# *Diurnal Variations of 3D-Wind Cloud Height and Winds from Hurricanes and PBL*

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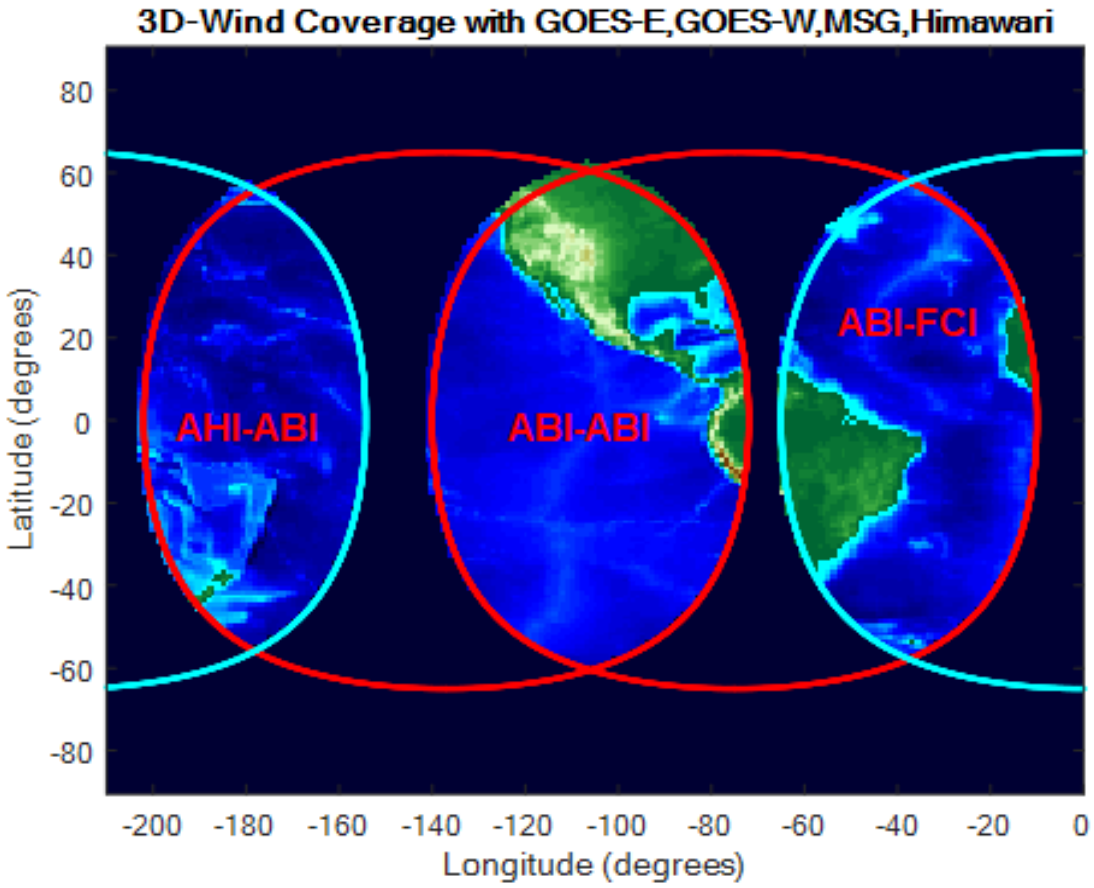
**Acknowledgments**

- NASA Terra Project
- NASA High-End Computing (HEC) Program
- NASA Sun-Climate Research

# Outline

- GEO-GEO stereo observations
  - AHI-ABI and ABI-ABI algorithms (Carr et al., 2020)
  - Future ABI-FCI
  - Full diurnal coverage with IR bands
- 3D-Wind retrievals from G16-G17 for IWWG “Golden Day” (2019d293) delivered to ICARE
  - 5-days (2019d291-d295): G17 loop heat pipe (LHP) impact
  - 5-days (2023d032-d036): G16-G18
- Applications
  - Diurnal variations of severe storms (e.g., Tropical Storm Imelda 2019)
  - Tonga volcanic ejection height (Carr et al., 2022)
  - Cloud diurnal variations in planetary boundary layer (PBL), middle troposphere, convective outflow, and tropical tropopause (this study)

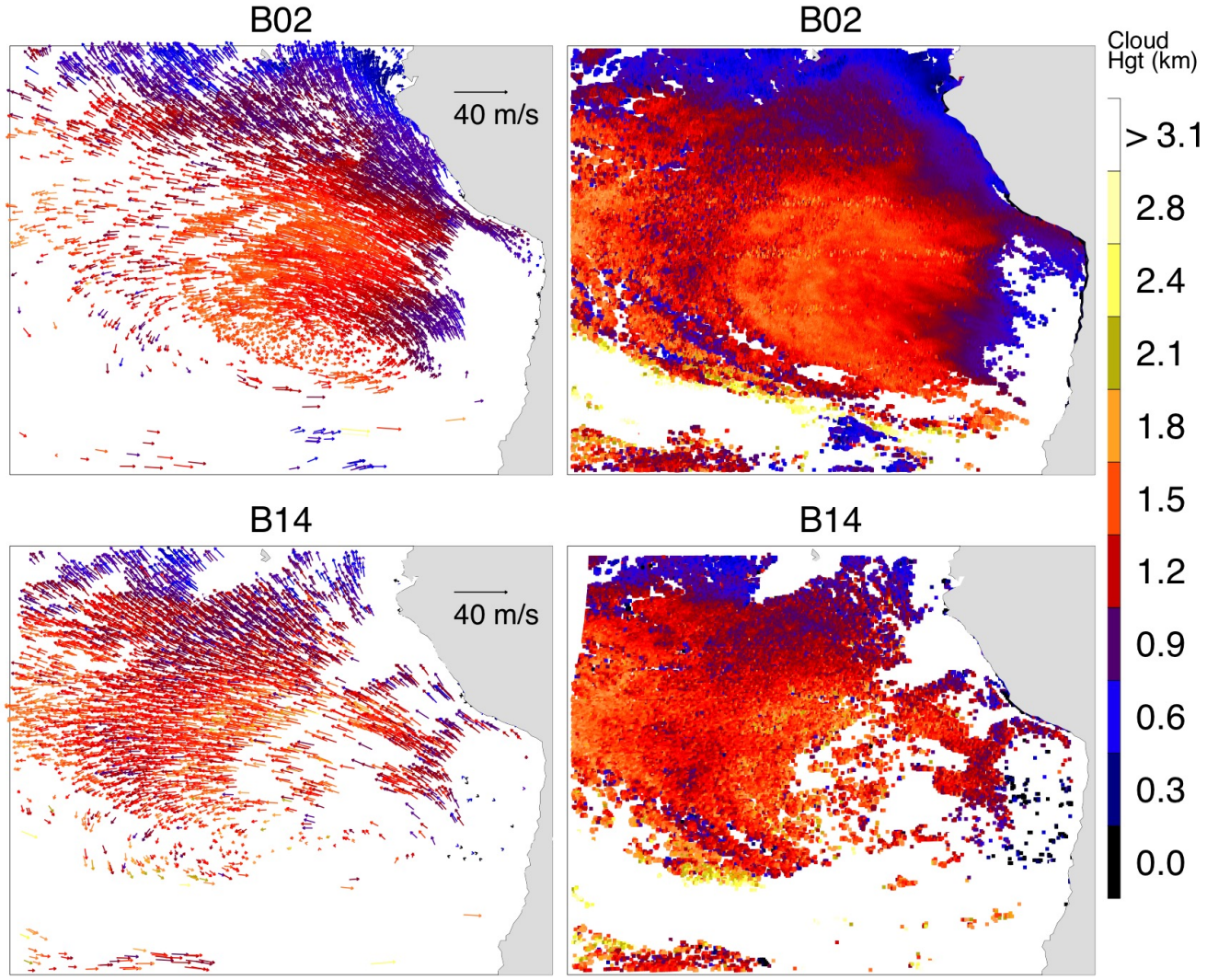



Carr et al. (2020)

# 3D-Wind Applications

- PBL
  - Cold air outbreak
  - Stratocumulus-to-cumulus transition
  - Orographic clouds
- Deep Convective Systems
  - Tropical cyclones
  - Severe weather
- Wildfire plume and Air Quality
  - Pyrocumulonimbus (pyroCb) cloud
  - Plume transport

G16-G17 Stereo Winds and Height




Carr et al. (2020)

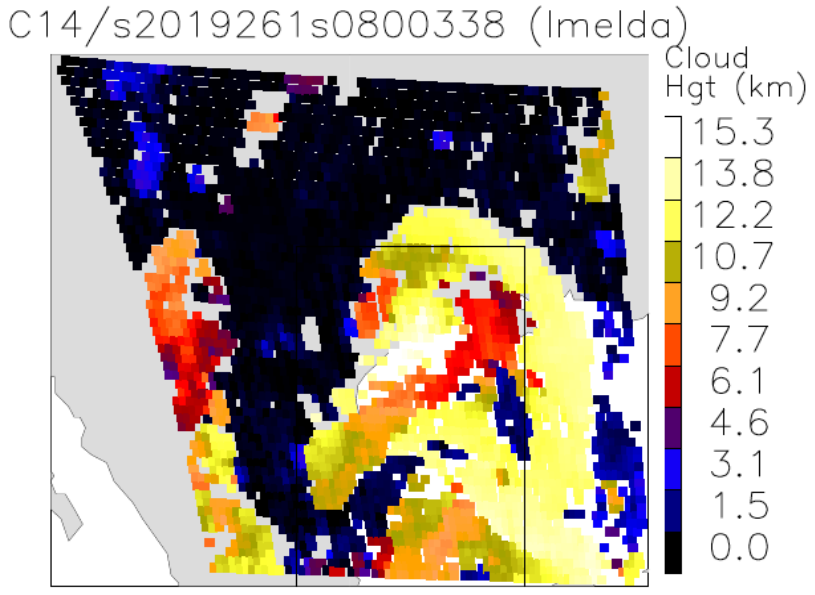
# Diurnal Variation of Tropical Storms

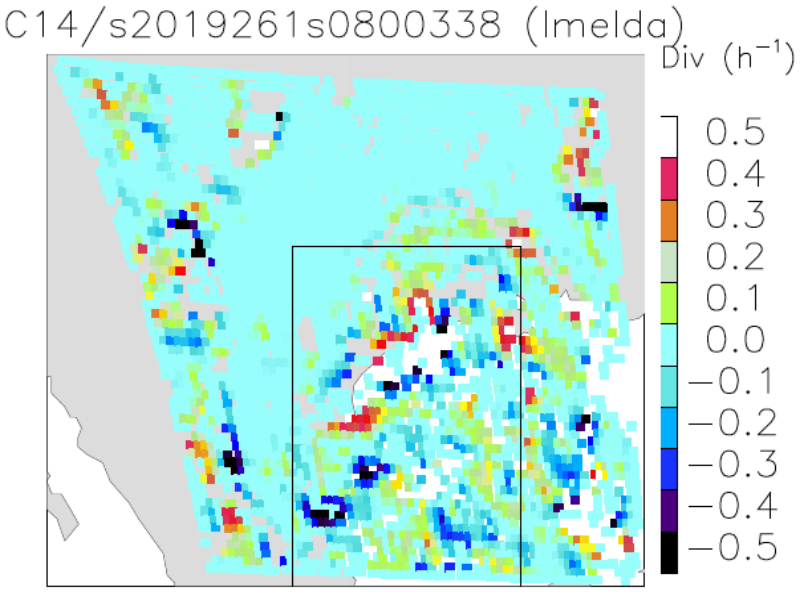
Carr et al. (2020)

