Contributions of ACE Mission to Understanding the Earth's Radiation Budget

Norman G. Loeb

NASA Langley Research Center, Hampton, VA

June 20th, 2008, NASA GSFC

Outline

1) The Earth's Energy Budget from Multiple Data Sources.

2) Aerosol Direct Radiative Effect by Aerosol Type.

3) Aerosol-Cloud Interactions Using Satellite Observations.

⇠

Is ACE a process mission, monitoring mission, or both?

Process Mission (PM): ~5-years of optimal set of measurements aimed at improving understanding of specific set of processes (e.g., aerosol-cloud interactions; atmosphere-ocean interactions, etc.).

Pros: High information content for evaluating/developing model improvements; Likely higher spatial resolution.

Cons: Cannot measure response of climate system to climate forcing; May not resolve controversial public debates on decadal changes (e.g., in TOA and surface radiation budget).

Monitoring Mission (MM): 15+ year mission comprised of multiple copies of less expensive instruments that can detect changes in the climate system. Is ACE the beginning of a new aerosol/cloud/ocean monitoring system?

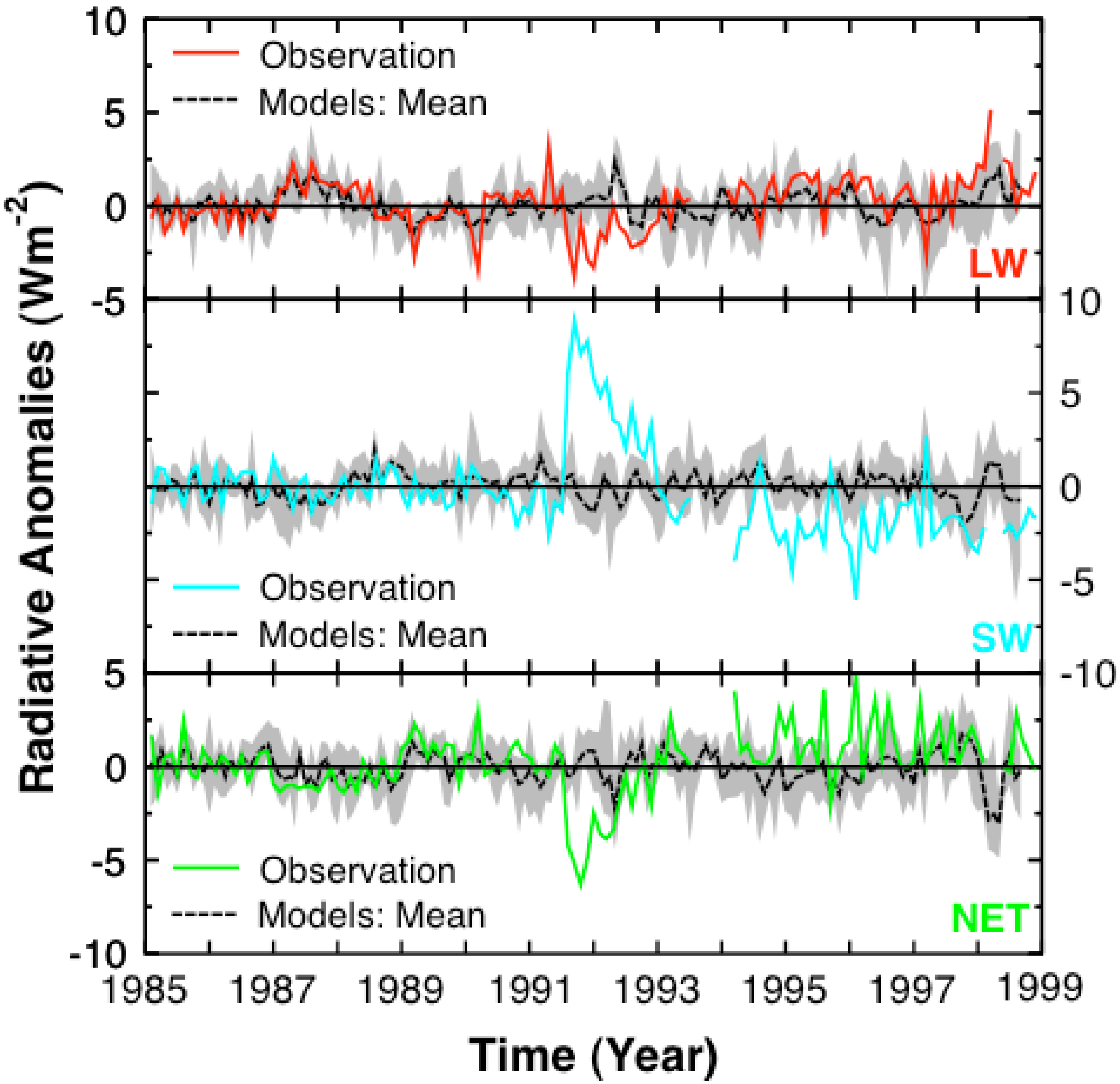
Pros: Records response of clouds/aerosols/ocean to climate forcing.

