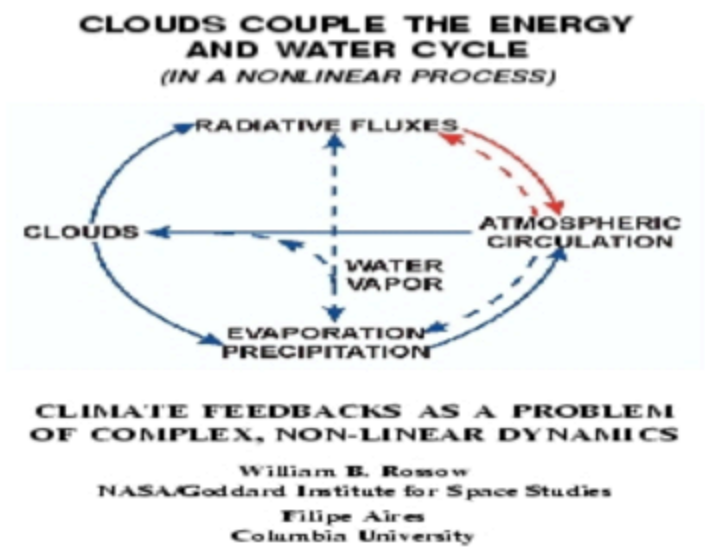
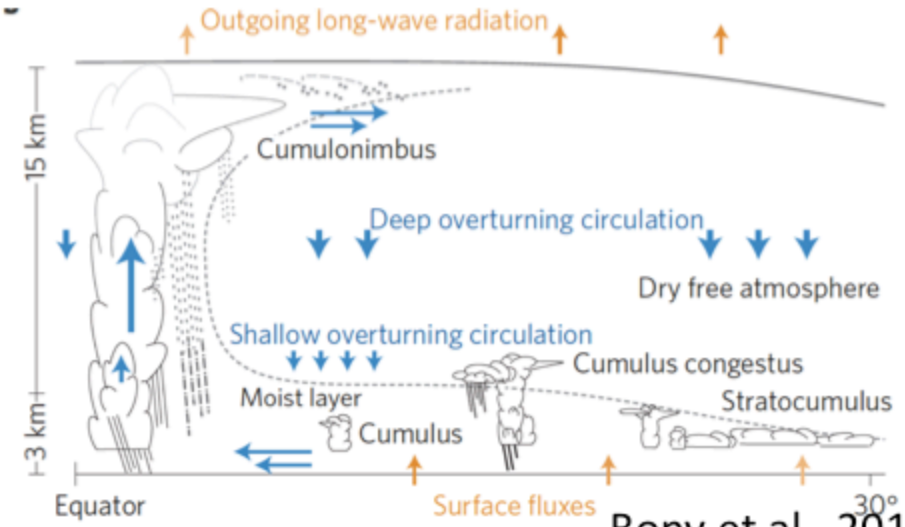
Global Cloud Type Distributions and Their Roles in Coupling the Global Water and Energy Cycles

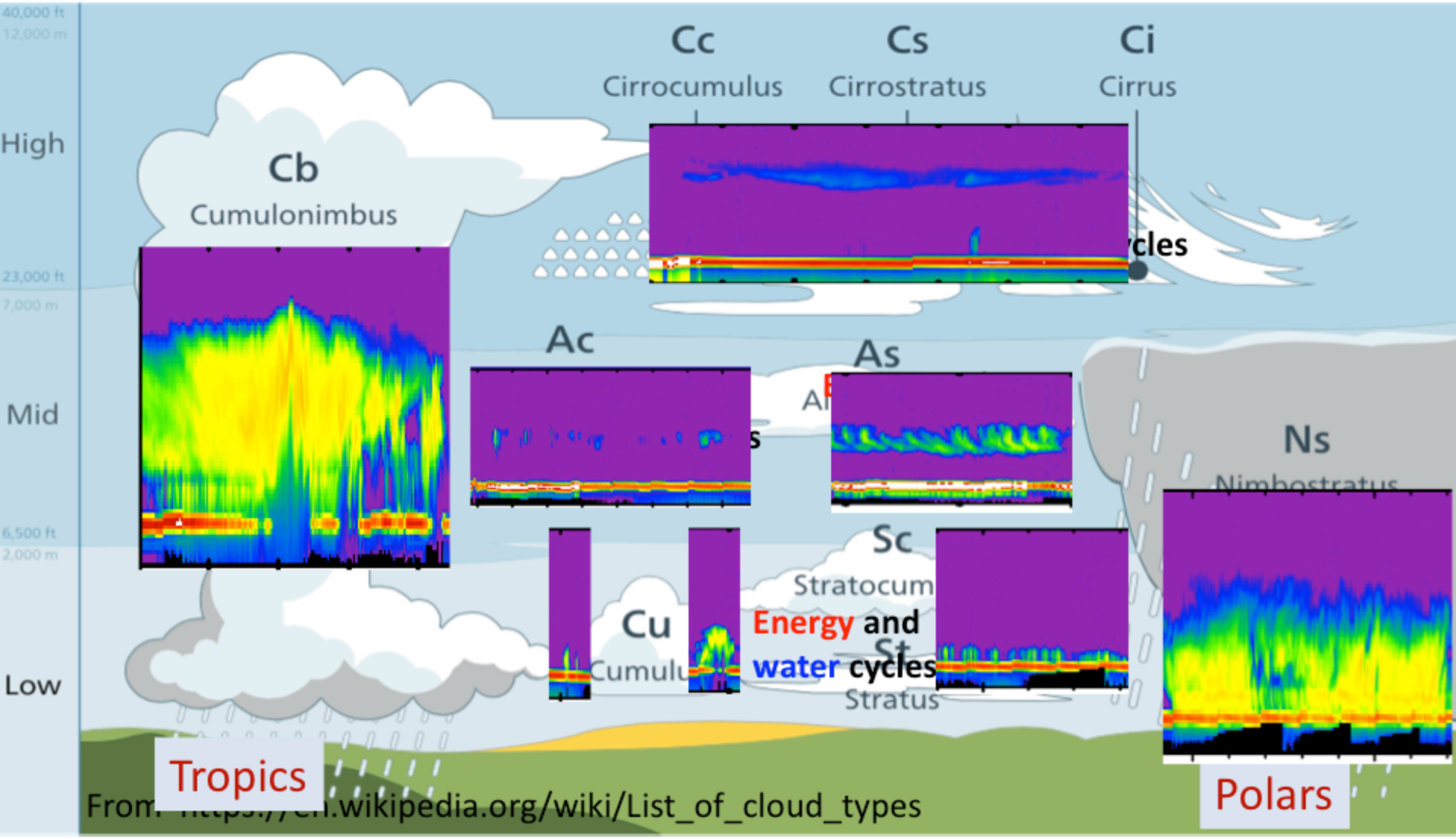
Zhien Wang, Sujan Khanal, and Min Deng
University of Wyoming
and
Tao Luo
Anhui Institute of Optics and Fine Mechanics, China





