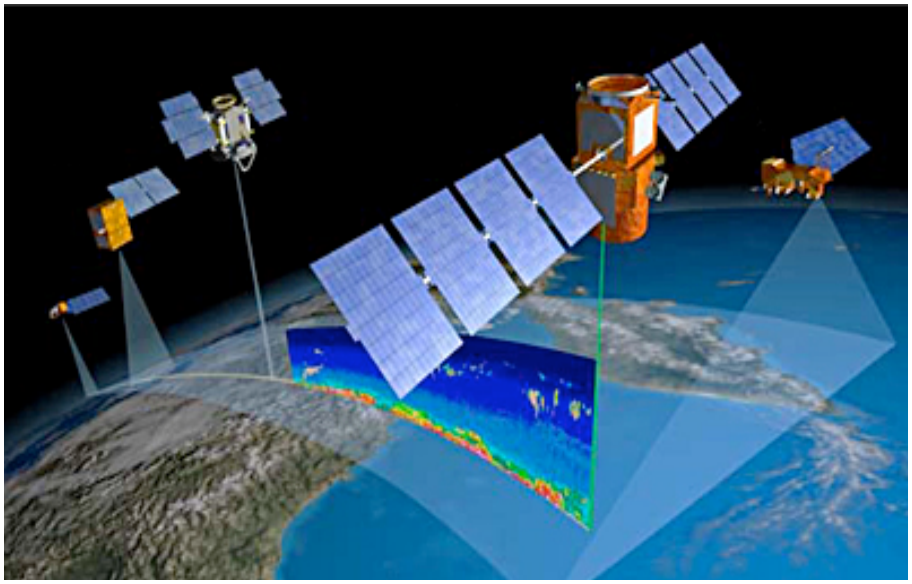
A glance at compensating errors between low-level cloud fraction and cloud optical properties using satellite retrievals



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Structure

Overview of satellites, data sets and simulators used.

Evaluation of LMDZ and ECHAM6 with observations:

- cloud radiative forcing
- vertical distribution of clouds
- cloud optical properties

Implications to cloud-climate feedbacks

Conclusions

Evaluate representations of clouds and their properties,
using satellite retrievals,
to better understand cloud-climate feedbacks.

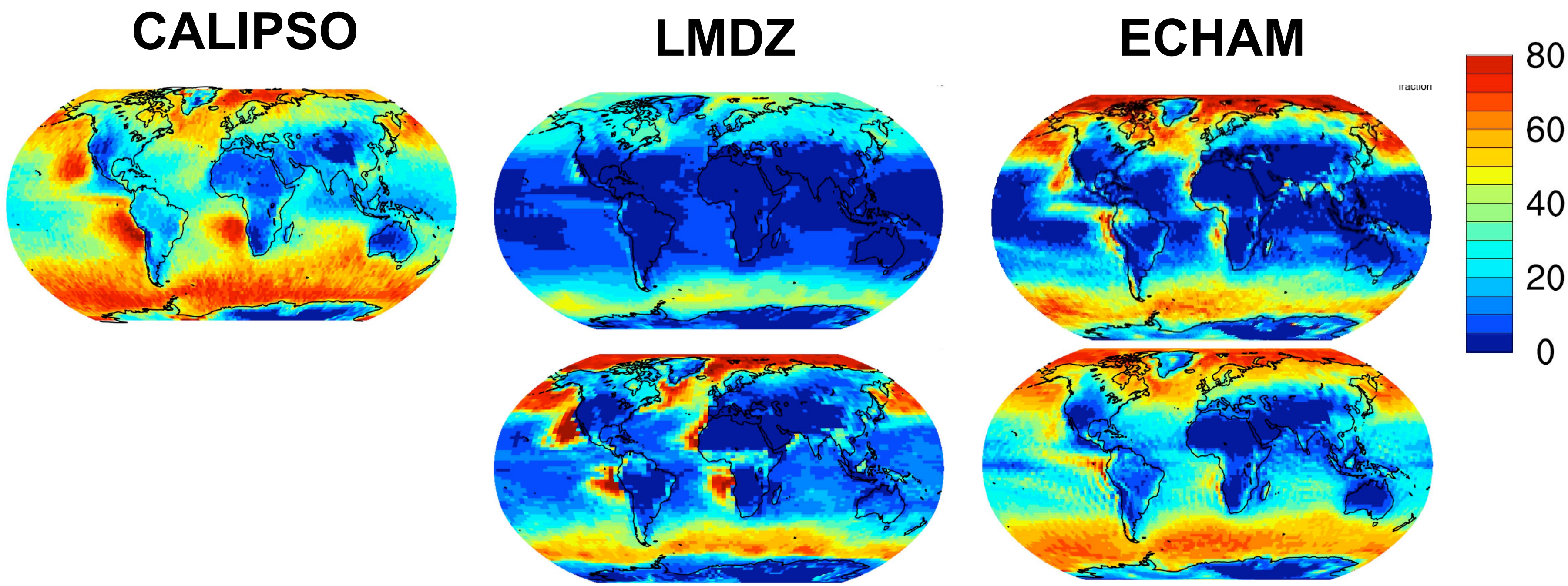
Satellite Products

- CALIPSO GOCCP, grid 2x2, 06/2006 - 12/2008, monthly & daily data
  - Total/High/Mid/Low level cloud cover maps
- Parasol grid 2x2, 06/2006 - 12/2008, monthly & daily data
  - Reflectance
- CERES Flash_TISA, grid 2x2, 01/2008 - 12/2008, monthly data
  - Cloud Radiative Forcing at top of atmosphere.

Combine information regarding the vertical structure of multi-layered clouds from active satellite instruments with passive satellite instruments.

