The Impacts of Precipitating Ice Radiative Forcing on Land Surface Temperature, Surface Air Temperatures and Land Surface Processes in Contemporary GCMs using Satellite Observations

Jui-Lin (Frank) Li

GOAL

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

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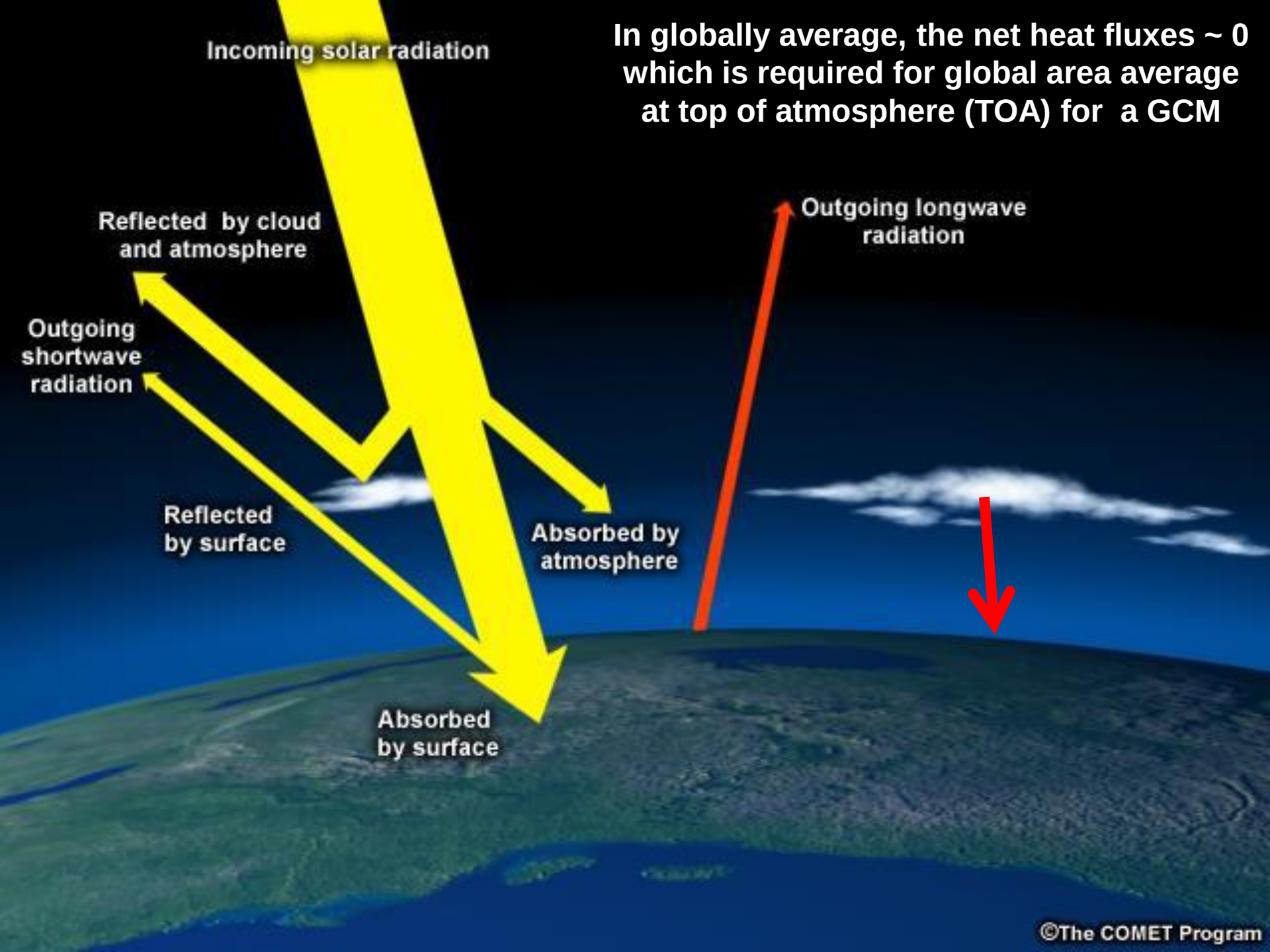
In La Guajira, one of the worst affected areas, the land surface is in the process of desertification.

Photo source: World Food Program


In globally average, the net heat fluxes ~ 0 which is required for global area average at top of atmosphere (TOA) for a GCM
Incoming solar radiation
Reflected by cloud and atmosphere
Outgoing shortwave radiation
Reflected by surface
Absorbed by atmosphere
Outgoing longwave radiation
Absorbed by surface
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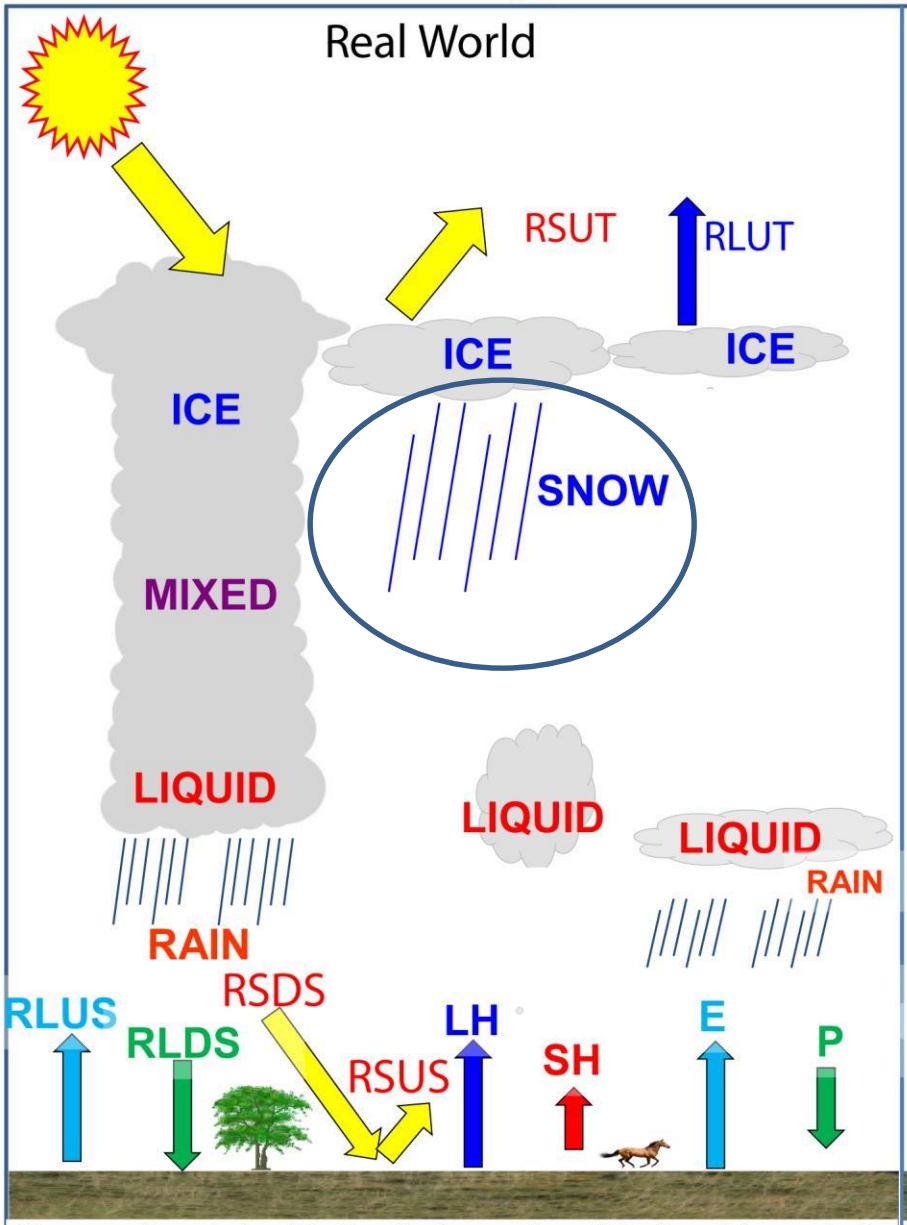
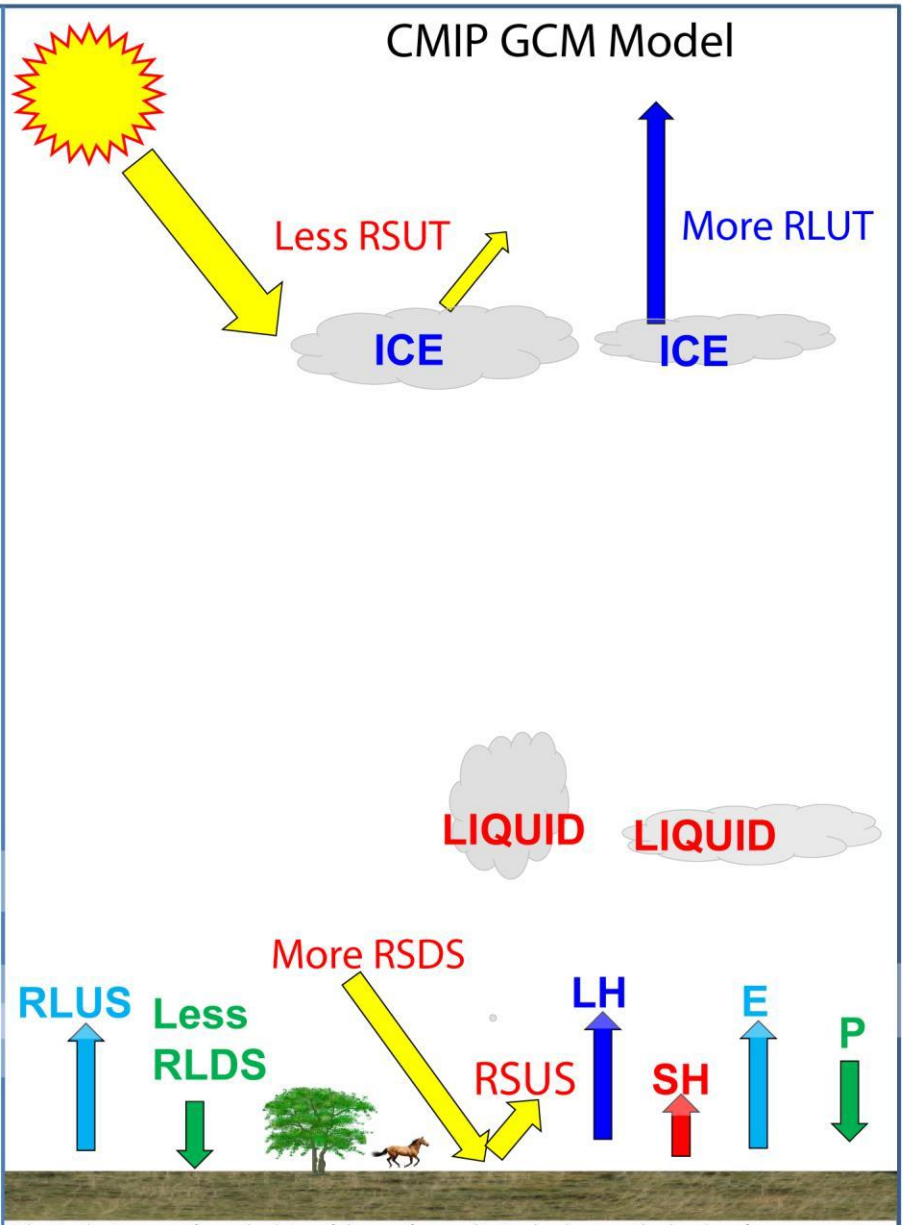
Energy and Water Budgets over Land Surface



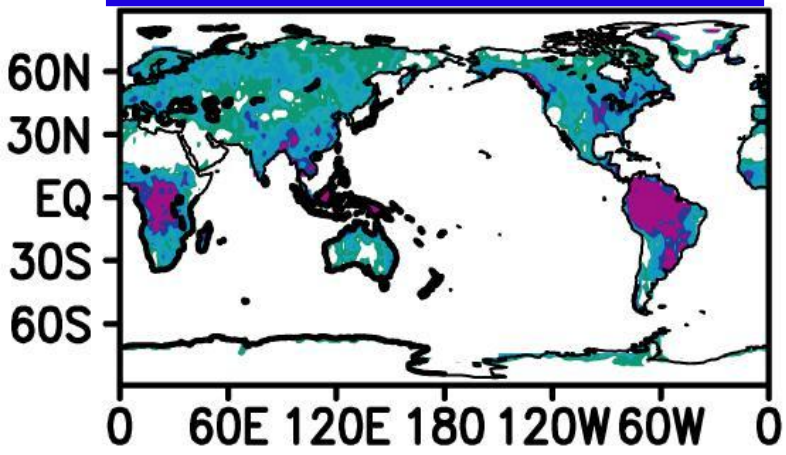
The amount of water in the soil is affected by the net surface radiative flux and the strength of the surface evaporation associated with ground water and precipitation.



