Contributions of the NASA CALIPSO/CloudSat Missions and its Science Team, and the Future of NASA Mission-Related Research Efforts

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With:

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Current Status of CALIPSO and CloudSat Missions

Instrument Status:

- Both instruments stopped taking observations in 2023.

Mission Status:

- Mission teams are working on producing and archiving final data products.
  - All CALIPSO version 5 (final version) data processing has been completed and will be archived at the ASDC and ICARE. V5 is not yet available.
  - The CALIPSO final report has been submitted and is going through approval process, will be published as a NASA Technical Report (~Spring, 2026).
  - CloudSat final data processing is continuing after delays and won't be complete until October, 2026.
  - Will be available from the GSFC DAAC October, 2026.

CCST Science Team Status:

- The CALIPSO/CloudSat Science team lasted from 2006 – 2025 – (I managed since 2009).
- ROSES 24 combined PMM/CCST solicitation was the last NASA CCST solicitation.
  - 39/121 proposals identified as "selectable." (19 from CCST funds)
  - Many of the CCST proposals proposed work with EarthCARE - as requested in solicitation.
  - 4 PMM and 1 CCST proposals were selected and provided funding.
  - Ability to select proposals was constrained by FY 2026 Budget Uncertainty
  - Converting more "Selectable" proposals to "Selected" will depend on eventual FY 26 budget.

