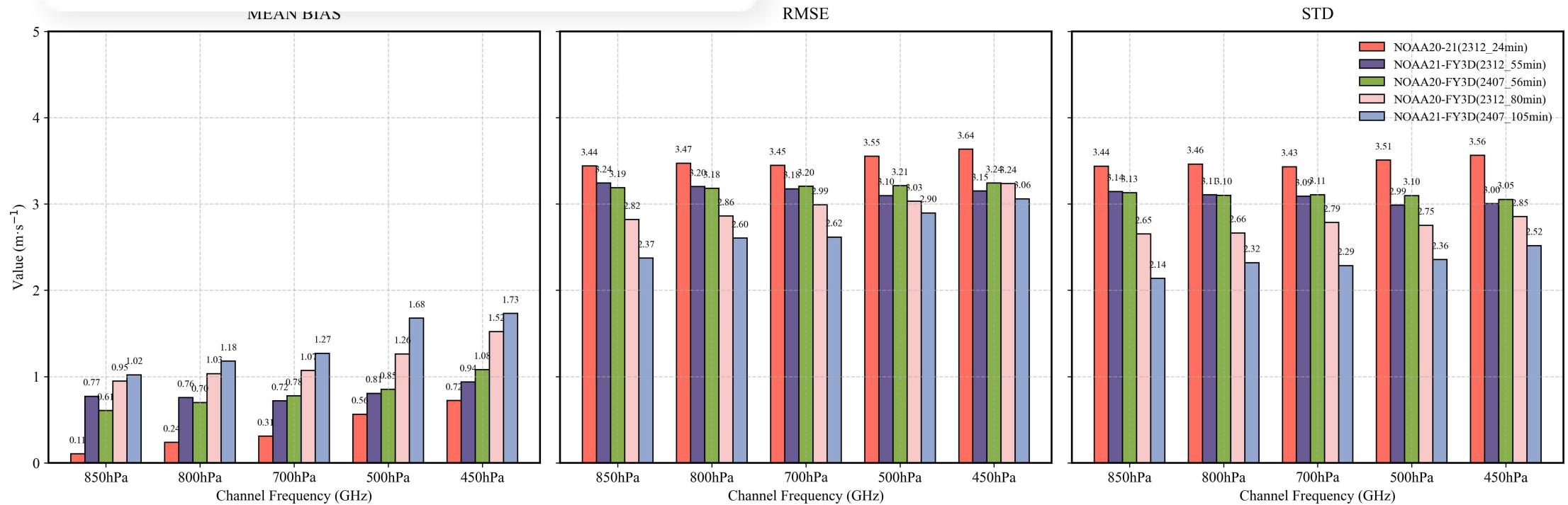
Comparison of Wind Field Retrieval Biases Across 5 Channels Under Fixed and Dynamic Altitude Assignment

EXP3.—Impact of time intervals

- Dec. 2023, NOAA20-NOAA21 (24min)
- Dec. 2023, NOAA21-FY3D (55min)
- July 2024, NOAA20-FY3D (56min)
- Dec. 2023, NOAA20-FY3D (80min)
- July 2024, NOAA21-FY3D (105min)



