Transferring the knowledge from ARM observations and CRM to improving GCM Simulations of Precipitation Characteristics

Xiaoqing Wu (wuxq@iastate.edu) and Zachary Mangin
Department of Geological and Atmospheric Sciences
Iowa State University (ISU)

1. Introduction

Convection, precipitation and cloud processes are key components of the global water and energy cycle and operate on a wide range of time and space scales. Their representation in general circulation models (GCMs) is crucial for simulating climate mean state and variability. In last decade, understanding of physical processes associated with cloud systems has been gained from ARM observations and cloud-resolving model (CRM) simulations. However, transferring of knowledge to GCMs is a challenging task. Recently, we incorporated five modifications, including the improved convection scheme (closure, trigger and convective momentum transport), the mosaic treatment of subgrid cloud variability and the cloud scheme, into ISUGCM which is based on a version of NCAR GCM. Global impacts of improved convection and cloud representation shown in ten-year (1980-1989) GCM simulations with observed sea surface temperatures (SST) are encouraging. ISUGCM simulations are compared with observations and NCAR CAM5 in this poster.

2. ISU General Circulation Model

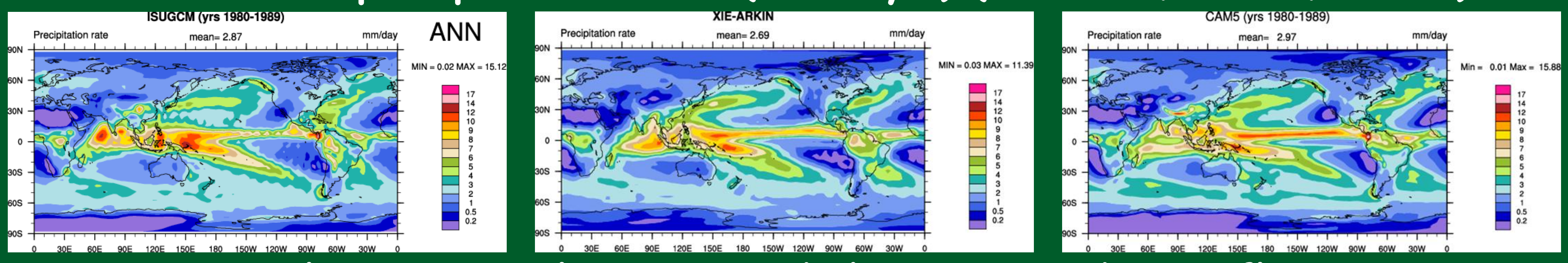
Based on a version of NCAR GCM, but with

1) Modified Zhang-McFarlane deep convection scheme
- Revised convection closure assumption consistent with CRM concept
- CRM-based trigger condition of deep convection
- CRM-validated convective momentum transport

2) Modified cloud and radiation parameterization schemes
- CRM-validated mosaic treatment of subgrid cloud variability
- CRM-derived vertical scaling factor of in-cloud water content

3. Climate mean state

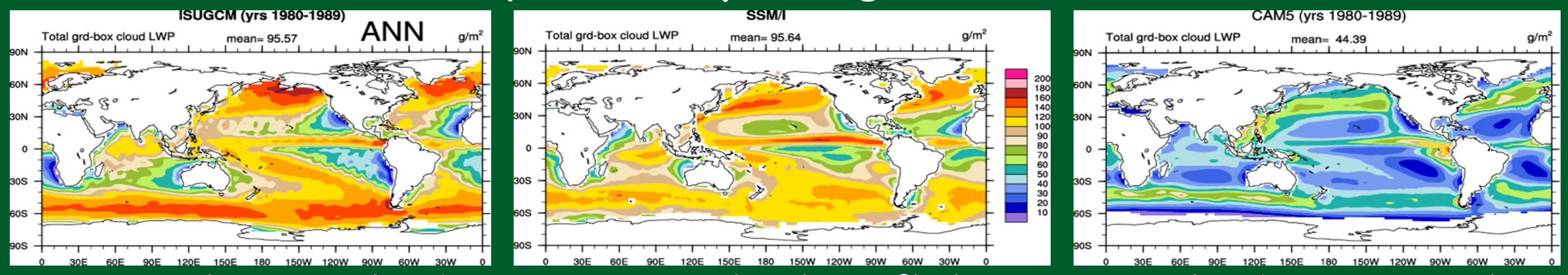
Annual mean precipitation rates (mm day^{-1}) (ISUGCM, CMAP, CAM5)



