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Assessing the Radiative Impacts of Precipitating Clouds on Winter Surface Air Temperatures and Land Surface Properties in GCMs Using Observations

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GOAL

Using A-Train Data Observation to Reveal the Impacts of Precipitating Ice on the Radiation Budgets and Land Surface Temperatures (LST) in Global Coupled Climate Models

Key Contributors
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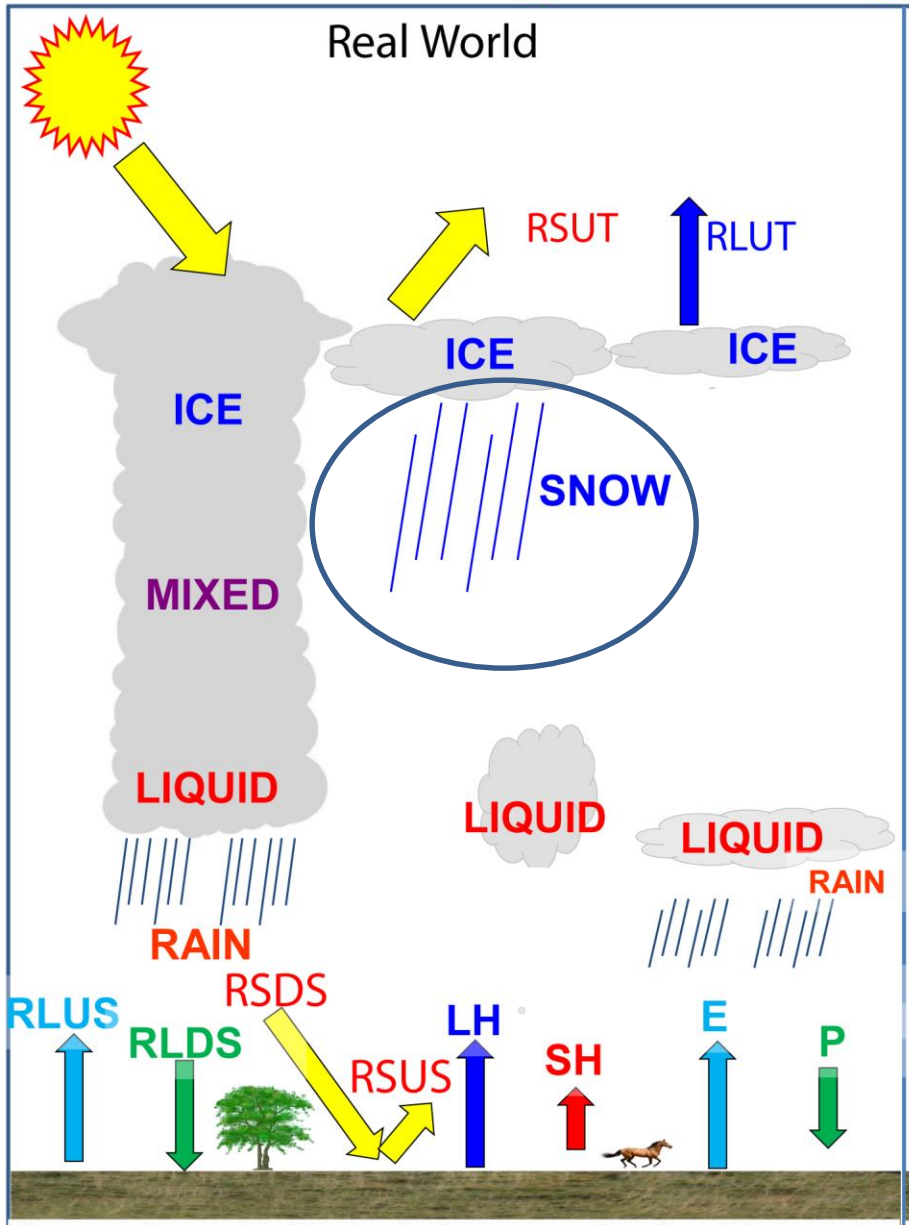
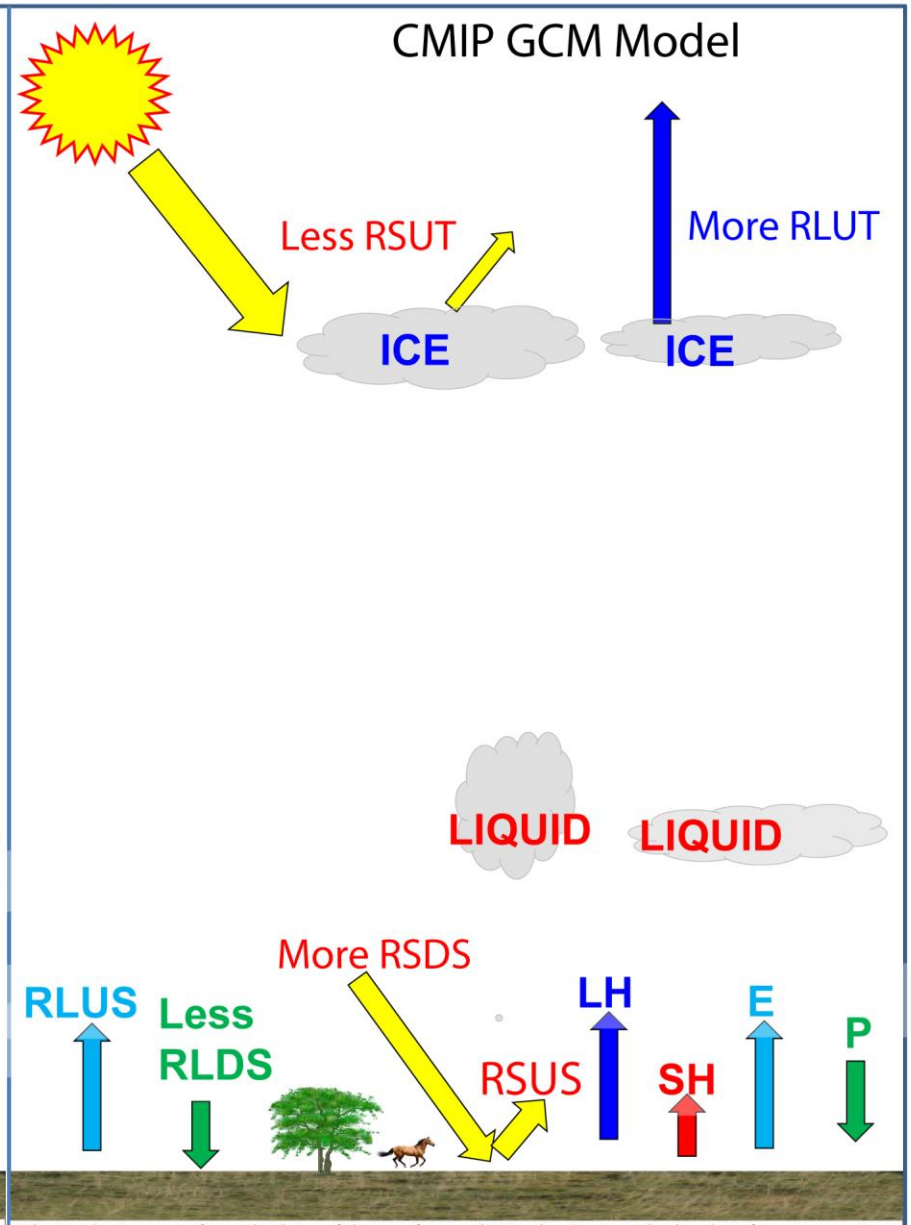
In La Guajira, one of the worst affected areas, the land surface is in the process of desertification.

Photo source: World Food Program

Energy and Water Budgets over Land Surface



The amount of water in the soil is affected by the net surface radiative flux and the strength of the surface evaporation associated with ground water and precipitation.



