Proposal for the Space-borne Integrated Path Differential Absorption (IPDA) Lidar for Lower Tropospheric Water Vapor Observations

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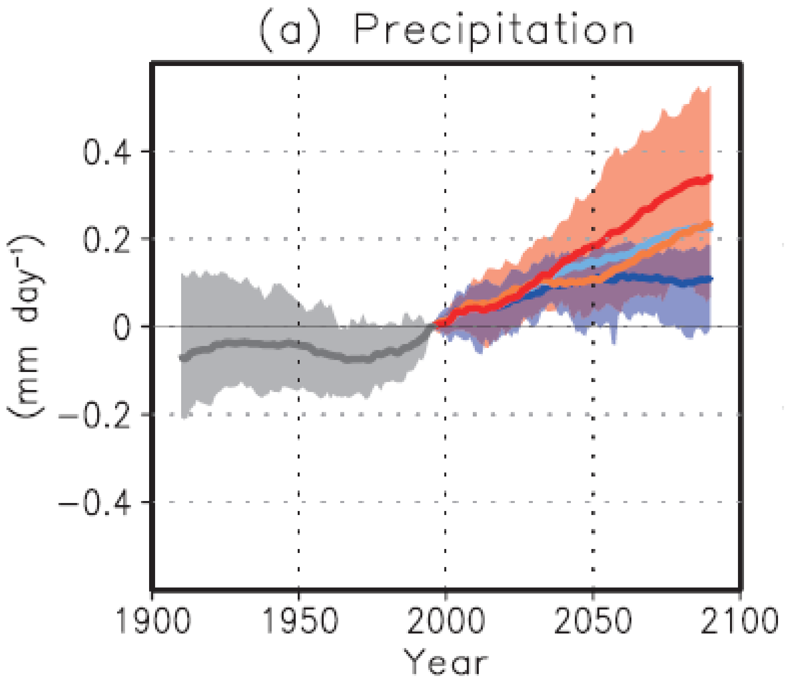
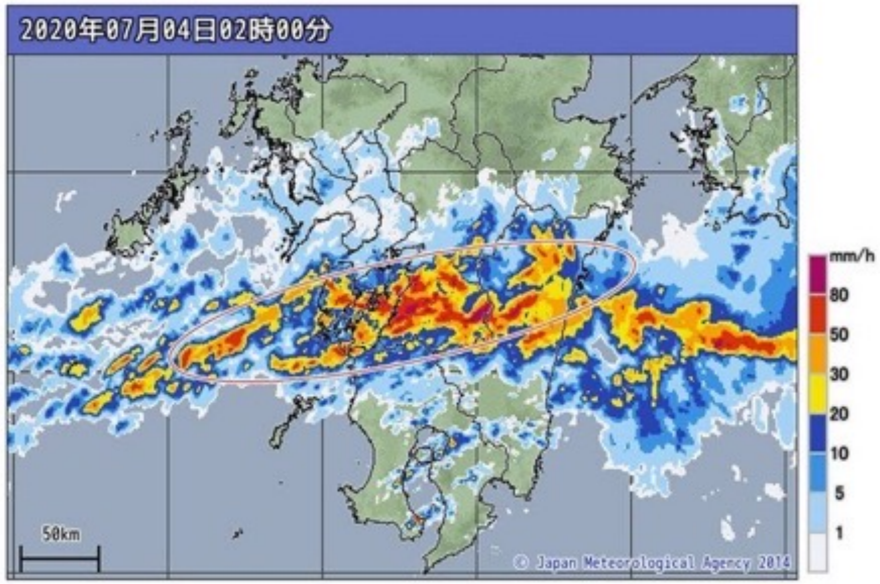
Background: Climate Warming Increases the Potential Heavy Rainfalls

The strongest effect of climate change on monsoons is the increase in atmospheric moisture associated with warming of the atmosphere, resulting in an increase in total monsoon rainfall.

