DAYTIME TOP-OF-THE-ATMOSPHERE CIRRUS CLOUDS RADIATIVE FORCING PROPERTIES AT SINGAPORE

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Cirrus cloud Facts

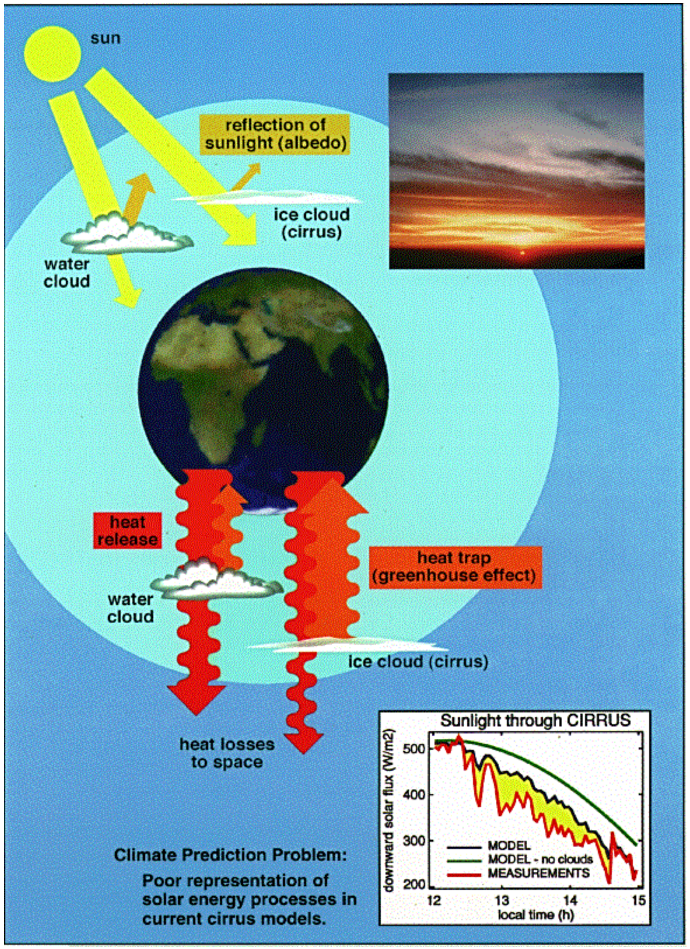
- High level clouds (>12 Km Mid-Lat) consisting purely of ice crystals
- Ice Super Saturated Regions (ISSR) are potentially cirrus formation regions
- Homogenous freezing is probably the dominant freezing mechanism in low temperature / high altitude regimes (< 235 K) [Koop et al., 2004].
- Cirrus clouds 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 by 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?



The Micro-Pulse Lidar Network: MPLNET

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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!

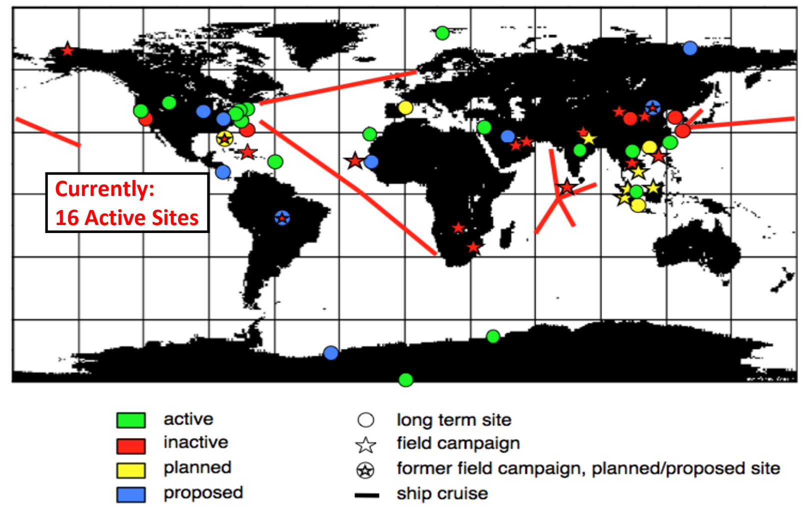
MPLNET is funded by the NASA Radiation Sciences Program and the Earth Observing System