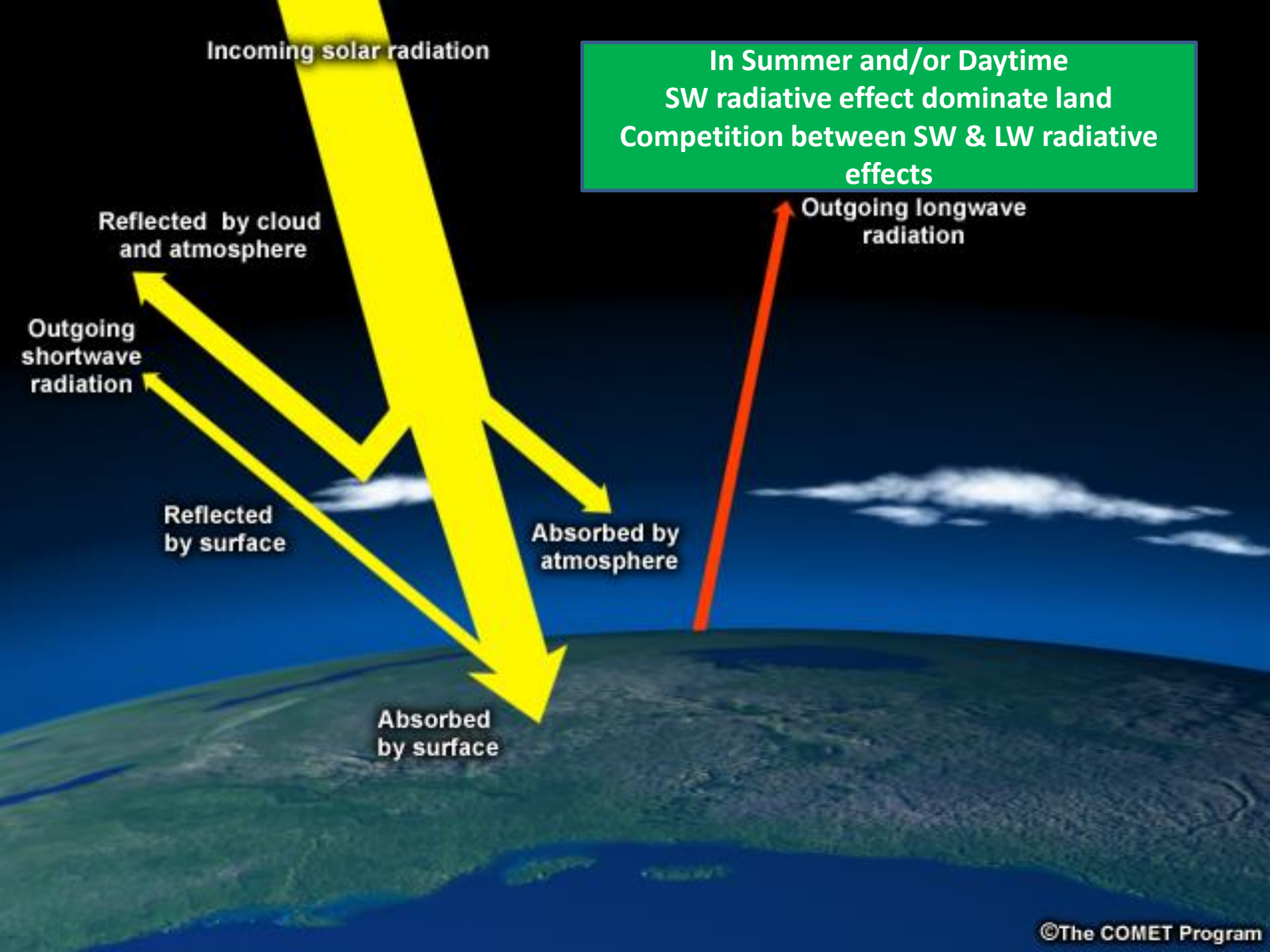
What is the impacts from the bias of the surface radiative budget on the land surface properties such as soil moisture, temperatures, evapotrasparent etc.

IPCC AR5 Report:

Clouds play a critical role in climate and regional/global water and energy cycle yet representing clouds and their radiative effects in regional and global climate models remains a challenge.

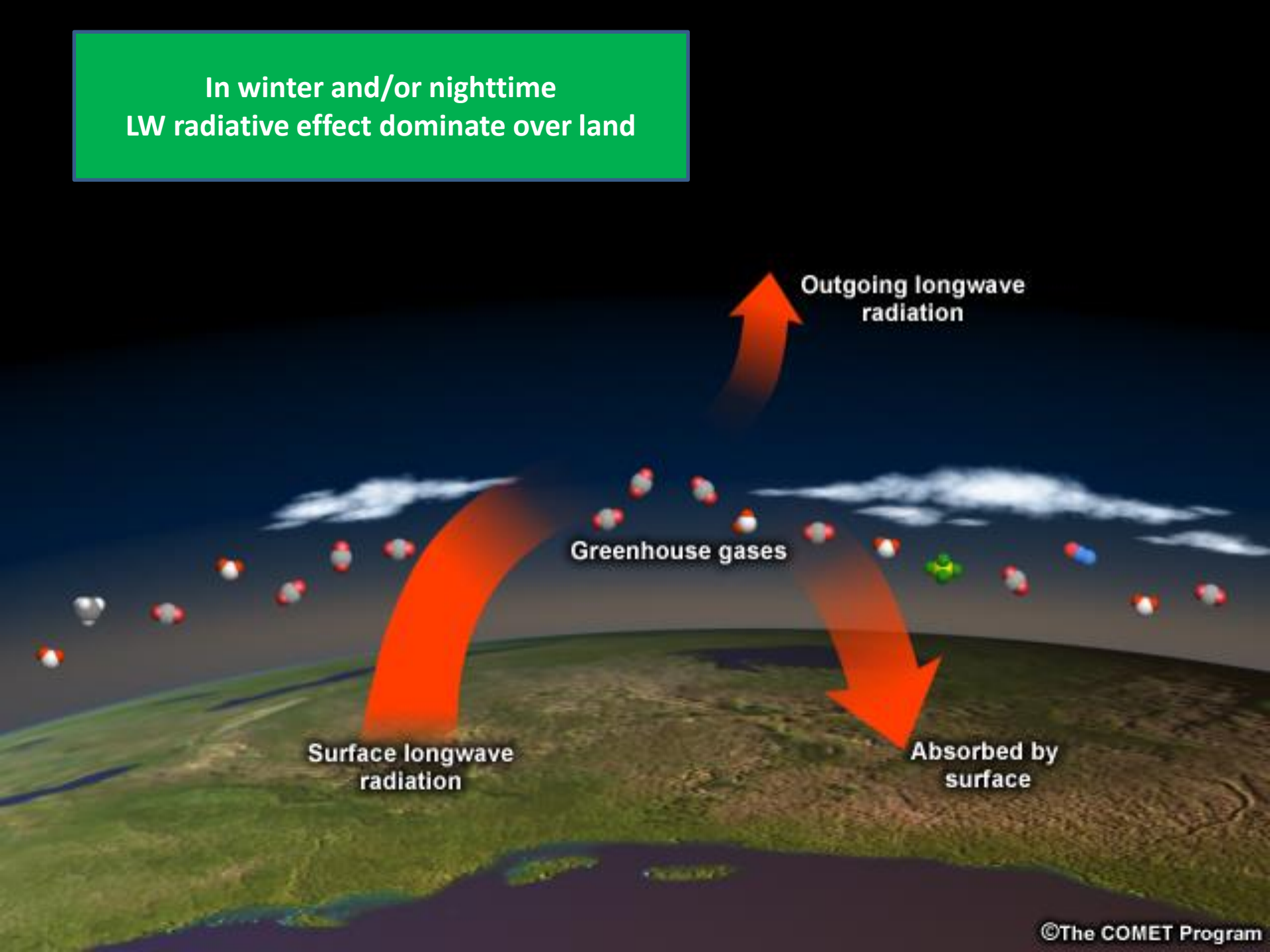
Improving the predictive capabilities of climate models requires a coordinated analysis of the interactions between clouds, radiation, and precipitation using both models and observations.

In particularly important *in fully coupled climate systems*.

