

THE RADIATIVE IMPACT OF OPTICALLY THIN CIRRUS CLOUDS IN THE SHORTWAVE RADIATION BUDGET

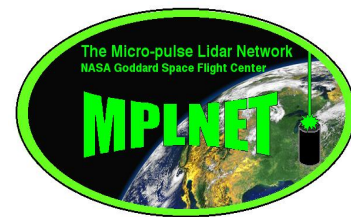
S. Lolli and the MPLNET Team



NASA –JCET Goddard Space Flight Center, Greenbelt 20771, MD, USA



The Micro-Pulse Lidar Network: MPLNET



Principal Investigator:

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CALIPSO Validation Activities:

Judd Welton, James Campbell

AERONET & Synergy Tool Partnership:

Brent Holben, NASA GSFC Code 614.4

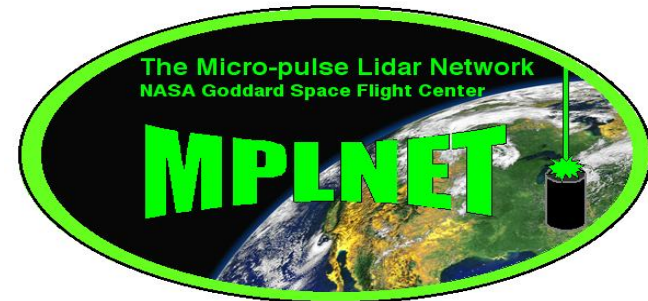
Dave Giles, NASA GSFC Code 614.4

NASA SMARTLABS Field Deployments:

Si-Chee Tsay, NASA GSFC Code 613

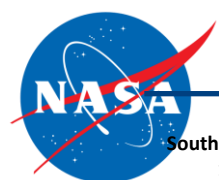
Site Operations & Science Investigations

.... many network partners around the world



MPLNET information and results shown here are the result of efforts by all of our network partners!

MPLNET is funded by the NASA Radiation Sciences Program and the Earth Observing System

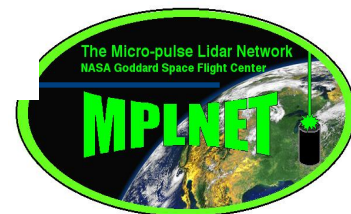


South Pole MPLNET Site:
1999-current

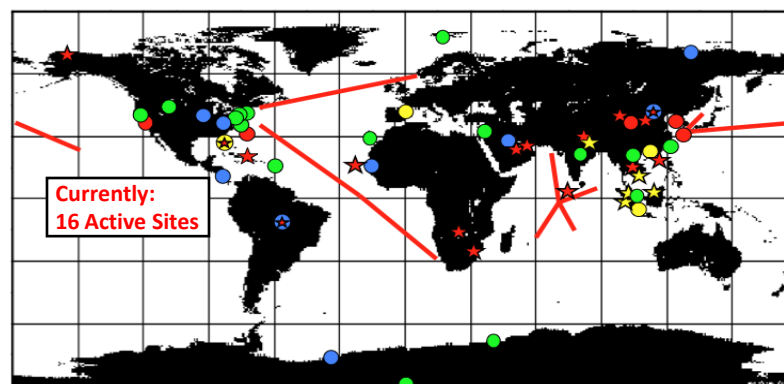


MPLNET Overview

Micro Pulse Lidar
(GSFC Patent)



MPLNET Sites: 2000 - current



- | | |
|---|--|
| ■ active | ○ long term site |
| ■ inactive | ☆ field campaign |
| ■ planned | ⊗ former field campaign, planned/proposed site |
| ■ proposed | — ship cruise |

* most sites co-located with AERONET

MPLNET: 8.8 Trillion Laser Shots, 59 Mminutes of data and counting...

- A federated network of micro pulse lidar sites around the world, coordinated and lead from Goddard Space Flight Center
- **Co-location with related networks, including NASA AERONET**
- Local, regional, and global scale contributions to atmospheric research
- Satellite validation
- Aerosol climate and air quality model validation
- Impact of aerosol & cloud heights on direct and indirect climate effects
- Support for wide variety of field campaigns

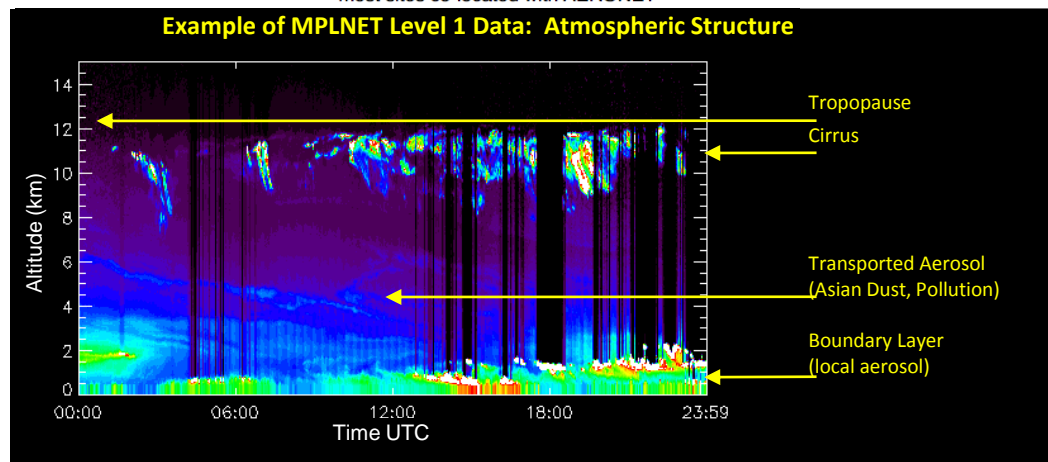
What's New?

- Penang new site August 2014, Barcelona June 2015
- More sites in Africa and in South America
- Ongoing interactions with both Aerocom and ICAP communities (climate and operational air quality modeling)

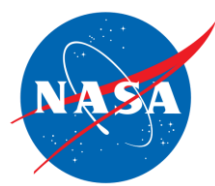
Investigators, Partners, & Collaborators:

- Principal Investigator: Judd Welton/612
- Brent Holben/618
- Si-Chee Tsay/613
- Sebastian Stewart/SSAI/612
- Simone Lolli/JCET-UMBC/612
- Phillip Haftings/SSAI/612
- James Campbell/NRL
- Larry Belcher/SSAI/612
- Jasper Lewis/JCET/612
- All Network Partners Worldwide

Example of MPLNET Level 1 Data: Atmospheric Structure

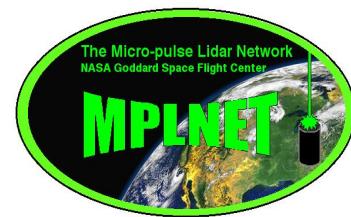


<http://mplnet.gsfc.nasa.gov>



The New V3 Website

<http://kimura.gsfc.nasa.gov>



- Home
- ▶ Sites
- ▶ Data
- Publications
- News
- ▶ About Us
- ▶ Links

Update June 2012: 7 Trillion Laser Pulses, 47 Million Minutes of Data, and Counting!

