Ship-based coherent DIAL measurement of water vapor and wind vertical distributions in the lower troposphere -Initial result-

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Masaki Katsumata, and Satoru Yokoi (Japan Agency for Marine-Earth Science and Technology)



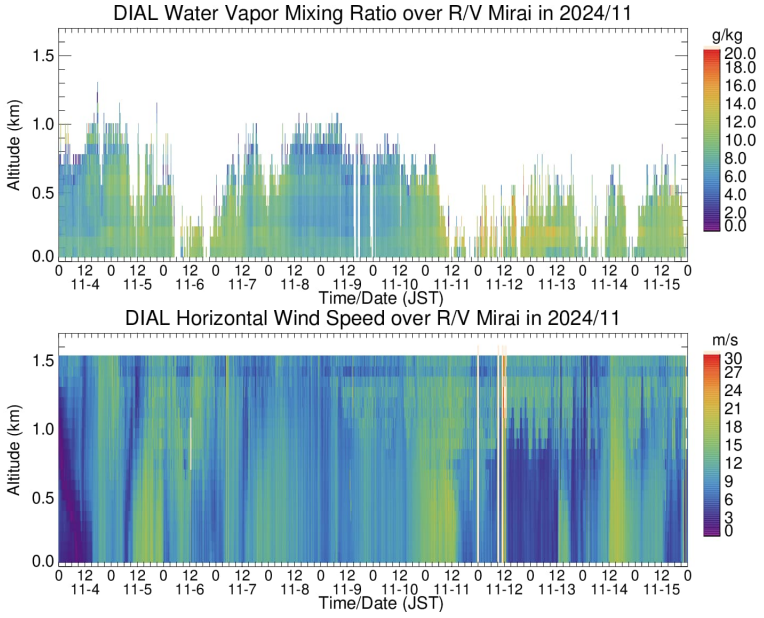


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Abstract:

- We have been developing a ship-based coherent DIAL for measuring lower tropospheric water vapor and wind
- Validation experiments were made over the Northwest Pacific in May-November 2024
- The measured data agreed fairly with the radiosonde data
- We are improving the lidar system and data analysis procedure





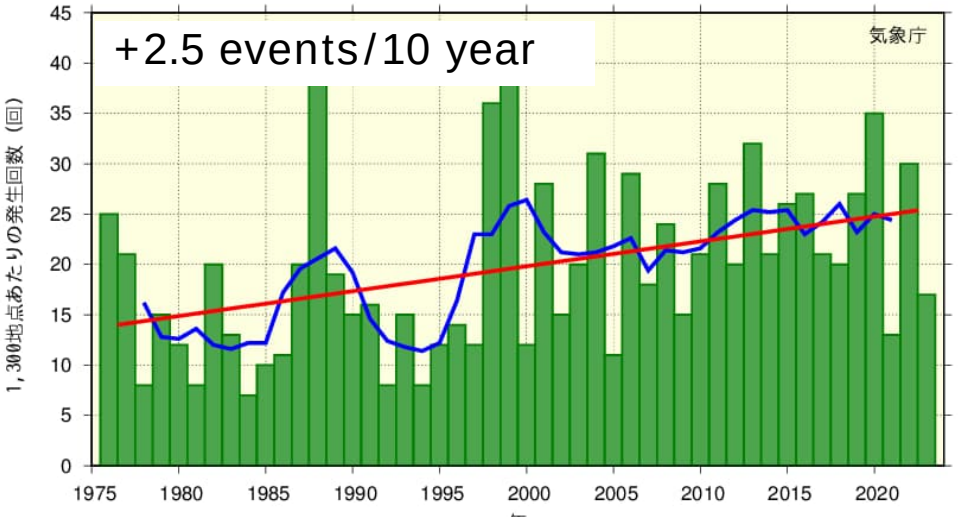
1. Background

- The frequency of occurrence of torrential rainfall has been increasing in Japan for the last fifty years.