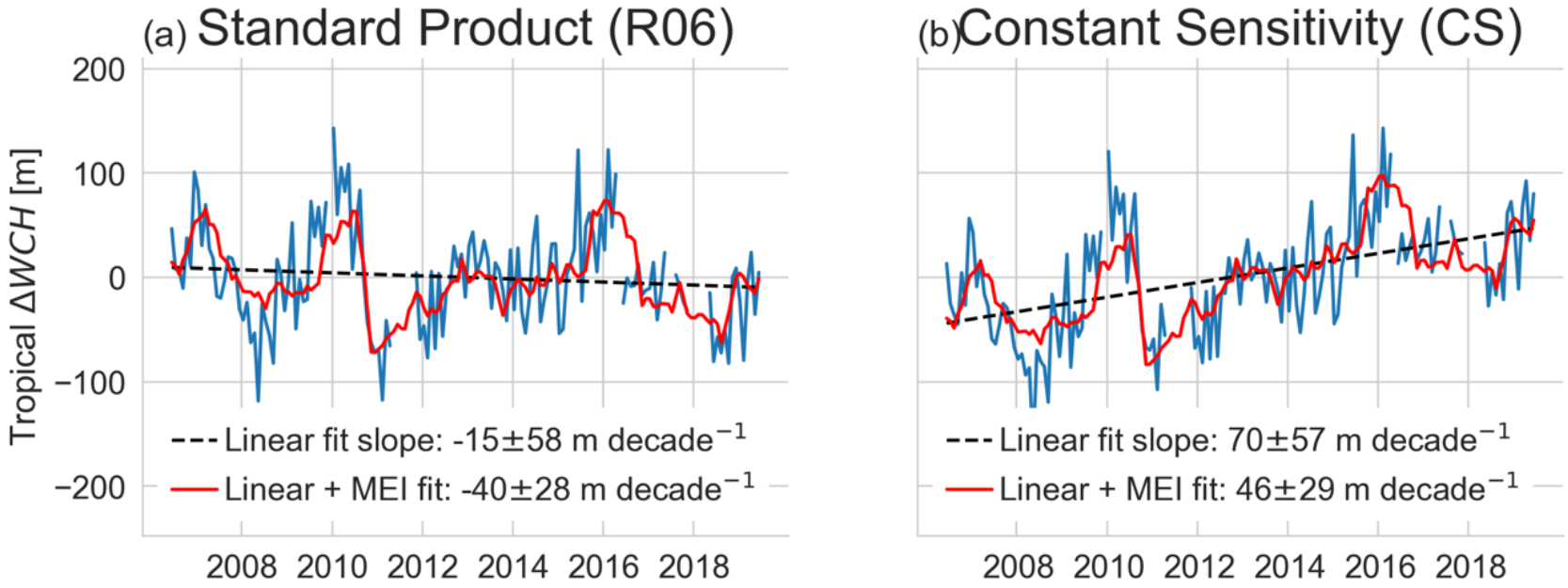
FUNDED IN ROSES 24 CCST SOLICITATION

A merged CloudSat/EarthCARE radar climate data record

PI: Matthew Lebsock, JPL COI: Roger Marchand, U. Washington

Objective

We will develop a radar Climate Data Record (CDR) that intercalibrates and combines CloudSat and EarthCARE reflectivity measurements, and accounts for changes in sampling and sensitivity (among other factors). We will analyze the CDR to ensure consistency of the product, while also looking for expected climate trends.



Changes in tropical (30 °S—30 °N) weighted cloud height properties from the standard CloudSat product (a) and from the constant sensitivity product (b). The dashed black line is a simple linear regression while the red line is a best fit to multiple regression which, in addition to slope and intercept, includes the MEI (ENSO) with a four-month lag. In each case the legend reports the slope component of the fit with the $p<0.05$ confidence interval.