MPLNET Overview

South Pole MPLNET Site:
1999-current

Micro Pulse Lidar
(GSFC Patent)

MPLNET Sites: 2000 - current

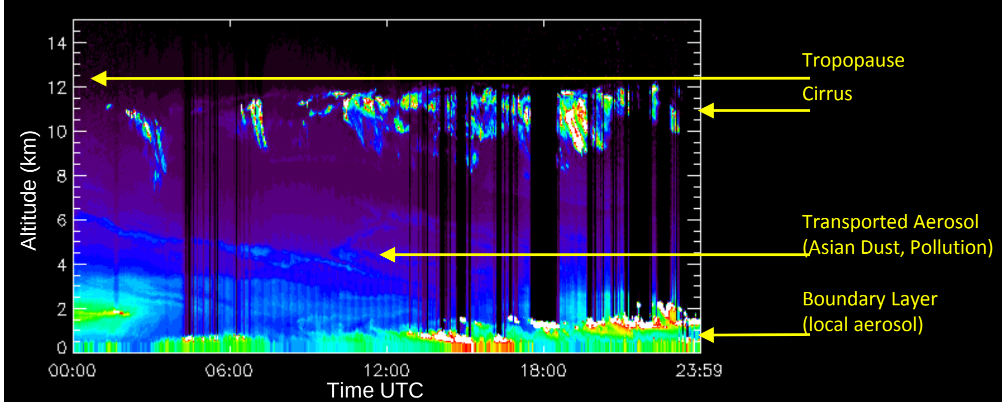


* most sites co-located with AERONET

MPLNET: 8.8Trillion 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

Example of MPLNET Level 1 Data: Atmospheric Structure



What's New?

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

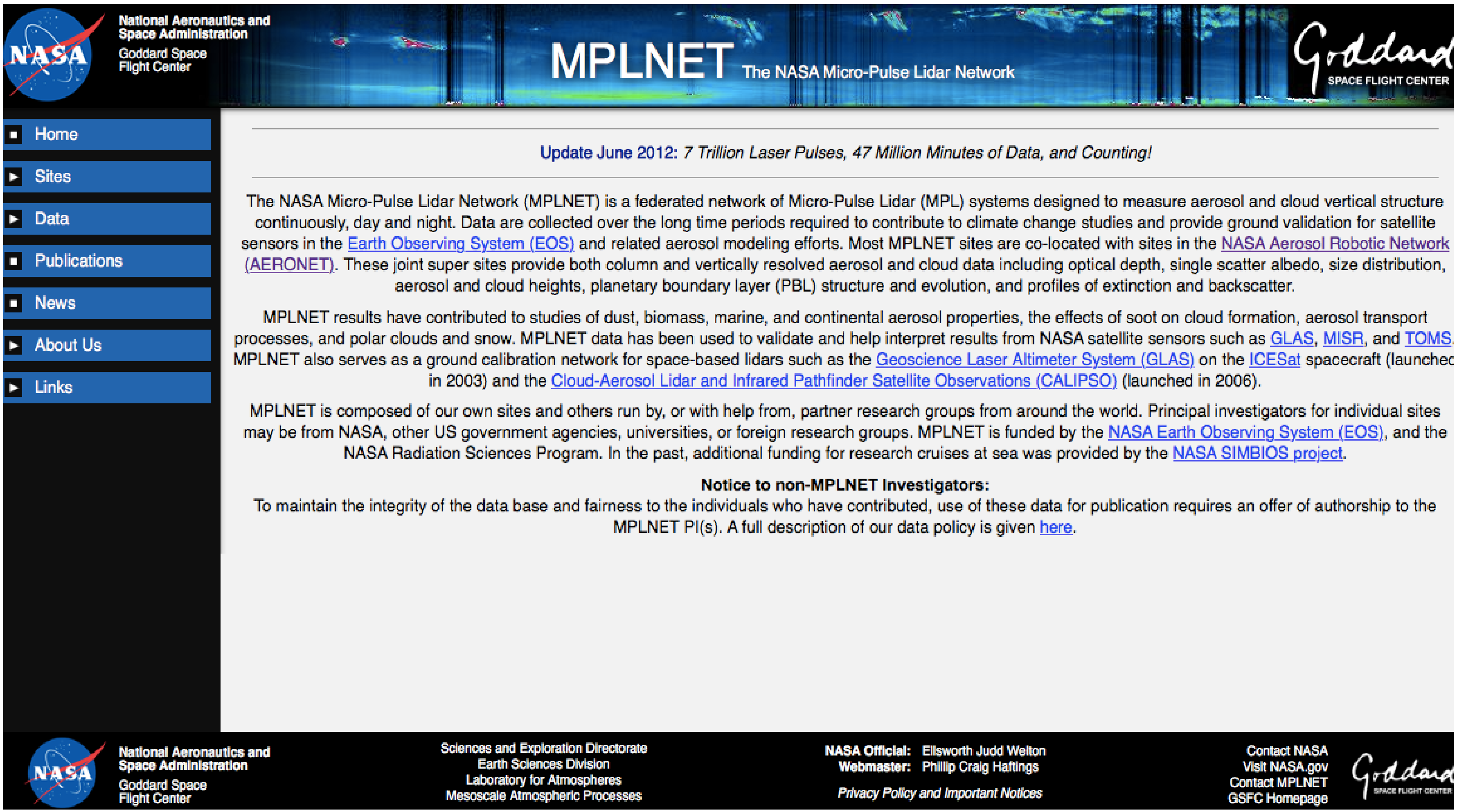
Investigators, Partners, & Collaborators:

- 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

http://mplnet.gsfc.nasa.gov

The New V3 Website

http://mplnet.gsfc.nasa.gov


National Aeronautics and Space Administration
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MPLNET The NASA Micro-Pulse Lidar Network

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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.

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Sciences and Exploration Directorate
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Laboratory for Atmospheres
Mesoscale Atmospheric Processes

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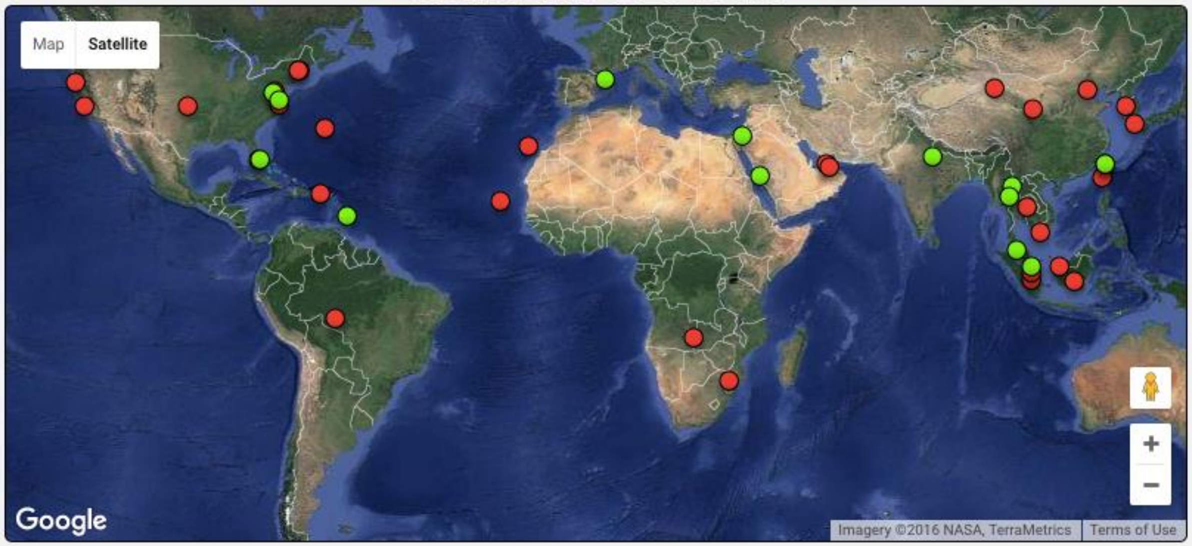
Browse MPLNET Data:



Site: Select a site... Filter: Year... V3 Status...