- Bias increase with larger time intervals
- Rmse and STD decrease

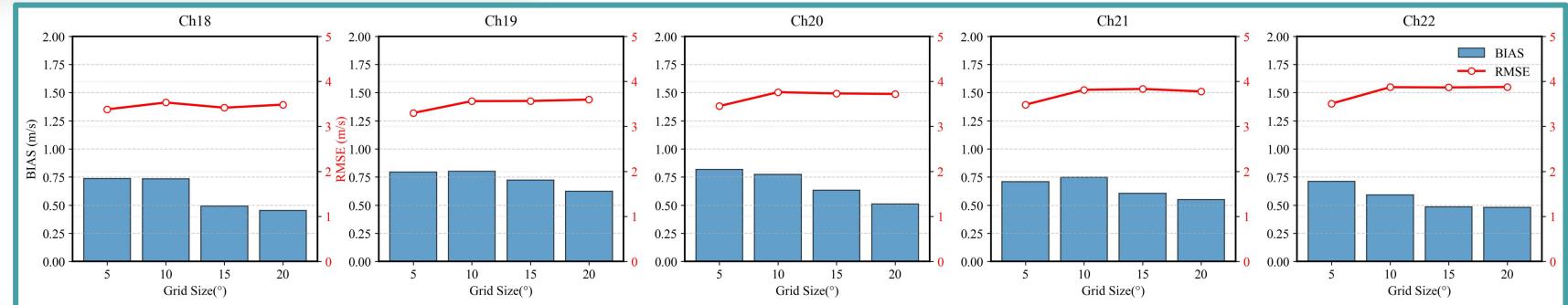


Mean bias, Rmse and STD of 5 time intervals to the 3 satellites

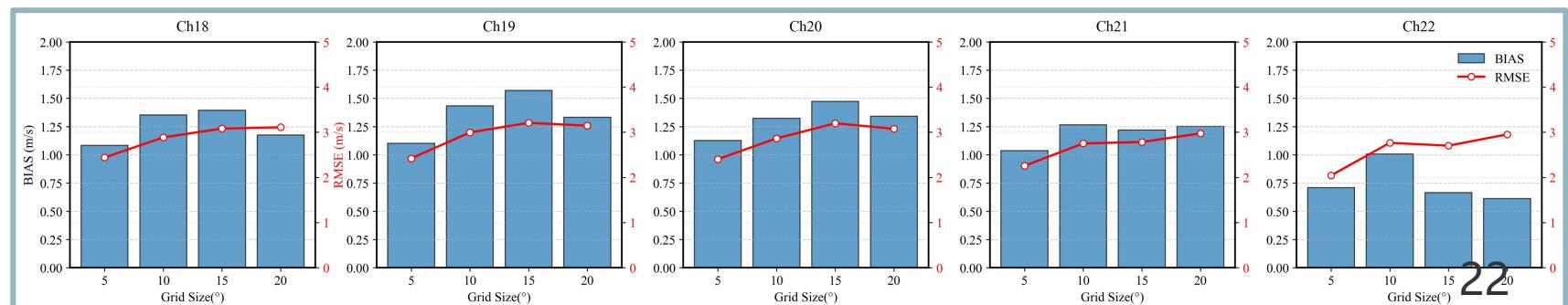
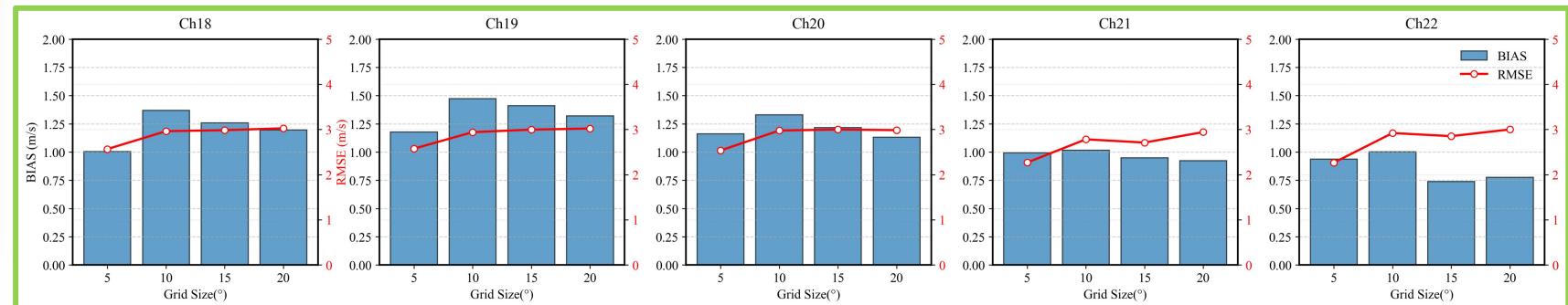
EXP3.—Impact of hybrid tracking area

- 3 time intervals for NOAA2/21, and FY3D, Dec. 2023
- Various of BIAS and RMSE to hybrid tracking area