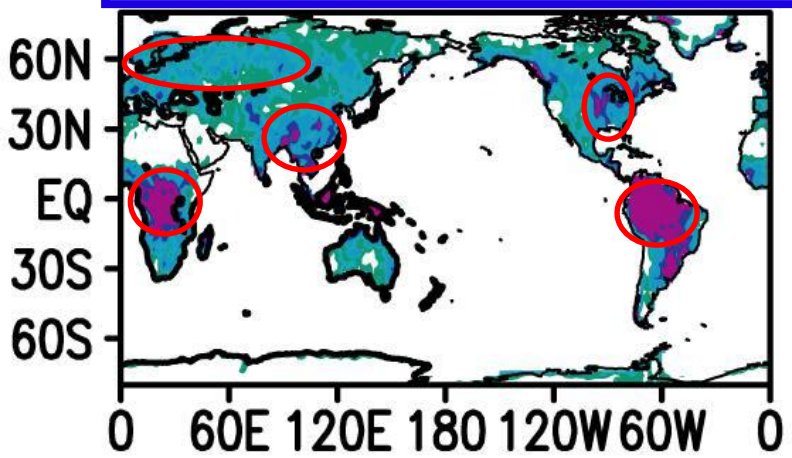
What is the impacts from the bias of the surface radiative budget on the land surface properties such as soil moisture, temperatures, evapotrasparent etc.

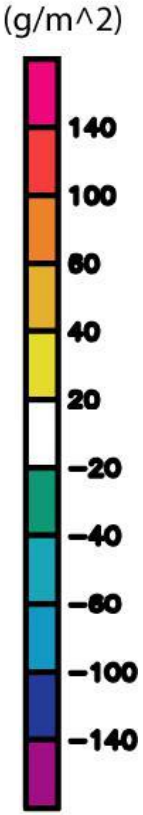
Evaluation of Total Ice Water Path in CMIP3/CMIP5 Models Using CloudSat-CALIPSO Data

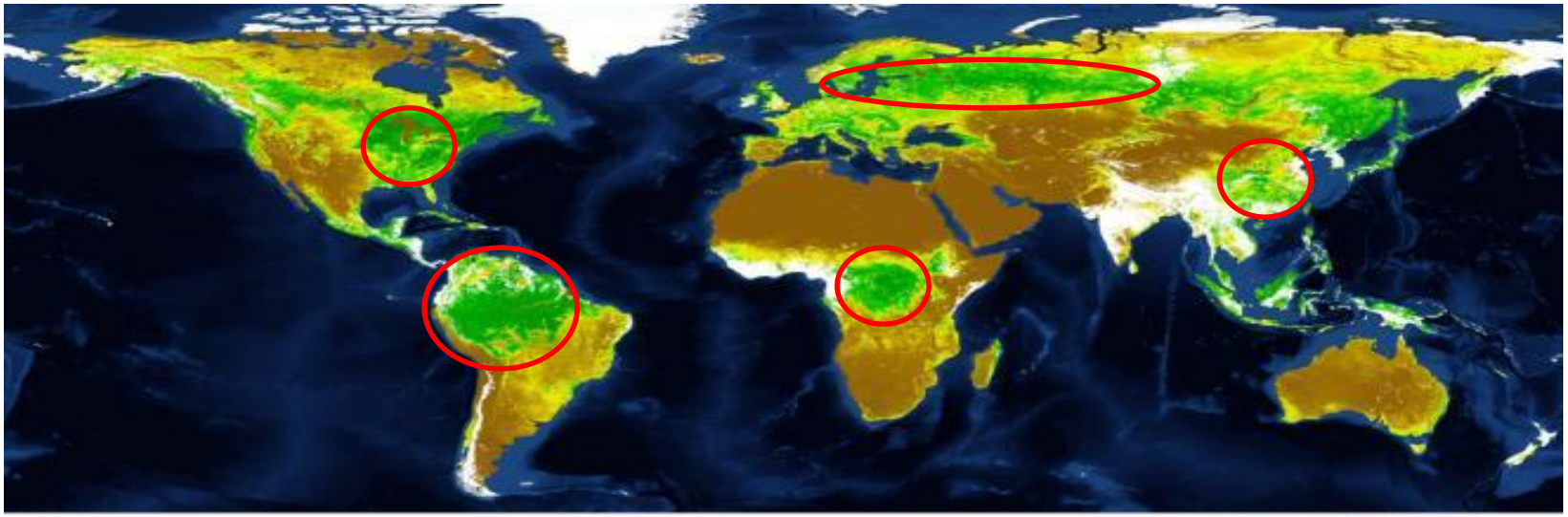
CMIP3 - Total Ice Water Path



CMIP5 - Total Ice Water Path





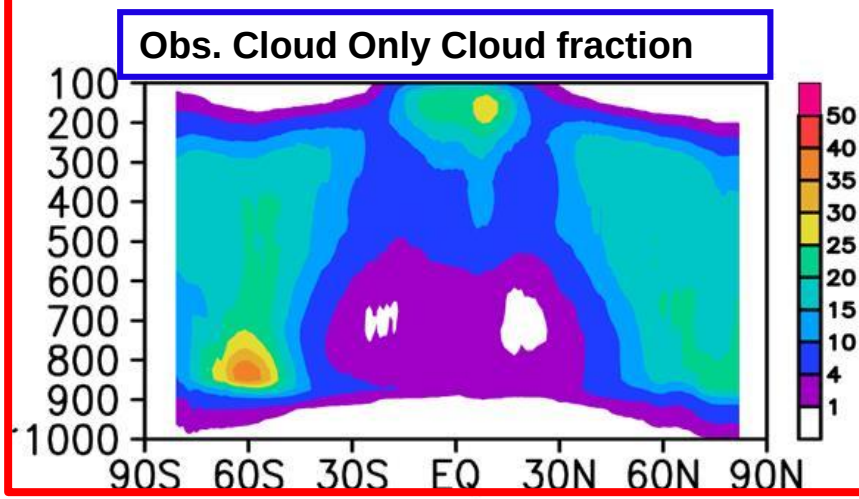


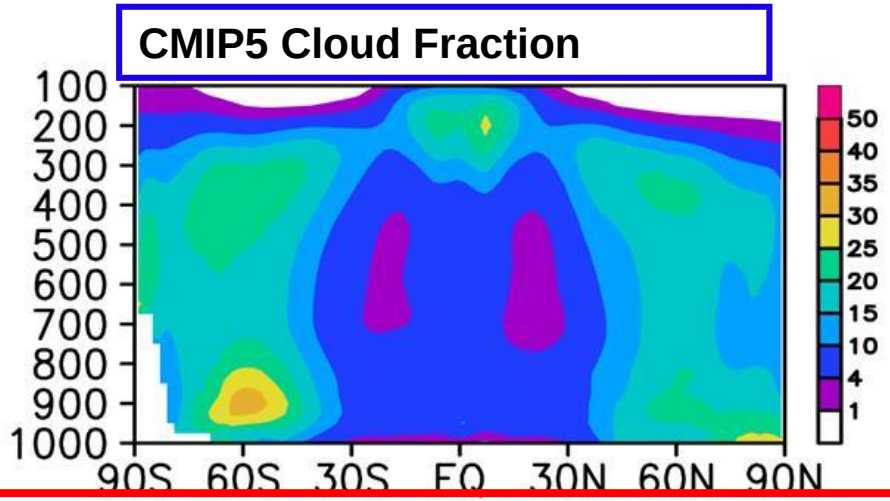
Leaf Area Index

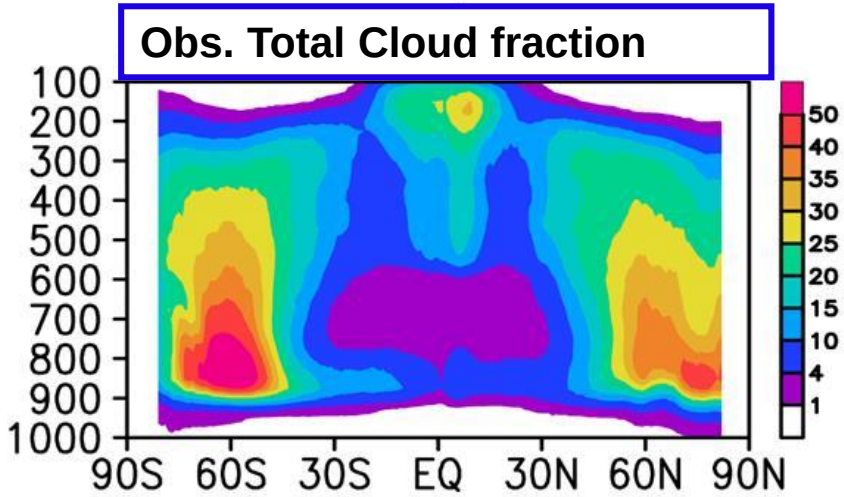
Data source: SPOT-VEGETATION

geoland

Evaluation of Total Cloud Fraction in CMIP5 Models







Obs. Cloud Fraction:

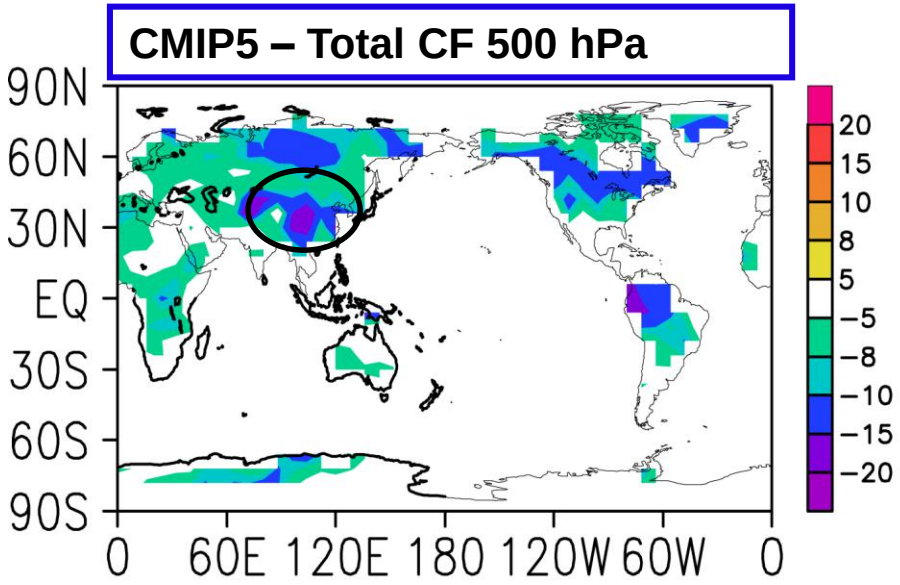
Derived from CloudSat-CALIPSO Data

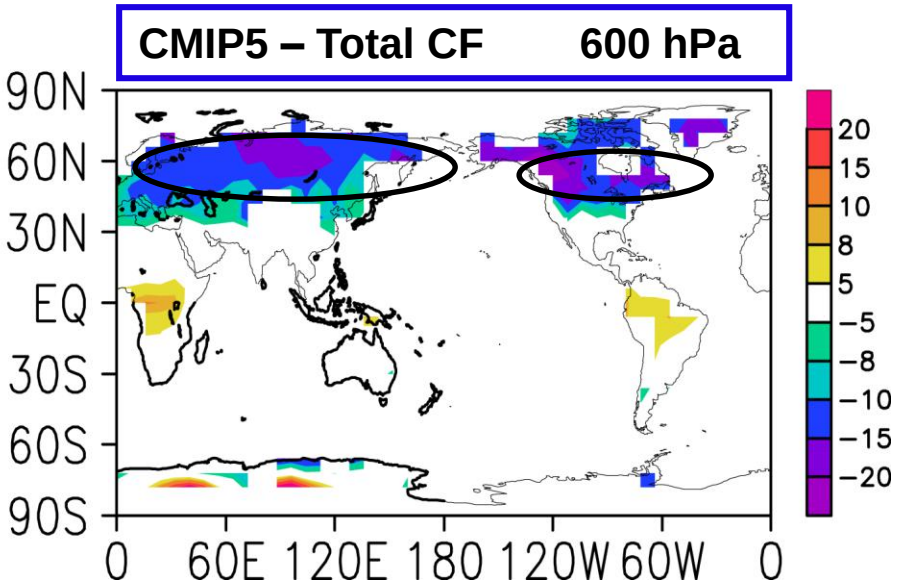
Total: Valid cloud detected

Cloud Only: Exclusion of precipitating & convective profiles using Flags

(Lee et al. 2016)