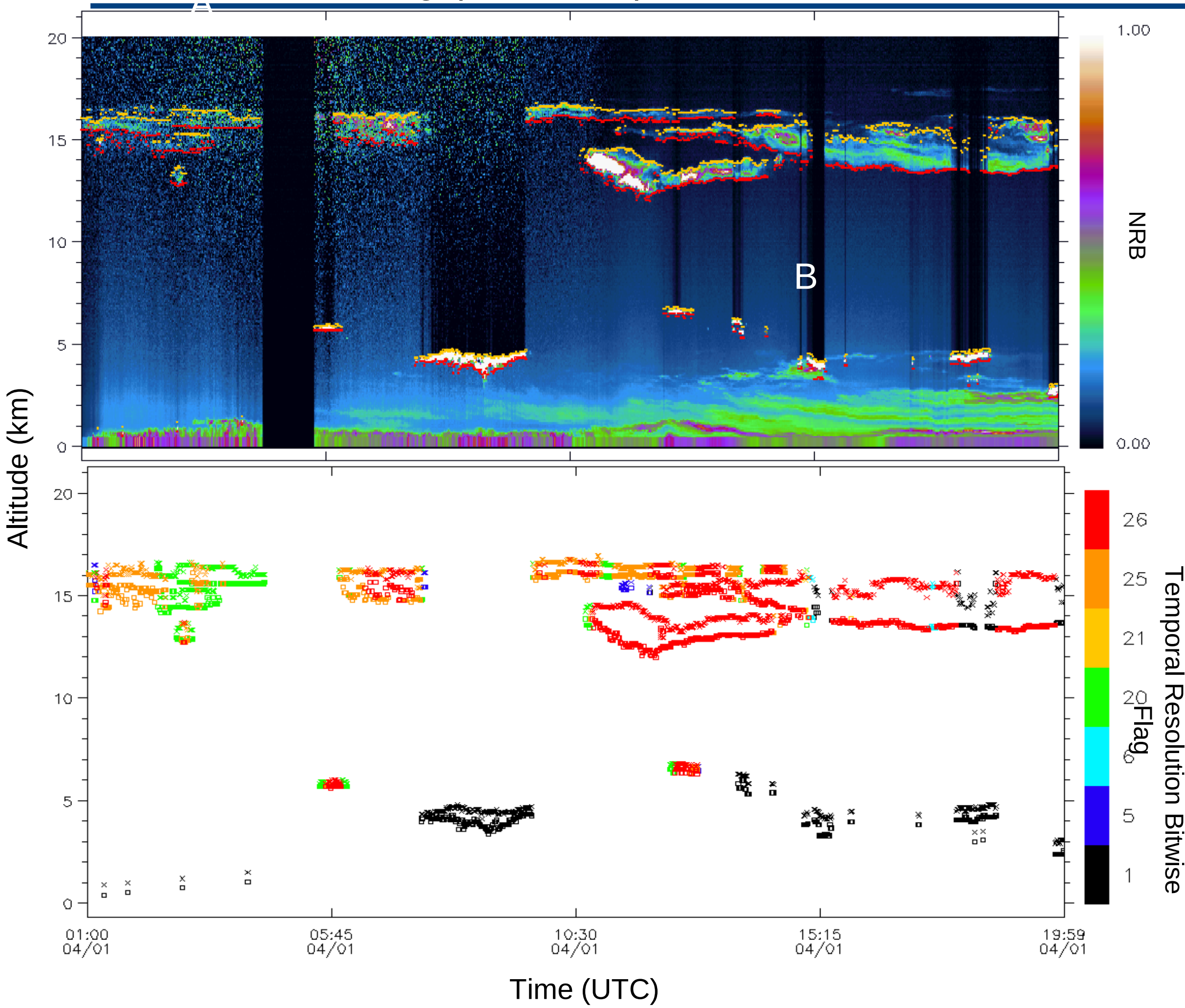
Showing 50 out of 51 MPLNET sites. (1 site hidden by filter.)

