



# Stereo-3D Observing of Volcanic Plumes

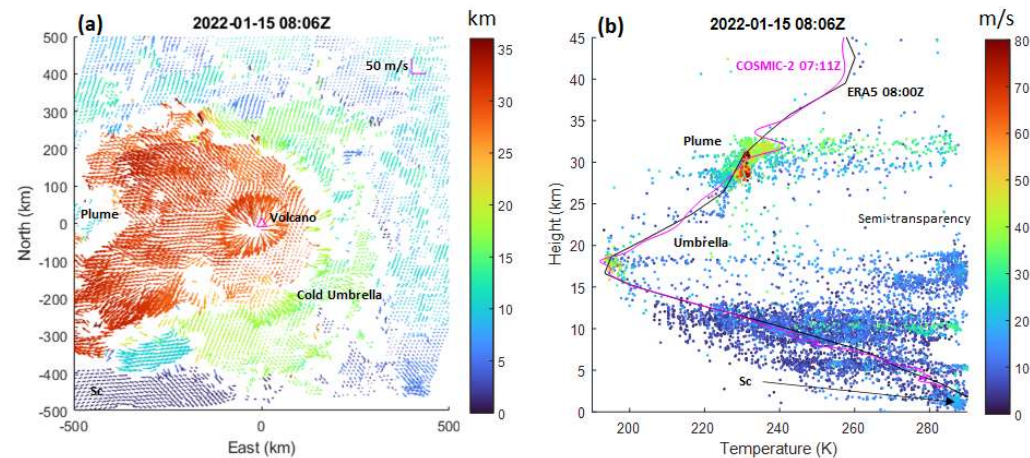
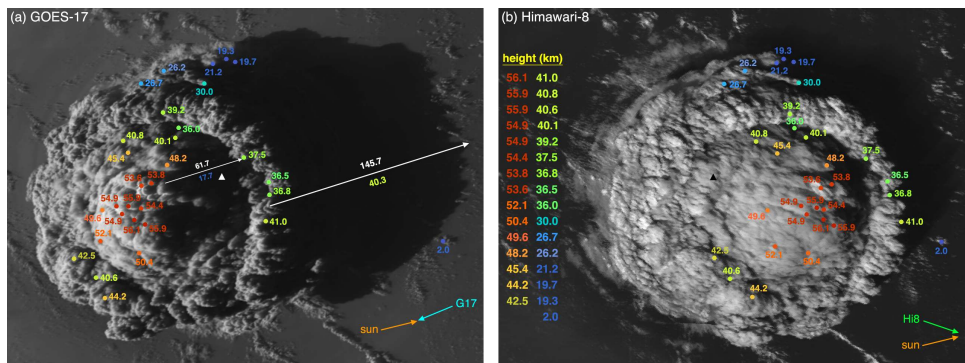
James L. Carr, Carr Astronautics, Greenbelt, MD 20770 USA, [jcarr@carrastro.com](mailto:jcarr@carrastro.com)

Ákos Horváth, Meteorological Institute, Universität Hamburg, Hamburg, Germany

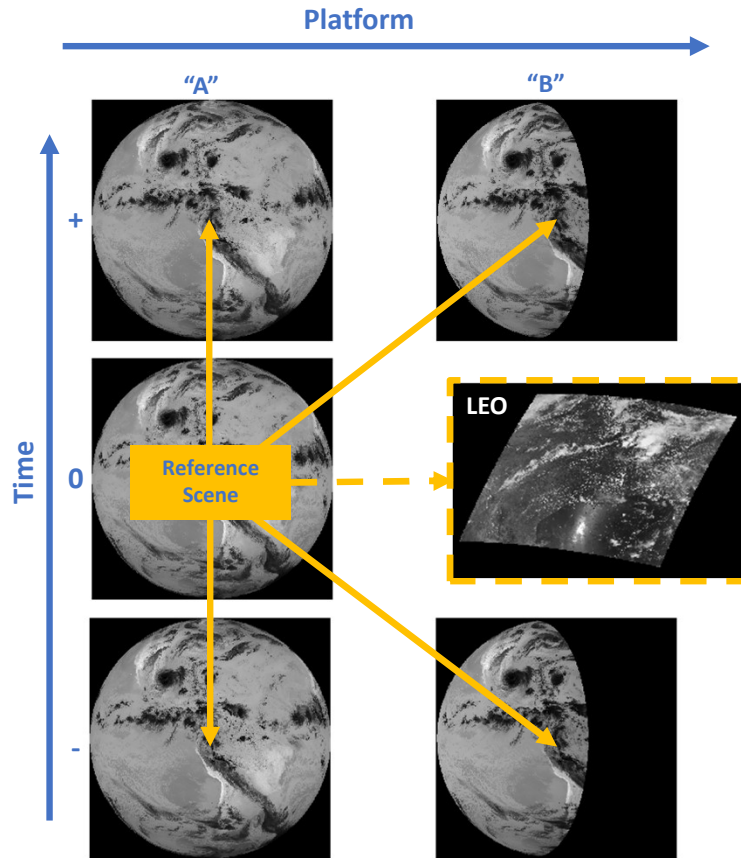
Dong L. Wu, NASA/GSFC, and Mariel D. Friberg, NASA/GSFC and University of Maryland



- Satellite stereo observing is a powerful tool for resolving the 3D structure and dynamics of volcanic plumes. We have applied these methods to eruptions of Hunga Tonga-Hunga Ha'apai (lofted as high as **55 km!**), La Soufrière, and Raikoke.
- Our Poster presents some of our work using GOES-R, Himawari, and Terra/Aqua in various pairs and complementary GNSS-RO observations confirming our results.



