Harmony-TIR: production and assessment of cloud-top winds and heights from GEO-GEO and SLSTR stereo retrieval using the MISR approach

Rui Song and Jan-Peter Muller

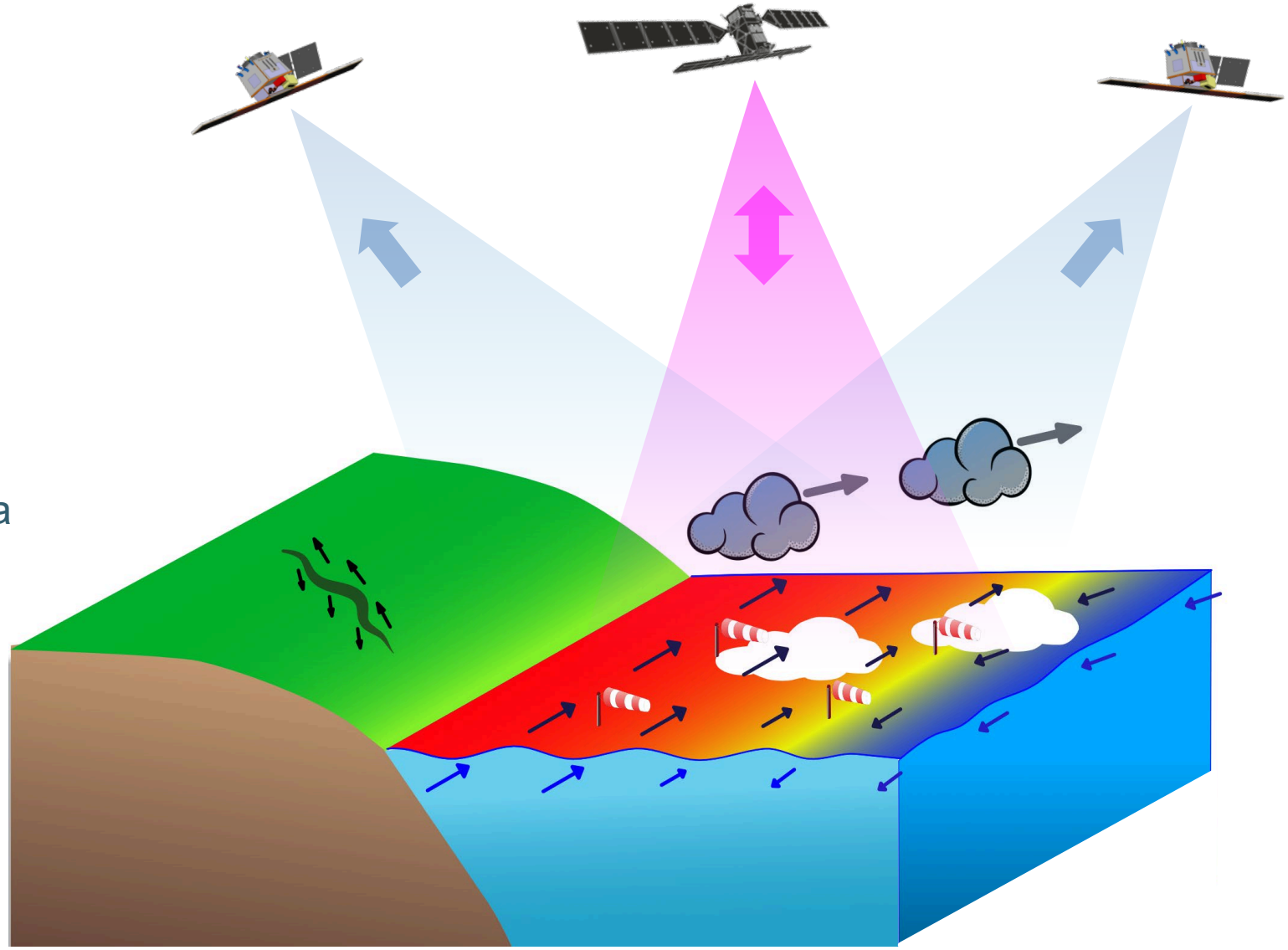
Imaging Group, University College London, Department of Space and Climate Physics, Mullard Space Science Laboratory, Holmbury St. Mary, Surrey, RH5 6NT, UK

rui.song@ucl.ac.uk, j.muller@ucl.ac.uk

Harmony Observation concept: stereo phase

Line-of-sight diversity for high resolution

- 3-D surface deformation (DInSAR)
- Ocean surface motion (Doppler)
- Surface winds (scatterometry)
- Improved directional surface wave spectra
- Sea Surface (skin) temperature
- **Cloud-top motion (TIR time-lapse) and height (TIR parallax)**

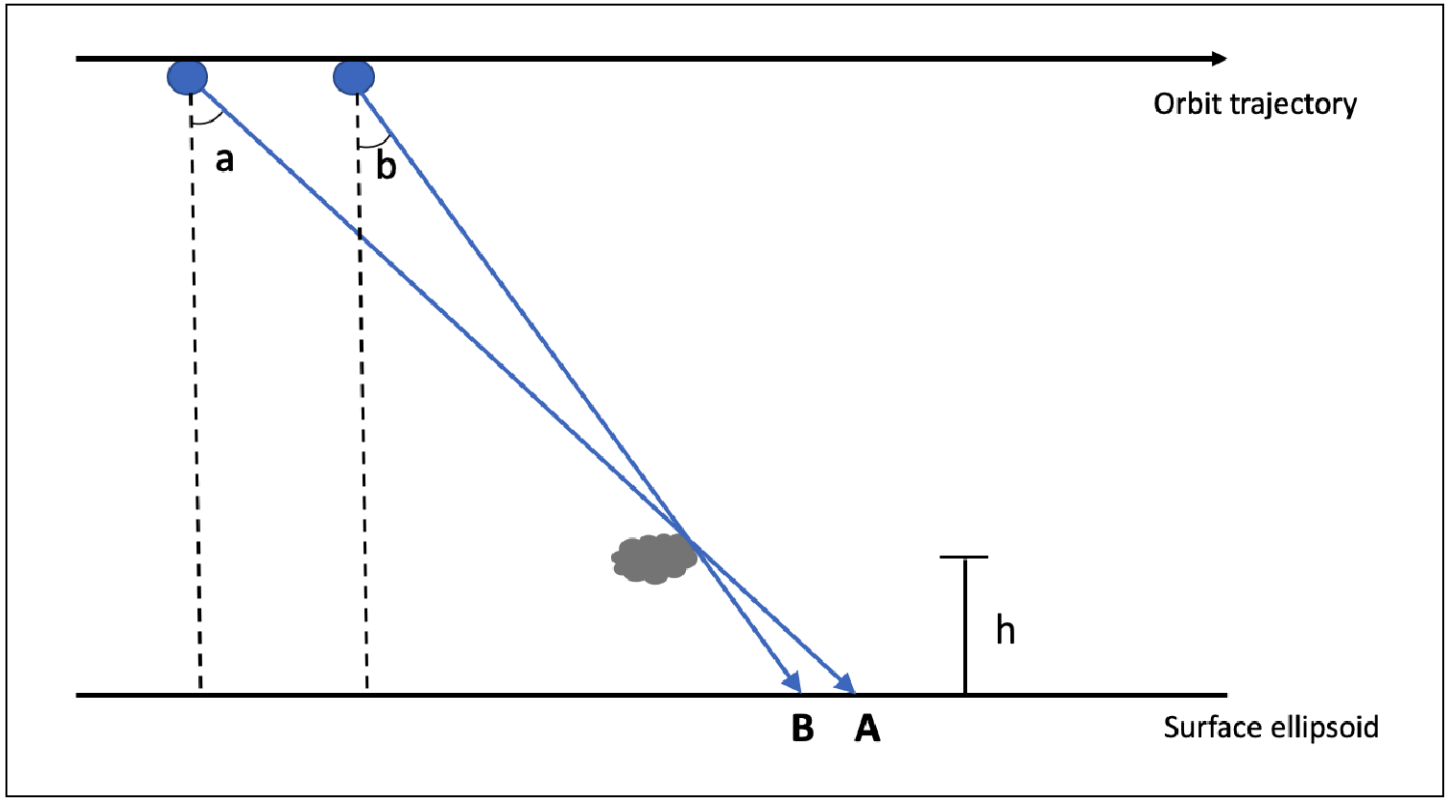


Steps for calculating stereo Cloud-Top Height (CTH): simplified geometry

1. Derive a disparity map from stereo-pairs using the MISR M2 matching method [1].
2. Derive CTHs using Equation (1) based on M2 calculated disparity values for SIMULTANEOUS stereo-pairs:

$$CTH = \frac{\overline{AB}}{\tan a - \tan b} \qquad (1)$$

For example, at time t_0, $\overline{AB}$ is the disparity calculated from images at two different views with *a* and *b* as the viewing zenith angles from the two different views.



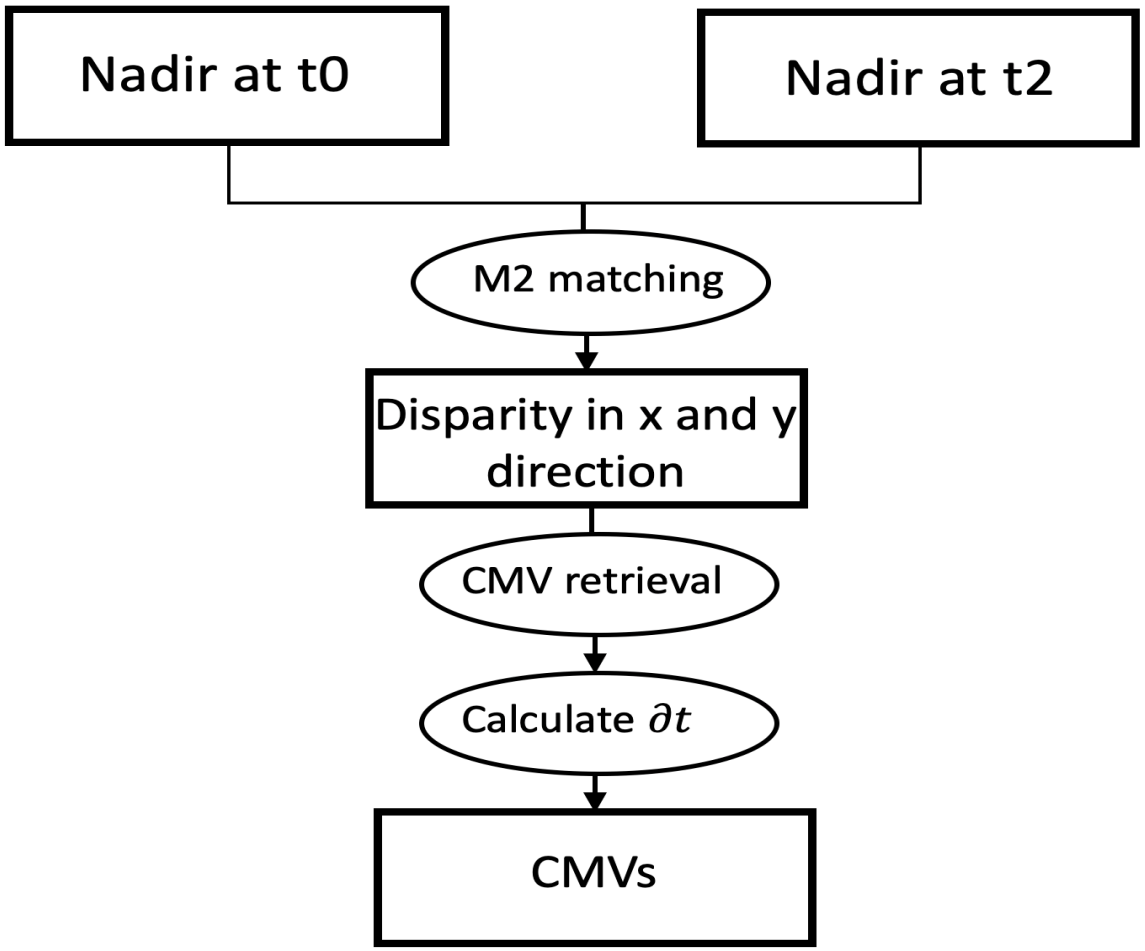
[1] Muller, J.; Mandanayake, A.; Moroney, C.; Davies, R.; Diner, D.; Paradise, S. MISR stereoscopic image matchers: Techniques and results. *IEEE Trans. Geosci. and Rem. Sens.* **2002**, *40*, 1547–1559.doi:10.1109/TGRS.2002.801160

Steps for calculating CMV: simplified geometry

1. CMV is calculated based on two nadir view images at times t_0 and t_2, which are least affected by image distortions assuming that the cloud-top does not change in the interim.
2. CMV in the horizontal (x,y) direction is directly calculated from the disparity map from matching nadir images
3. Given the disparity in the x direction as Dx and disparity in the y direction as Dy, the wind speed ν can be calculated using Equation (2):

$$\nu = \frac{\sqrt[2]{Dx^2+Dy^2} * R}{(t2-t1)} \quad (2)$$

where R is pixel resolution [2]



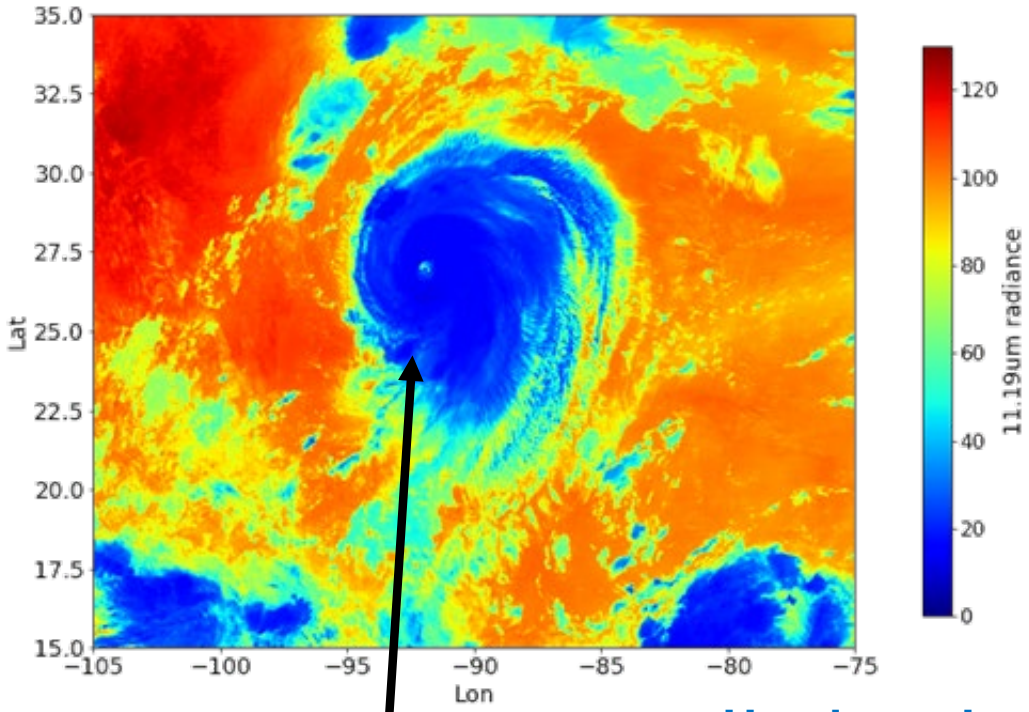
[2] MISR Level 2 Cloud Product Algorithm Theoretical Basis. JPL D-73327. https://eospso.gsfc.nasa.gov/sites/default/files/atbd/MISR_L2_CLOUD_ATBD-1.pdf