Important Changes to NASA ESD Science Team Organization

Sat 1

3 Year ST → 3 Year ST → 3 Year ST → 3 Year ST → • • • •

Satellite 1 Competed Science Team

Sat 2

3 Year ST → 3 Year ST → 3 Year ST → 3 Year ST → • • • •

Satellite 2 Competed Science Team

Previous: Independent Science Teams for each instrument beginning ~ 1 year post launch, continuing until End of Mission

Sat 1

3 Year ST → 3 Year ST

Satellite 1 Competed Science Team

Sat 2

3 Year ST → 3 Year ST

Satellite 2 Competed Science Team

Sat 3

3 Year ST → 3 Year ST

Multi-Source Integrated Observatory (MIO) Program

Organized around themes: water, …..

Funding from ESD "Research Spheres"

Atmosphere, Biosphere, Cryosphere/Geosphere, Hydrosphere

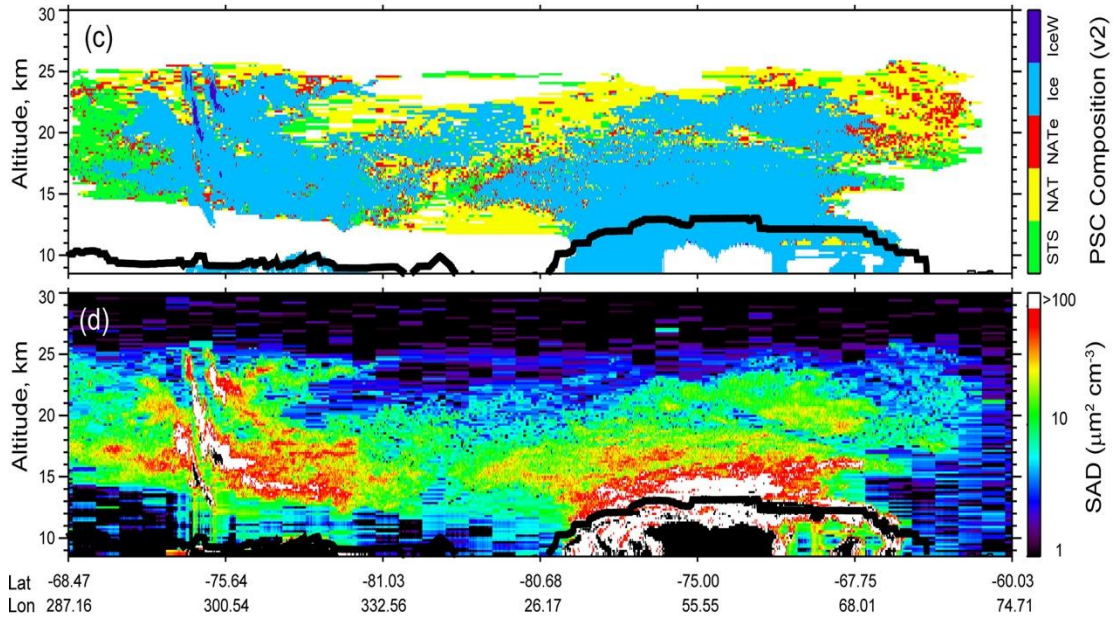
New: Independent Science Teams for each instrument beginning ~ 1 year post launch for 2 cycles only, with subsequent incorporation into Multi-Integrated Observatory Program