# General Stereo “3D Winds” Method

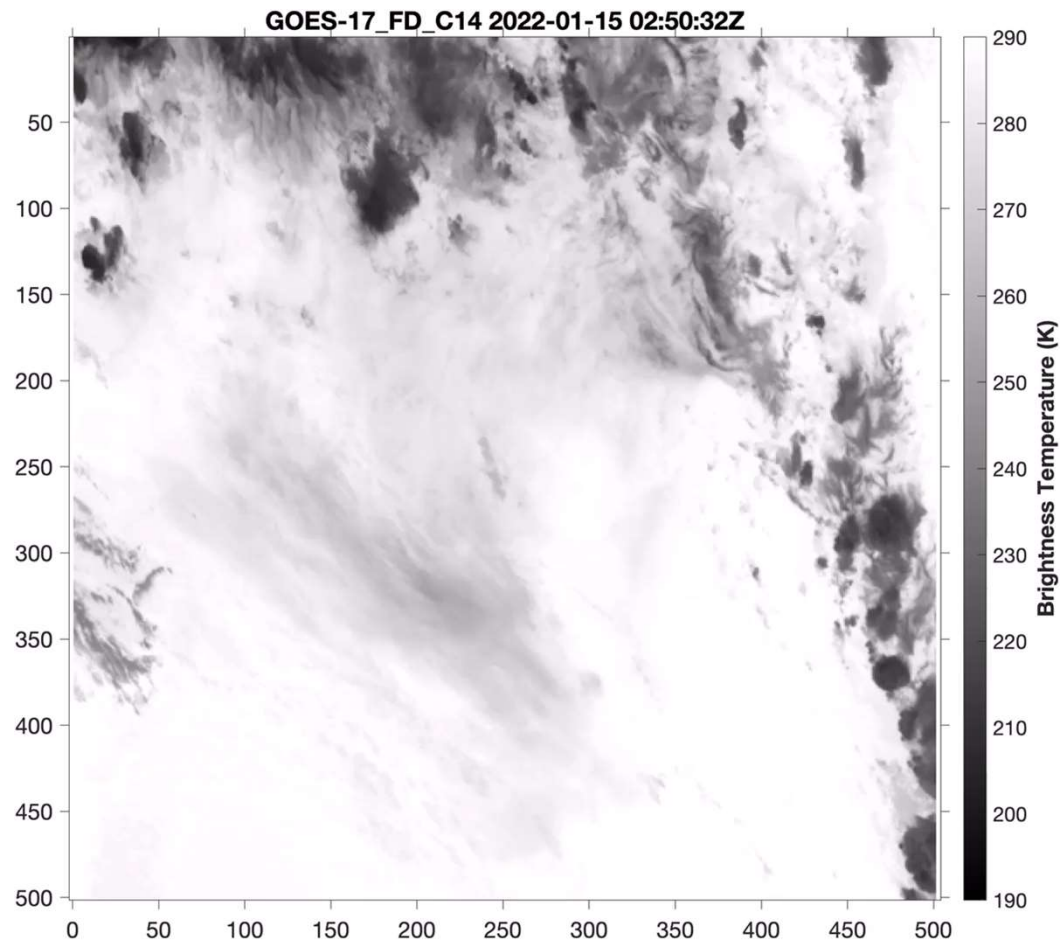


- Remap “B” satellite into geometry of “A” satellite; common configurations:
  - Triplet GEO + Doublet GEO
  - Triplet GEO + Single MODIS/VIIRS
  - Multi-Angle MISR + Triplet GEO
- Measure disparities of features matched to Reference Scene
  - Same Platform = Motion
  - Cross Platform = Parallax + Motion
- Tag or model match times relative to Reference Scene
- Jointly retrieve motion vector and height for templates or nested tracks
- Quality Filter

Synchronized Observations Not Needed

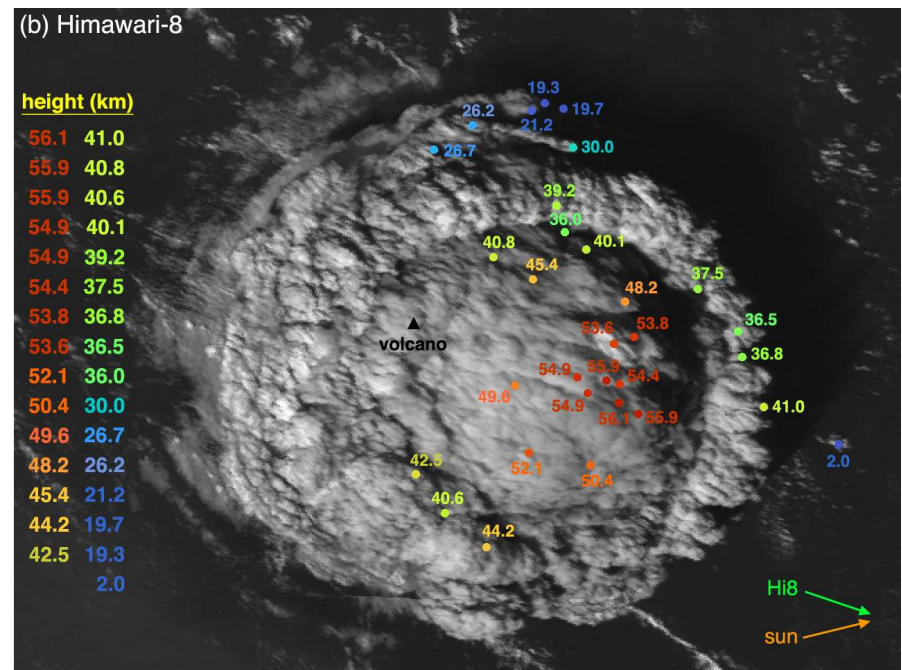
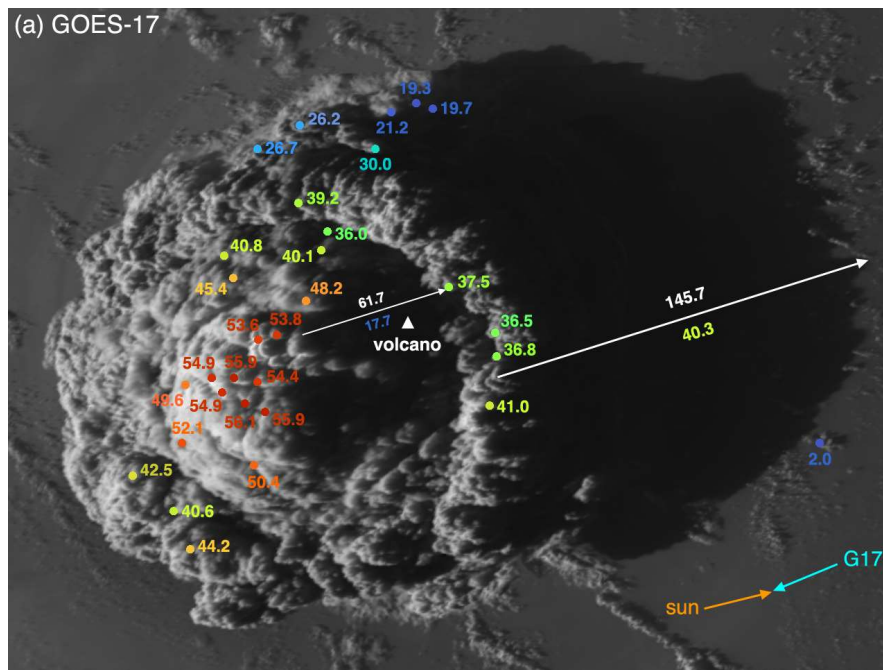
- Working on LEO-LEO capability