The NASA Micro-Pulse Lidar Network (MPLNET) is a federated network of Micro-Pulse Lidar (MPL) systems designed to measure aerosol and cloud vertical structure continuously, day and night. Data are collected over the long time periods required to contribute to climate change studies and provide ground validation for satellite sensors in the [Earth Observing System \(EOS\)](#) and related aerosol modeling efforts. Most MPLNET sites are co-located with sites in the [NASA Aerosol Robotic Network \(AERONET\)](#). These joint super sites provide both column and vertically resolved aerosol and cloud data including optical depth, single scatter albedo, size distribution, aerosol and cloud heights, planetary boundary layer (PBL) structure and evolution, and profiles of extinction and backscatter.

MPLNET results have contributed to studies of dust, biomass, marine, and continental aerosol properties, the effects of soot on cloud formation, aerosol transport processes, and polar clouds and snow. MPLNET data has been used to validate and help interpret results from NASA satellite sensors such as [GLAS](#), [MISR](#), and [TOMS](#). MPLNET also serves as a ground calibration network for space-based lidars such as the [Geoscience Laser Altimeter System \(GLAS\)](#) on the [ICESat](#) spacecraft (launched in 2003) and the [Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations \(CALIPSO\)](#) (launched in 2006).

MPLNET is composed of our own sites and others run by, or with help from, partner research groups from around the world. Principal investigators for individual sites may be from NASA, other US government agencies, universities, or foreign research groups. MPLNET is funded by the [NASA Earth Observing System \(EOS\)](#), and the NASA Radiation Sciences Program. In the past, additional funding for research cruises at sea was provided by the [NASA SIMBIOS project](#).

Notice to non-MPLNET Investigators:

To maintain the integrity of the data base and fairness to the individuals who have contributed, use of these data for publication requires an offer of authorship to the MPLNET PI(s). A full description of our data policy is given [here](#).



Sciences and Exploration Directorate
Earth Sciences Division
Laboratory for Atmospheres
Mesoscale Atmospheric Processes

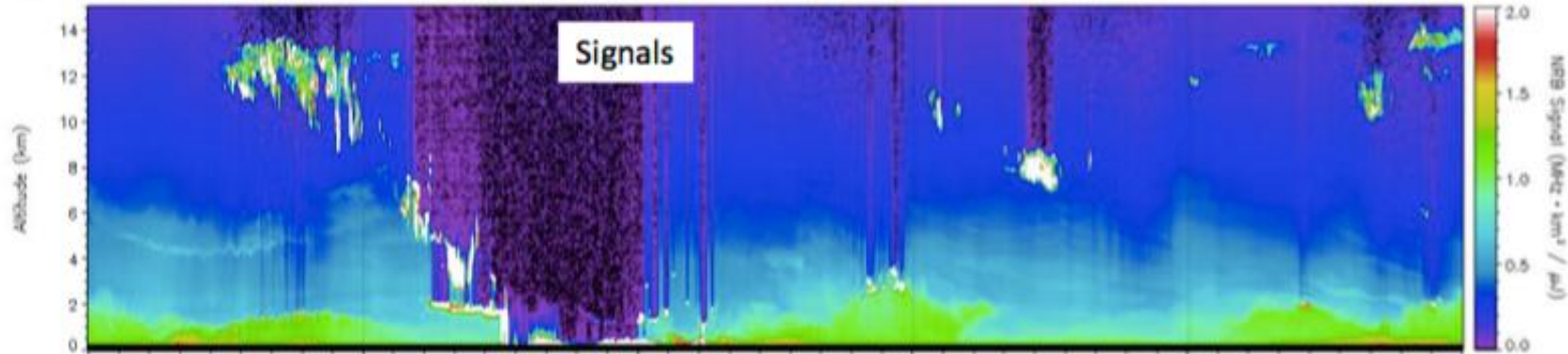
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[GSFC Homepage](#)

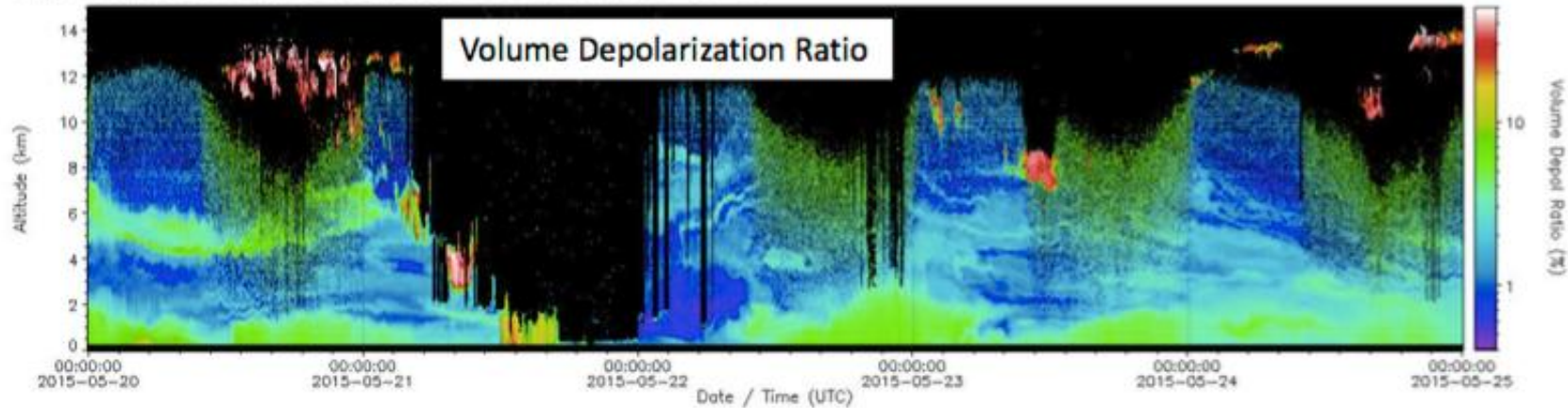




MPLNET RA L1_NRB: GSFC_ra, 2015-05-20 to 2015-05-25



MPLNET RA L1_VDEPOL: GSFC_ra, 2015-05-20 to 2015-05-25



$$NRB(\lambda, R) = \frac{[N_S(\lambda, R) - N_B] T_m^2 T_a^2}{C} R^2$$

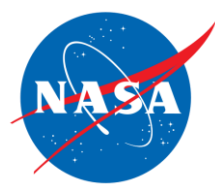
Incorporate both older MPLs and new polarized MPLs

New signal averaging scheme:

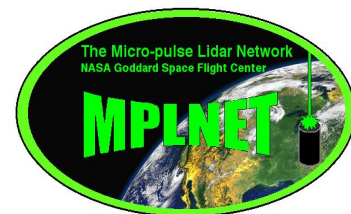
running boxcar average, re-gridded to 1 minute

this applies to all higher level products (-> aerosol retrievals up to cloud edge)