Cons: More difficult to unscramble underlying processes when changes in system do occur.

-> Climate science required both PM and MM.

Tropical (20ºS - 20ºN) TOA Radiation Anomalies: Observations vs. Climate Models

(ERBS Nonscanner WFOV; 1985-1999)



Edition 3 ERBS with altitude & day/night corrections.

Decadal Changes (1980s to 1990s)

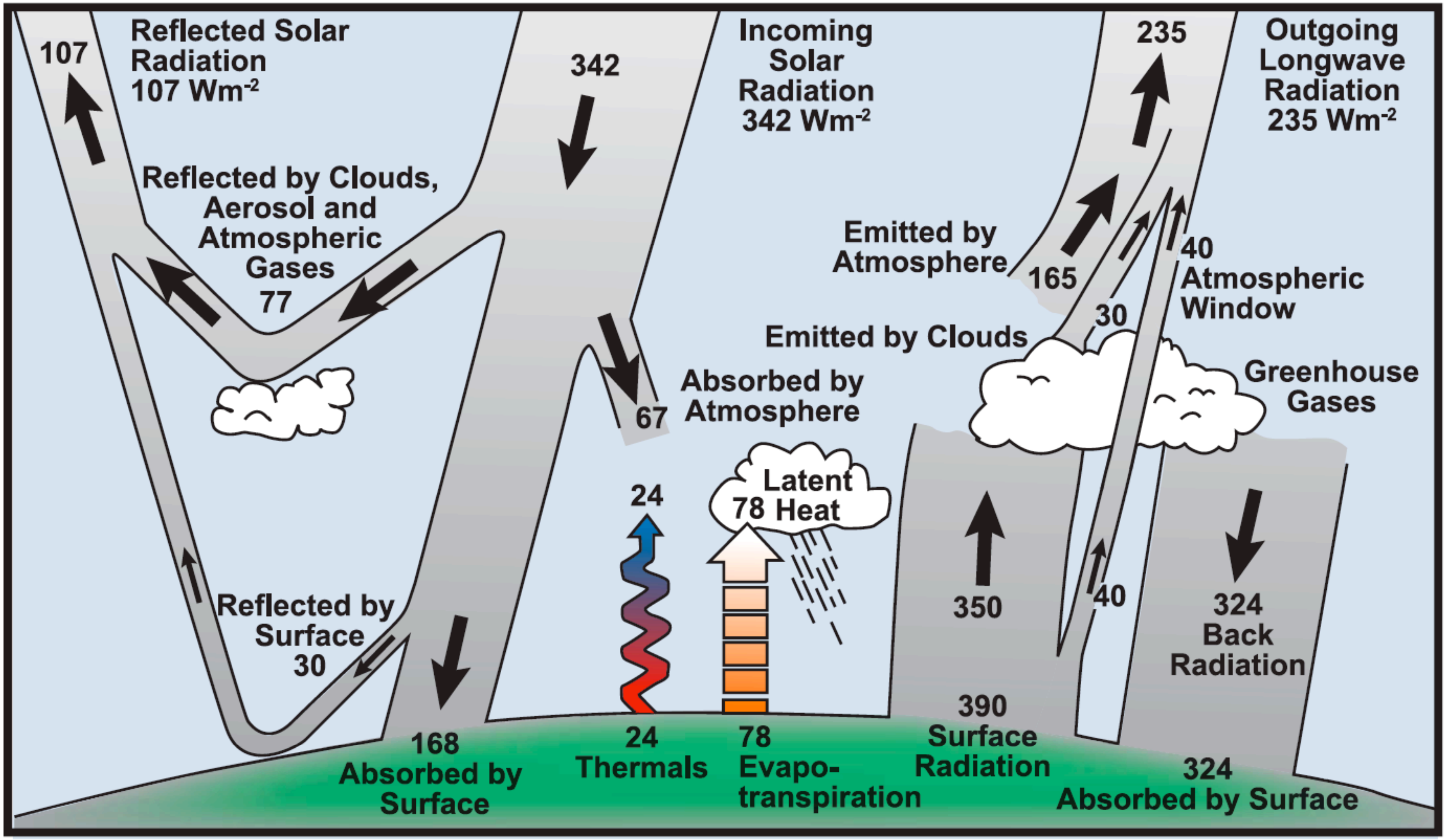
LW: 1.6 Wm^{-2}

SW: -3.1 Wm^{-2}

NET: 1.5 Wm^{-2}

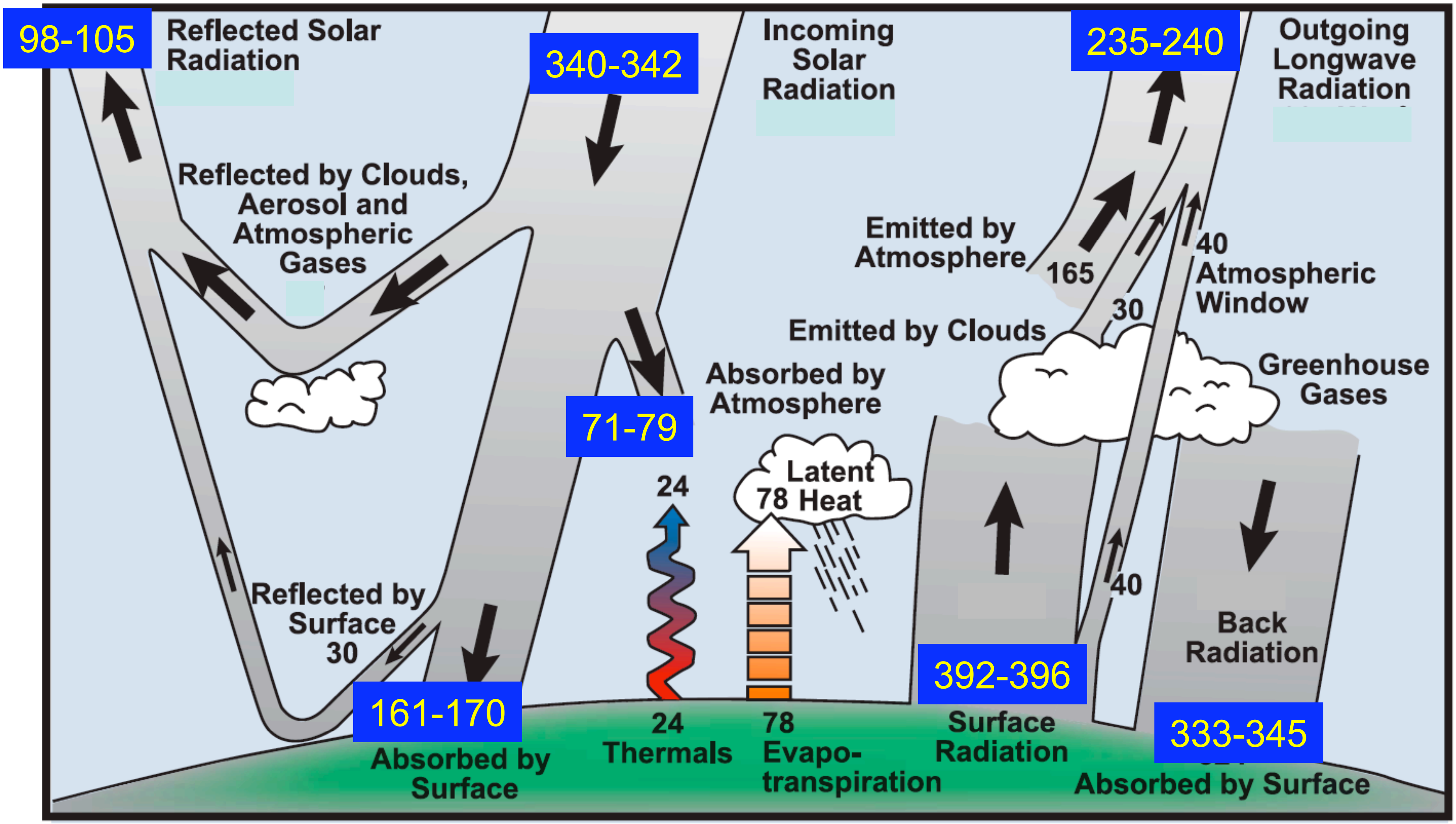
Wong et al., (2006) J. Climate

Earth's Annual and Global Mean Energy Balance



FAQ 1.1, Figure 1. *Estimate of the Earth's annual and global mean energy balance. Over the long term, the amount of incoming solar radiation absorbed by the Earth and atmosphere is balanced by the Earth and atmosphere releasing the same amount of outgoing longwave radiation. About half of the incoming solar radiation is absorbed by the Earth's surface. This energy is transferred to the atmosphere by warming the air in contact with the surface (thermals), by evapotranspiration and by longwave radiation that is absorbed by clouds and greenhouse gases. The atmosphere in turn radiates longwave energy back to Earth as well as out to space. Source: Kiehl and Trenberth (1997).*

Earth’s Annual and Global Mean Energy Balance



FAQ 1.1, Figure 1. *Estimate of the Earth’s annual and global mean energy balance. Over the long term, the amount of incoming solar radiation absorbed by the Earth and atmosphere is balanced by the Earth and atmosphere releasing the same amount of outgoing longwave radiation. About half of the incoming solar radiation is absorbed by the Earth’s surface. This energy is transferred to the atmosphere by warming the air in contact with the surface (thermals), by evapotranspiration and by longwave radiation that is absorbed by clouds and greenhouse gases. The atmosphere in turn radiates longwave energy back to Earth as well as out to space. Source: Kiehl and Trenberth (1997).*

CERES Integrated Data for Radiation/Cloud/Aerosol
(TOA, Surface and Atmosphere Fluxes)