Site	Latitude	Longitude	Altitude	AERONET Site	Version	Status	Principal Investigator
Barcelona	41° 23′ 9″ N	2° 7′ 1″ E	0.125 km	Barcelona	V3 Only	Active	-
Doi_Ang_Khang	19° 55′ 48″ N	99° 3′ 0″ E	1.536 km	Doi_Ang_Khang	V2 & V3	Active	Si-Chee Tsay
EPA-NCU	24° 58′ 0″ N	121° 10′ 52″ E	0.135 km	EPA-NCU	V2 & V3	Active	George Lin
GSFC	38° 59′ 33″ N	76° 50′ 23″ W	0.050 km	GSFC	V2 & V3	Active	Judd Welton

The new V3 Cloud Algorithm

J. Lewis et al., 2015

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.
- The algorithm is applied to 2012 NRB data at GSFC.
- Algorithm output: **17011** detected single layer cirrus cloud extinction profiles.

Parameterization for FLG Radiative Transfer Model

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

From GEOS-5

- Power Law depending on temperature

$Dge(z)=a*exp(b*T)$ a, b depending on T

From Lidar

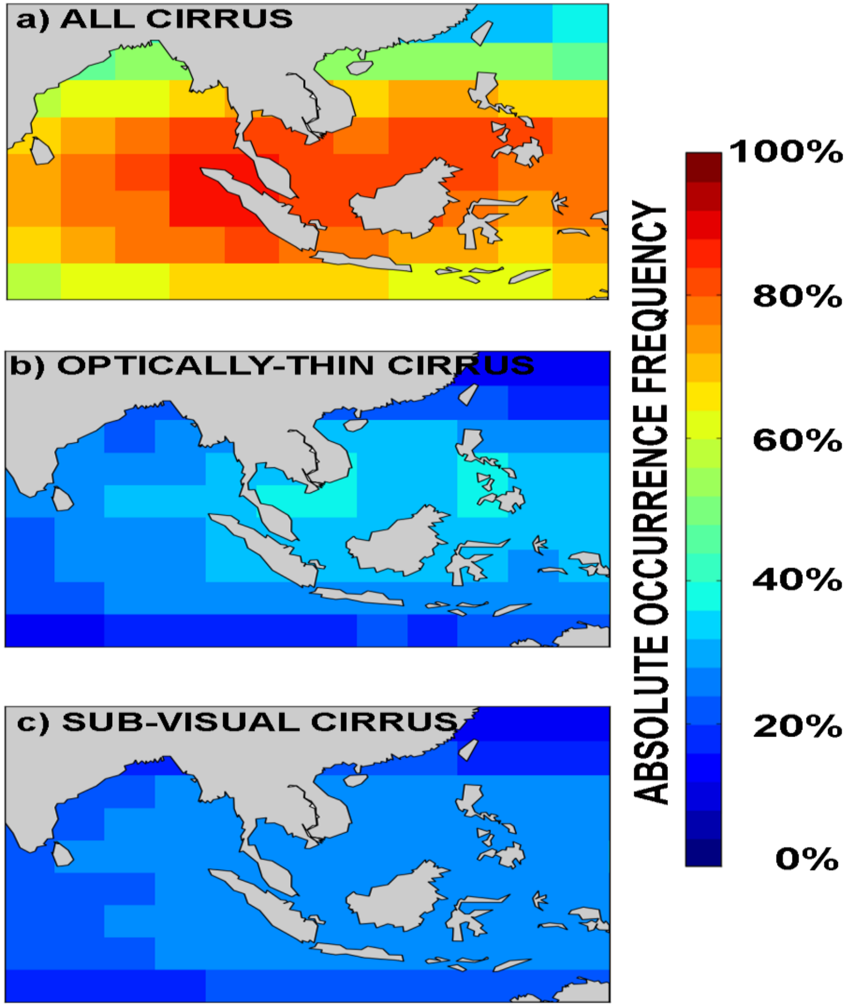
- Ice Water Content :