Bony et al. 2015

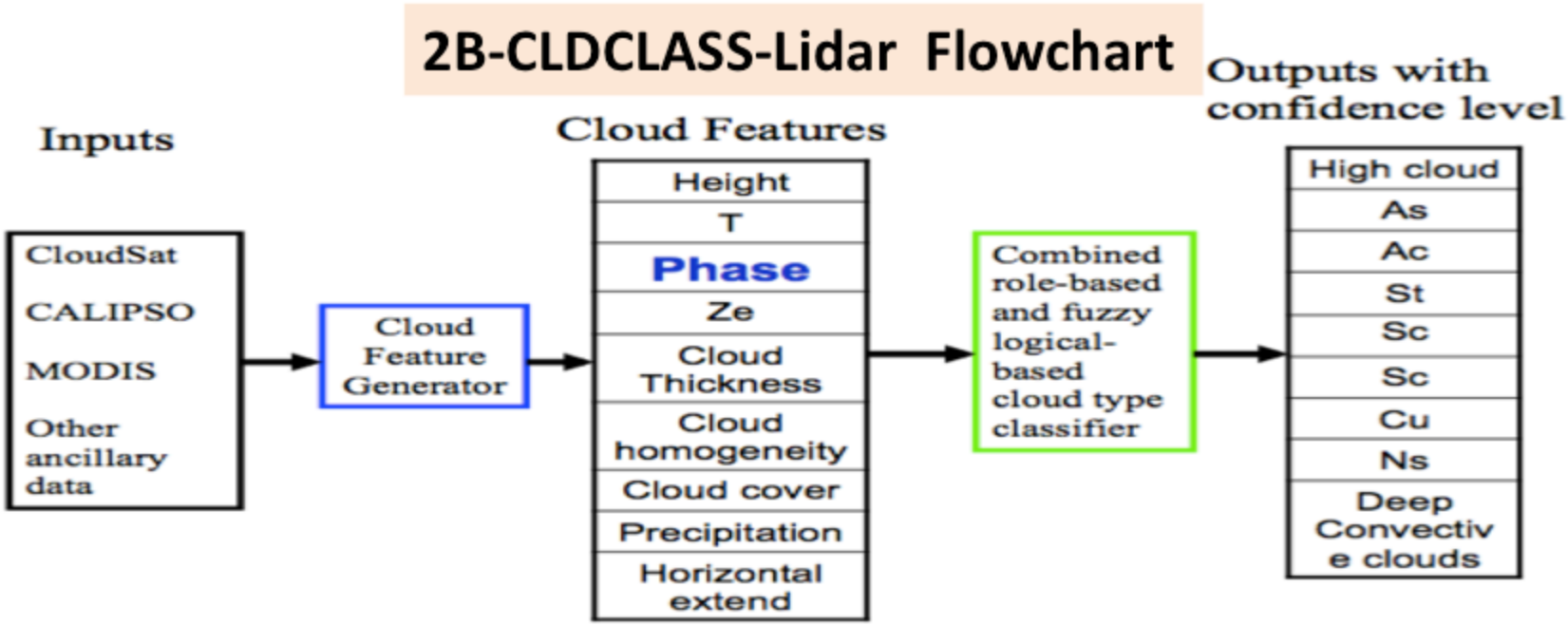
Cloud Types, Their Roles in the Water and Energy Cycles, and Identifications



From: https://en.wikipedia.org/wiki/List_of_cloud_types

CloudSat Cloud Classification Products

- Radar-only (2B-CLDCLASS)
- Radar-lidar combined (2B-CLDCLASS-Lidar)