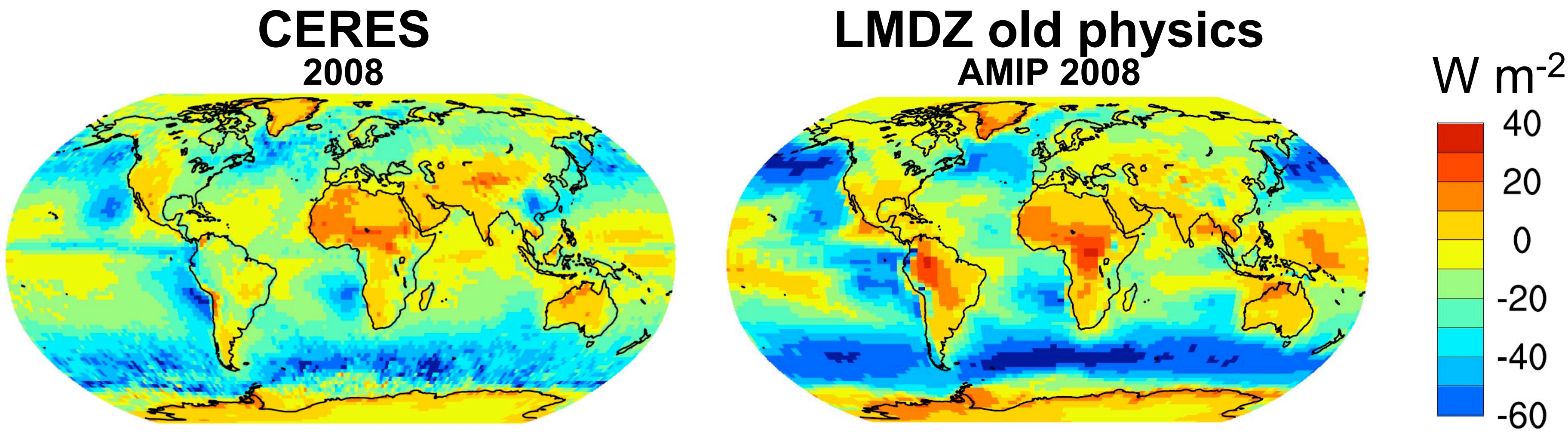
Low-Level Cloud Cover

Period: 06/2006 to 12/2008
(LMDZnew & ECHAM5 JJA)

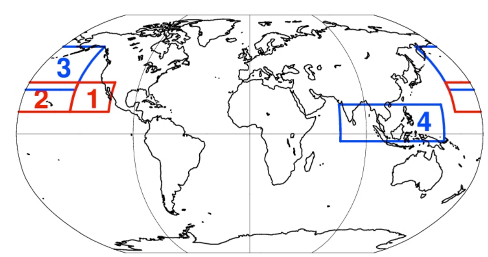


- Tropical, marine boundary layer clouds identified as primary cause for inter-model differences, in particular **trade cumulus clouds** and stratocumulus-to-cumulus transitions (Bony and Dufresne, 2005).
- Lack of low-level clouds in models should drastically impact shortwave component radiative budget; and hence net radiative balance.

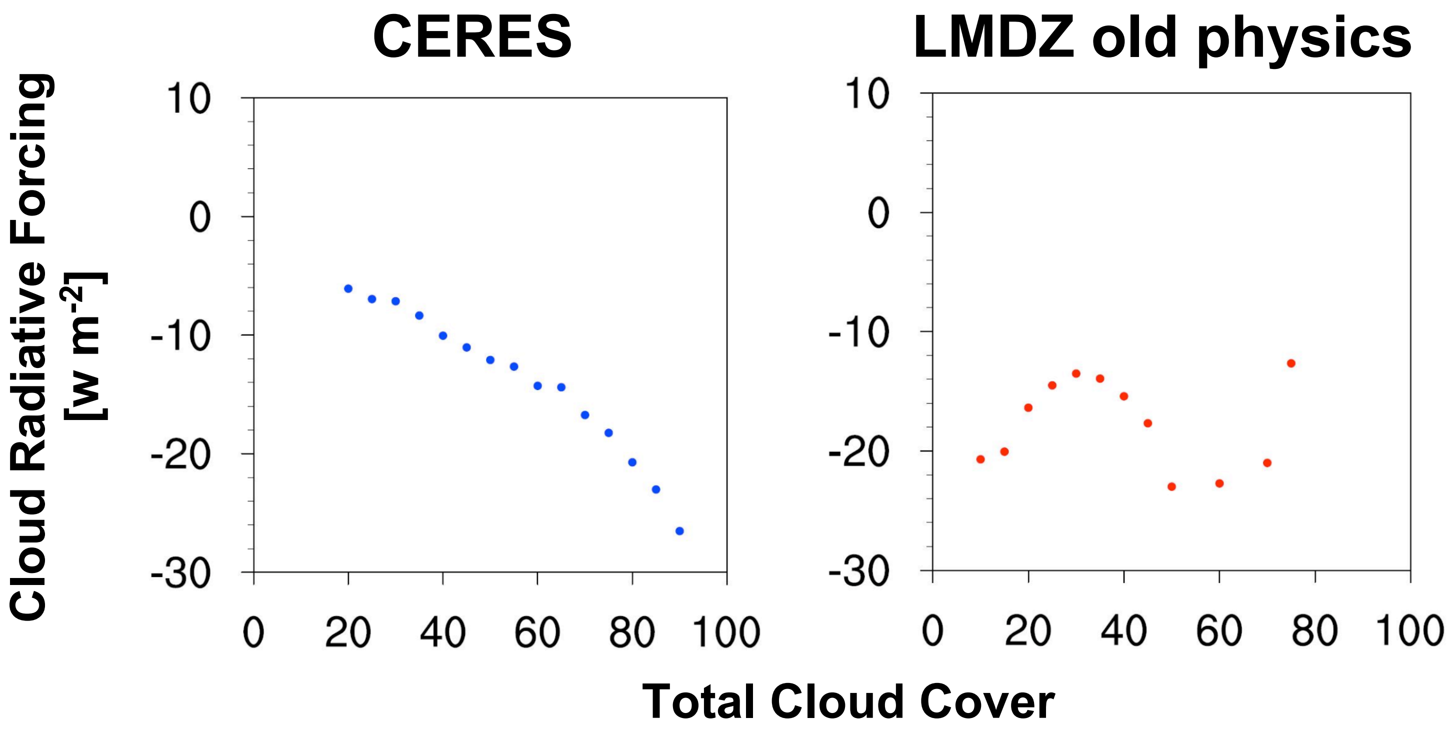
Cloud Radiative Forcing



- Difference in Cloud Radiative Forcing (CRF) less than differences in low-level cloud cover, which contributes to SW forcing.
- Implies compensating effects in models.
- Focus on subsidence regimes.