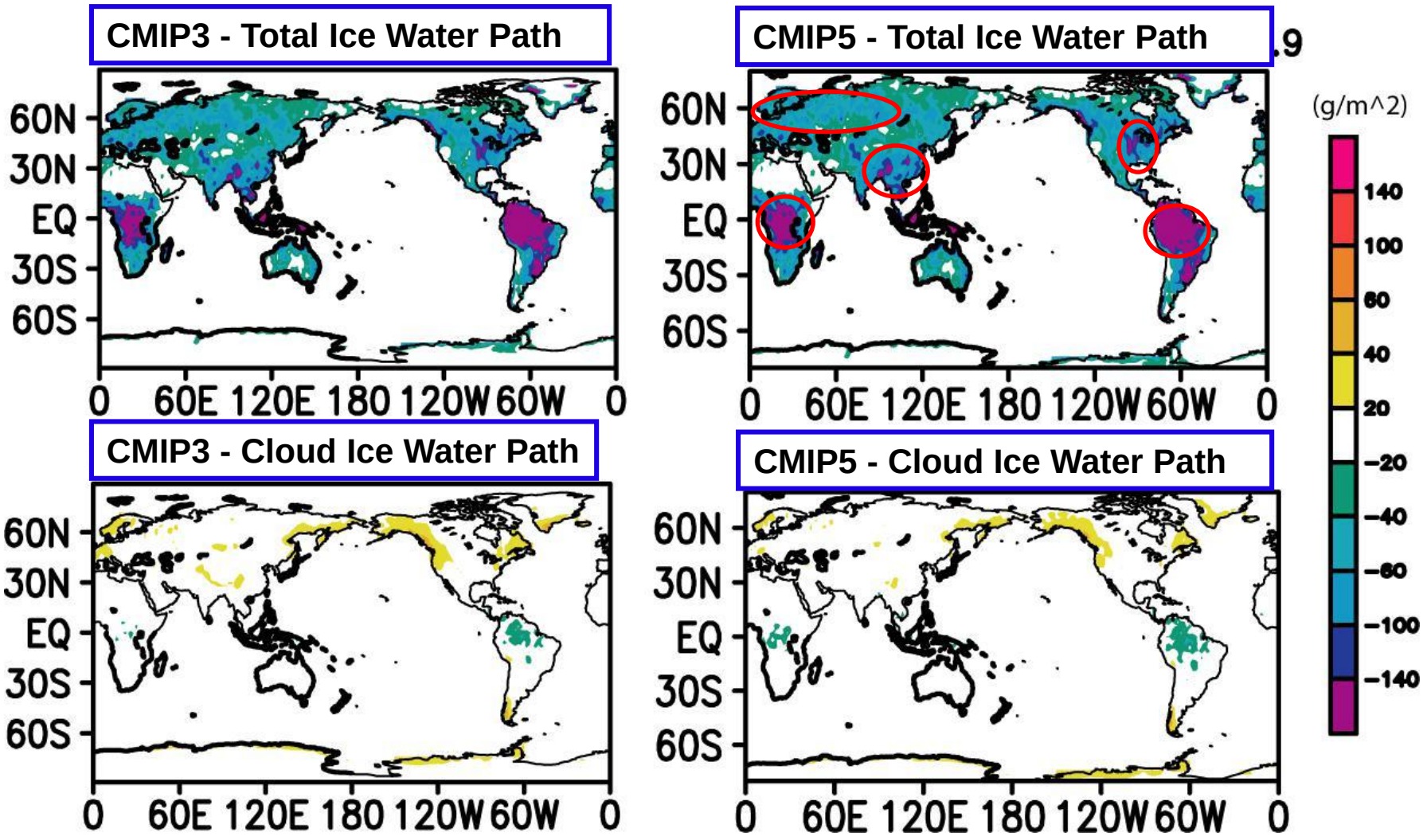
Bias of Total Cloud Fraction vs CloudSat-CALIPSO in CMIP5 Models over LAND





(Lee et al. 2016)

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



CMIP models are doing good job on “cloud only” IWP vs Obs.

The LST (skin radiative temperature, Ts) can be directly determined by the surface energy budget for the gross, GCM grid-box scale as following:

$$LST \sim (1-\alpha) Downward\ SW + \varepsilon\ Downward\ LW$$

Or

$$LST \sim Net\ Downward\ SW + Downward\ LW$$

α: *Surface albedo*

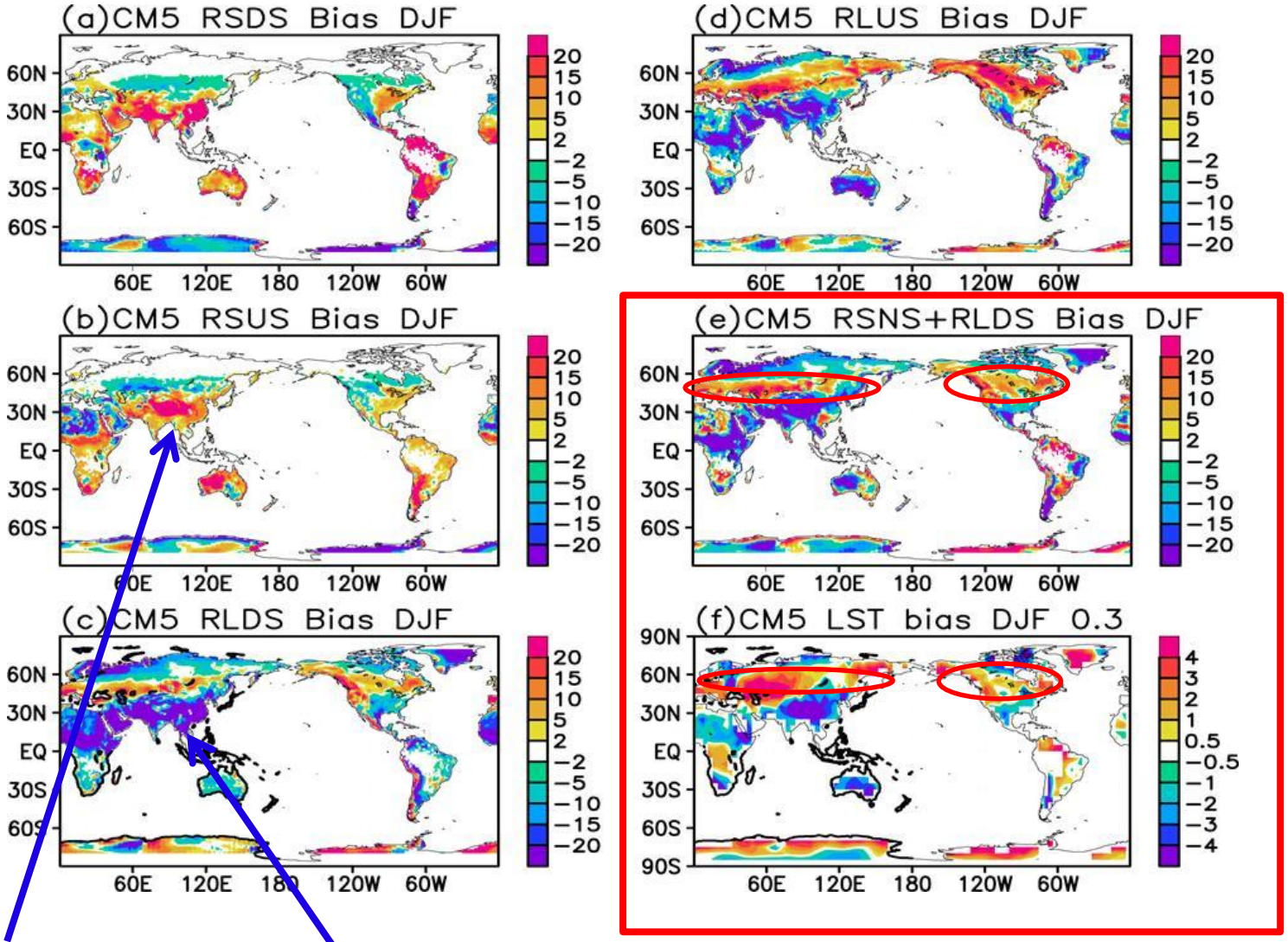
ε: *Surface emissivity*

LST

➔ SAT & Surface sensible heat➔ PBL state

➔ Cloud/Convection formation➔ precipitation

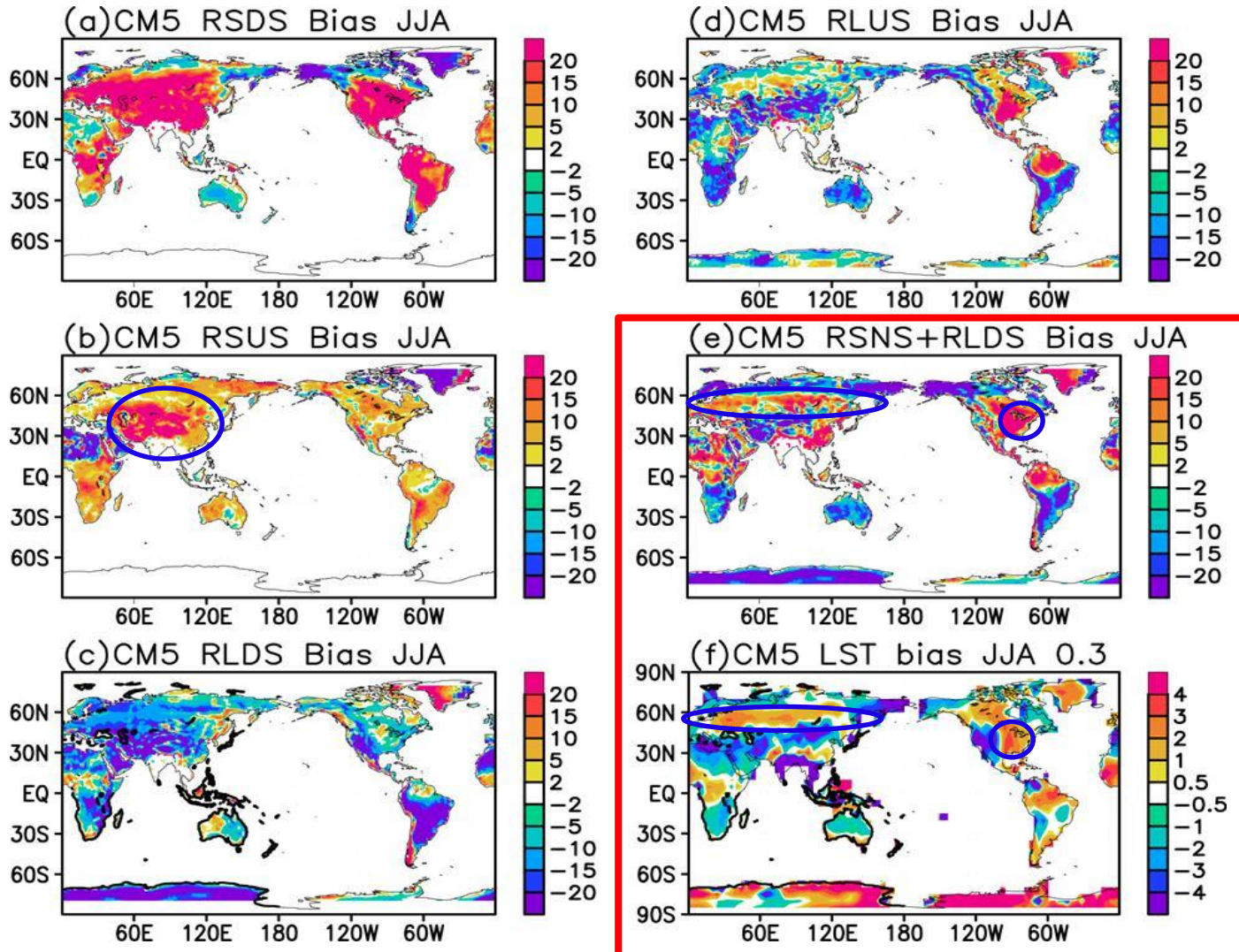
Evaluation of LST and Radiation Budgets in CMIP5 Models Against CERES-EBAF



Albedo cooling & greenhouse effects

LST ~ RSNS + RLDS

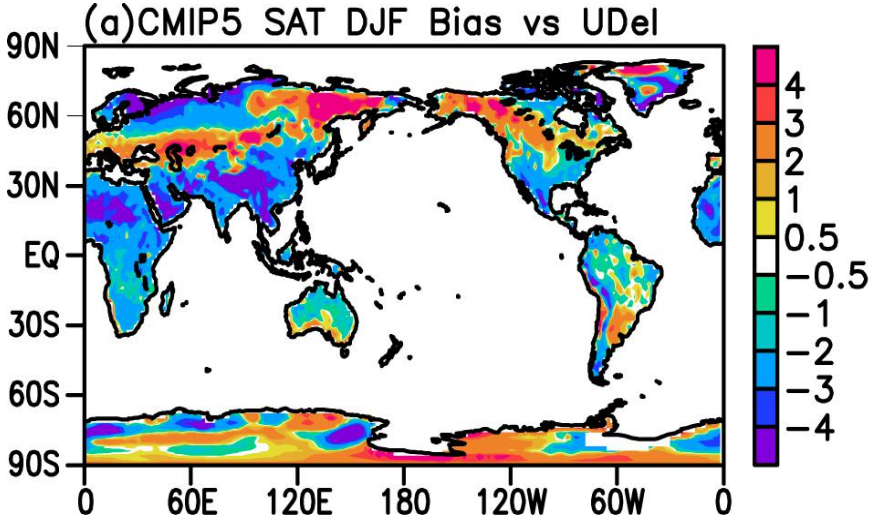
Evaluation of LST and Radiation Budgets in CMIP5 Models - Summer

