Evaluation of SCM Precipitation

Hua Song[1], Wuyin Lin[1], Yanluan Lin[2], Leo Donner[2], Audrey Wolf[3], Anthony Del Genio[4], Roel Neggers[5], and Yangang Liu[1]

1. ASD/BNL 2. NOAA/GFDL 3. CU 4. NASA GISS 5. KNMI

Data and Models

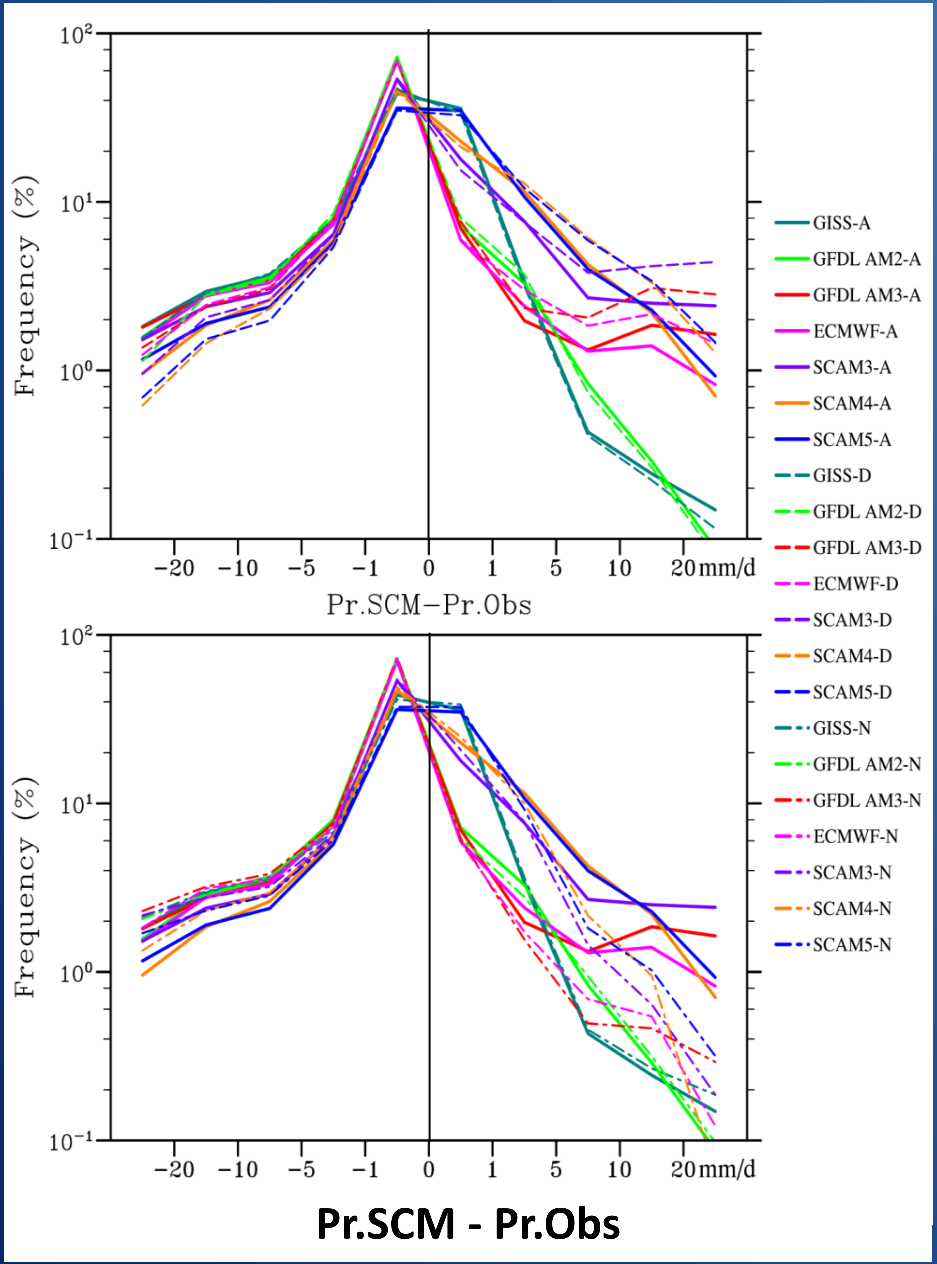
- 3-year hourly data (Jan1999-Dec2001) from observation and 7 SCMs
- Observation: the hourly ABRFC gridded (4km x 4km) rain gauge adjusted WSR-88D radar measurements over the domain (Xie et al. 2004)
- 7 SCMs: NCAR CAMs, GFDL AMs, GISS ModelE and ECMWF IFS
- SCMs are forced with the same continuous large-scale forcing data plus the relaxation term ($\tau_a = 3hrs$).