Input Data

CERES Crosstrack Broadband

CERES Hemispheric Scan ADMs

MODIS Cloud/Aerosol/Snow&Ice

Microwave Sea-Ice

Aerosol Assimilation Data

4-D Assimilation Weather Data (fixed climate assimilation system)

Geostationary 3-hourly Data

Consistent Calibration

Output Data

ERBE-Like TOA Fluxes (20 km fov, 2.5 deg grid)

CERES Instantaneous TOA/Sfc/Atmosphere
- **20km fov (SSF, CRS products)**
- **1° gridded (SFC, FSW products)**
- **Fluxes, cloud & aerosol properties**

CERES Time Averaged TOA/Sfc/Atmosphere
- **3-hourly, daily, monthly**
- **1º gridded (SRBAVG, AVG, ZAVG products)**
- **Fluxes, cloud and aerosol properties**

High level of data fusion; up to 11 instruments on 7 spacecraft all integrated to obtain climate accuracy in top to bottom fluxes.

Energy Budget Derived From Future Measurements

TOA

Incoming Solar: **TSIS**
Outgoing SW, LW: **CERES**
Absolute Calibration: **CLARREO**

ATM

Cloud Properties: **VIIRS, ACE?**
Aerosol Properties: **VIIRS, ACE**
Temperature/Humidity: **CrIS, ATMS, CMIS, PATH, GPSRO, CLARREO**
Atmospheric Composition: **ASCENDS, GEO-CAPE, GACM**

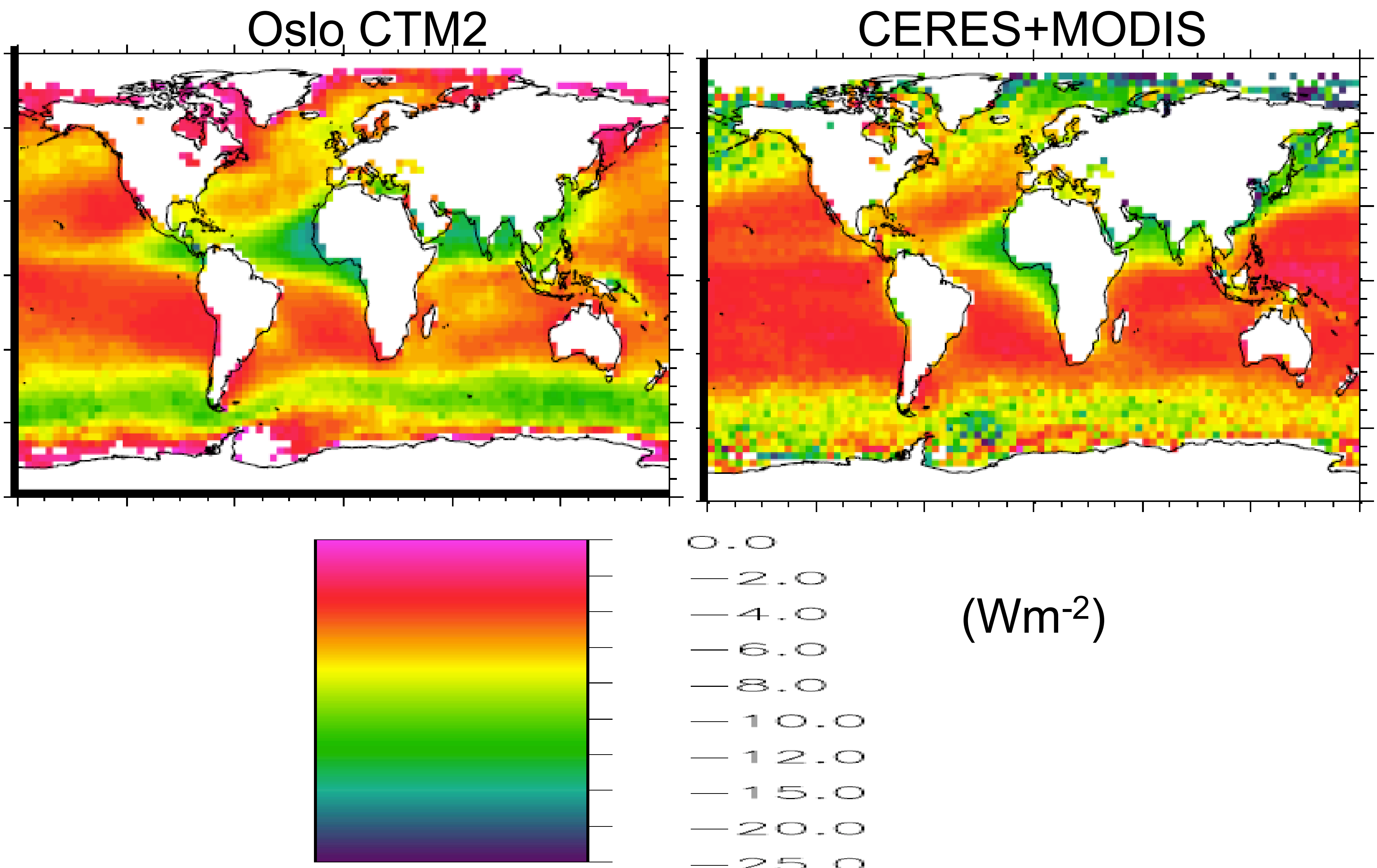
SFC

Surface Reflectance: **VIIRS**
SST: **VIIRS, CMIS, PATH**
Skin Temp: **VIIRS, CMIS**
Precip: **CMIS, PATH**
Surface Type: **HyspIRI**
Soil Moisture: **SMAP**