Hawaiian Shallow Cumulus



- Modelled clouds over Hawaiian region are too reflective.
- Differences in CRF for a given cloud fraction can be due to:
  - biases in vertical distribution of cloud cover; or
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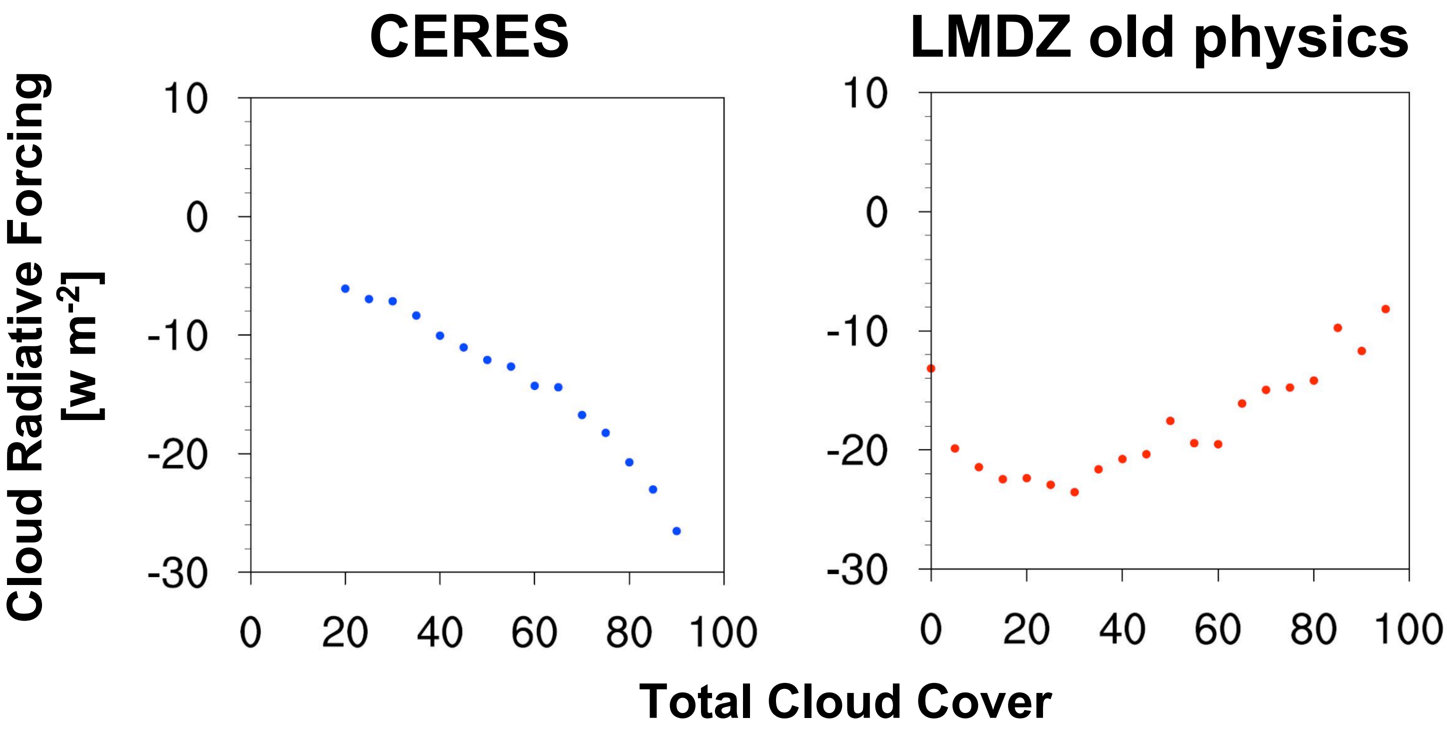

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Vertical Distribution of Clouds