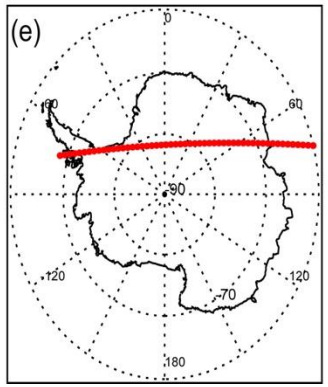
Science Team Characteristics, 2006 - 2025

Total Funding, 2025 Dollars	**123.4 M**
Number of Unique PIs	109
Number of Unique Investigations	178
Average Funding per Investigation	231 k

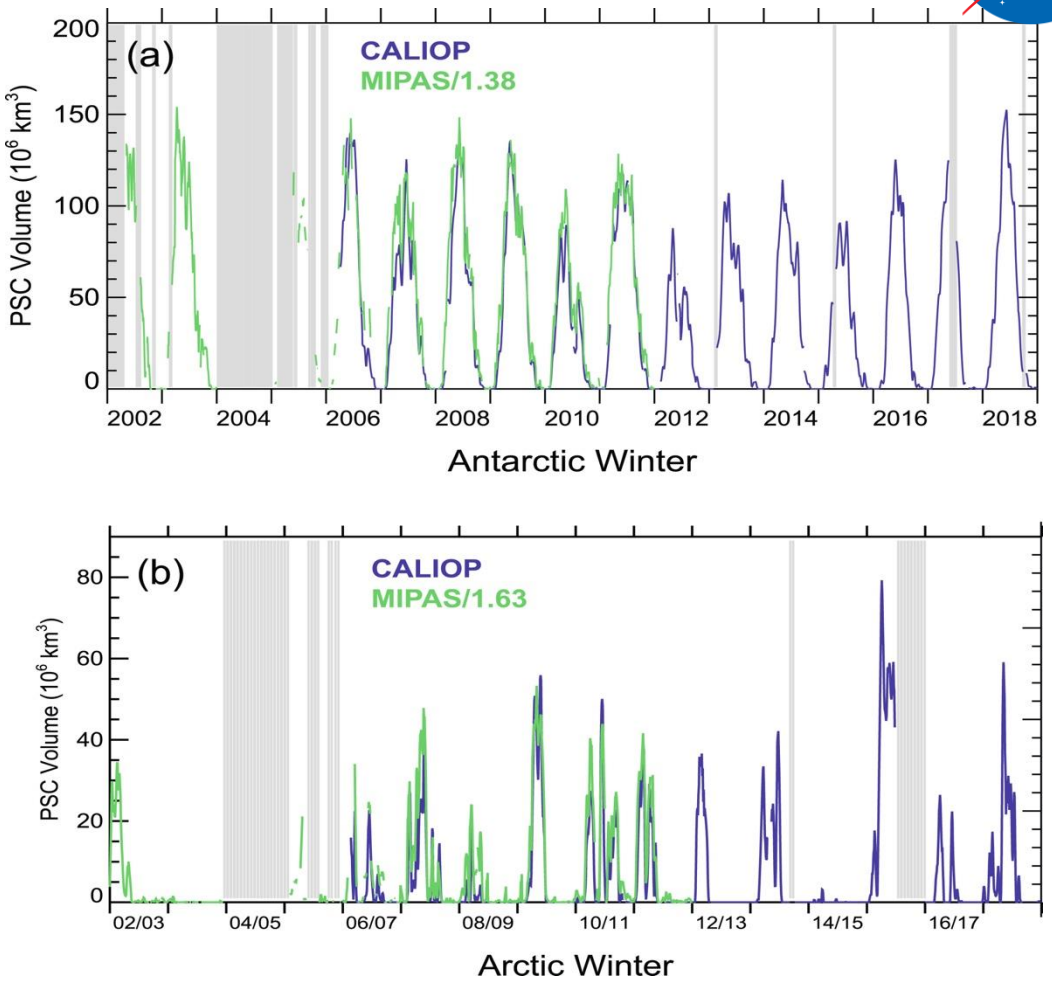
- Science Team funding was not only source of NASA funding for CALIPSO/CloudSat – several other programs funded studies:
  - Radiation Sciences Program
  - Atmospheric Chemistry, Modeling and Prediction (ACMAP)
  - Modeling, Analysis and Prediction (MAP)
  - Interdisciplinary Science Program
  - Terra/Aqua Science Team
  - Precipitation Measurement Mission