Few impact available to hybrid tracking area



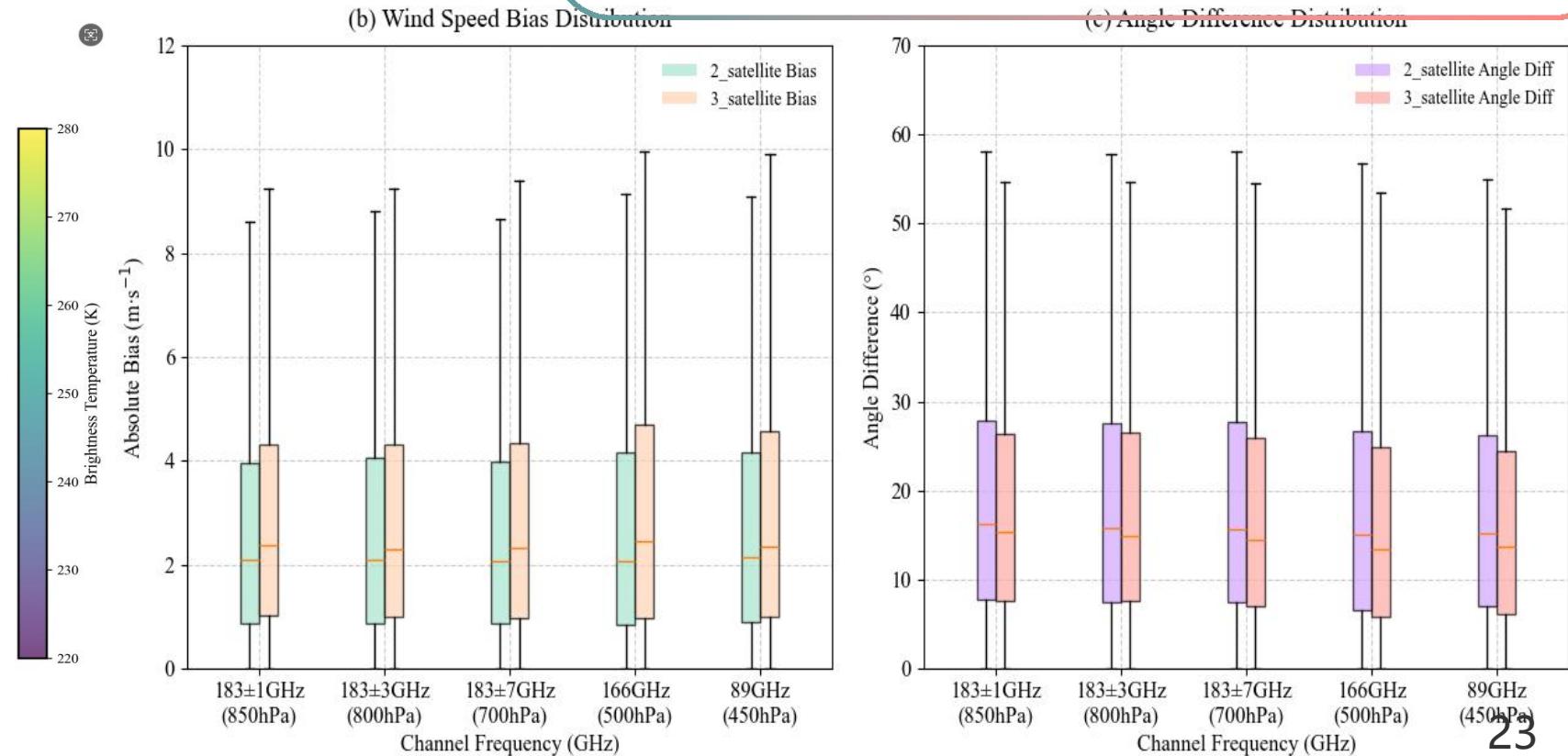
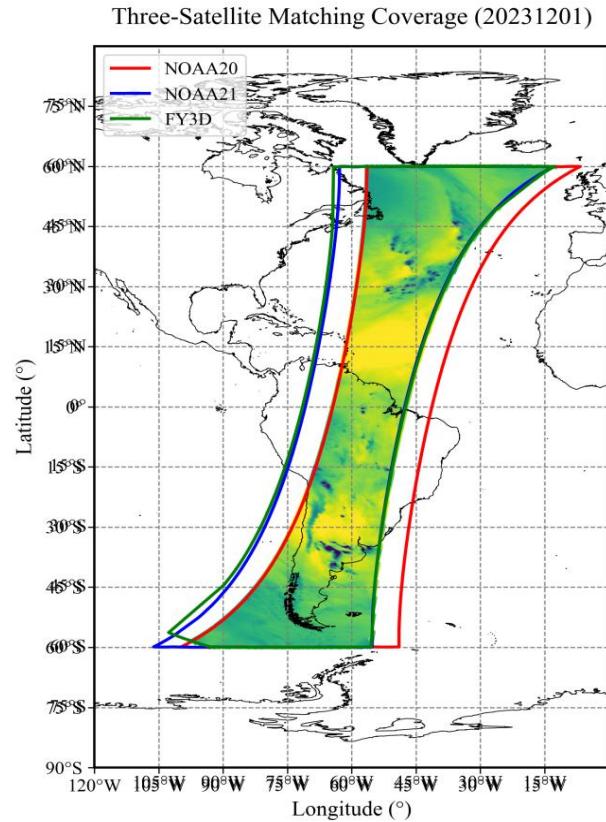
- NOAA20-21
- NOAA20-FY3D
- NOAA21-FY3D