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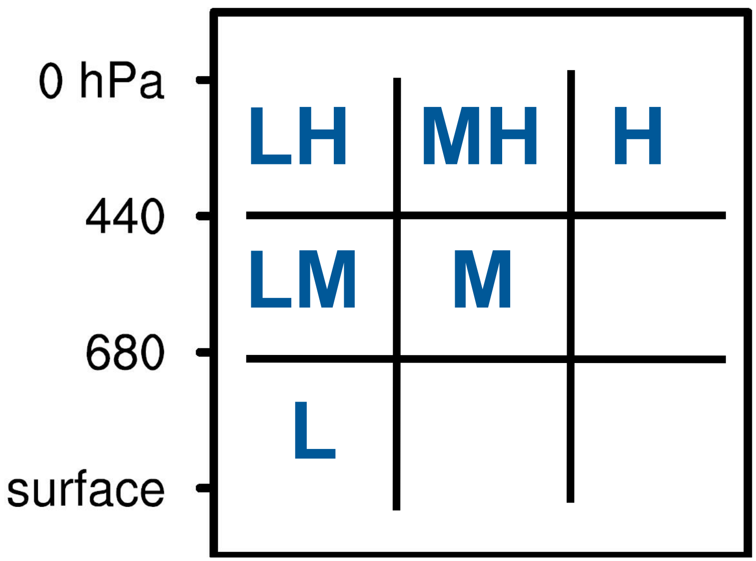
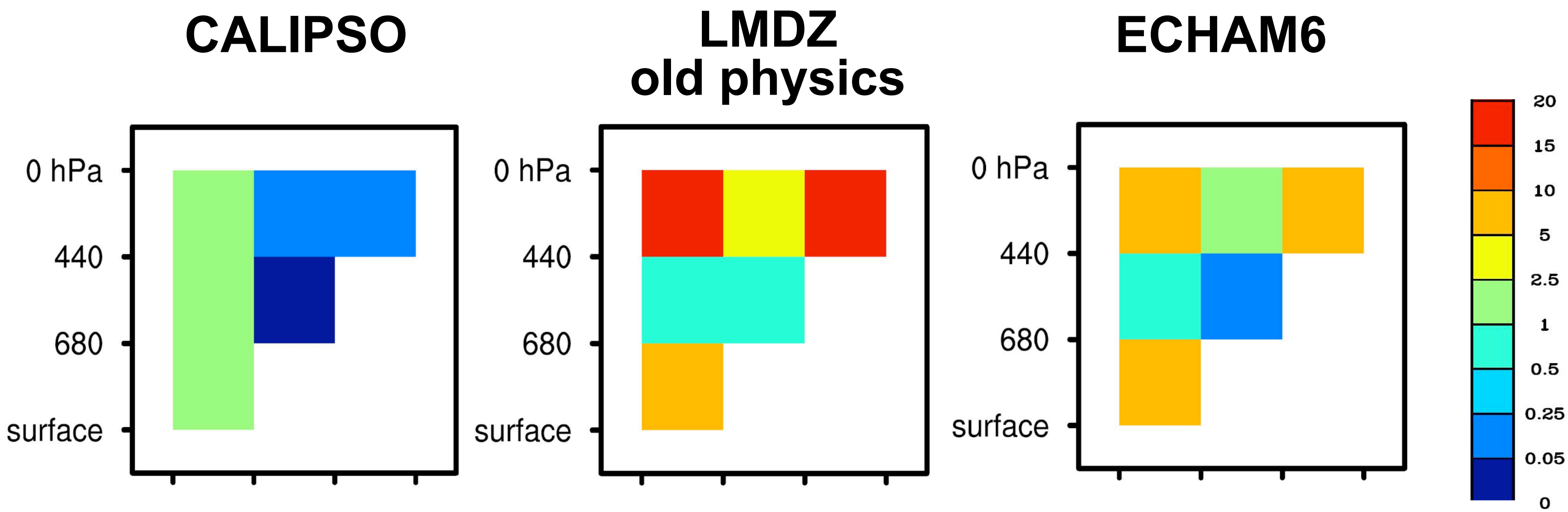


- Cloud cover distribution frequency of occurrence:
  L – Low-level clouds
  M – Mid-level
  H – High-level
- Assuming 'Only Low-level' clouds when mid and high-level clouds are less than 5%
- Plot excludes combination of:
  - All Low & Mid & High
  - Empty Low & Mid & High

Vertical Distribution of Clouds



- Frequency of 'High & Low' combination vastly overestimated in models despite being in a subsidence region.
- Radiative impact of low-level clouds diminished due to high-level clouds.
- Optical thickness of higher-level clouds governs depth to which the lidar and radar signal can penetrate into the atmosphere.

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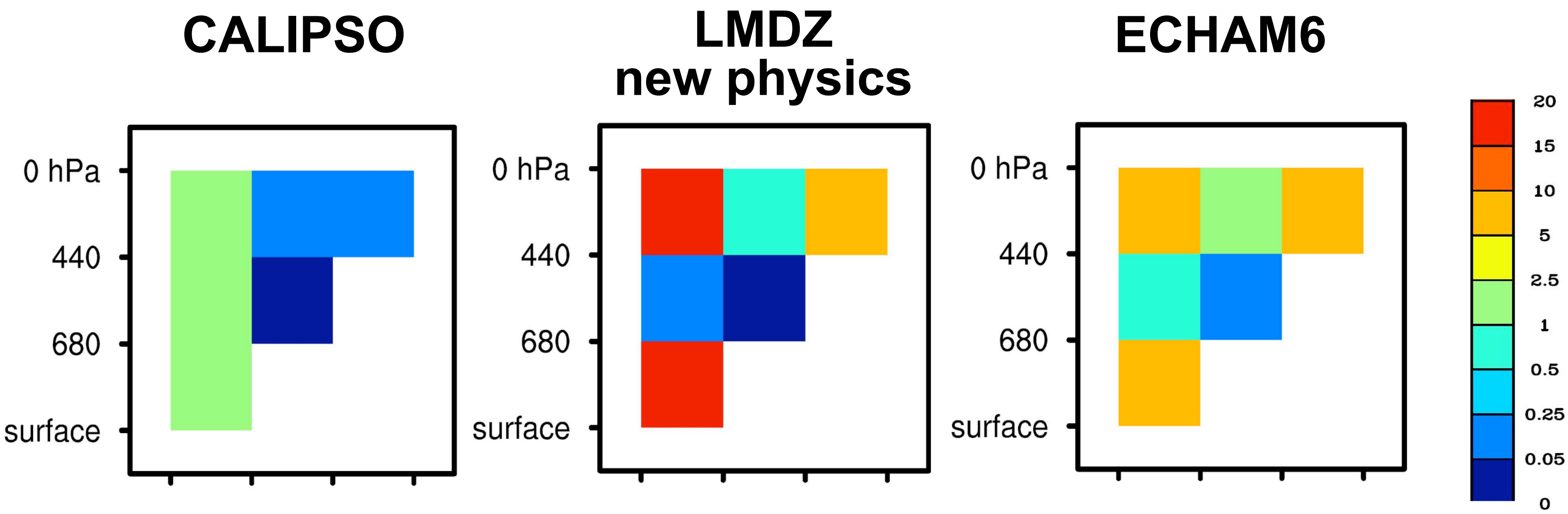

