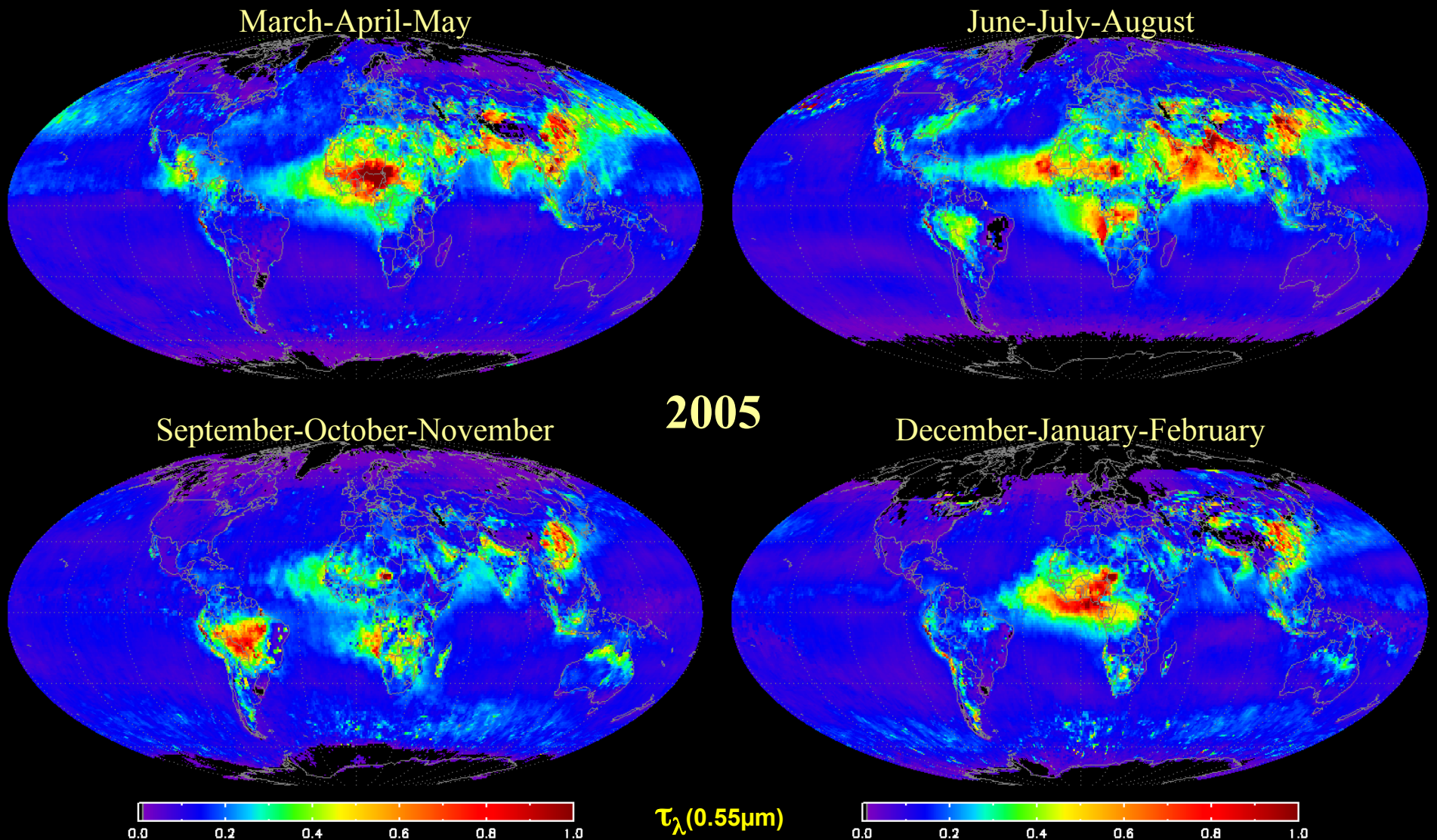
Aerosol-Mediated Changes in Cloud Radiative Frocing

Zhanqing Li， Jie Peng

University of Maryland

Aerosol Optical Depth (Deep Blue & MODIS Composite)

- ***Year-round aerosols***
  - East-Southeast China, *mega-city/smoke*
  - Indo-Gangetic Plain, *mega-city/dust*
  - Africa, Saharan dust (less in SON)
- ***Seasonal aerosols***
  - East Asia, dust (MAM)
  - Southwest Asia, dust (JJA)
  - Southeast Asia, smoke (DJF-MAM)
  - S. America, smoke (JJA-SON)
  - Africa, smoke (SON-DJF)
  - Southwest Asia, haze (MAM)



How can aerosol indirect effects alter Cloud radiative forcing ?

- ❖Twomey effect *(Microphysics, Twomey, 1977)*
- ❖Life time effect (frequency, *Albrecht, 1989)*
- ❖Semi-direct effect (amount, *Hansen, 1997)*
- ❖Invigoration effect *(Geometry, Koren, 2008)*

Exploitation of All-kinds of Observations

In-depth and extensive analysis Of multiple datasets to reveal the Effects of aerosols on cloud, Precipitation & Radiation

Observations

- **SGP TWP** — Best quality
- **Multiple AMF Sites** — Ideal location
- **Aircraft RACORA** — In-situ truth
- **A-Train Satellites** — Global coverage
- **China IOP & routine** — Long-term

Revealing Aerosol Effects → **Understanding Aerosol effects** → **Quantifying Aerosol effects**