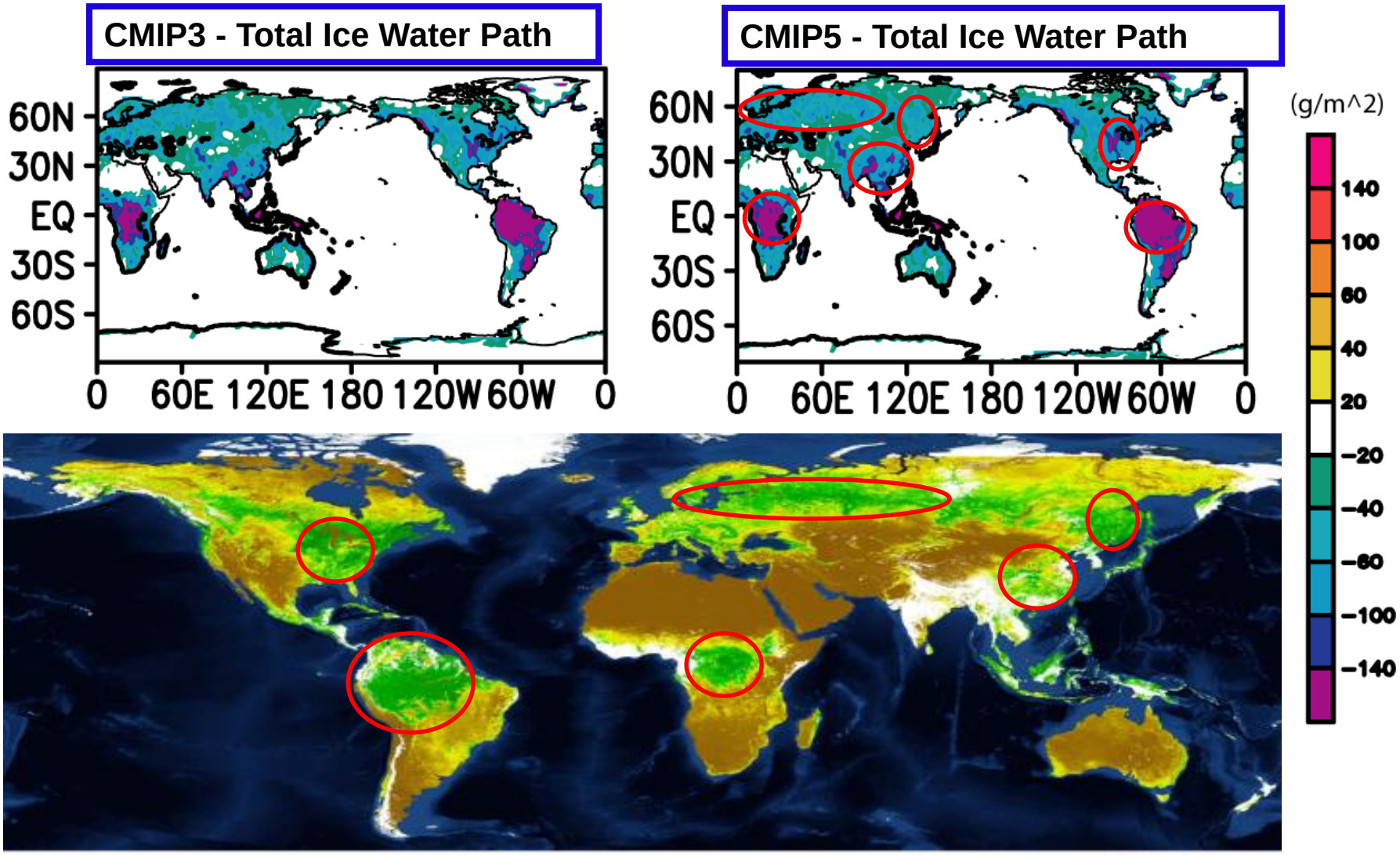


In Summer and/or Daytime
SW radiative effect dominate land
Competition between SW & LW radiative effects

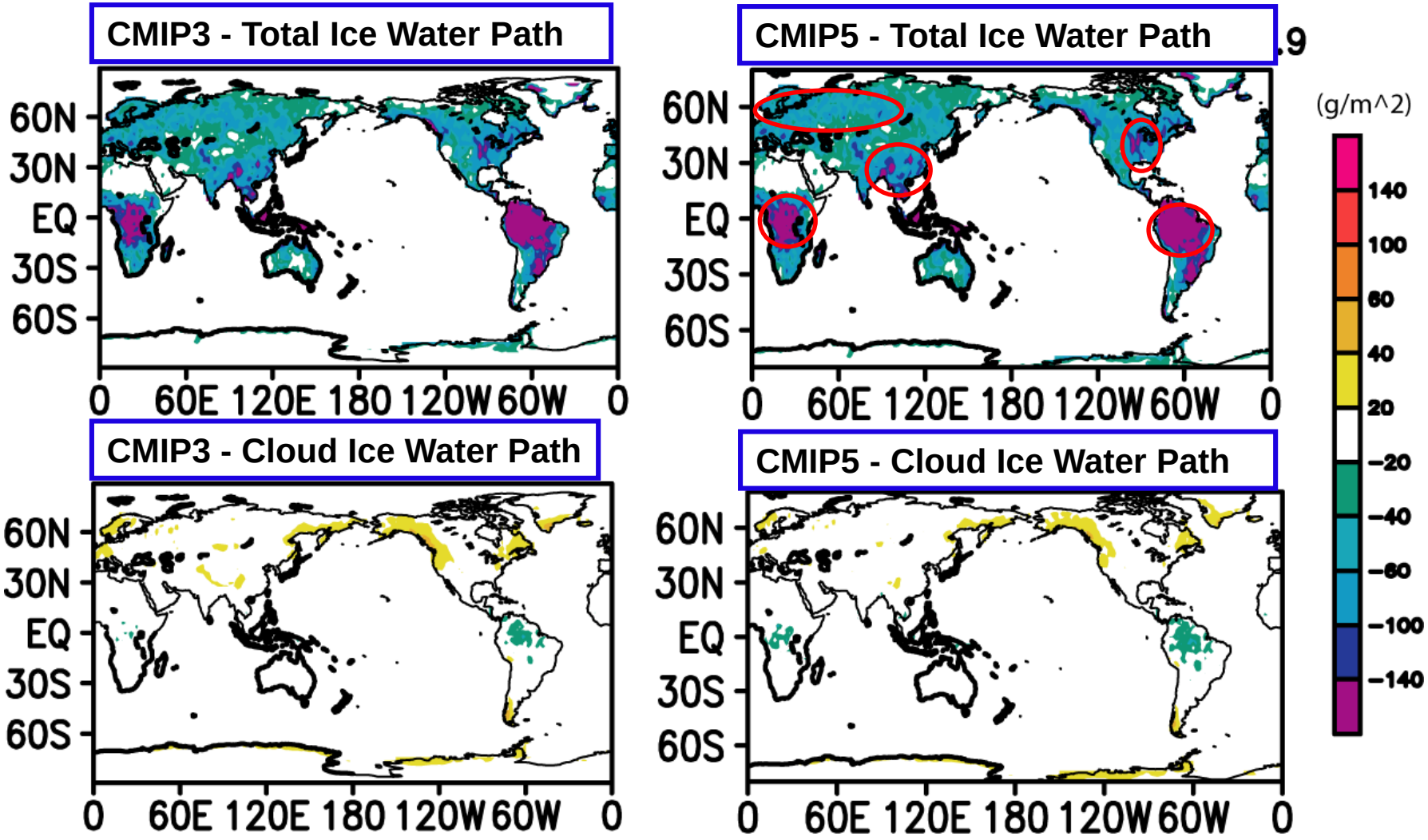
In winter and/or nighttime
LW radiative effect dominate over land



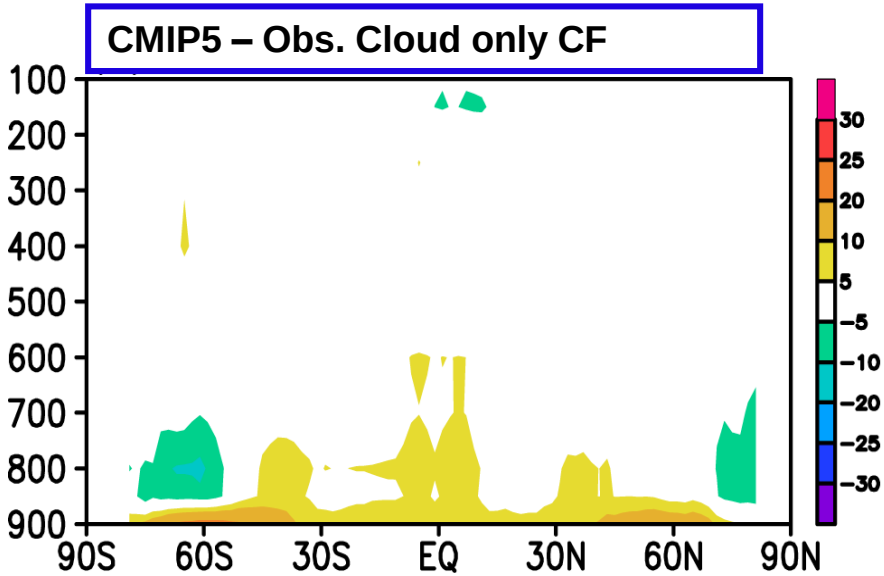
Evaluation of Total Ice Water Path in CMIP3/CMIP5 Models Using CloudSat-CALIPSO Data