Geo-Geo simultaneous stereo and GOES time sampling

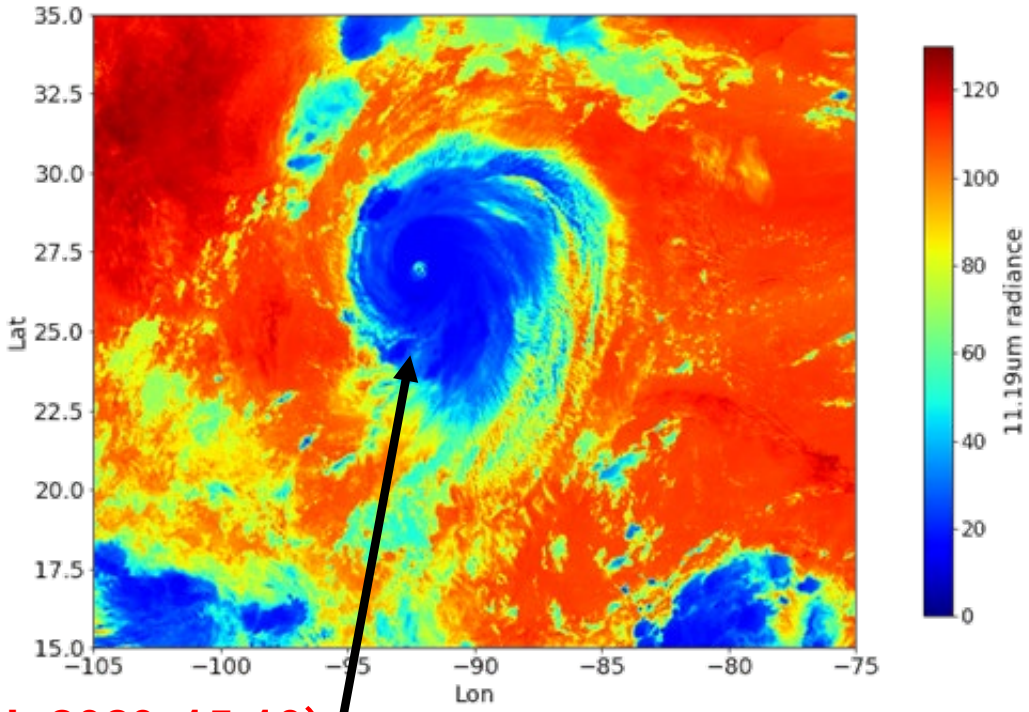
- Exploration of impact of view-angle on CTH/CMV retrieval using GOES-stereo
- GOES-16+17 and GOES-17+Himawari have simultaneous views in visible (GOES 500m VISIBLE band 2@660nm and 2km TIR band 13/14@10.85µm)
- Acquired every 10 minutes, we can explore CTH from stereo
- Exploration of CMV from single view disparity wrt nadir between 2 successive views
- GOES also has Mesoscale mode every 1 minute for severe storm systems so we can explore CMV field similar to what is planned with Harmony

GOES Brightness Temperature Measurements

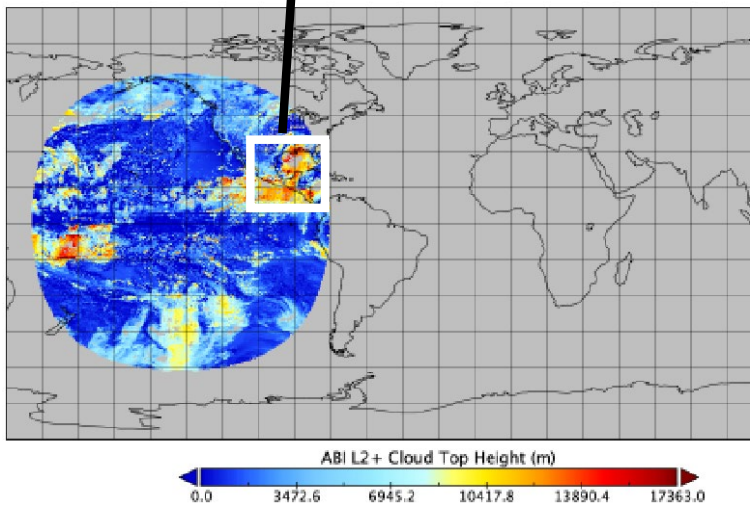
GOES-17



GOES-16

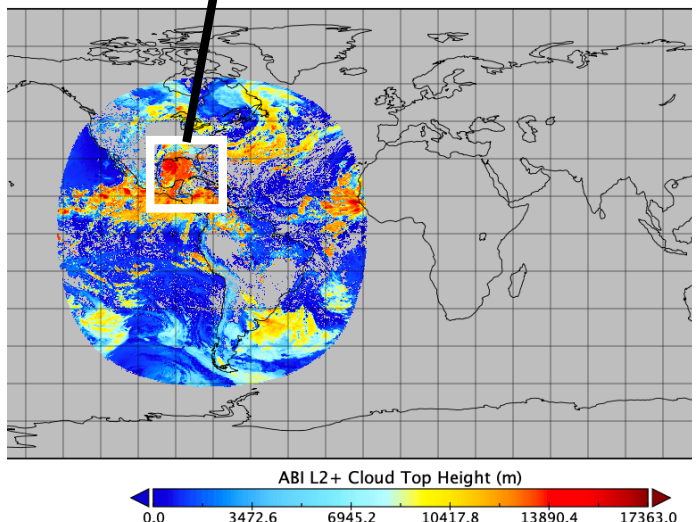


Hurricane Iselle（Aug 26th 2020, 15:10）

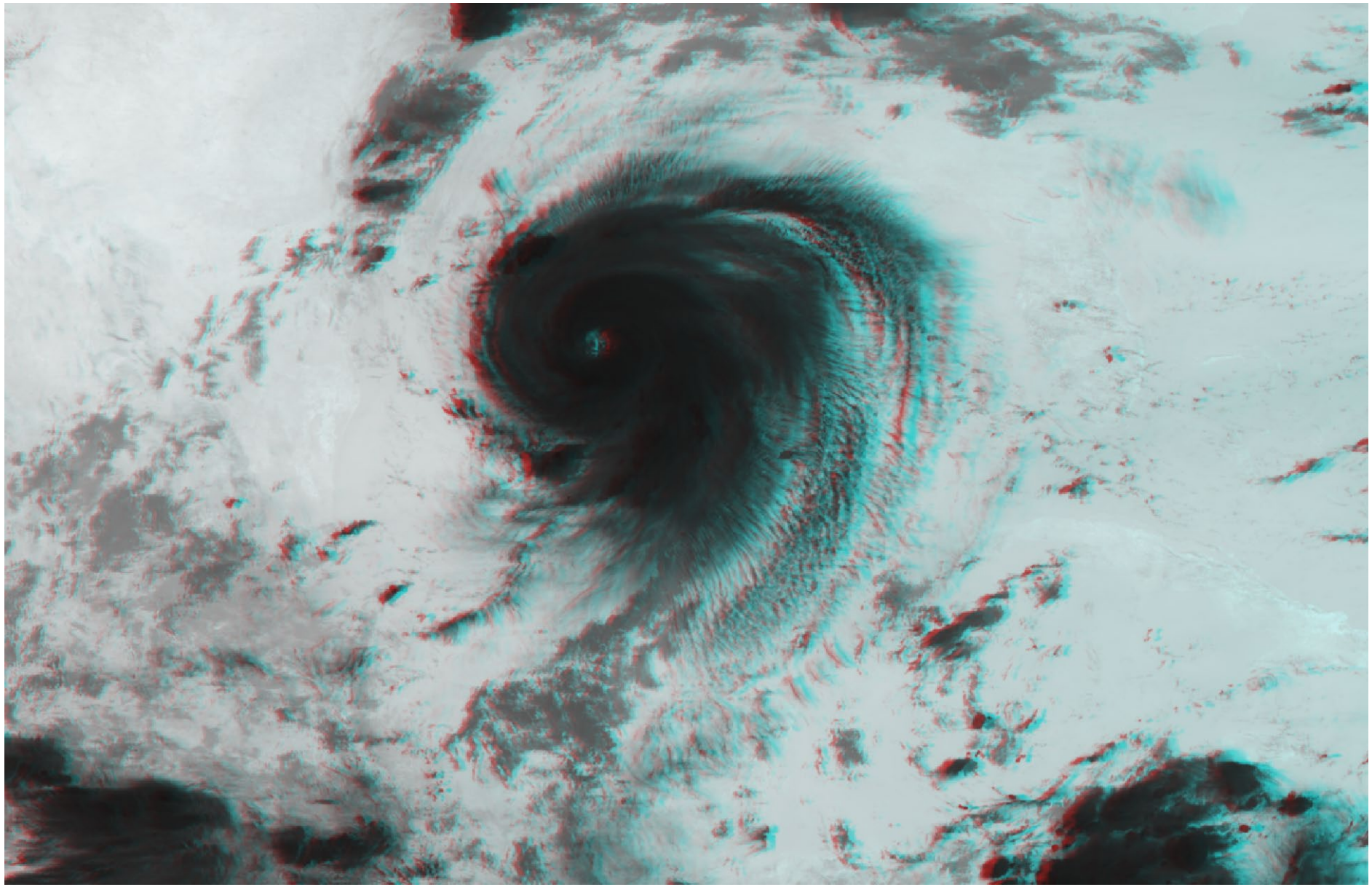


GOES-17

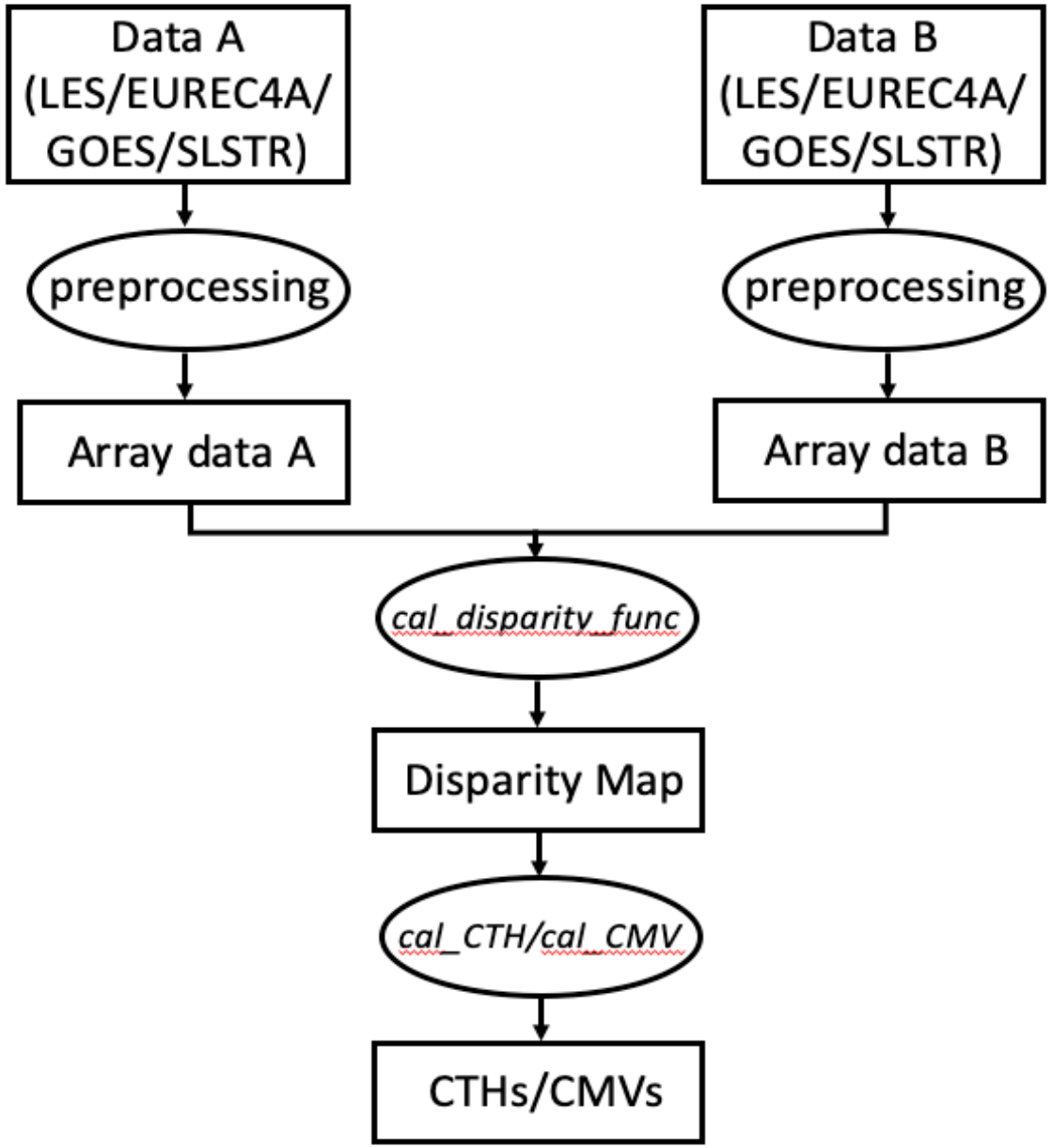
GOES-16



GOES17+16 Stereo anaglyph-hurricane (you will need red/cyan or red/green glasses to view)