CALIPSO/CloudSat ST Contribution: Polar Stratospheric Clouds





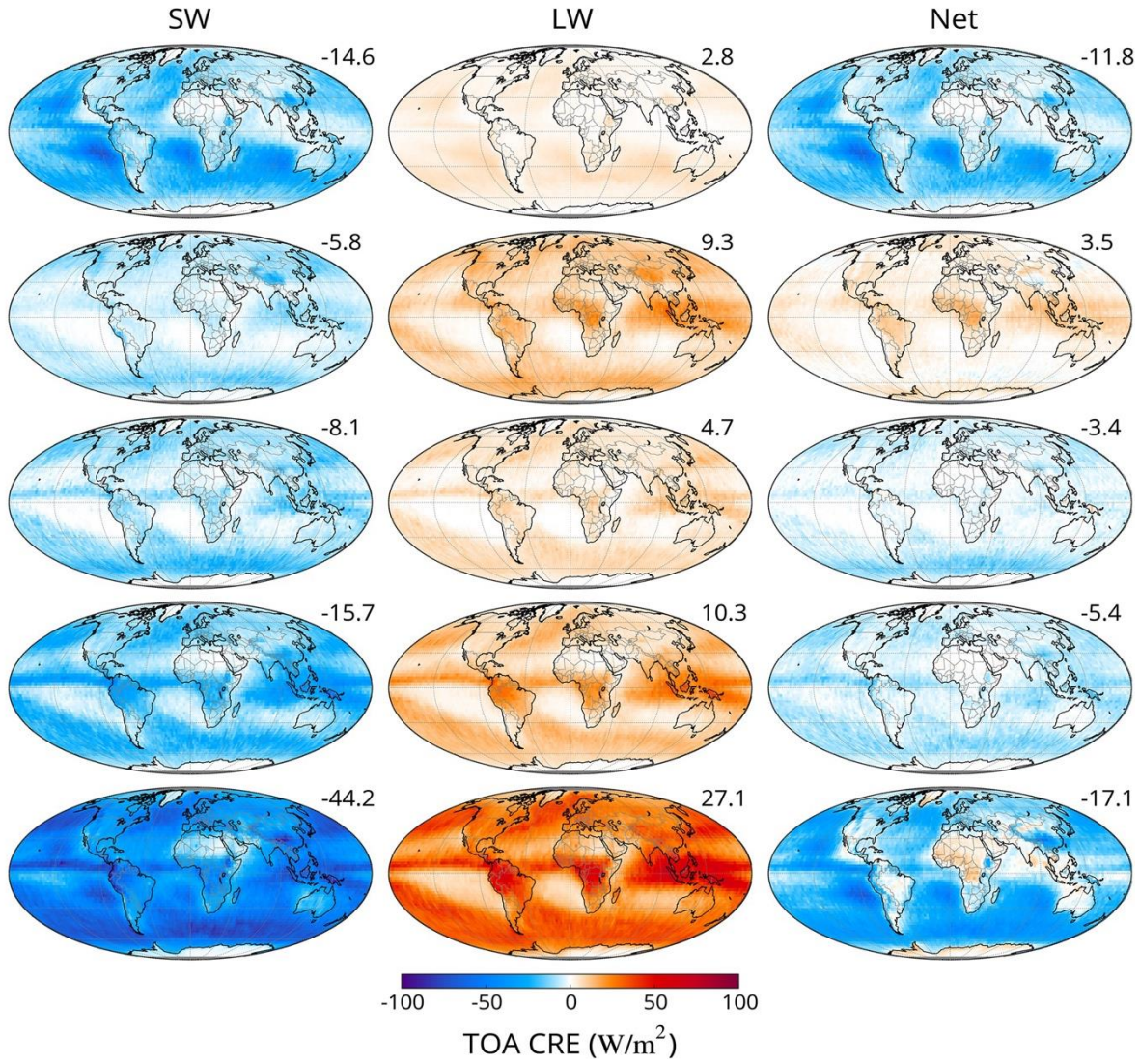
CALIPSO orbit across the Antarctic on July 17, 2008 of (c) inferred PSC composition; (d) estimated SAD, and (e) map showing location of orbit track. Thick black line in panels (c) and (d) indicate the MERRA-2 tropopause heights.