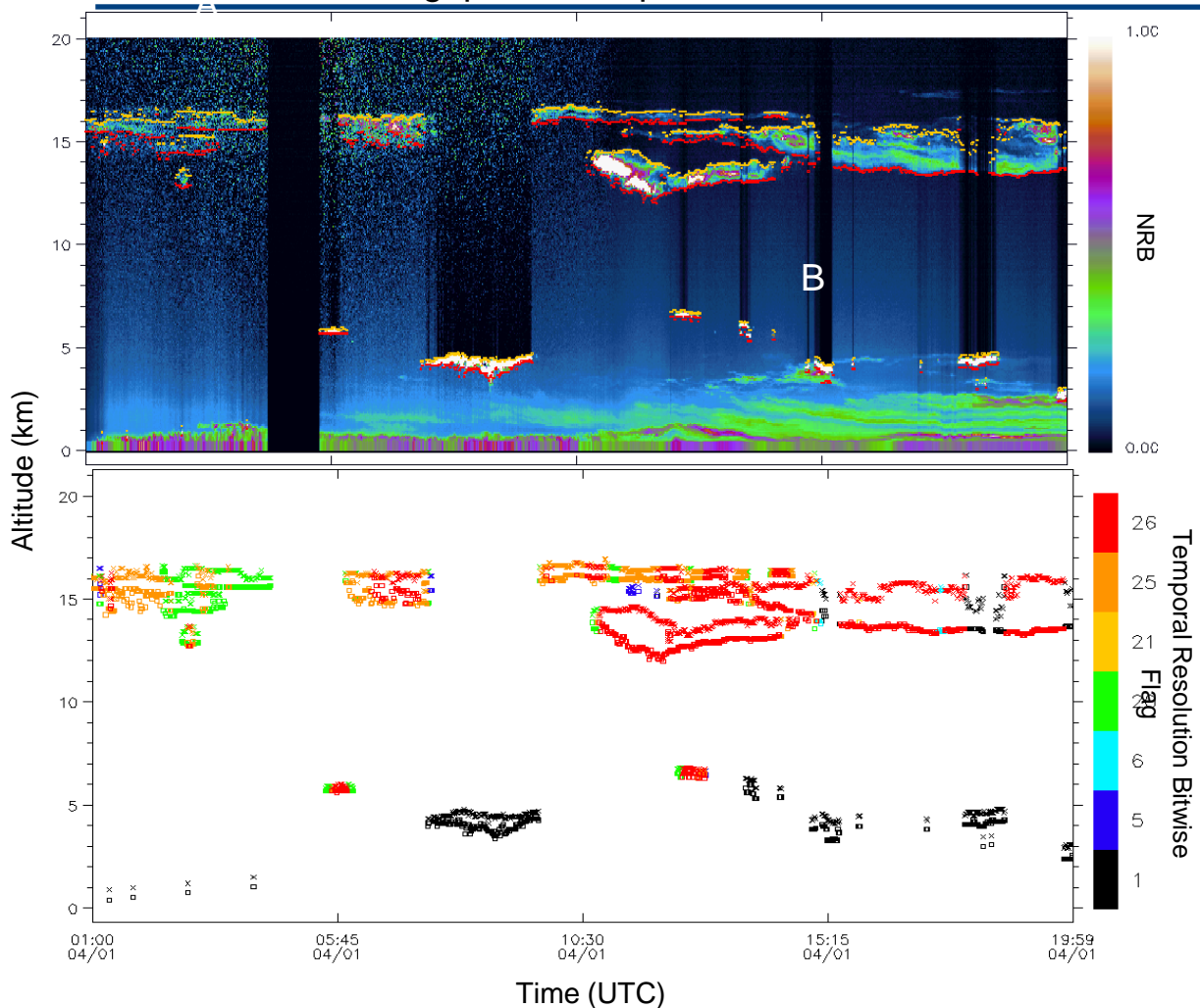
- no data acquired (no raw lidar signal data)
- instrument status (temps, energy, calibrations)
- Failed retrieval (no PBL, Fernald fail, etc)
- Specific product screen (ex. L15V_AER)



The new V3 Cloud Algorithm:



Singapore, 01 April 2012



- A multi-temporal averaging scheme is used to improve performance in weak signal-to-noise.
- Data flags will indicate the temporal resolution used as well as the number of 1-minute profiles included in the average.
- Other data flags indicate:
 - Cirrus (Ice) clouds
 - Day/Night retrievals
 - Data quality
 - Attenuation limit
 - Retrieval Method (GCDM or UCDM)

MPLNET: Version 3 Update



MPLNET Data Products: Version 2 (2006-current) *nctcdf 3, error propagation from raw data to final product*

Level 1: Lidar Signals, Instrument Diagnostics
Latency: < 1.5 hrs most sites, others next day.
No QA Flags, No QA Screening.

Level 1.5: **L1.5b:** Aerosol, PBL, and Cloud Heights
L1.5a: Aerosol Backscatter, Extinction, Optical Depth,
Lidar Ratio (at AERONET times and 24/7 day-to-night)
Latency: next day. Limited QA Flags, No QA Screening.

Level 2: Same as L1.5 above, except no PBL, aerosol only with AERONET
Latency: X months+ after Level 2 AERONET is available.
QA Screening applied.

MPLNET Data Products: Version 3 (in development) *utilizes GEOS-5 met, all data files netcdf 4 CF Compliant*

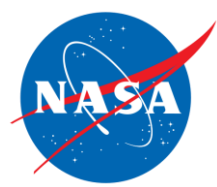
Level 1: Lidar Signals, Instrument Diagnostics, **Volume Depol Ratio**
Latency: < 1.5 hrs. **QA Flags provided**, No QA Screening.

*Online Data Ordering Too
Subset packaging
other formats: nc3, GALION?*

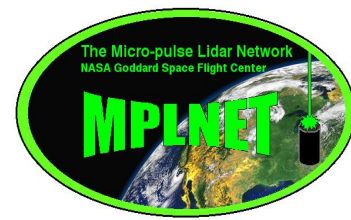
Level 1.5: **Cloud:** Heights, **Phase, Thin Cloud Extinction & Optical Depth**
Aerosol: Height, Backscatter, Extinction, AOD, Lidar & **Depol Ratio**
PBL: Height, PBL AOD
Latency: **< 1.5 hrs for browse images**, data next day. **QA Flags provided**, No QA Screening.

Level 1.5V: **Cloud:** Heights, Phase, Thin Cloud Extinction & Optical Depth
Aerosol: Height, Backscatter, Extinction, AOD, Lidar & Depol Ratio
PBL: Height, PBL AOD
Latency: **< 1.5 hrs for browse images, data next day. ICAP < 1.5 hrs. QA Flags provided, QA Screening.**

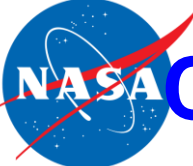
Level 2: Same as L1.5 above.
Latency: X weeks after Level 2 AERONET is available.
QA Flags provided, QA Screening applied.