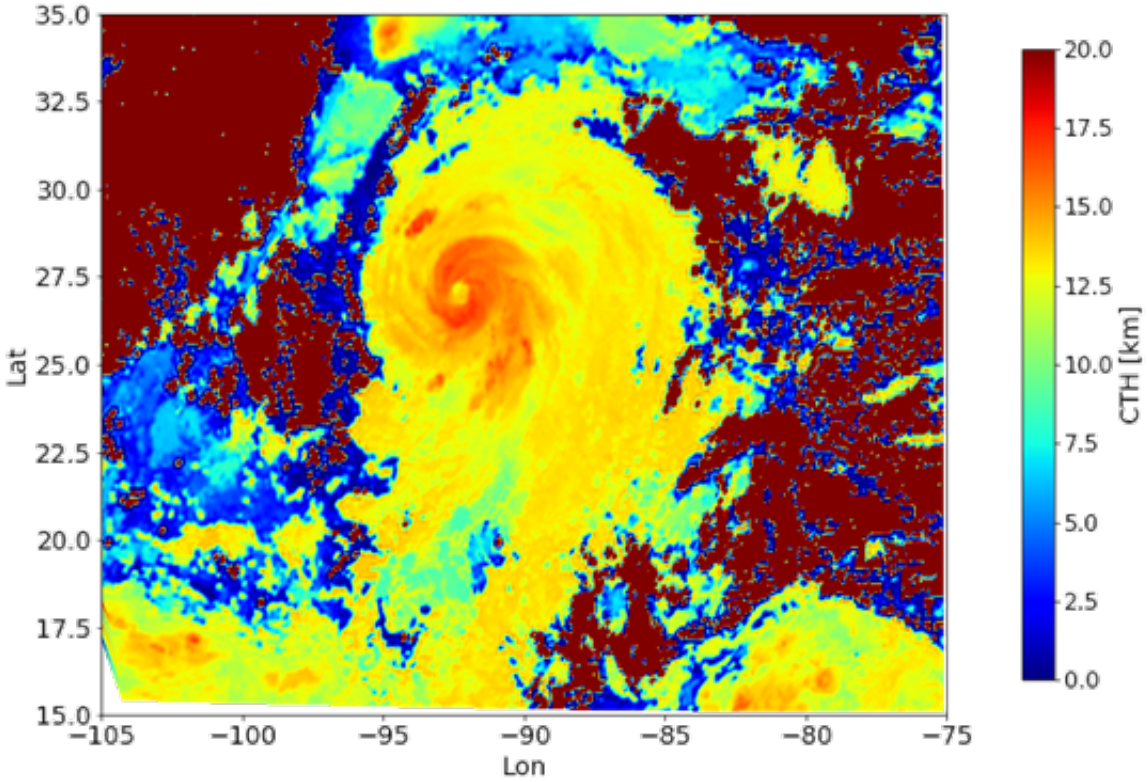


Processing Chain of CTH & CMV Retrievals

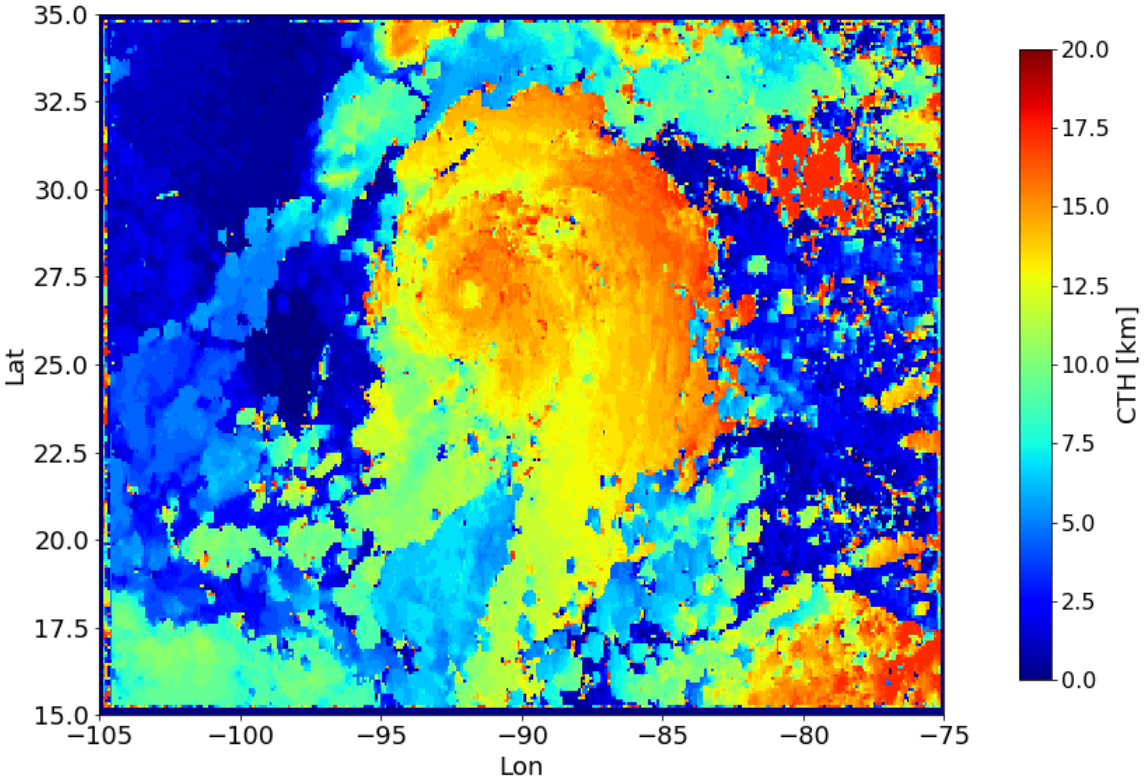


Comparison of CTH Retrievals

GOES-16 Brightness temperature CTT- CTHs
Aug 26th 2020, 15:10



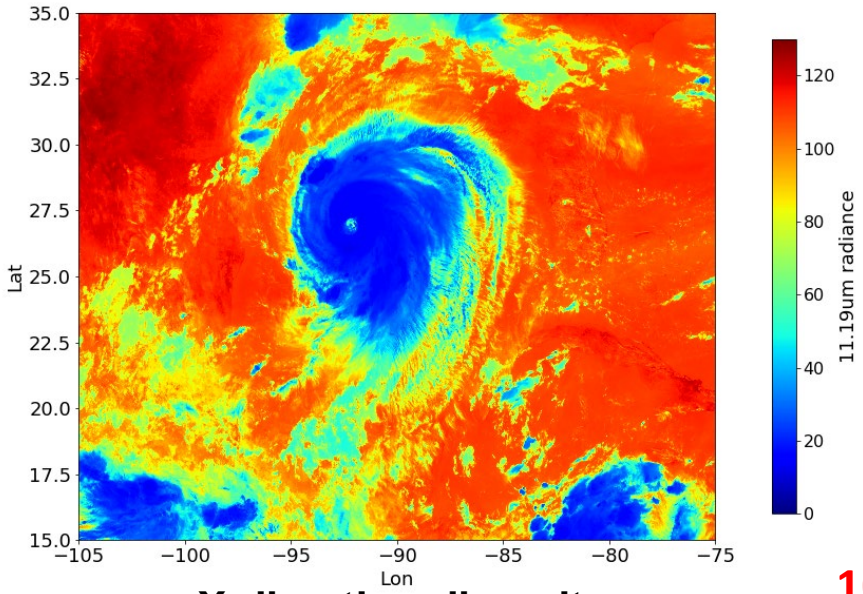
GOES17-GOES16 stereo b13 scaled CTHs
Aug 26th 2020, 15:10