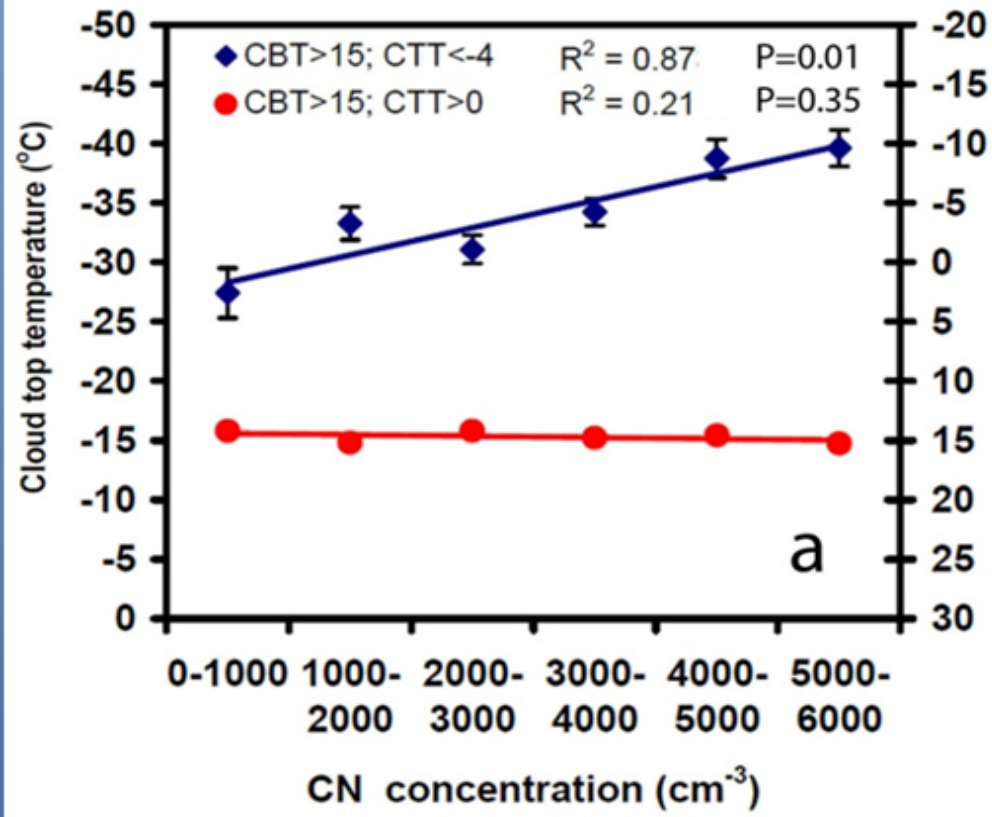
nature geoscience

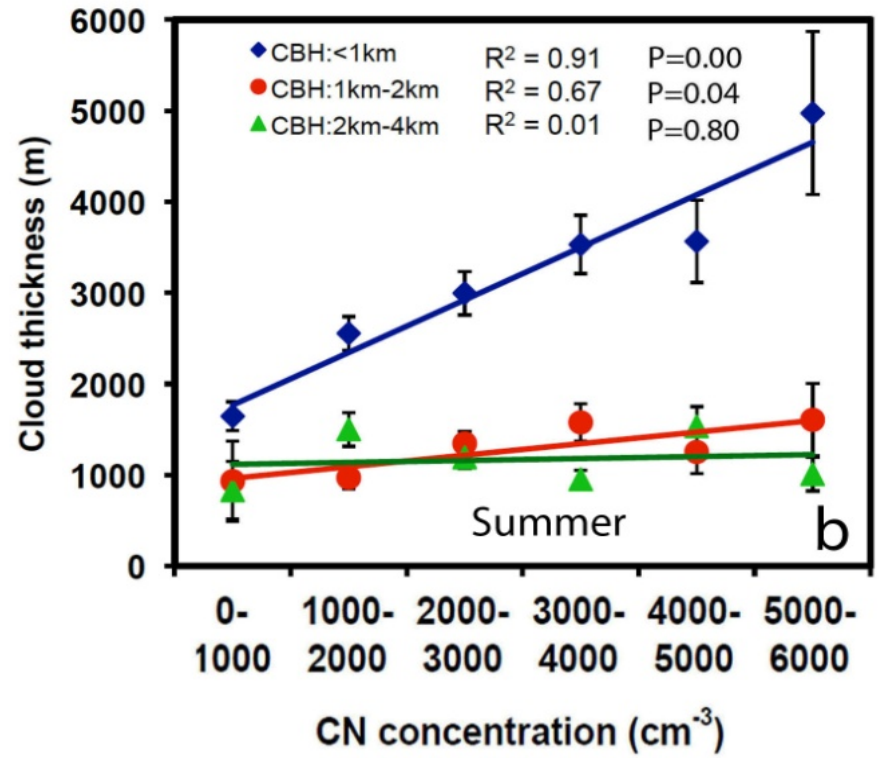
ARTICLES

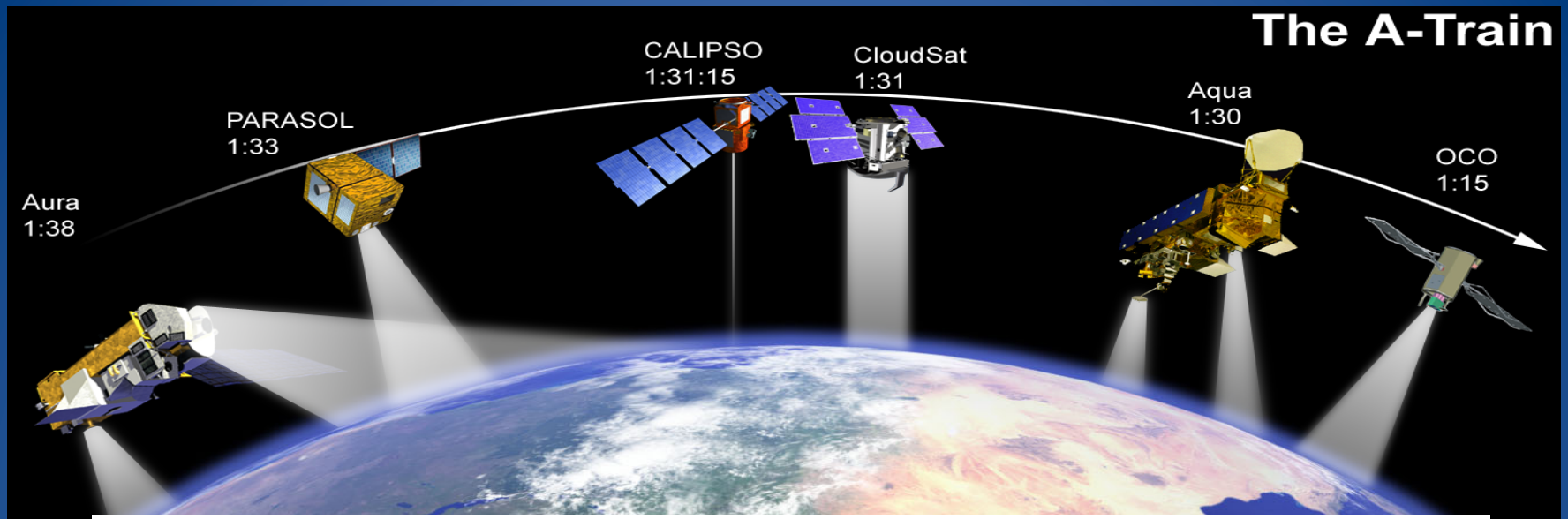
PUBLISHED ONLINE: 13 NOVEMBER 2011 | DOI: 10.1038/NGEO1313

Li et al., 2011

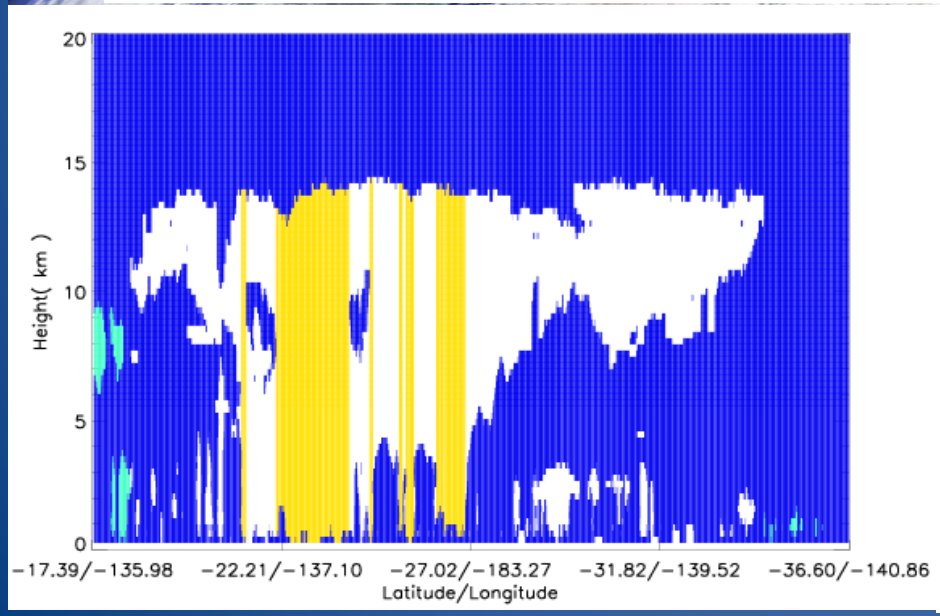
Long-term impacts of aerosols on the vertical development of clouds and precipitation

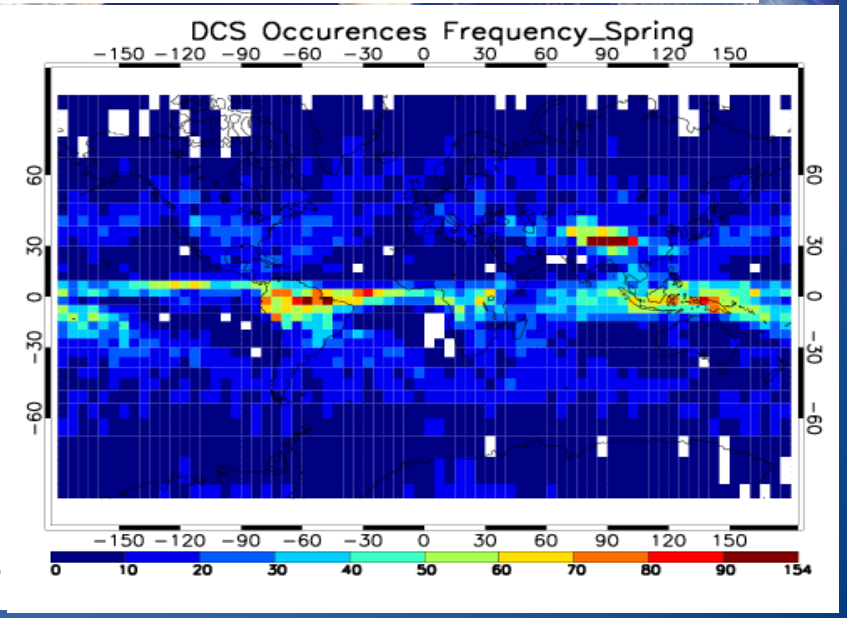






Identification of DCC from A-Train Sensors





Peng et al (2013)

Using combination of A-train Satellite data to investigate Invigoration Effect

- Region: 20N-20S
- Time: 2007-2010

- Collocation

CPR/CloudSat-MODIS/Aqua(Daytime only)
CPR/CloudSat-CALIPO/CALIPSO(Daytime and Nighttime)

- Results will be showed as:

(a) CM(CloudSat/MODIS):Daytime only for Land and ocean

Part 1:Daytime only

Cloud properties: CPR/CloudSat

Aerosol properties: MODIS/Aqua

CM: CloudSat and MODIS

Warm: (a) CTT < -4 ℃ (b) CBT >15 ℃

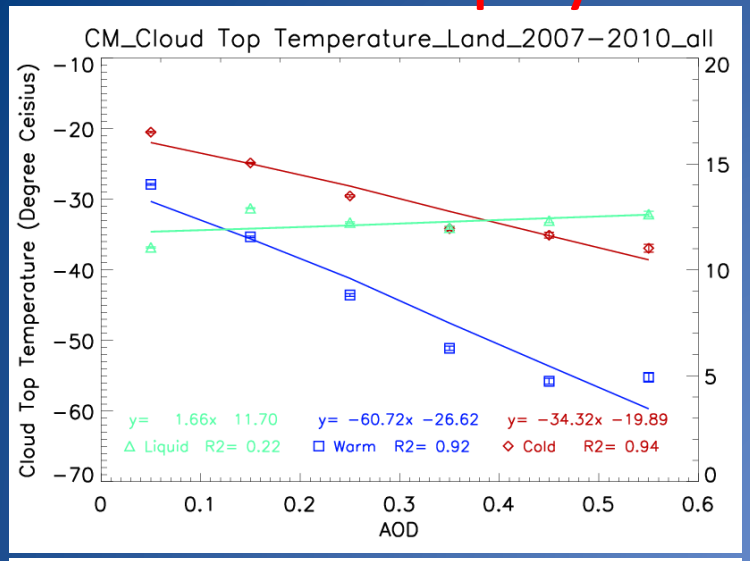
Cold: (a) CTT < -4 ℃(b) CBT >0 ℃ & CBT < 15 ℃