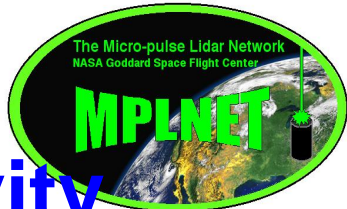
Cirrus cloud Facts



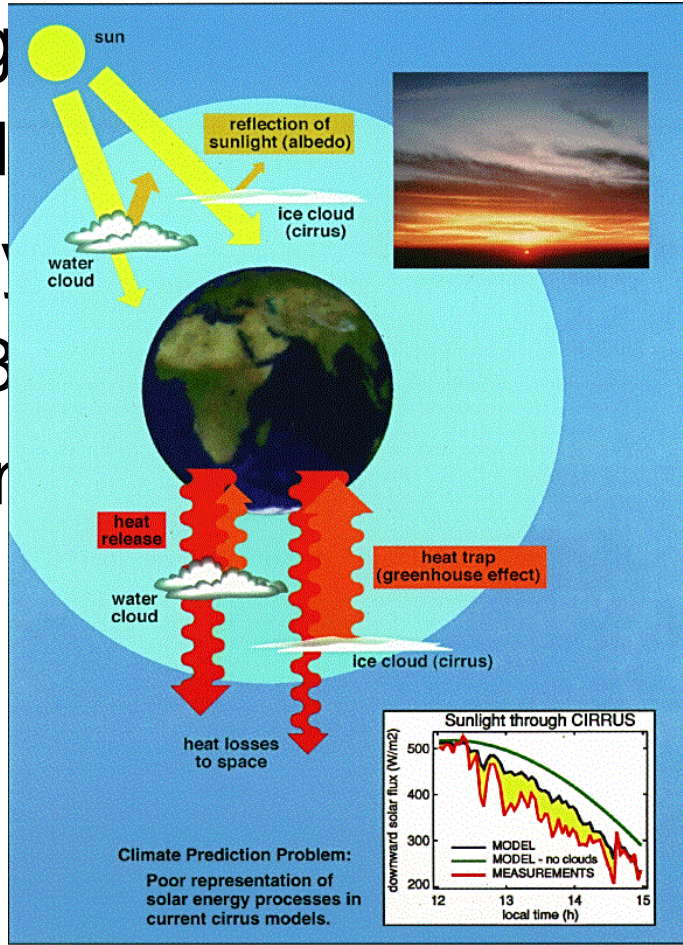
- High level clouds (>12 Km Mid-Lat) consisting purely of ice crystals
- Ice Super Saturated Regions (ISSR) are potentially cirrus formation regions
- Homogenous freezing is probably the dominant freezing mechanism in low temperature / high altitude regimes (< 235 K)
- Cirrus clouds coverage about 20%-30% of the earth surface (up to 70% in the tropics)

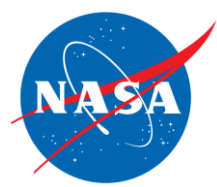


Cirrus Clouds still main source of uncertainty in climate model sensitivity

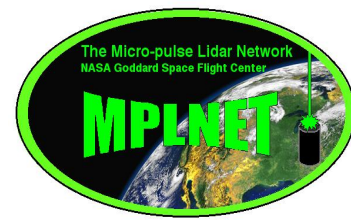


- Modulators of earth radiation budget
- Quantitative information is needed observation, especially on optically thin sub-visible clouds (COD<0.03)
- Cirrus Clouds net radiative forcing
 - Solar Albedo Effect(**C**)
 - Infrared greenhouse effect(**W**)
 - Which effect is outweighing?





Cirrus Clouds Parameterization



Cloud Extinction Profiles are transformed into IWC and Dge profiles through Heymsfield parameterization

- Power Law depending on temperature

$$Dge(z) = a * \exp(b * T) \quad a, b \text{ depending on } T^*$$

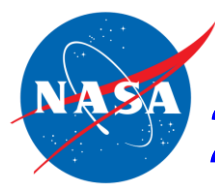
- Ice Water Content :