Torrential rain in Kurume City, 10 July 2023

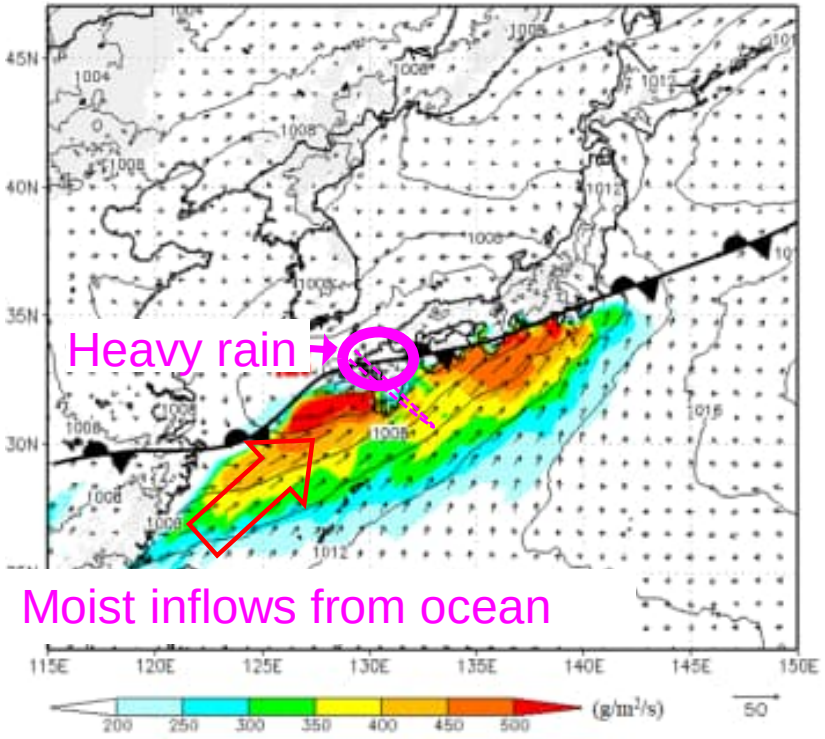
Annual occurrence of heavy rain (80 mm/hour)



1975 2023

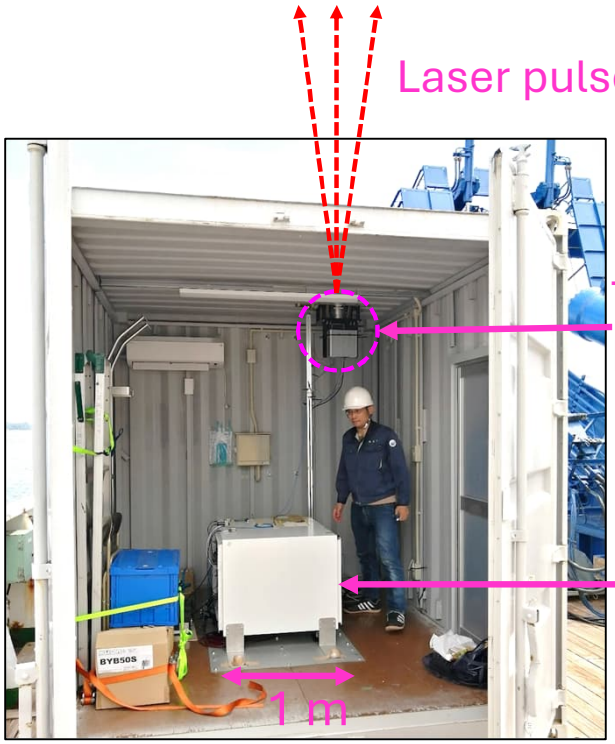
1. Background

- For a better understanding and early prediction of heavy rainfall, it is desirable to detect moist inflow wind side from ocean beforehand.



To meet the requirement, we are developing a ship-based coherent differential absorption lidar (DIAL) measuring the vertical distributions of water vapor and wind.

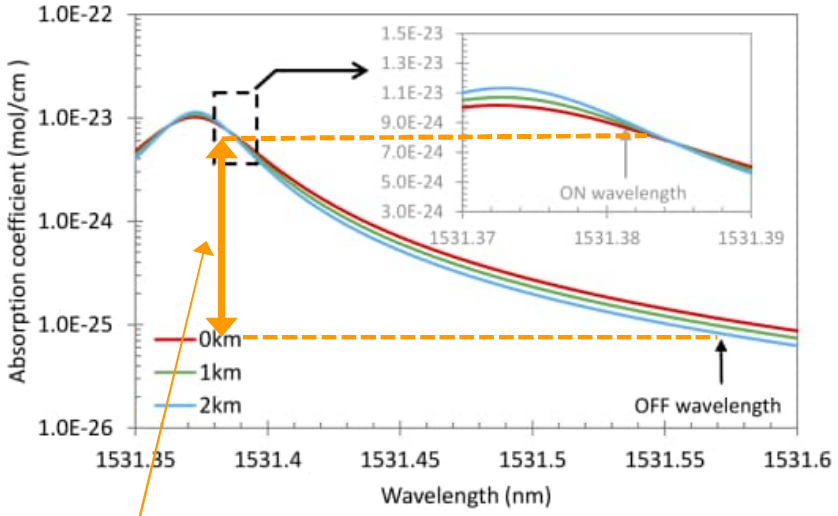
2. Coherent DIAL for water vapor and wind measurements