# Hunga Tonga-Hunga Ha'apai Eruption on 15 Jan 2022 ~4:00Z



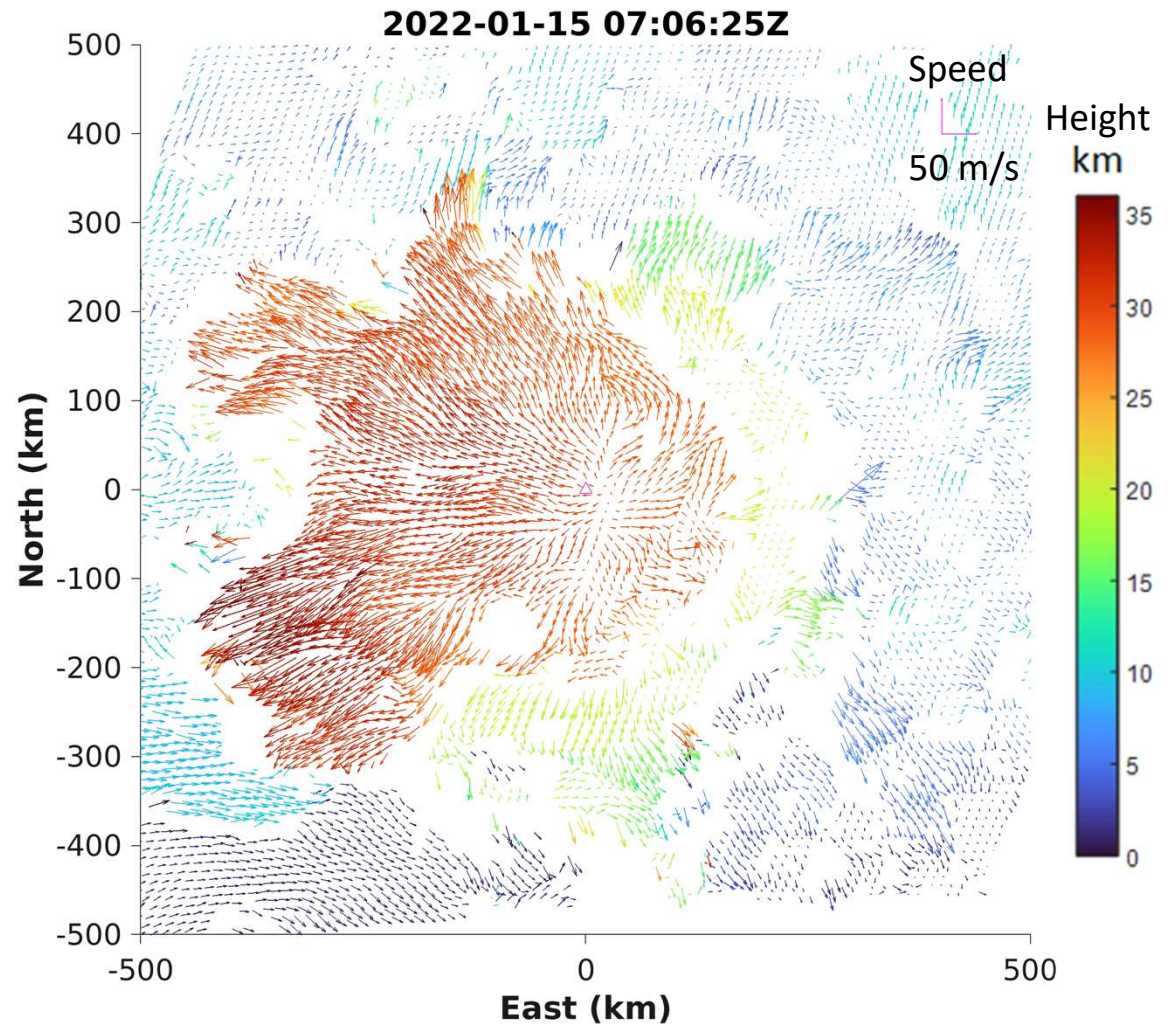
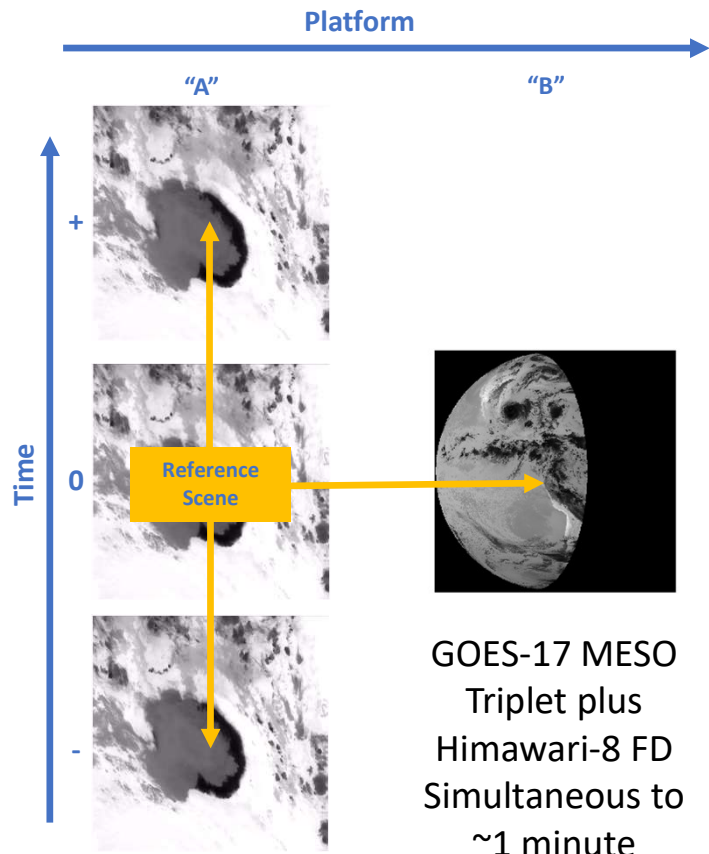
# HT-HH Manual Stereo Photogrammetry

- Eruption in its early phase was too turbulent to allow feature tracking over 10-minute Full Disk refresh time of GOES-17 and Himawari-8