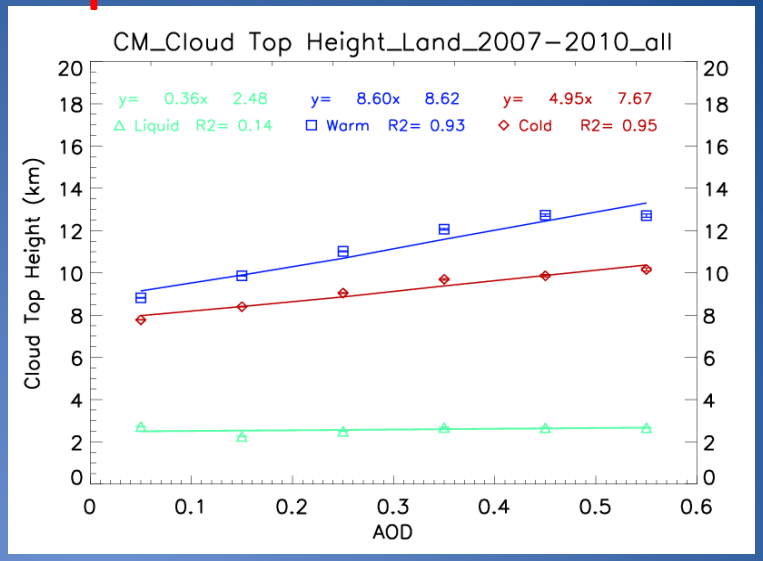
Liquid: (a) CTT > 0 ℃

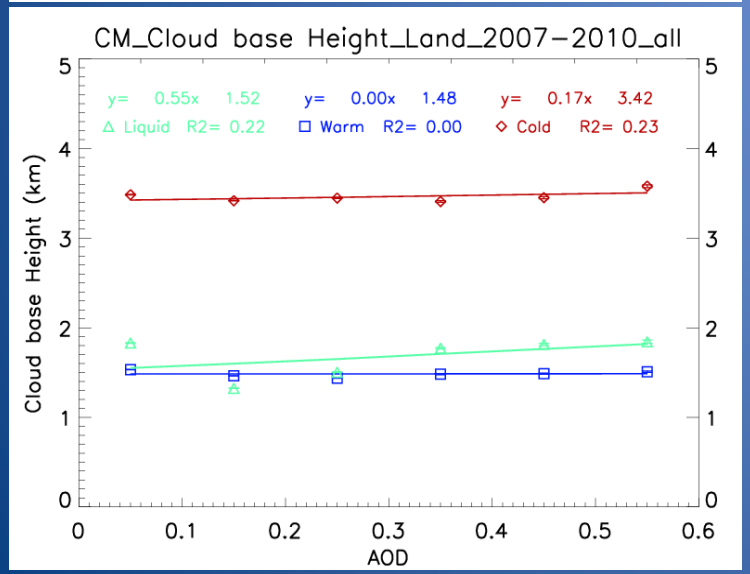
Table Sample numbers for different cloud types of CM

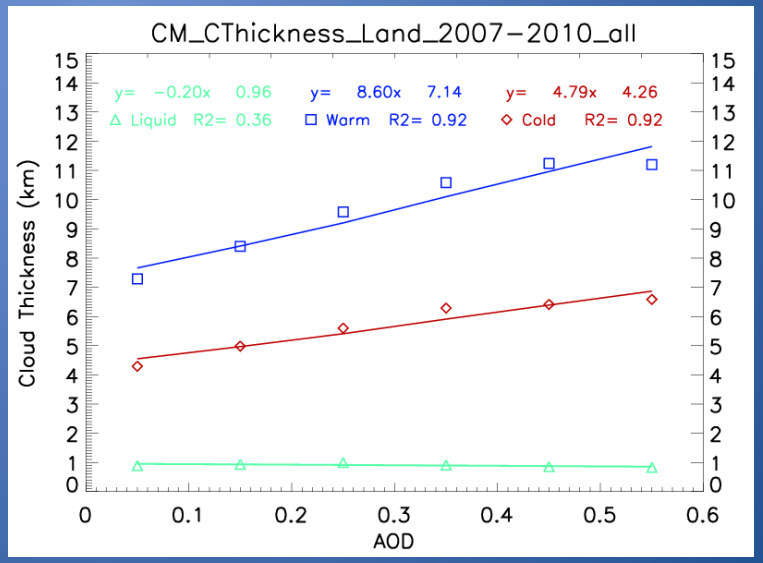
Ocean/AI	**0-0.0152**	**0.0152-0.0231**	**0.0231-0.0351**	**0.0351-0.0534**	**0.0534-0.0811**	**0.0811-0.1233**	**0.1233-0.1874**	**0.1874-0.2848**	**0.2848-0.4329**	**0.4329-0.6579**
Liquid	3595	6500	12429	22304	31956	31748	15444	4396	1900	699
Warm	28	44	80	181	420	662	500	197	69	26
Cold	71	99	212	395	882	1180	881	345	139	40
Land/AOD	0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5-0.6				
Liquid	8159	16461	5976	2204	1117	655				
Warm	459	1118	855	442	239	125				
Cold	1119	2292	1763	927	449	282				

Cloud macro physical properties VS AOD over land







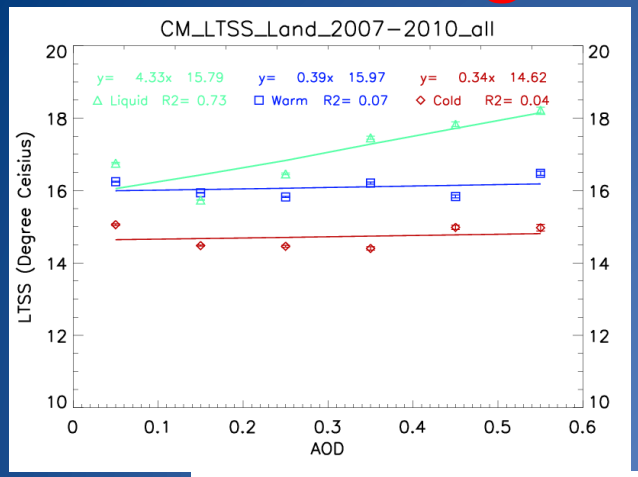


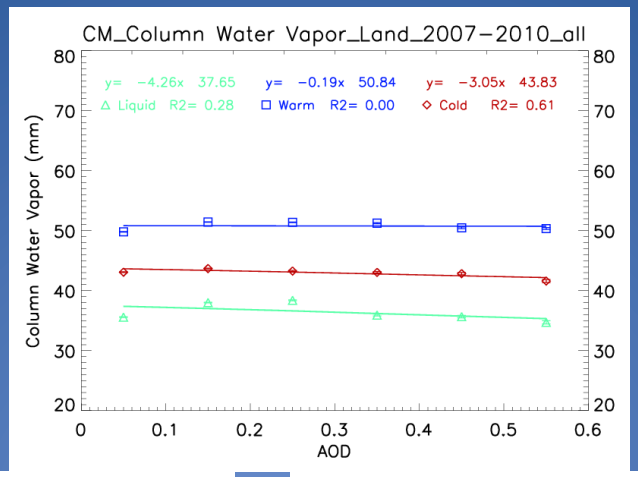
With the increase of AOD :1) Mix-Phase cloud become thicker and higher

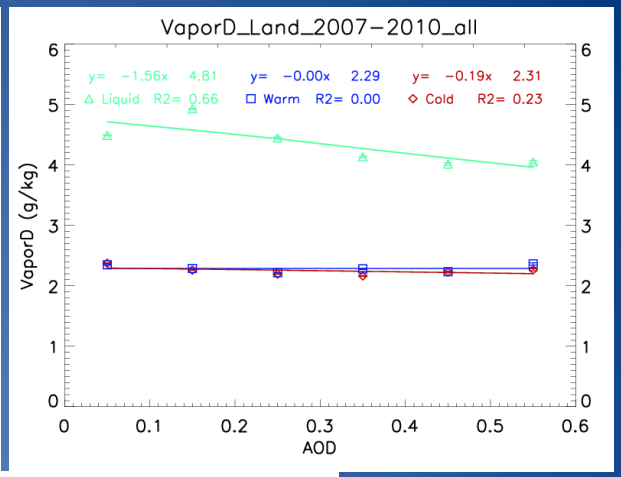
2) Liquid clouds have no significant change