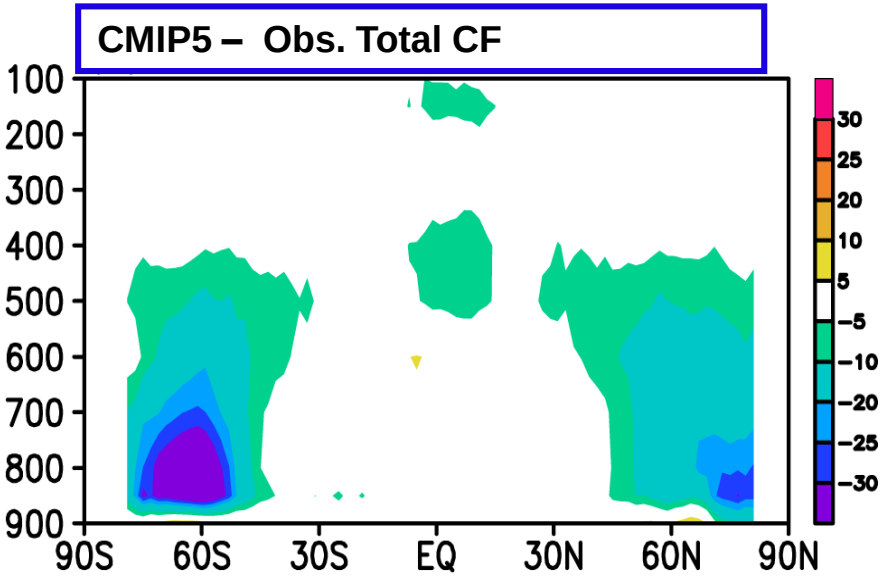


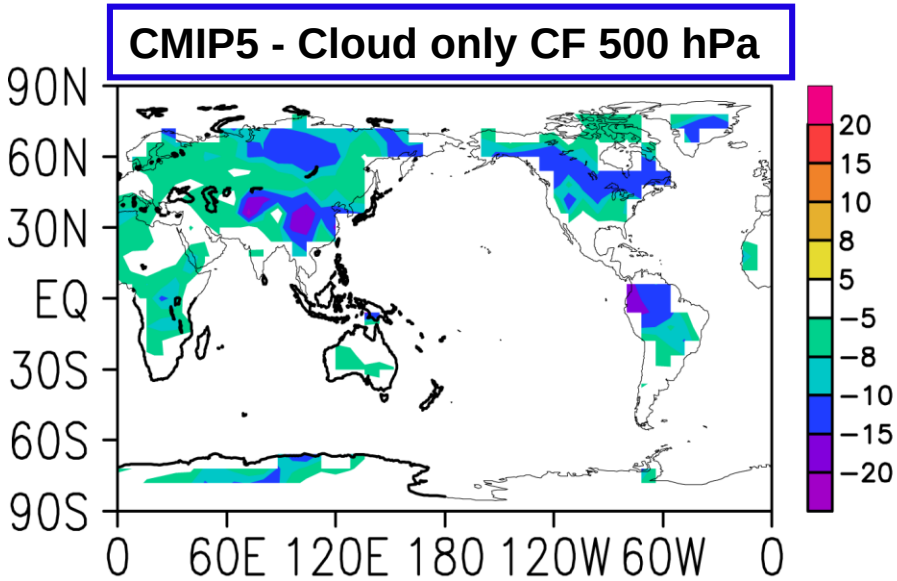
Evaluation of Total Ice Water Path in CMIP3/CMIP5 Models Using CloudSat-CALIPSO Data