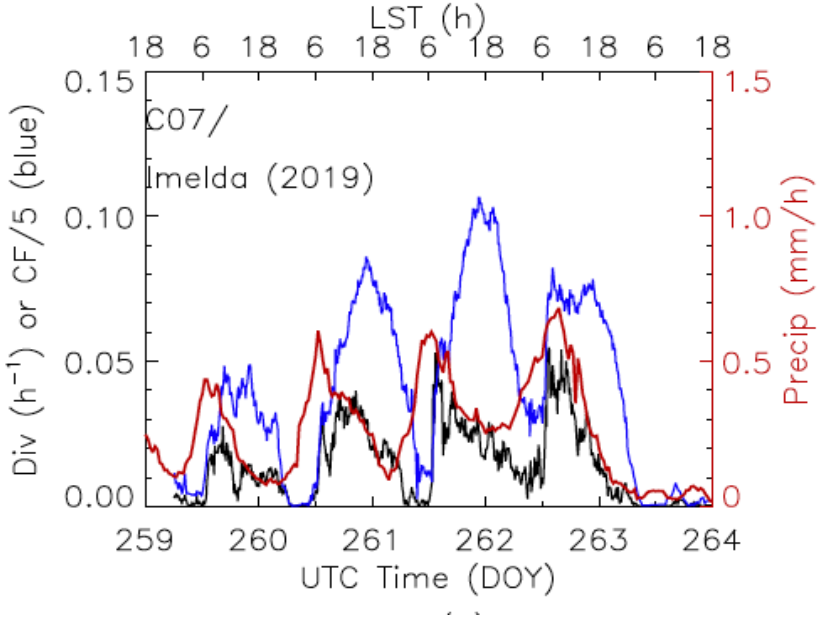
- Dense wind measurements to derive cloud top divergence at z >11 km
- Strong diurnal cycles in upper-level cloudiness and divergence, and in precipitation
- Precipitation leads upper-level divergence by ~6 hours

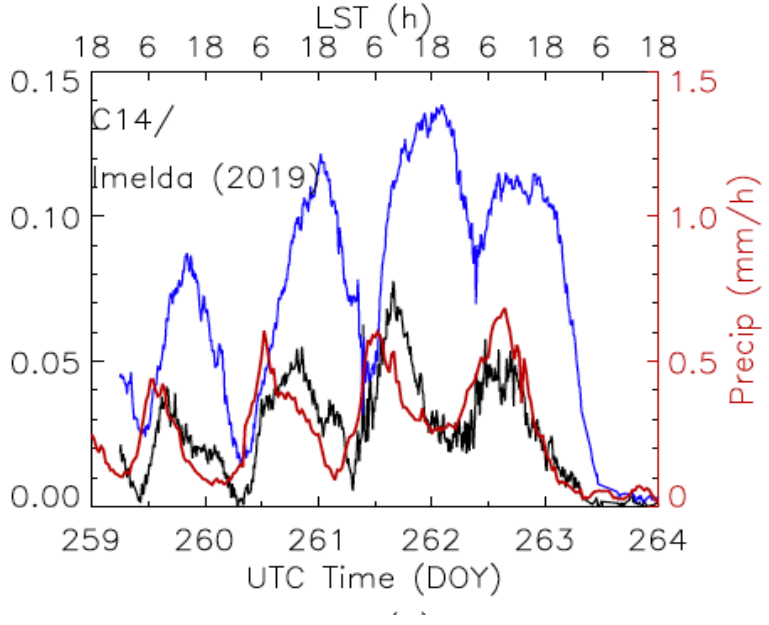
**Divergence**
**Cloud fraction**
**IMEG Precipitation**

## Tropical Storm Imelda (2019)



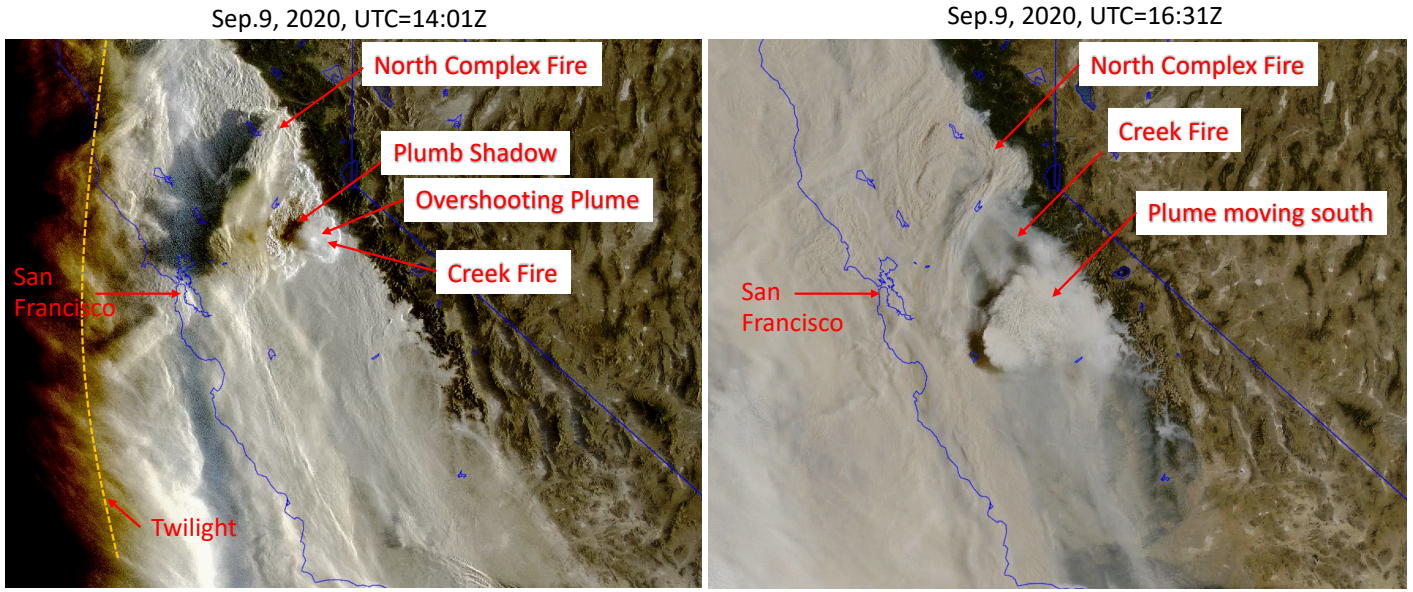
# Wildfire plume and Air Quality

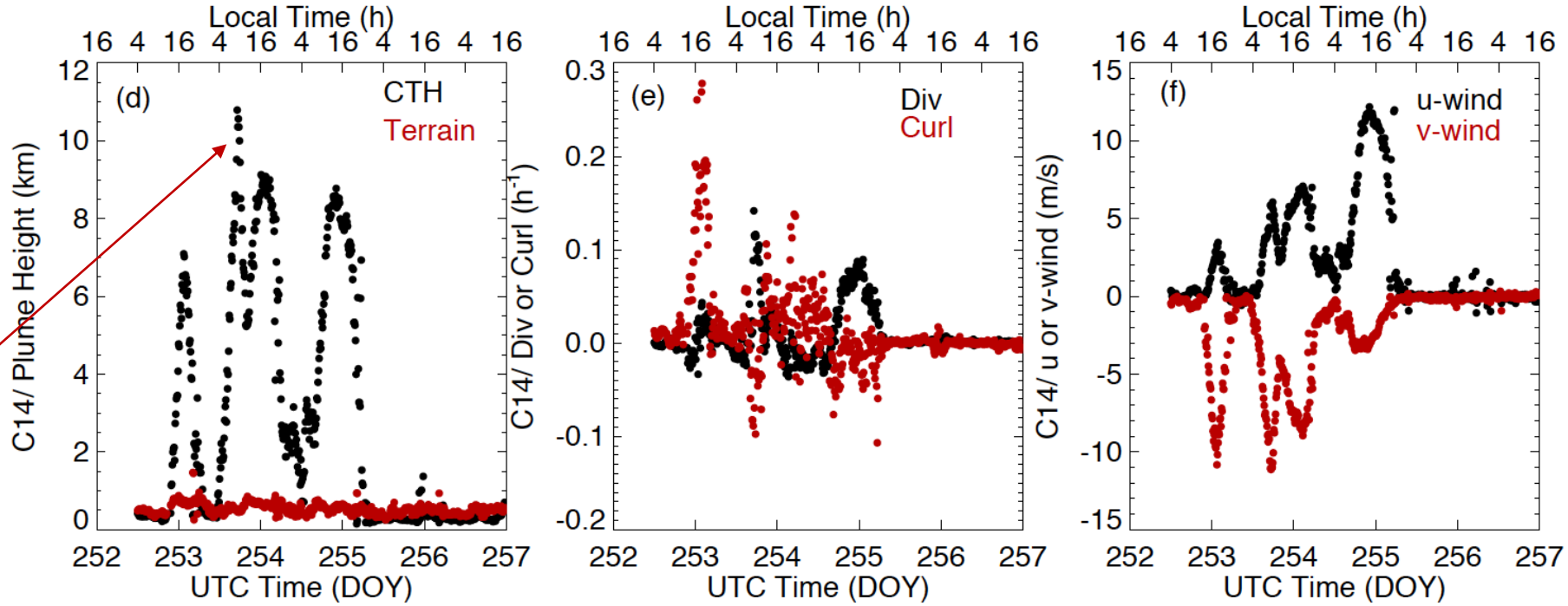
Carr et al. (2020)

- Intense and deadly wildfire season in the West Coast in 2020
- Strong diurnal cycles in plume height and winds
- Wide spread of fire plume and poor air quality
- pyroCb retrieved from stereo plume height