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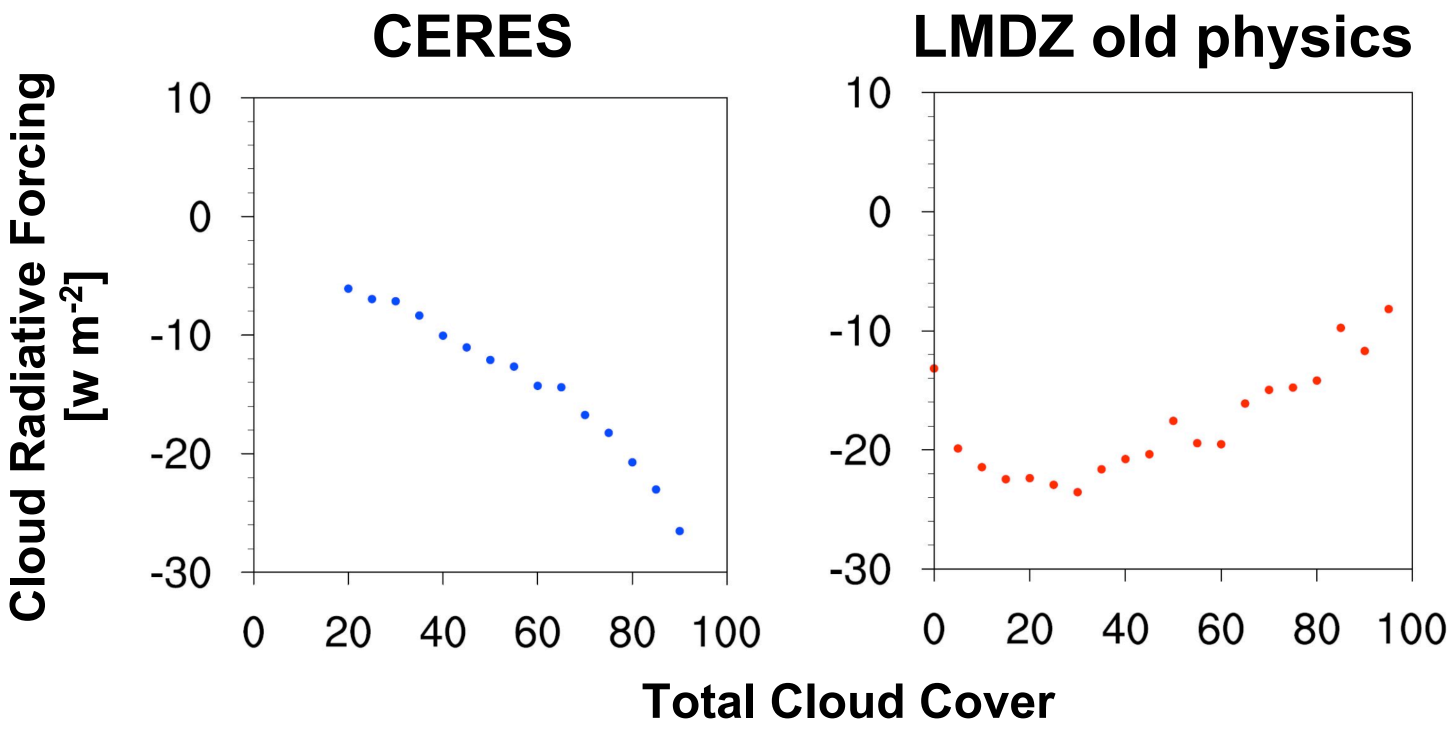
Composed from daily means over HAWAII