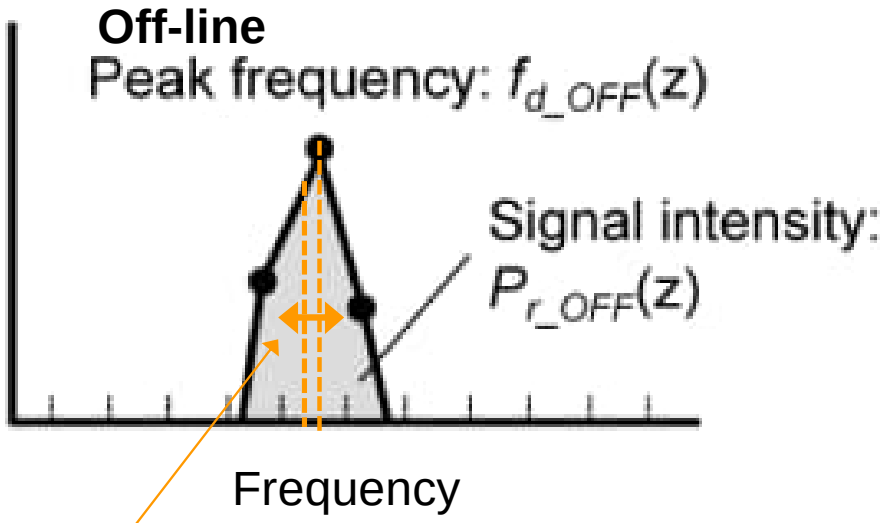


Laser wavelength	1531.3814 nm(On) 1531.5537nm(Off)
Energy/repetition	20 μJ/pulse / 32 kHz
Transmit directions	4 directions (11.2° off-zenith)
Transmit/Receive telescope diameter	10 cm
Observed quantities	**Water vapor density** **3-dimensional wind**
Observation range	0.1–1 km (Water vapor) 0.1–1.6 km (Wind)
Vertical Resolution	75 m
Temporal resolution	10 minute (Water vapor) 10 second (Wind)
Observation condition	Without thick cloud (below cloud base)

Imaki et al., Appl. Opt. (2020), Opt. Express (2020)

How to obtain water vapor density and wind speed from Coherent DIAL signal



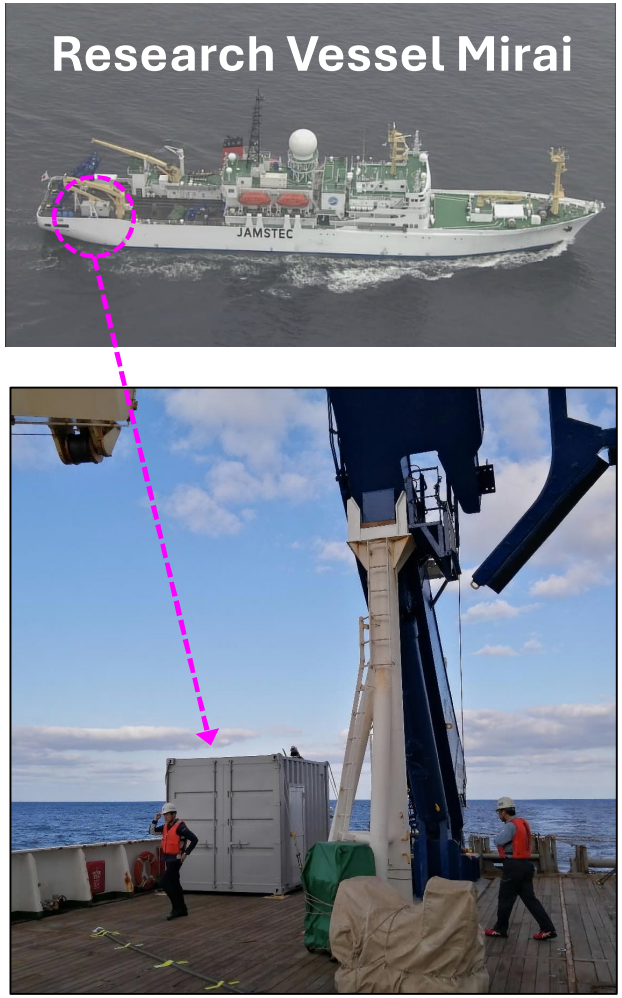


- **Water vapor** density is obtained from the difference of signal intensities of on- and off-wavelengths
- On-wavelength is locked using the HCN cell by the absorption line center of R18 branch close to the on-wavelength

- **Wind speed** is obtained from the Doppler shift of
- off-wavelength signal
- The shift is obtained from the difference of the peak (Doppler-shifted) and intermediate (laser) frequencies