Disparity for CMV Retrievals

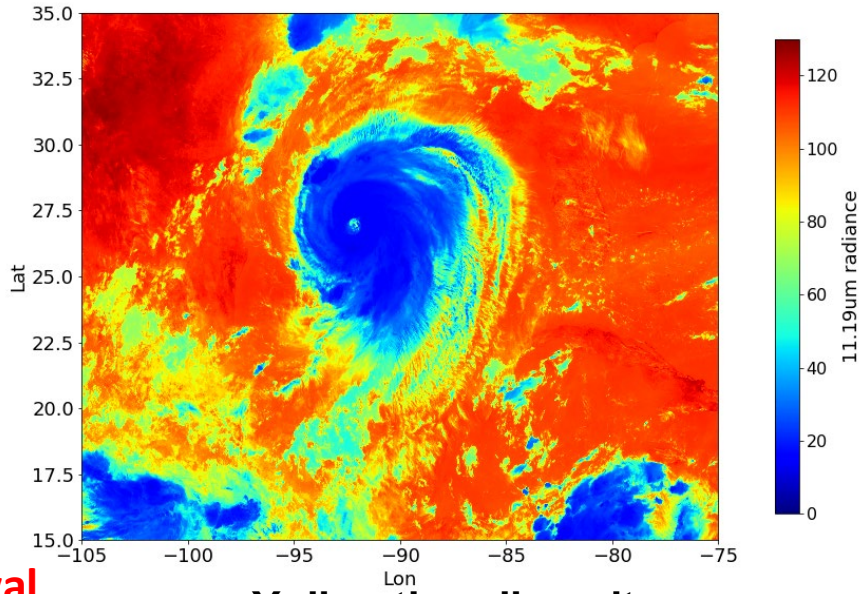
GOES-16 radiance Band-14 radiance

UTC 15:20, 26th Aug 2020



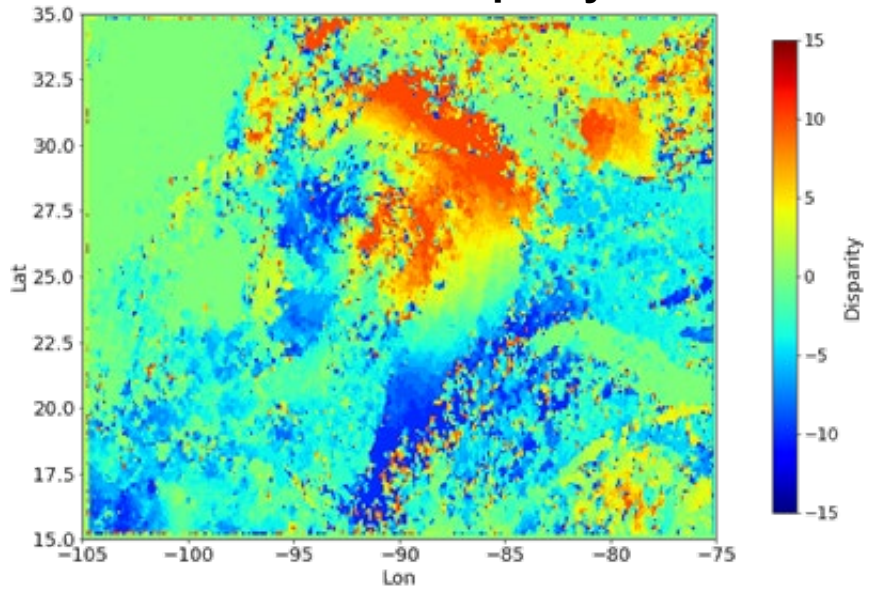
GOES-16 radiance Band-14 radiance

UTC 15:30, 26th Aug 2020

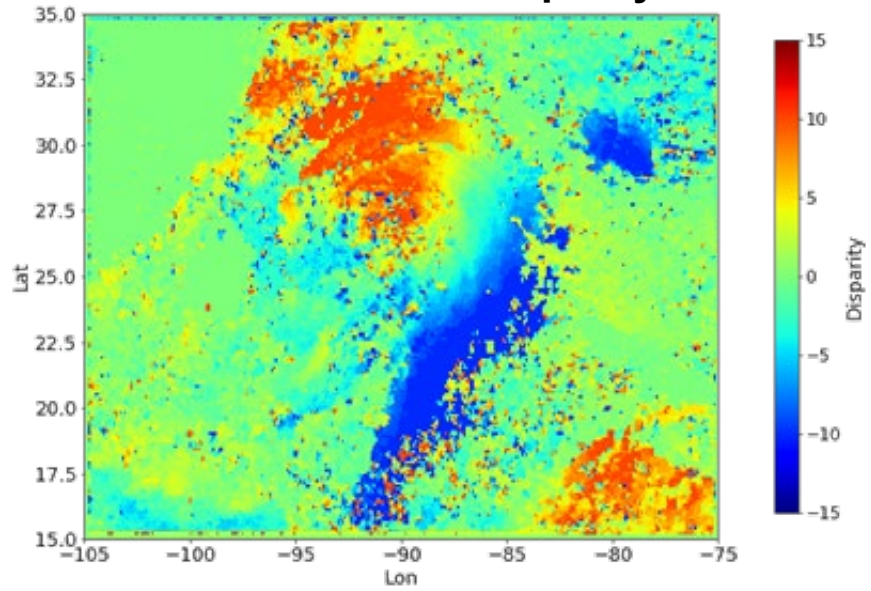


10-minute time interval

X-direction disparity

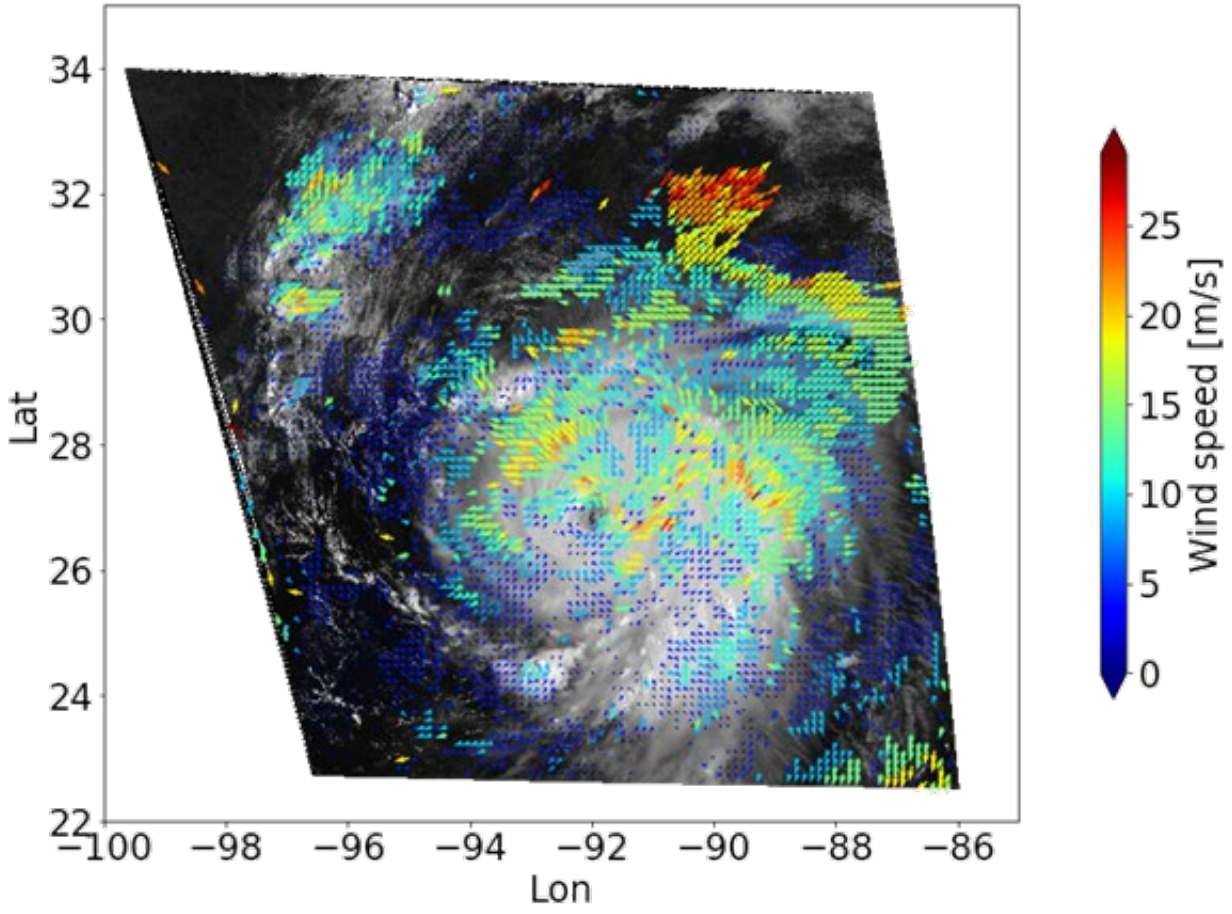


Y-direction disparity

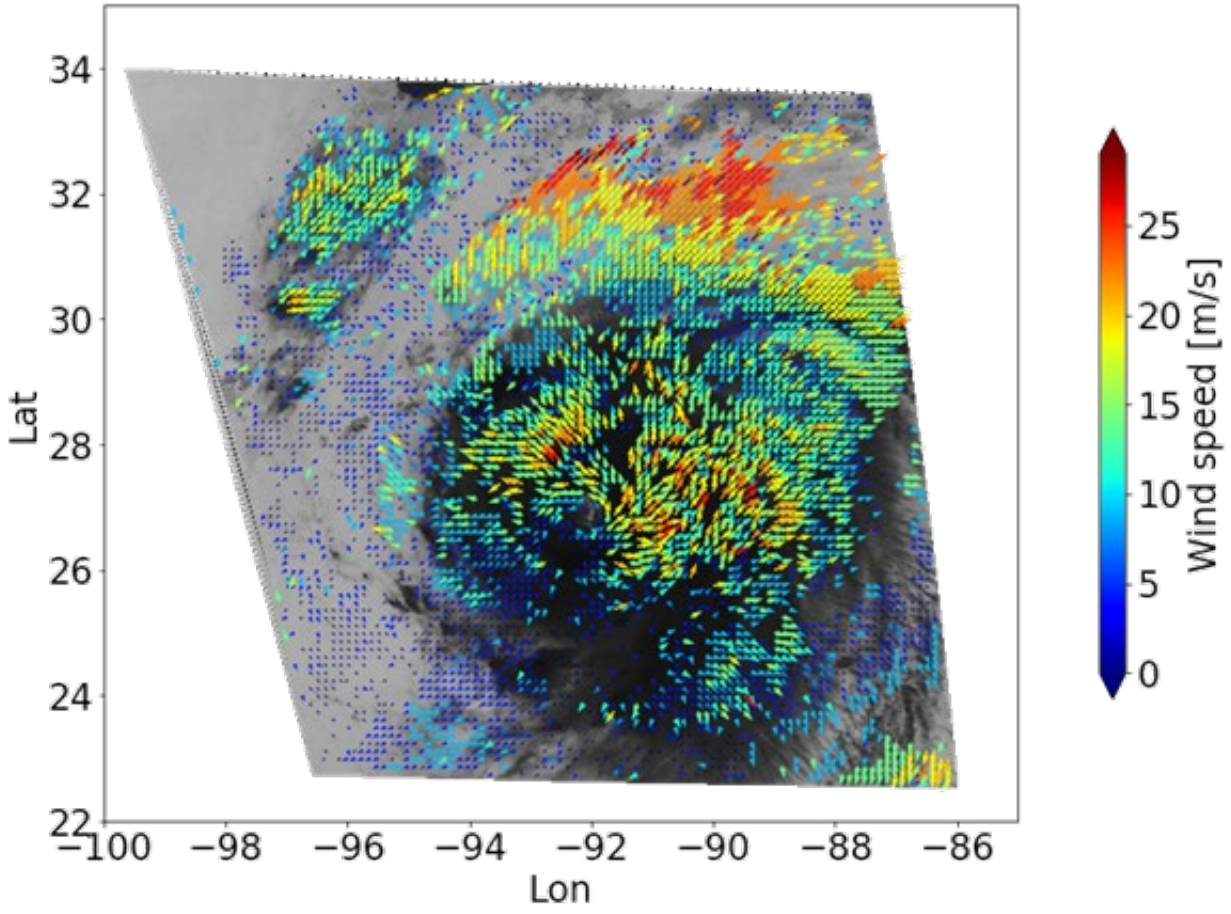


CMV Retrieval at 2-minute Interval

500m Band-2 (660nm) wind retrievals
at Aug 26th 2020, 15:00

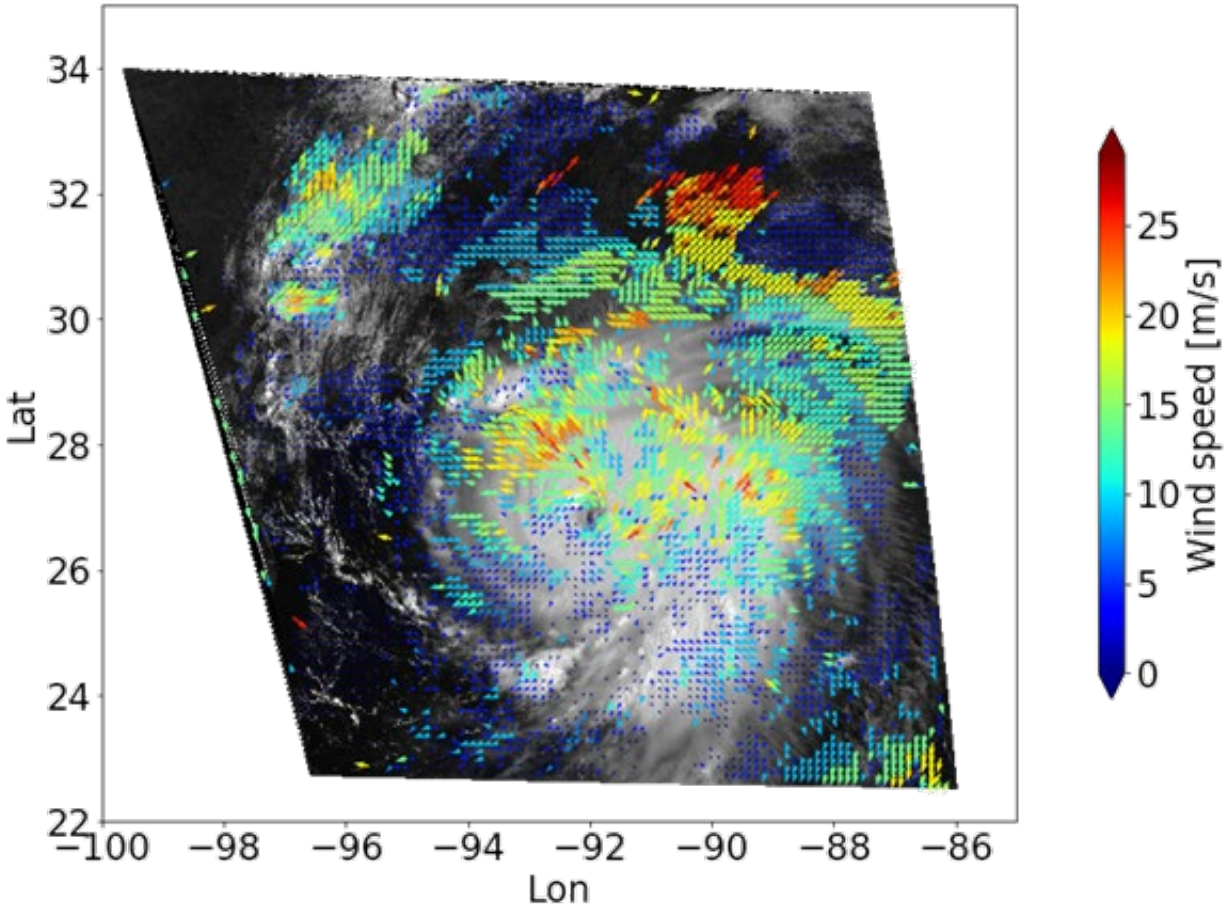


2km Band-13 (10.85µm) wind retrievals
at Aug 26th 2020, 15:00

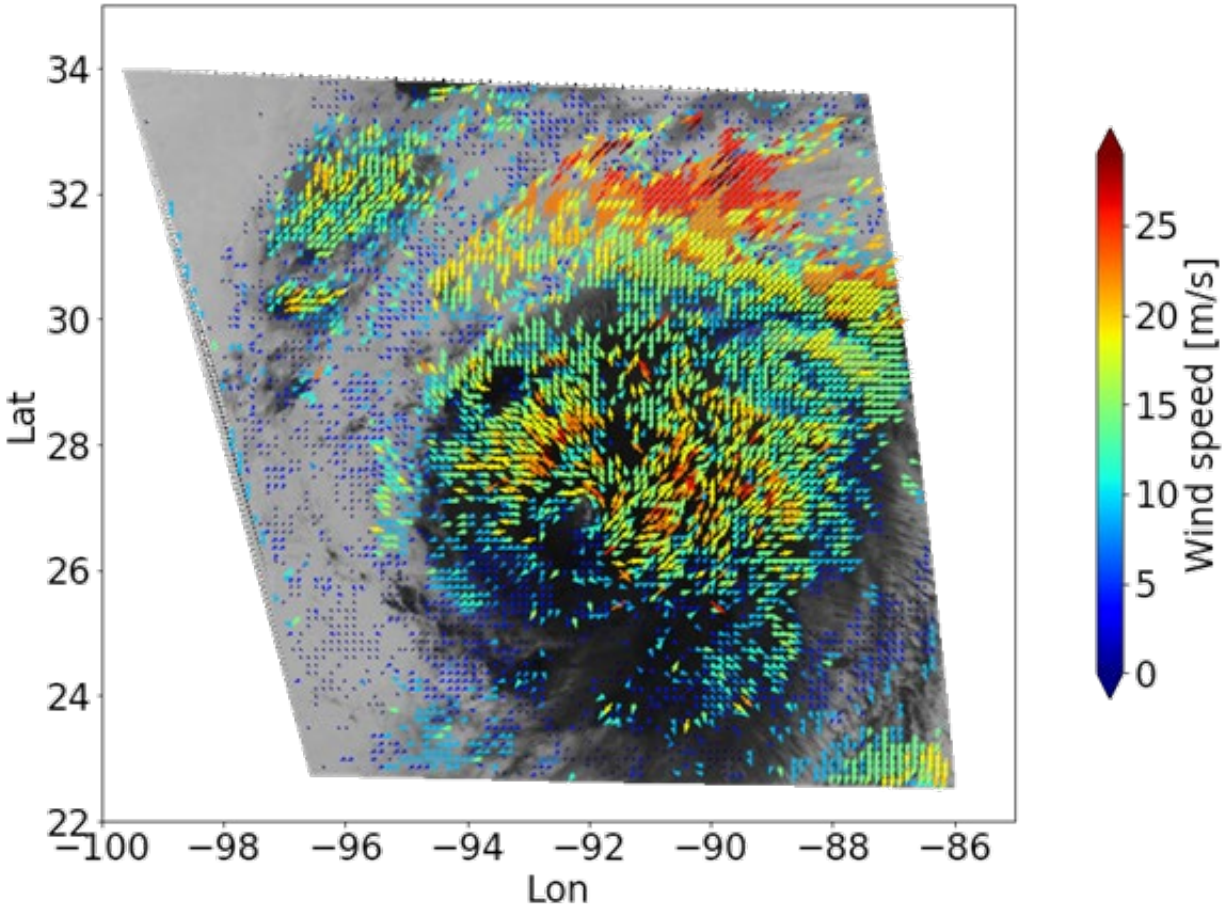