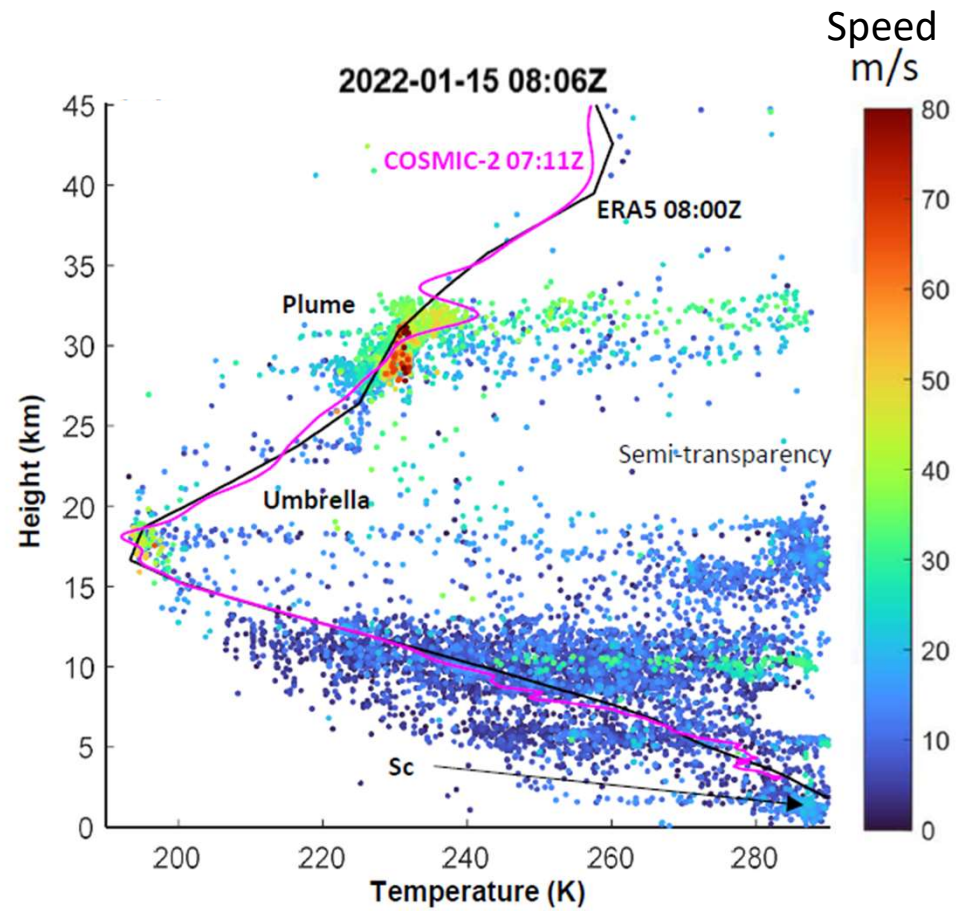
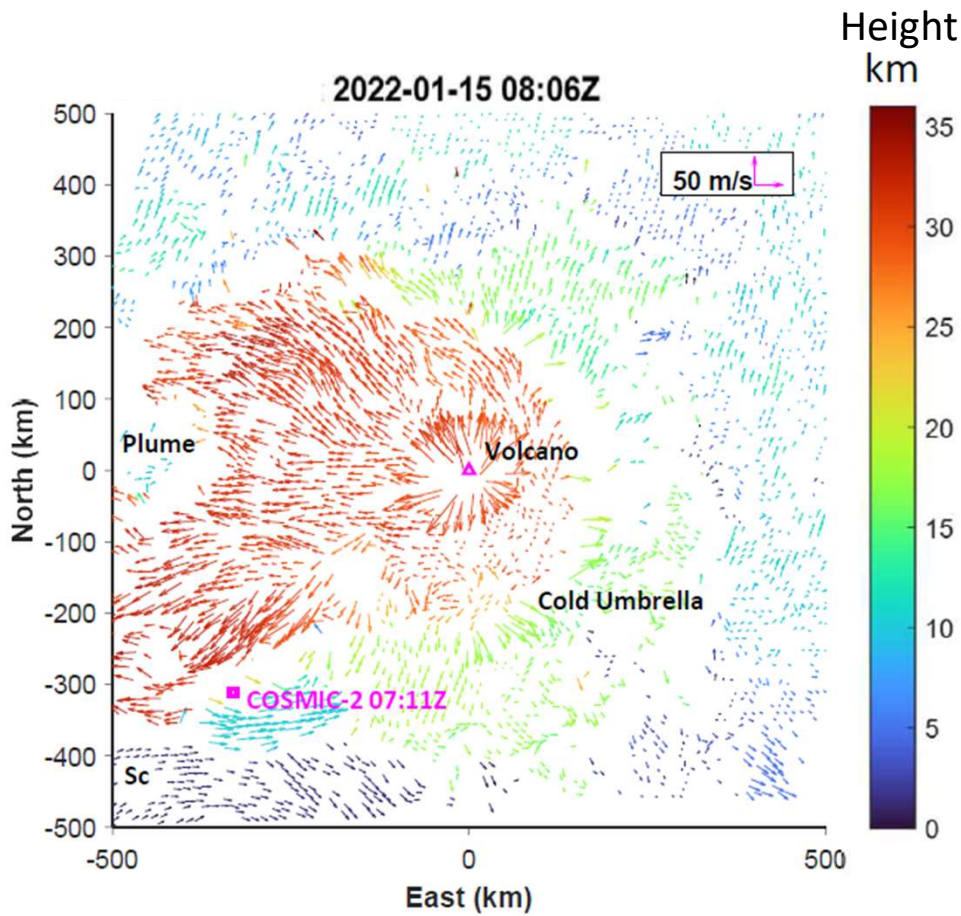


Carr, J. L., Horváth, Á., Wu, D. L., & Friberg, M. D., “Stereo plume height and motion retrievals for the record-setting Hunga Tonga-Hunga Ha'apai eruption of 15 January 2022”, *Geophysical Research Letters*, **49**, e2022GL098131. <https://doi.org/10.1029/2022GL098131>