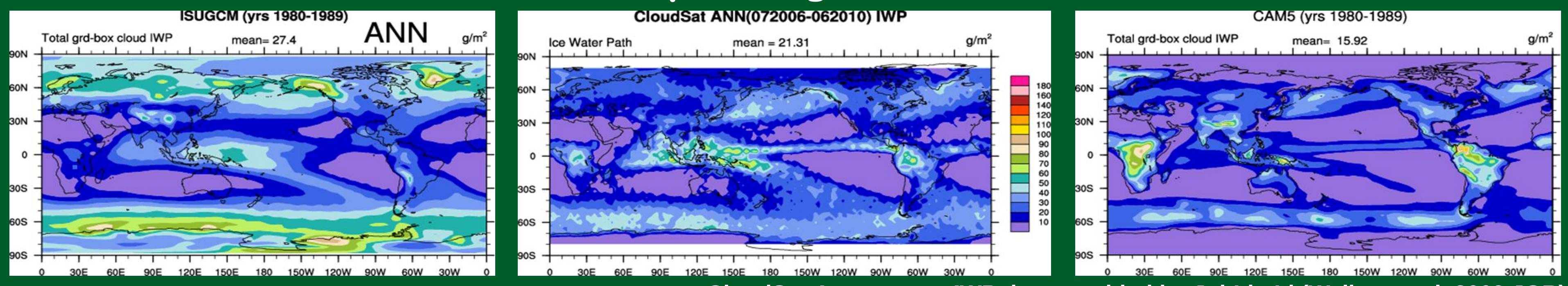
Annual mean TOA longwave and shortwave radiative fluxes

Flux(Wm^{-2})	F_{LW}(TOA)	F_{SW}(TOA)
ISUGCM	233.5	236.4
ERBE	233.9	234.0
CAM5	236.9	239.4

Annual mean cloud liquid water paths (g m^{-2}) (ISUGCM, SSMI, CAM5)