**pyroCb**

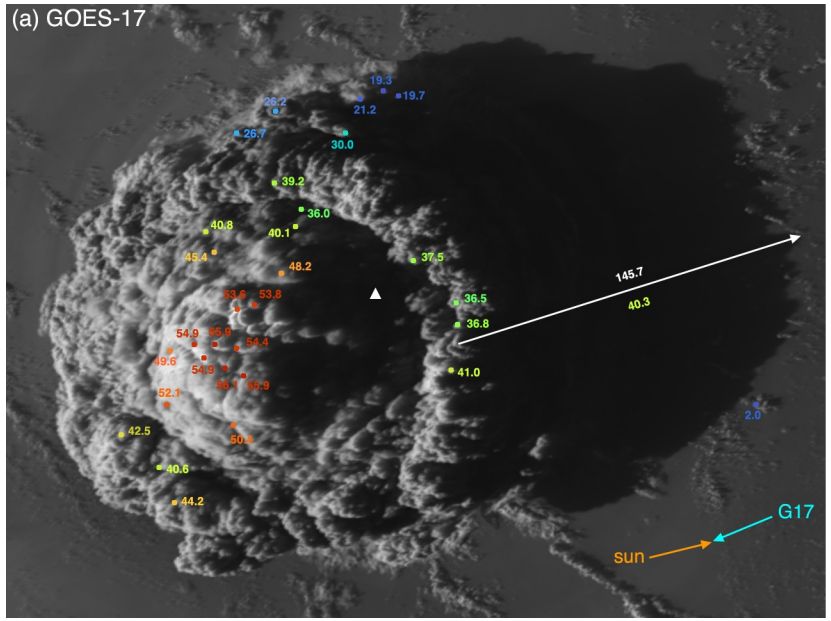
## California Creek Fire (Sep 2020)

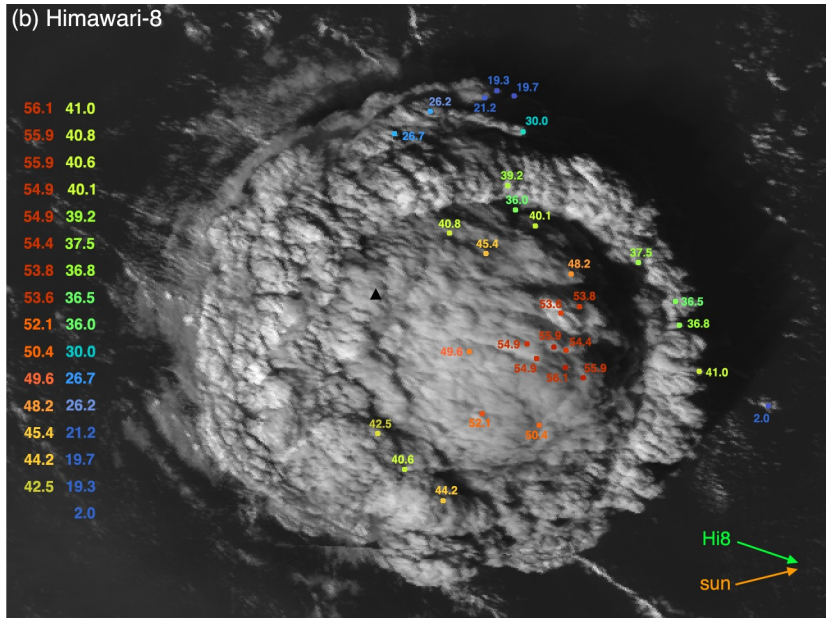


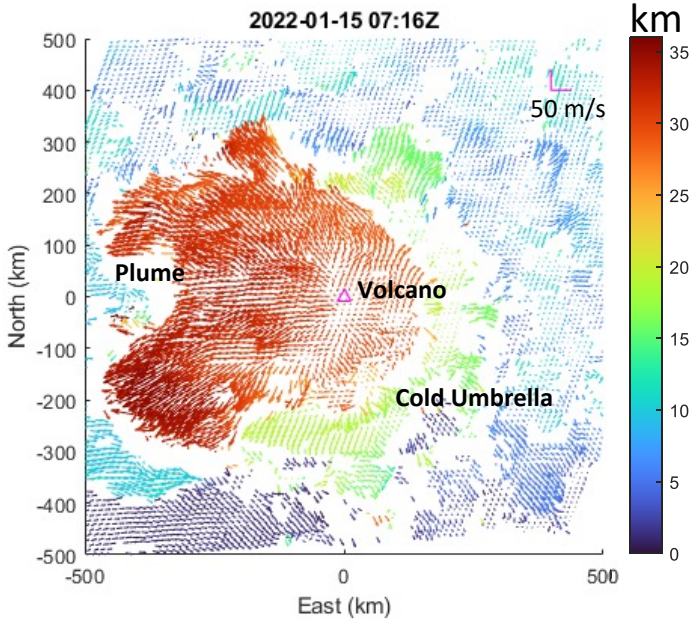
# Tonga Volcanic Plumes from G17-H8

Carr et al. (2022)

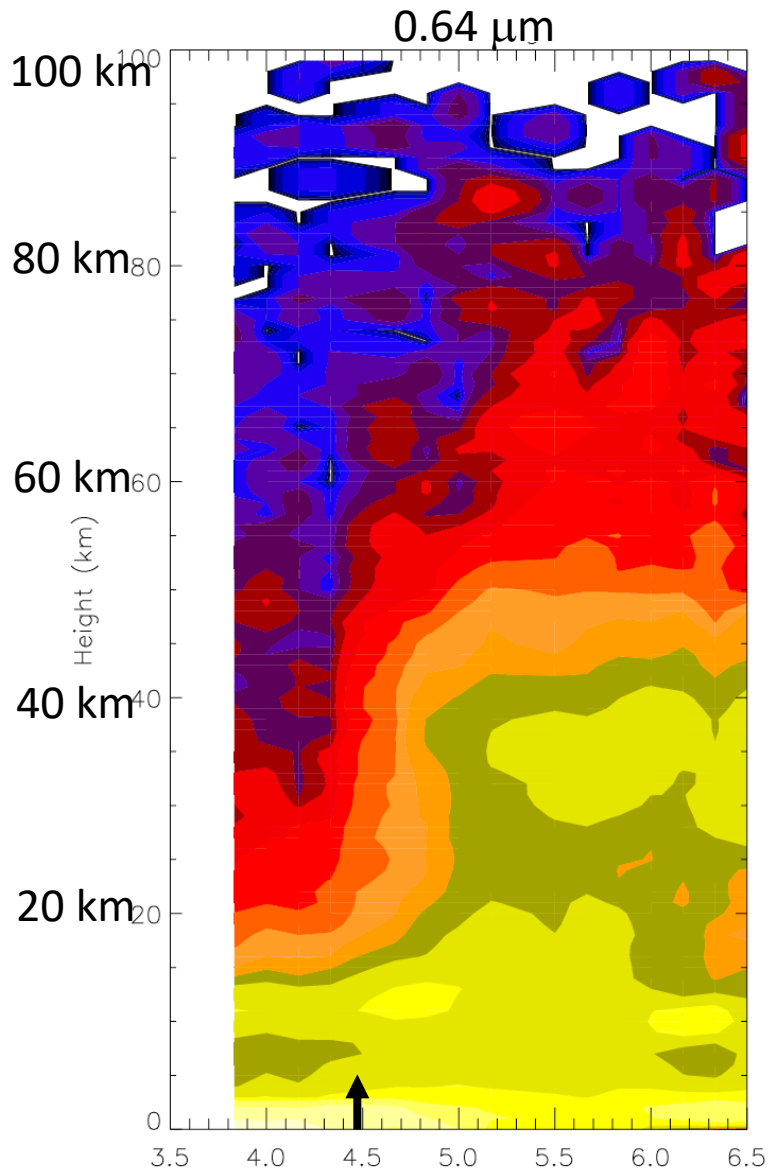



- Stereo height from GOES-17 and Himawari-8 pairing
- Plumes reached as high as ~55 km on 15 January 2022
- G17 MESO (1-min) data from 07:05Z-13:50Z used for stereo retrievals




Higher plumes?