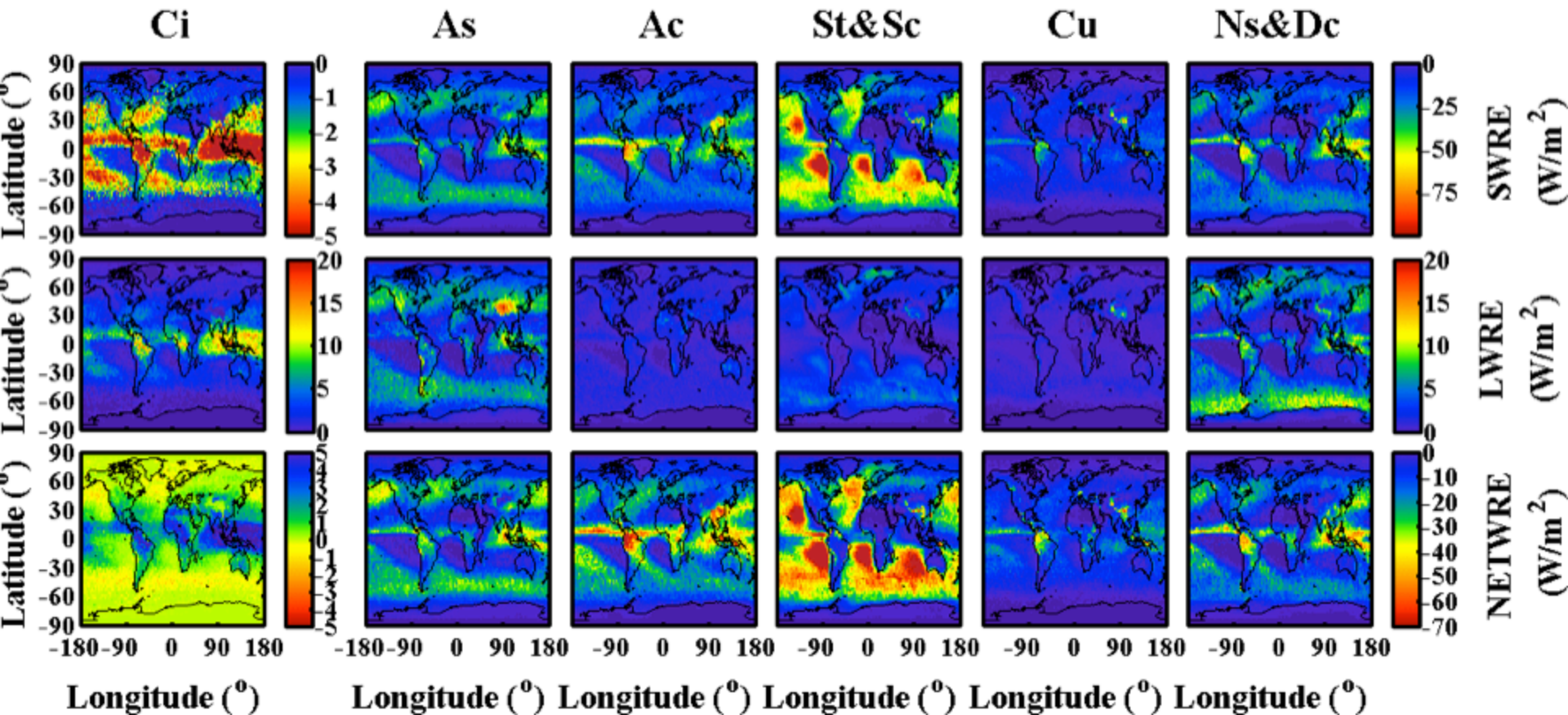


Data and Approaches

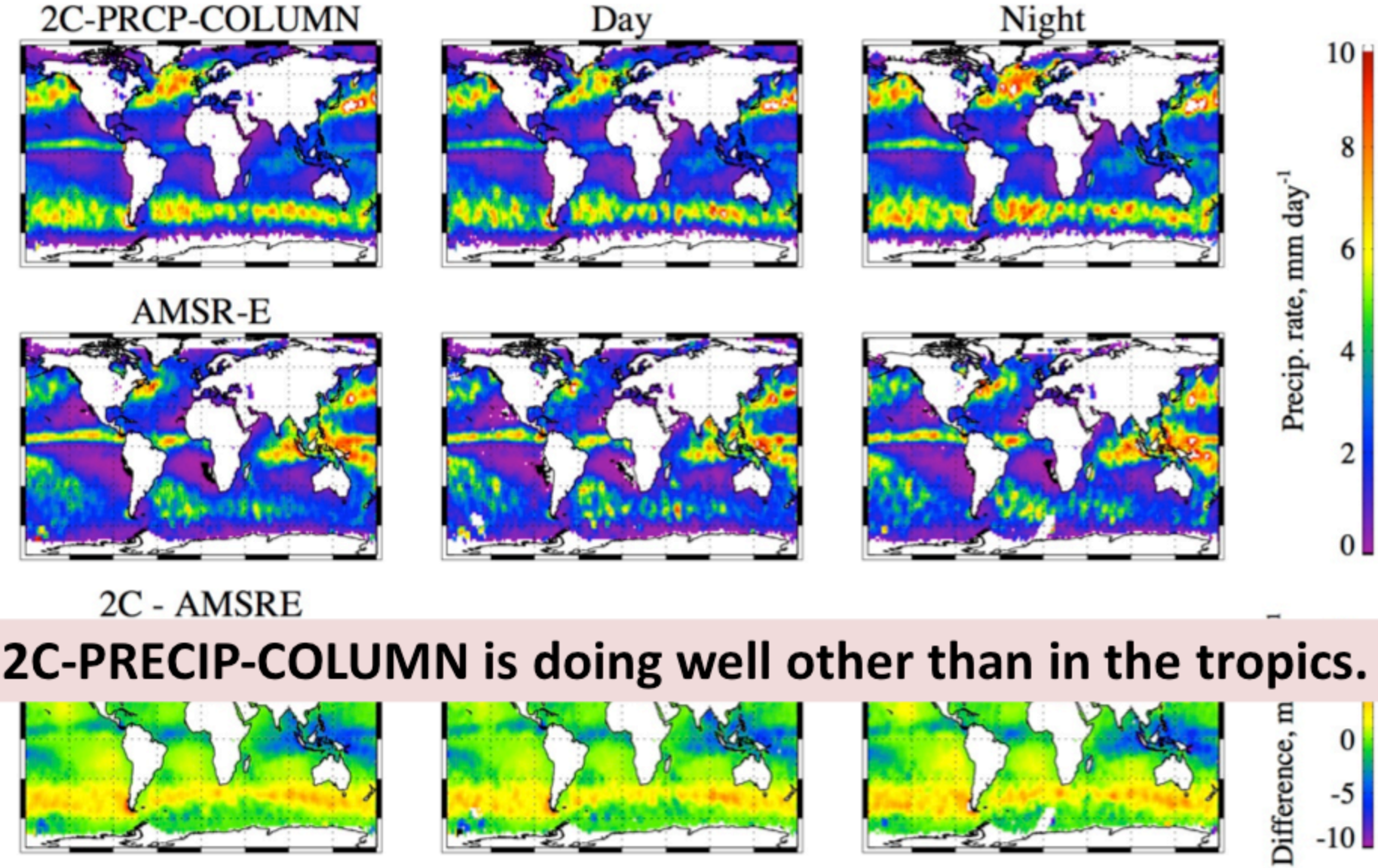
- **Cloud types**:
  - 2B-CLDCLASS-lidar data (2006-2016)
- **TOA cloud radiative forcings**:
  - CERES FlashFlux product from Aqua
  - Cloud types were collocated within CERES (25x25 km) .
  - Single type dominated CERES data were used.
- **Precipitation:**
  - 2C-Precip-column (ocean-only)
  - AMSR-E (ocean-only)
  - GPCP

Cloud Type Dependent TOA Cloud Radiative Forcings

Daytime only

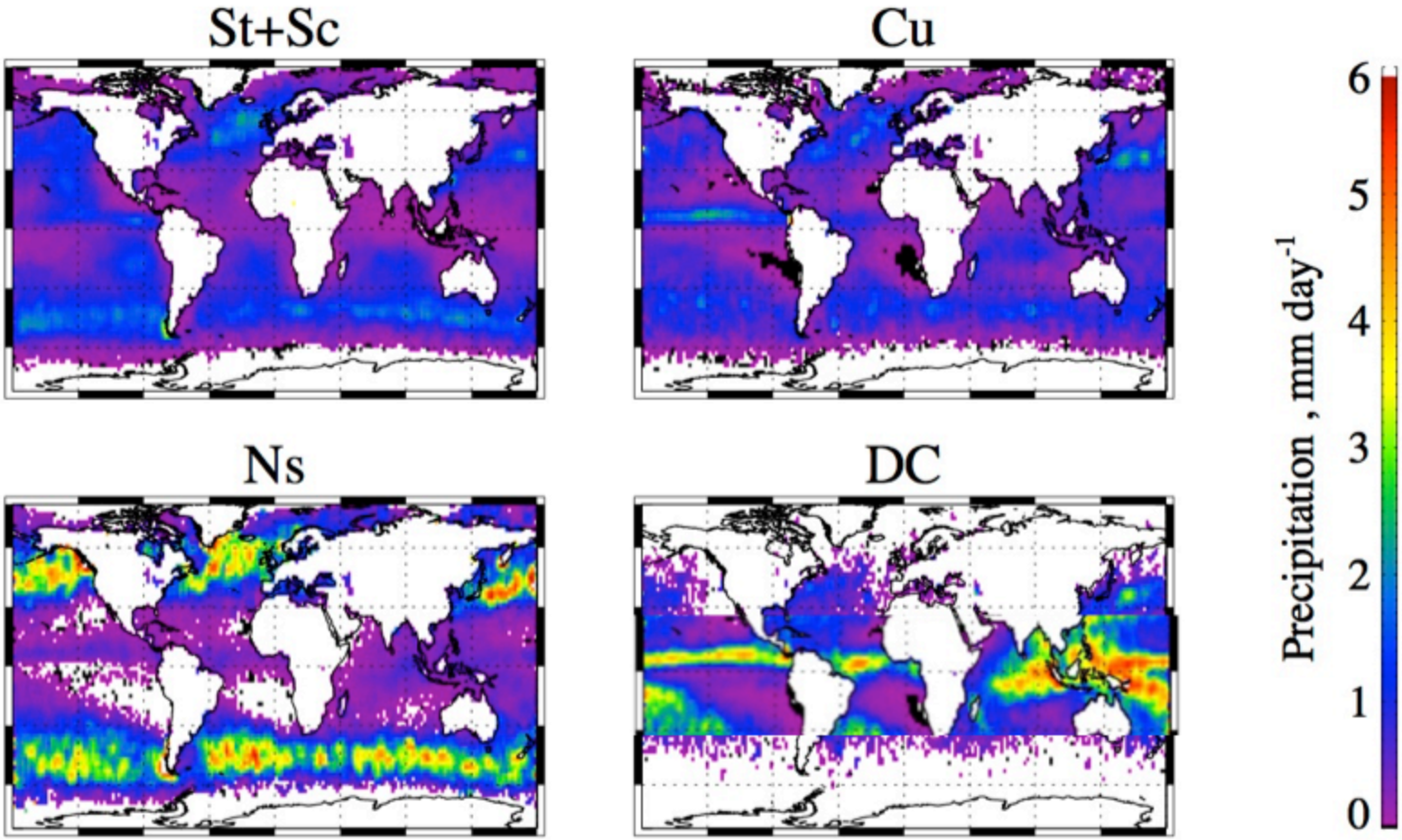


Precipitation Estimation Comparison



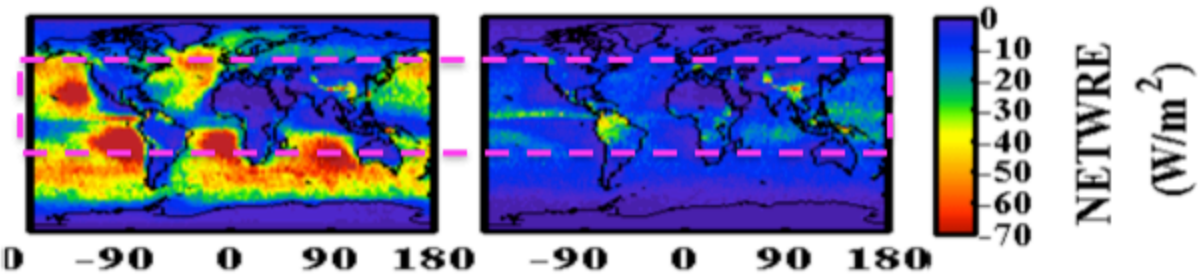
2C-PRECIP-COLUMN is doing well other than in the tropics.