Improvements to Surface Radiation Budget

- Significant improvement in estimating surface radiation budget will come from observations of vertical distribution of:
  - -Temperature/water vapor
  - -Aerosol absorption
  - -Cloud base height
- Will help address several areas:
  - - Future “global dimming/brightening”.
  - - Constraint on LH+SH exchange between sfc & atmos.
  - - Improved constraint on solar irradiance into ocean (-> mixed-layer ocean dynamics).
  - - Role of clouds and aerosols in modulating ice-albedo feedback.
- Ideally, long-term measurements are needed (e.g., ACE-LITE?).

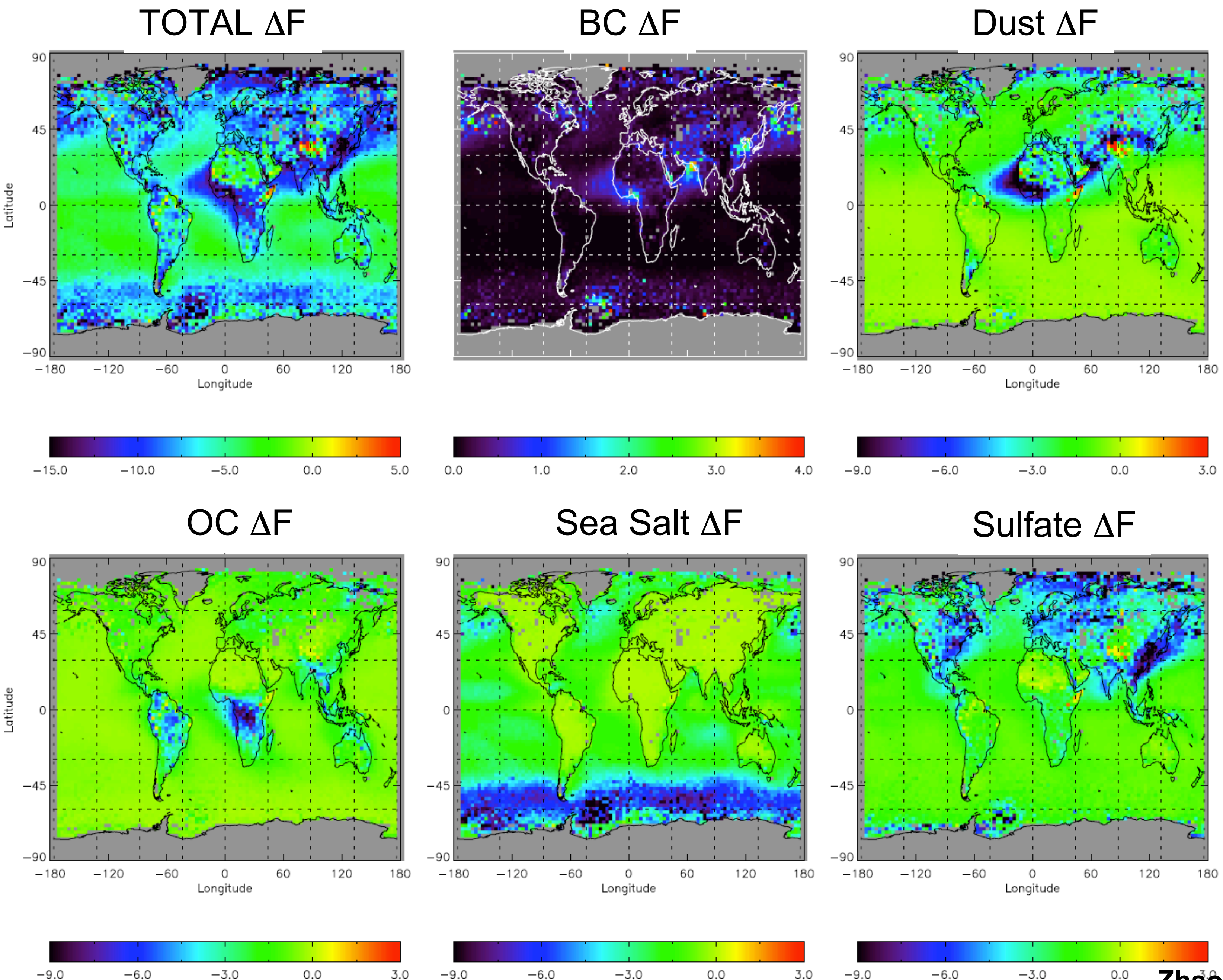
Direct Radiative Effect of Aerosols over Ocean: Model vs CERES