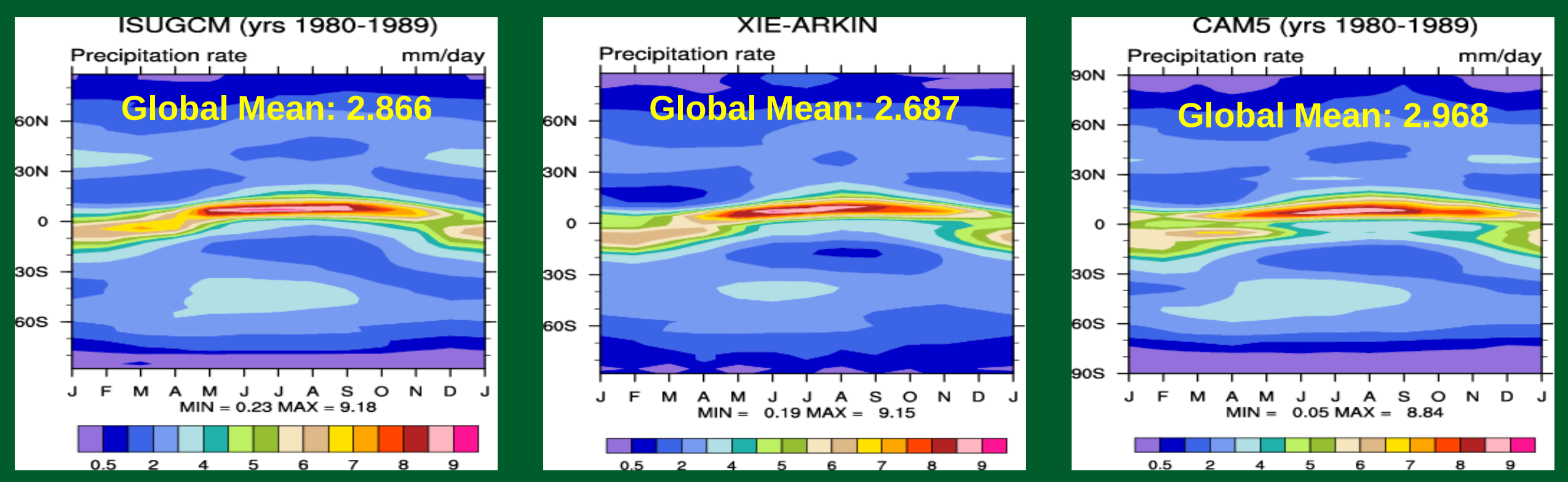


Annual mean cloud ice water paths (g m^{-2}) (ISUGCM, CloudSat, CAM5)



CloudSat 4-year mean IWP data provided by Jui-Lin Li (Waliser et al. 2009 JGR)