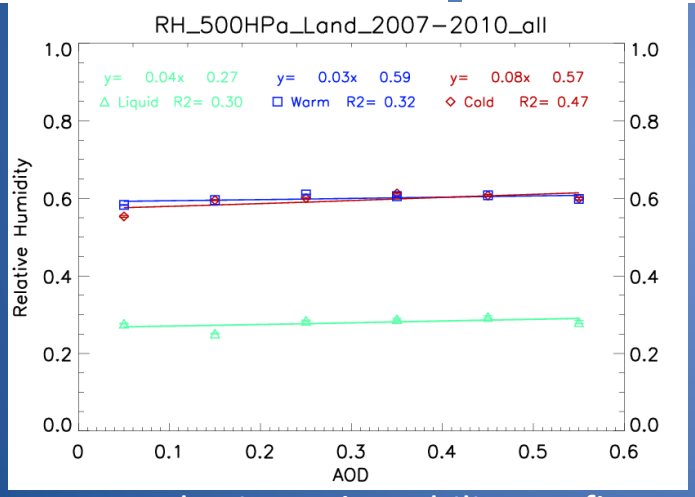
3) Cloud base height do not change with AOD

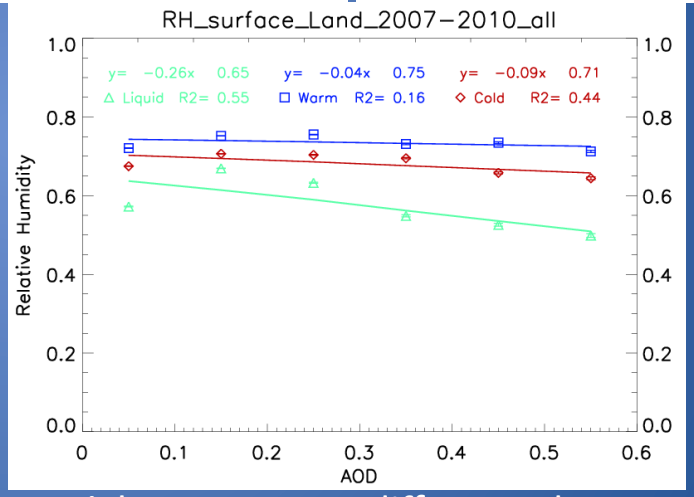
Meteorological Parameters VS AOD over land











LTSS: lower tropospheric static stability, Define as potential temperature difference between the surface and the 700 hPa pressure level [*Klein and Hartmann*, 1993]

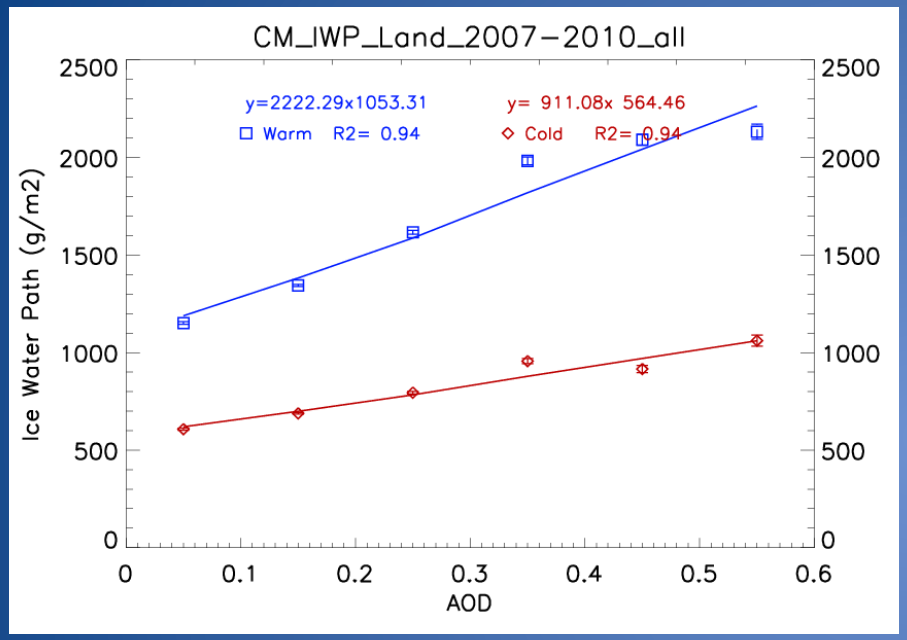
VaporD:

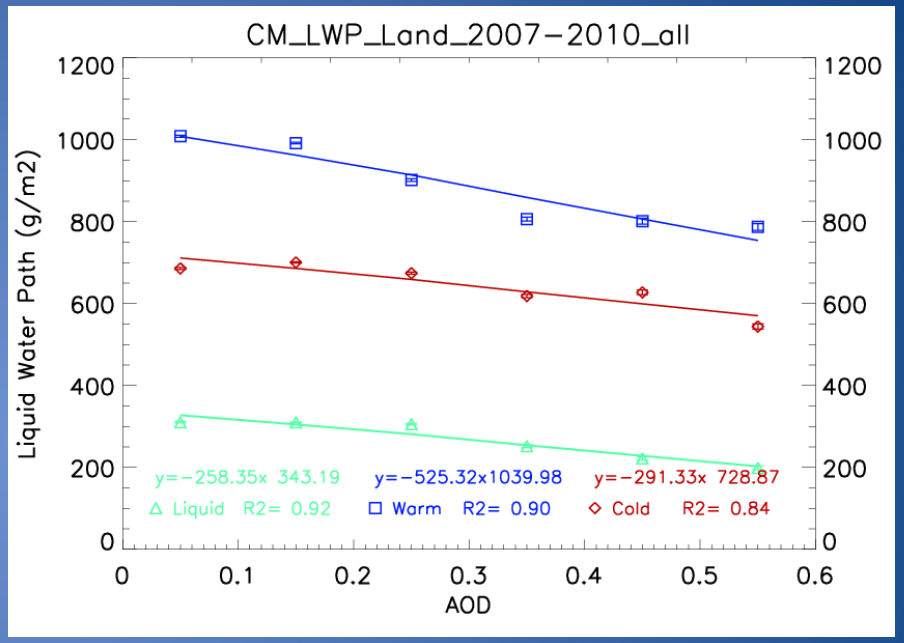
Mean value of differences between Saturated specific humidity and current specific humidity for all layers between 500hPa and 700hPa

No significant trend of meteorological parameters indicate the large scale dynamic dominate