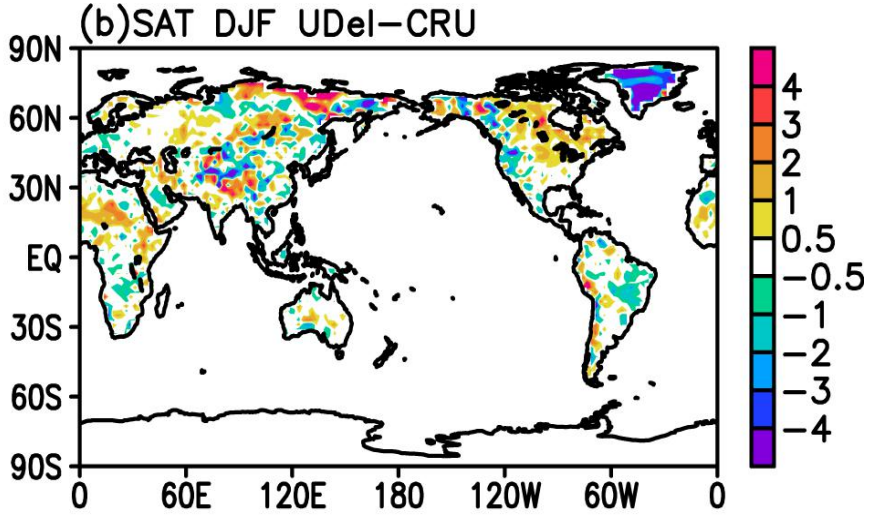


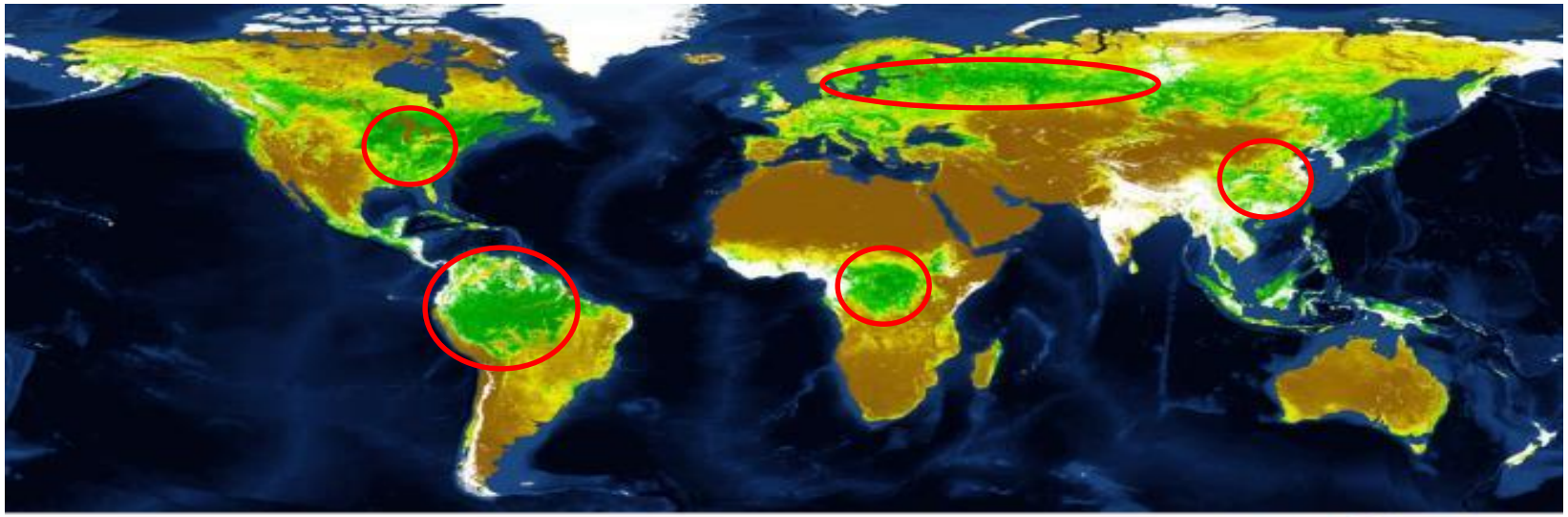
Albedo cooling & greenhouse effects

$LST^4 \sim RSNS + RLDS$

Evaluation of Surface Air Temp. in CMIP5 Models Using Udel Station Data





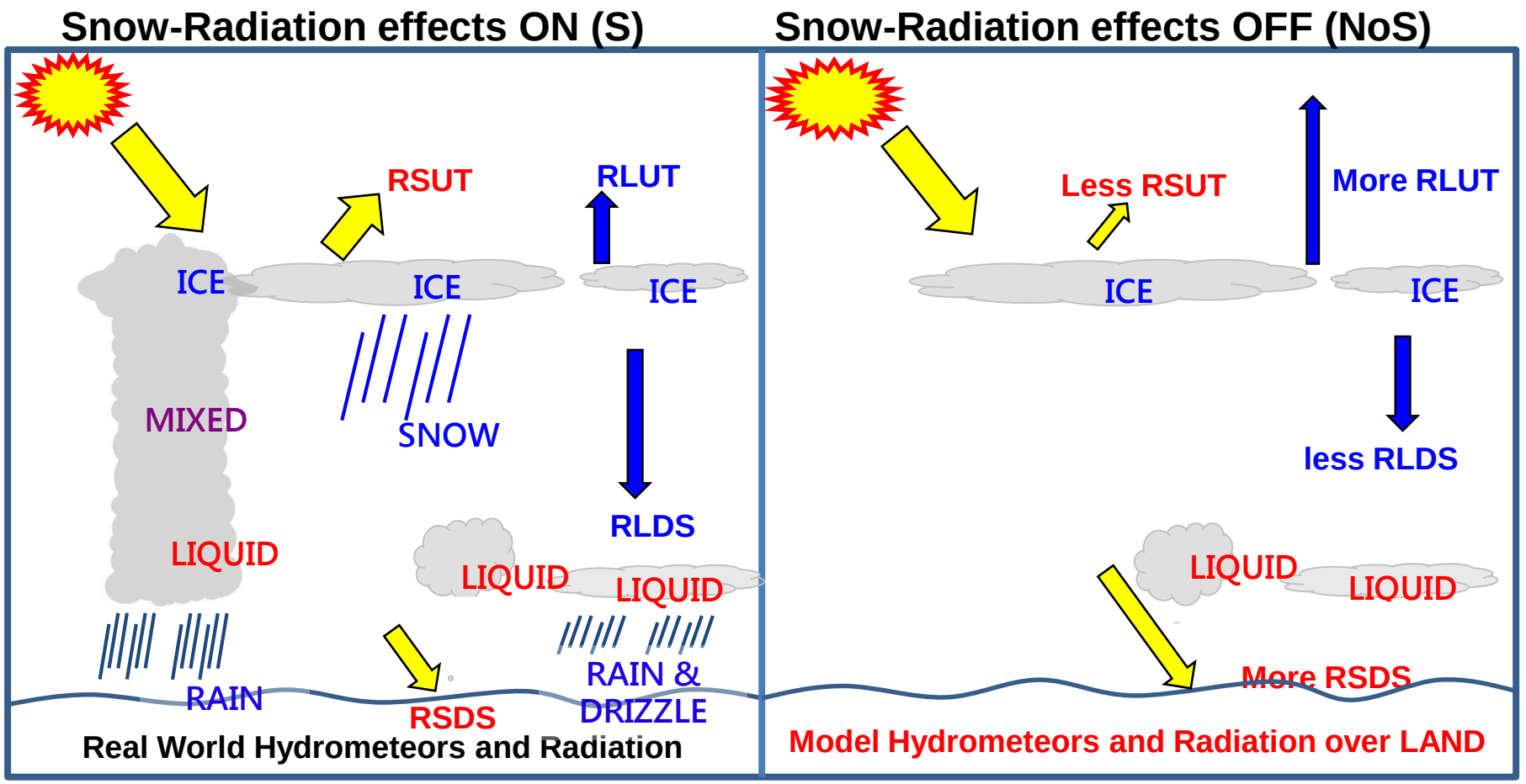


Leaf Area Index

Data source: SPOT-VEGETATION

geoland

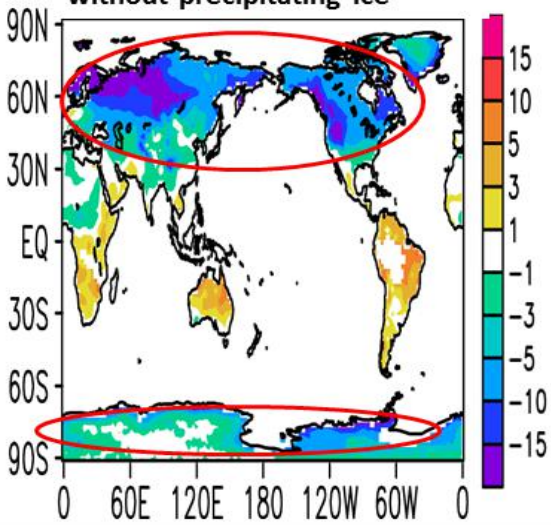
NCAR CESM1-CAM5 Snow-Radiation Effects Sensitivity Tests



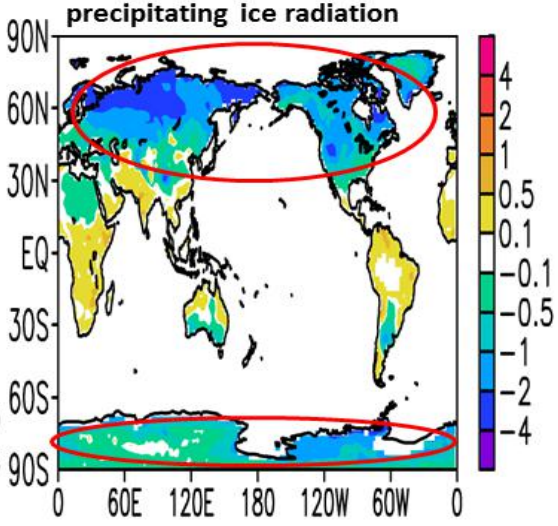
- **NCAR CESM1-CAM5: Exclusion of radiative diagnostic snow**
  - **CESM1-CAM5-POP2: CMIP5 Historical Configuration (140 Years)**
    - **NoS = snow-radiation interaction OFF**
    - **S = snow-radiation ON**

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

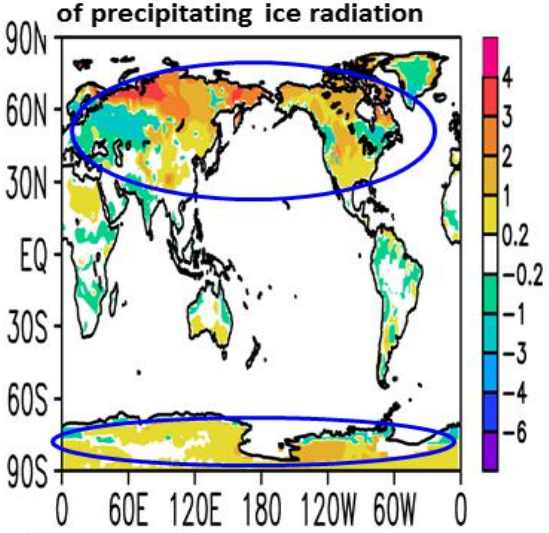
(a)Radiative Forcing Changes without precipitating ice