$$\frac{\partial \bar{T}}{\partial t} = \underbrace{-\vec{\bar{v}} \cdot \nabla \bar{T} - \bar{\omega}\frac{\partial \bar{T}}{\partial p} + \frac{\bar{\omega}}{c_p}\alpha}_{} + P_T + \underbrace{\frac{\bar{T}_{obs} - \bar{T}}{\tau_a}}_{}$$

$$\frac{\partial \bar{q}}{\partial t} = \underbrace{-\vec{\bar{v}} \cdot \nabla \bar{q} - \bar{\omega}\frac{\partial \bar{q}}{\partial p}}_{\text{Large-scale forcing}} + P_q + \underbrace{\frac{\bar{q}_{obs} - \bar{q}}{\tau_a}}_{\text{Relaxation}}$$

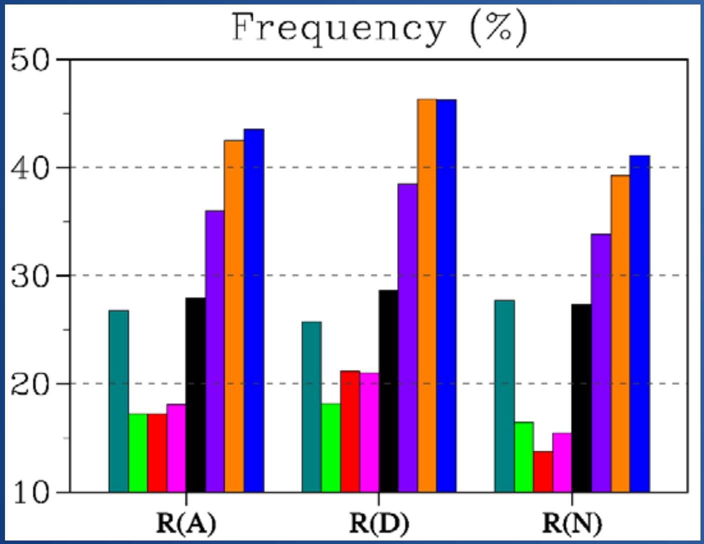
Large-scale forcing **Relaxation**

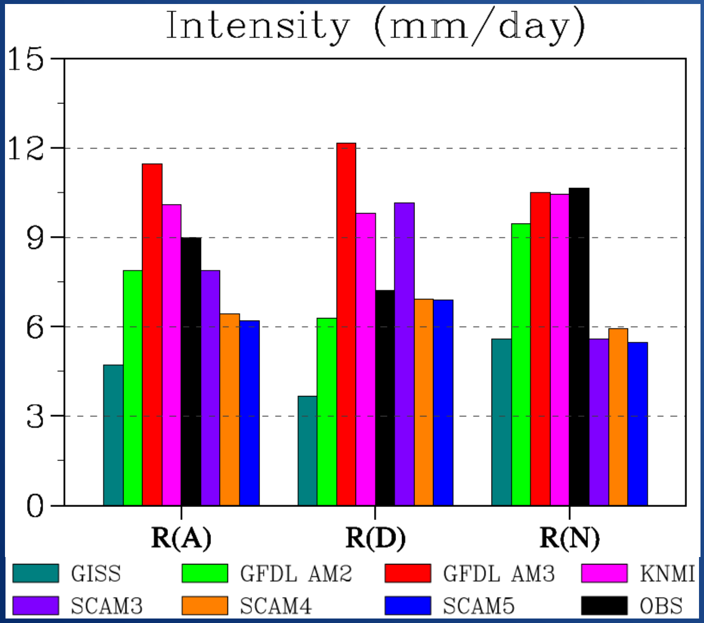
Frequency of model-observation differences in precipitation