The Oslo CTM2 is an off-line global aerosol-chemistry transport model driven with meteorological data from the ECMWF

Myhre et al. (2008)

Aerosol Direct Radiative Effect by Type: CERES+GOCART



Zhao et al., 2008

Global Mean Aerosol Direct Radiative Effect (ADRE):

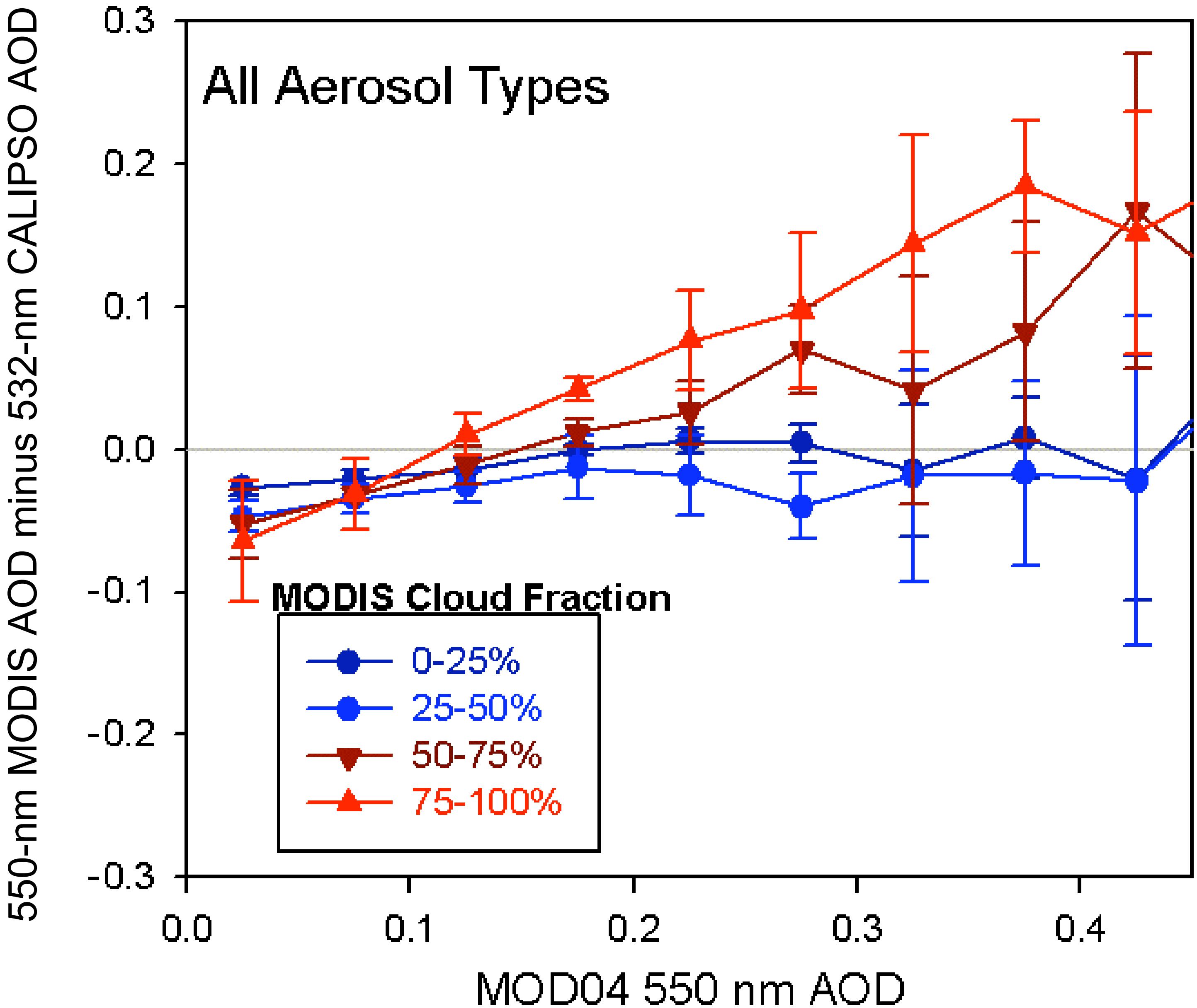
(Wm^{-2})	Clr-Sky	All-Sky
TOA	-6	-3
ATM	5	4
SFC	-11	-7