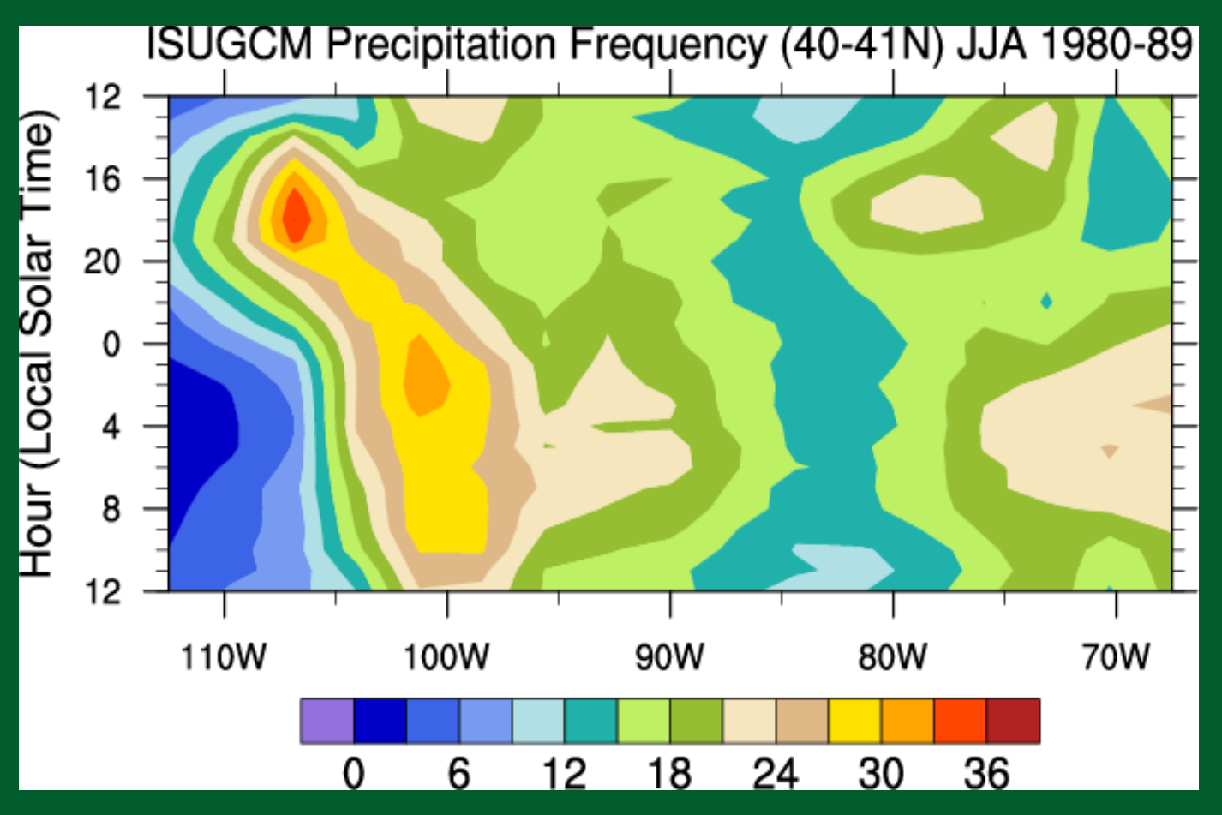
4. Annual cycle

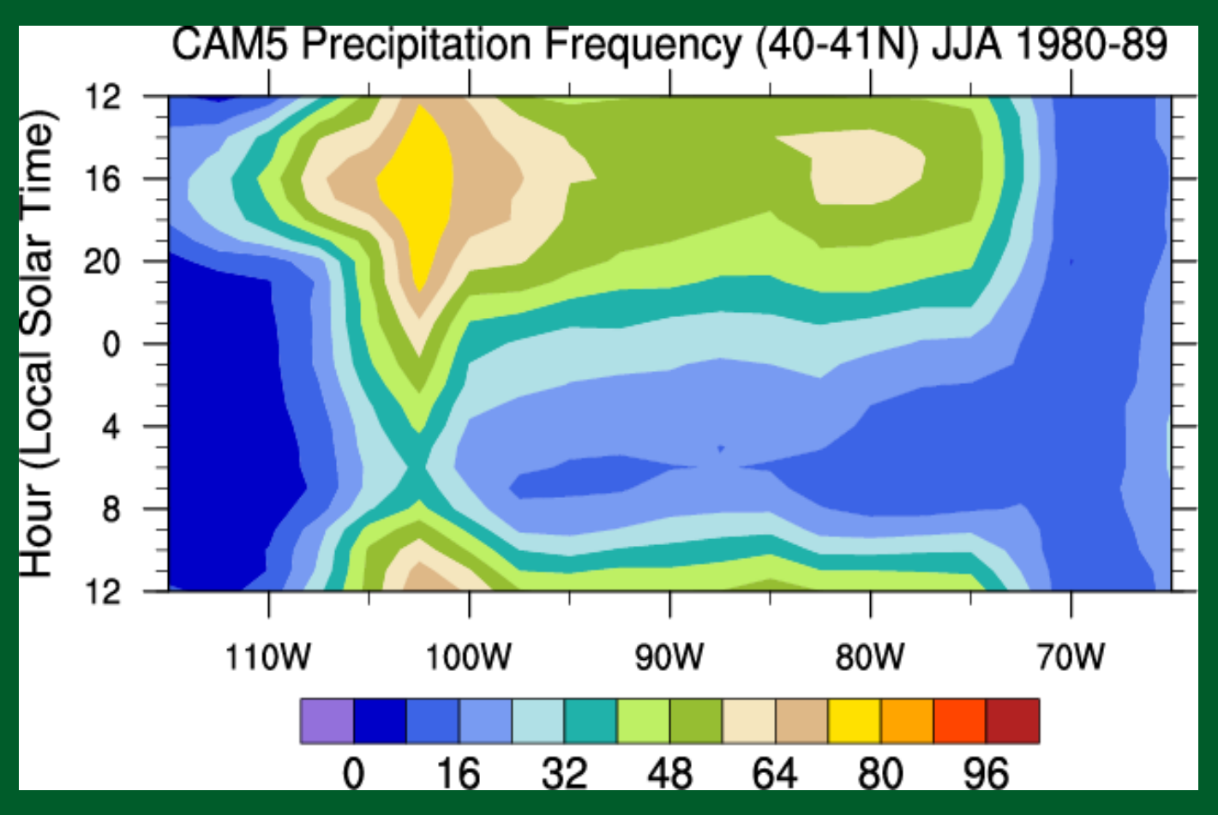


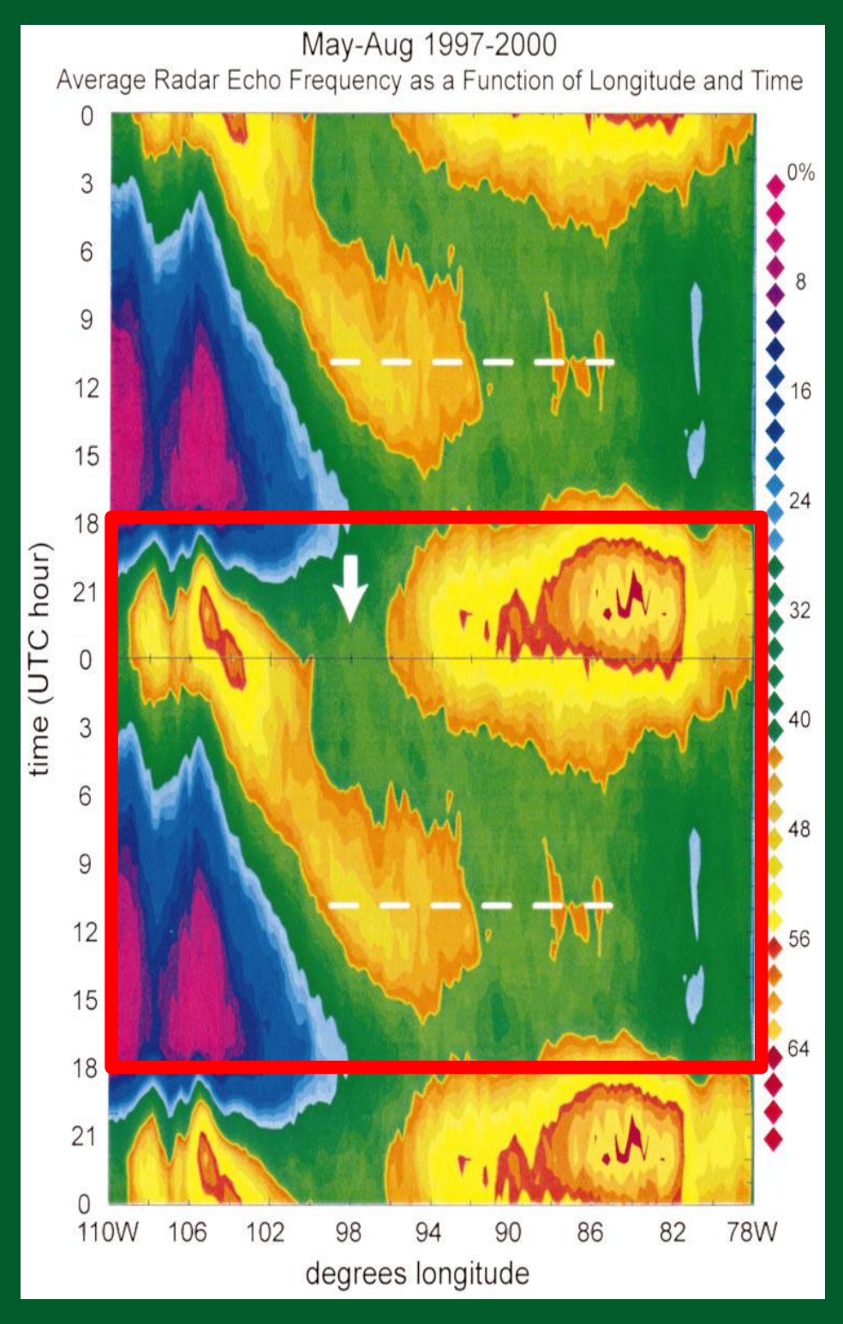
Zonally-averaged global precipitation (mm day^{-1}) (ISUGCM, CMAP, CAM5)

5. Diurnal cycle

Diurnal variation of summer precipitation frequency averaged between (40-41°N) over US (ISUGCM, CAM5, Radar Echo)