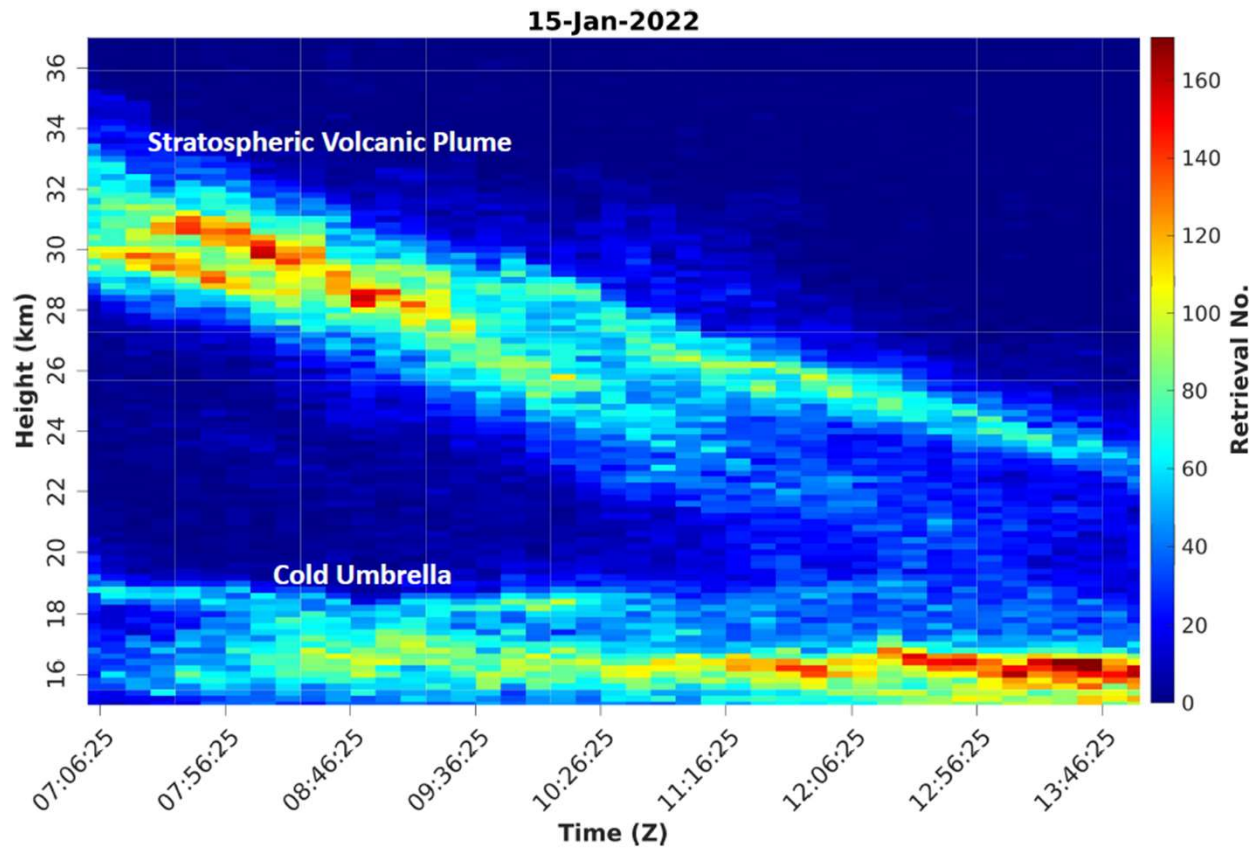
# Stereo 3D Winds Retrievals



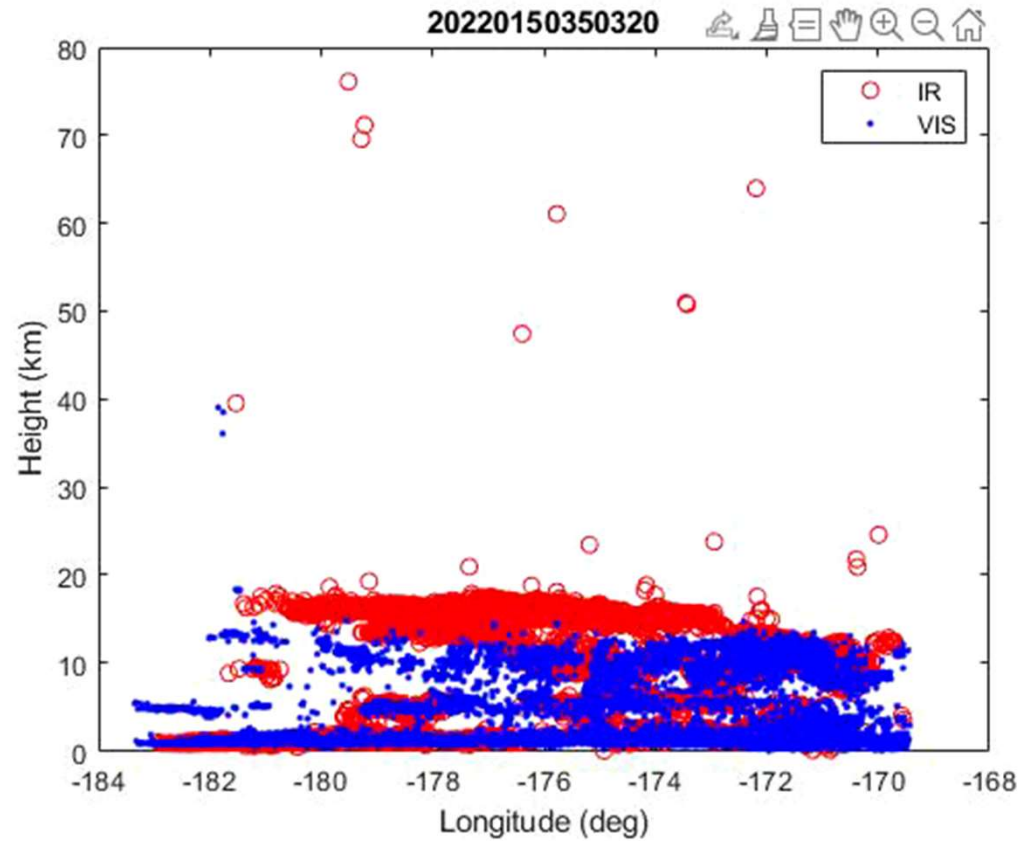
# Thermal Structure



# Evolution within Site MESO Domain



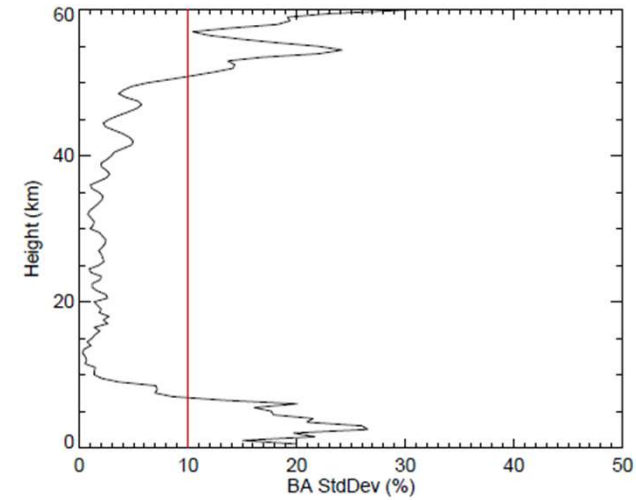
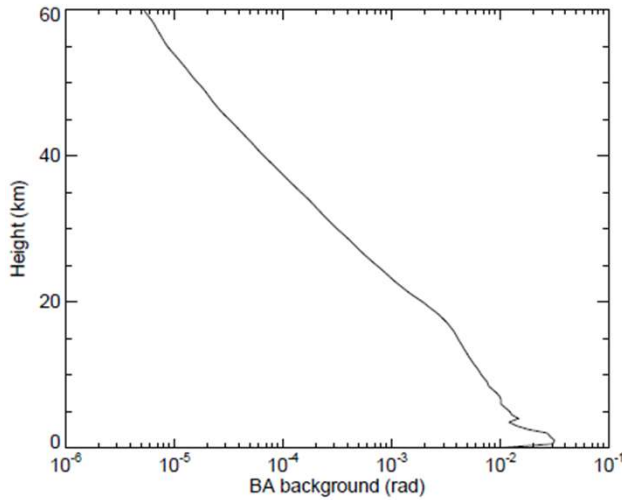