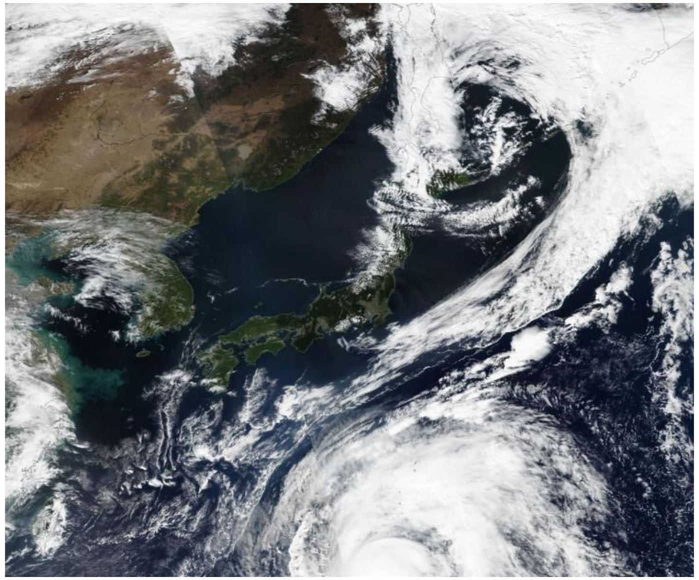
Heavy rainfall disasters in Japan are increasing year by year, and measures for disaster prevention and mitigation and national land resilience are urgently needed.



Time series of simulated anomalies over the global land monsoon domain for precipitation
IPCC Fifth Assessment Report (WG1)



Heavy rain due to the linear precipitation in Japan



Super Typhoon brought huge damage to Japan
(2019 Typhoon Faxai)

Objectives

- Measurements of water vapor profiles are very important in the studies of atmospheric dynamics, clouds, aerosols, and radiation.
- Water vapor is the predominant greenhouse gas and its vertical distributions are important in the global climate system.
- Water vapor data would lead to benefits in numerical weather prediction, such as localized heavy rainfall events and typhoon forecasting.

Science

Adaptation

Why Space-borne DIAL?

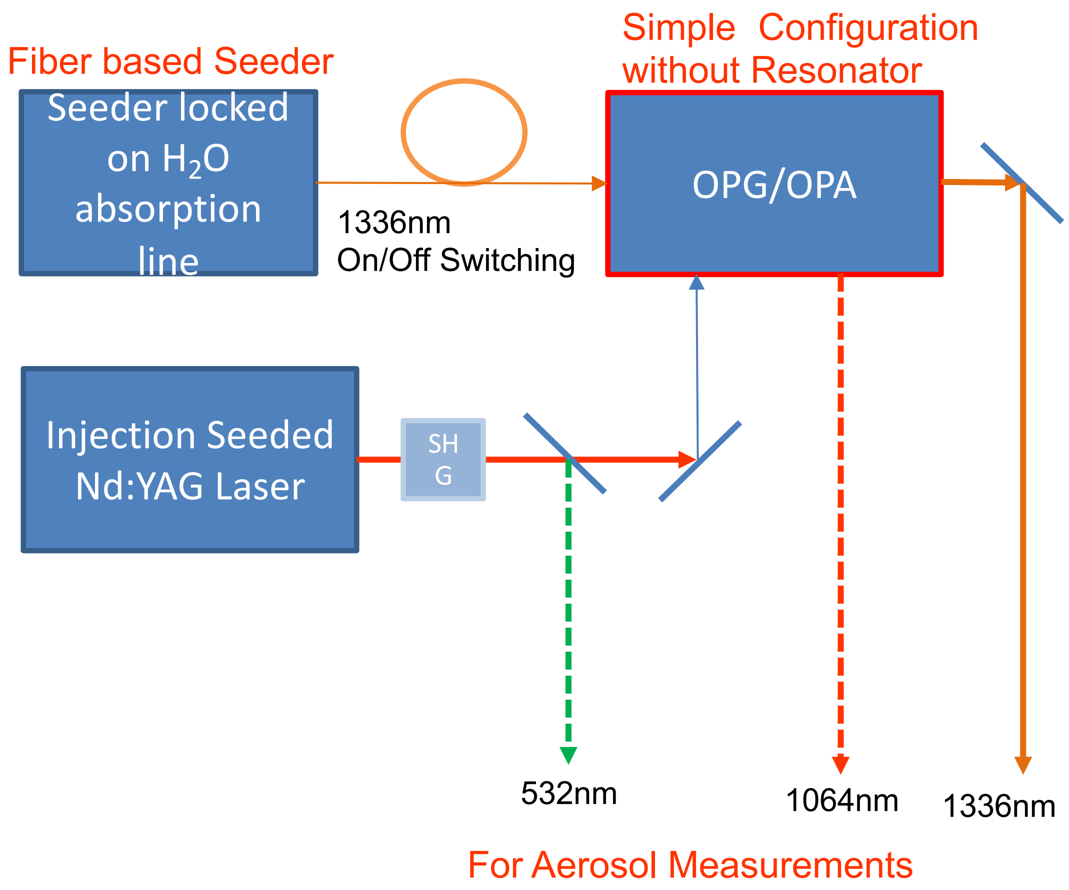
- Passive remote sensing techniques from space provide global coverage of water vapor distribution lacking good vertical resolution, while lidar remote sensing techniques can provide water vapor distribution with high vertical resolution.