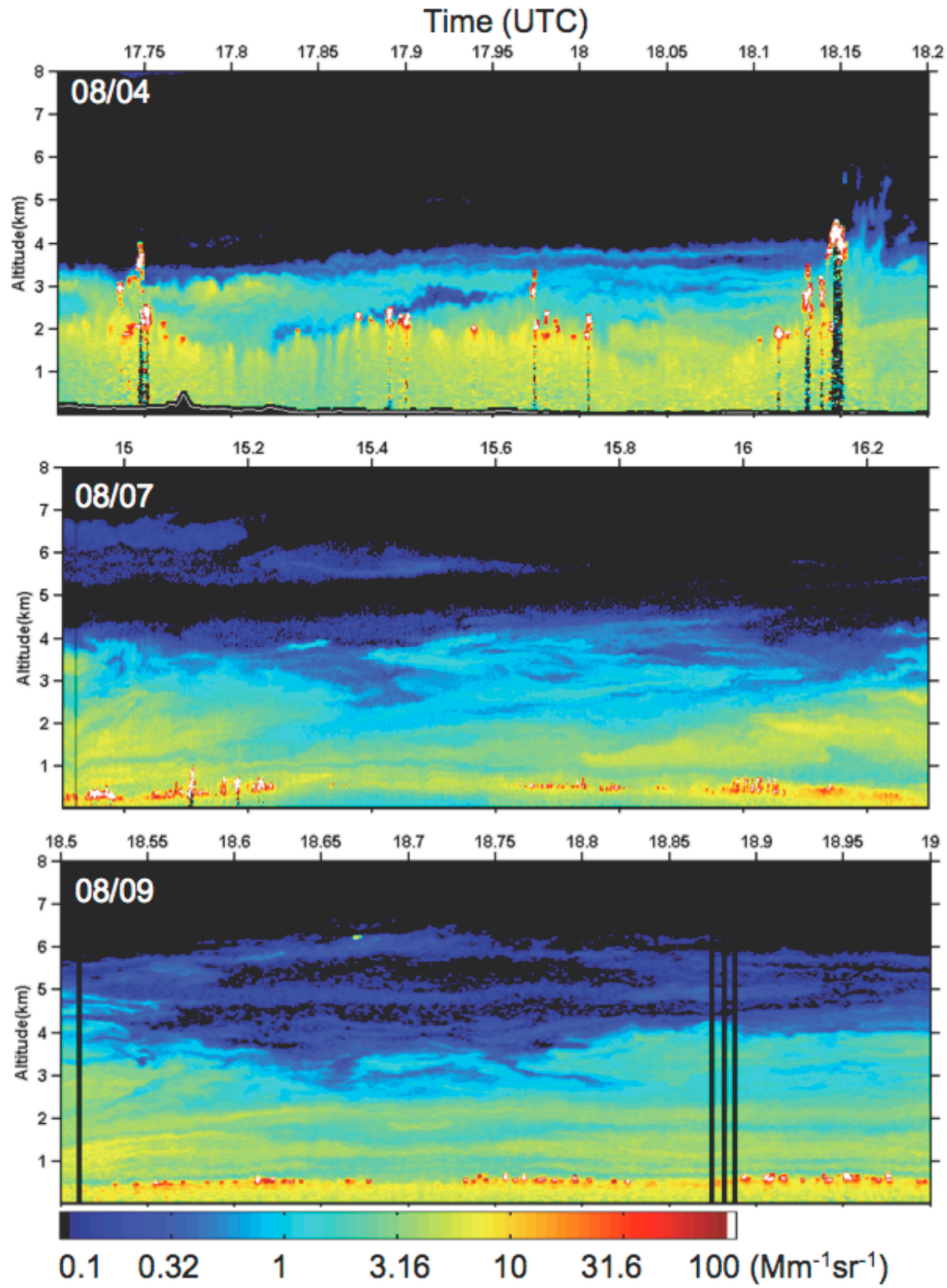
- Increase at surface is due to absorption in atmosphere by aerosols.

->Need column absorption to accurately compute SFC ADRE.
->Need vertically resolved layer absorption for heating rates in atmosphere (could have strong influence on dynamics in some regions).

Kim & Ramanathan (2008)