$$IWC(z) = \alpha(z) * 0.303 * Dge(z)$$

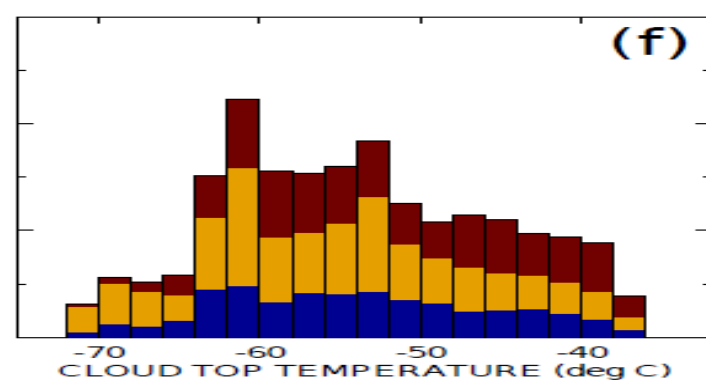
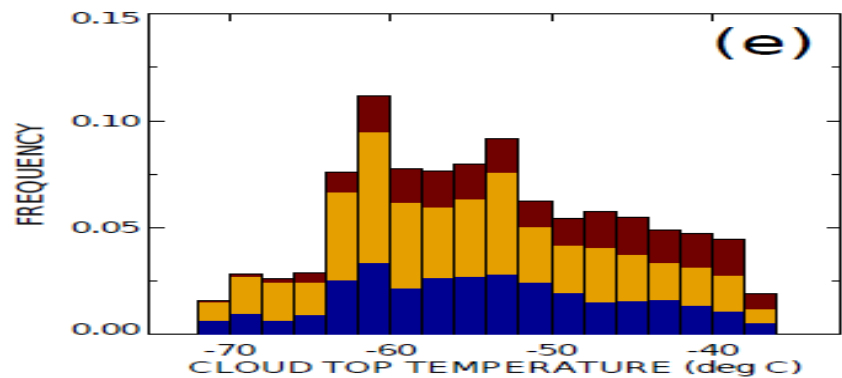
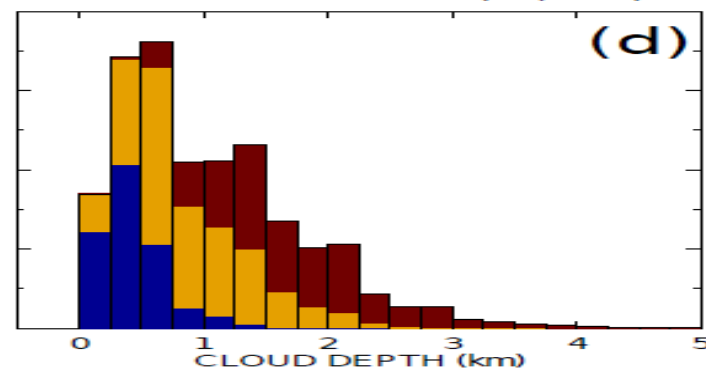
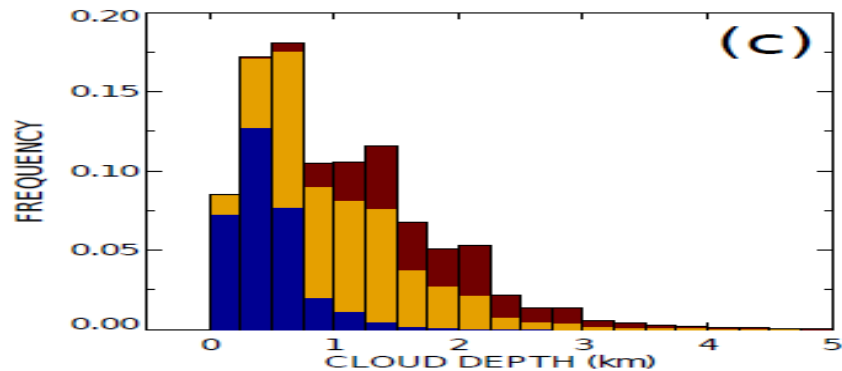
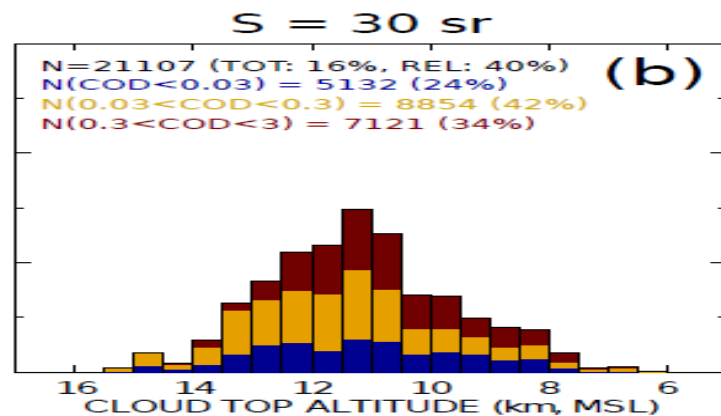
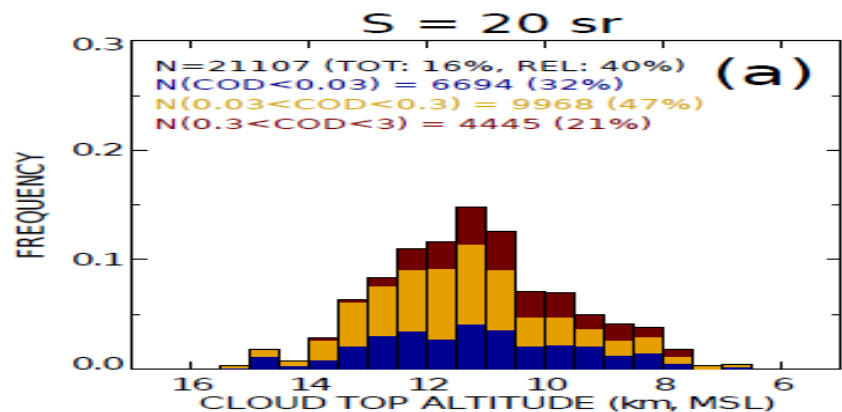
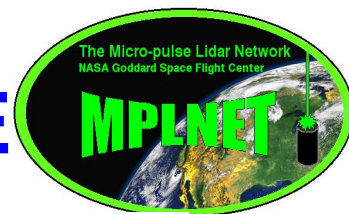
- Cloud Net Radiative Forcing

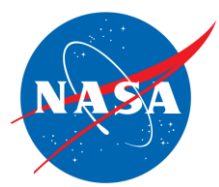
$$CRF^{net} = CRF^{sw} + CRF^{lw} \quad \text{with} \quad CRF^{sw, lw} = F_{cl}^{sw, lw} - F_{clr}^{sw, lw}$$