CALIOP and scaled MIPAS daily PSC volumes for 2002–2018 for (a) Antarctic, May-September and (b) Arctic, December-March. Light gray vertical stripes indicate periods with no data. Note the different scales in (a) and (b).

Tritscher, I., Pitts, M. C., Poole, L. R., Alexander, S. P., Cairo, F., Chipperfield, M. P., et al. (2021). Polar stratospheric clouds: Satellite observations, processes, and role in ozone depletion. *Reviews of Geophysics*, *59*, e2020RG000702. https://doi.org/10.1029/2020RG000702

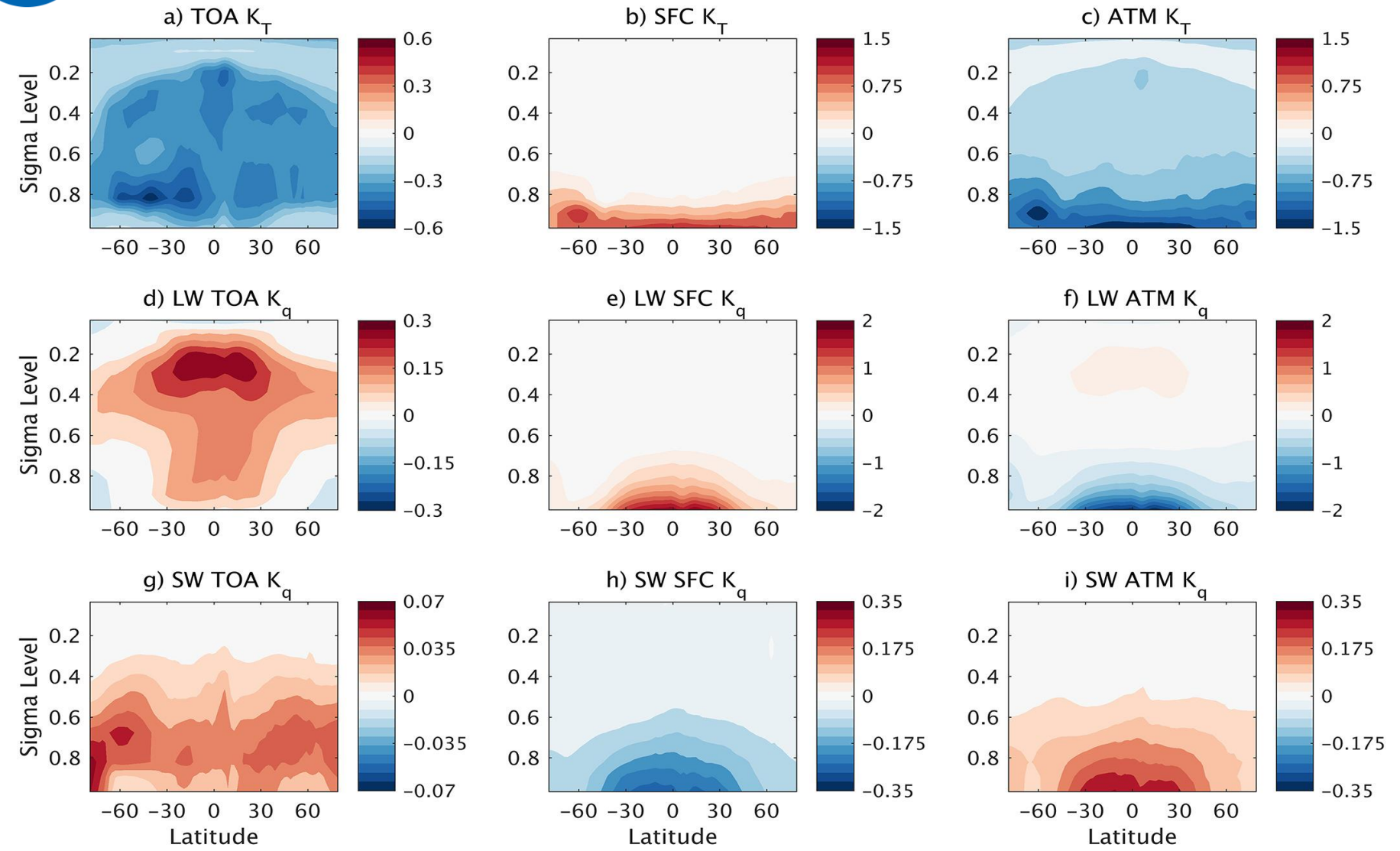
CALIPSO/CloudSat ST Contribution: TOA Cloud Radiative Effects



Annual average SW, LW, and net cloud radiative effects at the top of atmosphere (TOA). Radiative effects are separated by water phase (liquid, ice, mixed, and multilayered) using R05 FLXHR-LIDAR, 2007–2010.

Matus, A. V. and T. S. L'Ecuyer (2017), *J. Geophys. Res. Atmos.*, 122, 2559–2578, doi:10.1002/2016JD025951.