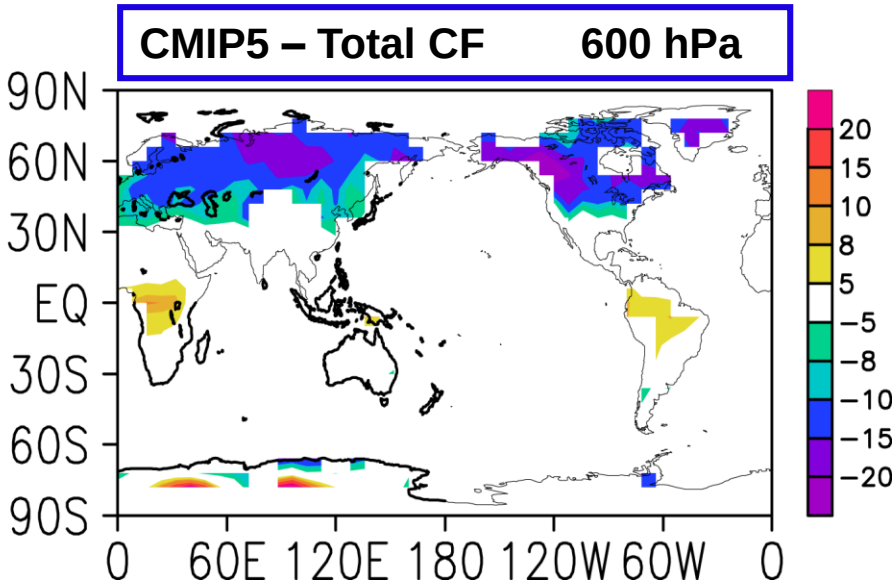


Bias of Total Cloud Fraction in CMIP5 Models



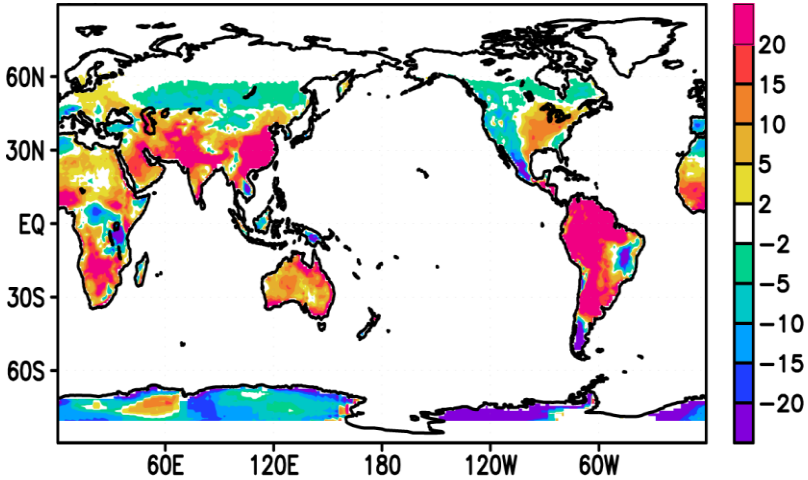




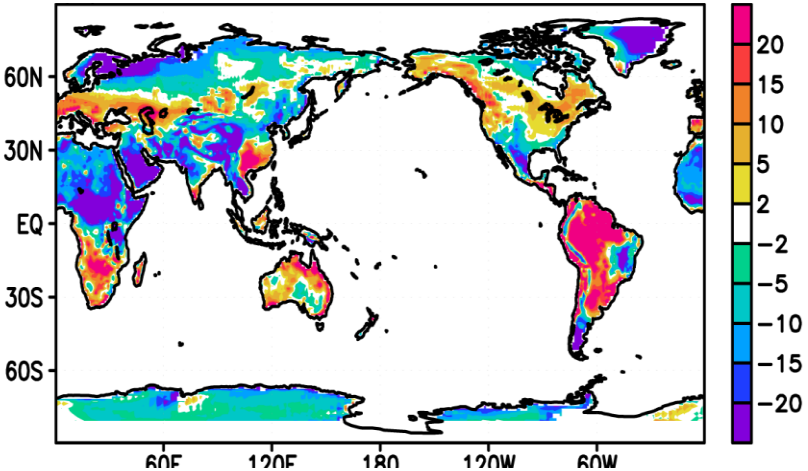


Biases of Winter Land Surface Radiation and LST in CMIP5

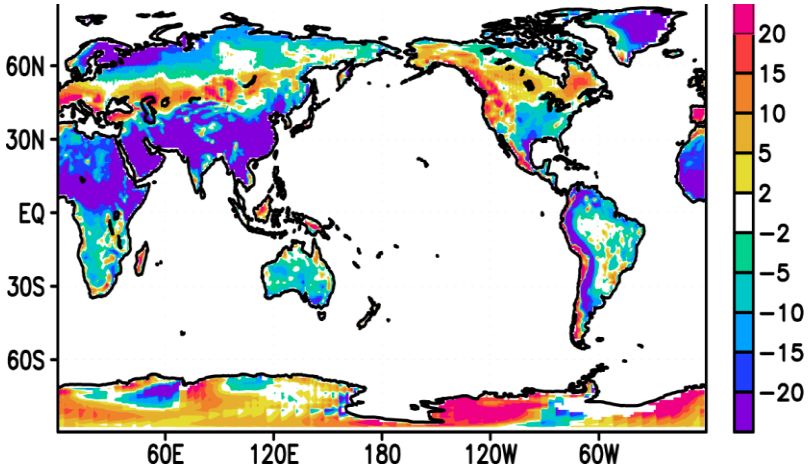
(a)Downward Surface SW CMIP5-CERES



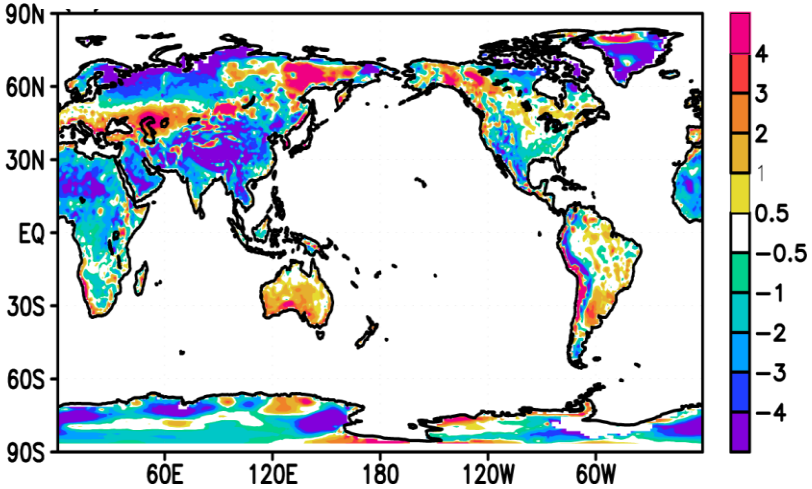
(c)Downward Net Radiation CMIP5 – CERES



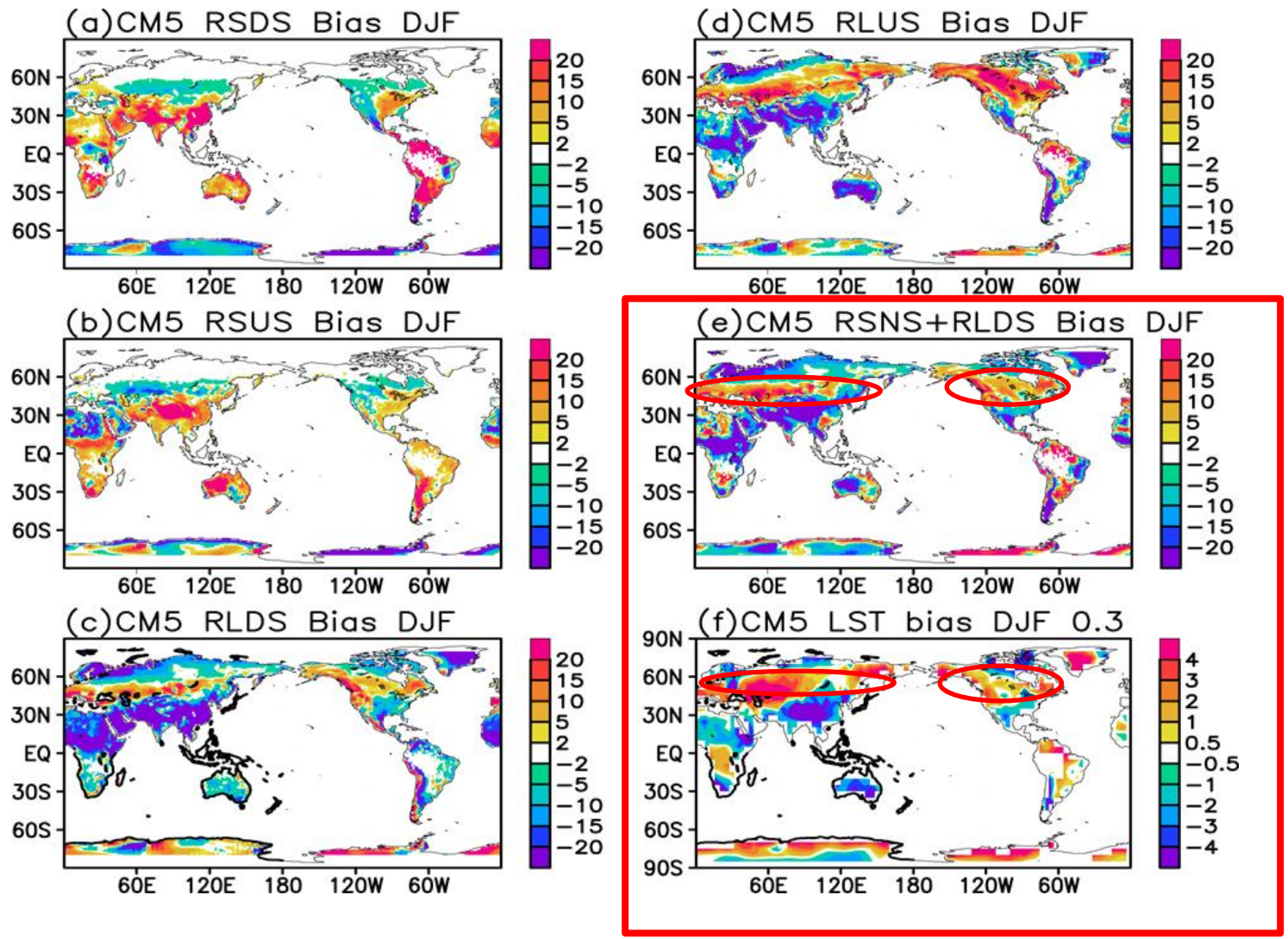
(b)Downward Surface LW CMIP5 – CERES



(d)Land Surface Temp. CMIP5 – MODIS



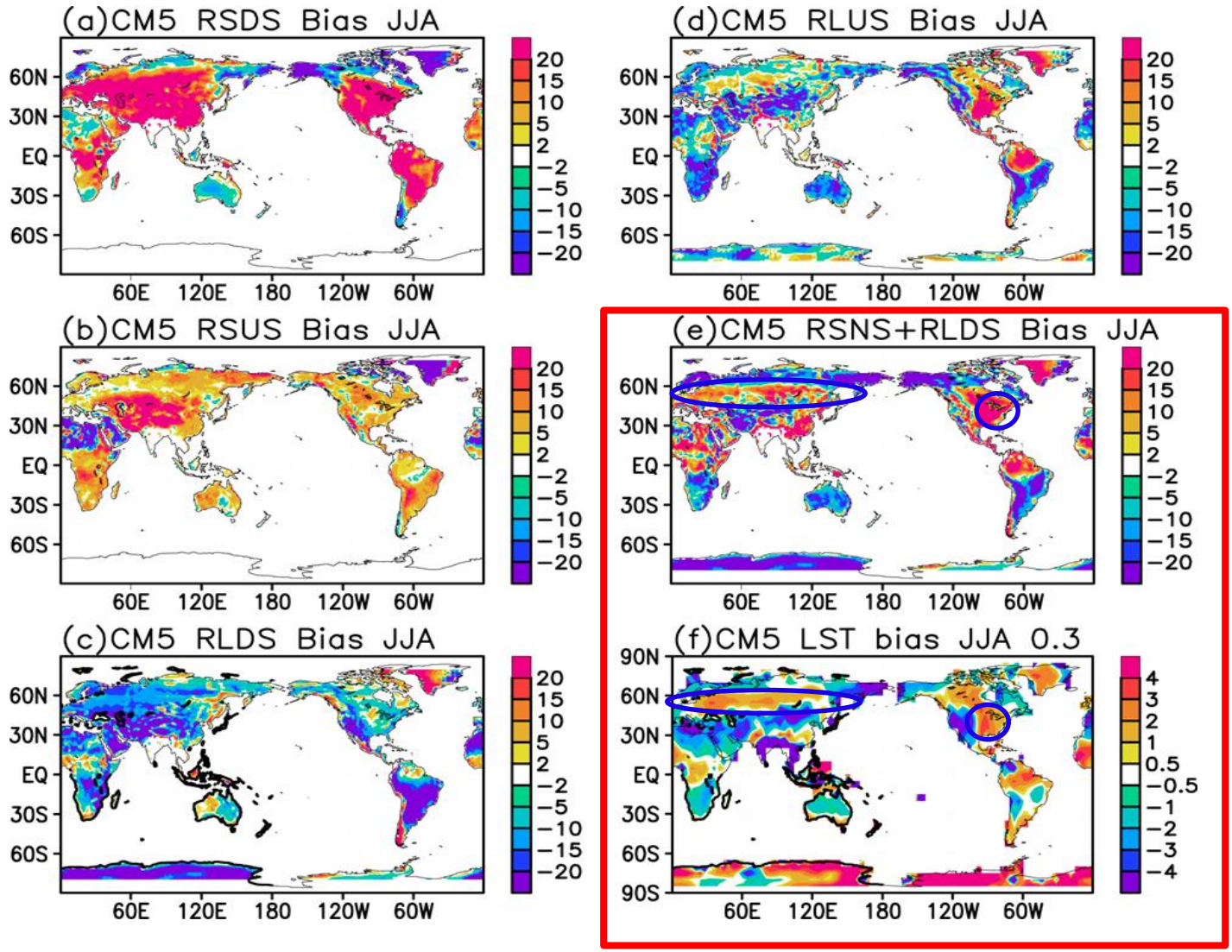
Evaluation of LST and Radiation Budgets in CMIP5 Models Against CERES-EBAF