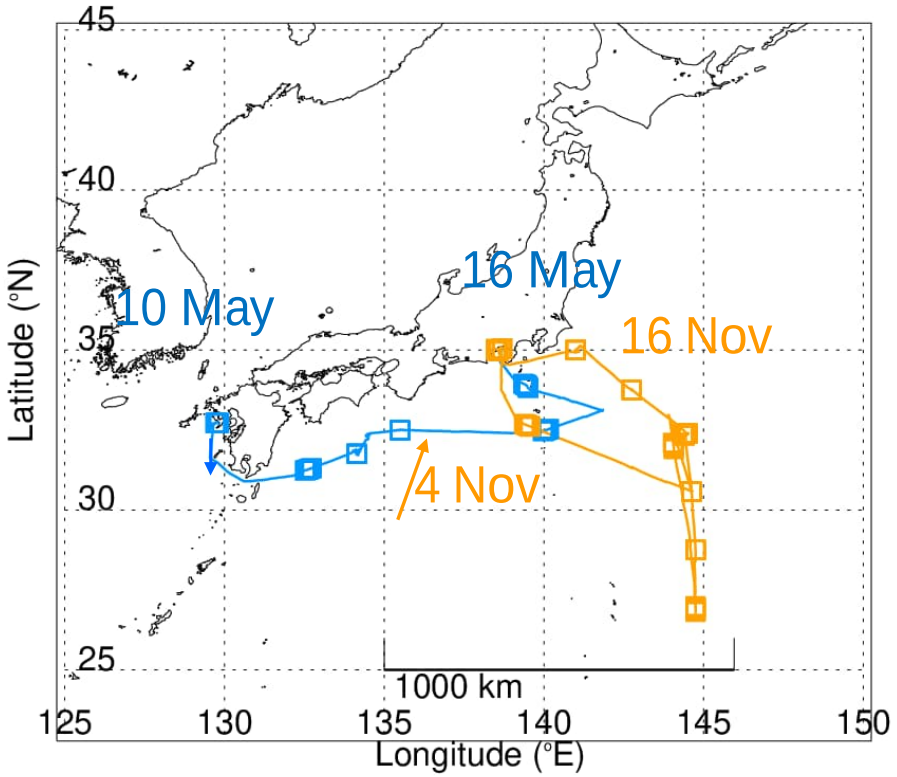
Imaki et al., Appl. Opt. (2020), Opt. Express (2020)