Hawaiian Shallow Cumulus



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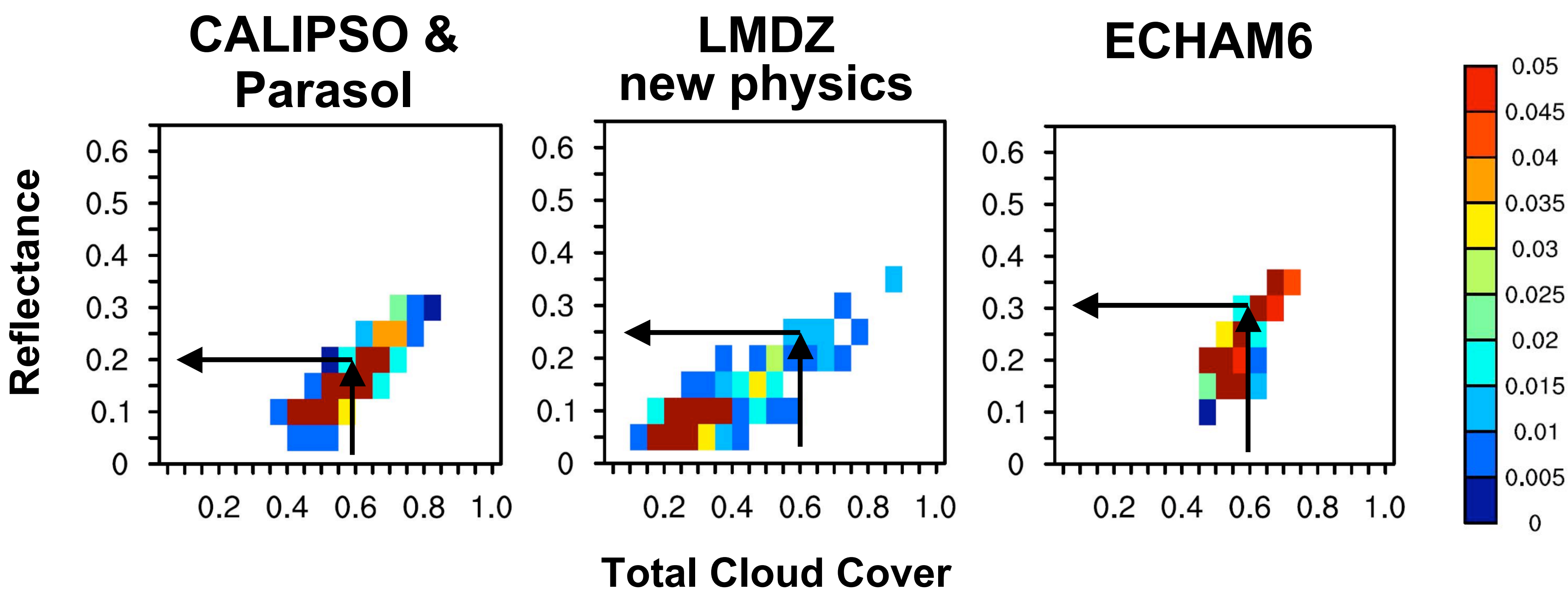
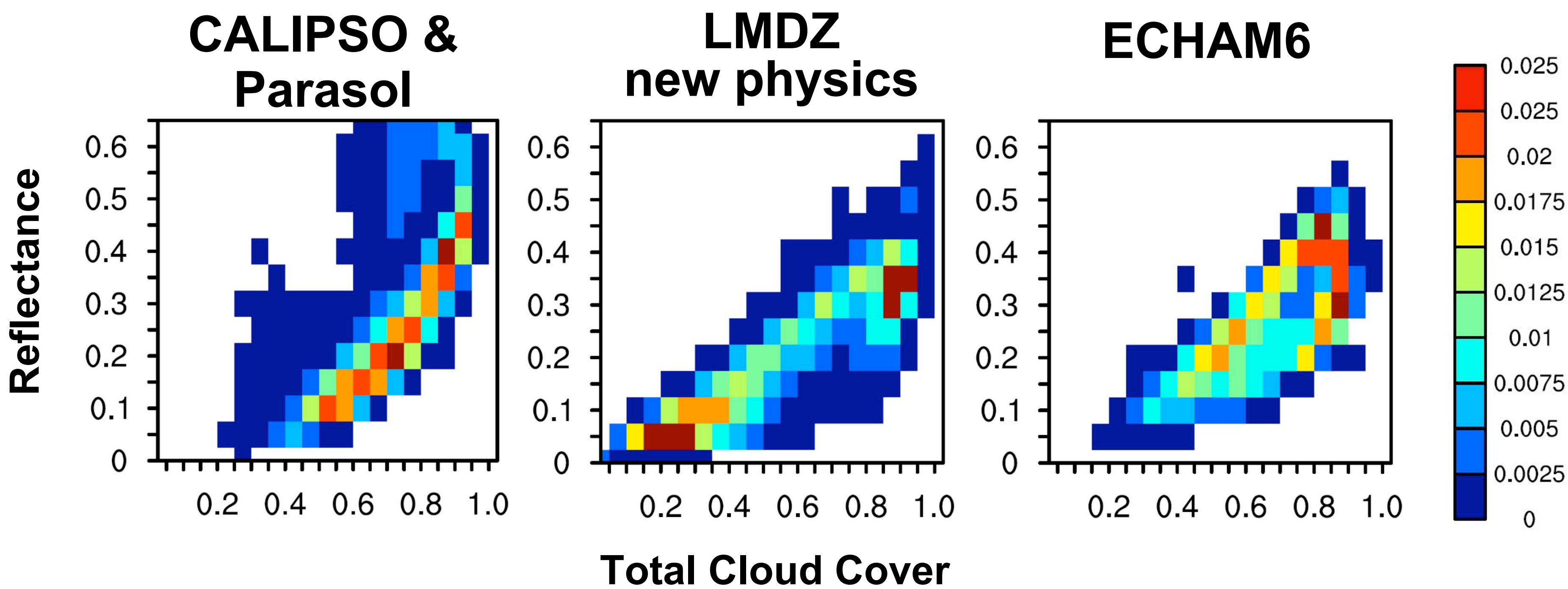
Cloud Optical Properties



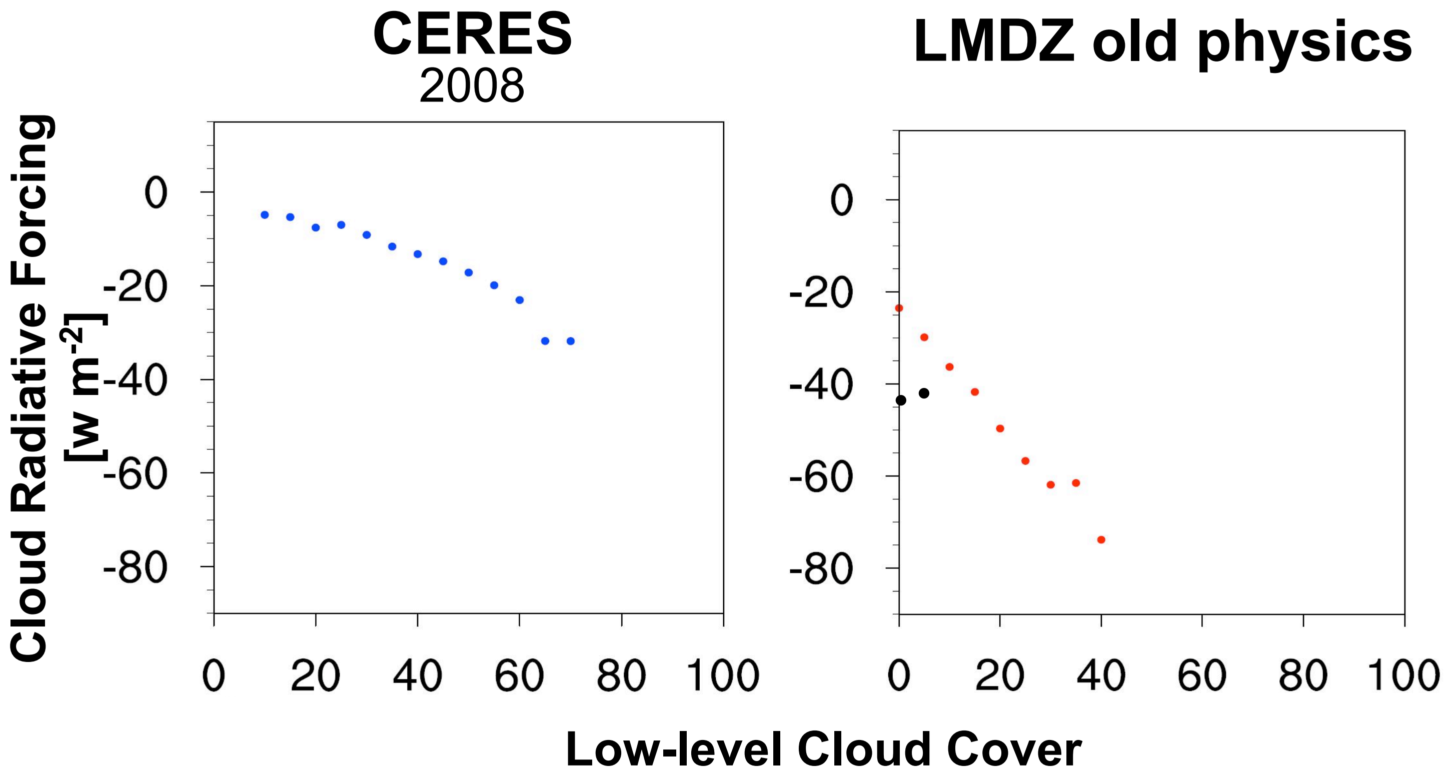
- For a given cloud cover, model reflectances are greater than in satellite data.