The variation showed above

Cloud properties VS AOD over land

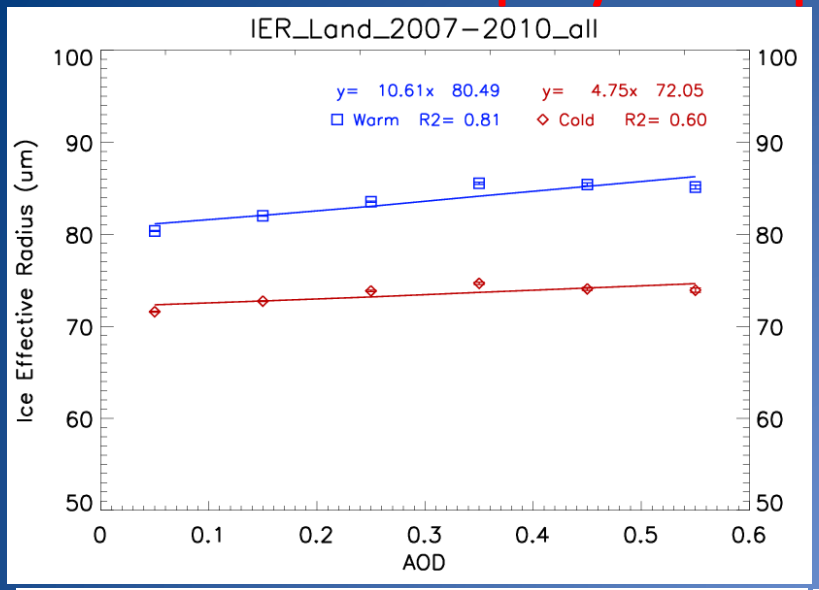


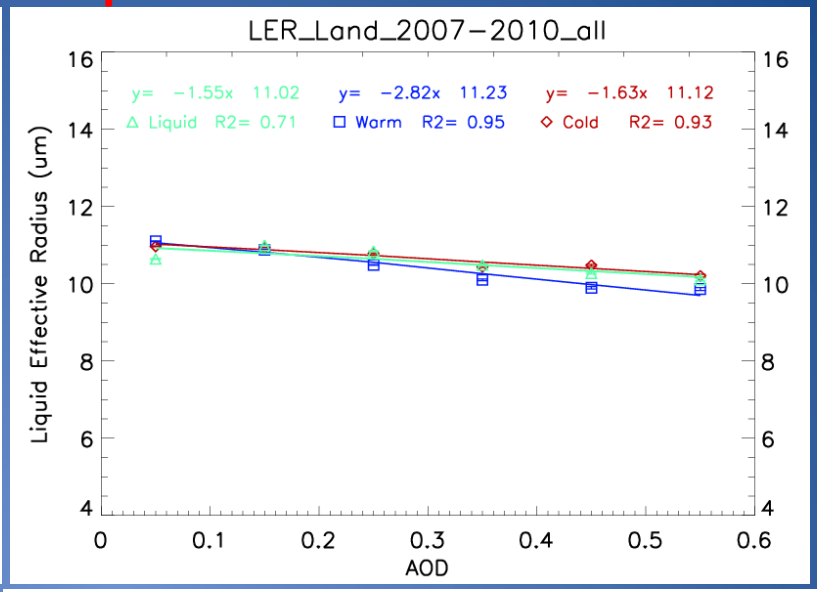


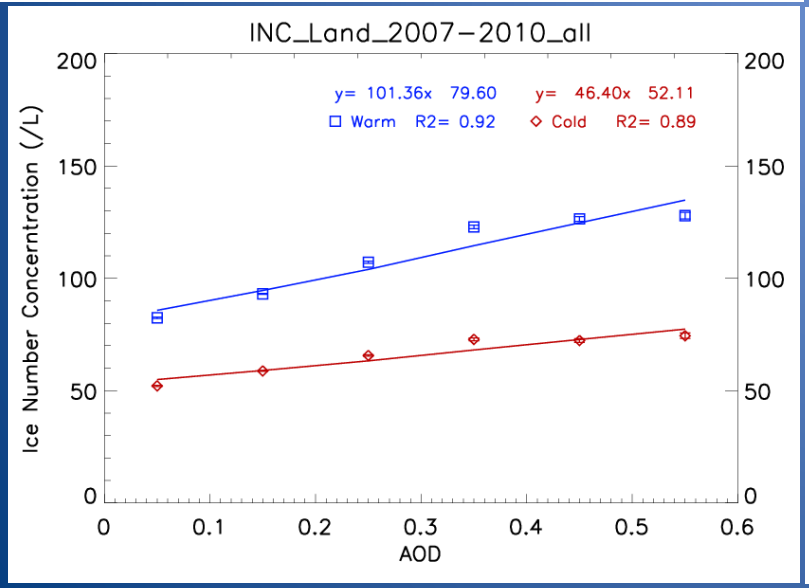
IWP: Ice water path
LWP: Liquid water path

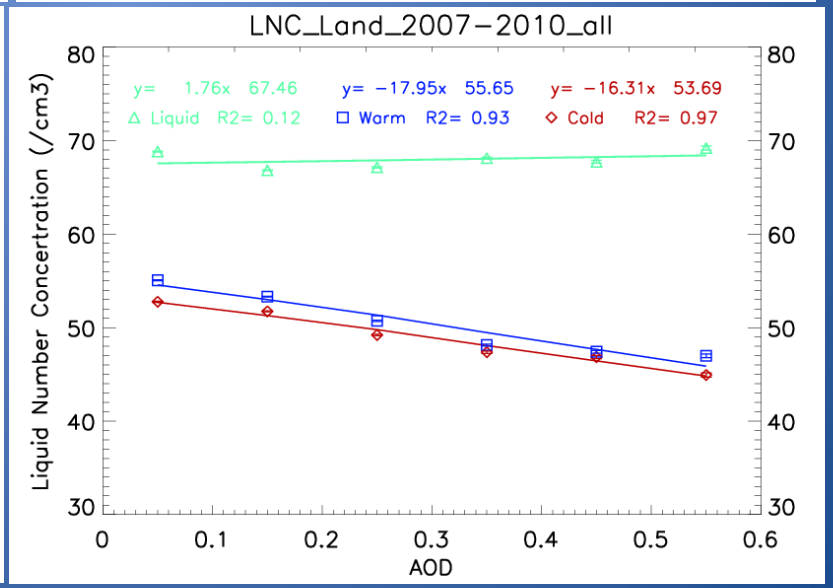
Increase of IWP indicates ice processed are enhanced under higher AOD scenes
No clear explanation for LWP

Cloud microphysical properties VS AOD over land









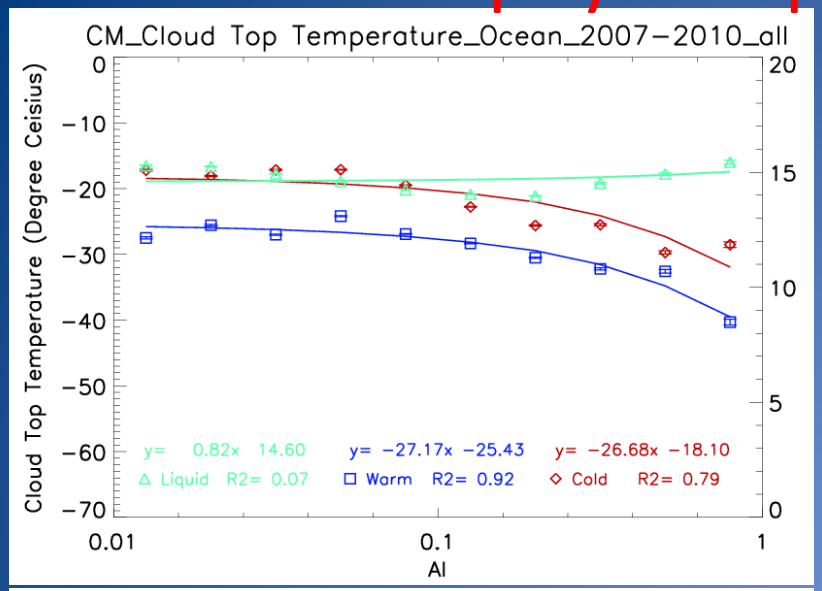
IER: Ice effective radius

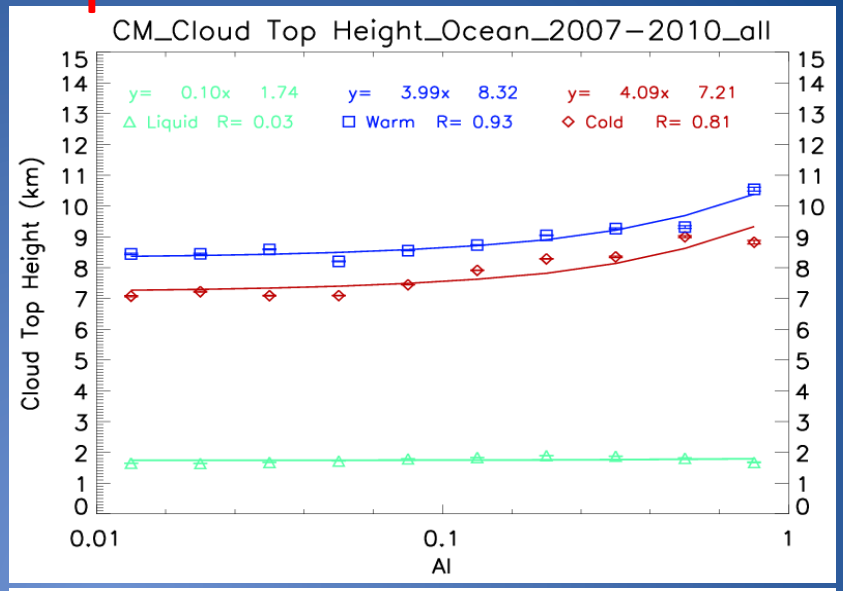
INC: Ice droplet number concerntration

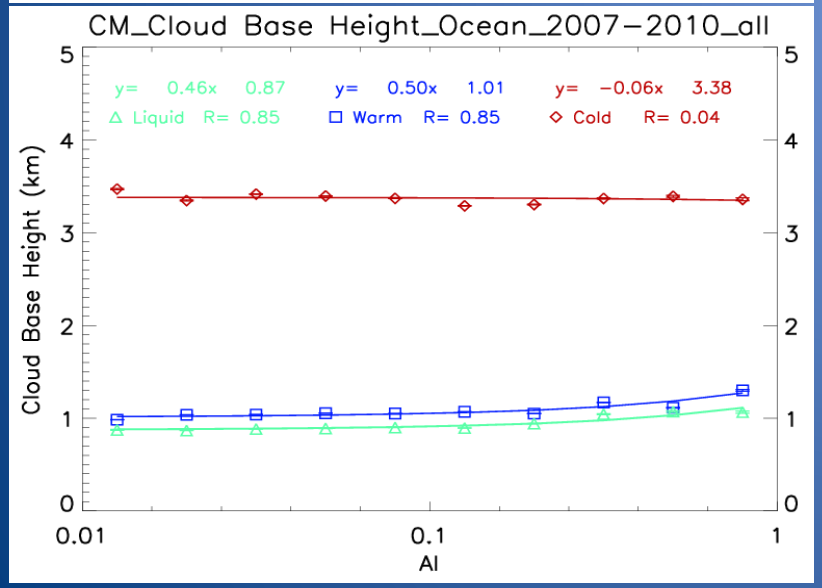
LER: Liquid effective radius

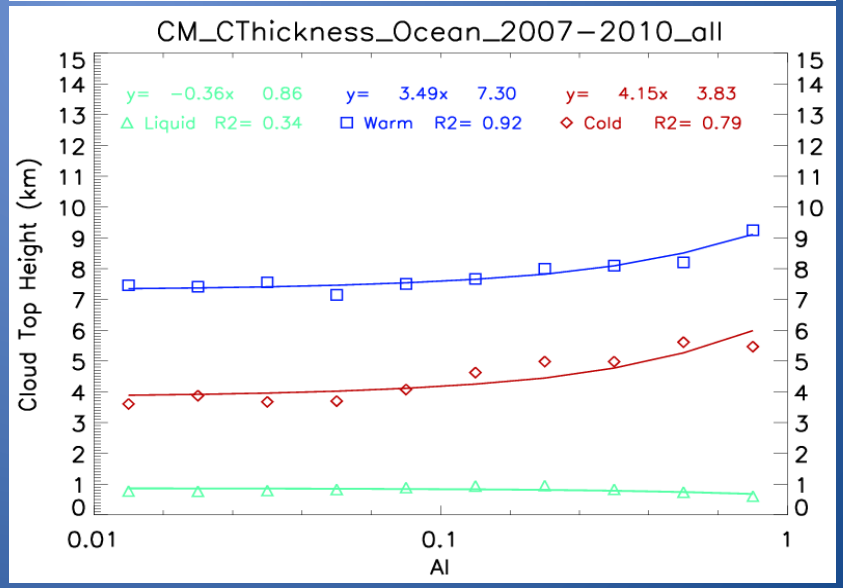
LNC: Liquid ice droplet number concerntration