* T profile is retrieved from Dulles WMO radiosounding network site ¹⁰

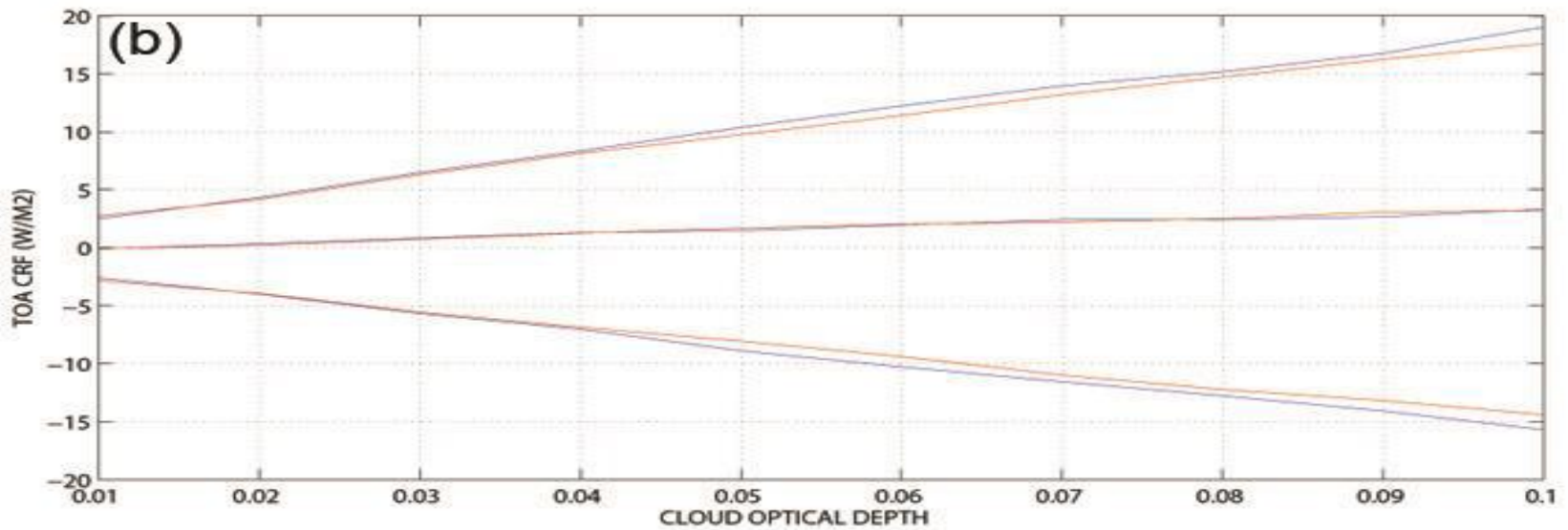
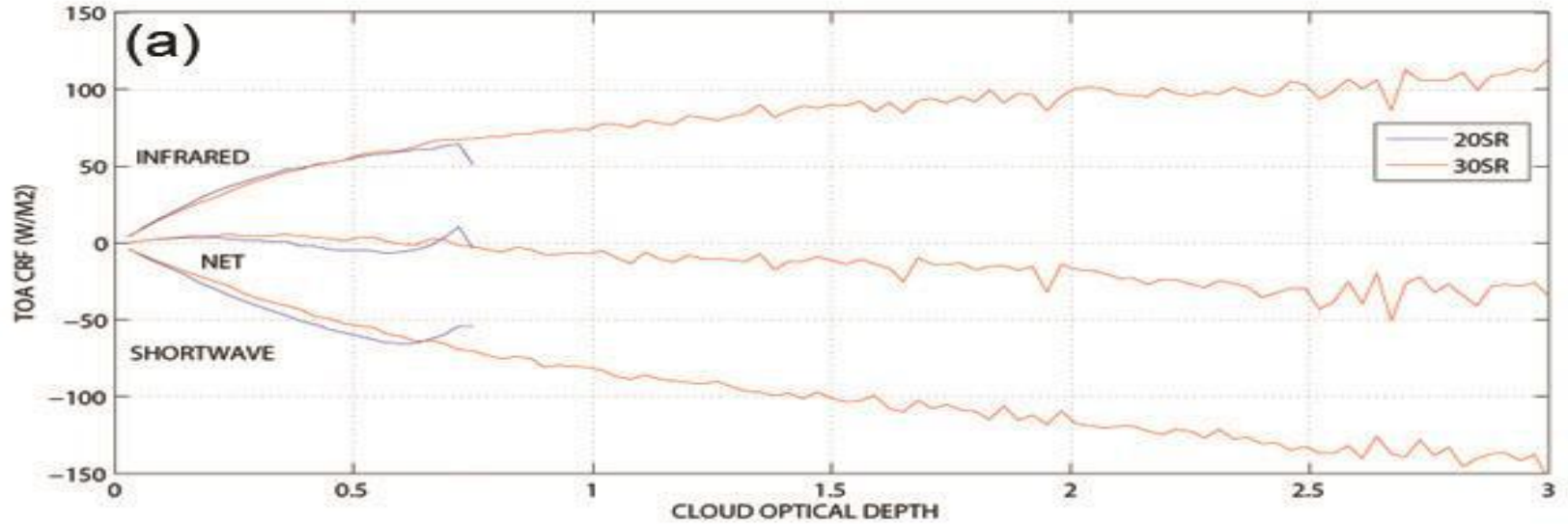
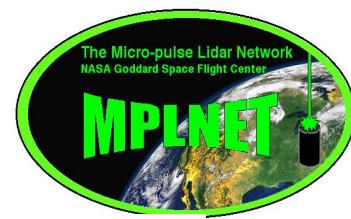


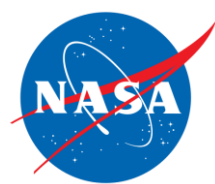
2012 DAYTIME GSFC AT GLANCE



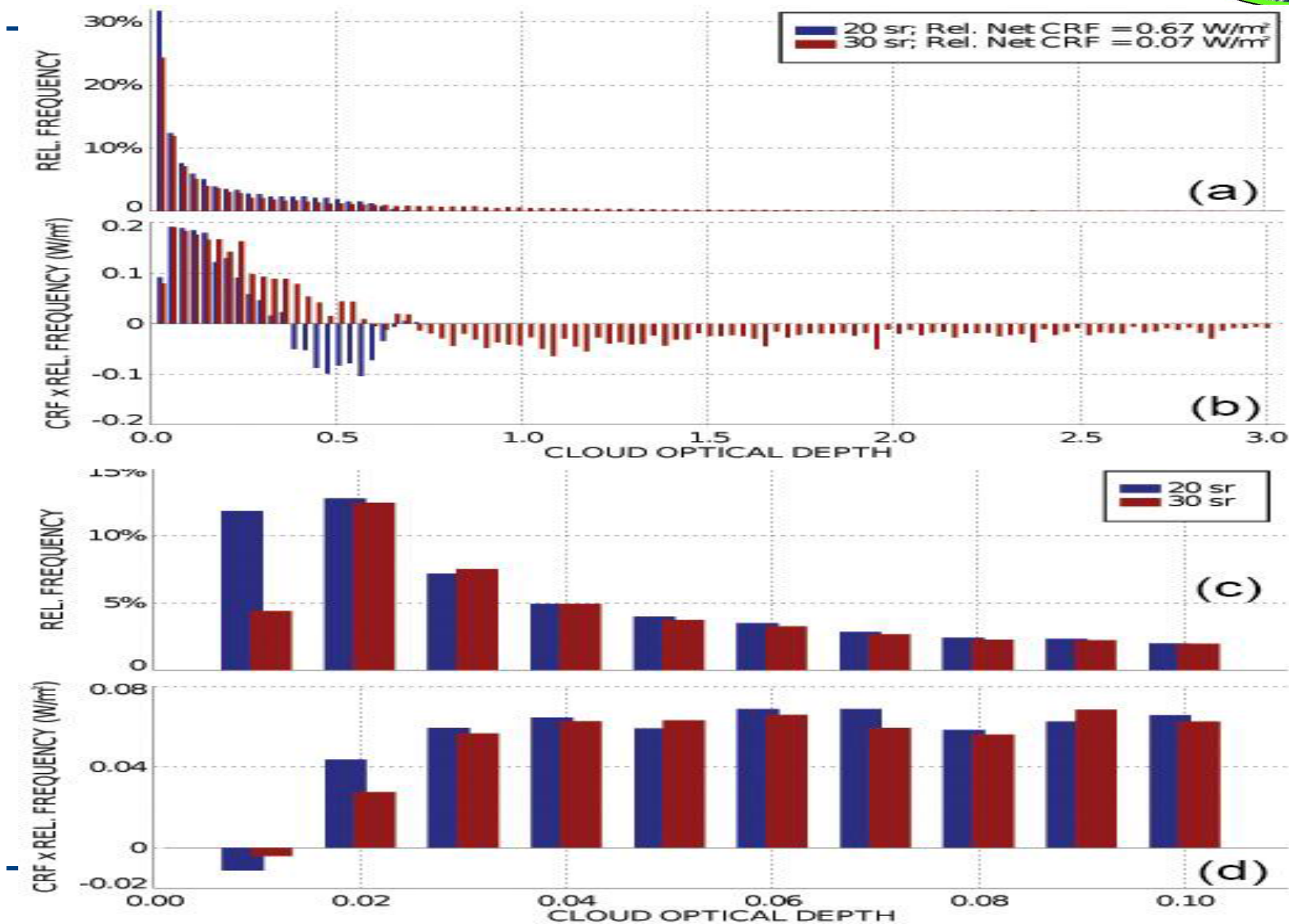
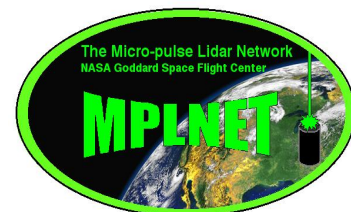