Cloud Optical Properties



- For a given cloud cover, model reflectances are greater than in satellite data.
- (Soon to be studied under 'Only Low-level cloud conditions).

Cloud Radiative Forcing Implications



- Only Low Clouds

- Modeled CRF under 'Only Low-level' cloud conditions are vastly different from observations.

Conclusions

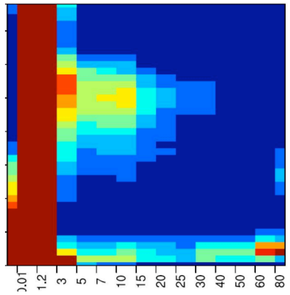
- ***How well do models represent the vertical distribution of clouds and their optical properties in the present climate?***
  - Frequency of high-level clouds overlying low-level clouds is overestimated.
  - For a given cloud cover, modelled clouds are often too reflective.
  - CRF modelled under 'only low-level cloud' conditions differ significantly from observations.
  - Satellite simulators are a valuable tool for model evaluation, though one must be aware of model and simulator assumptions.

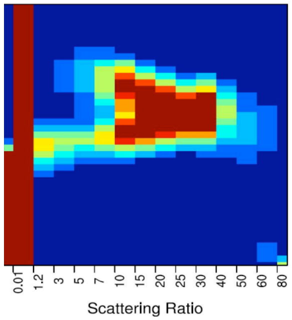
Outlook

- Study other cloud regimes: Californian Stratocumulus, Tropical Pacific,…

- Include more models within inter-comparison as CMIP5 experiments with COSP output become available.

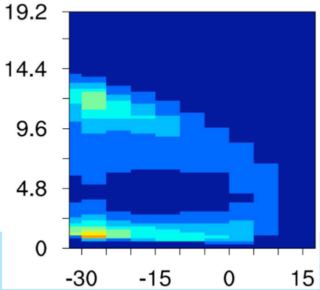
- Include comparison with other satellites and simulators
  - CloudSat and CALIPSO simulator products:
    - Lidar Scattering Ratio Histograms