- The DIAL technique is most available to perform high-resolution measurements of tropospheric water vapor distributions from space.

Proposed Space-borne Water Vapor DIAL System

Full / Modest specifications

Pulse Energy	20mJ/10mJ
Repetition Rate	500Hz (on/off pair)
Wavelength	1336nm
Telescope Aperture	0.8m/0.5m
Detector Q.E.	50%(APD)
Altitude	250km/400km
Velocity (ground)	7.8/7.7 km/s
Vertical Resolution	300～600m
Horizontal Resolution	10～300km



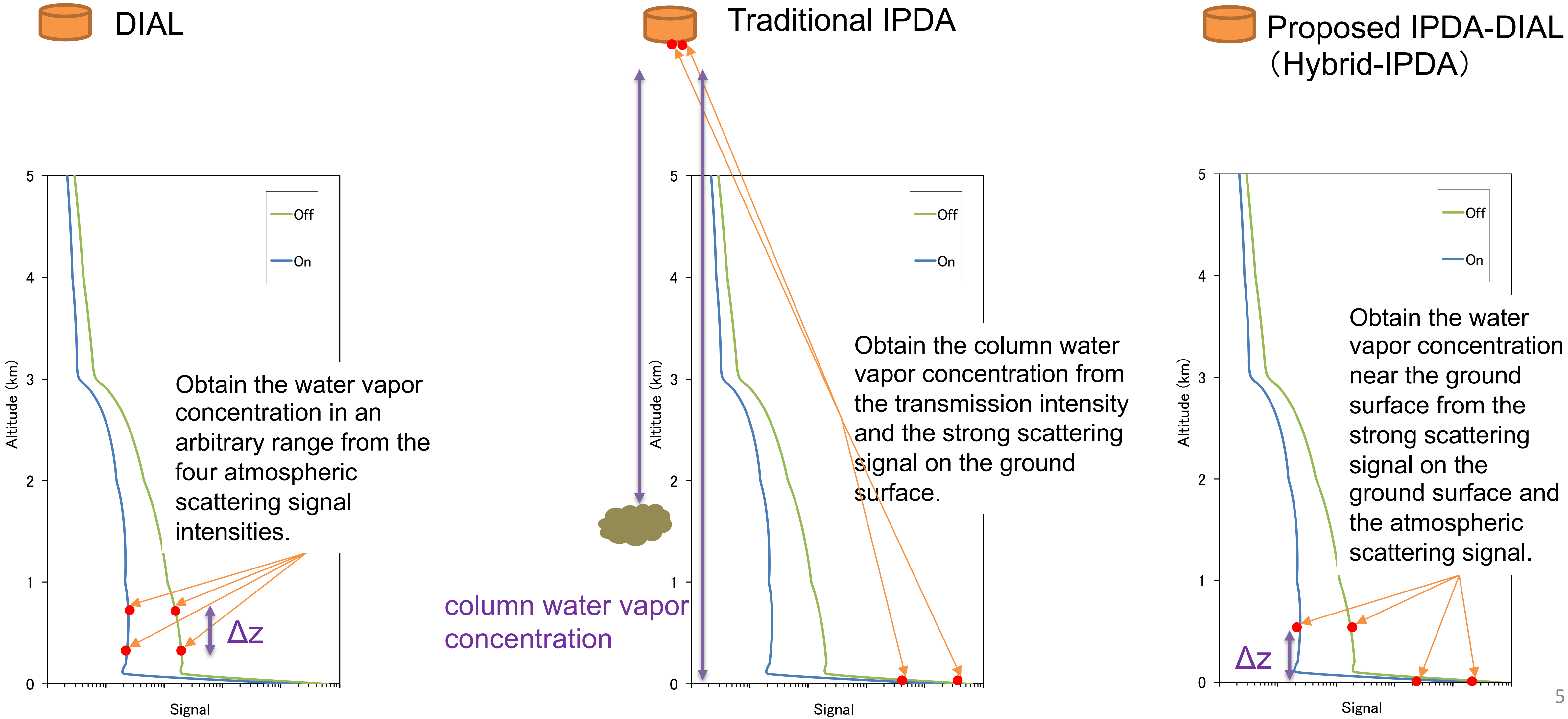
Estimation of Electrical Power (Transmitter only)