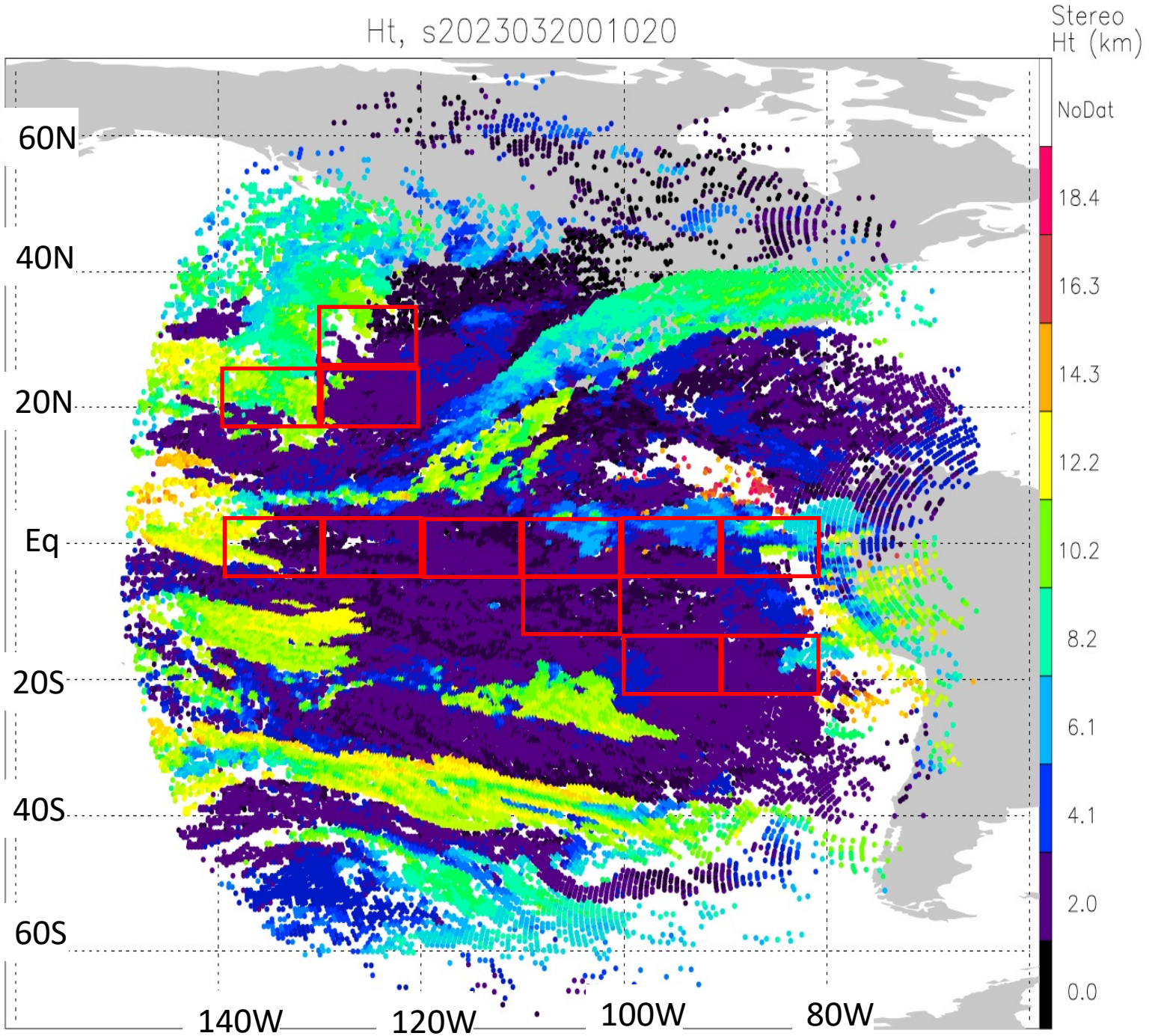



10-min FD refresh UTC, Jan 15, 2022

# Diurnal Variations of Tropical Clouds

- Complex cloud layers, interactions, and lifecycles
- Important for climate in Earth's radiation budget
- Difficult to model convective and multi-scale processes
- High spatiotemporal sampling needed to 3D cloud evolution

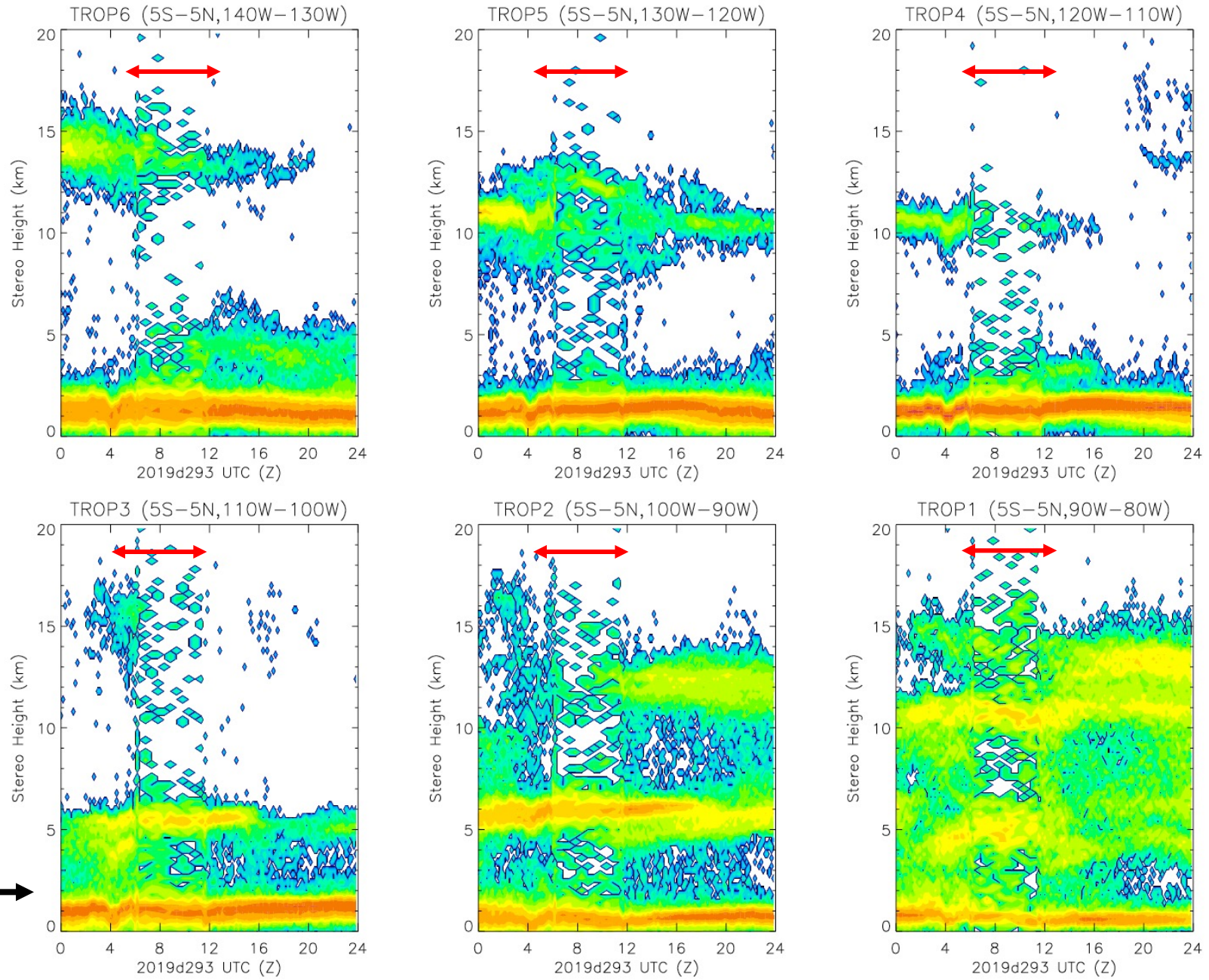
10-min G16-G18 pairing →



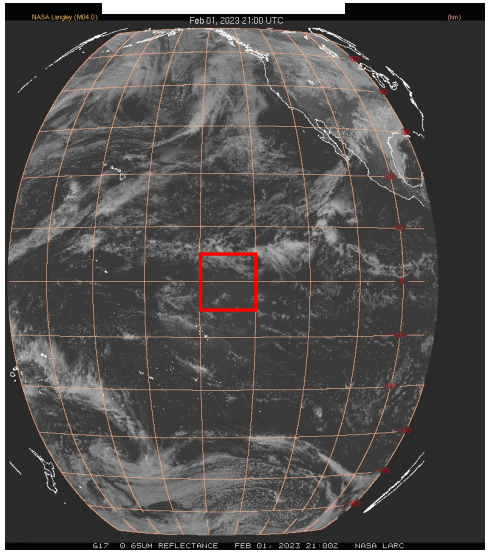
# Impacts G17 Loop Heat Pipe (LHP) Problem

- G17 LHP issue on IWWG "Golden Day" 2019d293
- Noisy stereo height retrievals in 06Z-12Z
- Systematic pointing error near 04Z?

Normalized PDF
For cloud height →



Feb 1, 2023



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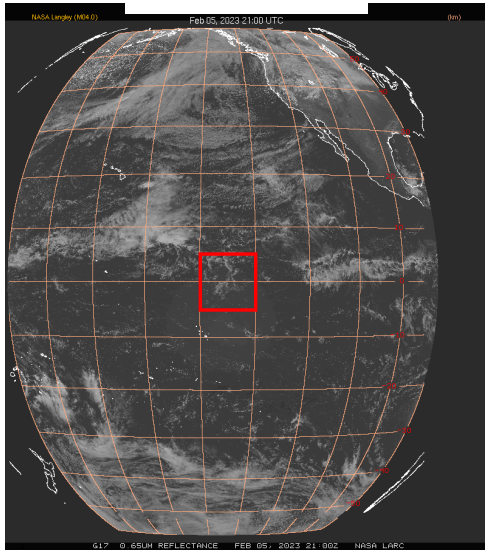
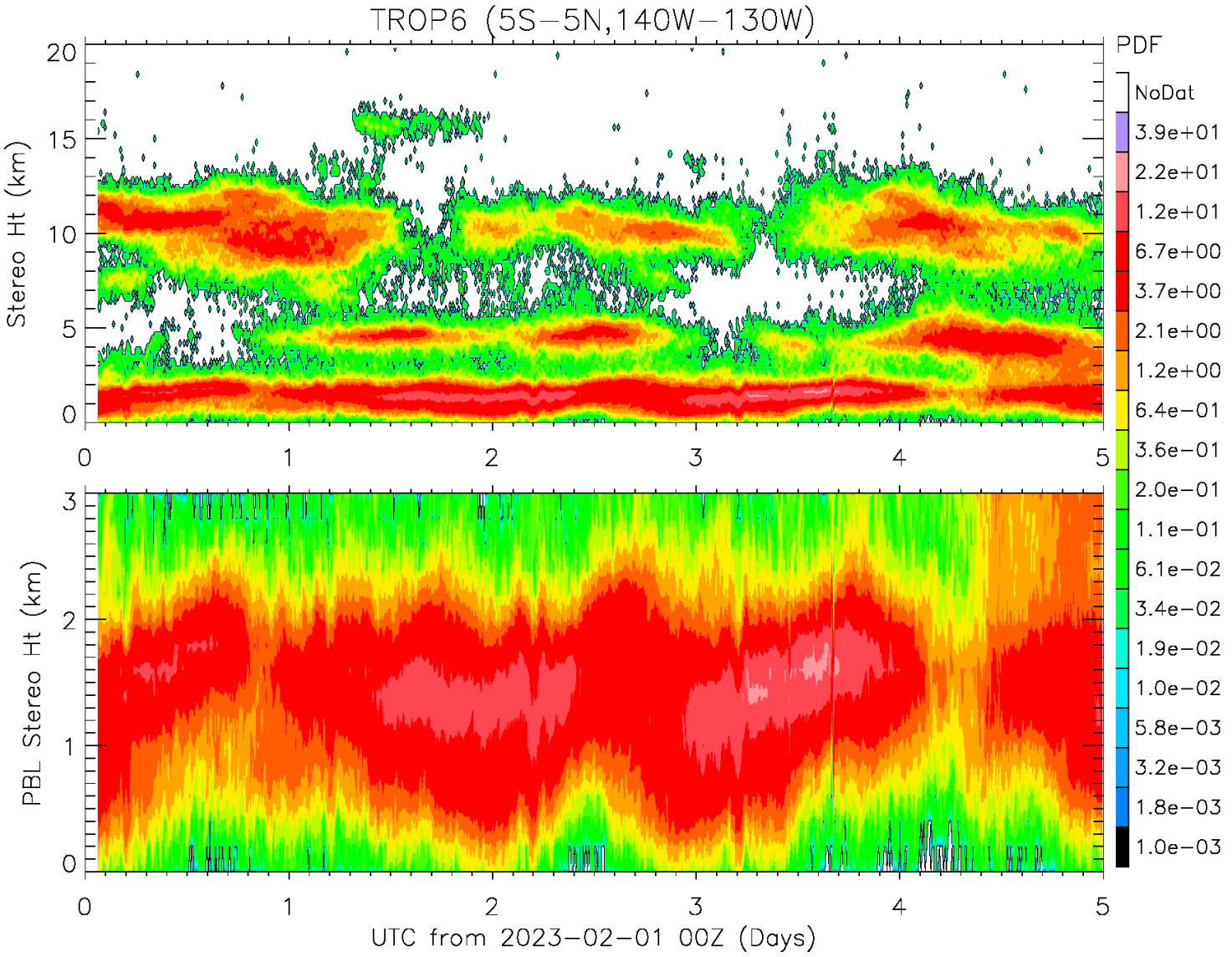