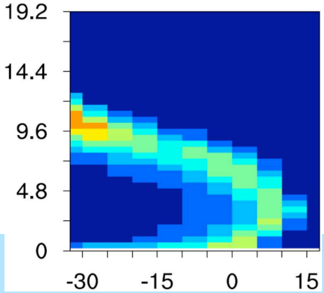




Hawaiian Trade Cumulus

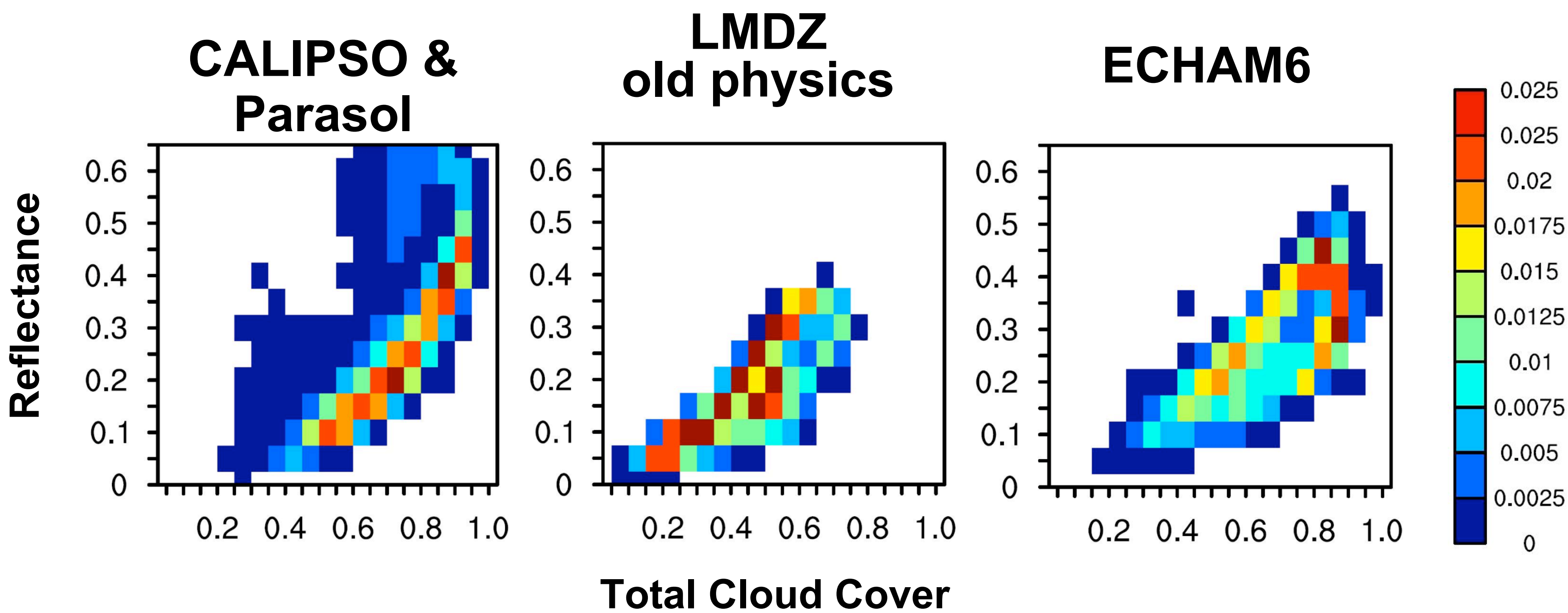
    - Radar Reflectivity Histograms





Backup Slides

Cloud Optical Properties



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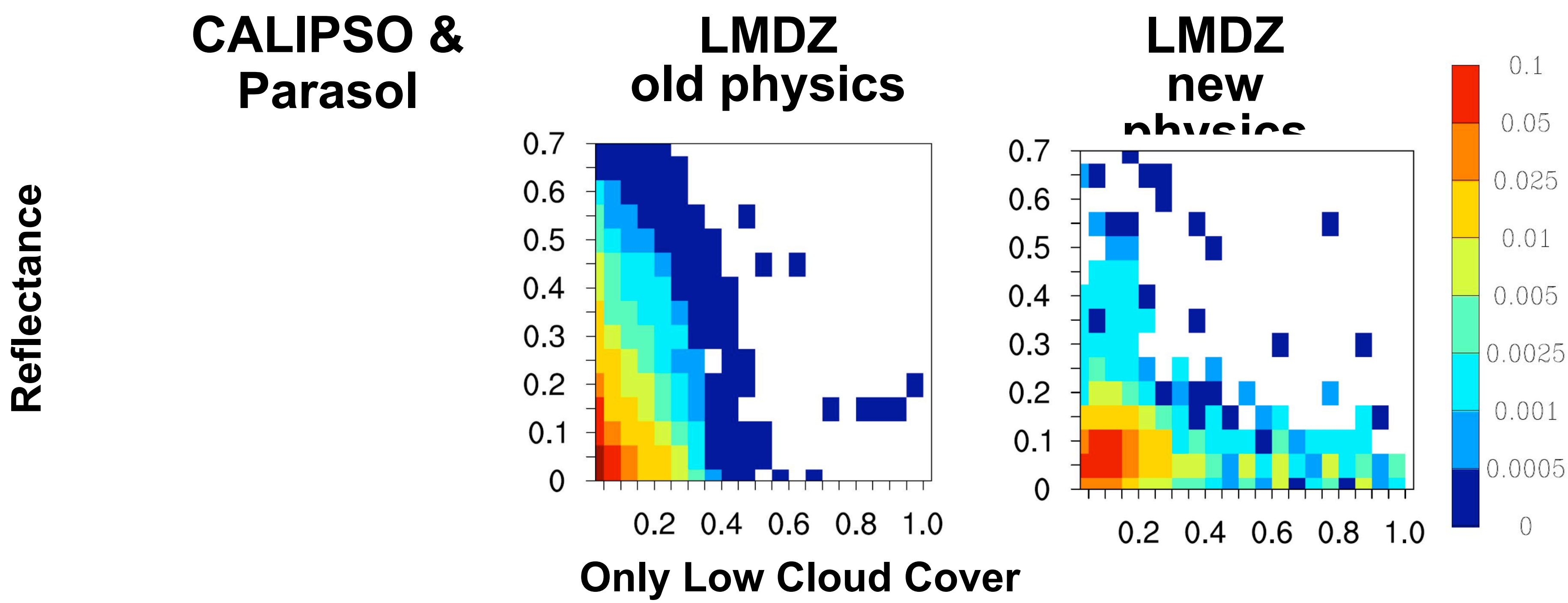

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Definitions

- **Cloud Radiative Forcing (CRF)**: The difference between net irradiances measured for average atmospheric conditions and those measured in the absence of clouds for the same region and time period.

- **Cloud-climate feedbacks (CCF)**: cooling and warming effects of clouds depend on the height, location, amount, and the microphysical and radiative properties of clouds, as well as their appearance of time with respect to the seasonal and diurnal cycles of the incoming solar radiation.

- **Boussinesq approximation** states density differences are sufficiently small to be neglected, except where they appear in terms multiplied by the acceleration due to gravity (g). Thus, process of neglecting density variation in inertia term but retaining it in the buoyancy (gravity term) is call the Boussinesq approximation.

- **dBZ:** The radar system measures a received signals in 'Volts'. This power ranges from 0V to 10000V easily - thus the need for the log scale. A return power of 0.1V to the radar would give -20dBZe, 1V yields 0dBZeand 250V yields 24dBZe. Since the power received by the radar is proportional to the sixth power of the particle's diameter, rain easily dominates the signal.In nutshell, negative dBZe mean a return power between 0 and 1V.
- Nondimensional "unit" of radar reflectivity which represents a logarithmic power ratio in decibels (dB) of reflectivity (Z). Z is 1 mm6 m-3, and related to the number of drops per unit volume and the sixth power of drop diameter.
  - One dBZ-scale of rain:
    - 40 heavy
    - 24-39 moderate
    - 8-23 light
    - 0-8 Barely anything