3. Observations over the Northwest Pacific in 2024

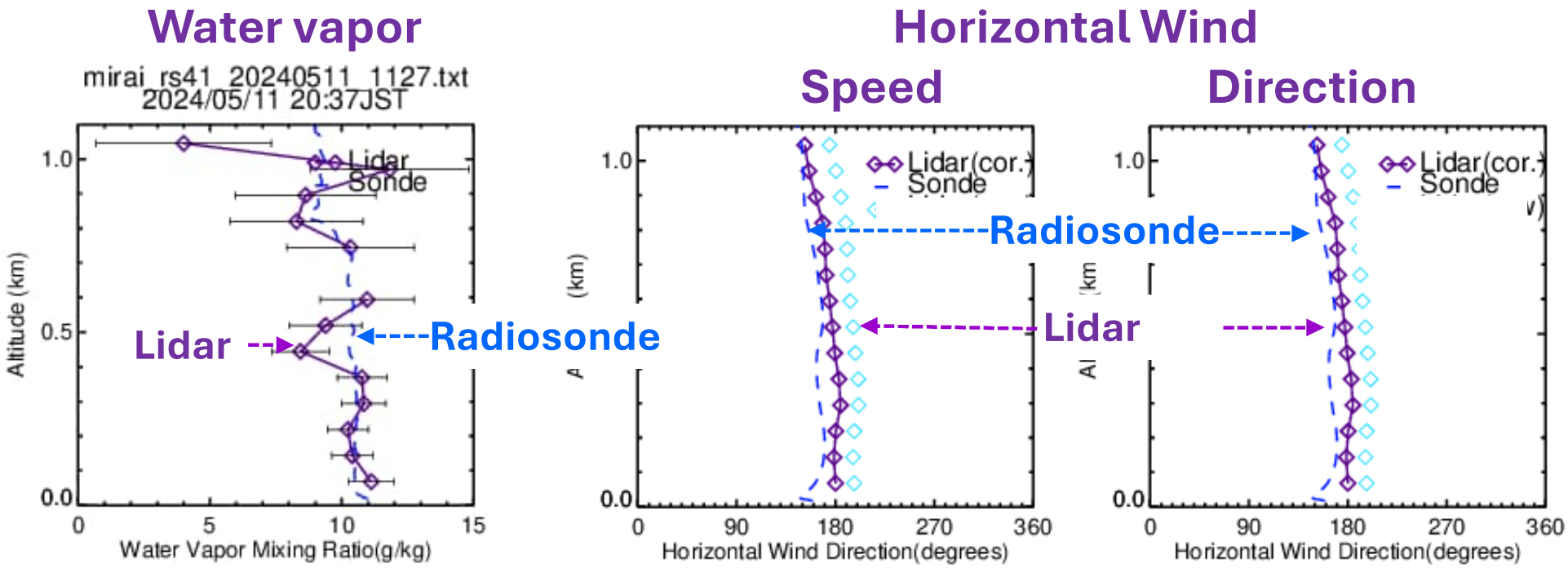


Cruise 1: 10–16 May

Cruise 2: 4–16 November



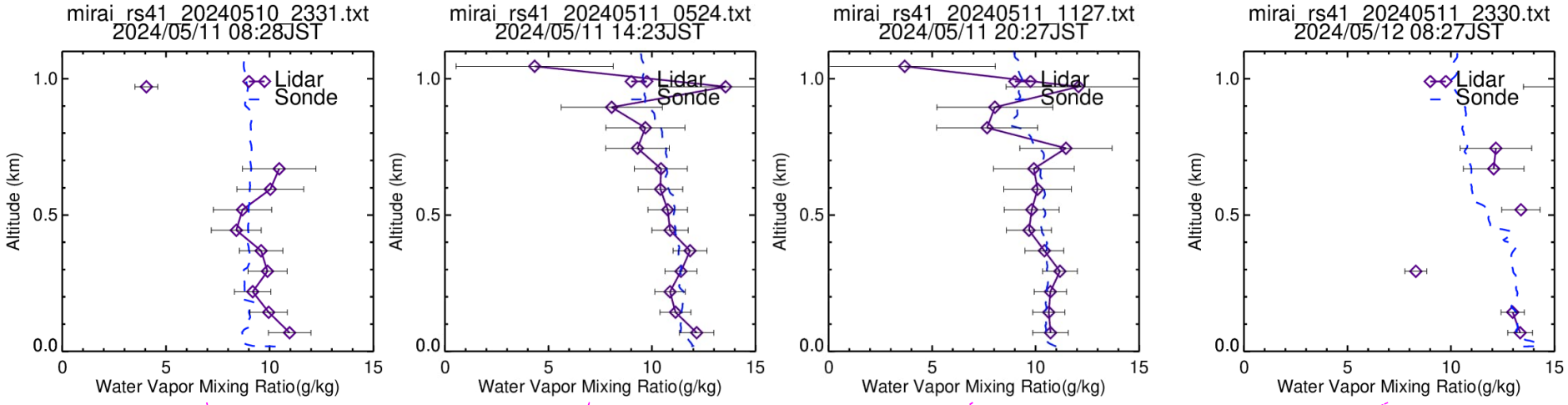
3. Comparison with radiosonde measurements in cruise 1(11 May)

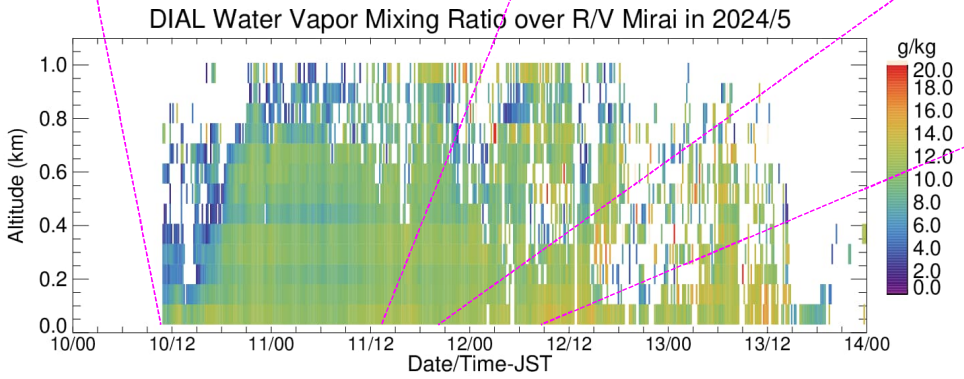


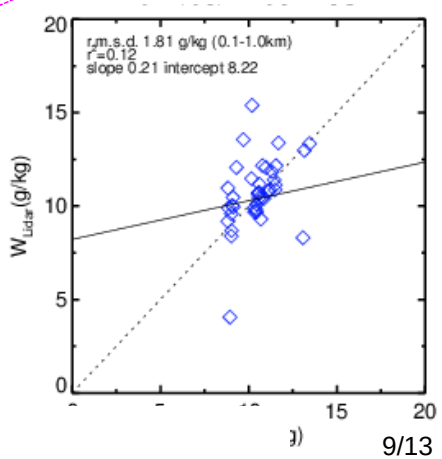
- Fair agreement of water vapor between 0.06 km and 0.8 km
- Good agreement of wind speed & direction between 0.06 km and 1 km

