Understanding stereo-opacity bias in MISR and CAMP2Ex P3 observations

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Contents

1. Motivation and Background

- Stereo CTH retrieval is a *purely geometric*, free from radiometric calibration and forward model issues.
- *Stereoscopic CTH detection in the visible to near-IR is very sensitive to low clouds* (highly reflective and textured).
- Stereo CTH errors arise from primarily 3 sources :
  a) Multi-angular radiance co-registration bias
  b) Wind-related errors
  c) Stereo-opacity bias
- This study aims to estimate these errors from satellite and CAMP2Ex retrievals.

2. Terra Record and MISR

- NASA's *20-year-long* mission – TERRA – has on-board, the Multiangle Imaging Spectroradiometer (MISR).
- Terra has exhibited great *orbital stability*.
- MISR stereo CTH is an important climate record. The first stereo instrument where *heights and winds were simultaneously retrieved.*
- Global validation not done previously for lack of active sensor to compare against.

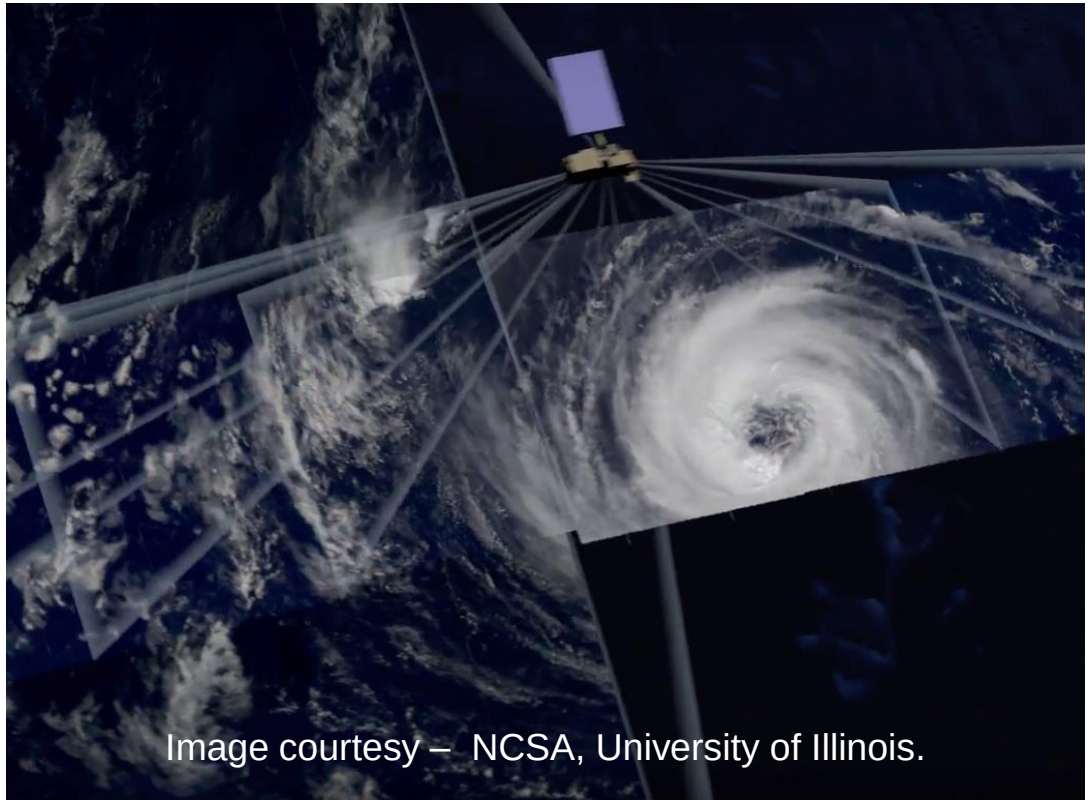


Image courtesy – NCSA, University of Illinois.