(b) LST Changes without precipitating ice radiation



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

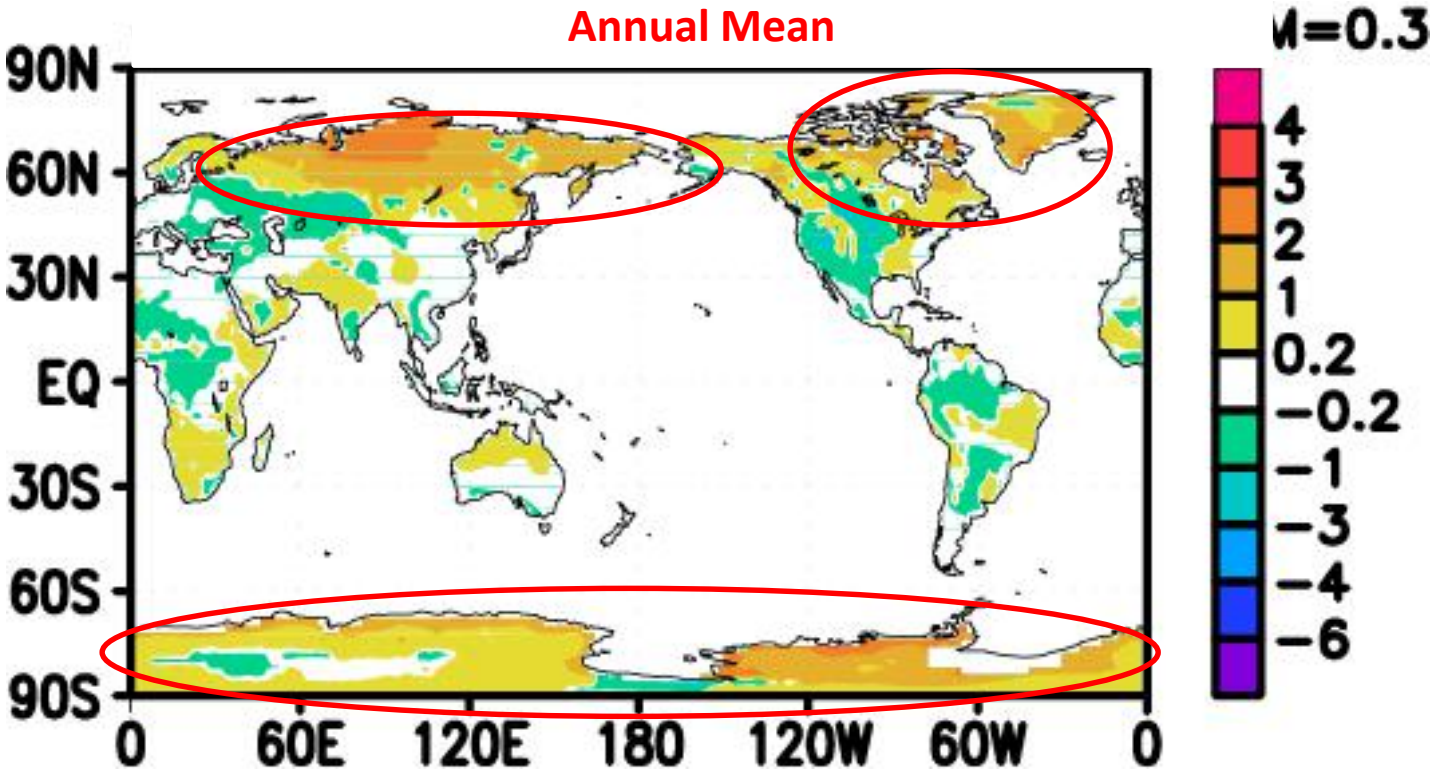


Exclusion of precipitating ice greenhouse effects in winter resulting a cold bias over mid- and high-latitudes (a warm bias caused by excessive solar absorption in summer, not shown).

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

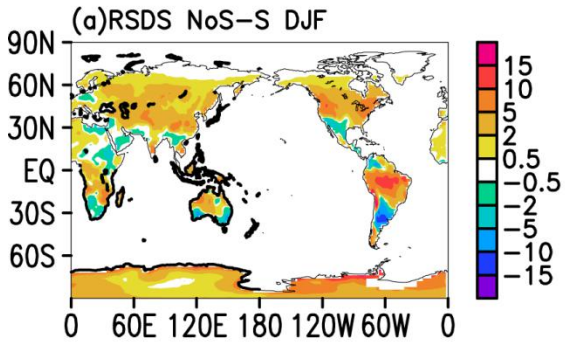
Impacts of Precipitating Ice Radiative Forcing on Land Surface Temperatures

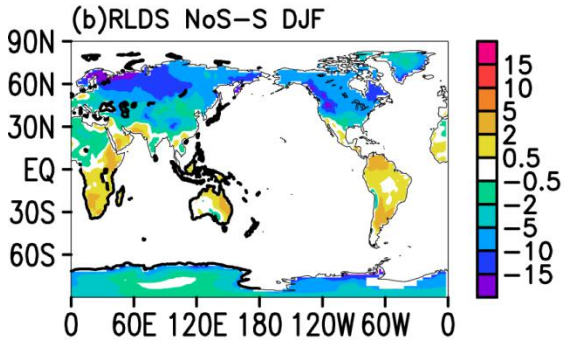
|NO-SNOW LST – MODIS LST| minus |SNOW-ON LST – MODIS LST|

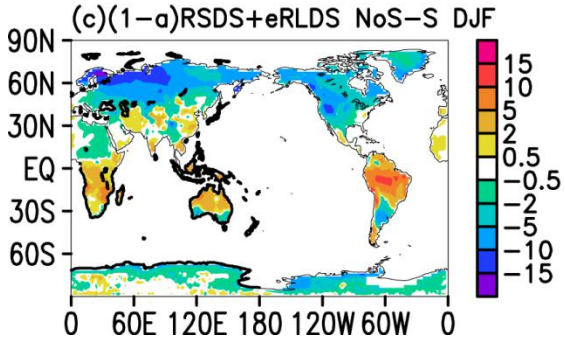


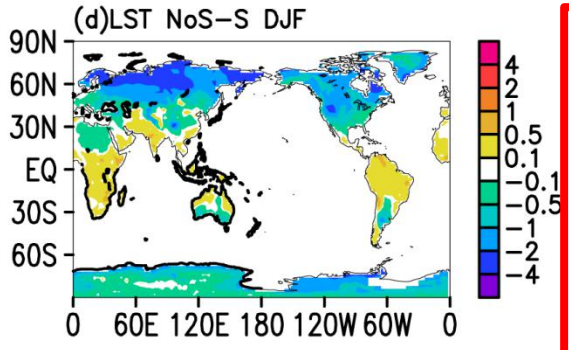
Inclusion of precipitating ice radiative effects reduces LST absolute bias up to 2~4 degree against MODIS LST data

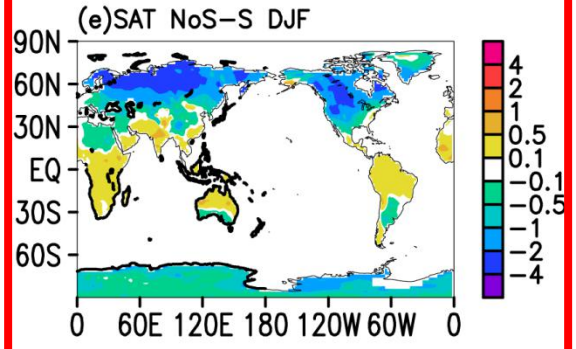
Impacts of Precipitating Ice Radiative Forcing on Land Surface AIR Temperatures (SAT)

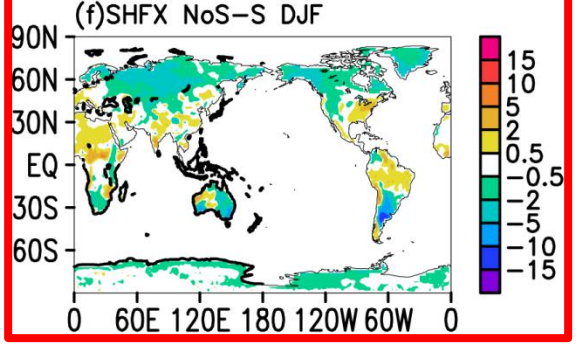


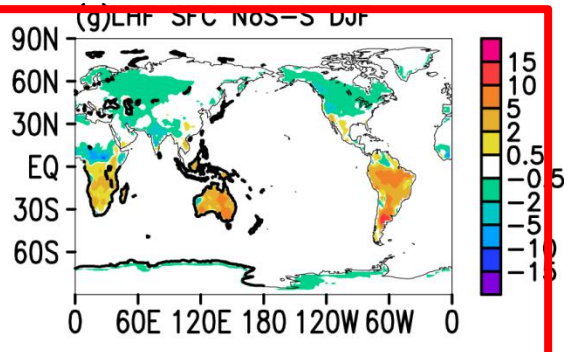


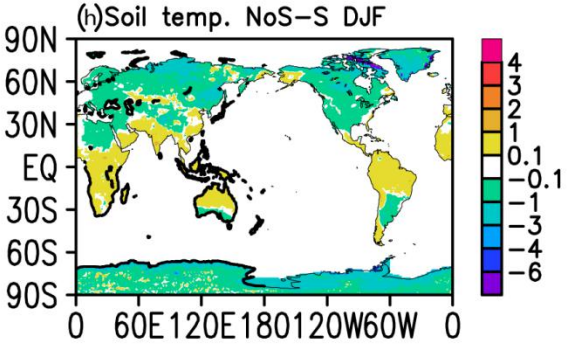






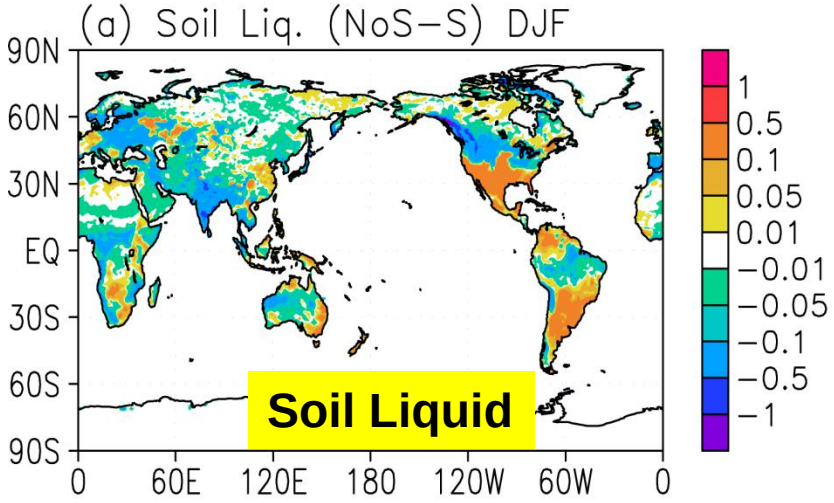


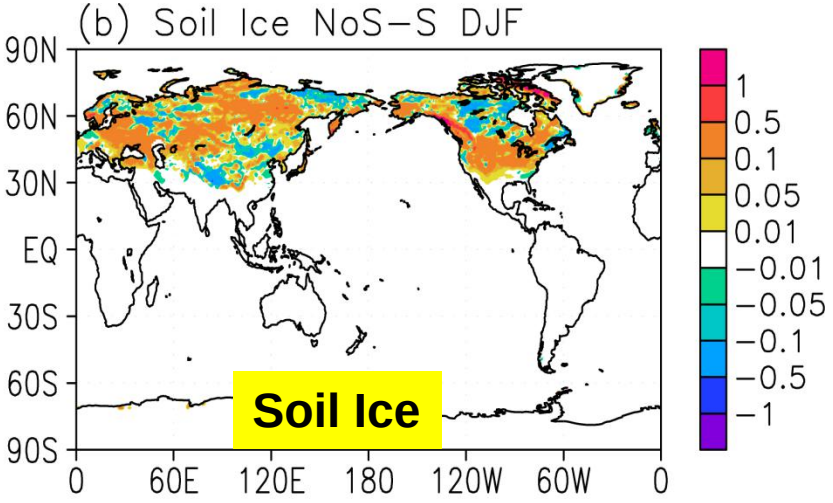


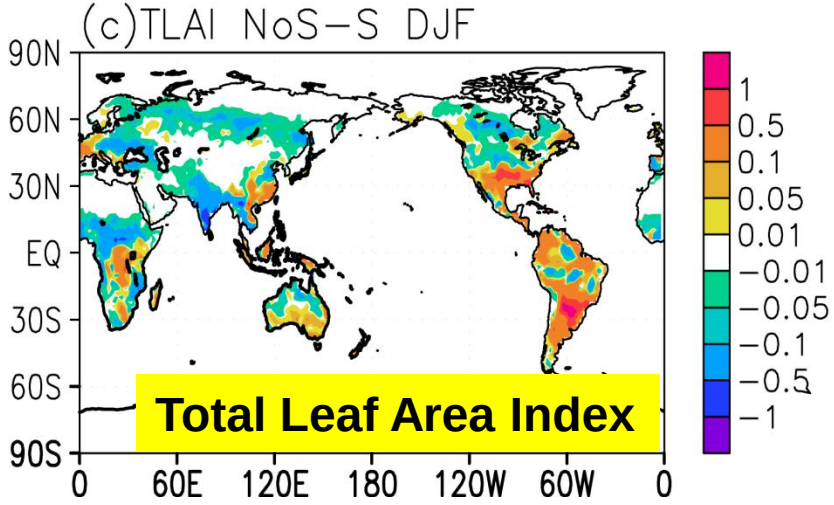


Decreased PBL depth!!