<= G18

# Cloud Height

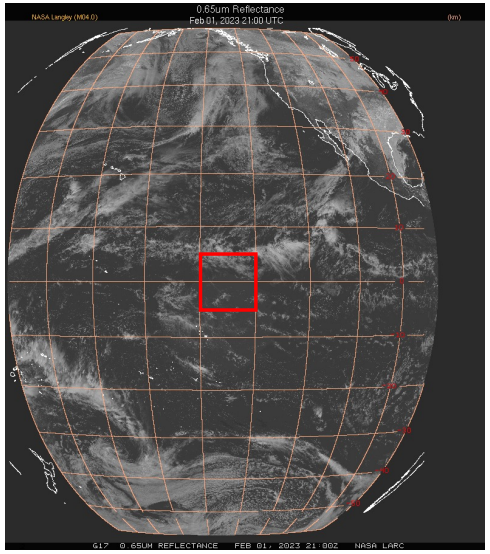



Four preferred cloud occurrence altitudes:

- PBL (0-2 km)
- Congestus (4-5 km)
- Convective outflow (8-12 km)
- Cirrus (15-16 km)

**GOES-WEST => G18 (Since Jan. 4, 2023)**

Feb 1, 2023

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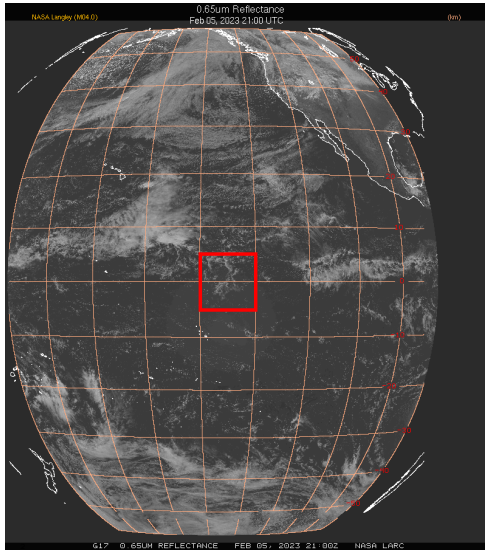
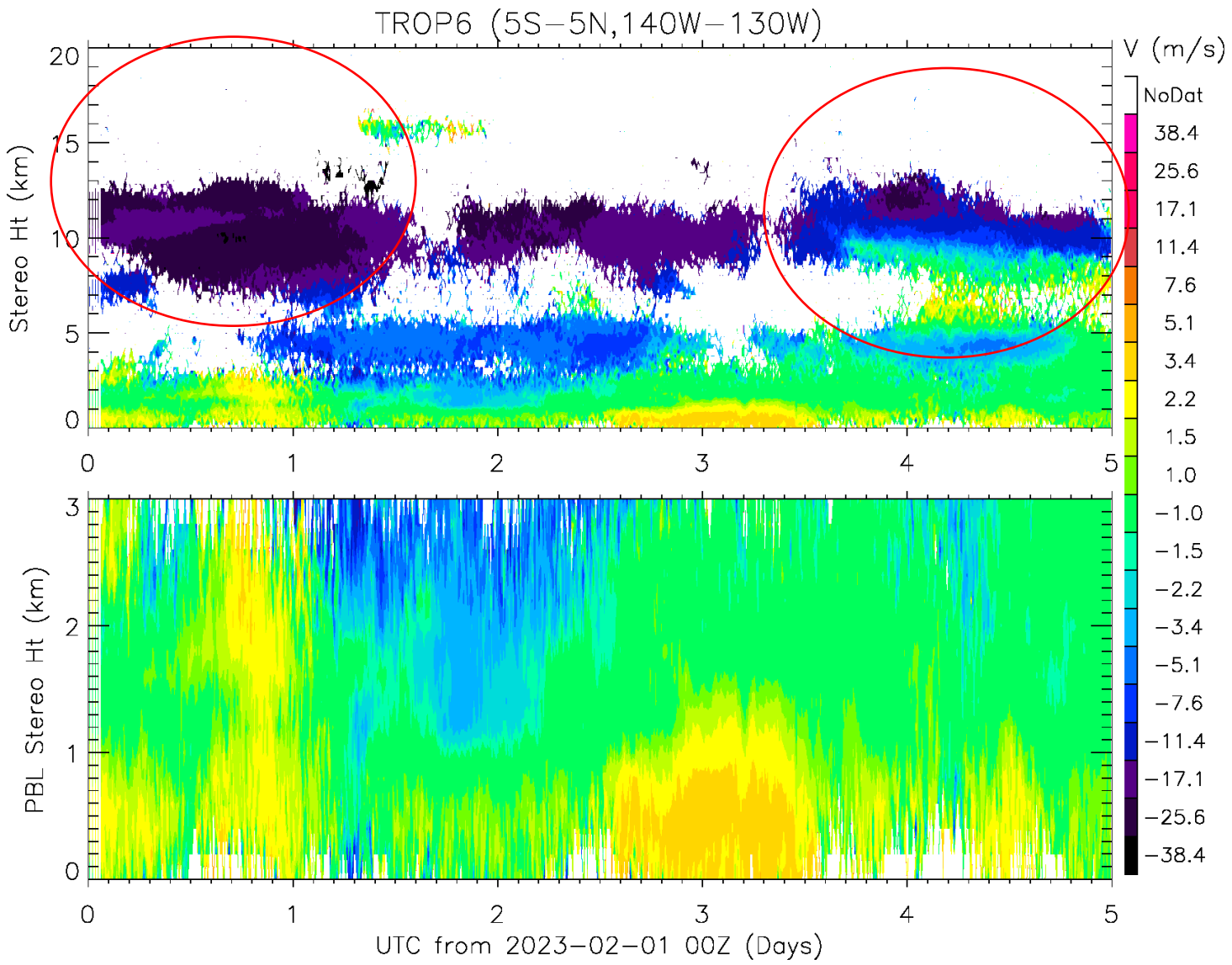


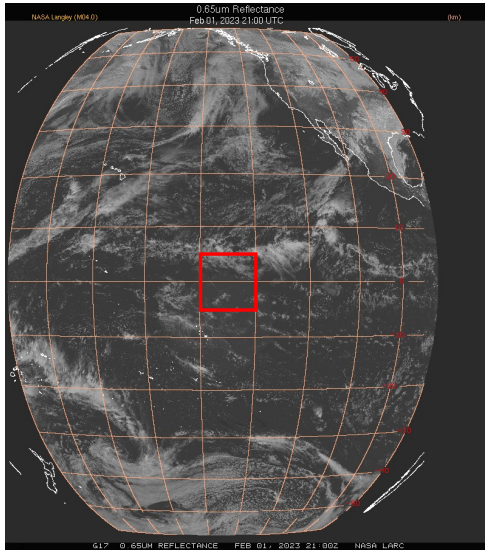

# <= G18

# Meridional Winds




- Good vertical resolution to observe wind shears in cloud layers
- Strong wind shear (+2 m/s at 8km to -30m/s at 12km) in convective outflow region with direction reversal
- Moderate wind shear between PBL and congestus region