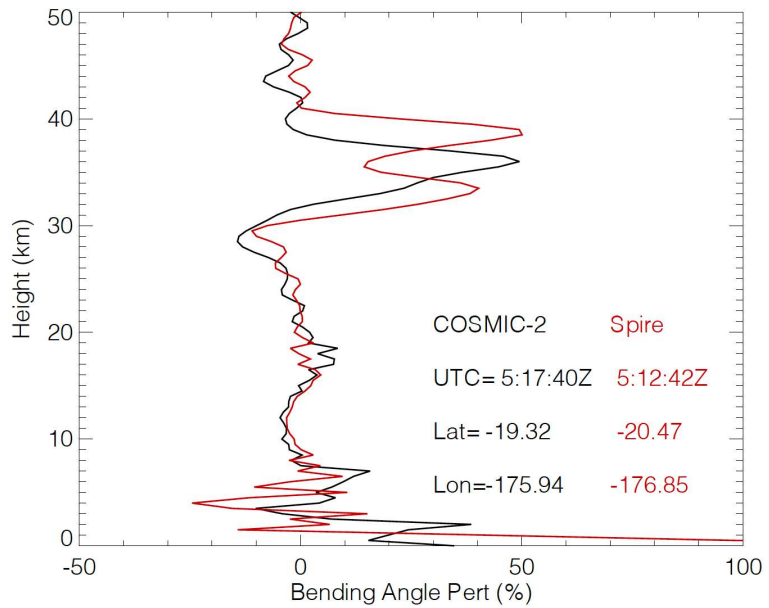
# “Zero-Wind” VIS & IR Height Retrievals





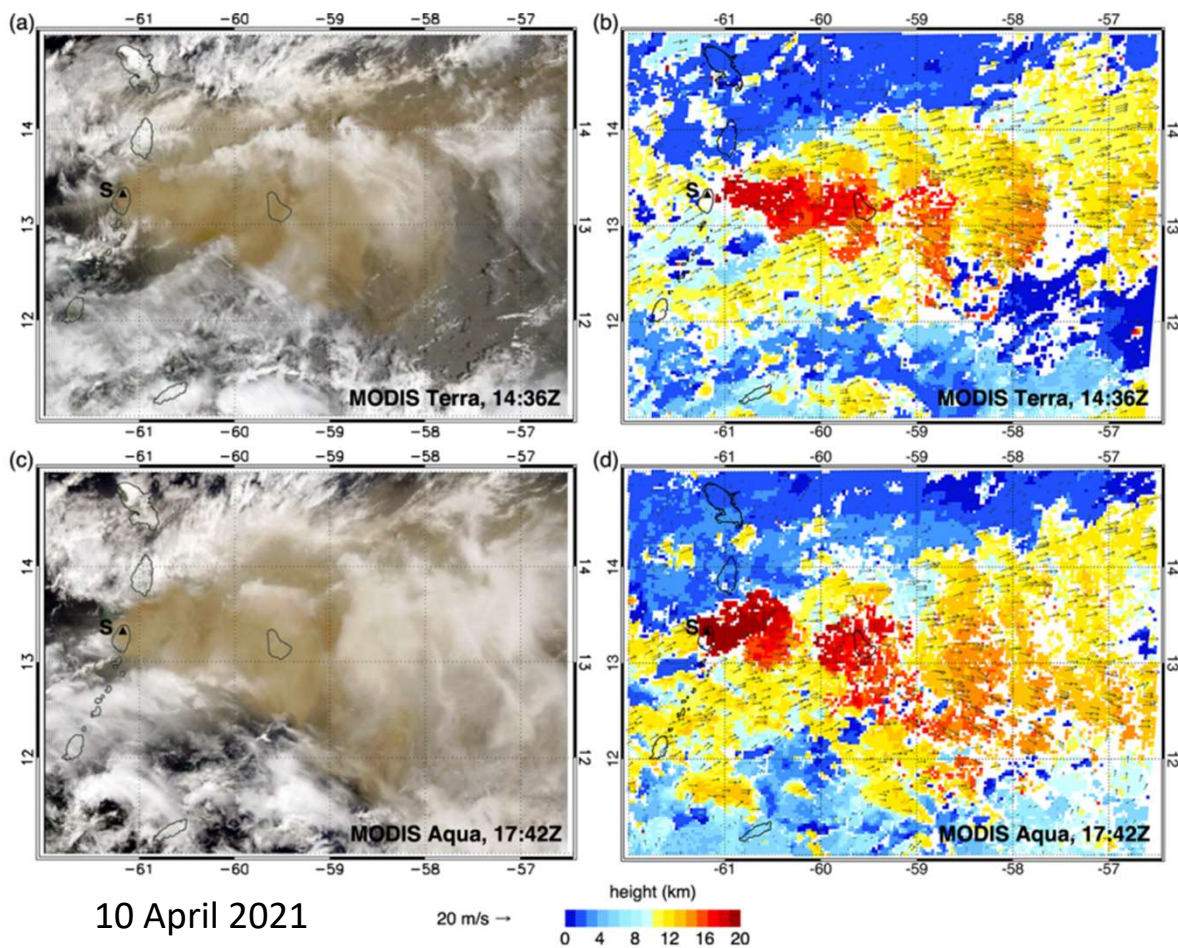
# GNSS-RO Bending Angle Anomalies

## Quiescent Bending Angle Variations



GNSS-RO One Day Prior and One Day Later,  $\pm 3^\circ$  Latitude,  $\pm 8^\circ$  Longitude