CALIPSO/CloudSat ST Contribution: Observed Radiative Kernels



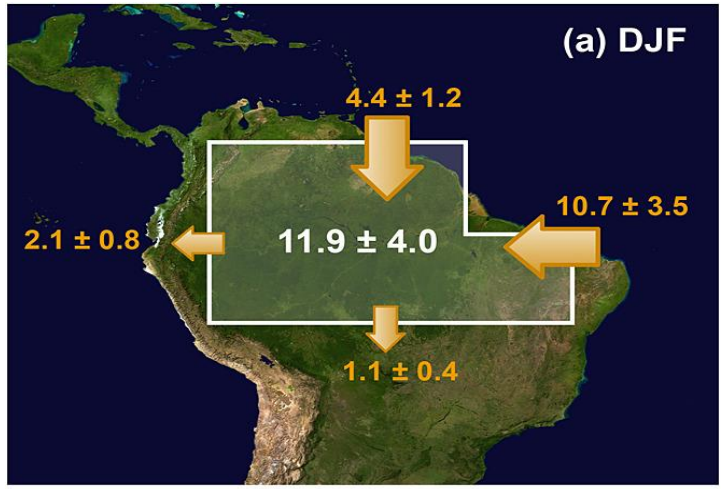
$$K_x = \frac{\partial R}{\partial X}$$

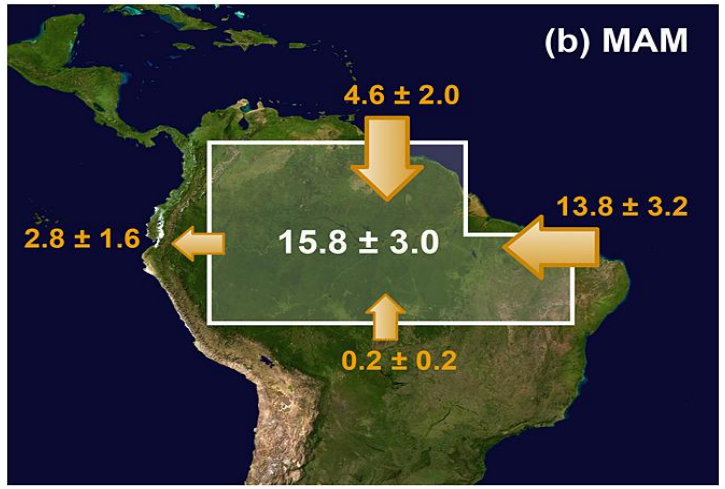
$$\lambda_\chi = K_\chi \frac{\partial \mathcal{X}}{\partial \mathrm{T}}$$

Zonal, annual mean all-sky air temperature (a–c), longwave water vapor (d–f), and shortwave water vapor (g–i) CloudSat radiative kernels ($W \cdot m^{-2} \cdot K^{-1} \cdot 100$ hPa) for the top-of-atmosphere (a, d, g), the surface (b, e, h), and the atmospheric column (c, f, i)..

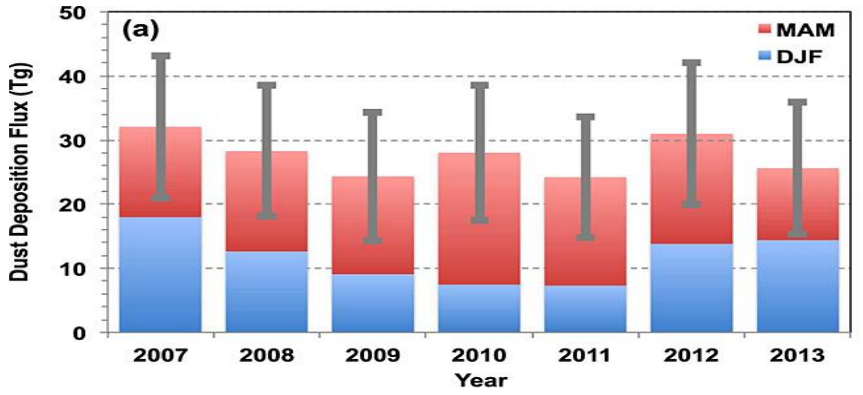
Kramer, Matus, Soden, L'Ecuyer - JGR Atmospheres, 124, (10), 5431-5444,, DOI: (10.1029/2018JD029021)