3. Comparison with CATS lidar

- CATS lidar operated out of the International Space Station (ISS) between 2015-2017.
- *Concurrent (<5 minutes) and collocated (<1 km) cloudy data points* from CATS and MISR were chosen for our study.
- CATS *top-layer height* = “True” CTH.
- Opacity of cloud layer is given by the *layer-integrated attenuated backscatter (γ)* from CATS.
- Terra MODIS CTH were also compared.

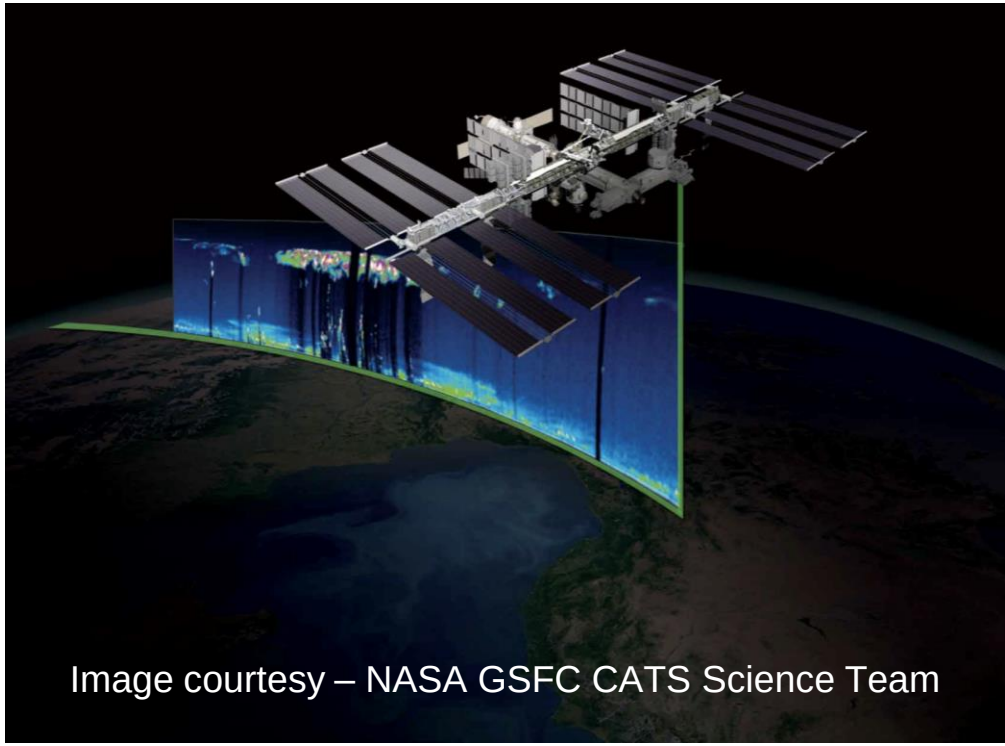
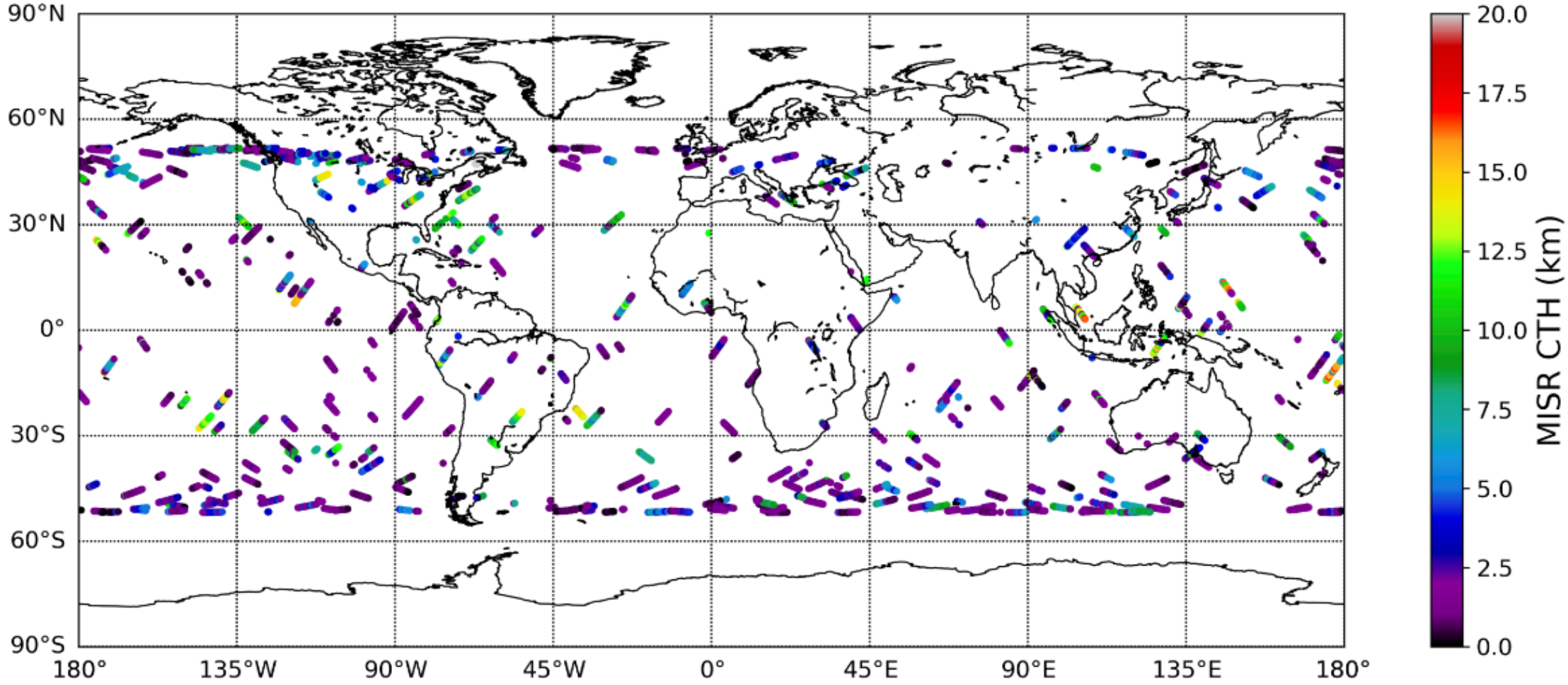