Cloud Type Dependent Precipitation Distribution

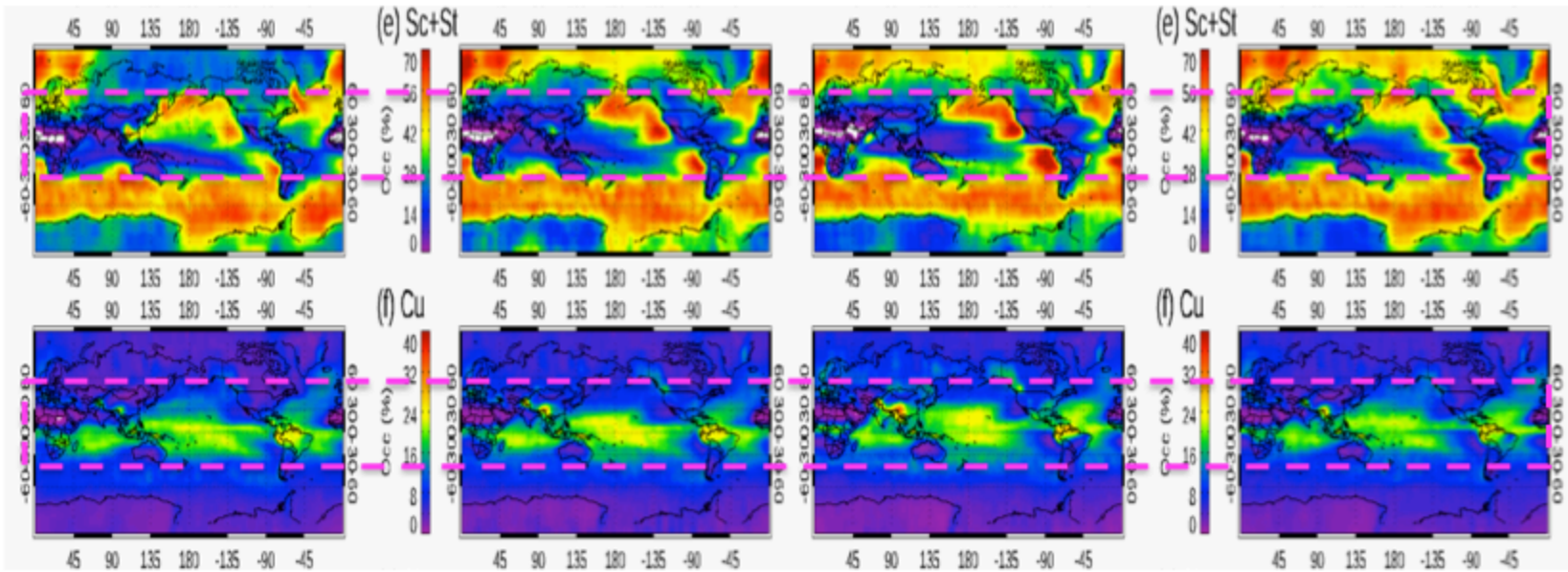


1. Deep convective and Ns clouds have their own territories.
2. The contributions of St+Sc and Cu are still significant to get regional energy balance right.

Seasonal Variations of Low-level Clouds



Jan-March April-June July-Sep Oct-Dec

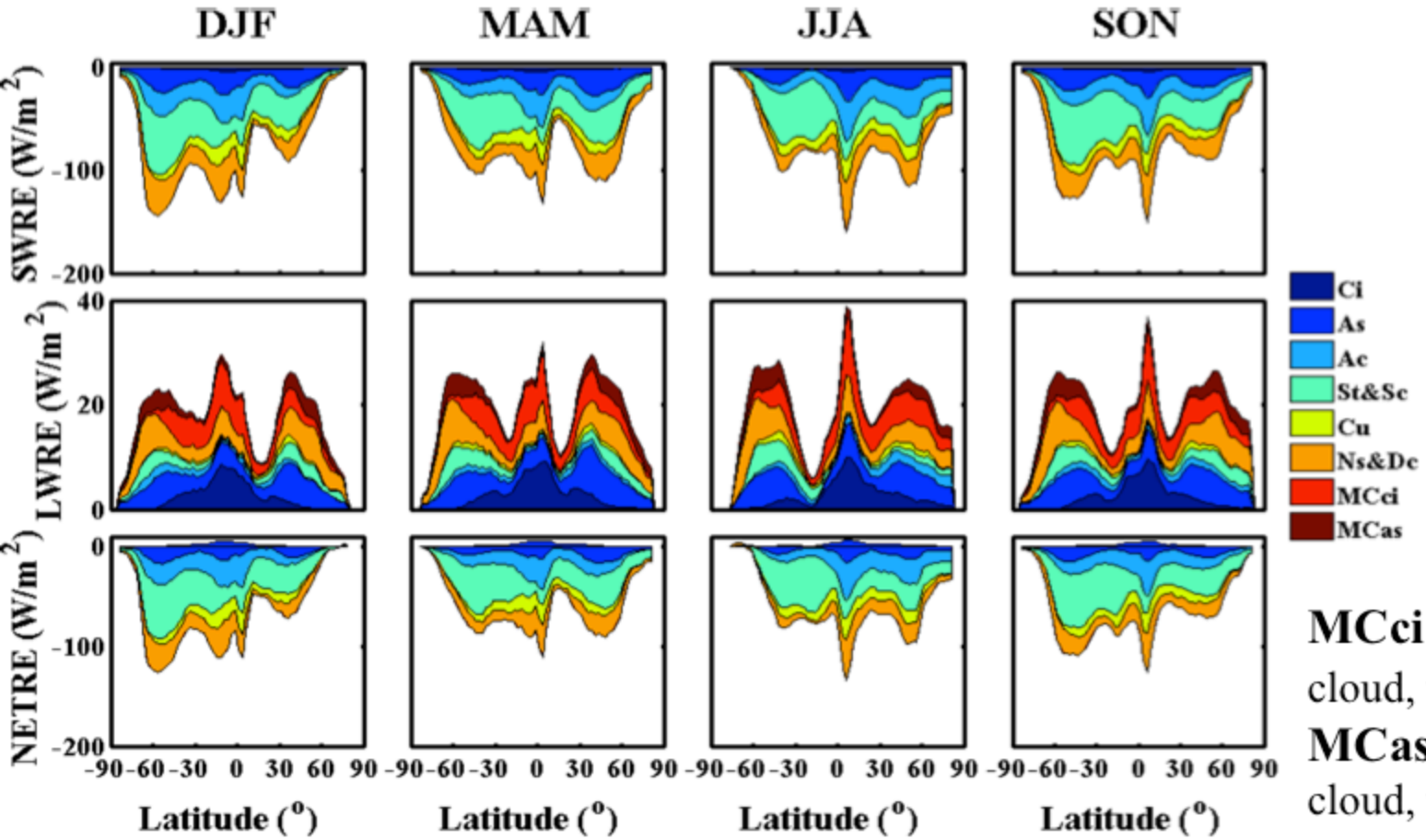


Arctic: Large seasonal variations– very low in Jan-March

Sc-Cu region: Large seasonal variations---**the challenging Sc-Cu transition problem**

Antarctic and the Southern Oceans: Very weak seasonal variations

Seasonal Variability of Cloud Type Dependent Radiative Forcing (daytime)