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

- Cloud Net Radiative Forcing

$CRF^{net}=CRF^{sw}-CRF^{lw}$ with $CRF^{sw,lw}=F_{cl}^{sw,lw}-F_{clr}^{sw,lw}$

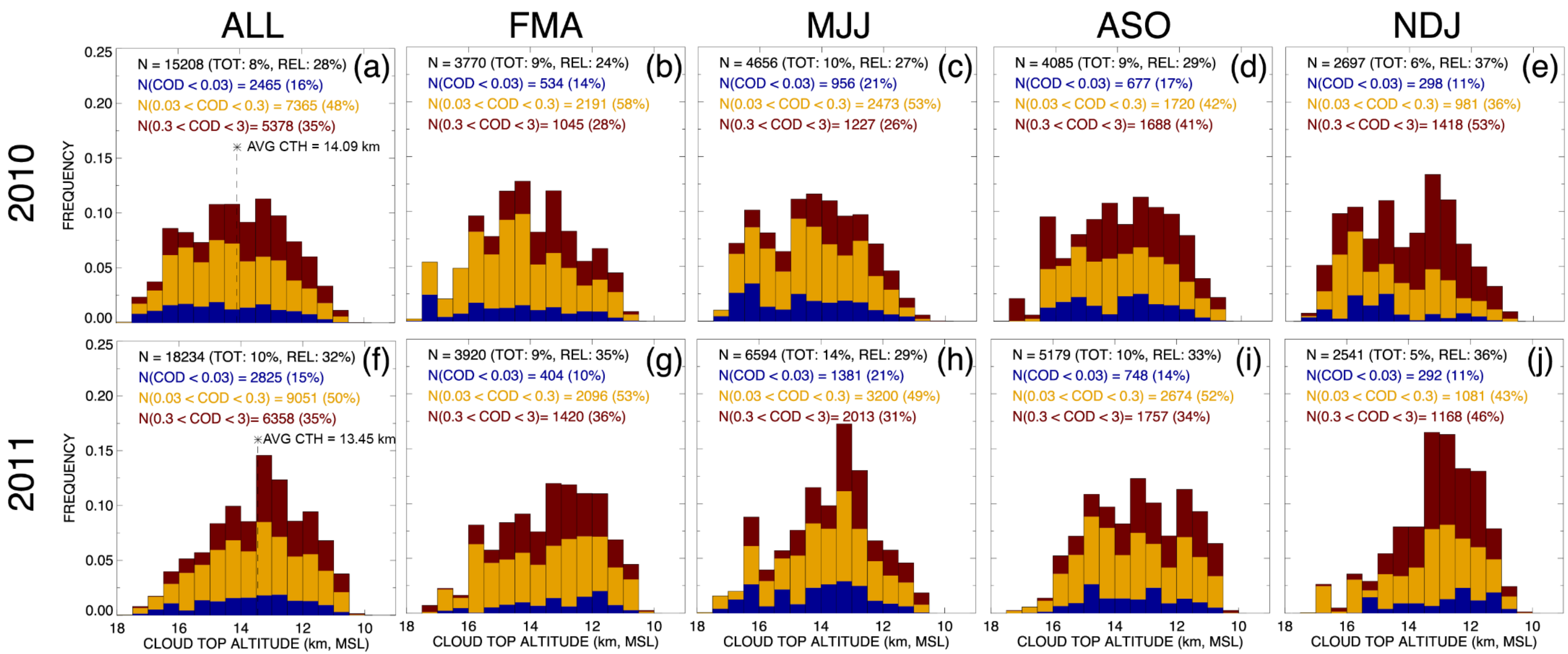
Cirrus Clouds SE Asia Frequency