Cloud macro physical properties VS AI over Ocean





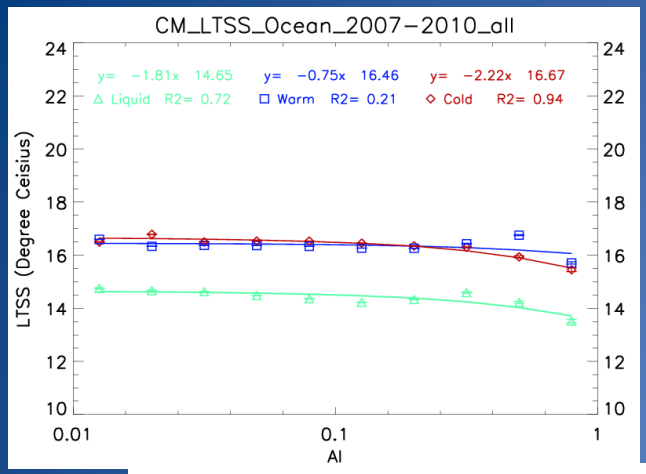


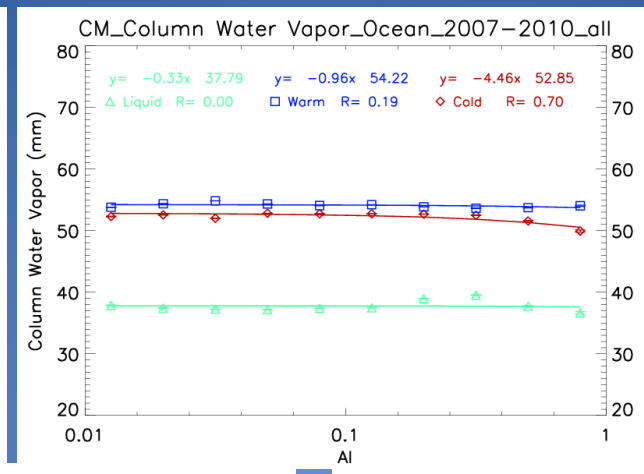


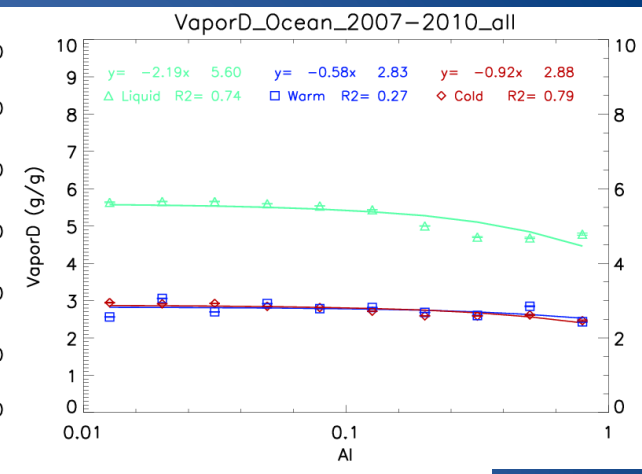
Cthickness: Cloud thickness

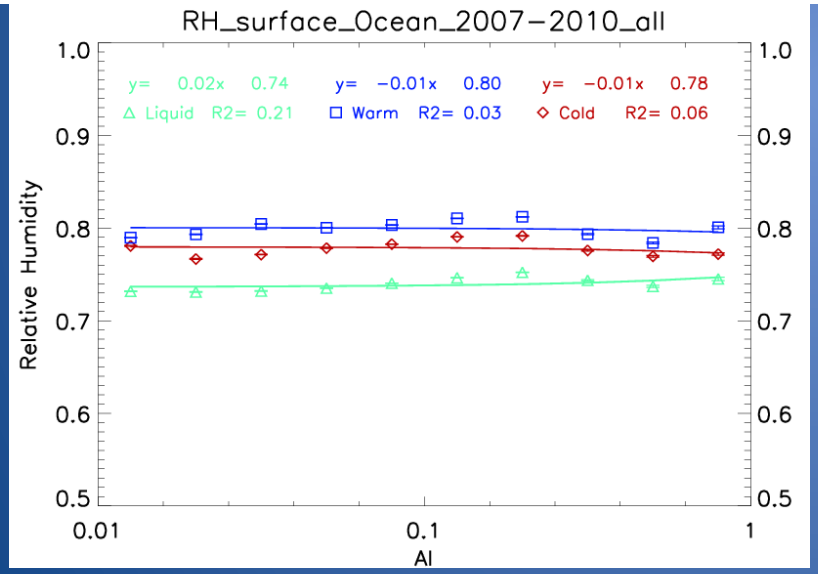
Macro physical properties also have the same trend with the situation over land

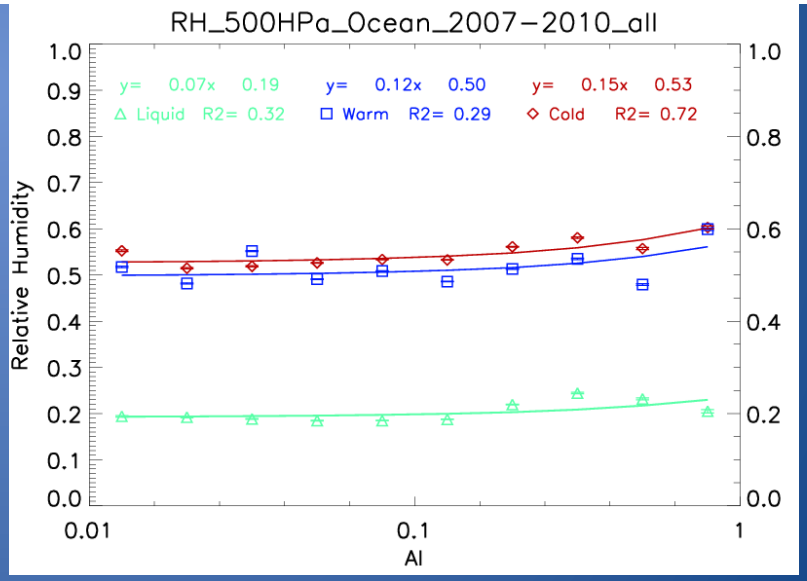
Meteorological Parameters VS AI over Ocean