CMV Retrieval at 2-minute Interval

500m Band-2 (660nm) wind retrievals
at Aug 26th 2020, 15:02

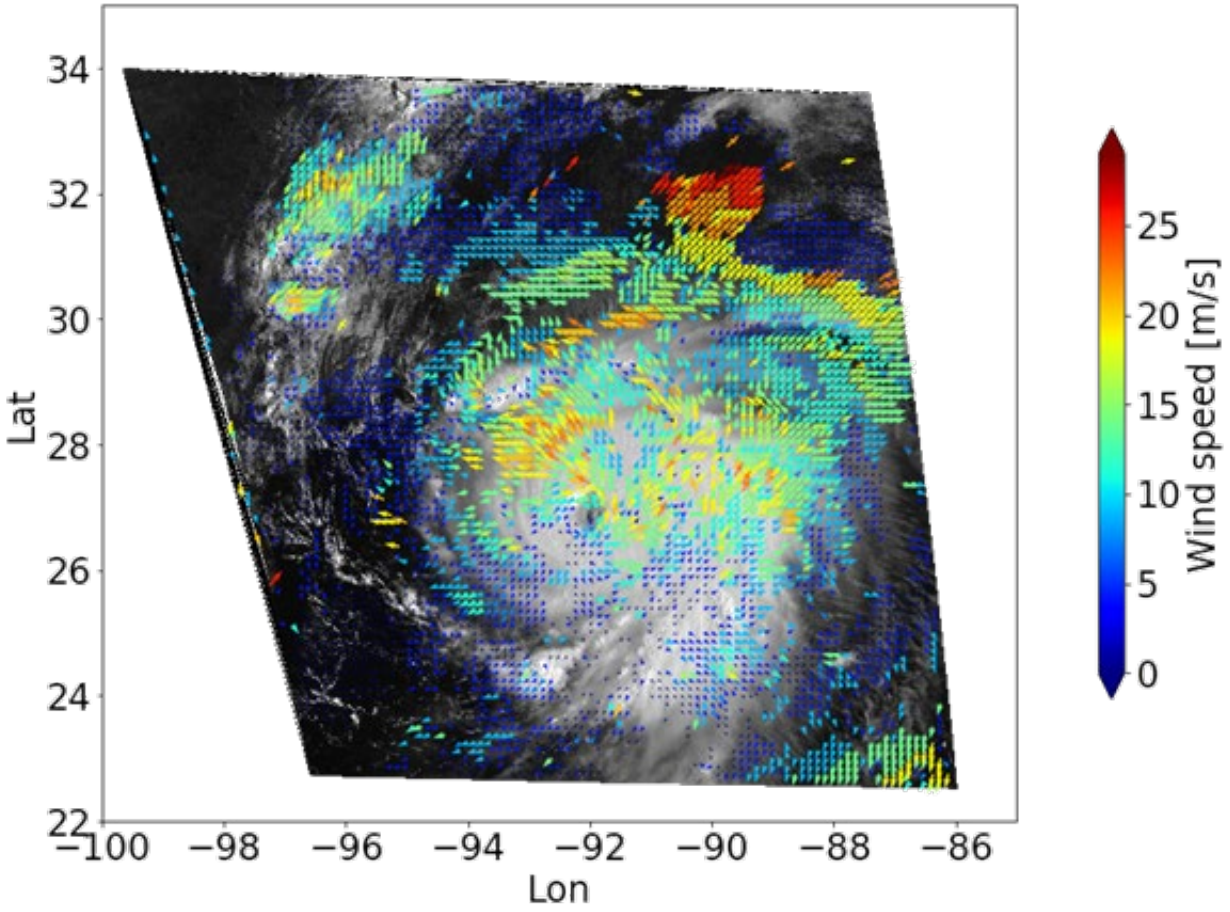


2km Band-13 (10.85µm) wind retrievals
at Aug 26th 2020, 15:02

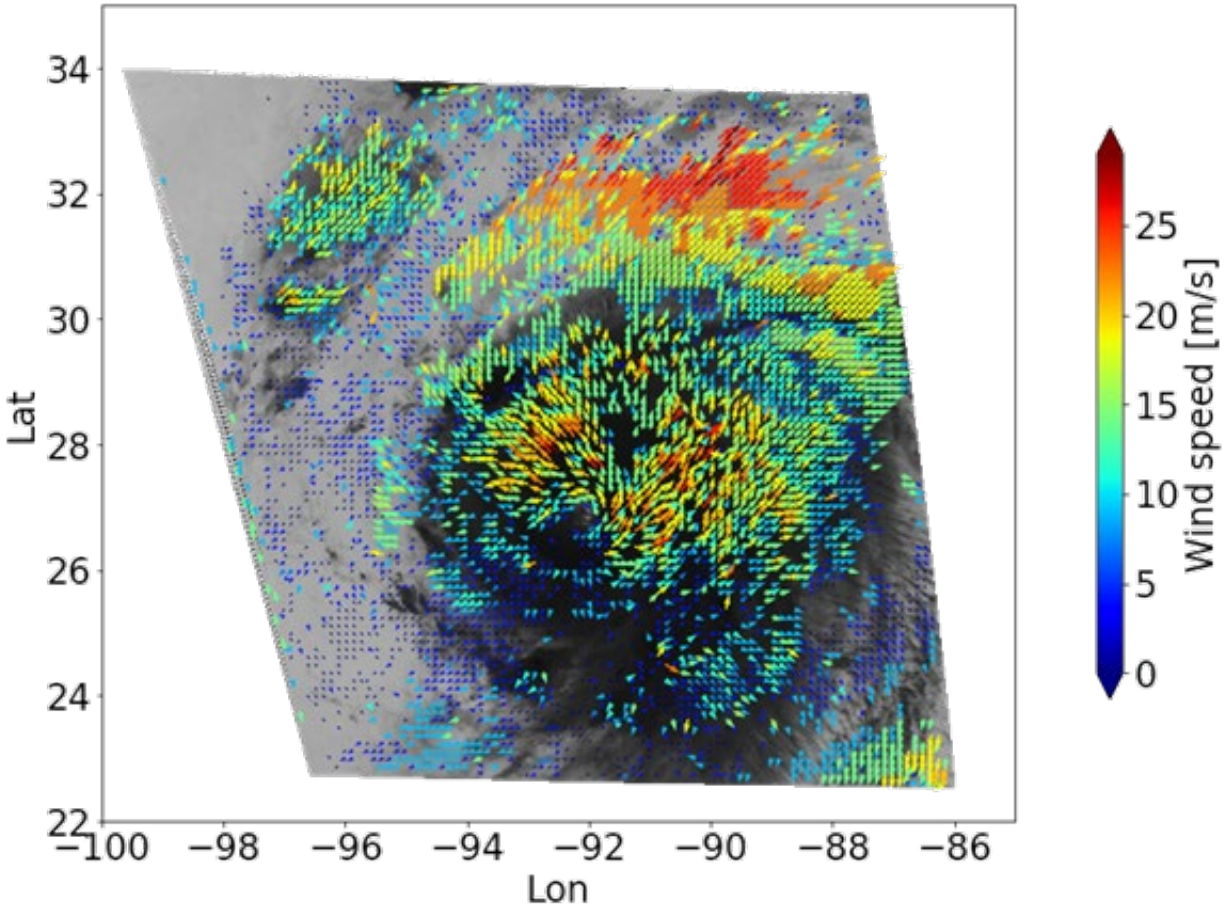


CMV Retrieval at 2-minute Interval

500m Band-2 (660nm) wind retrievals
at Aug 26th 2020, 15:04

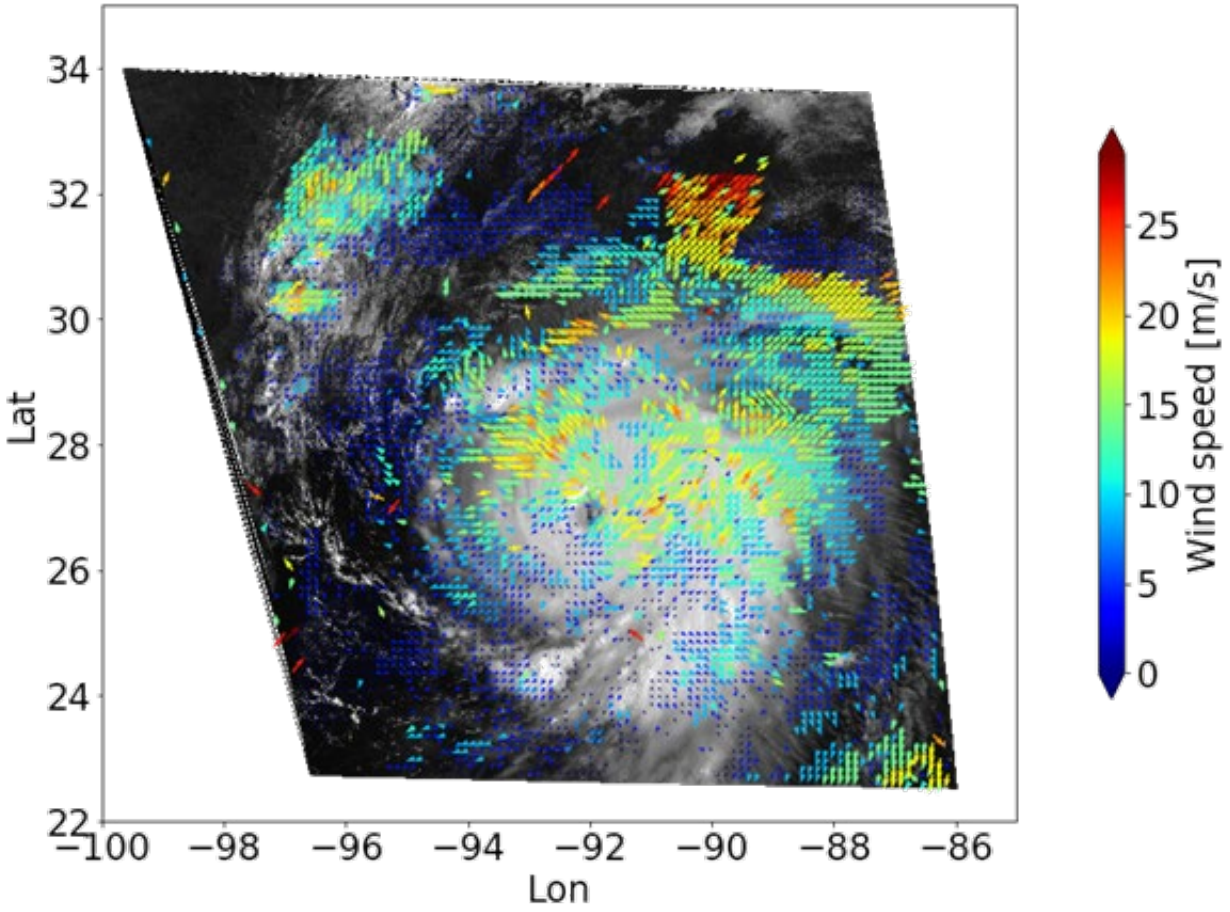


2km Band-13 (10.85µm) wind retrievals
at Aug 26th 2020, 15:04

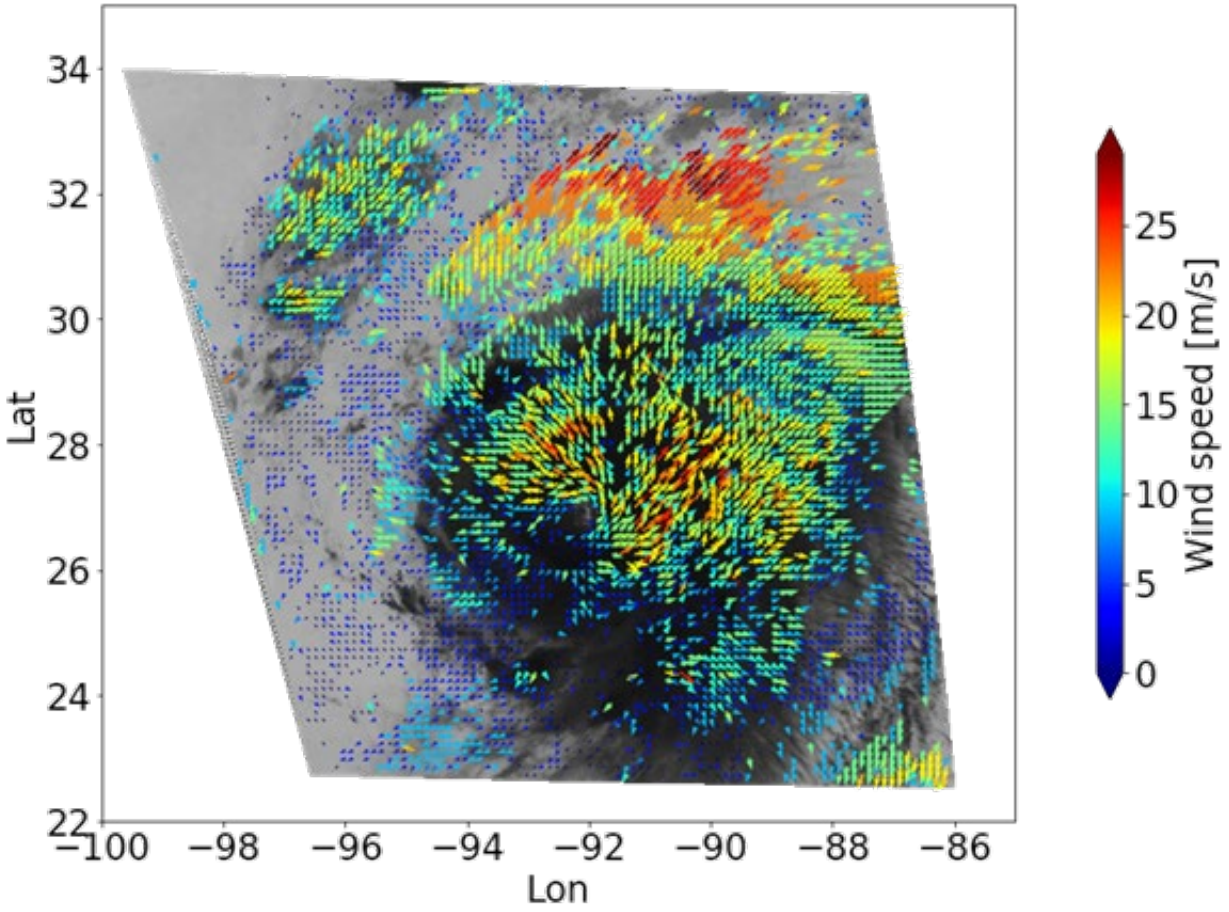


CMV Retrieval at 2-minute Interval

500m Band-2 (660nm) wind retrievals
at Aug 26th 2020, 15:06

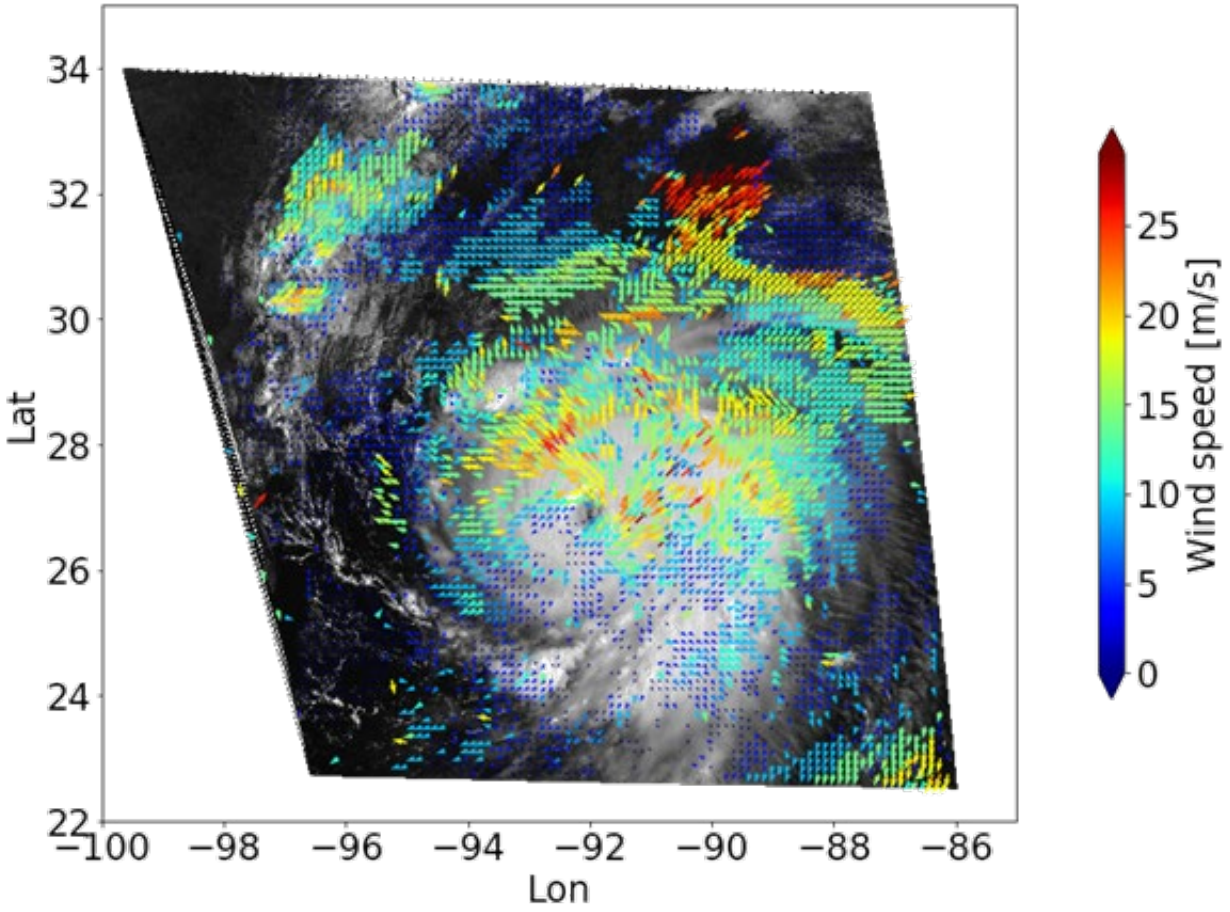


2km Band-13 (10.85µm) wind retrievals