*Wind data are corrected only for forwarding speed and direction of ship

3. Comparisons of water vapor with radiosondes during cruise 1

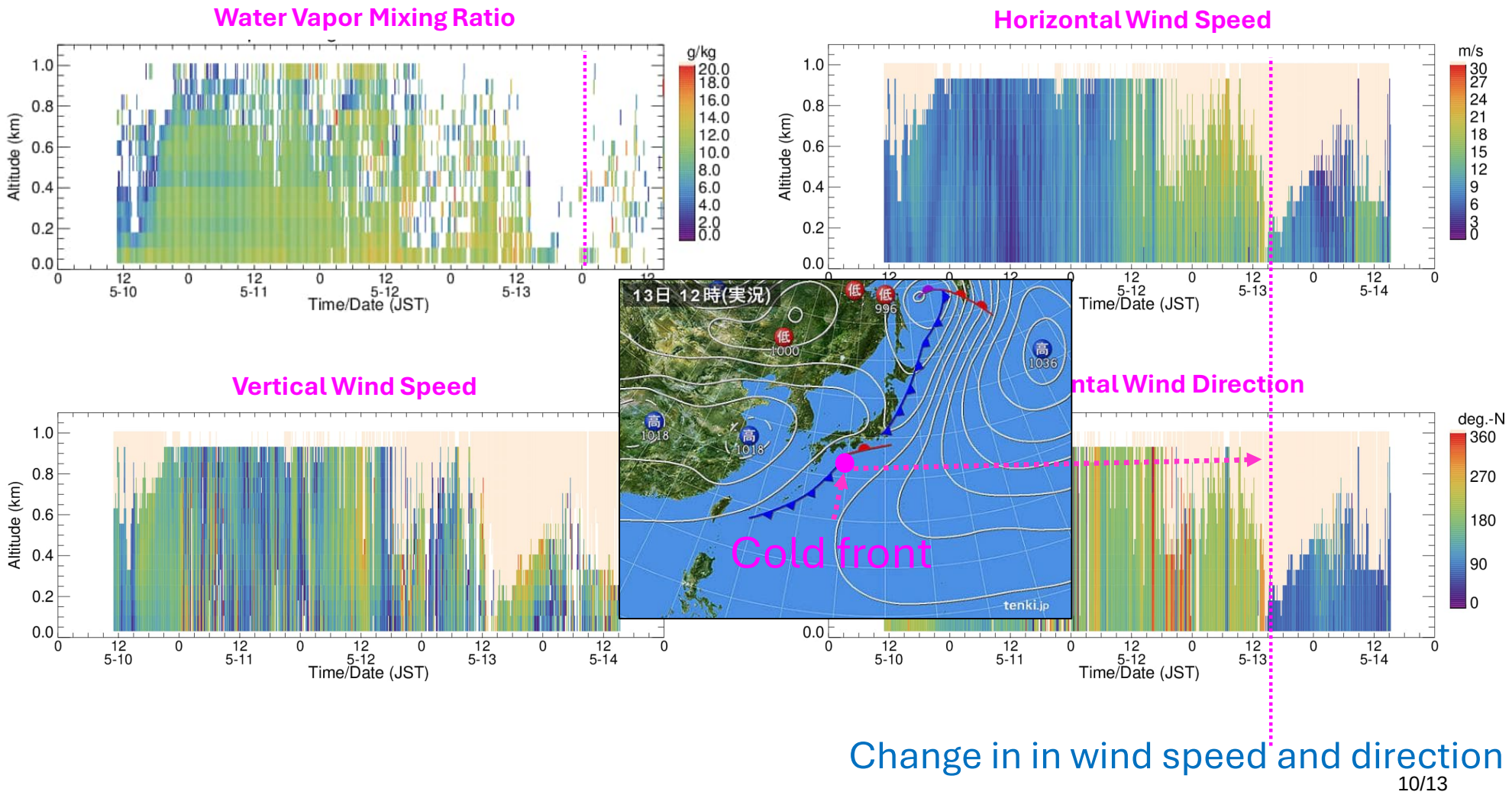






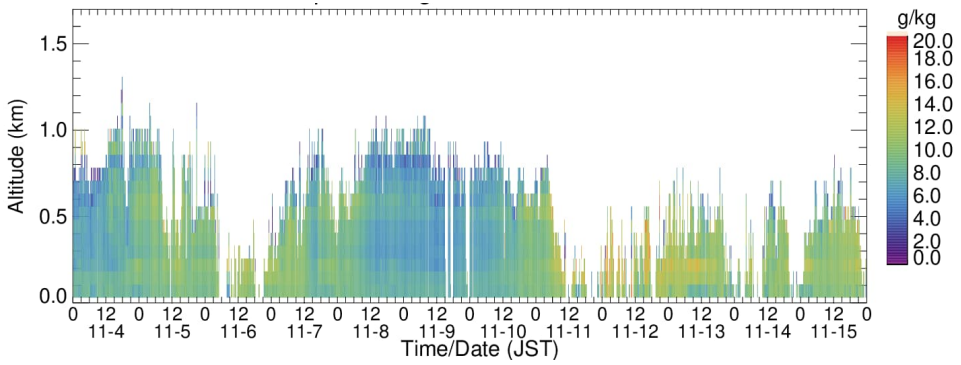
Quality control is being improved

3. Observational results during cruise 1 (10–14 May 2024)

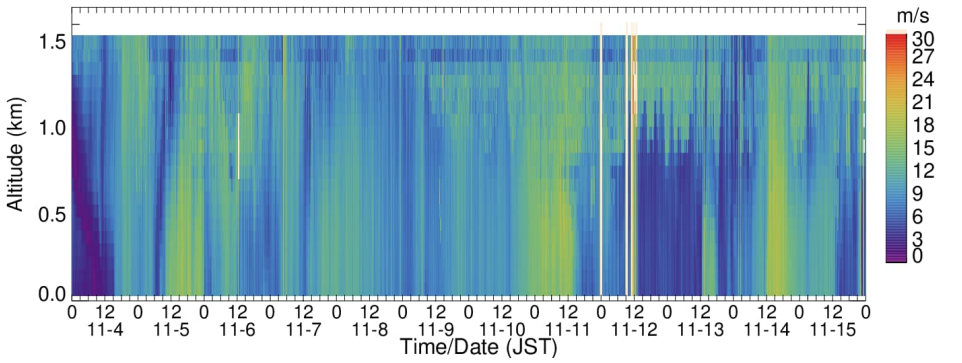


3. Observational results in cruise 2 (4–16 November 2024)

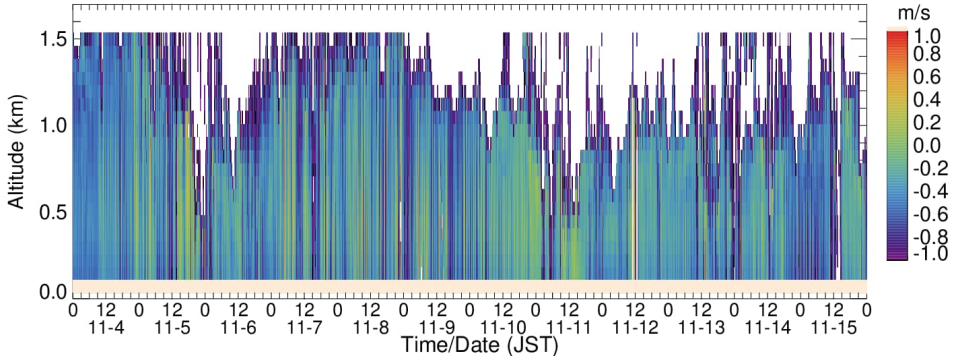
Water Vapor Mixing Ratio



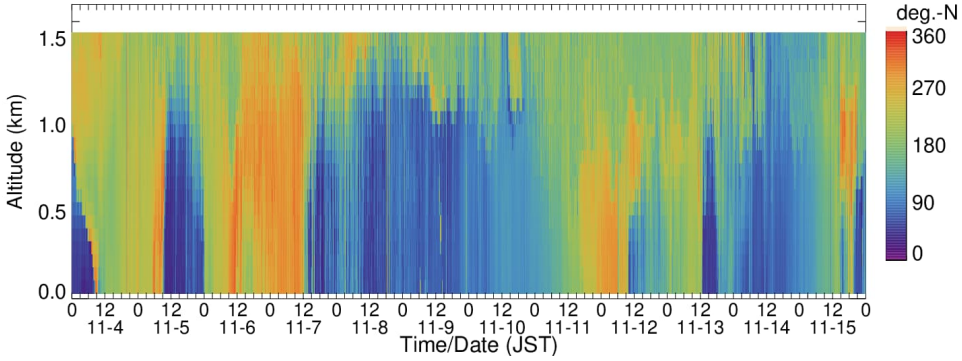