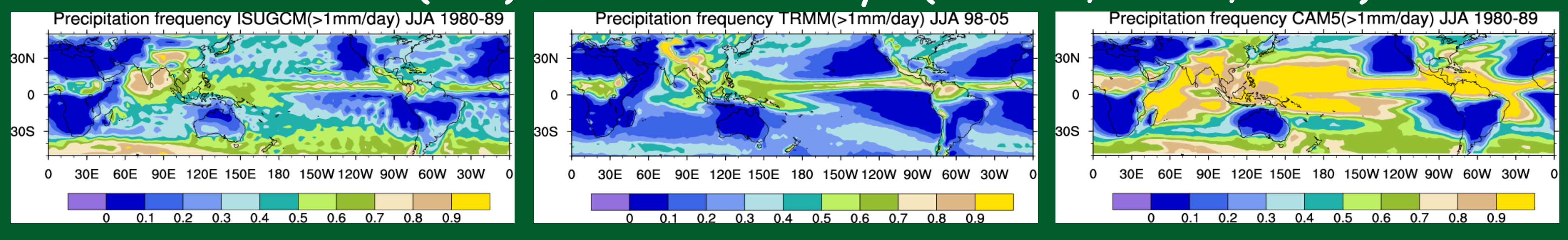




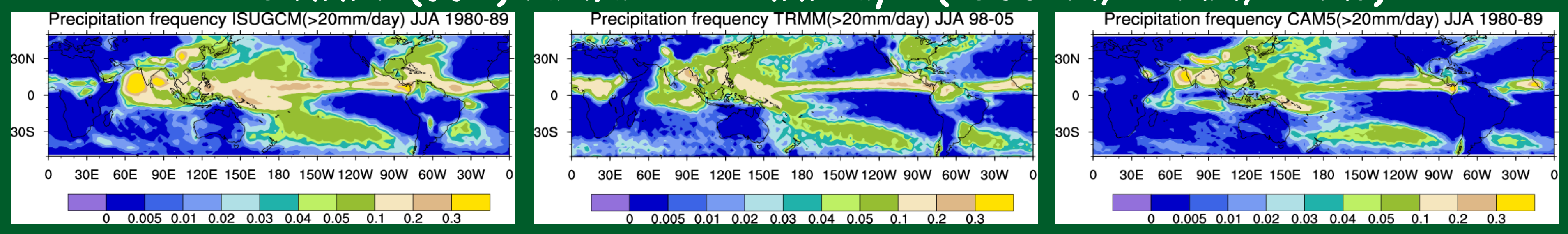
Carbone et al. (2002 JAS)

6. Precipitation frequency

Summer (JJA) rainfall > 1 mm day^{-1} (ISUGCM, TRMM, CAM5)