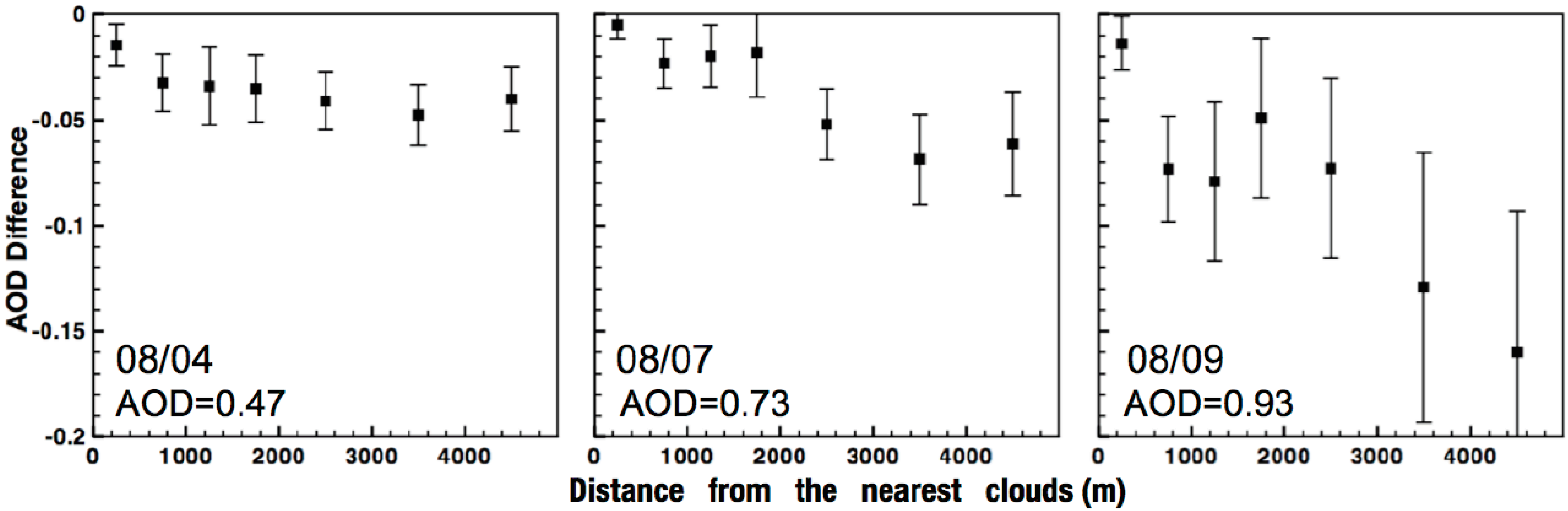
MODIS - CALIPSO AOD Difference by MODIS Cloud Fraction



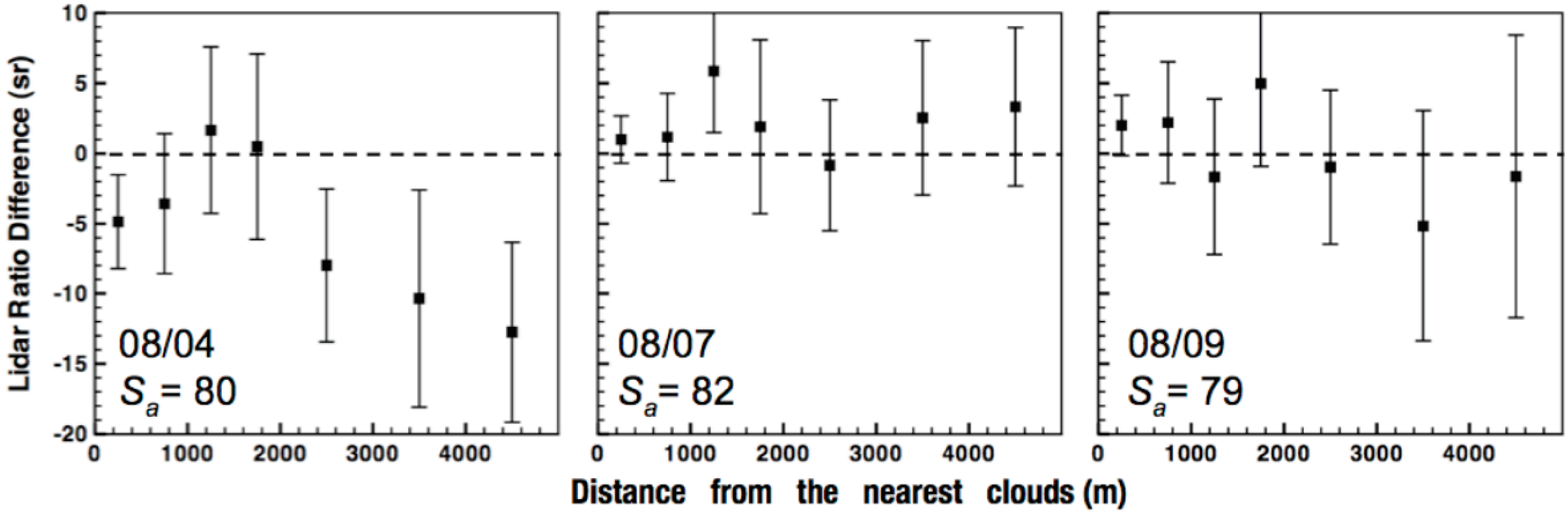


HSRL during CATZ Campaign

Spatial Variation in 532 nm Aerosol Optical Depth Near Clouds



Spatial Variation in 532 nm Lidar Ratio Near Clouds



Conclusions

- Can ACE data be used to assess longer term changes in aerosol/cloud/ocean variables (e.g., since CALIPSO/CloudSAT period)? May require A-Train-Like data products?
- Role of ACE for improving surface radiation budget.
  - -By how much will ACE improve it?
  - -Constraint on SH+LH exchange between sfc and atm.
- Vertical distribution of aerosol type, size distribution and single scattering albedo major step forward from CALIPSO capability.
  - - Quantify impact on atmos radiative heating, surface radiation, aerosol direct radiative effect, etc.
- Role of ACE in addressing aerosol-cloud interactions.
  - - Use ACE in conjunction with CRMs? If so, how? Are field campaigns what is really needed to move forward on this problem?