at Aug 26th 2020, 15:06

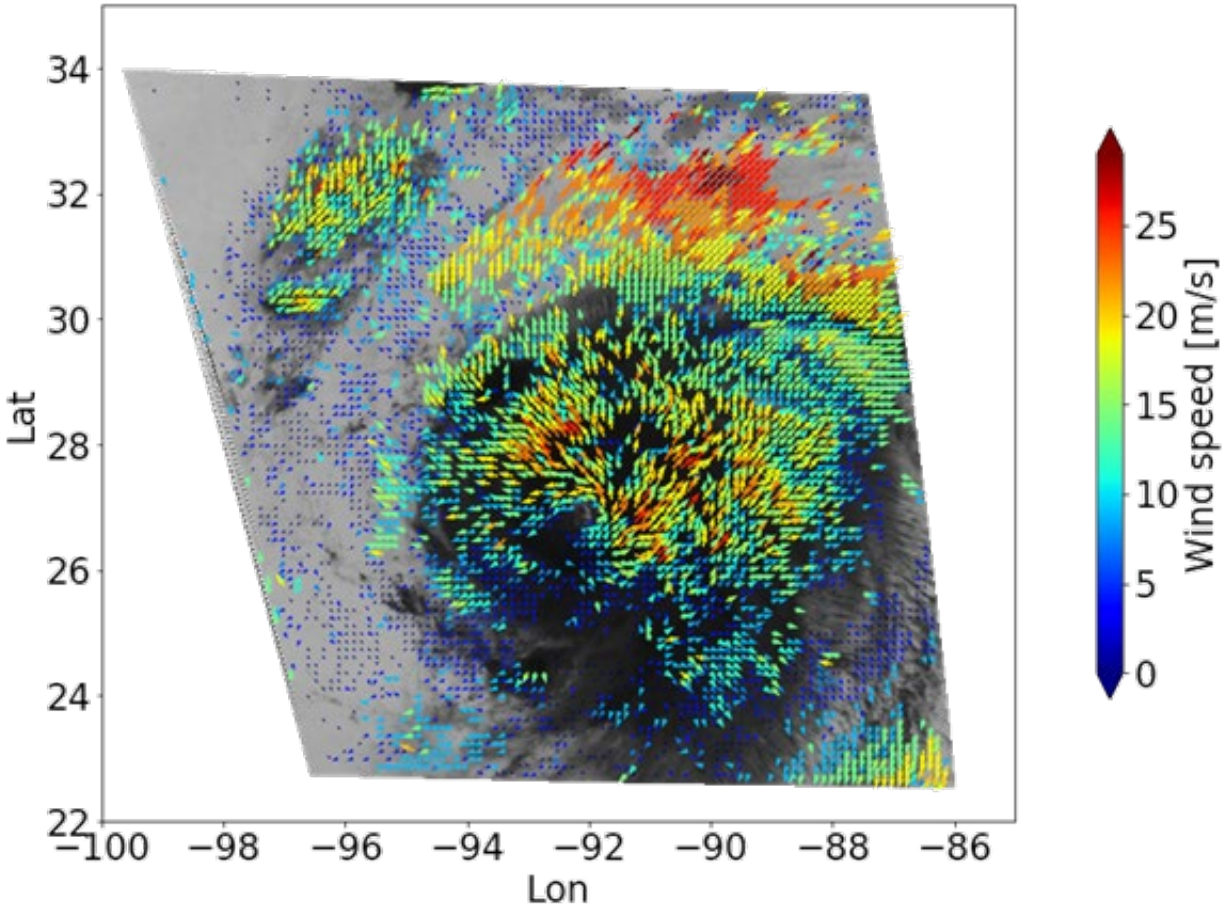


CMV Retrieval at 2-minute Interval

500m Band-2 (660nm) wind retrievals
at Aug 26th 2020, 15:08

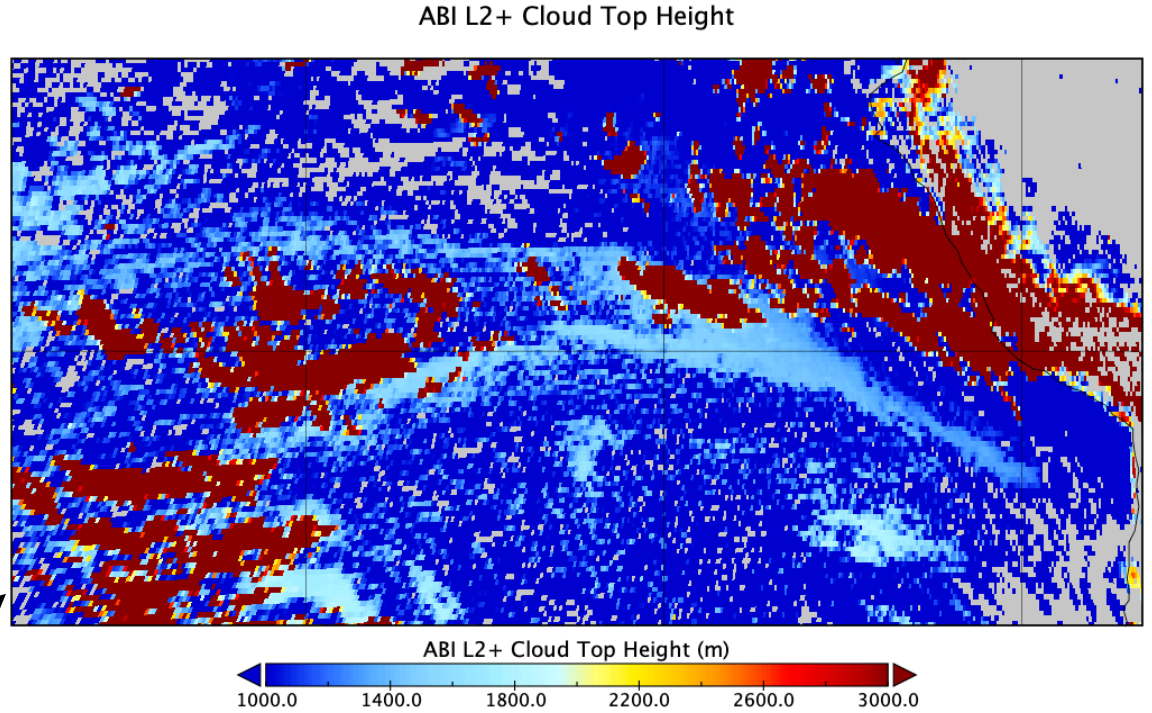


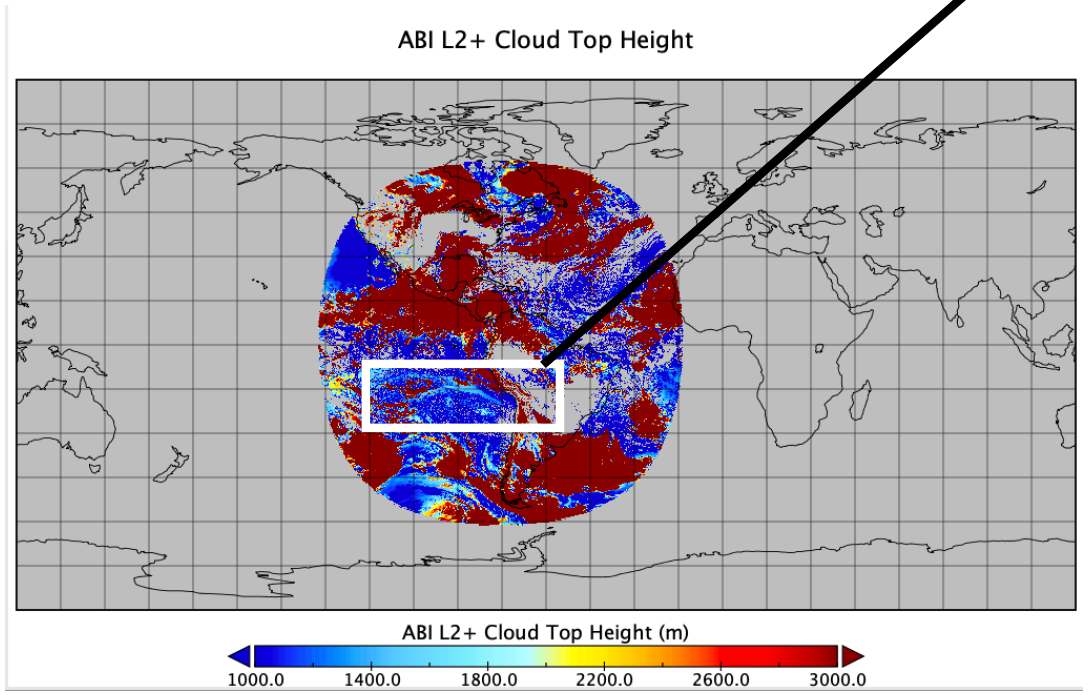
2km Band-13 (10.85µm) wind retrievals
at Aug 26th 2020, 15:08



Low level MABL clouds in the East Pacific

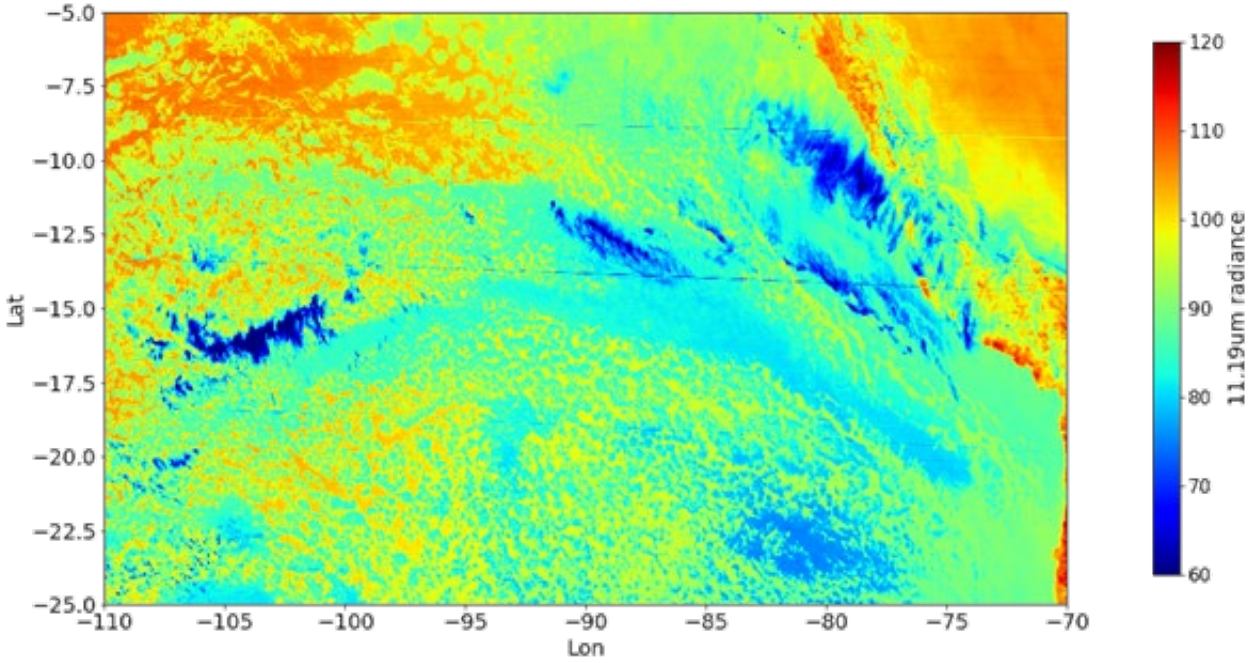
GOES-16 level-2 cloud-top temperature retrieved height from Band-14 on August 26th 2020@15:00 (UTC)



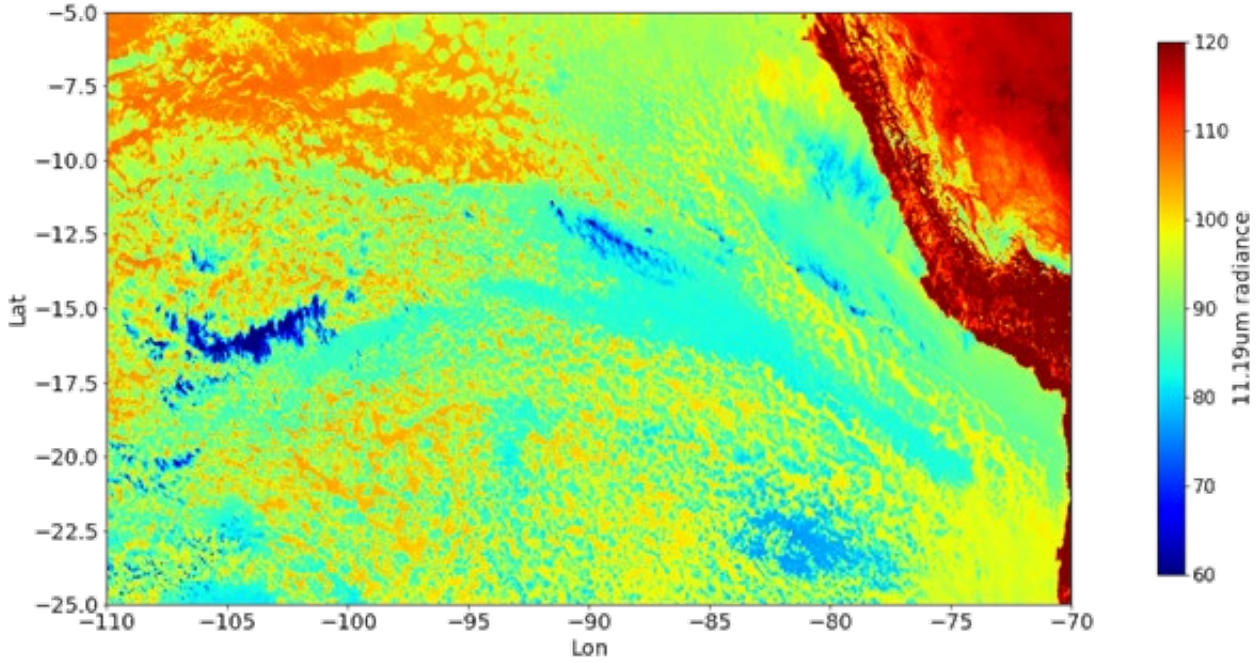


GOES Brightness Temperature Measurements

GOES-17 radiance Band-14 radiance on August 26th 2020@15:00 (UTC)