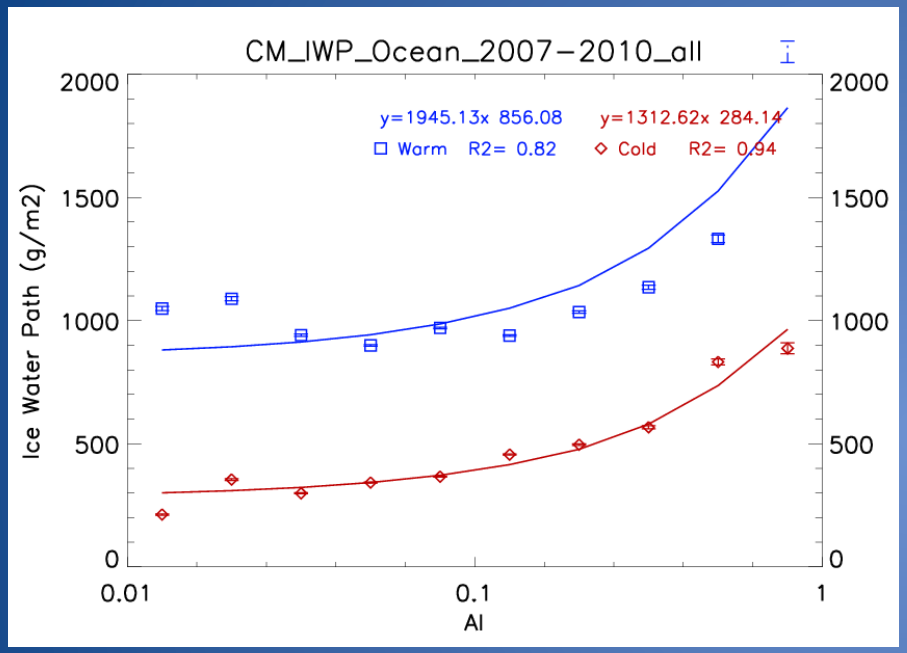


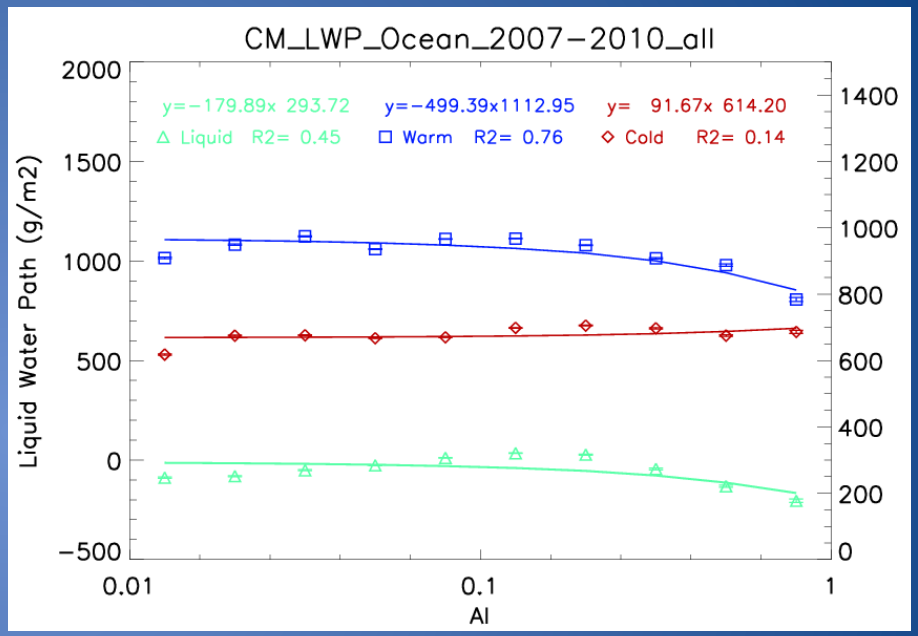




No significant trend of meteorological parameters indicate the large scale dynamic dominate
The variation showed above

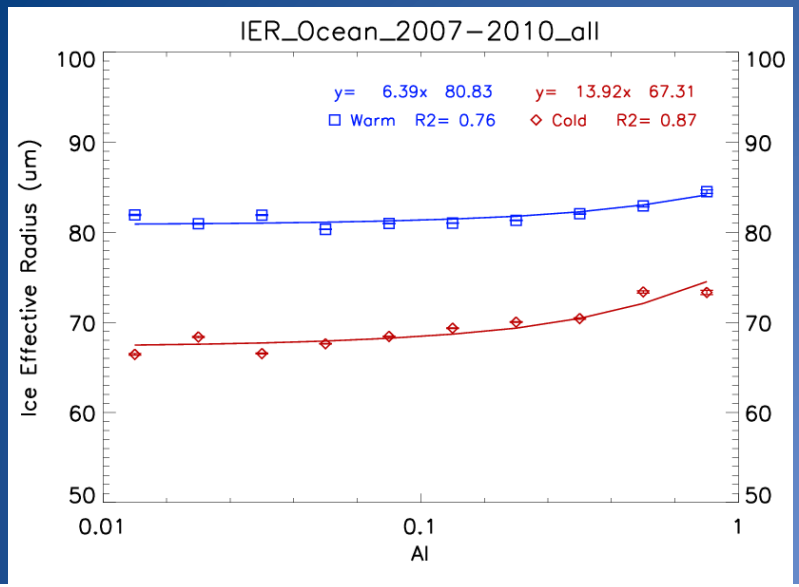
Cloud properties VS AI over Ocean

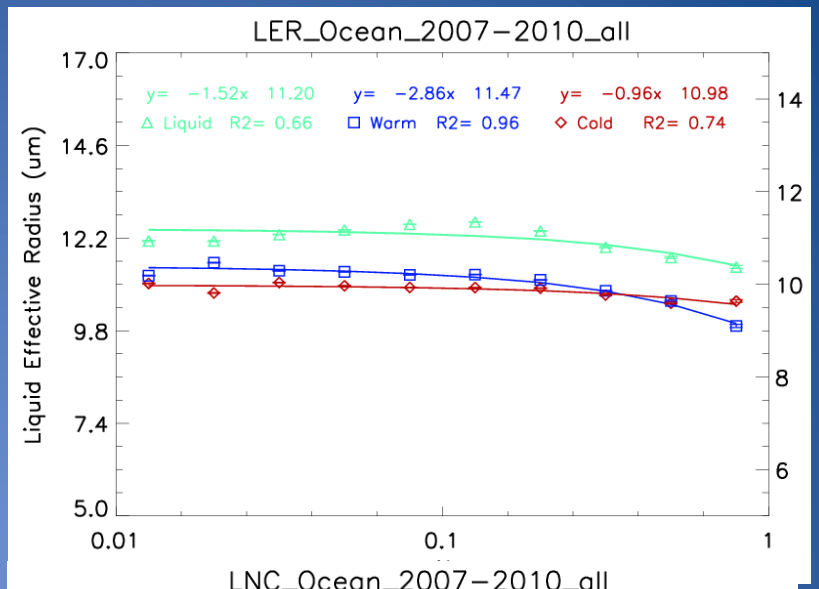


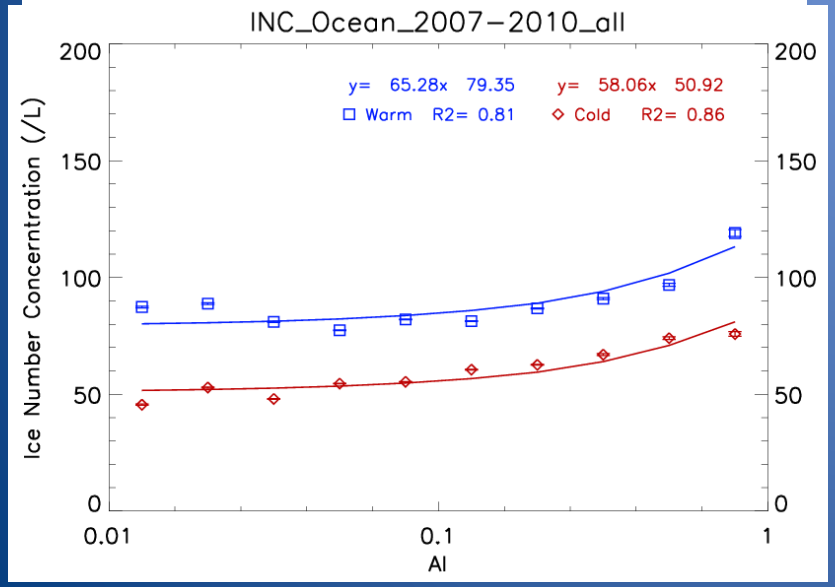


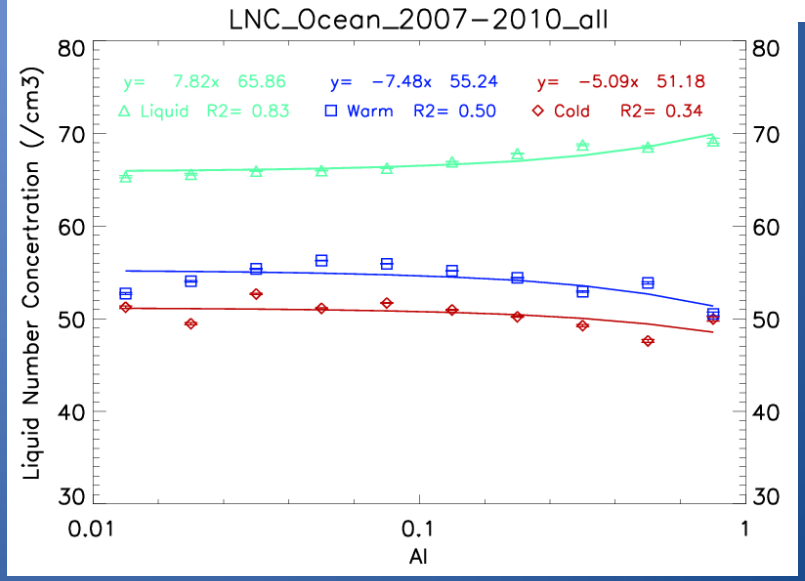
Increase of IWP indicates ice processed are enhanced under higher AI scenes
No clear explanation for LWP