Net Radiative Forcing vs. COD

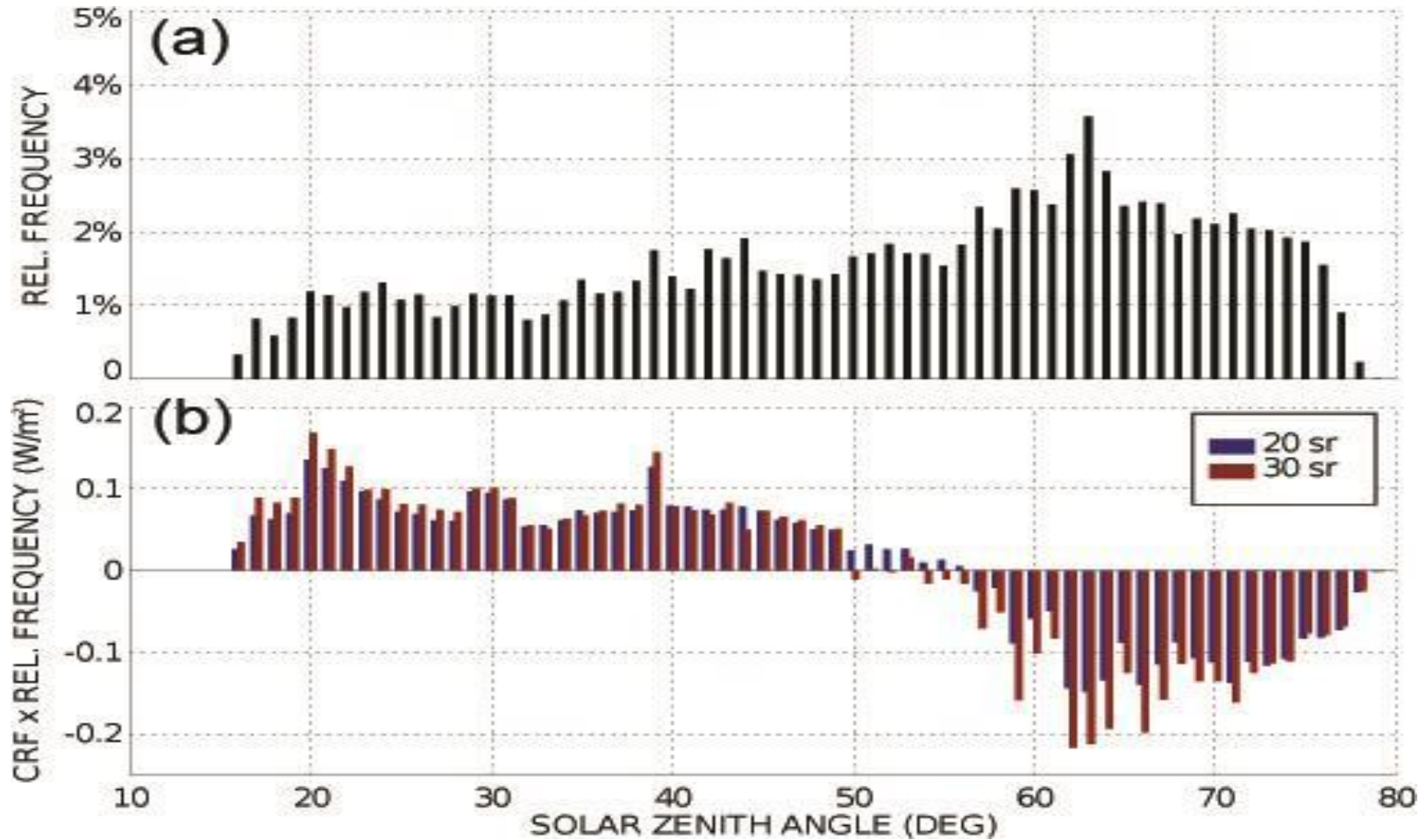




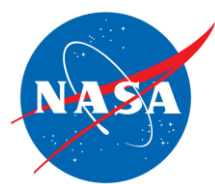
NORM DAYTIME NET FORCING



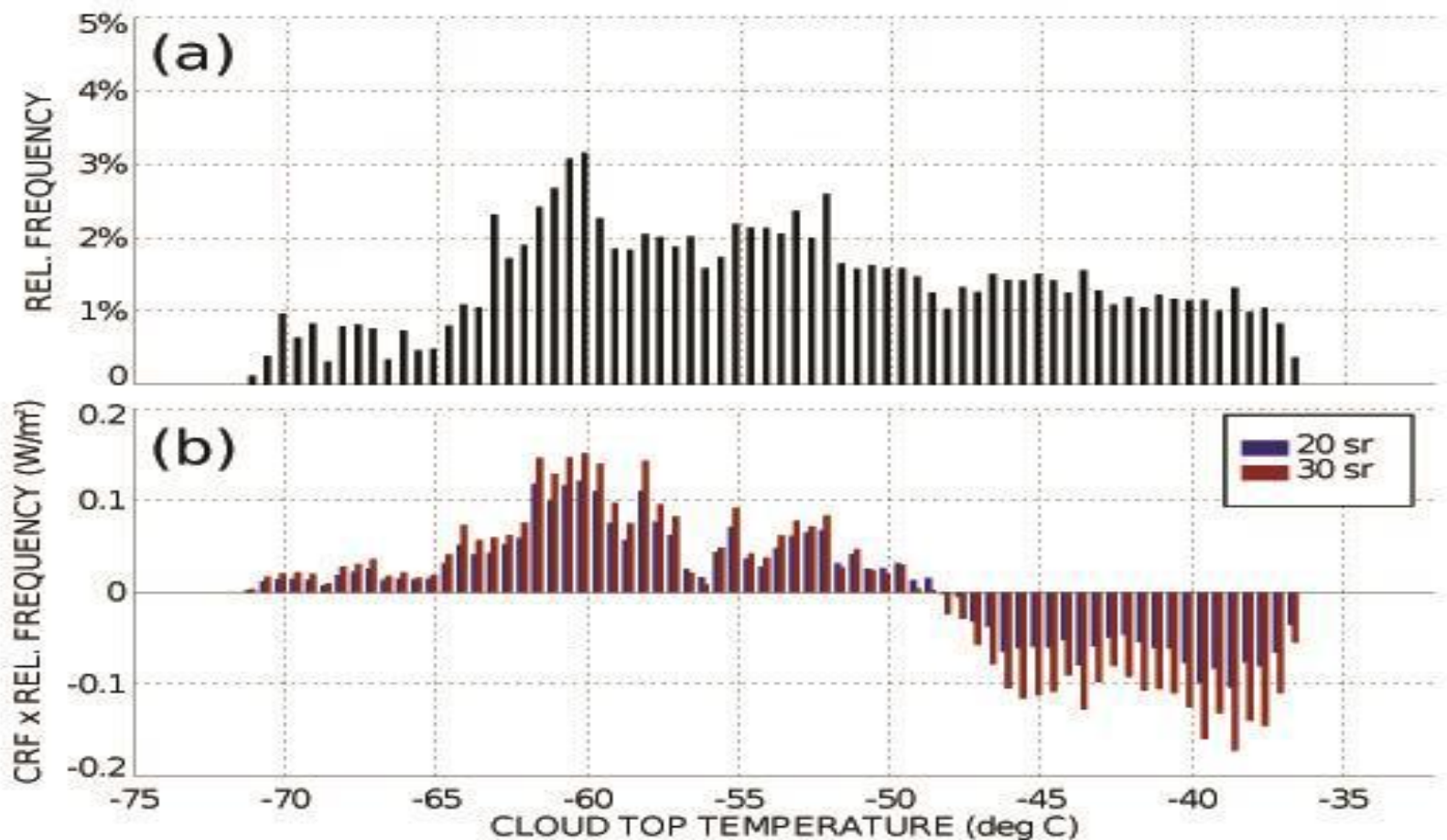
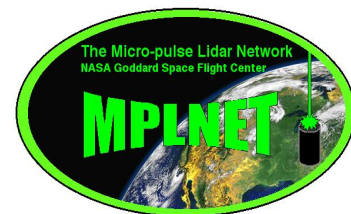
Net RF vs. SZA