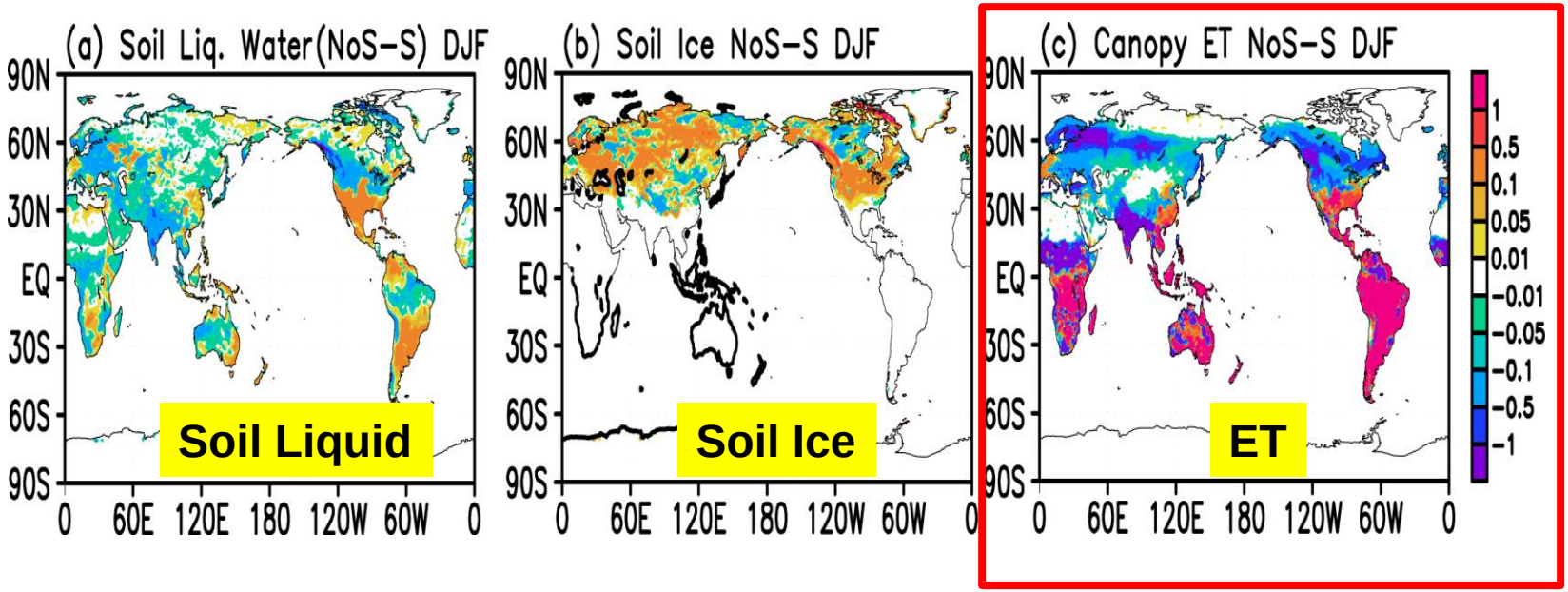
Impacts of Precipitating Ice Radiative Forcing on Land Surface Processes