Albedo cooling & greenhouse effects

LST ~ RSNS + RLDS

Evaluation of LST and Radiation Budgets in CMIP5 Models - Summer

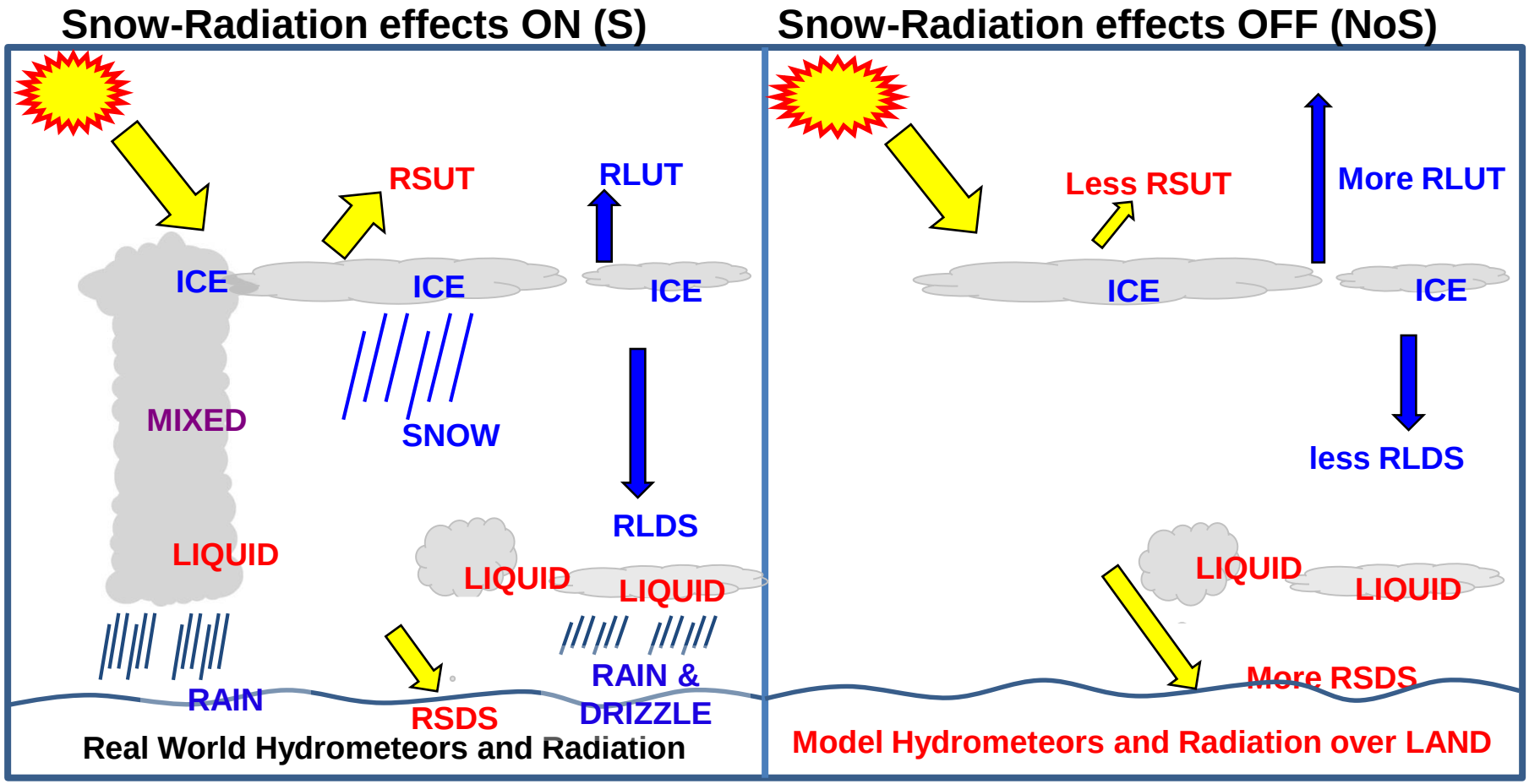


LST*[4] ~ *RSNS* + *RLDS

- **The falling large particle (snow) radiative effects is not included in most global climate models (GCMs).**

- **To what extent snow radiative forcing contributes to the GCMs' biases in surface radiation budgets and LST?**

NCAR CESM1-CAM5 Snow-Radiation Effects Sensitivity Tests



- **NCAR CESM1-CAM5: Exclusion of radiative <u>diagnostic snow</u>**

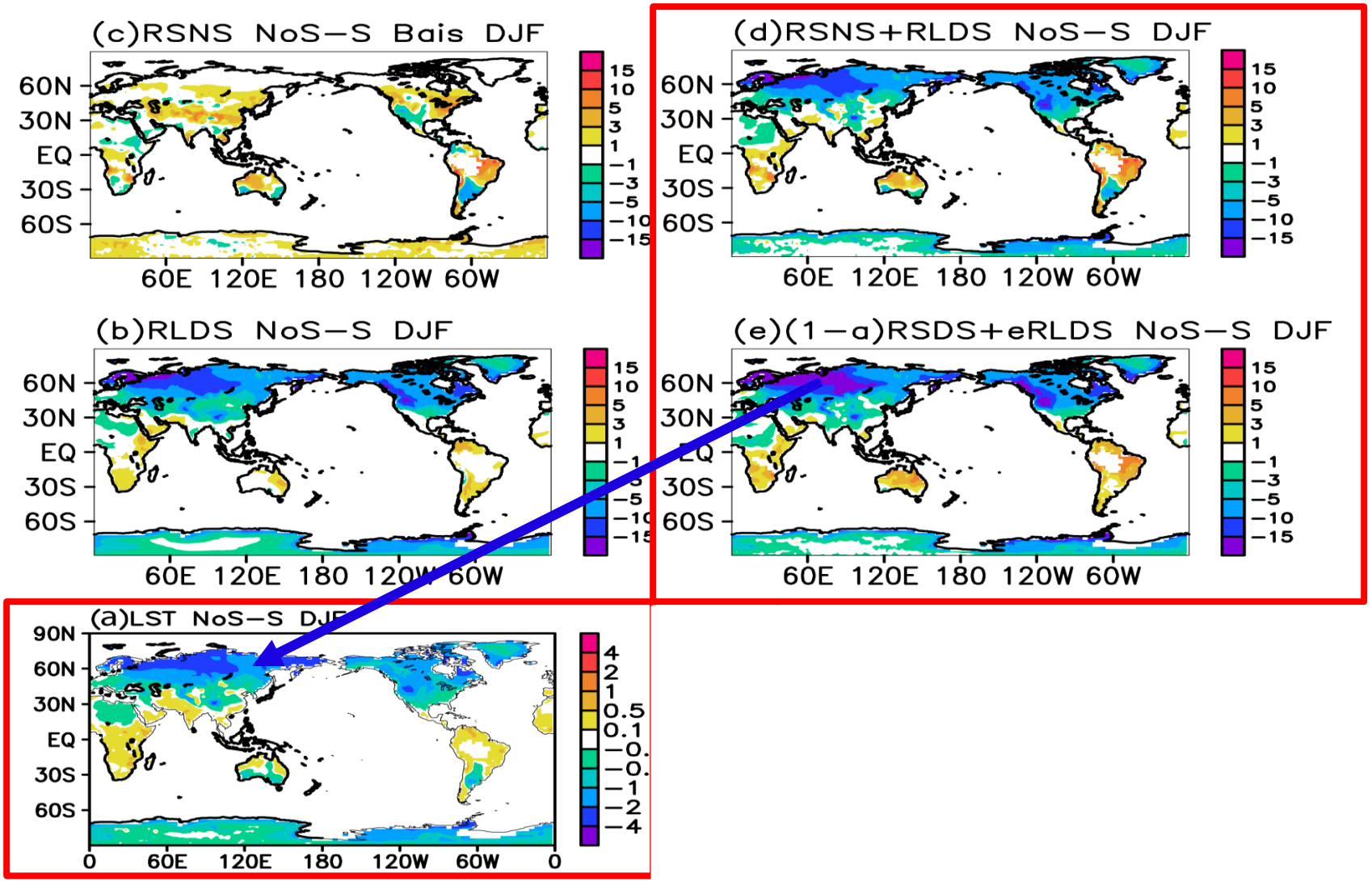
  - CESM1-CAM5-POP2: CMIP5 Historical Configuration (140 Years)