Cloud microphysical properties VS AI over Ocean



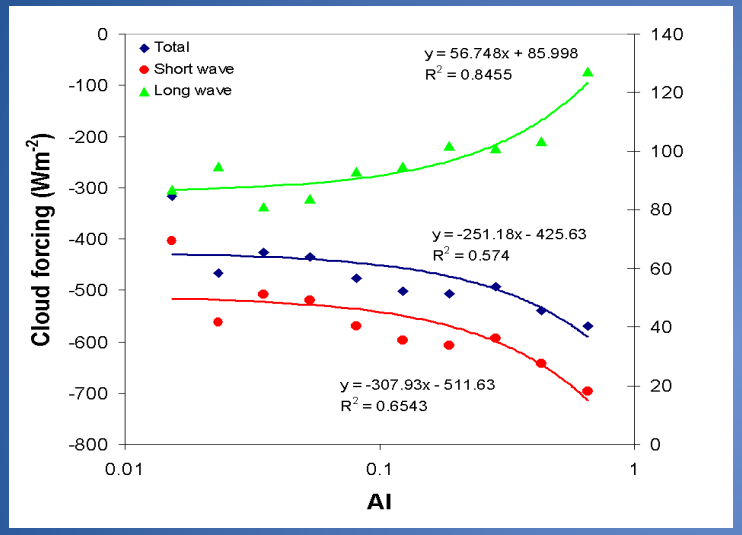




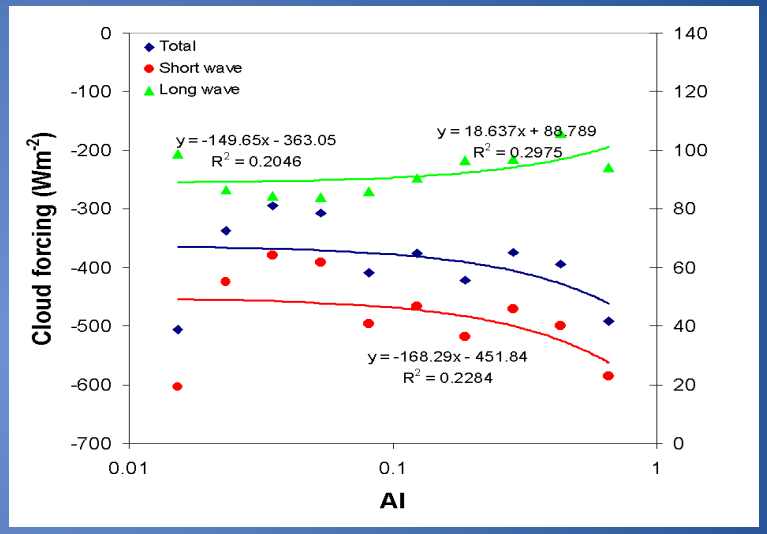


Impact on aerosol radiative forcing due to The macro- and micro-physcial changes by Aerosols A missing term in the climate forcing estimation

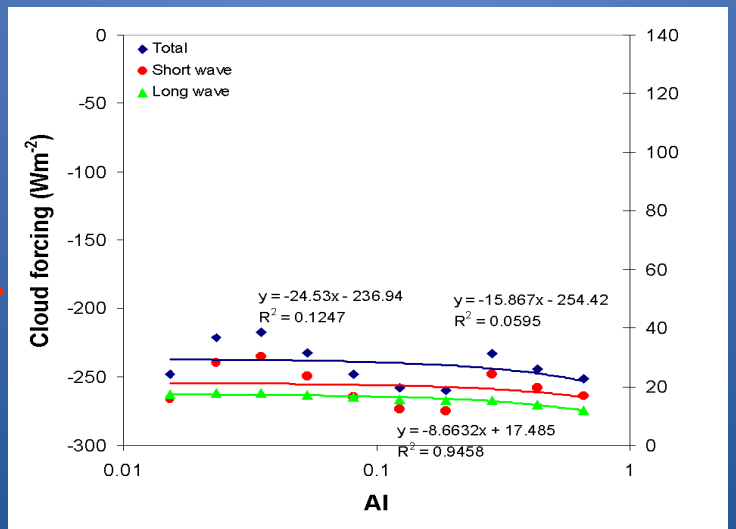
Warm base mixed-phase



Cold base mixed-phase

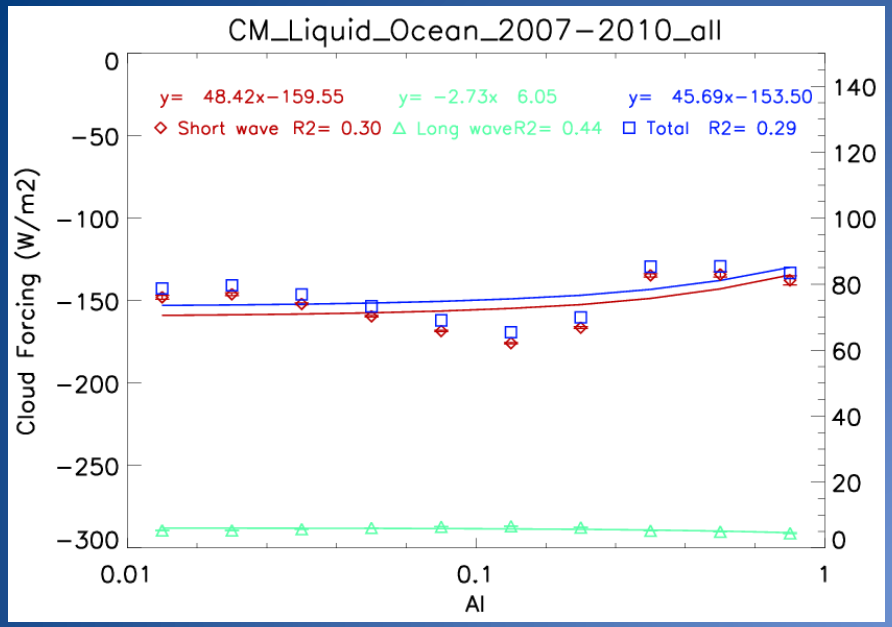


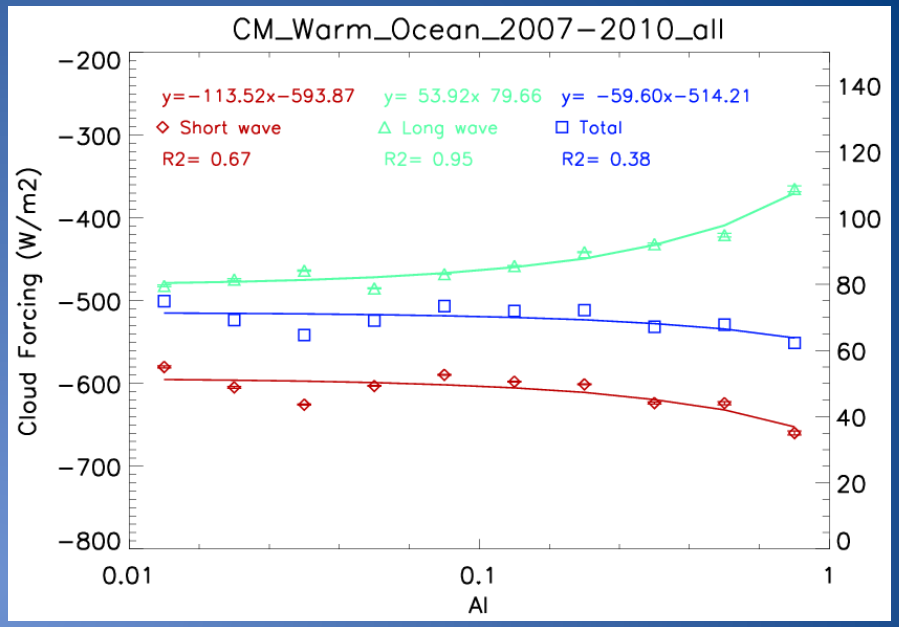
Only the microphysical effect is accounted for in the current estimates

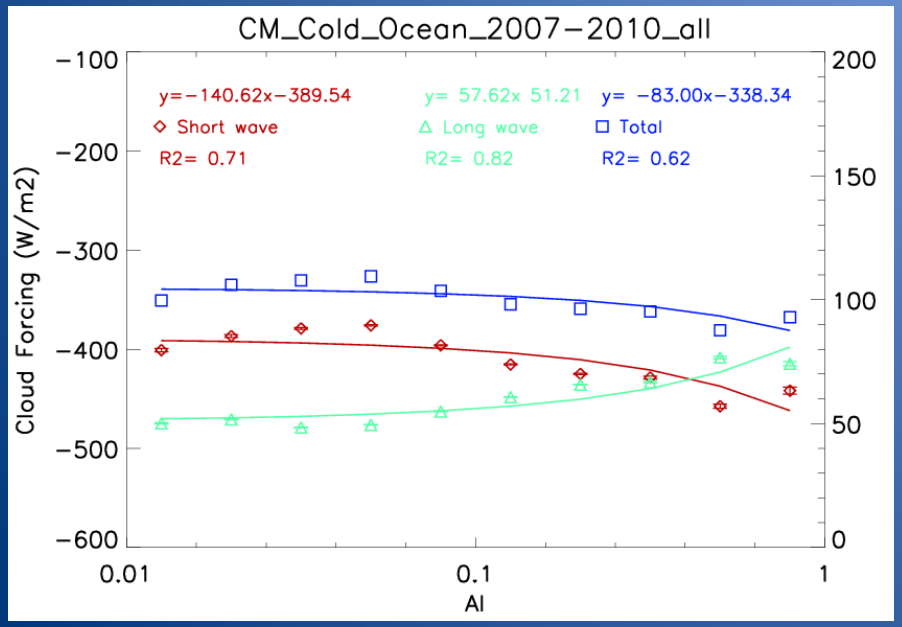


Liquid clouds – Microphysical effect

Instantaneous TOA Cloud Radiative Forcing VS AI over Ocean







AI: Aerosol index

Defined as the multiple of the aerosol optical thickness and Angstrom exponent.

AI=AOD X AE

Include both optical property and size property

The variation of cloud radiative forcing are the same with the situation over land

Summary

- Current estimates of aerosol-induced radiative forcing have missed a major components associated with the macrophysical (height, coverage/frequency) effect that seems much larger than the microphysical effect on individual cases.

- It is important to estimate aerosol effects by accounting for meteorological conditions, cloud regimes, day & night, etc.

- The aerosol effects are complex but a huge large social-economic consequence that have not been conveyed to the public relative to global warming.