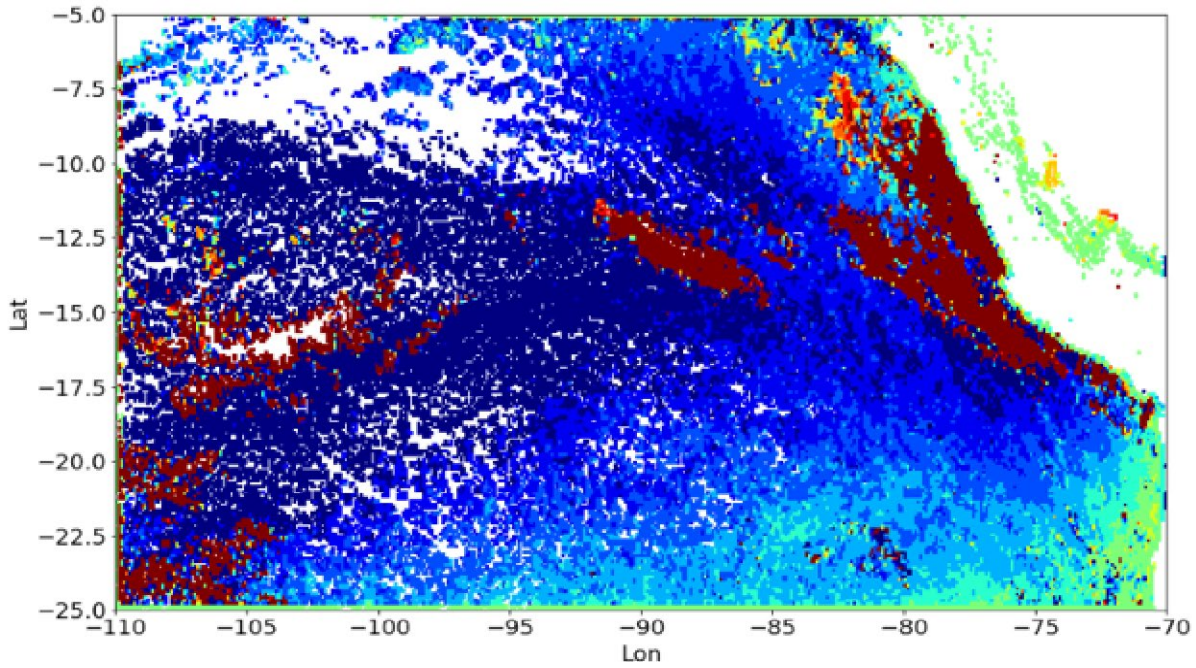
GOES-16 radiance Band-14 radiance on August 26th 2020@15:00 (UTC)



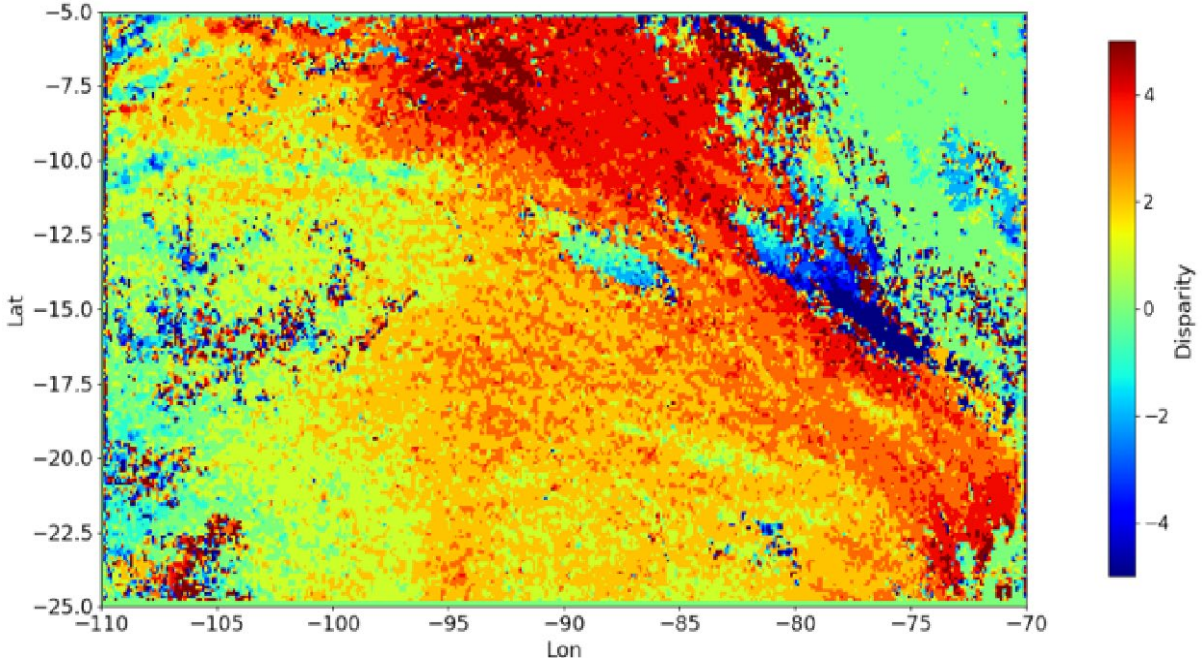
GOES17+16 Stereo anaglyph-MABL

Disparity for CMV Retrievals

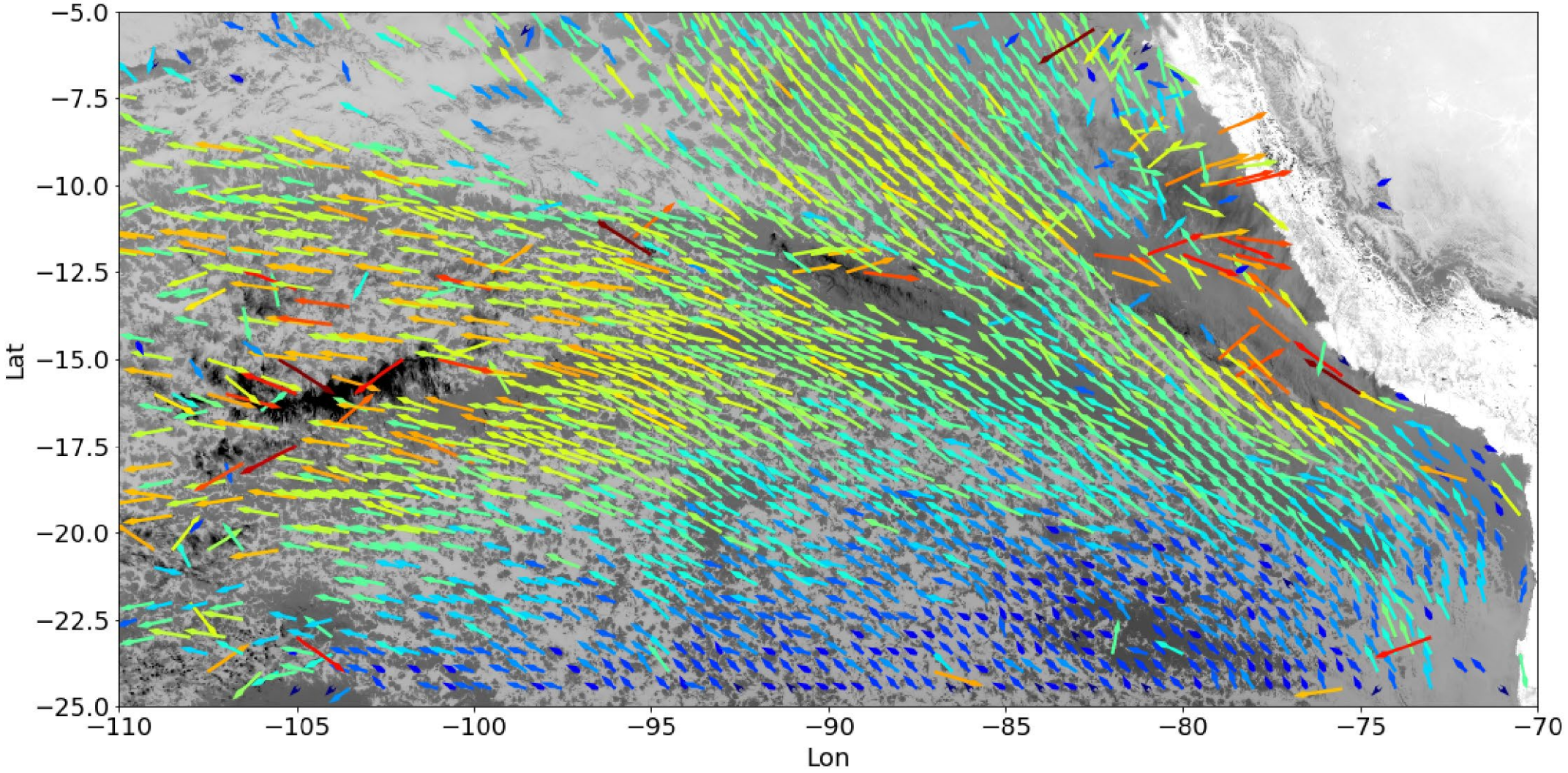
GOES-16 radiance Band-14 radiance August 26th 2020@15:00 (UTC)
X- disparity using GOES-16 band 14 images



GOES-16 radiance Band-14 radiance August 26th 2020@15:00 (UTC)
Y-disparity from GOES-16 band 14



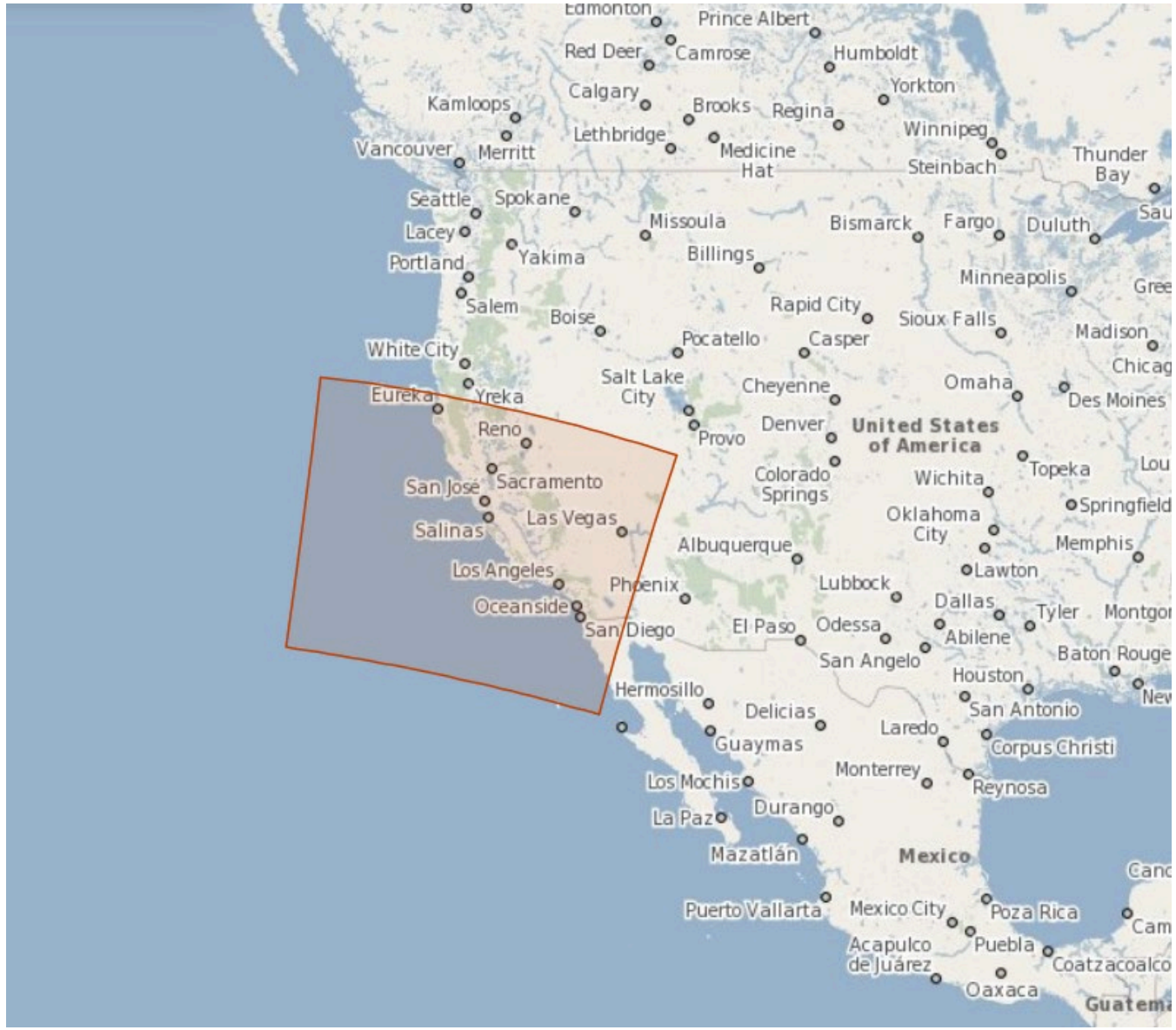
GOES16 10-minute interval wind vectors of MABL clouds