Feb 1, 2023

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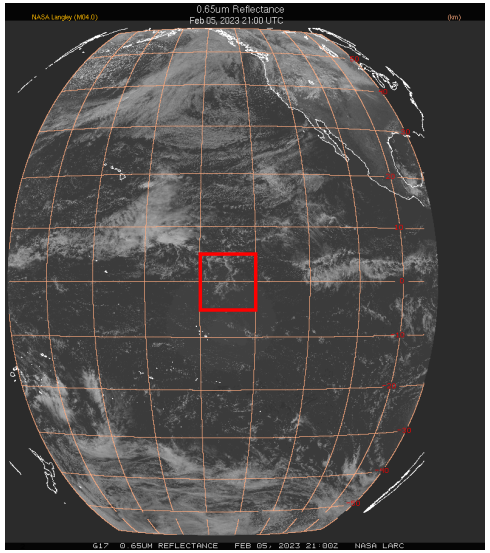
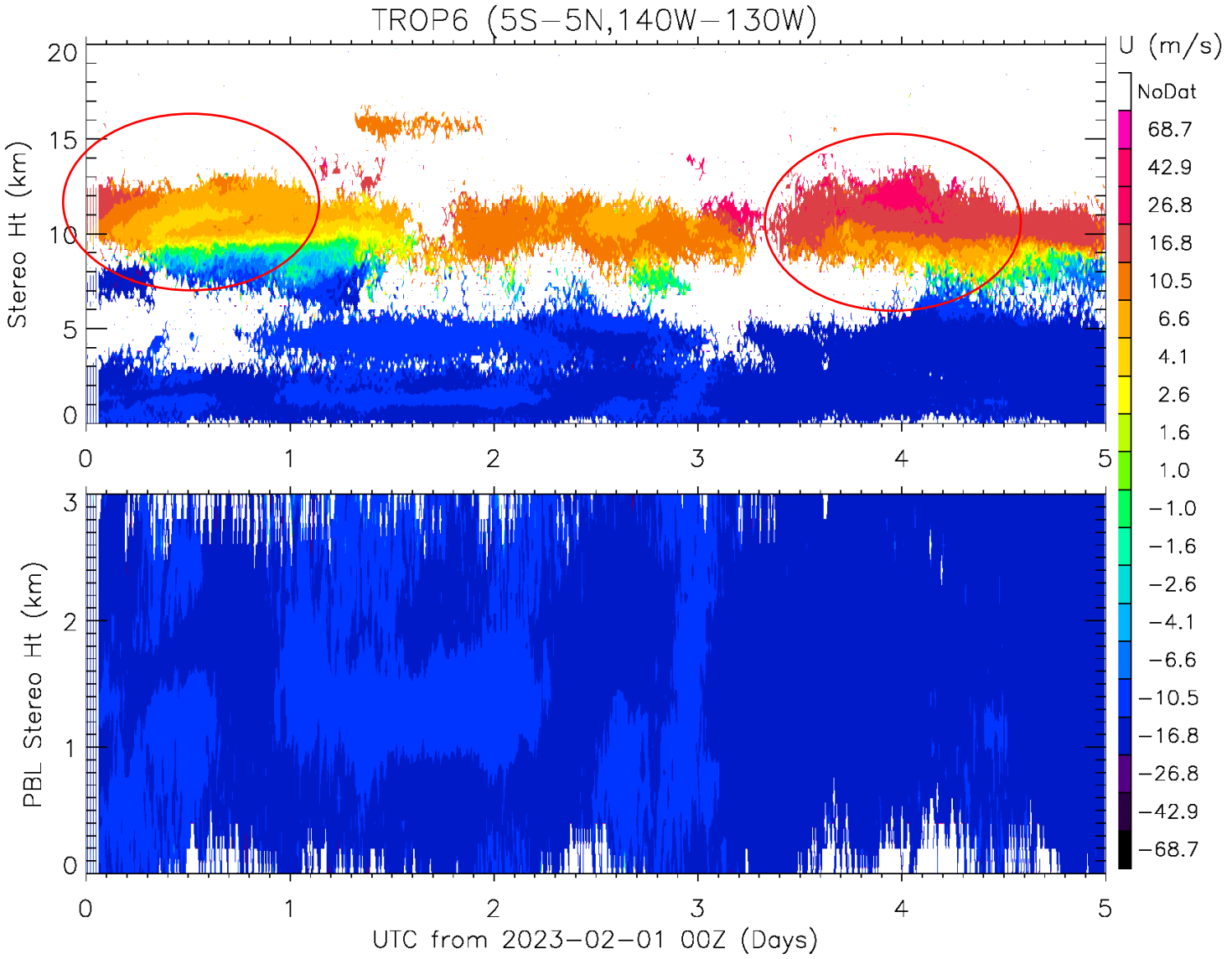
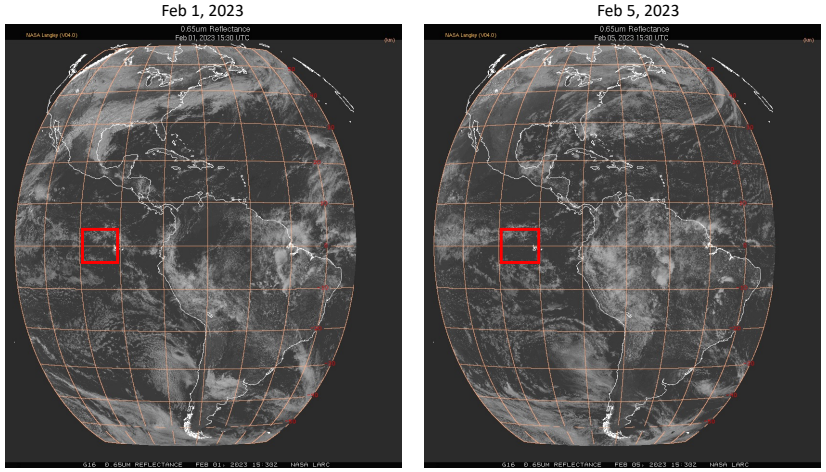



# <= G18

# Zonal Winds

- Strong zonal wind shear (+4 m/s at 8km to +50m/s at 12km) in convective outflow (8-12 km) region
- Weak zonal wind shear in PBL

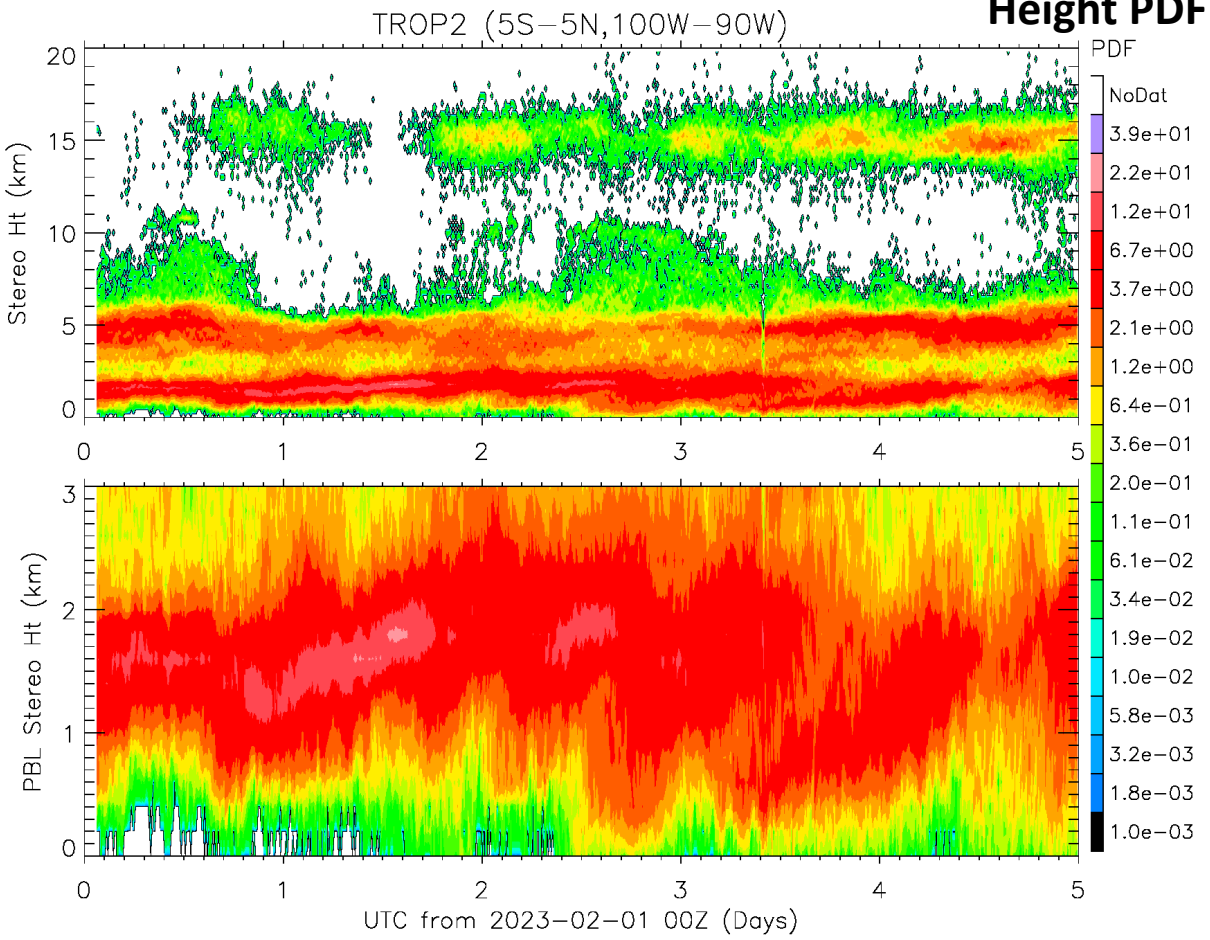




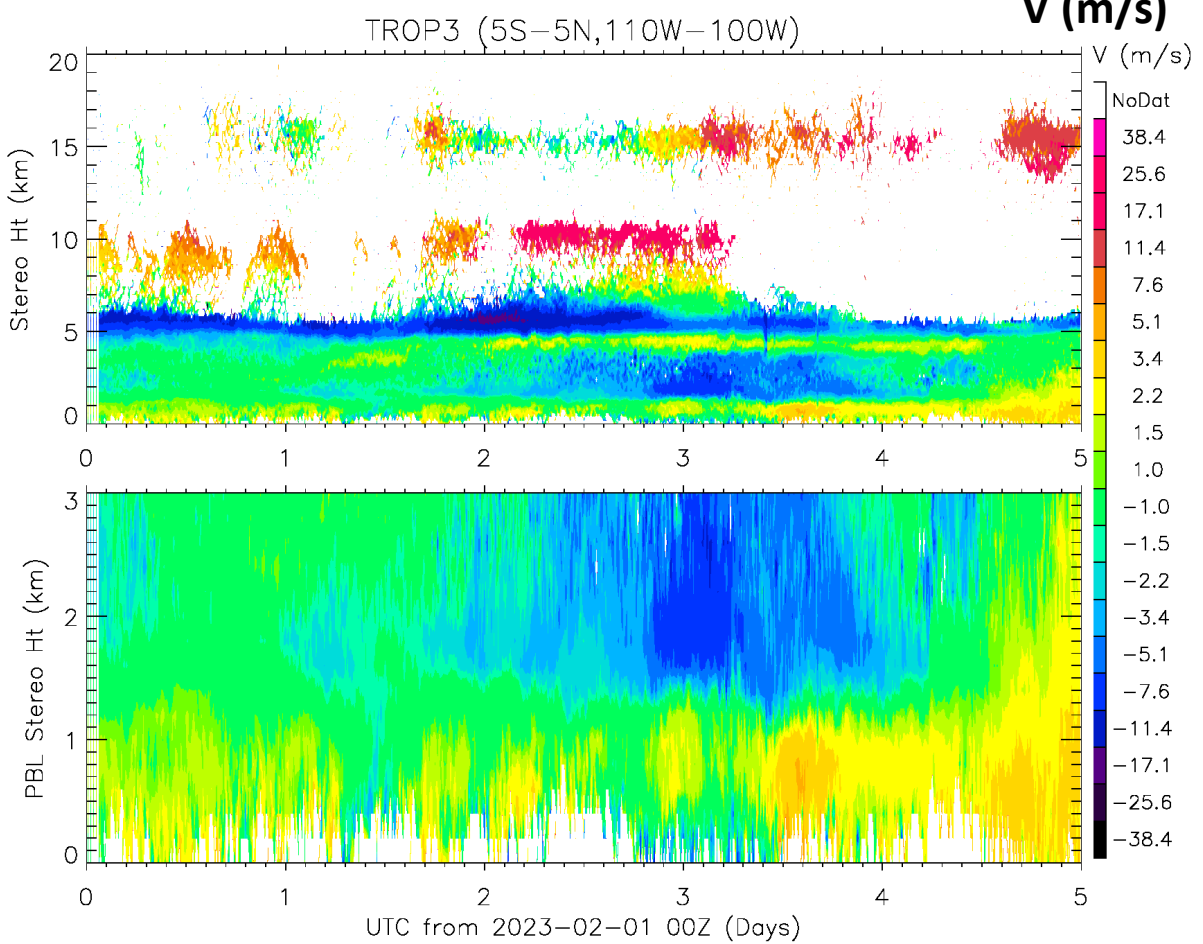

**<= G16**

- Meridional wind (**V**) shear critical for congestus cloud formation
- Strong vertical oscillations in V evident on Feb 2-3.