Image courtesy – NASA GSFC CATS Science Team

Level 2 Data

(a) MISR – TC_CLOUD v001 (1.1 km resolution)
(b) CATS - Version 2.01 Product (5 km horizontal, 60 m vertical resolution)

3. Comparison with CATS lidar



Global Map of CATS-MISR collocations with MISR CTH

3. Comparison with CATS lidar

Key Questions :

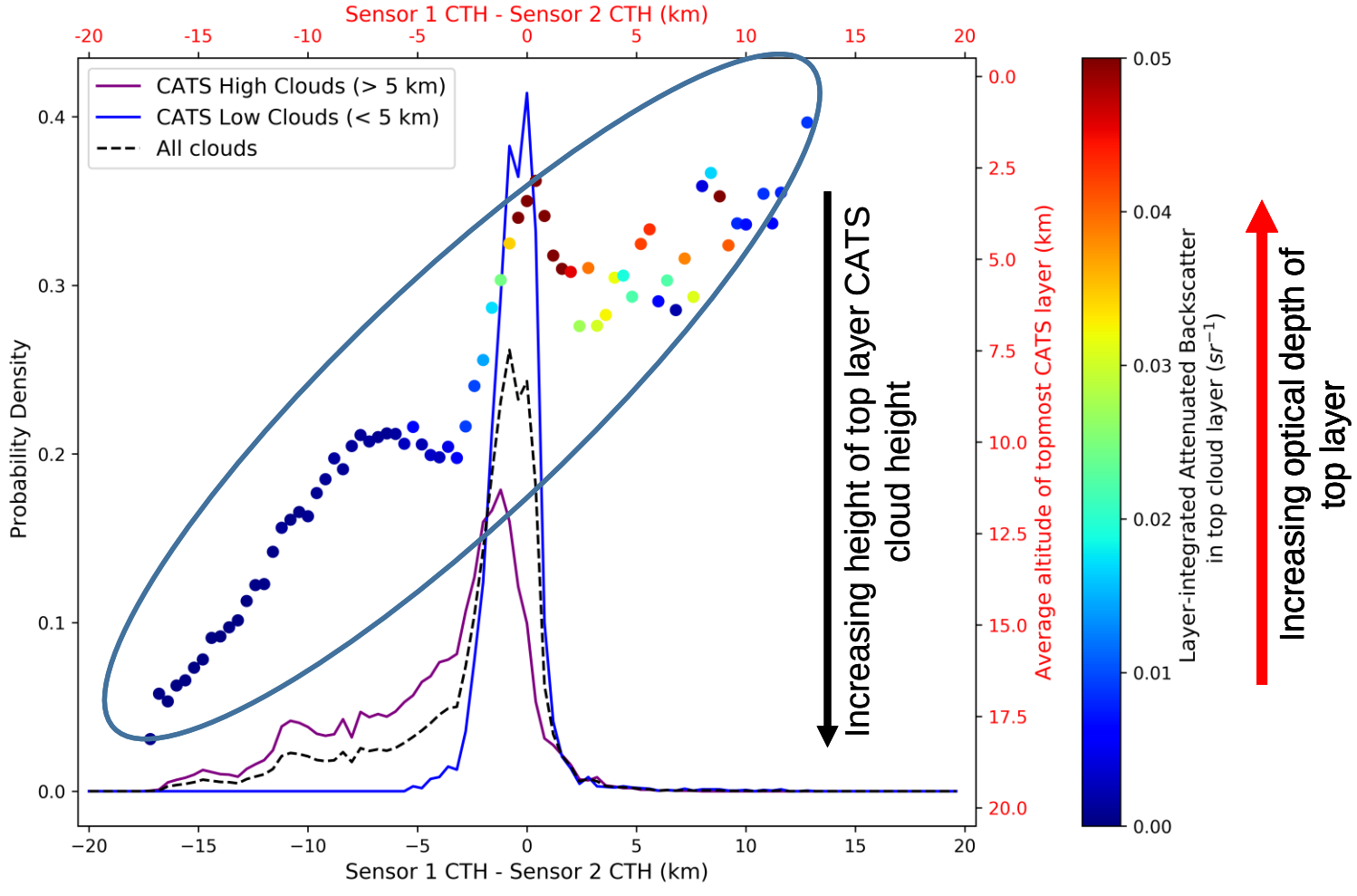
MISR is extremely sensitive to low-level clouds.

- What is the estimated bias and precision?
- How does CTH bias vary with cloud type?

MISR retrieves low-level CTH even in the presence of high cirrus.

- How thick does the cirrus have to be before stereo can detect it?

4. Methodology and Findings



Histograms are *approximately Gaussian.*

Bias : Deviation of peak or mode from zero.

Precision : FWHM/(2 log 2), where FWHM is the full-width at half maximum.

These statistics are not susceptible to outliers, unlike mean and SD.

4. Methodology and Findings

- **MISR CTH errors:**

  (a) Cloud altitude :
  - *Low clouds (CATS CTH < 5 km)* : -320 ± 254 m
  - *High clouds (CATS CTH > 5 km) :* -540 ± 593 m

  (b) Cloud opacity for low clouds:
  - *'Optically thin' (OD < ~1) :* -320 ± 309 m
  - *'Optically thick' (OD > ~1) :* -280 ± 257 m

- MISR is *sensitive to lower layer in a 2-layered system, if upper-layer OD < ~0.4*, hinting at the possibility of an **"opacity threshold"** required for detection.