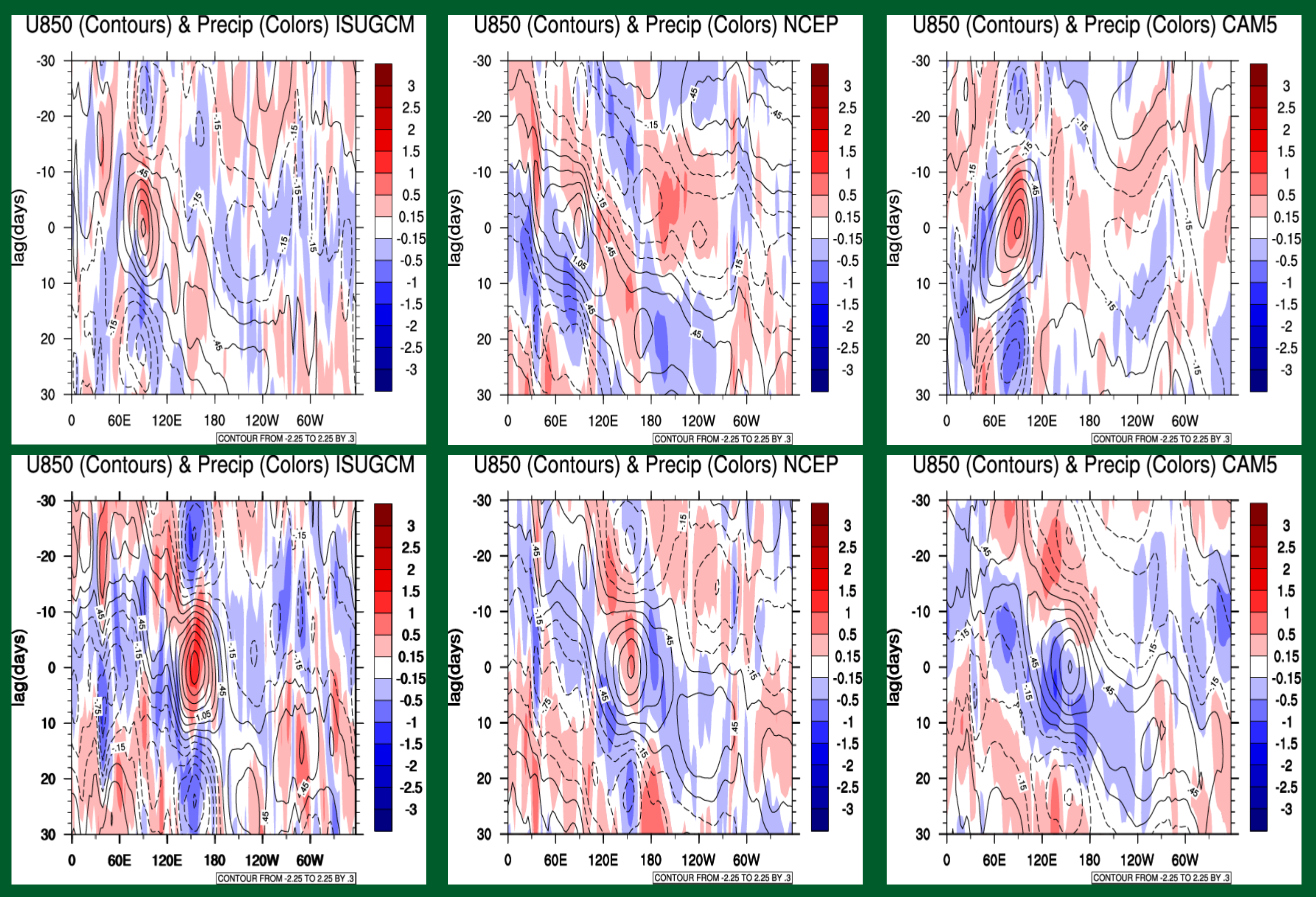
Summer (JJA) rainfall > 20 mm day^{-1} (ISUGCM, TRMM, CAM5)



7. Madden-Julian Oscillation (MJO)

Indian Ocean at 90°E

Western Pacific at 155°E



Ten-years (1980-89 October-April) lag correlations of 30-90-day band-passed daily equatorial (5S-5N averaged) 850-hPa zonal wind (contours) and precipitation (colors) onto the daily equatorial 850-hPa zonal wind time series at 90˚E (top) and 155˚E (bottom) for ISUGCM (left), NCEP (middle) and CAM5 (right).

8. Summary

Ten-year ISUGCM simulations with CRM and ARM observations-based modifications in representing convection and clouds show much improved diurnal cycle and frequency of precipitation, seasonal migration of ITCZ and MJO closer to available observations. The eastward propagation of summer precipitation peak from late afternoon over the Rockies mountain to early morning over the Great Plains are reproduced by the GCM simulations, which are largely affected by the convection closure assumption. Precipitation frequency is closely controlled by the trigger condition of deep convection. ISUGCM rains much less frequently as compared with TRMM and CAM5 over the Indian Ocean, Pacific and Atlantic, but produces more heavy precipitation over the North, Central and South America, Indian Ocean and western Pacific. The inclusion of subgrid cloud variability in the radiation calculation allows the simulated cloud (liquid and ice) water paths and the TOA radiative fluxes agreeing with the observations simultaneously. Moist convection is tied to the large-scale advection, occurs less frequent but more vigorous, and redistributes the momentum, which lead to improved MJO simulations.

Acknowledgement: This research is supported by the U.S. DOE ASR program under grant DE-FG02-08ER64559.