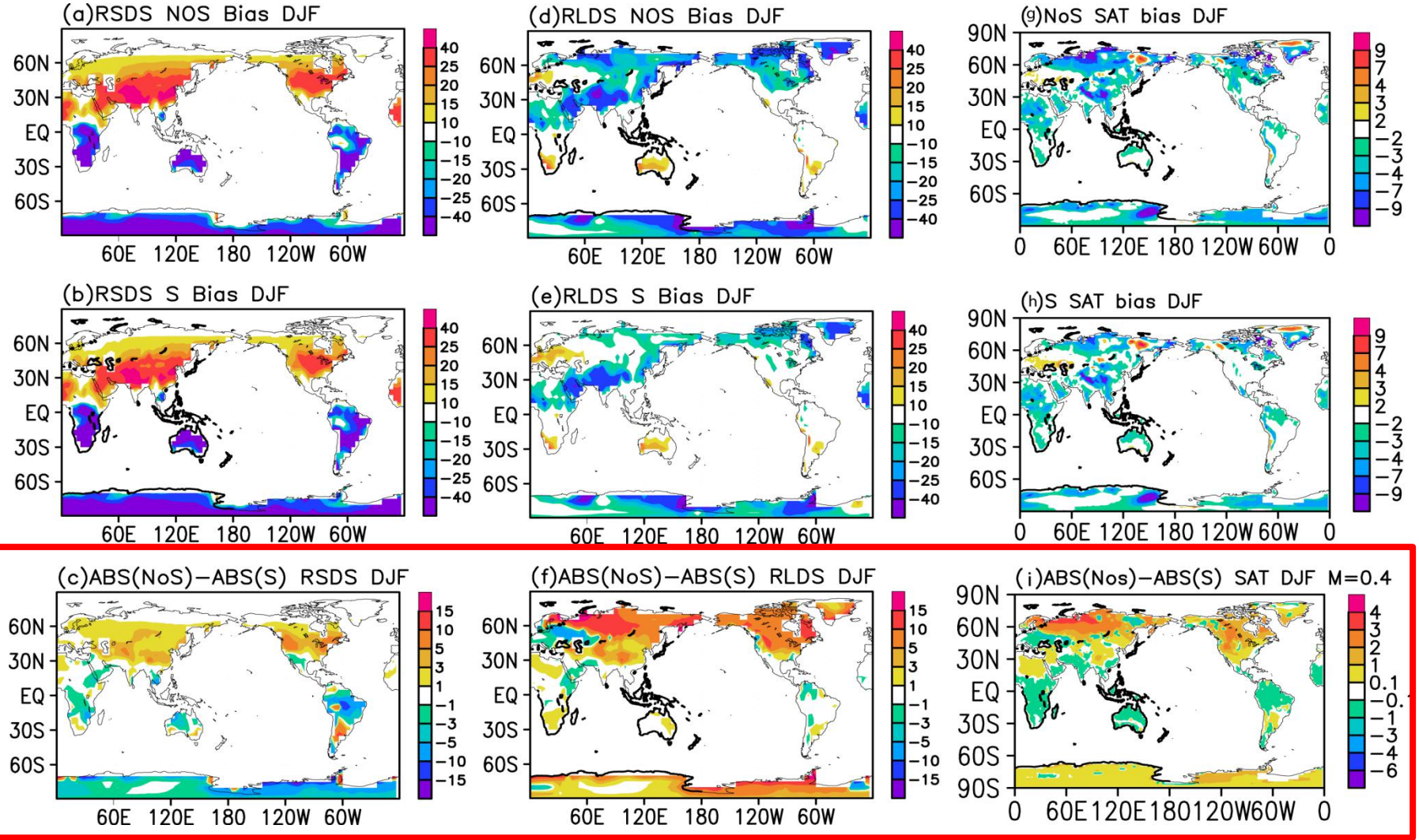




Impacts of Precipitating Ice Radiative Forcing on Ecosystem

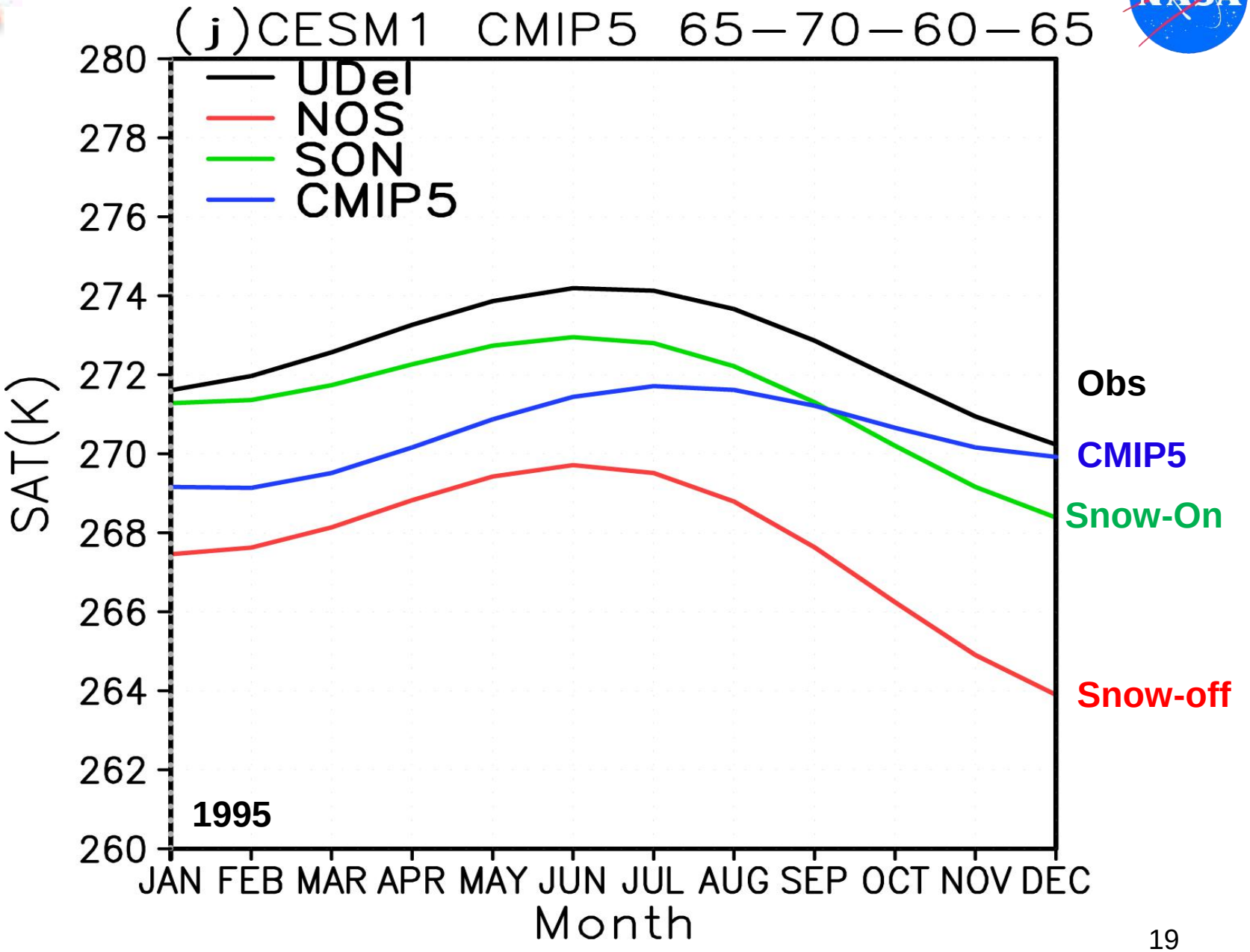


Improvement with the Inclusion of Precipitating Ice Radiative Forcing

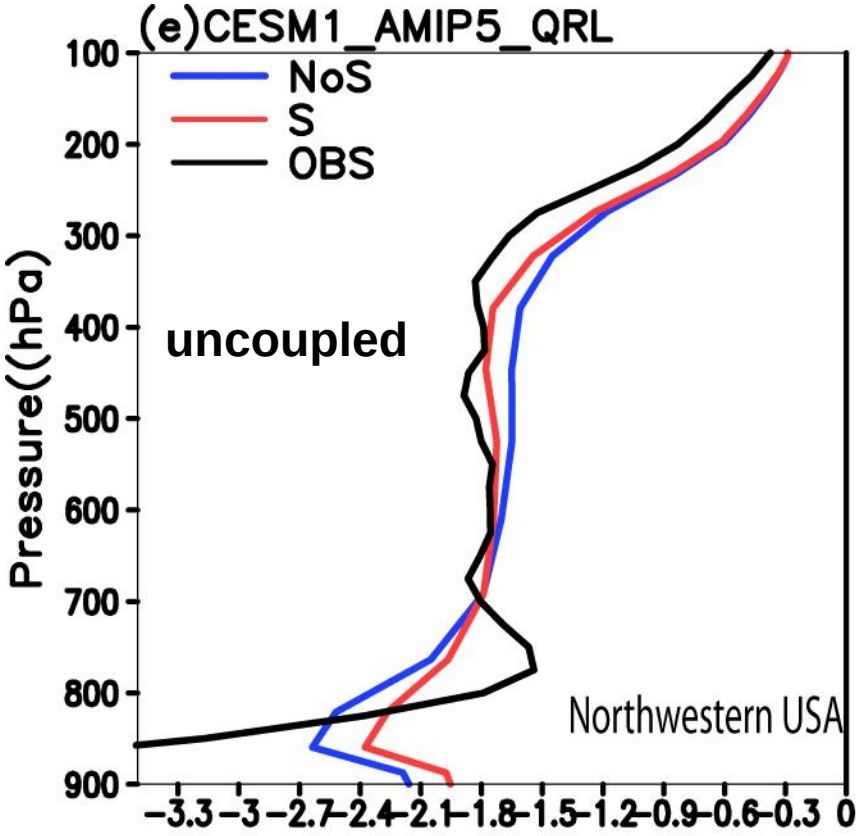


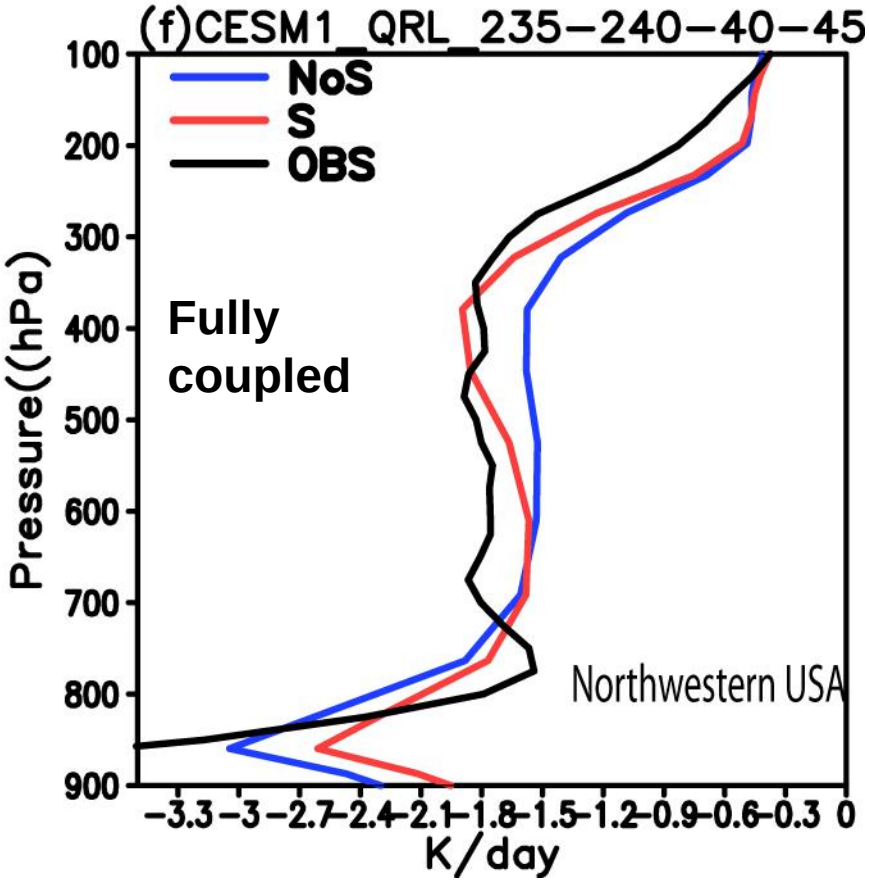
|NO-SNOW – OBS| minus |SNOW-ON – OBS|

Positive value indicates improvement


(j)CESM1 CMIP5 65−70−60−65
UDel
NOS
SON
CMIP5
SAT(K)
280
278
276
274
272
270
268
266
264
262
260
1995
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Month
Obs
CMIP5
Snow-On
Snow-off

Radiative LW Heating Profiles vs CloudSat-CALIPSO derived Obs.



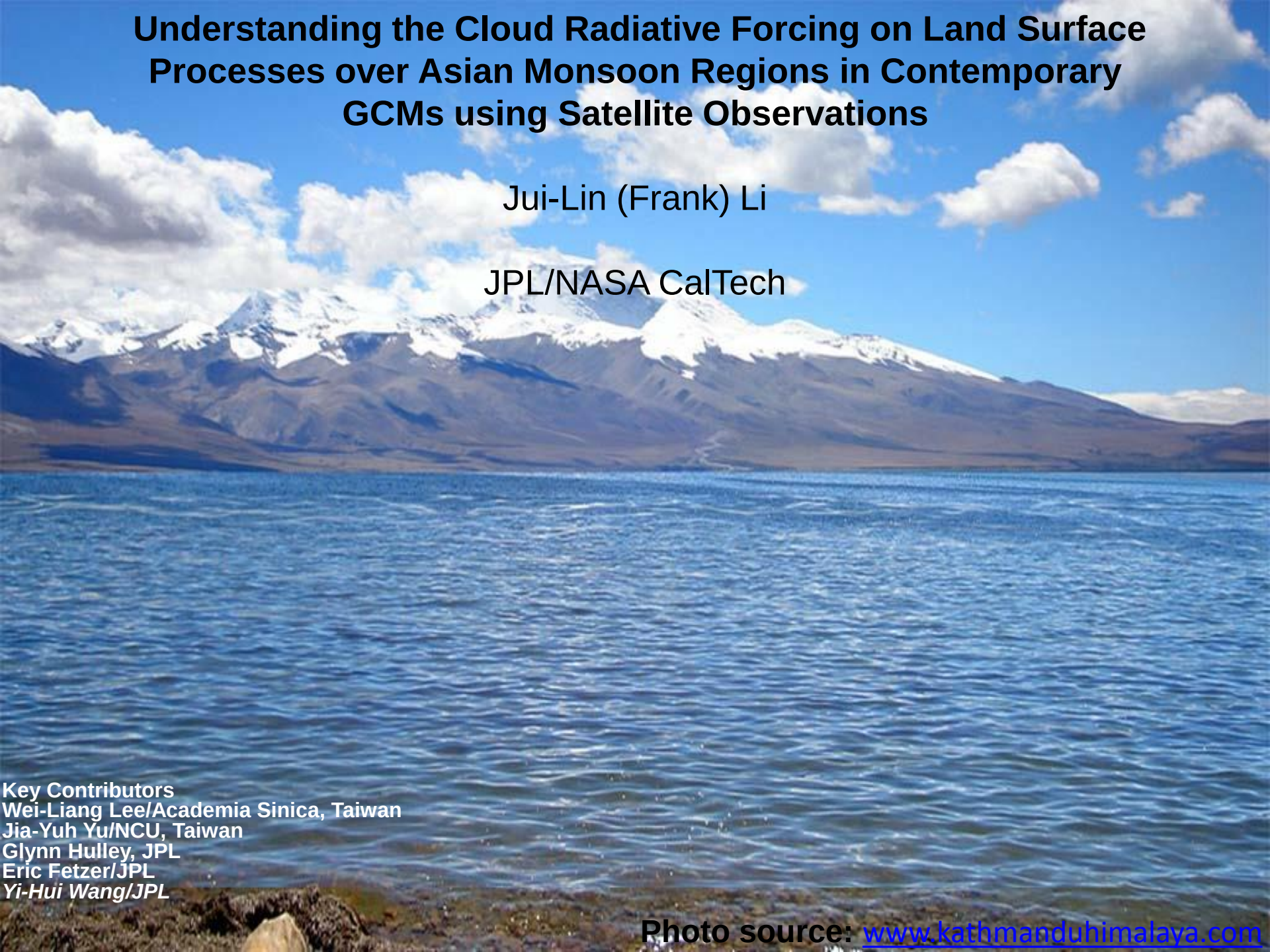


Similar improvement with snow-radiative effect included are found over regions such as western Europe, central China, East America

Understanding the Cloud Radiative Forcing on Land Surface Processes over Asian Monsoon Regions in Contemporary GCMs using Satellite Observations

Jui-Lin (Frank) Li

JPL/NASA CalTech



Key Contributors
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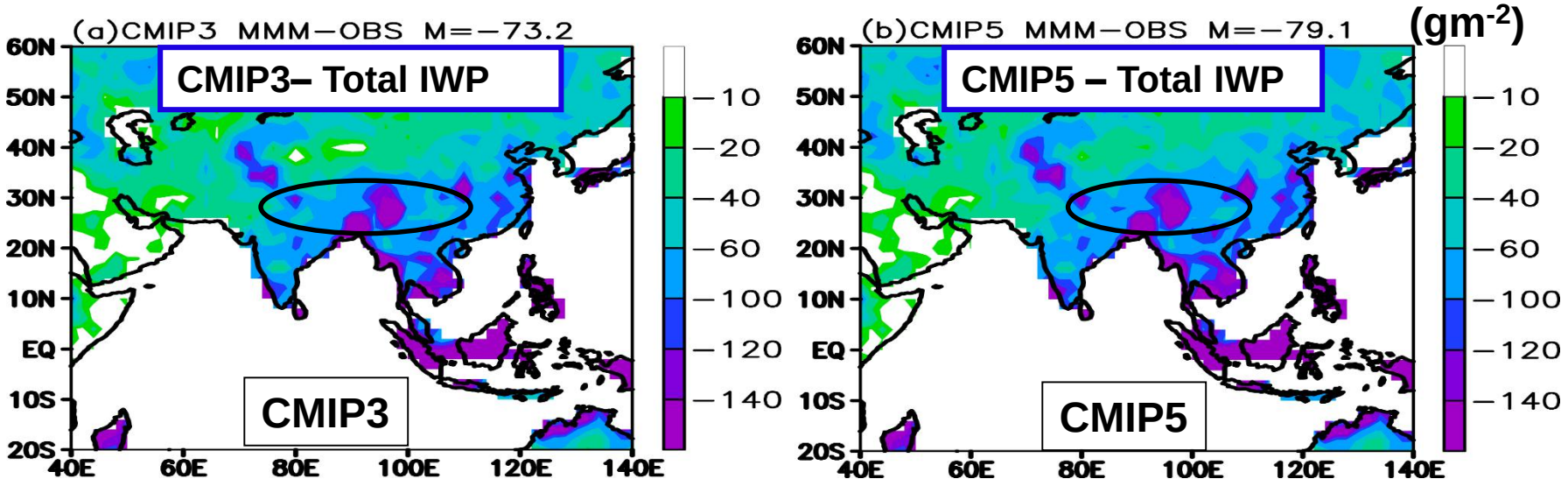
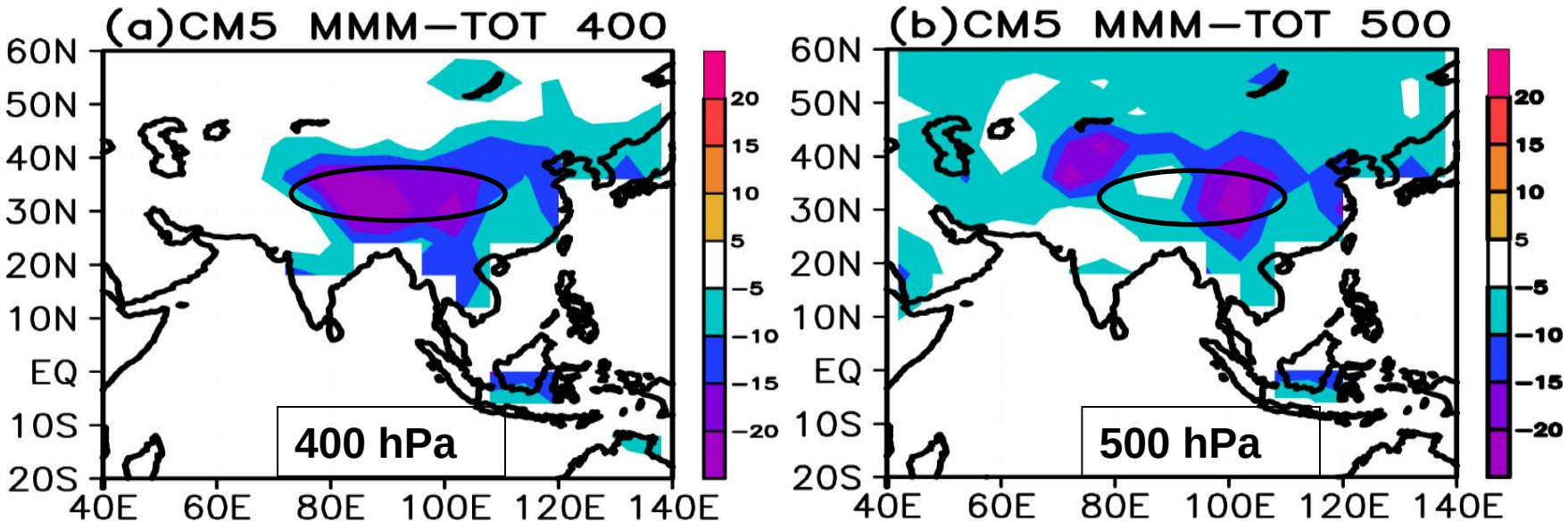
Photo source: www.kathmanduhimalaya.com