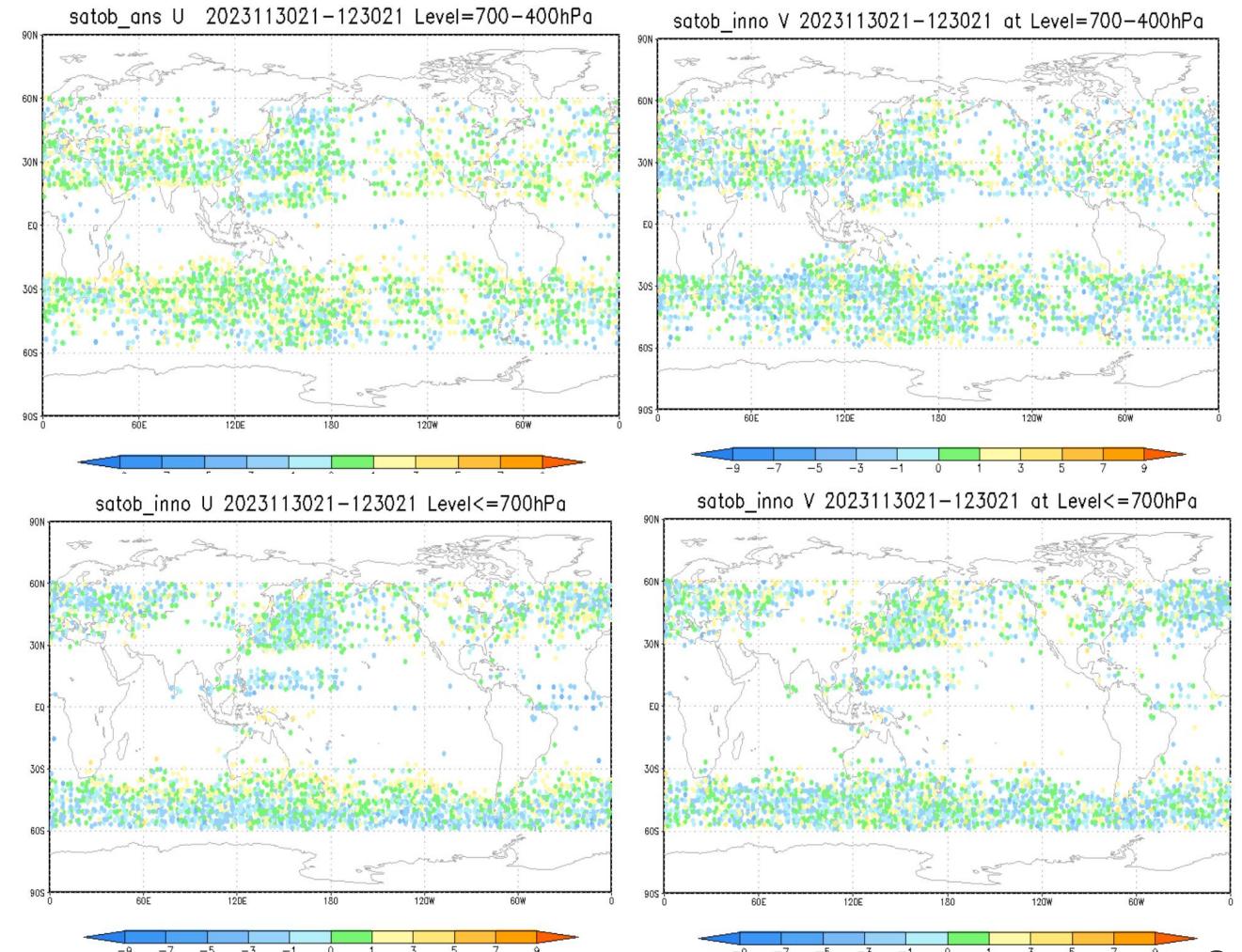
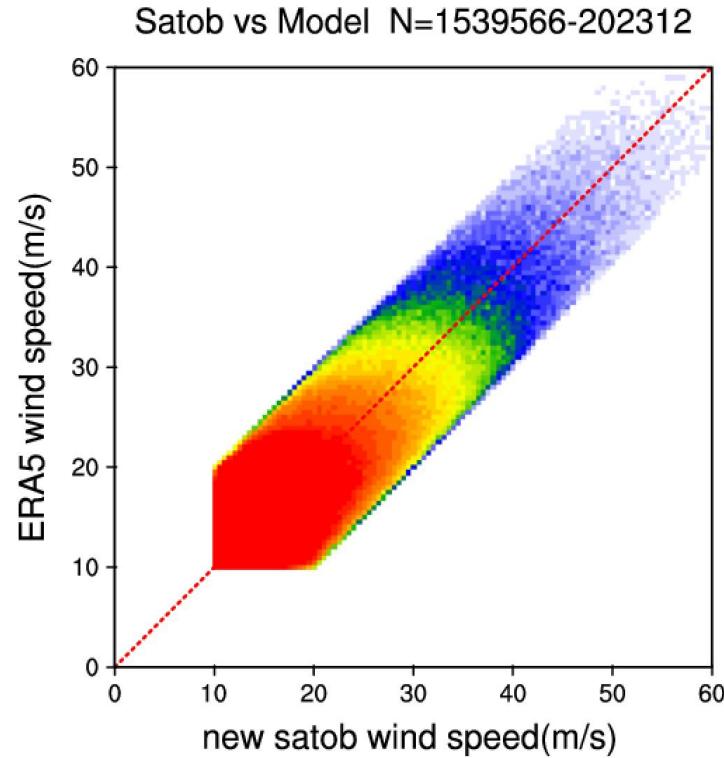
EXP3.— Retrieval of three satellites in a time series