# La Soufrière 2021



10 April 2021

## GOES-17 Side View

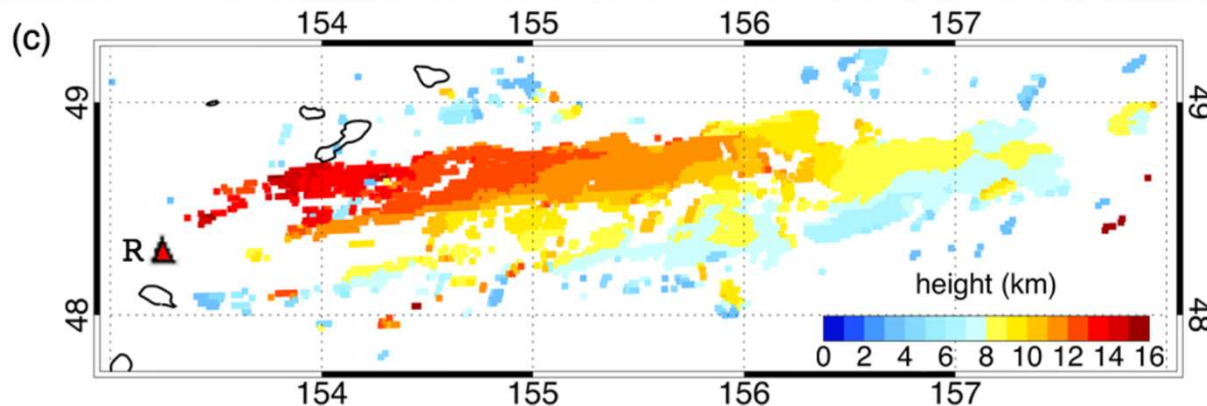
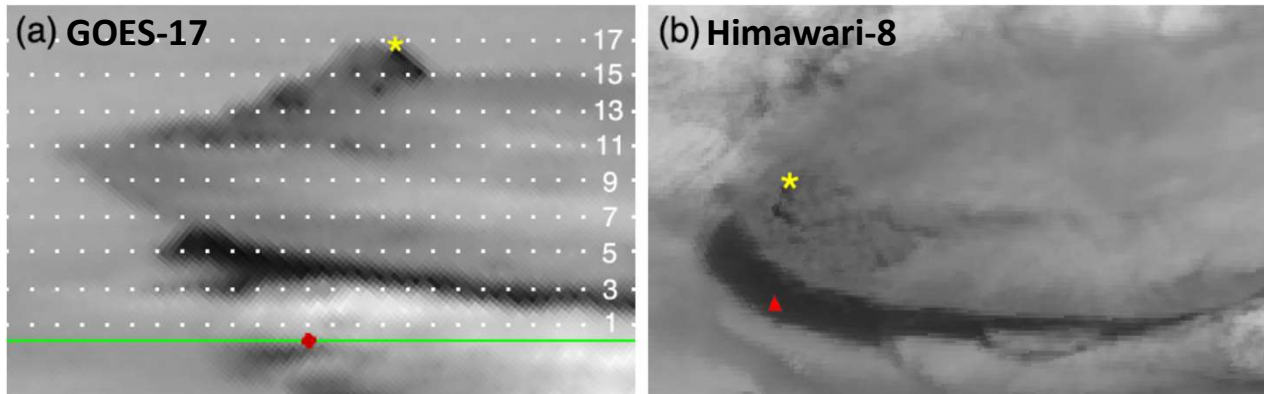


13 April 2021

## <- GOES-16 + MODIS Stereo

Horváth, Á., Carr, J. L., Wu, D. L., Bruckert, J., Hoshyaripour, G. A., and Buehler, S. A.: Measurement report: Plume heights of the April 2021 La Soufrière eruptions from GOES-17 side views and GOES-16–MODIS stereo views, *Atmos. Chem. Phys. Discuss.* [preprint], <https://doi.org/10.5194/acp-2022-253>, in review, 2022.