**Height PDF**




**V (m/s)**



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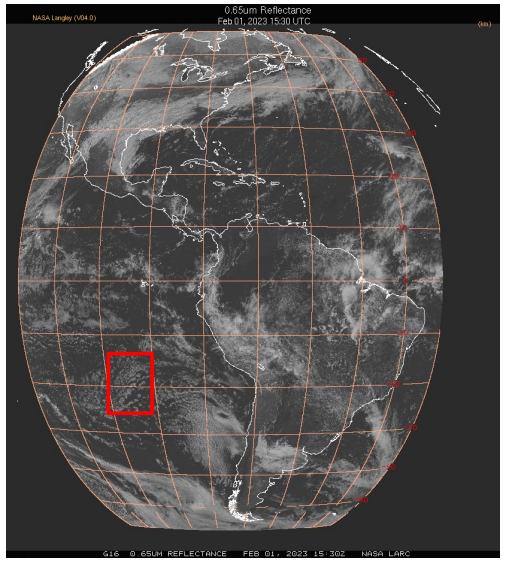


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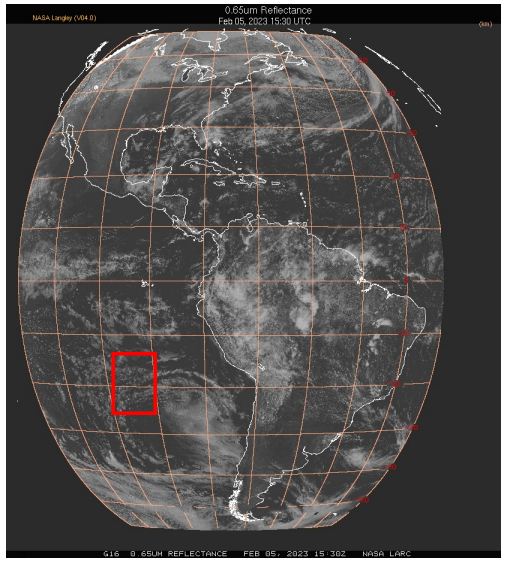
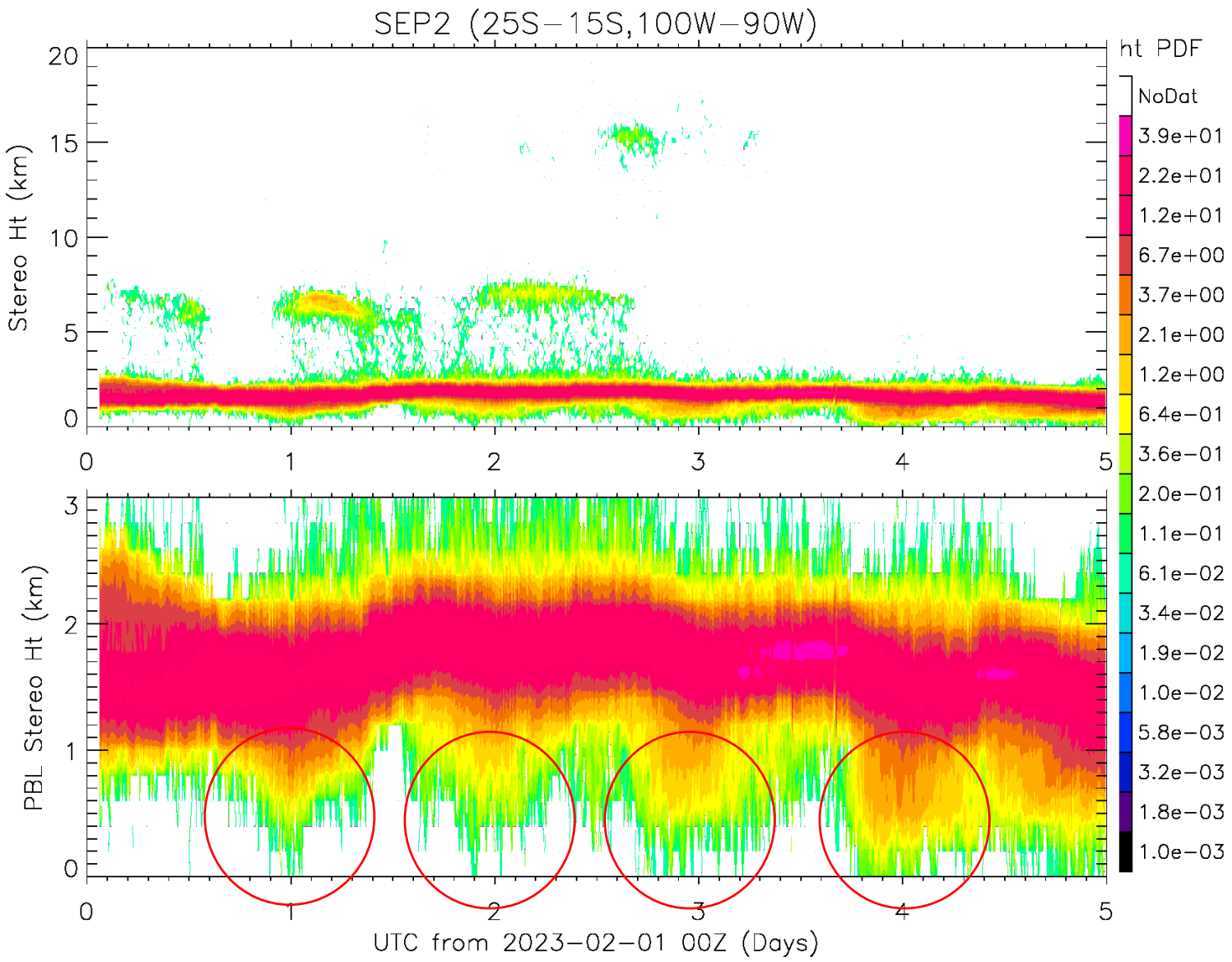


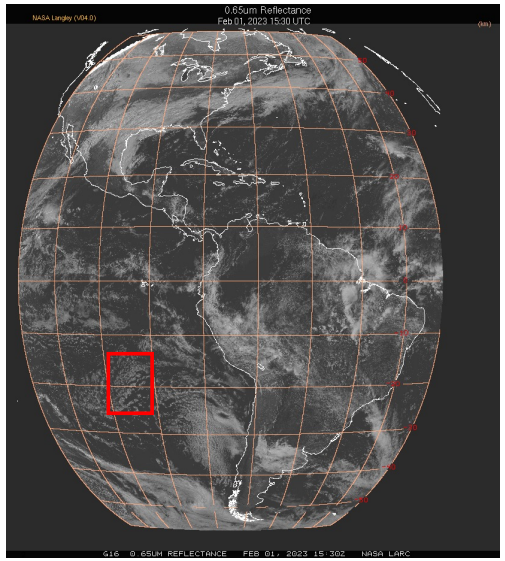

<= G16

# Cloud Height




- Closed-to-open cell transition in marine stratocumulus over the Southeast Pacific (SEP)
- Evidence of precipitation at lower level from broken stratocumulus
- Strong diurnal variation of the closed-to-open cell transition

Feb 1, 2023

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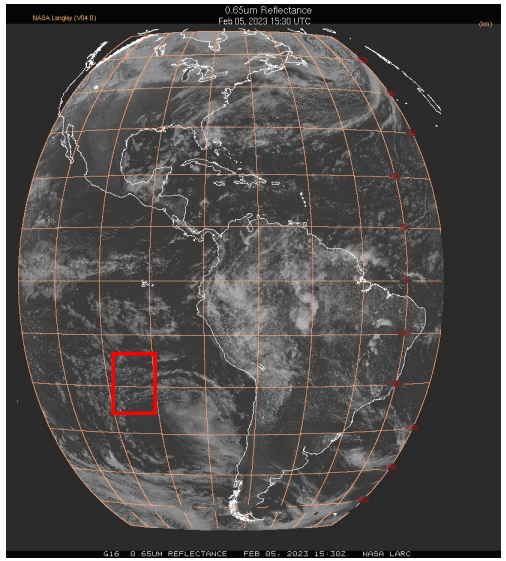
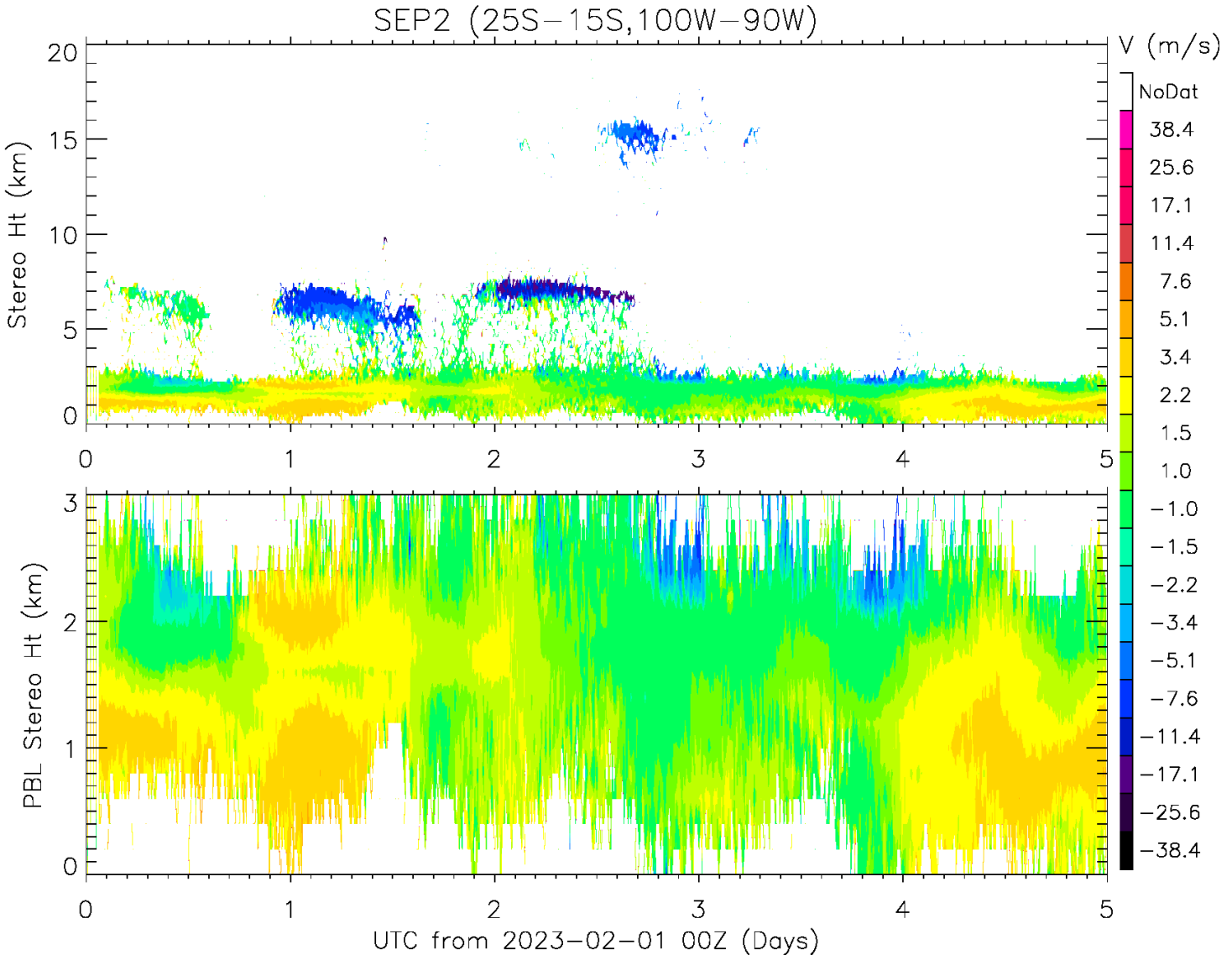
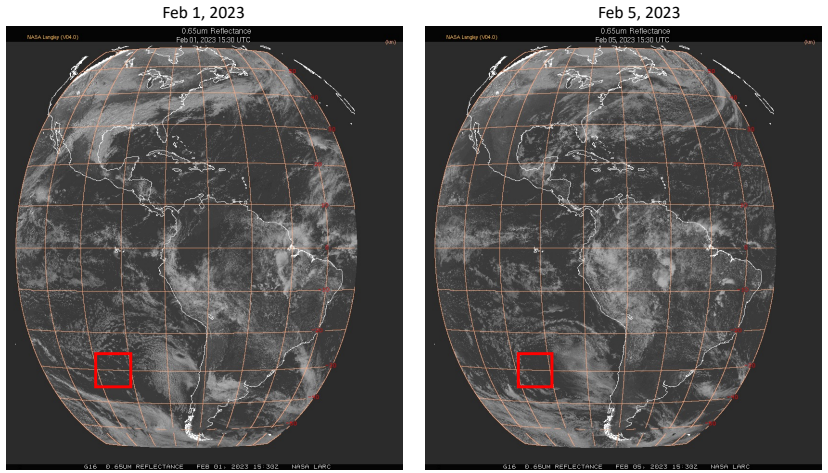