MCci: Multiple-layer cloud, topped by Ci

MCas: Multiple-layer cloud, topped by As

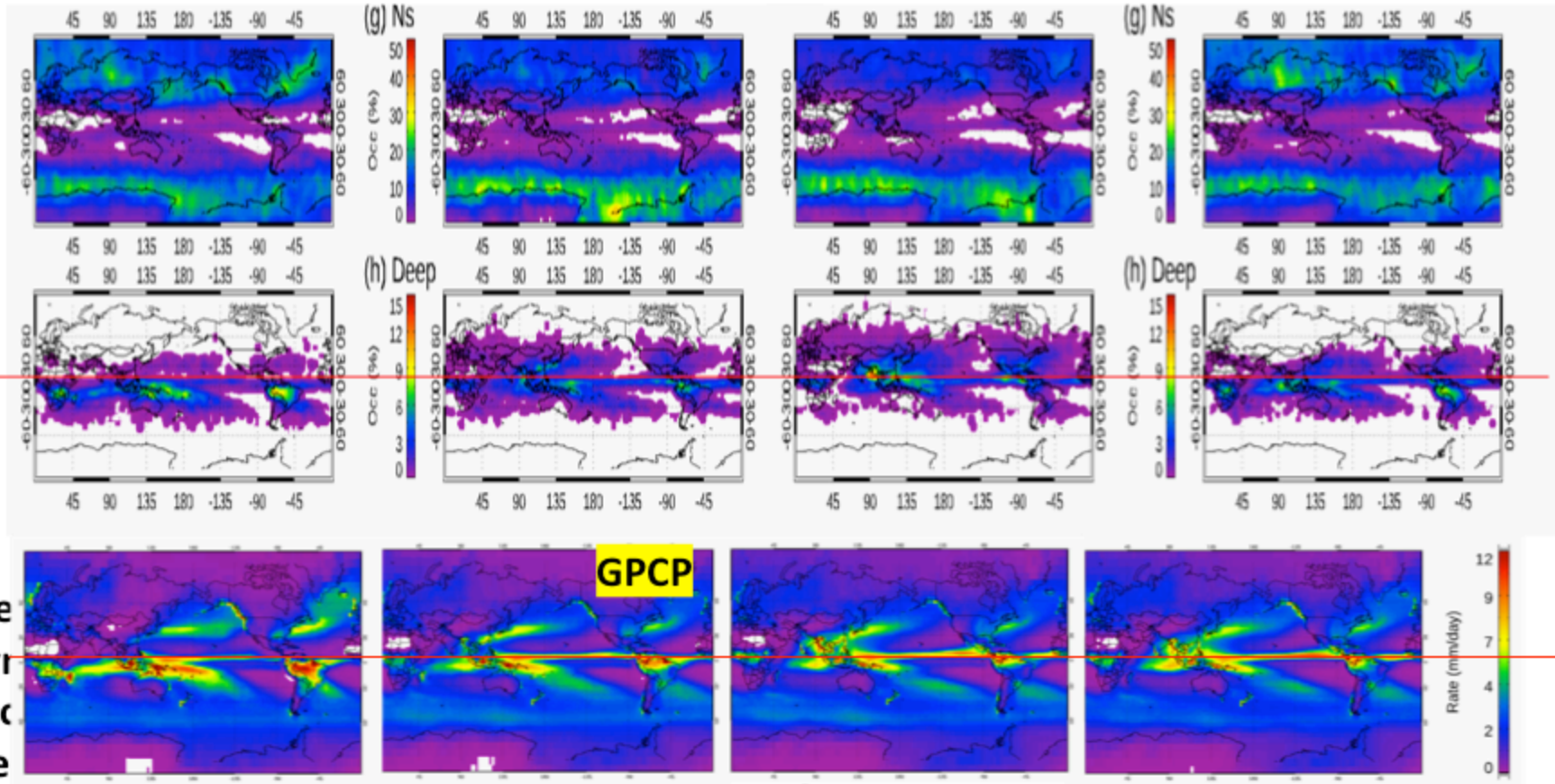
1. Large contributions of Sc+St clouds, especially in the southern hemisphere.
2. Middle-level clouds are important too!