CALIPSO Data 2006-2015

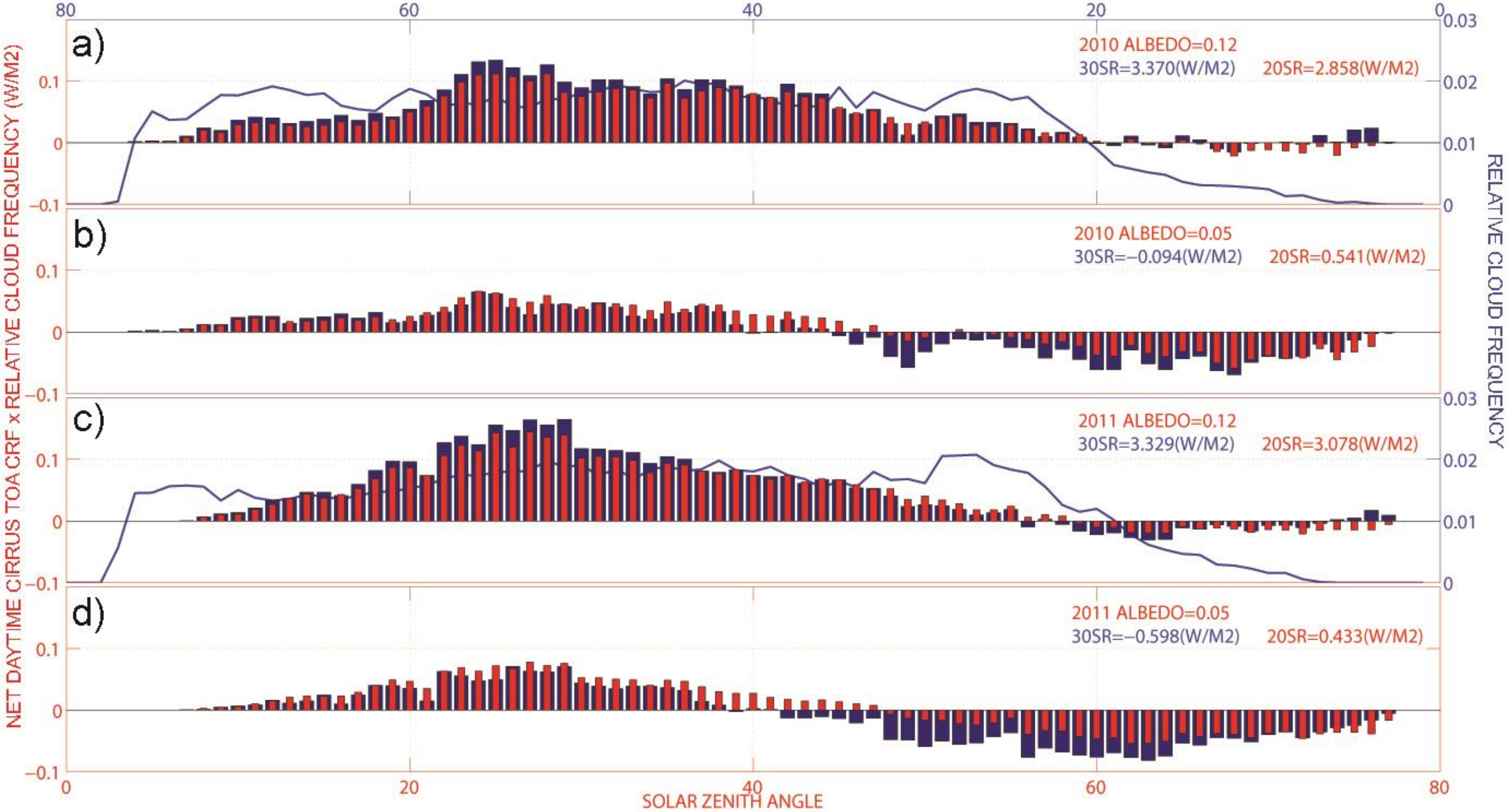
- SEA Absolute cirrus cloud frequencies over water
- Depolarization channel, -37C threshold (Campbell et al., 2015)
- Singapore close to **80%**