Bias of Total Ice Water Path in CMIP3/CMIP5 Models



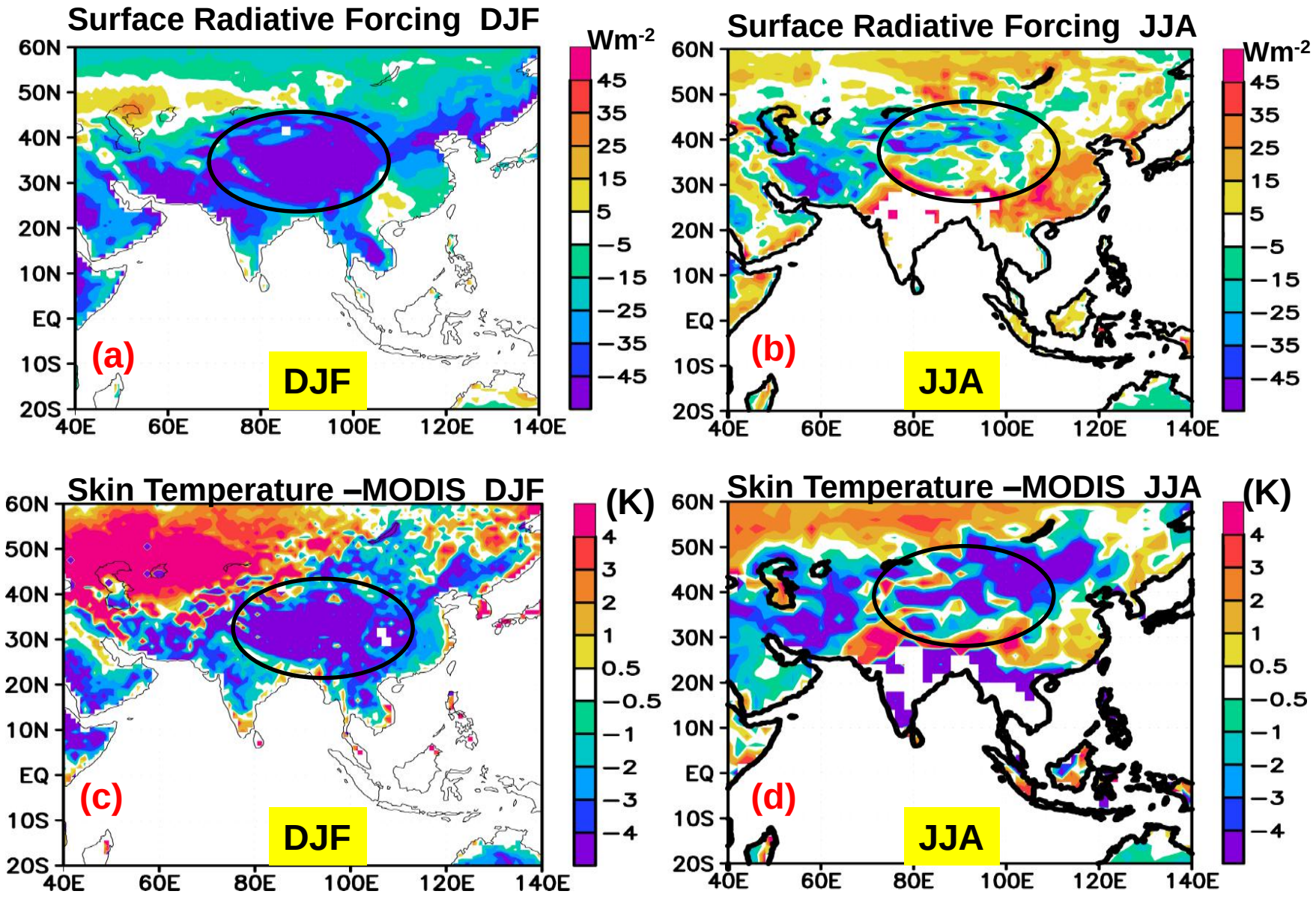
Models in CMIP3 and CMIP5 do not consider falling ice hydrometeor, the zero-th order TIWP bias is resemble to each other between CMIP3 & CMIP5 over High Mountain Asia (HMA).

Bias of Total Cloud fraction in CMIP3/CMIP5 Models

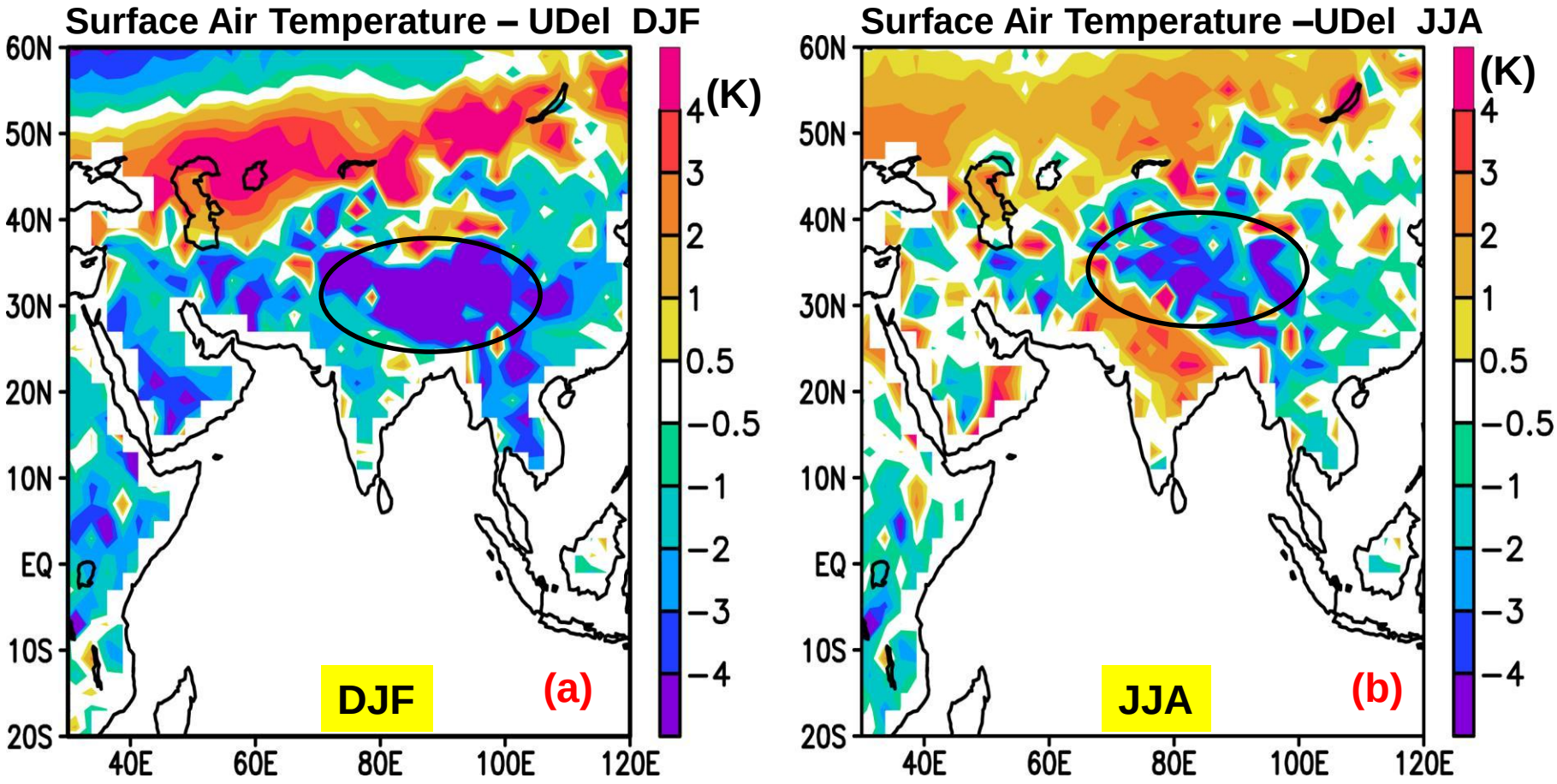


CMIP5 minus total CloudSat-CALIPSO derived Cloud Fraction (all possible dectectd cloud) (new data set)

Bias of Radiation Budgets and LST in CMIP5



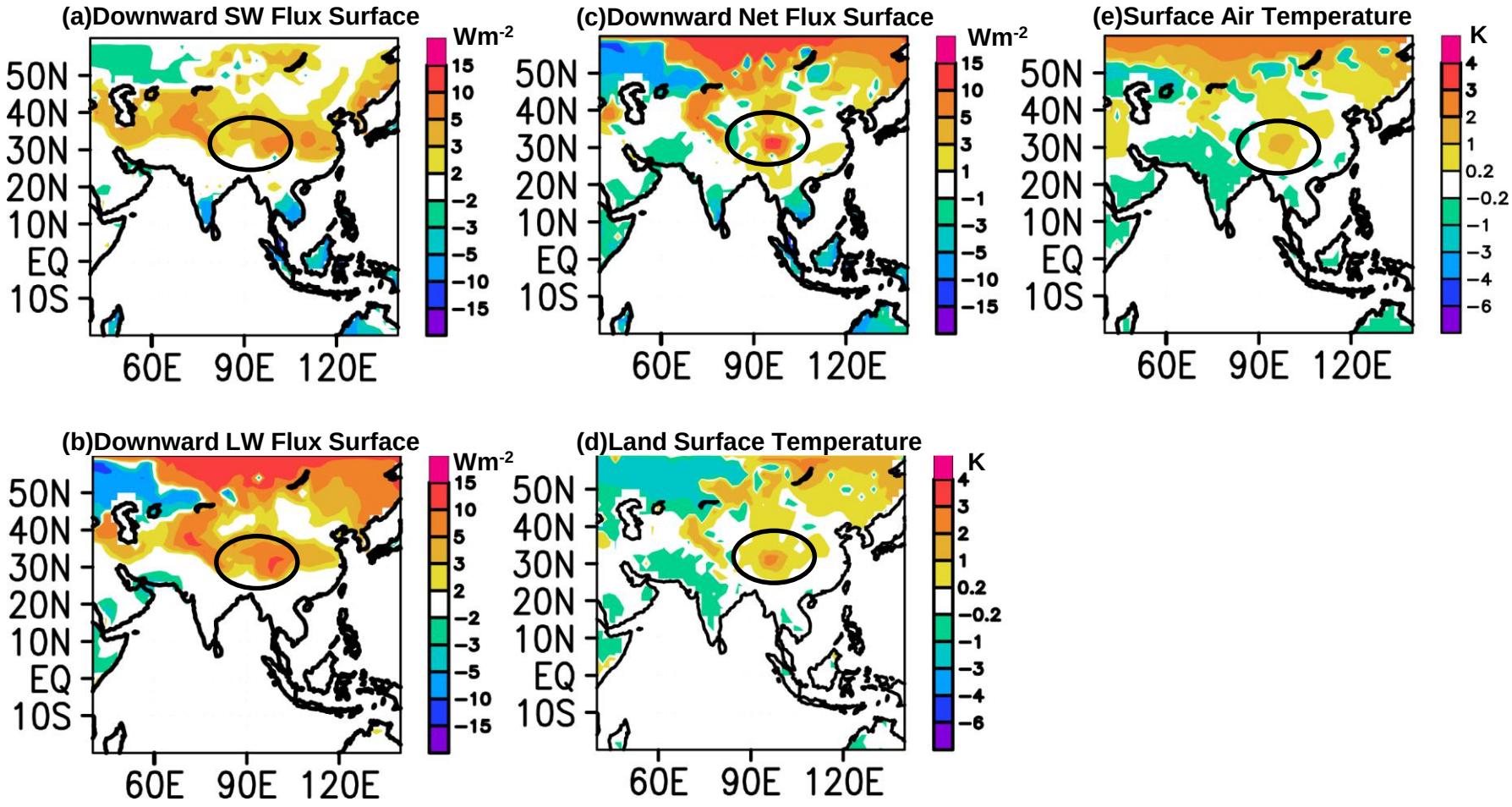
Bias of Surface Air Temperature Against Udel Data in CMIP5



LST & SAT Biases -4 to -8 K

Improvement with the Inclusion of Precipitating Ice Radiative Forcing – Winter over HMA

|SNOW OFF – OBS| minus |SNOW ON – OBS|



Inclusion of precipitating ice radiative effects reduces radiative fluxes up to 10~15 Wm^{-2} And LST/SAT absolute bias up to 2~3 degree against Obs.

Summary

Using CloudSat-CALIPSO total IWP & CF & heating profiles and MODIS, 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 CF & IWP (optically too thin)

In Summer
SW radiative effect
Increase downward SW radiation

In Winter
Clouds LW greenhouse effect
reduce downward LW radiation

Too Warm Land Surface Temperatures or too cold LST over High Mountain (Tibet) due to albedo effect

Too Cold Land Surface Temperatures

The precipitating radiative forcing is critical in reducing biases of the modeled LST & SAT 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, 2016, 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. **120, doi:10.1002/2015JD023776.**