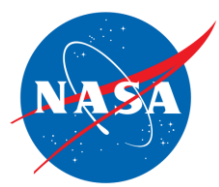
Existence of a gradient in forcing with latitude ? ¹⁴



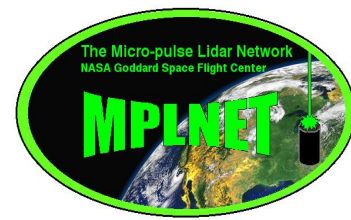
Net RF vs. Cloud Top



-37 C threshold to distinguish ice cloud

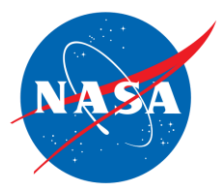


What to take home

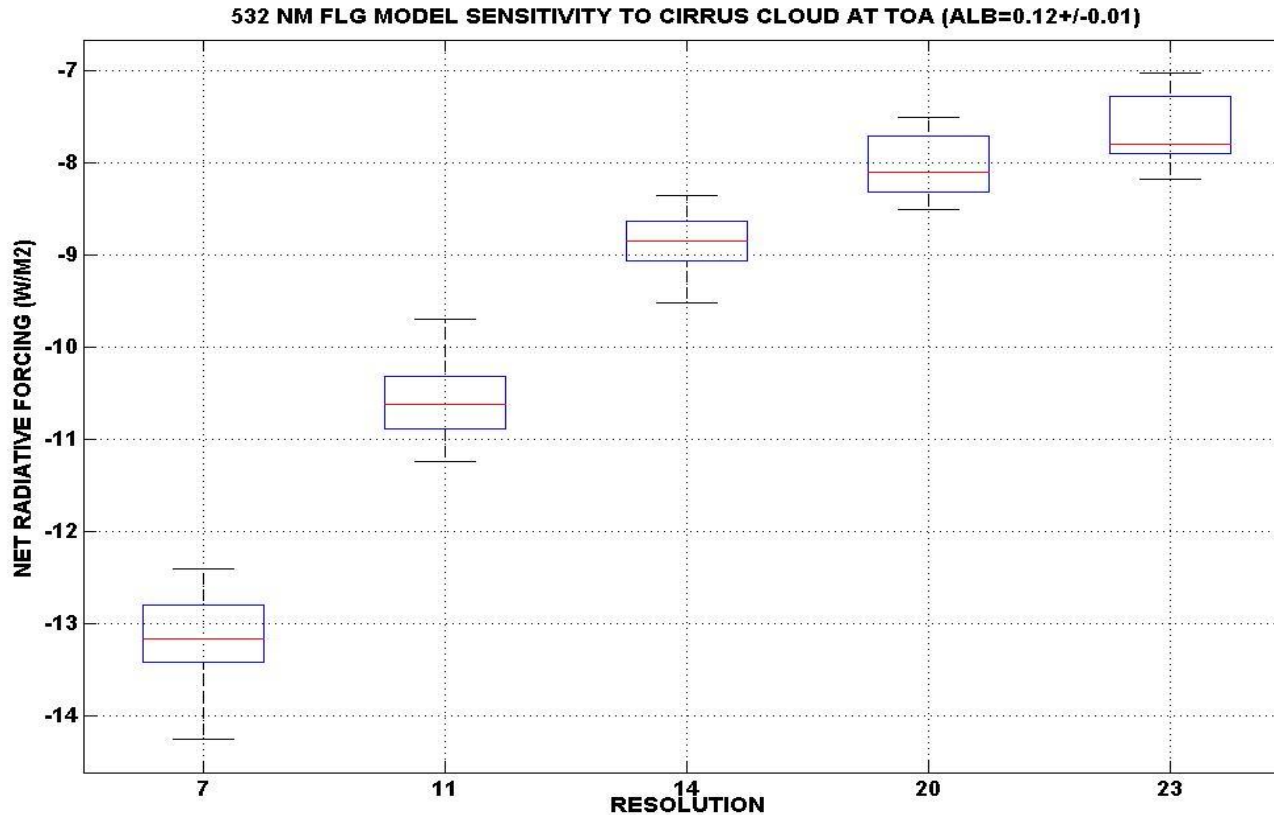
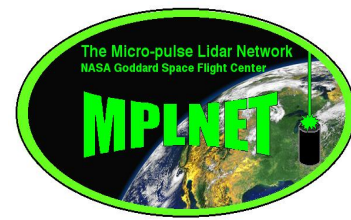


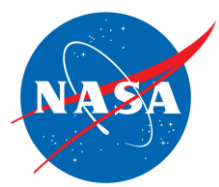
- MPLNET furthers our understanding of global cloud physical processes => analysis over the last decade showed that **optically-thin cirrus clouds are the most common cloud type.**
- Cloud forcing likely varies with **latitude** and **season**, with cirrus clouds exerting less positive forcing and eventually net TOA **cooling** during daytime.

=> Increase **thermal gradients** and **baroclinicity** in summer

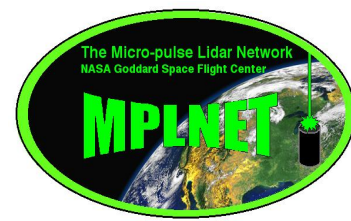


What about FLG sensitivity? Are the results reliable?





Thank you



MPLNET STAFF

- *PI: Judd Welton/612*
- *James Campbell/NRL*
- *Jasper Lewis/JCET-UMBC/612*
- *Simone Lolli/JCET-UMBC/612*
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