  NoS = snow-radiation interaction OFF

  S = snow-radiation ON

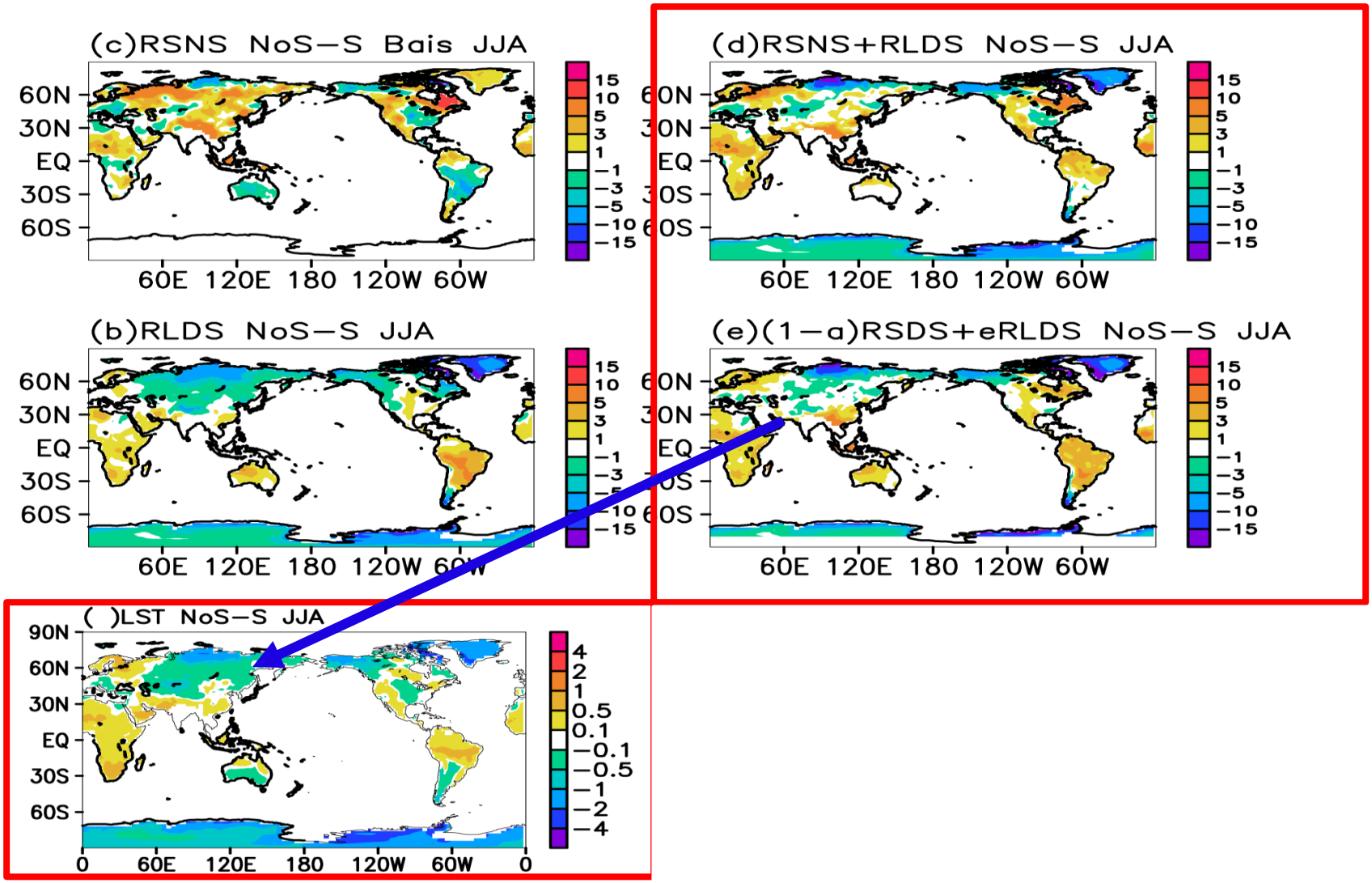
Impacts of Precipitating Ice Radiative Forcing on LST - Winter

NO-SNOW minus SNOW-ON



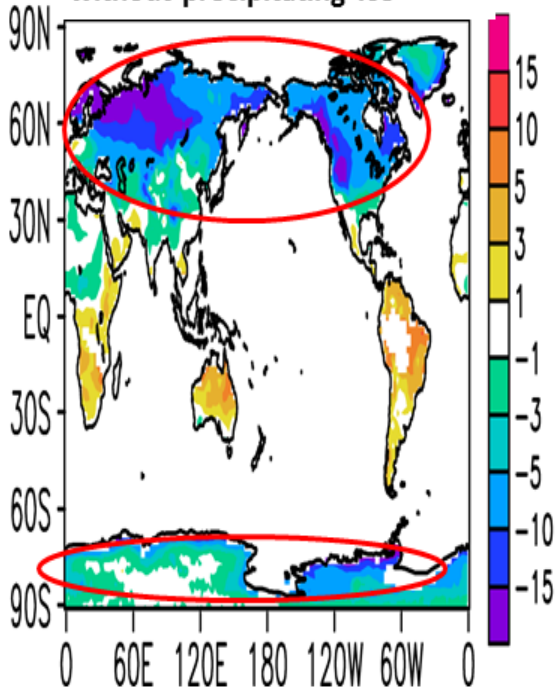
Impacts of Precipitating Ice Radiative Forcing on Surface Radiation Budgets & LST - Summer

NO-SNOW minus SNOW-ON

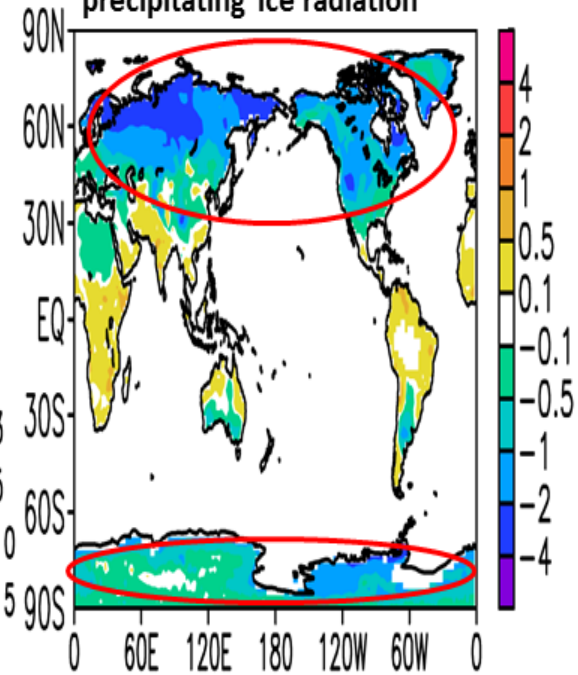


Impacts of Precipitating ice Radiative forcing on Radiation Budget and Land Surface Temperatures in DJF

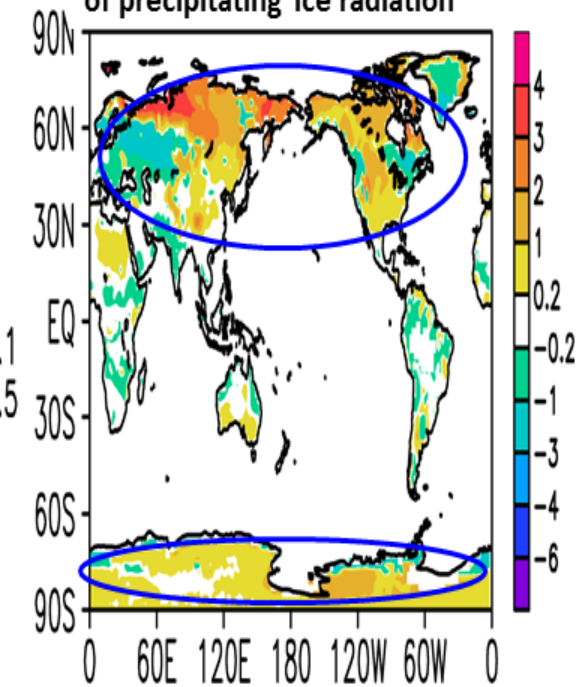
(a)Radiative Forcing Changes without precipitating ice