Seasonal Variations of Deep and Ns Clouds and Precipitation

Jan-March | April-June | July-Sep | Oct-Dec

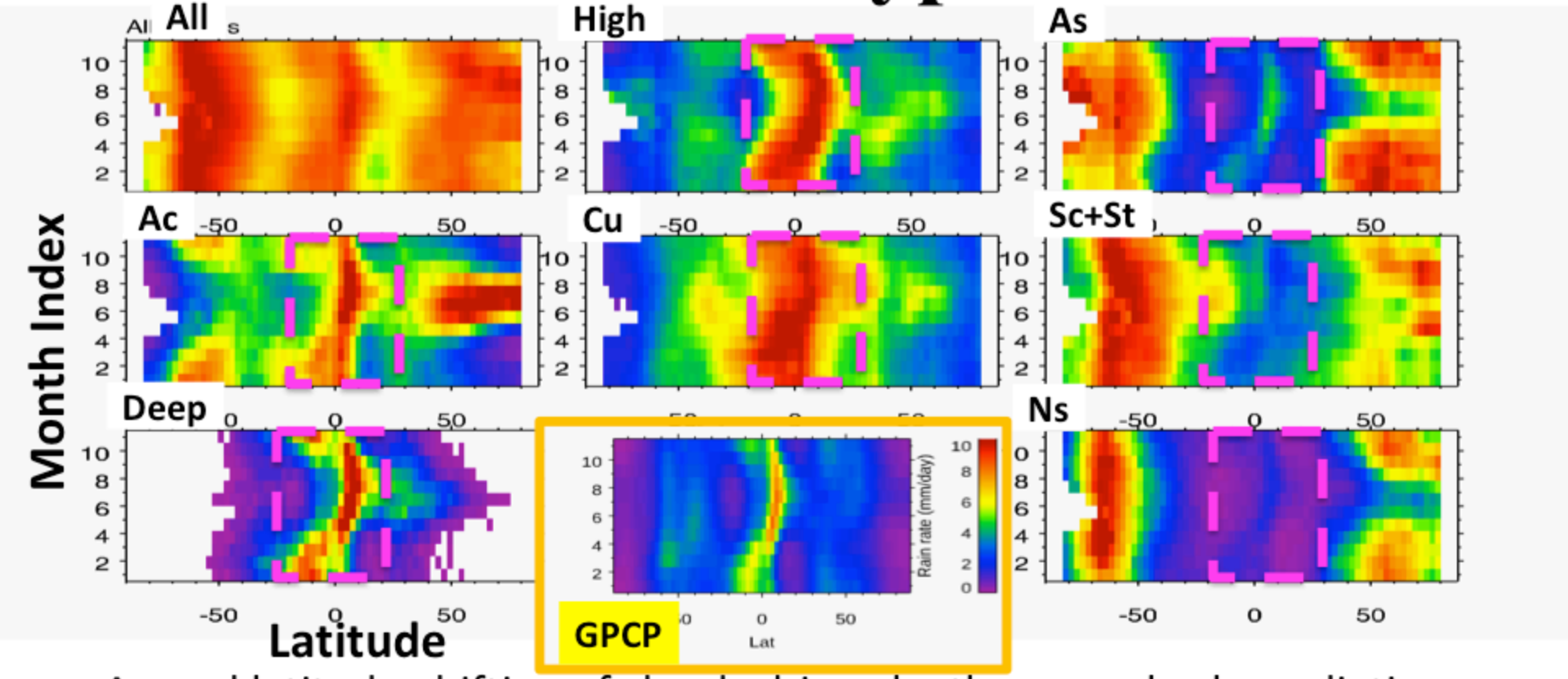
Ns

Deep



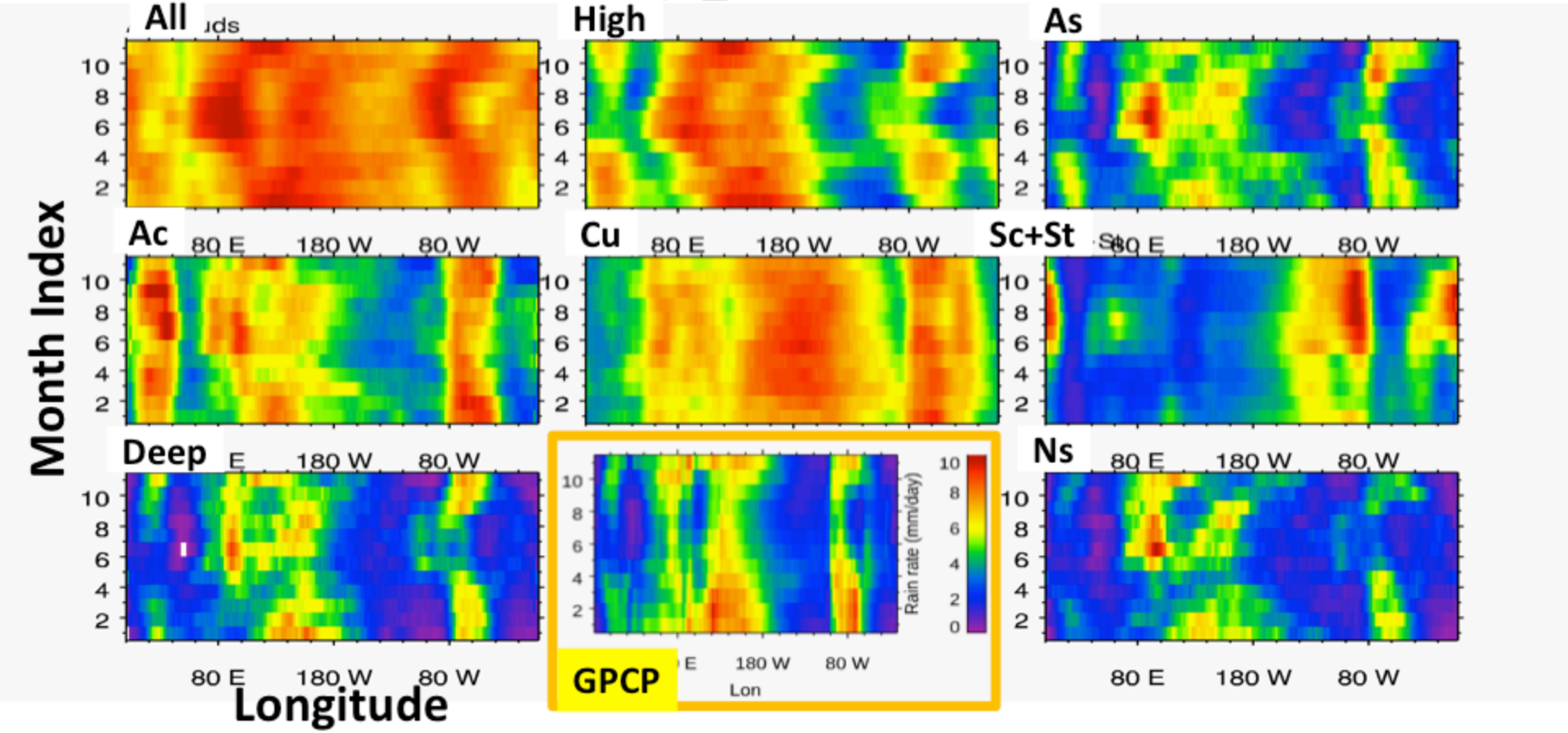
- Dee
(dyr
- Ns c
- The

Annual Cycles of Zonal Mean Cloud Types



- Annual latitude-shifting of clouds driven by the annual solar radiation cycle.
- High latitude As and Ns clouds are also driven by large-scale dynamics and thermodynamics.

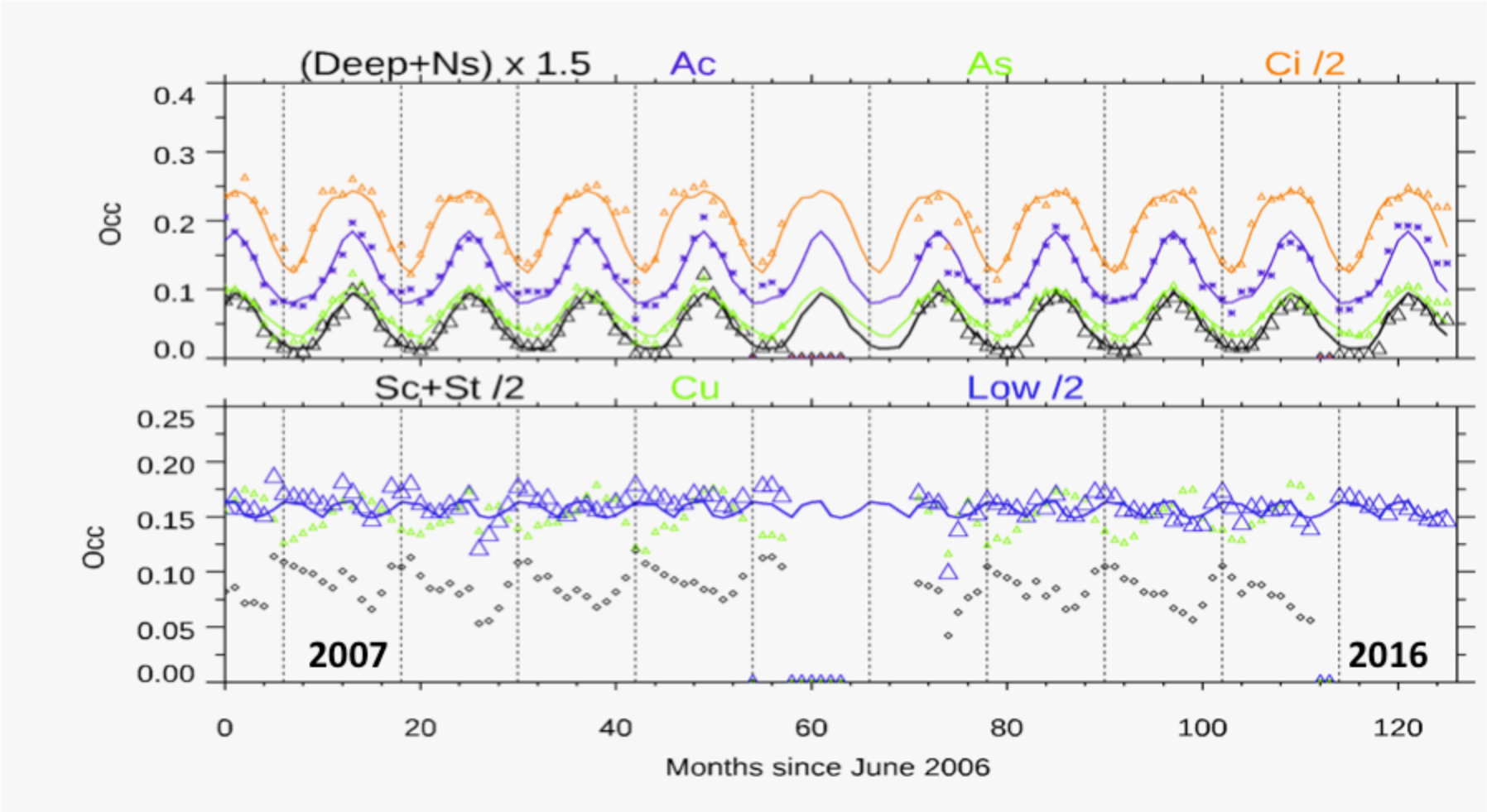
Annual Cycles of Meridional Mean Cloud Types (20S-20N)



- For Low clouds, Sc and St are more localized than Cu.
- High, Ac, Sc, and deep convective clouds share similar spatial-temporal pattern.