SLSTR stereo CTH

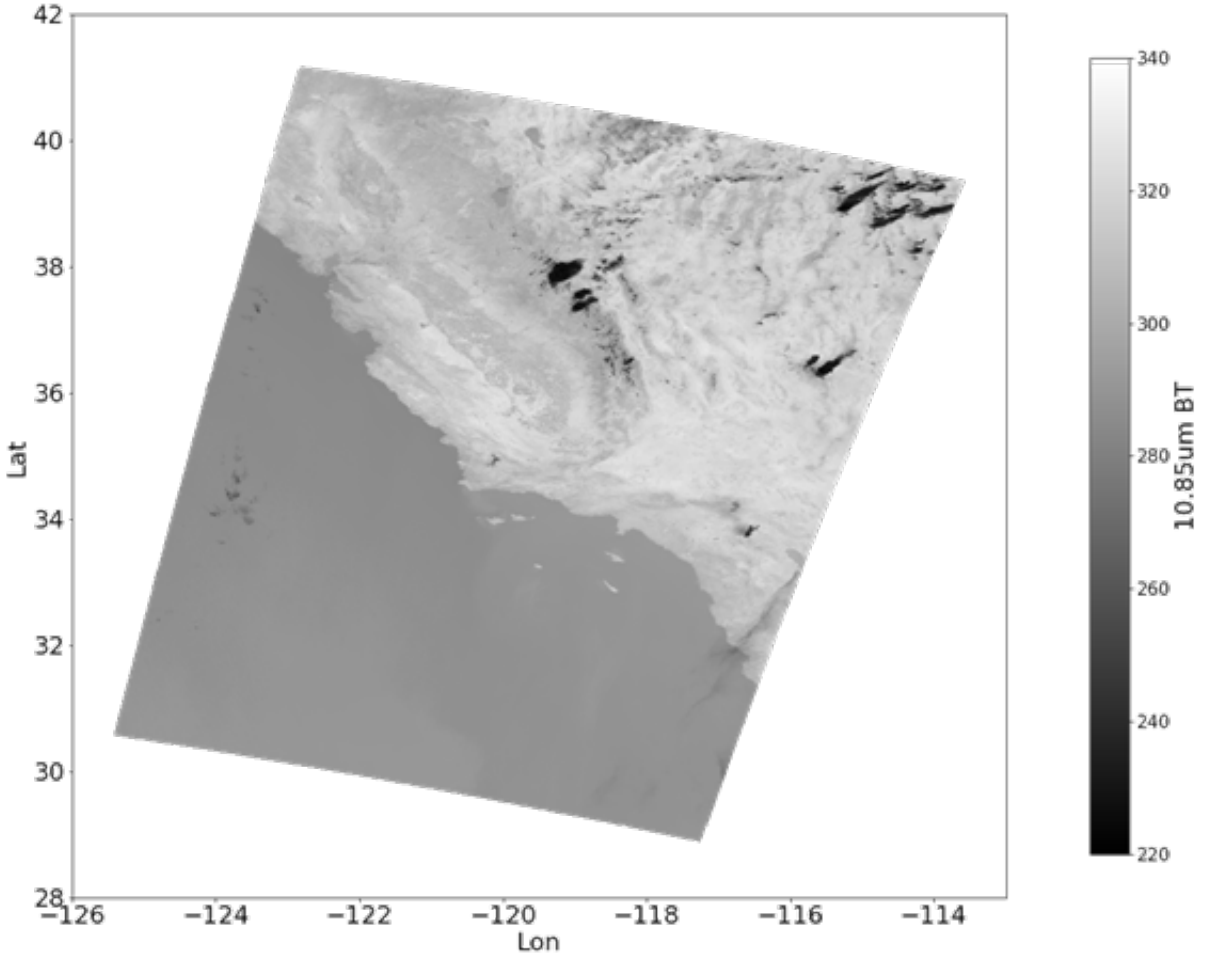
- Sentinel-3 SLSTR acquired data in Tandem mode (30 seconds apart)
- Cannot be used for CMV as time interval too short cf scan time of 151 seconds
- Most SLSTR scans are poorly co-registered - only one example is shown here of low-to-mid level clouds in the CA area

SLSTR Data at California, USA

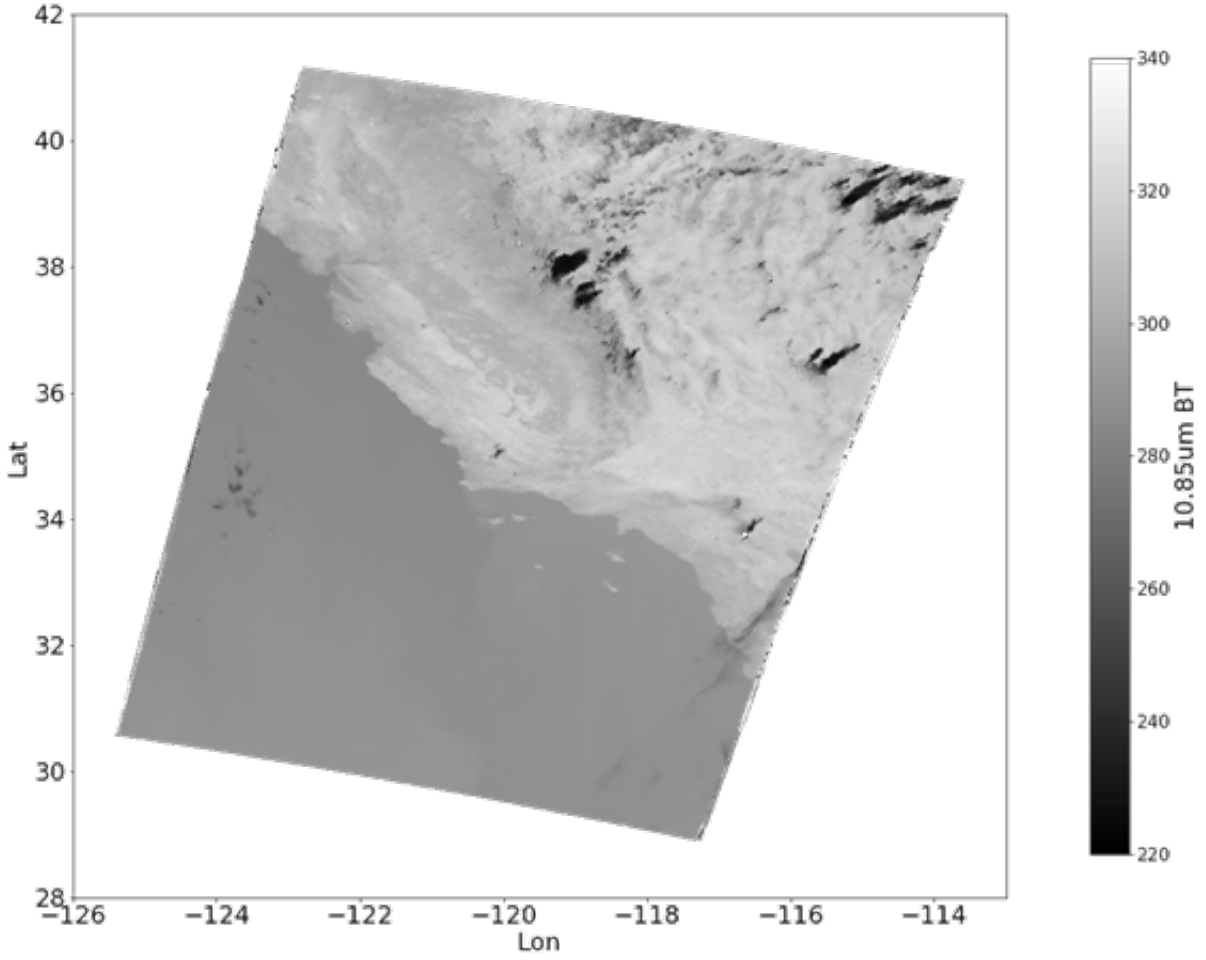


SLSTR Data from Nadir & Oblique Views

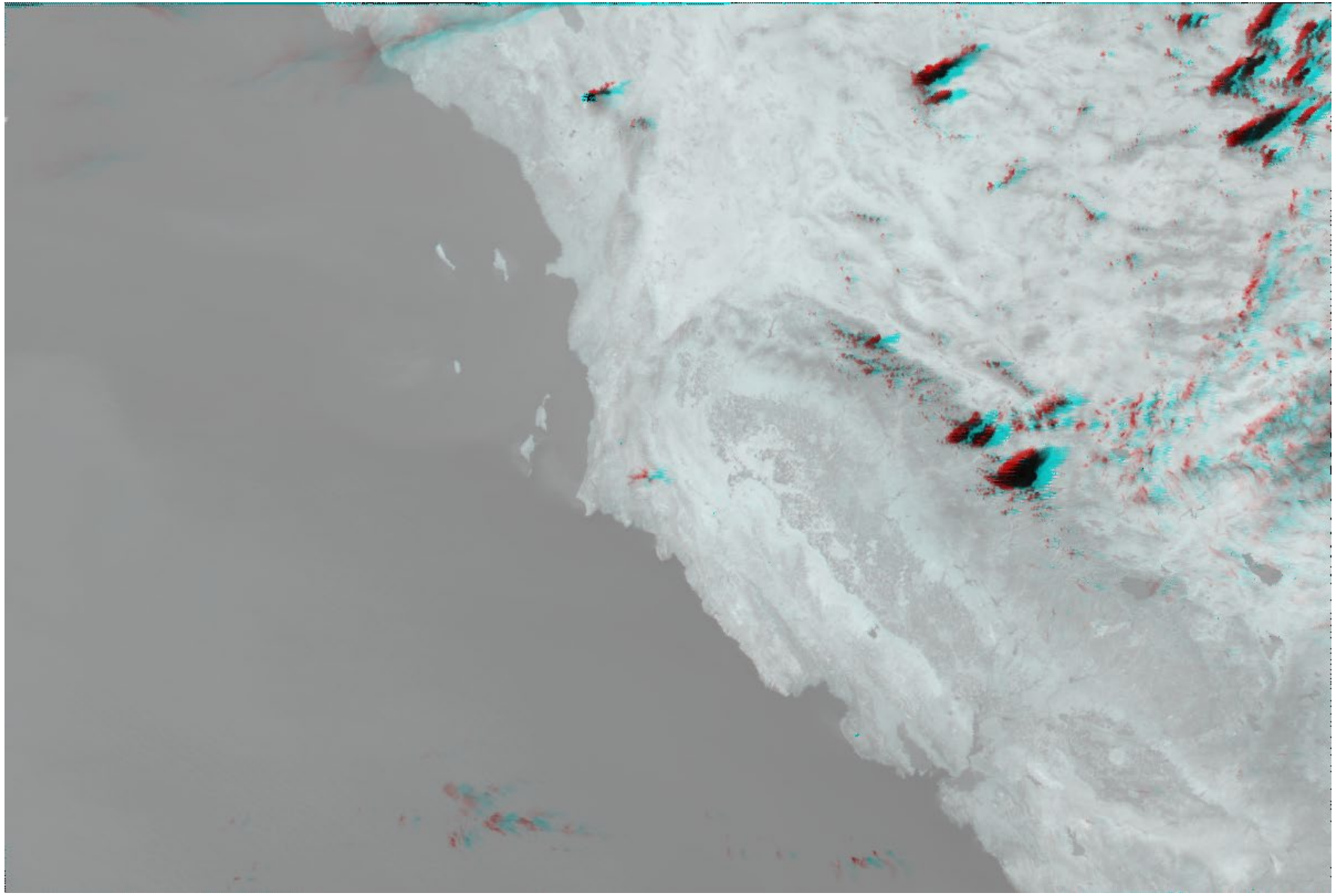
10.85um brightness temperature
Nadir view



10.85um brightness temperature
Oblique view

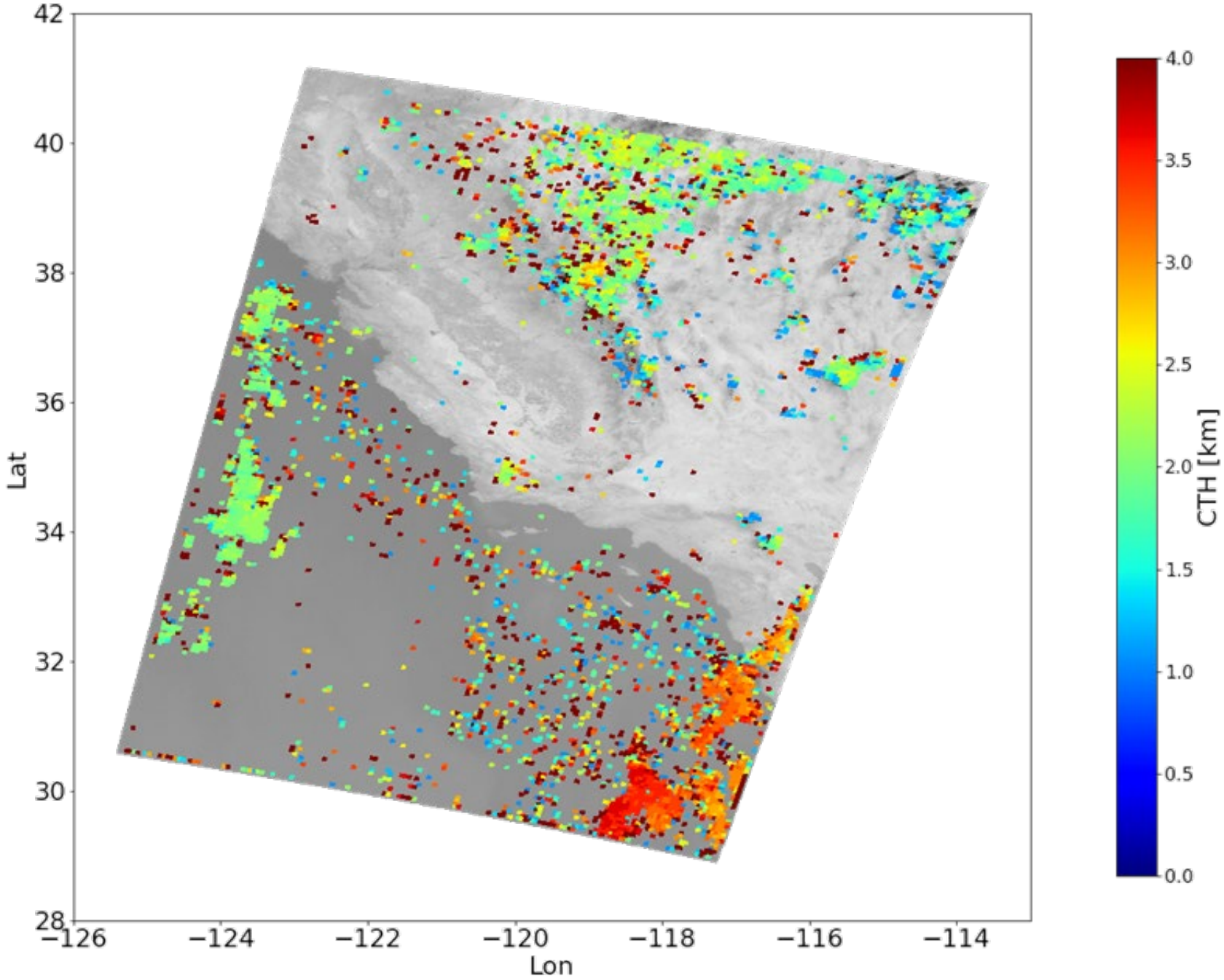


SLSTR Stereo anaglyph-hurricane



R band: oblique view
G band: nadir view
B band: nadir view

SLSTR CTH Retrievals



N.B. M2 very sensitive to noise in the sensor

Summary and Future work

- This study introduces a framework for retrieving cloud-top winds and heights from stereo EO measurements
- The M2 method has been applied to retrieve CTHs from parallax and CMVs from time series
- Applied to GOES16-GOES17 Stereo over Hurricane Iselle and low level MABL clouds over East Pacific
- M2 method has also been demonstrated to apply to the SLSTR nadir and oblique stereo over CA to retrieve parallax from which CTHs can be calculated
- Plan to develop geometry models for GOES and SLSTR so that 3D CTHs and CMVs can be derived for studies of hurricanes/Typhoons with Sentinel-1 SAR and from MABL cloud development over Pacific area