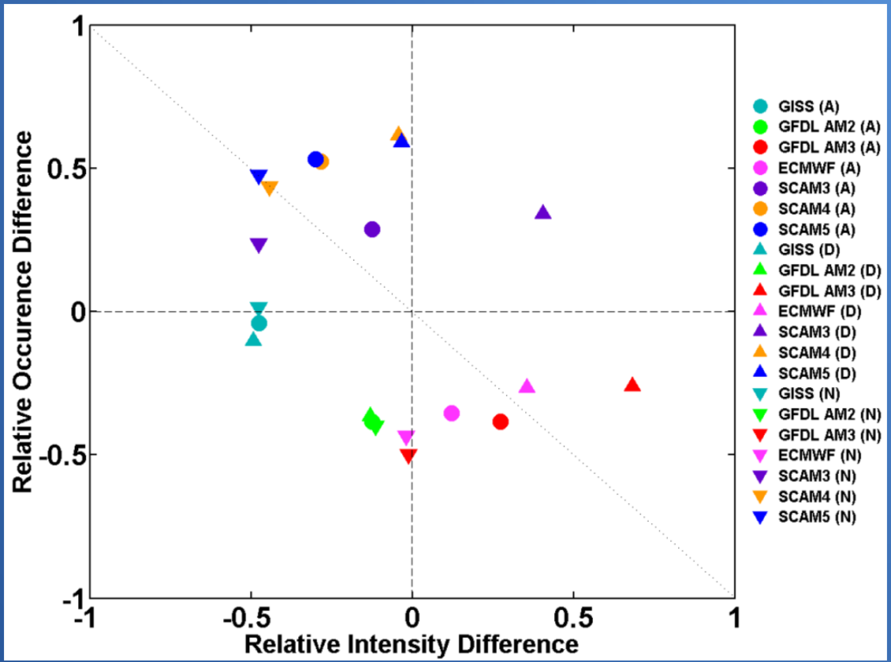


- Frequency of model-observation difference peaks at small values (<1mm/d).
- SCMs underestimate the observed surface precipitation more frequently than they overestimate.
- Fewer underestimation and more overestimation events in SCMs (except GISS and GFDL AM2) in daytime than in nighttime
- Much fewer overestimation events in GISS and GFDL AM2 SCMs

Frequency and mean intensity of rain events (Pr>0.1mm/day)