MPLNET DATA, Singapore 2010-2011



MPLNET
NET RF vs. COD

MPLNET
NET RF vs. SZA



MPLNET
NET RF vs. CTT

SEASONAL TRENDS

	FEB-MAR-APR				MAY-JUN-JUL				AUG-SEP-OCT				NOV-DEC-JAN			
SFC ALBEDO	0.05		0.12		0.05		0.12		0.05		0.12		0.05		0.12	
S-RATIO (sr)	20	30	20	30	20	30	20	30	20	30	20	30	20	30	20	30
2010 (W/m^2)	1.13	0.82	3.14	3.78	0.75	0.55	2.62	3.28	0.14	-0.72	2.76	3.18	-0.11	-1.52	2.83	3.83
2011 (W/m^2)	0.94	-0.32	3.82	4.01	0.94	0.61	3.07	3.74	0.51	-0.38	3.08	3.43	-1.97	-4.51	1.57	0.72

<u>*Difficult to characterize any trend*</u>

- NDJ stands out for exhibiting exclusively net **negative** forcing
- MJJ is the only over-water period the estimates are all **positive**
- Compelling that minimum over water in 2011 (-4.51 W/m2, NDJ) is in direct contrast with max over land (4.01 W/m2, FMA)

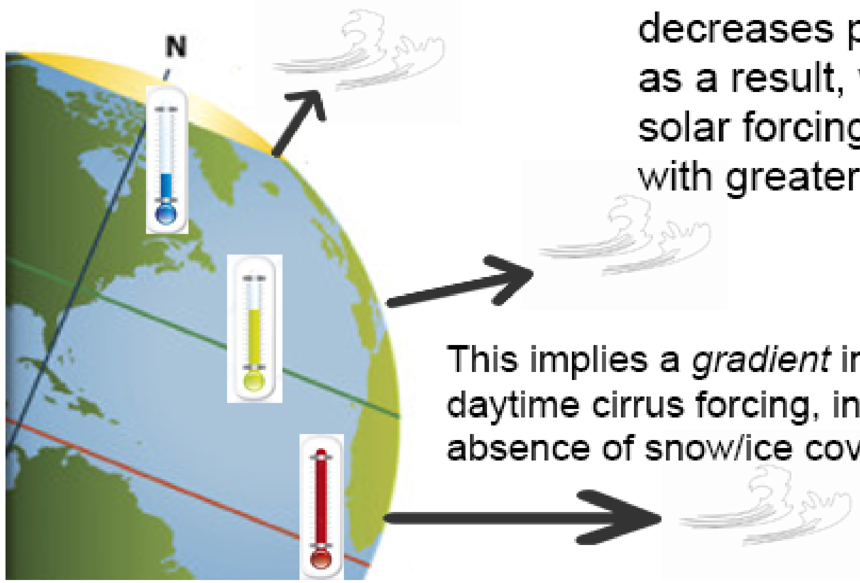
CONCLUSIONS

- TOA CRF is estimated to be **2.8-3.3** W/m2 (2010) and **3-3.3** W/m2 (2011) over land,
- TOA CRF is estimated **-0.094**-**0.541** W/m2 (2010) and **-0.598**-**0.433** W/m2
- Seasonal estimates are consistent, with NDJ showing lower values with respect other months
- Novelty: cirrus being *the only genus* that can readily induce both *positive and/or negative daytime TOA CRF*, depending on their physical characteristics
- Global oceans are subject to **negative** daytime TOA CRF, presuming the forcing sign changes meridionally at lower latitudes than believed likely over the lands.

What's next?

<u>How daytime cloud forcing may vary with latitude and season?</u>

There is a gradient in cirrus cloud heights and surface temperatures from higher/warmer to lower/colder between the equator and poles. Infrared cloud forcing decreases poleward, as a result, whereas solar forcing increases with greater SZA.



This implies a *gradient* in net daytime cirrus forcing, in the absence of snow/ice cover.

Thank you

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