# <= G16

# Meridional Winds



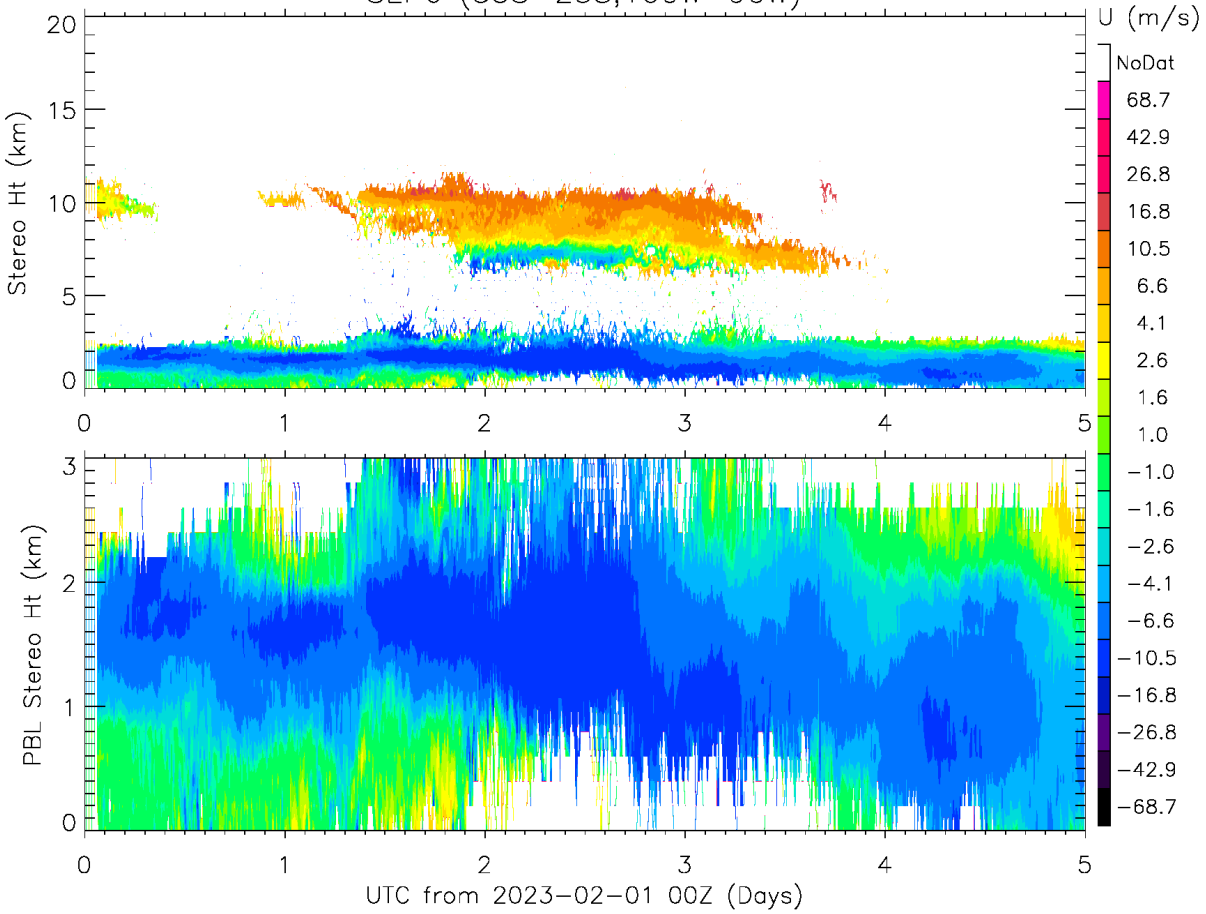

- Wind shears play a minor role in the diurnal cycle of closed-to-open cell transition



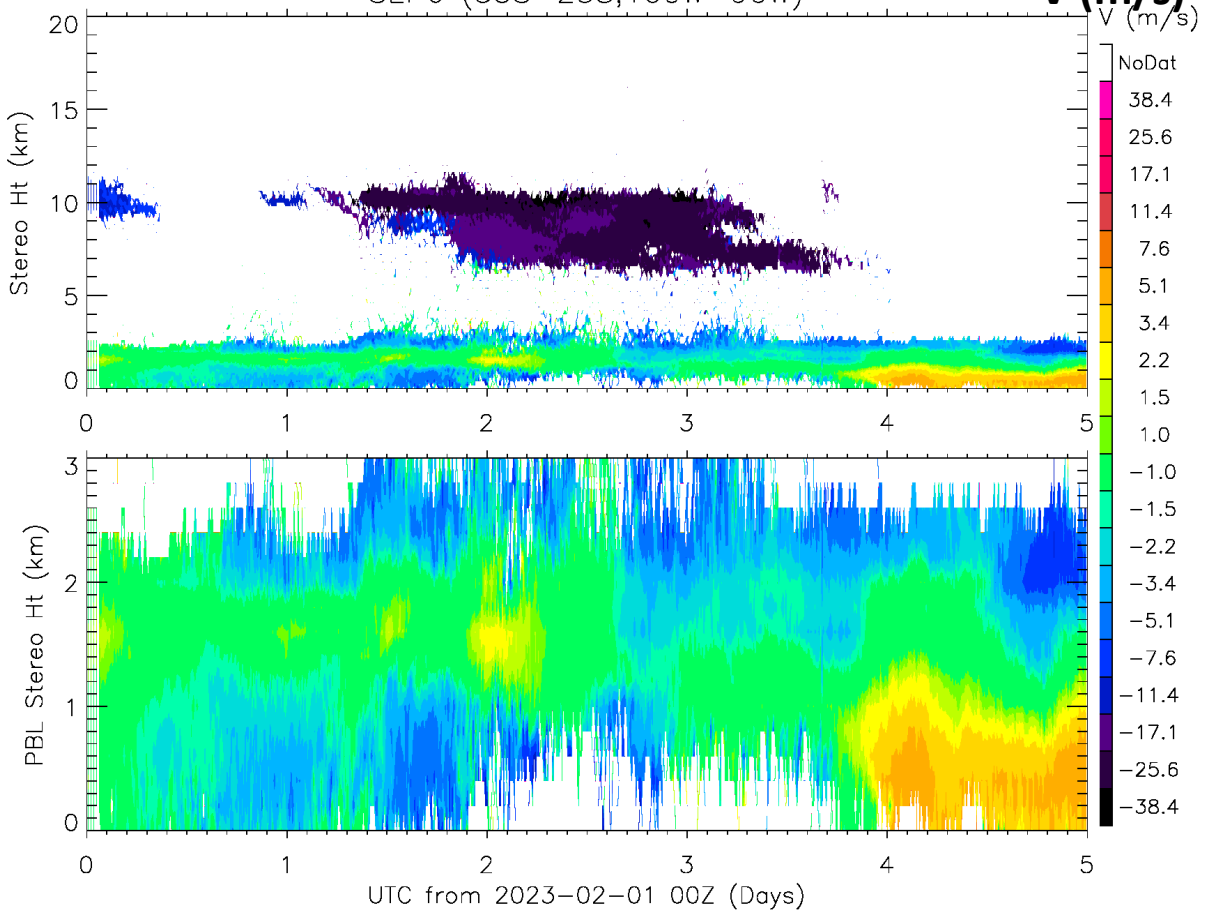

**<= G16**

- Large wind shear between surface and PBL top
- Different directions of near-surface winds (e.g., scatterometer) and PBL cloud winds

**U (m/s)**




**V (m/s)**



# Summary

- Excellent vertical resolution from stereo wind measurements reveals layered dynamical structures between PBL clouds and convective outflows
- Vertical wind shears appear to have an important role in cloud formation
- There is strong diurnal variation in the closed-to-open cell transition over the SE Pacific with evidence of precipitation at lower level from broken stratocumulus
- Near-surface winds (e.g., scatterometer) and PBL cloud winds can differ substantially in wind directions