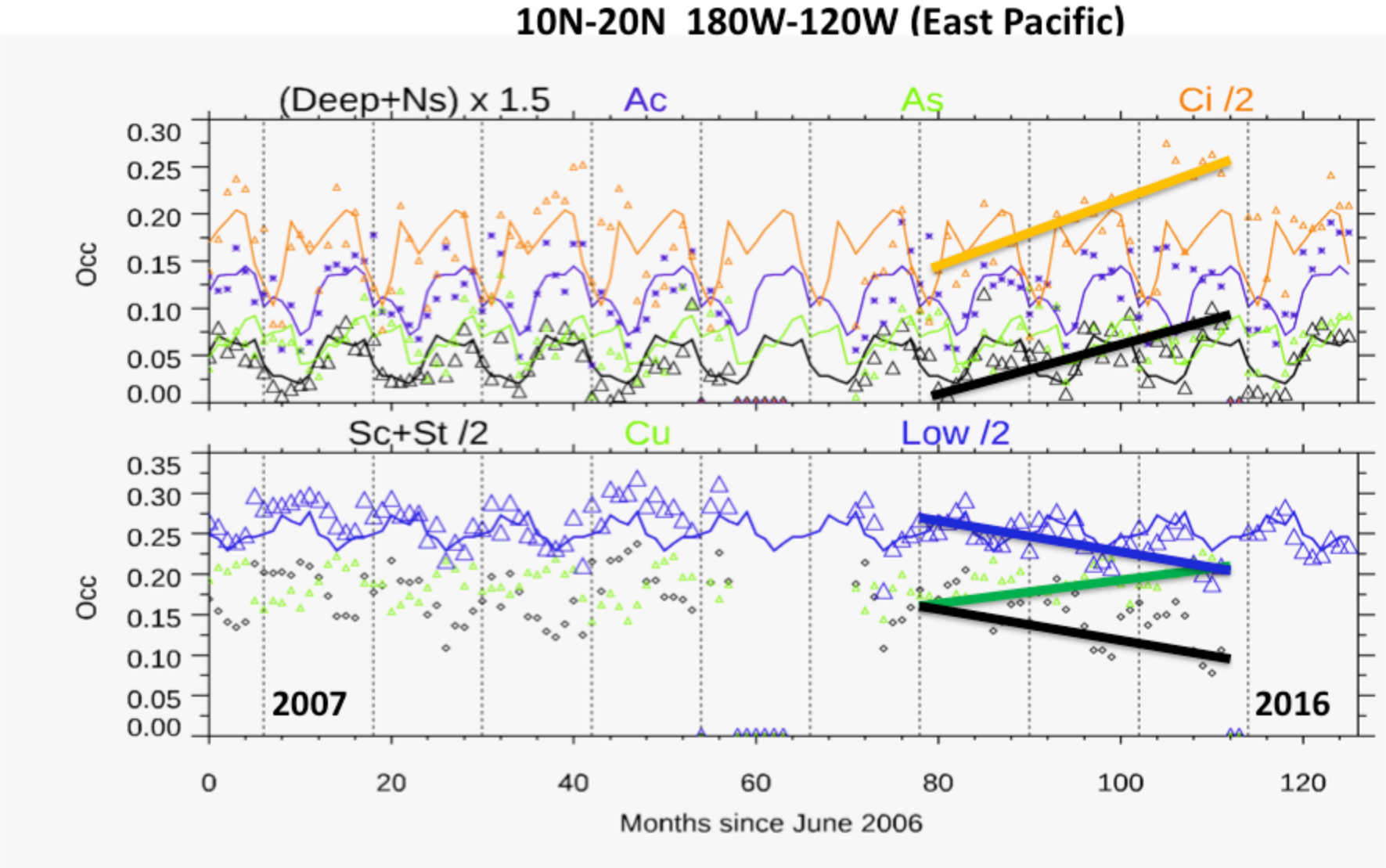
Interannual Cloud Variations

10N-20N 180W-180E



No Clear Signal of ENSO in zonal averaged cloud amounts

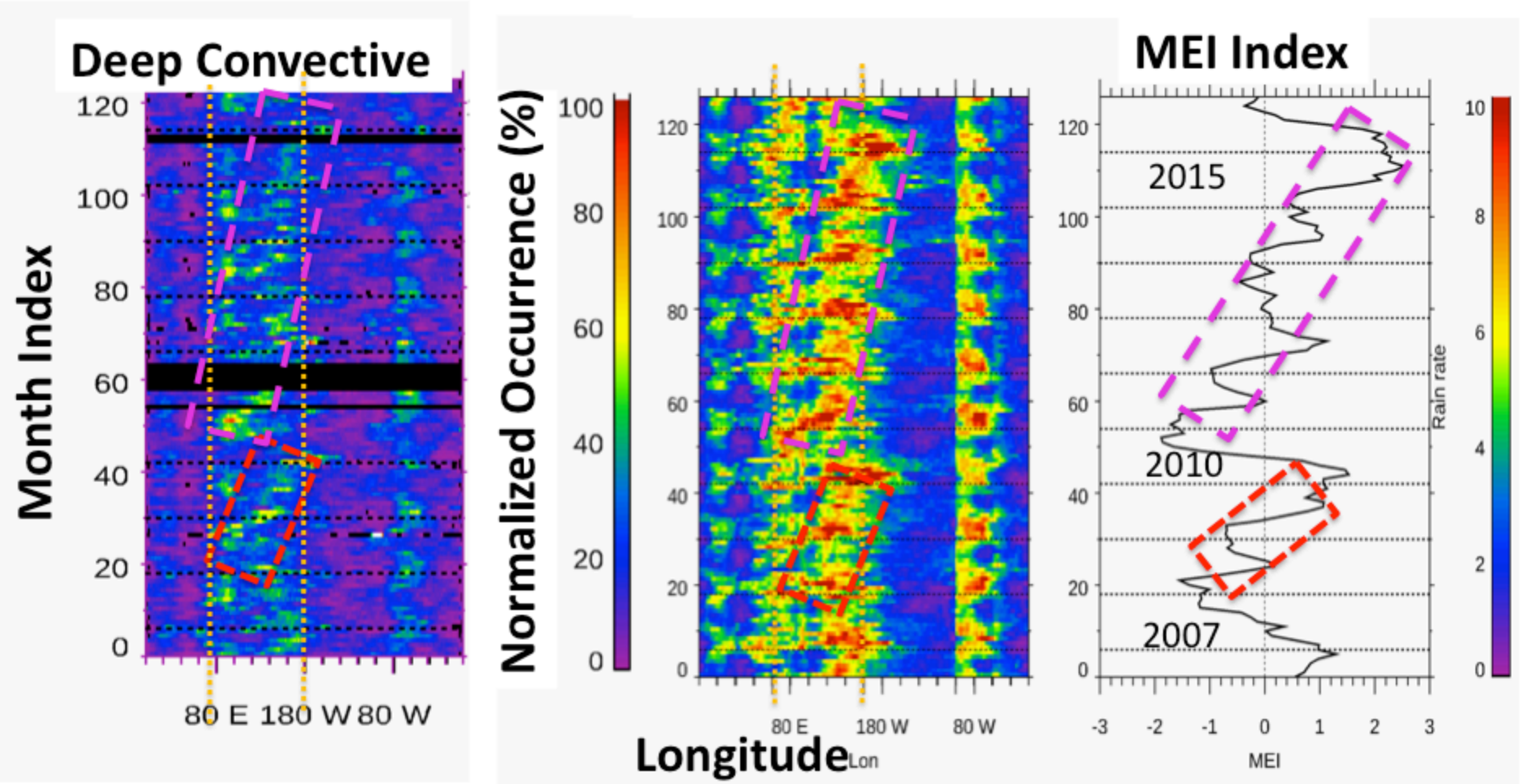
Interannual Cloud Variations



Strong regional cloud type responses to the recent ENSO event.