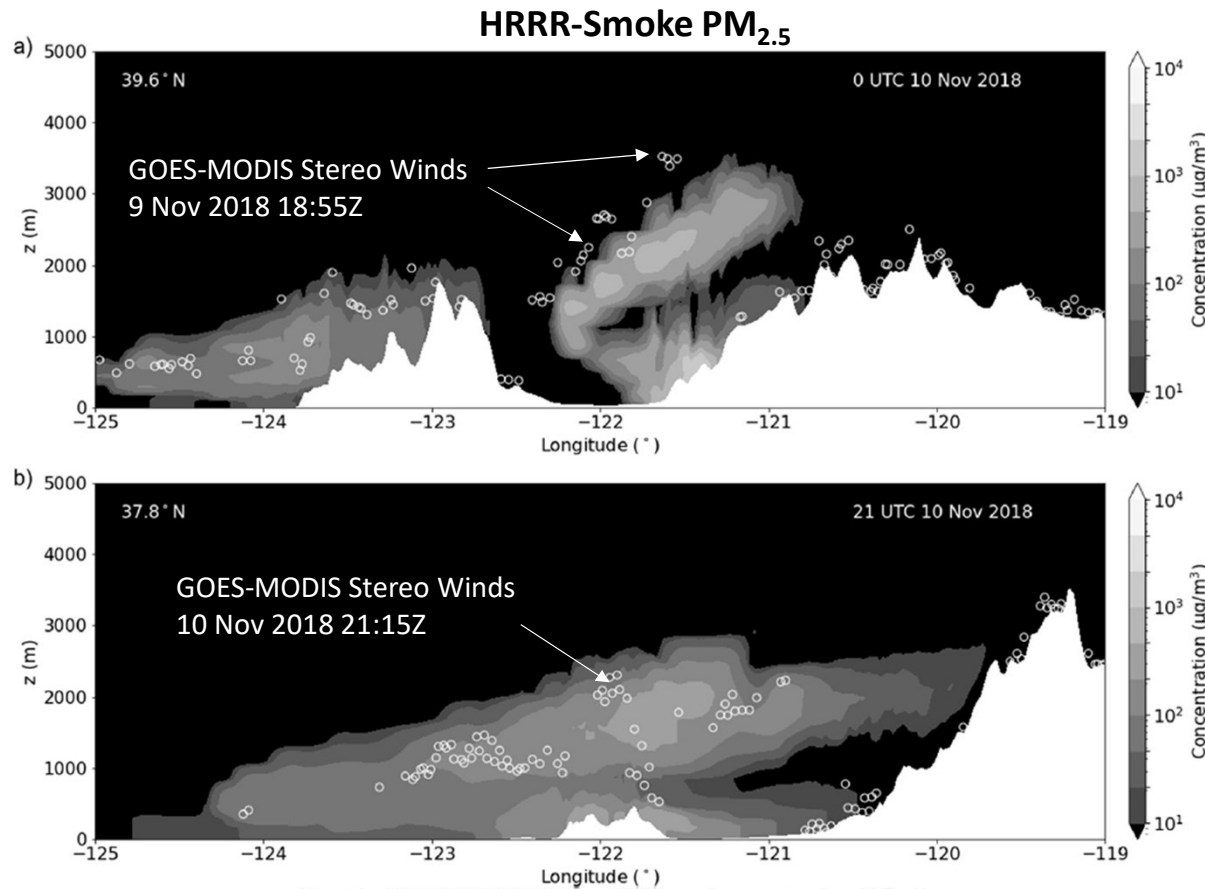
# Raikoke 2019



Horváth, Á., Carr, J. L., Girina, O. A., Wu, D. L., Bril, A. A., Mazurov, A. A., Melnikov, D. V., Hoshyaripour, G. A., and Buehler, S. A.: Geometric estimation of volcanic eruption column height from GOES-R near-limb imagery – Part 1: Methodology, *Atmos. Chem. Phys.*, 21, 12189–12206, <https://doi.org/10.5194/acp-21-12189-2021>, 2021.

Horváth, Á., Girina, O. A., Carr, J. L., Wu, D. L., Bril, A. A., Mazurov, A. A., Melnikov, D. V., Hoshyaripour, G. A., and Buehler, S. A.: Geometric estimation of volcanic eruption column height from GOES-R near-limb imagery – Part 2: Case studies, *Atmos. Chem. Phys.*, 21, 12207–12226, <https://doi.org/10.5194/acp-21-12207-2021>, 2021.

# Camp Fire 2018 Smoke

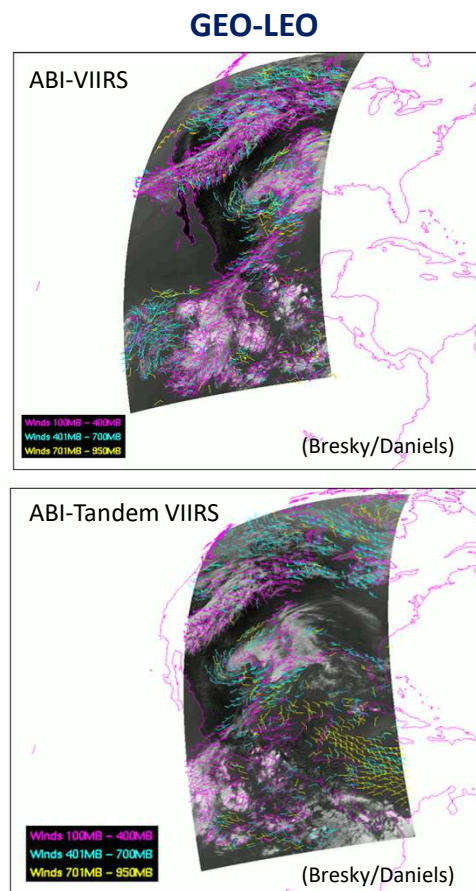
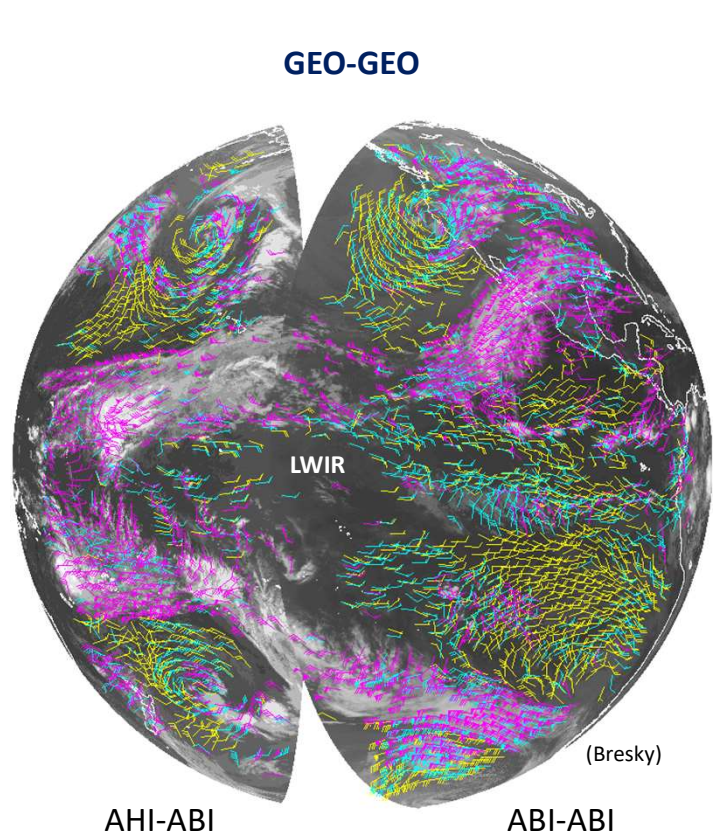


**Stereo 3D Winds is a Great Tool for Studying Wildfire Smoke Plumes too!**

**Stereo observations will improve model initializations for improved Air Quality predictions.**

Chow, F. K., K. A. Yu, A. Young, E. James, G. Grell, I. Csiszar, M. Tsidulko, S. Freitas, G. Pereira, L. Giglio, M. D. Friberg, and R. Ahmadov, High-resolution smoke forecasting for the 2018 Camp Fire in California, BAMS, Preprint <https://doi.org/10.1175/BAMS-D-20-0329.1>

# And for Meteorology



Carr, J.L.; Wu, D.L.; Daniels, J.; Friberg, M.D.; Bresky, W.; Madani, H. GEO-GEO Stereo-Tracking of Atmospheric Motion Vectors (AMVs) from the Geostationary Ring. *Remote Sens.* **2020**, *12*, 3779. <https://doi.org/10.3390/rs12223779>

Carr, J.L.; Wu, D.L.; Wolfe, R.E.; Madani, H.; Lin, G.; Tan, B. Joint 3D-Wind Retrievals with Stereoscopic Views from MODIS and GOES. *Remote Sens.* **2019**, *11*, 2100. <https://doi.org/10.3390/rs11182100>

Carr, J. L.; Wu, D. L.; Kelly, M. A.; Gong, J. MISR-GOES 3D Winds: Implications for Future LEO-GEO and LEO-LEO Winds. *Remote Sens.* **2018**, *10*, 1885. <https://doi.org/10.3390/rs10121885>

**<- NOAA Prototype  
Operational Products**