Horizontal Wind Speed



Vertical Wind Speed



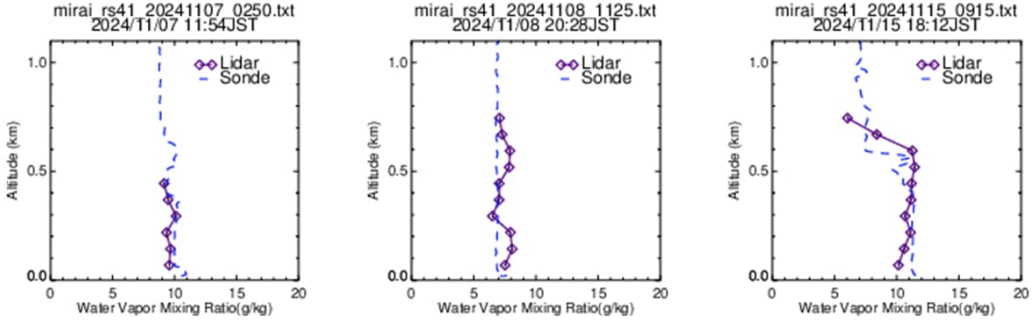
Horizontal Wind Direction

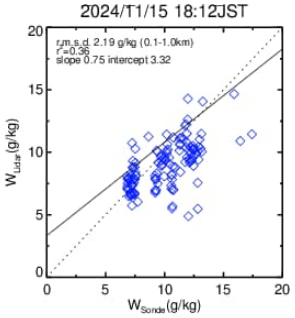


Wind data are corrected for ship motion using gyro data

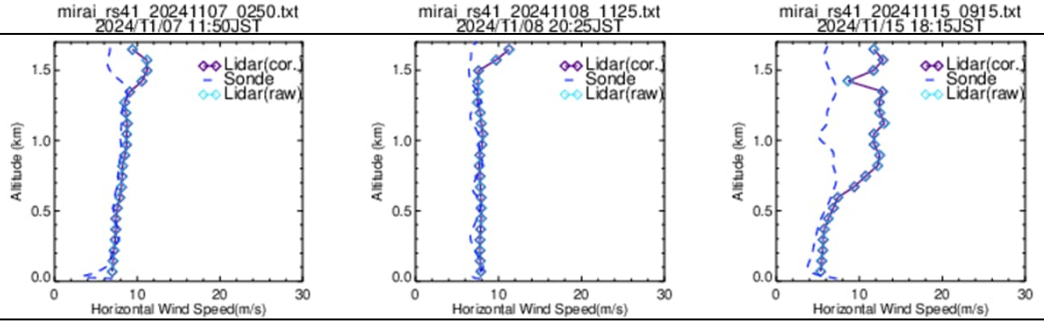
3. Comparisons with radiosonde measurements in cruise 2

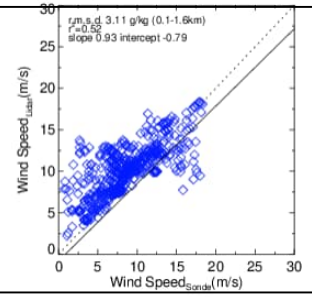
Water Vapor Mixing Ratio



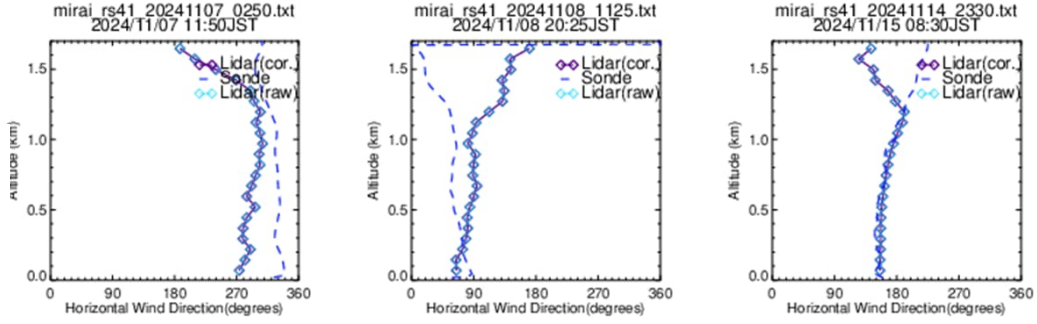


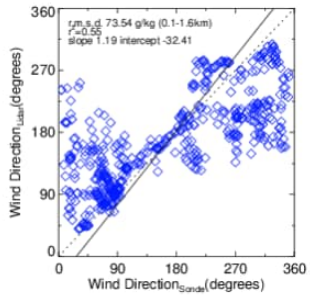
Horizontal Wind Speed





Horizontal Wind Direction





- Quality control and motion-correction are being improved

4. Summary

- Ship-based coherent DIAL measuring lower tropospheric water vapor and wind has been developing
- Measurements over the Northwest Pacific in May-November 2024
- The measurement data agreed fairly with the radiosonde data

5. Next step

- To improve the quality control and data processing (e.g., ship motion correction and real-time data analysis)

Questions?

This study is supported by JSPS grant No. 22H00250.