Interannual Variations Tropical Deep Convection and Precipitation and ENSO

20S-20N



Summary and Thoughts

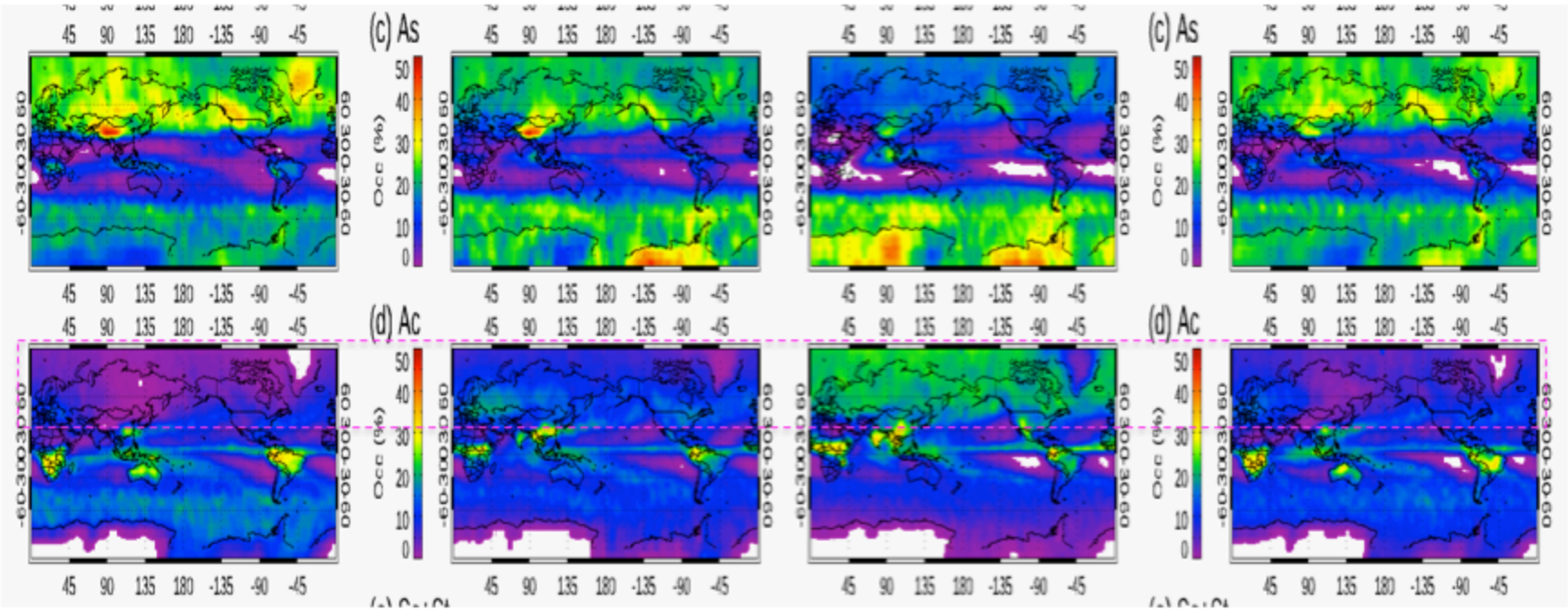
- Over 10-year CloudSat and CALIPSO measurements offer reliable global cloud type distributions and their seasonal variations.
- Better understanding the linkages of **different type clouds** and their roles in the **water** and **energy cycle** is necessary to realistically simulate **cloud feedbacks** in models.
- CloudSat cloud type products together with other A-train measurements offer an essential data source to better understand the interactions of **cloud-radiation-circulation (dynamics)-thermodynamics**.

Seasonal Variations of As and Ac

Jan-March | April-June | July-Sep | Oct-Dec

As

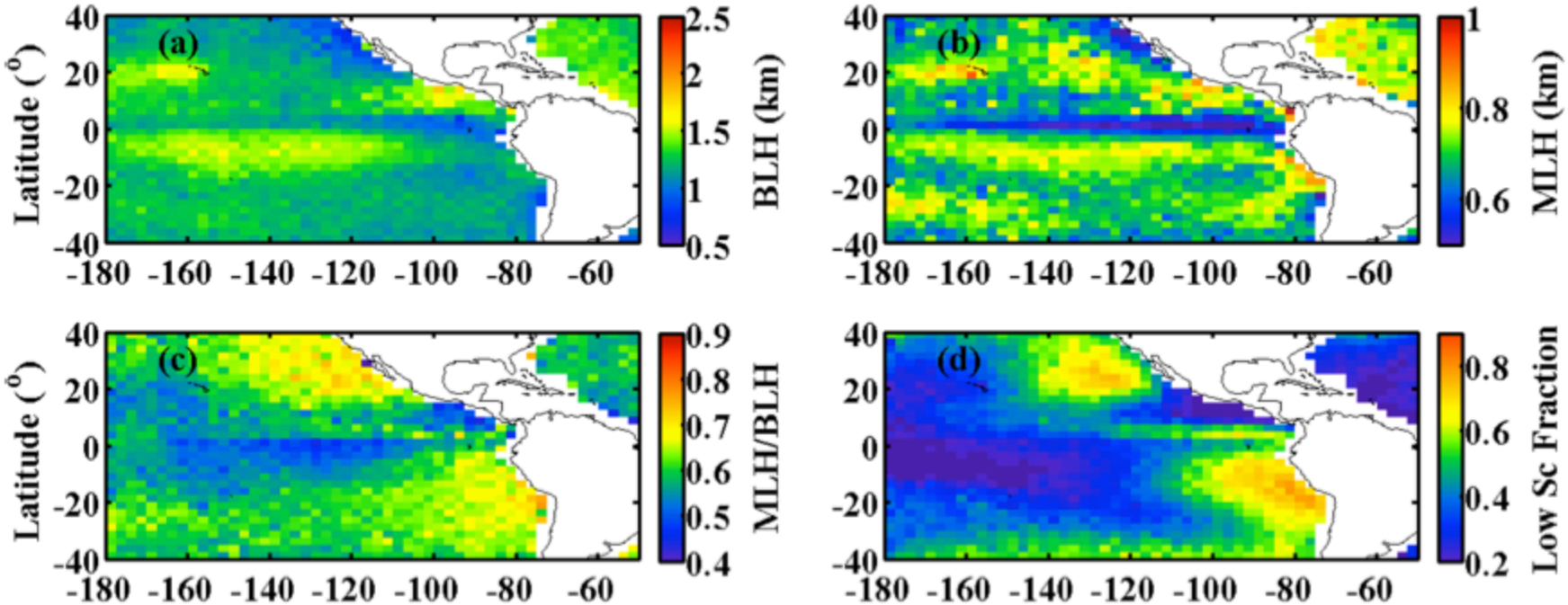
Ac



MABL Decoupling Structure

stratocumulus to Cu transition

4-year mean cloud BLH and MLH distributions



The magnitude of MABL decoupling

Luo et al., Atmos. Chem. Phys., 16, 5891–5903, 2016

Dynamics

Thermodynamics

Microphysics

Water Vapor Supply

Cloud Types