(b) LST Changes without precipitating ice radiation



(c) Improved LST with the inclusion of precipitating ice radiation

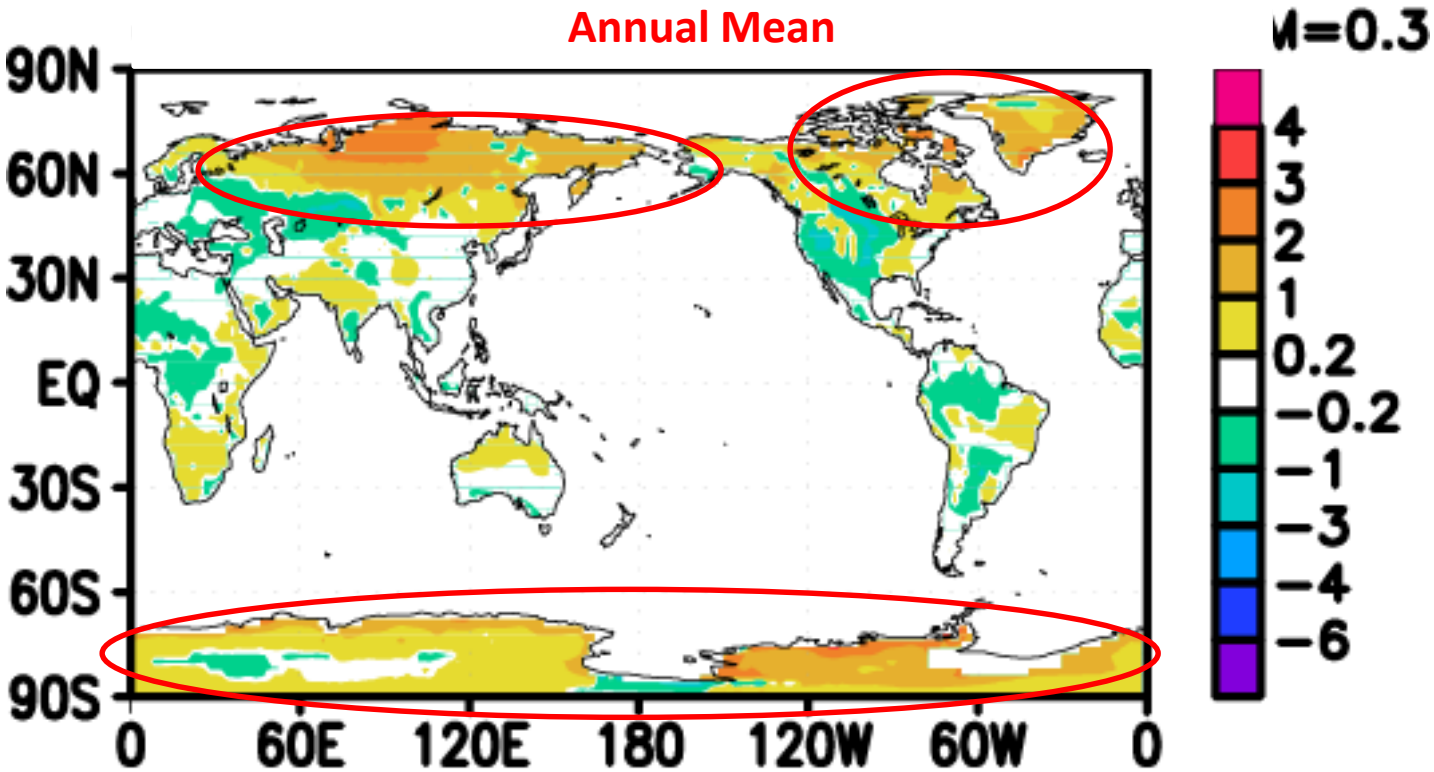


Exclusion of precipitating ice greenhouse effects in winter resulting a cold bias over mid- and high-latitudes (a warm bias caused by excessive solar absorption in summer, not shown).

Inclusion of precipitating ice radiative effects improves the LST simulation (positive values) up to 1~3 degree

Impacts of Precipitating Ice Radiative Forcing on Land Surface Temperatures

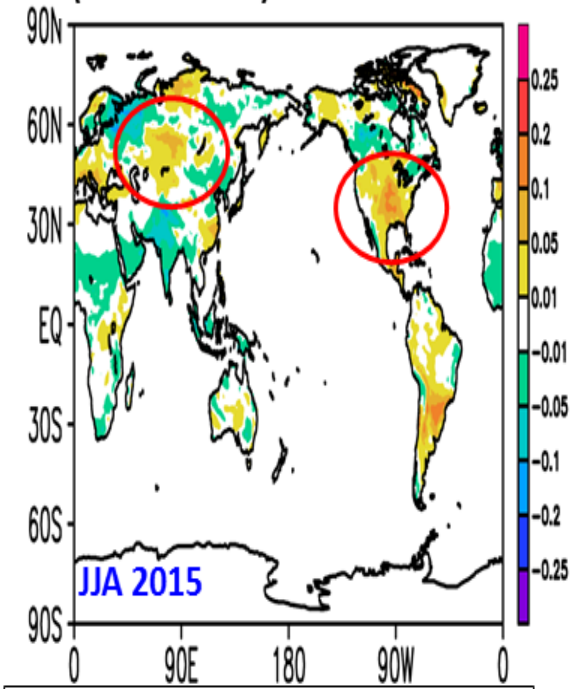
|NO-SNOW LST – MODIS LST| minus |SNOW-ON LST – MODIS LST|



Inclusion of precipitating ice radiative effects reduces LST absolute bias up to 2~4 degree against MODIS LST data

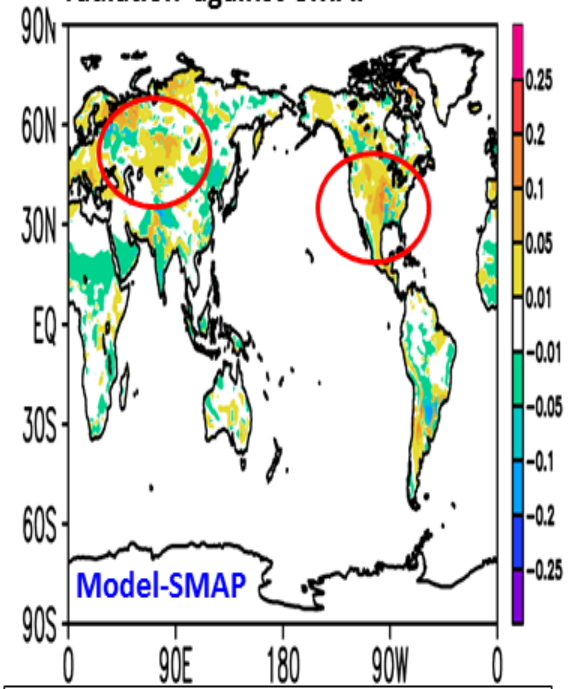
Impacts of Precipitating Ice Radiative forcing on Soil Moisture Simulation in JJA 2015

(a)Soil Moisture Changes without precipitating ice Radiative Forcing (Factor of four)



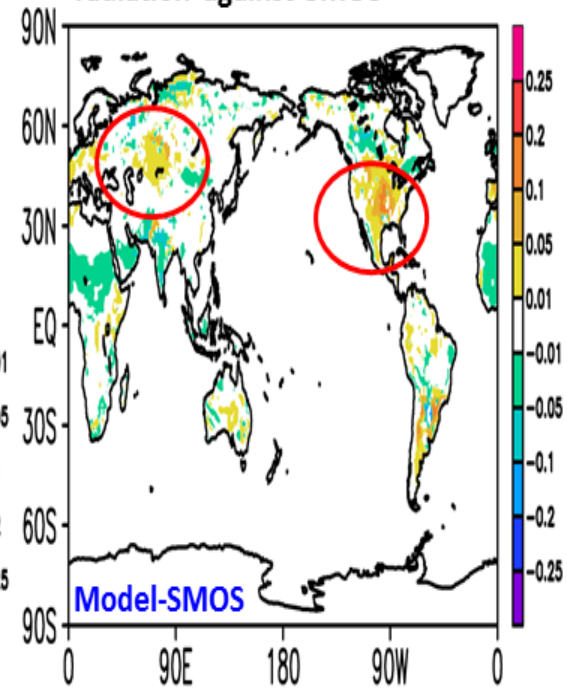
Exclusion of precipitating ice greenhouse effects in summer resulting a too moist, for example, over North America (red circle)

(b) Improved Soil Moisture with the inclusion of precipitating ice radiation against SMAP



Inclusion of precipitating ice radiative effects improves the soil moisture simulation (positive values) up to 25-30%

(c) Improved Soil Moisture with the inclusion of precipitating ice radiation against SMOS



Inclusion of precipitating ice radiative effects improves the soil moisture simulation (positive values) up to 20-25%

Summary

Using CloudSat-CALIPSO total ice water path and AMSR-E LST, and CERES radiation, We identify the followings biases commonly seen in most CMIP models:

Precipitating ice radiative forcing is NOT considered in most GCMs

Substantial underestimated total ice water path (optically too thin)

In Summer and/or Daytime
SW radiative effect
Increase downward SW radiation

In Winter and/or Nighttime
Clouds LW greenhouse effect
reduce downward LW radiation

Too Warm Land Surface Temperatures

Too Cold Land Surface Temperatures

The precipitating radiative forcing is critical in reducing biases of the modeled LST and radiation budgets over land.

Thanks for your Listening

Reference:

Li, J.-L. F., W.-L. Lee, Jia-Yuh Yu, G. Hulley, Eric Fetzer, Yi-Chun Chen,Yi-Hui Wang, : The Impacts of Precipitating Clouds Radiative Effects on Land Surface Properties in Contemporary GCMs and Advanced Reanalysis Data using Satellite Observations, J. Geophys. Res. Atmos., In press.