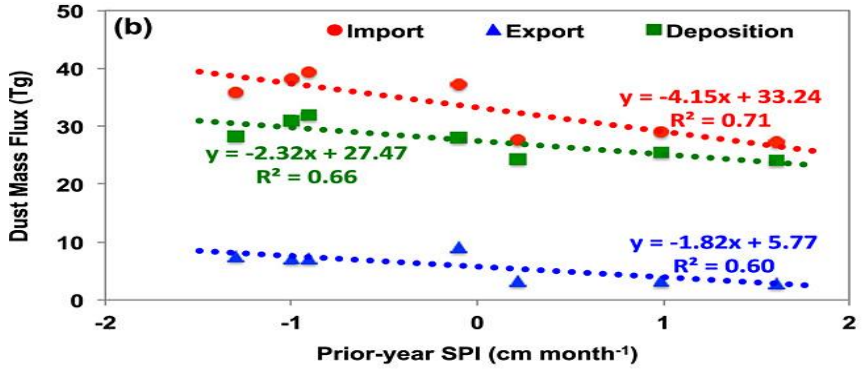
CALIPSO/CloudSat ST Contribution: Dust Transport to Amazon

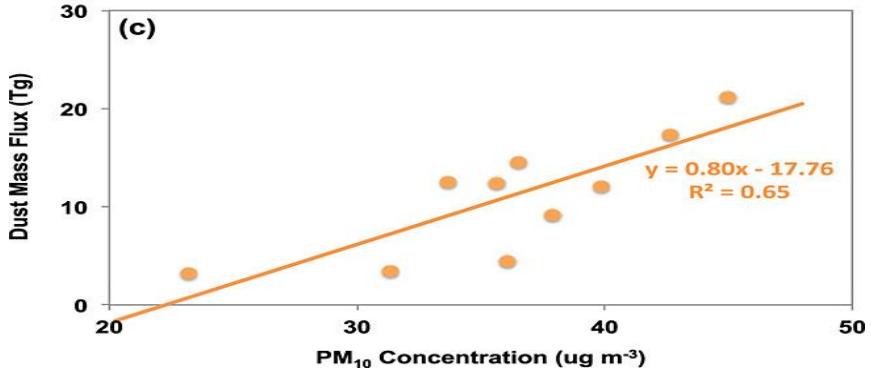




CALIOP-estimated seasonal dust mass fluxes (orange), and deposition (white): (a) DJF and (b) MAM. (Tg).







(a) CALIOP estimates of dust deposition (Tg) into the Amazon Basin (blue for DJF and red for MAM)
(b) Correlation of DJF + MAM total dust import, export and deposition with prior-year Sahel Precipitation Index (SPI).
(c) Correlation of seasonal zonal dust mass into the Amazon Basin with PM10 at Cayenne French Guiana.

Yu, H., et al., (2015), *Geophys. Res. Lett.*, 42, 1984–1991. doi: 10.1002/2015GL063040.

Current NASA Radar/Lidar Development Efforts: Funded in ROSES 2023 Instrument Incubator Program

- **Next Generation of Intelligent Meteorological Radar with Built-in Understanding of the Scenery (NIMBUS) - Raquel Rodriguez Monje, Jet Propulsion Laboratory**
  - Develop and demonstrate an ultra-compact mm-wave multifrequency radar with onboard intelligence for profiling observations of clouds, convection and precipitation

- **Global Orbital Research with a Diurnal Observing Network (GORDON): Towards Realizing the Potential of Affordable Spaceborne Lidar - Matthew McGill, University of Iowa**
  - Focus on developing inexpensive smallsat/cubesat lidar approaches suitable for constellation flying.

Summary:

- Full mission CALIPSO/CloudSat data products will be freely available and constitute a significant resource for EarthCARE. Final products have not yet been uploaded to the NASA archives, but will be by end 2026.
- Significant opportunities to combine CC with EarthCARE data for e.g., trend studies.
- The CALIPSO/CloudSat Science Team produced many important results exploiting over the 19 years of funding it received. CCST papers in total approach 5,000.
- The future of NASA's involvement in active remote sensing focused on clouds and aerosols depends on available budget.
  - "The spirit is willing – but will the funding be weak?"
  - NASA Earth Science Technology Office (ESTO) is currently funding development efforts in radar and lidar remote sensing that may lead to future missions.
- The ball is now solidly in EarthCARE's capable hands, and an exciting future awaits!

Thank You Very Much for the Opportunity!