Power →	LD →	Nd:YAG(1064nm) →	OPG(1336nm)
240W	120W	40W	20W

- OPA (Optical Parametric Amplifier) system using QPM (Quasi Phase Matching) device is one path amplifier.
- OPA is advantageous for space use because it has less restrictions than conventional phase matching OPO.

Comparison of the Space-borne DIAL and IPDA

- Change the data processing method without changing the hardware
- Conventional DIAL observations are also possible

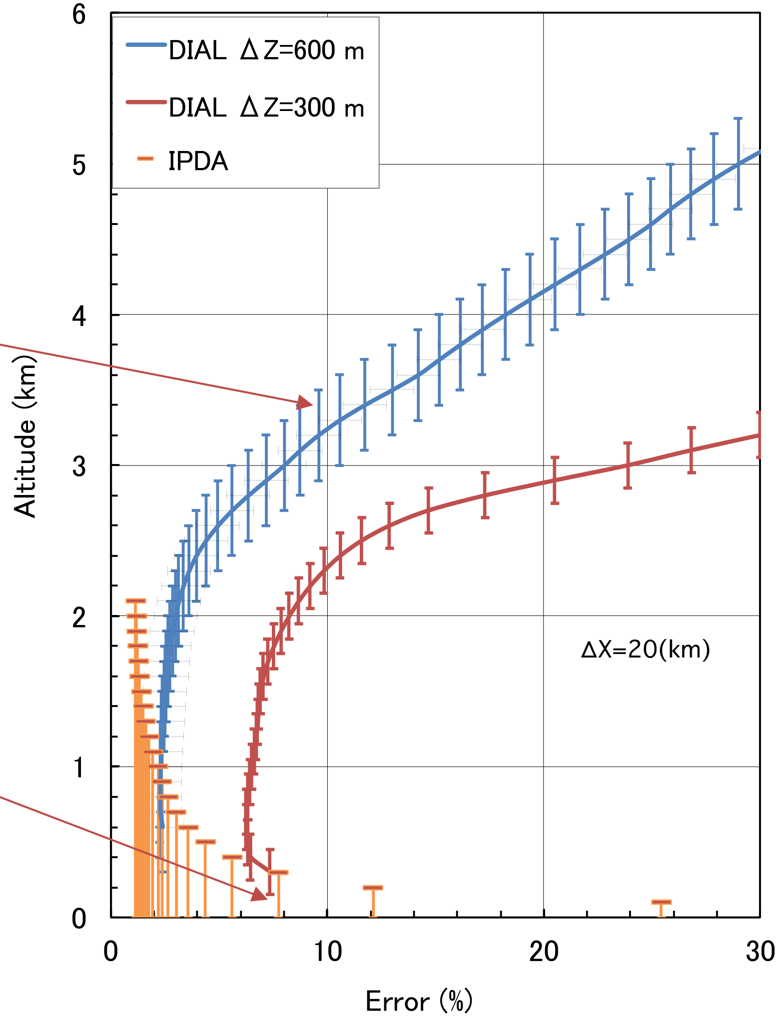


Random Error of Water Vapor Density for the Space-borne DIAL and Proposed IPDA

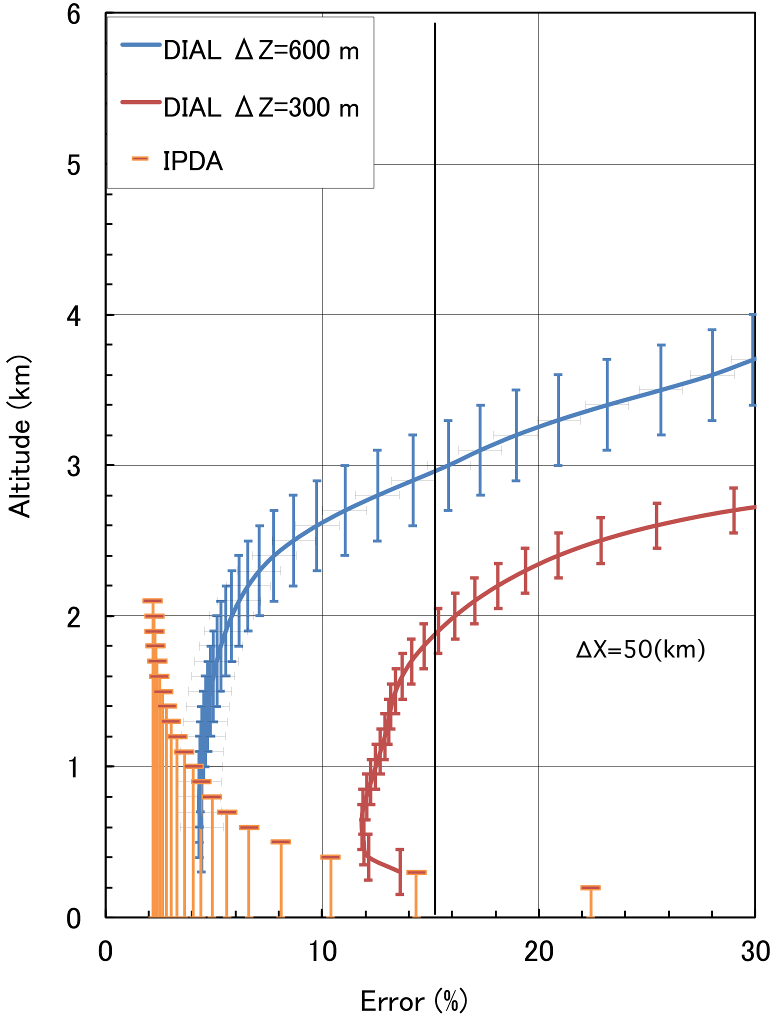
Represents the range of resolution, not the error bar !

IPDA：Statistical error of water vapor column density in the range from 0 to h, using ground reflection (z = 0) and scattering signals at each altitude (z = h)

Full specifications
DIAL error <10% : ～3.2km (Δz=600m)
IPDA error <10% : 0～300m



Modest specifications
DIAL error <15% : ～3km (Δz=600m)
IPDA error <15% : 0～300m



Conclusion

- Information on water vapor near the sea surface is important for forecasting heavy rainfall.
- Therefore, without changing the specifications of the proposed DIAL mission, we investigated the possibility of DIAL observations of near surface water vapor using both the atmospheric backscattering and the surface reflection signals with the IPDA technique.
- Water vapor IPDA-DIAL observations using both sea-surface and atmospheric scattering signals can be made up to 300m below the surface with an error of less than 10% with conventional DIAL specifications.
- Even IPDA-DIAL observations with modest specifications can be made up to 300m below the surface with an error of less than 15%.
- Feasibility of IPDA-DIAL focused on oceanic subsurface water vapor observations important for heavy rainfall prediction was demonstrated.
- If the amount of water vapor in the atmospheric mixed layer (altitude around 500m from the sea surface in the tropics) can be measured with the space-borne IPDA-DIAL, the accuracy of latent heat flux measurement can be expected to improve.
- Also, if the wind speed and temperature near the sea surface can be measured at the same time as the amount of water vapor, it will be possible to calculate the latent heat and sensible heat for each snapshot.