5. Stereo-Opacity and Wind-related Bias

Only unbroken and single-layered clouds

Instrument	Overall		High (CATS CTH > 10 km)		Mid-level (10 km > CTH > 5 km)		Low (CATS CTH < 5 km)	
	Bias (m)	Precision (m)	Bias (m)	Precision (m)	Bias (m)	Precision (m)	Bias (m)	Precision (m)
MISR	-282	373	-305	396	-373	401	-237	302

MISR overall CTH bias : *-282 m.*

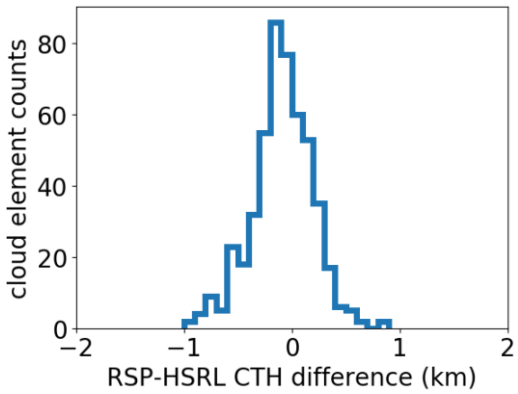
Contributors :

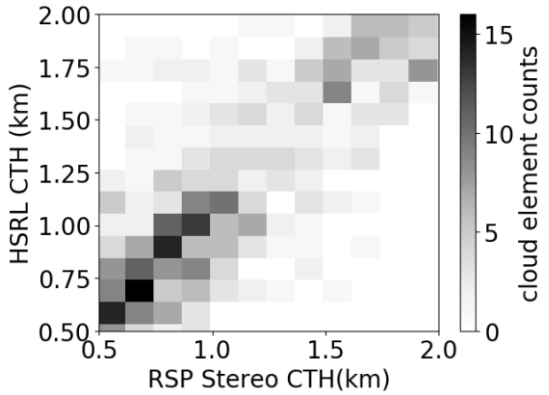
- **Radiance Co-registration error** : -28 m
- **Wind-driven bias** (*based on wind-height biases reported in Horvath 2013, compared to METEOSAT motion vectors*) :
  Low clouds: -144 m
  High clouds: -72 m
- **Stereo-Opacity Bias** *(limits estimated by first assuming biases to be free from wind-driven bias, and then including wind-driven bias)**:
  Low clouds : -65 to -209 m
  High clouds : -205 to -277 m

* First estimate of a stereo-opacity CTH bias

6. CAMP2Ex P3 estimates of Stereo Bias

(a) Stereo-Opacity Bias – Redo similar analysis using *RSP & HSRL* (Dongwei Fu) ~ -104 m.





(b) Wind-driven bias – Stereo reconstruction using all-sky camera (Jesse Ray Loveridge)

Wind estimates will be obtained from dropsondes and mini-reanalysis.

Near-surface retrievals can be used to inform co-registration errors.

7. Conclusions and Future Work

- **MISR vs CATS CTH Comparison**
  - First robust quasi-global validation of MISR Stereo CTH.
  - MISR *bias (-282 m)* and *precision (373 m)* are robust for decadal climate analysis.
  - *First estimate of stereo-opacity CTH bias (-65 to -277 m)*.
  - Independent estimates of global *wind-driven stereo CTH bias (-72 to -144 m), first against a lidar*.
- **Future work:**
  - Independent validation of findings against CAMP2Ex P3 observations, free from geo-collocation issues.
  - Radiative transfer simulation investigation into the physical nature of “opacity threshold” for stereo detection of a cloud layer.