- Dec. 1, 2023
- comparison between NOAA20-21 vs NOAA20-21-FY3D

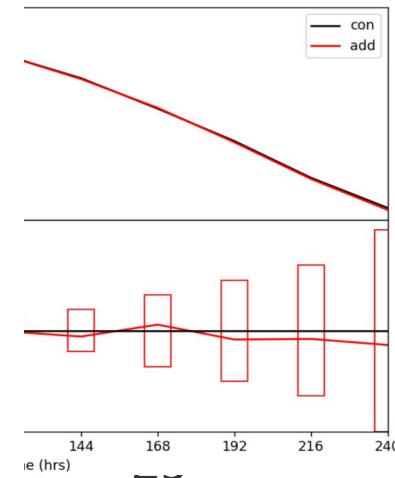
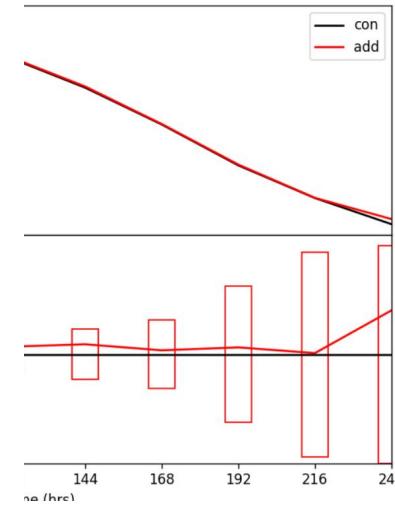
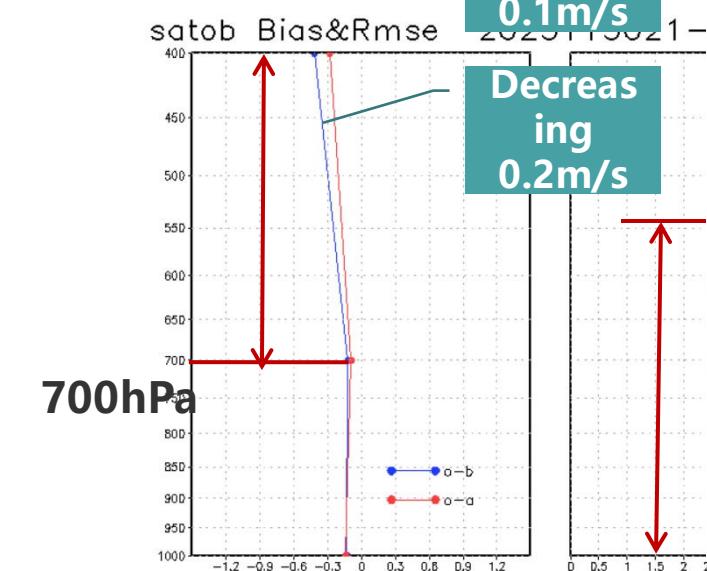
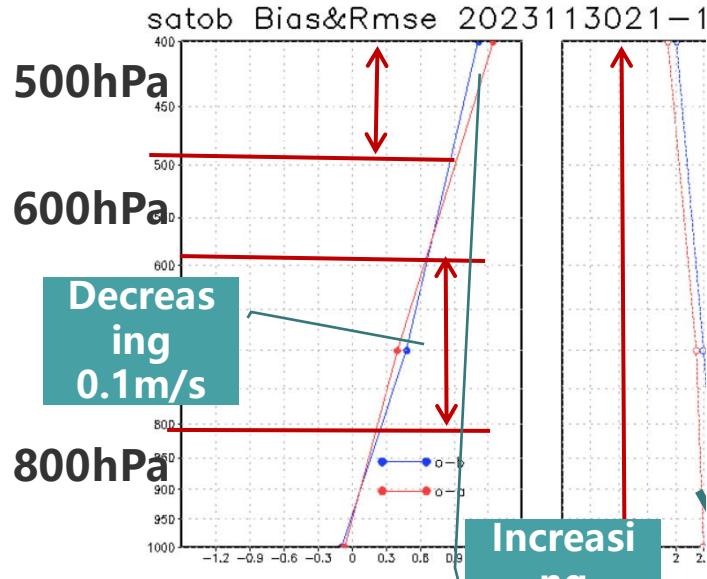
- Same overlapping areas to dual-satellites, and the number of retrievals remains unchanged
- Wind speed errors of each layer increase slightly
- Wind direction errors of each layer decrease



EXP4.—Impact to assimilation and to forecast

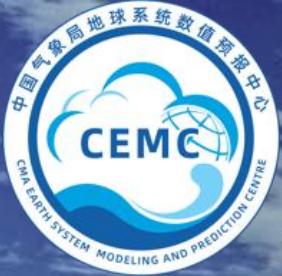


EXP4.—Impact to assimilation anf to forecast (continued)



Summary

- Pioneering to generate atmospheric three-dimensional wind distribution by a microwave vision
- A dense optical flow method characterized by pixel brightness temperature of microwave channel to retrieve global three-dimensional wind distribution
- Comparable in accuracy between our wind retrieval and products of METOP satellite
- A reduced error to velocity of low wind speed retrieval, and direction of high wind speed samples by Hybrid grid
- Increased bias of retrieved wind within larger temporal interval between satellites, while RMSE and STD decrease
- Comparable accuracy to retrieved wind between NOAA20/21/FY3D and NOAA20/21, while the retrieval quantity reduced
- Assimilation in the operational environment of CMA-GFS shows a positive impact on the forecasts of the Northern Hemisphere, the tropics, and East Asia, but a negative impact in Southern Hemisphere



Thank you!