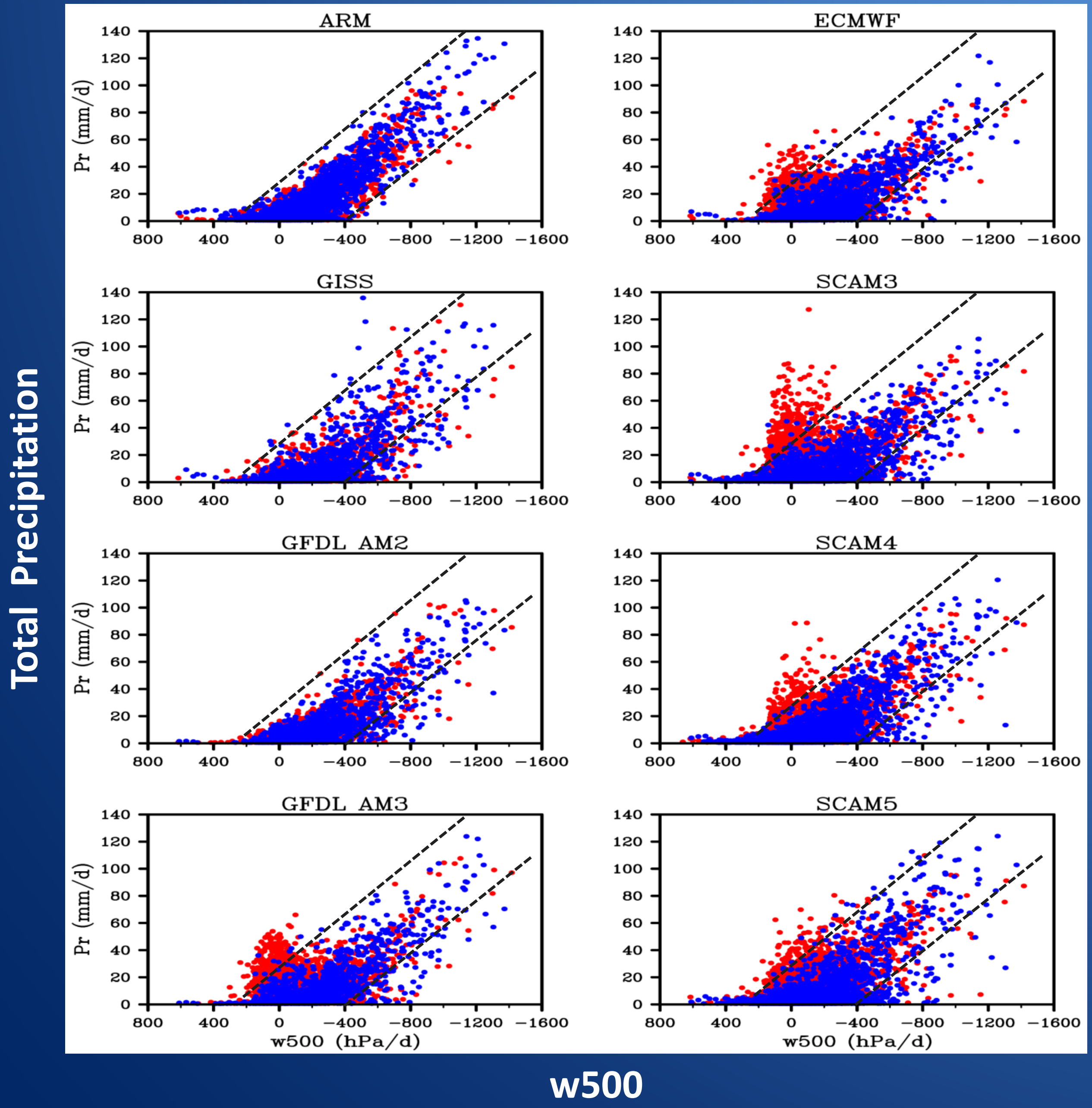


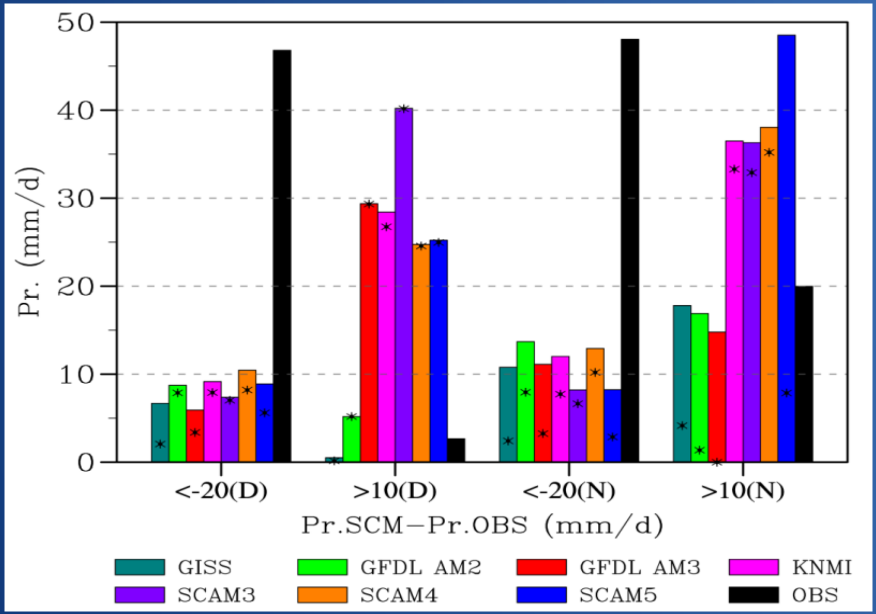


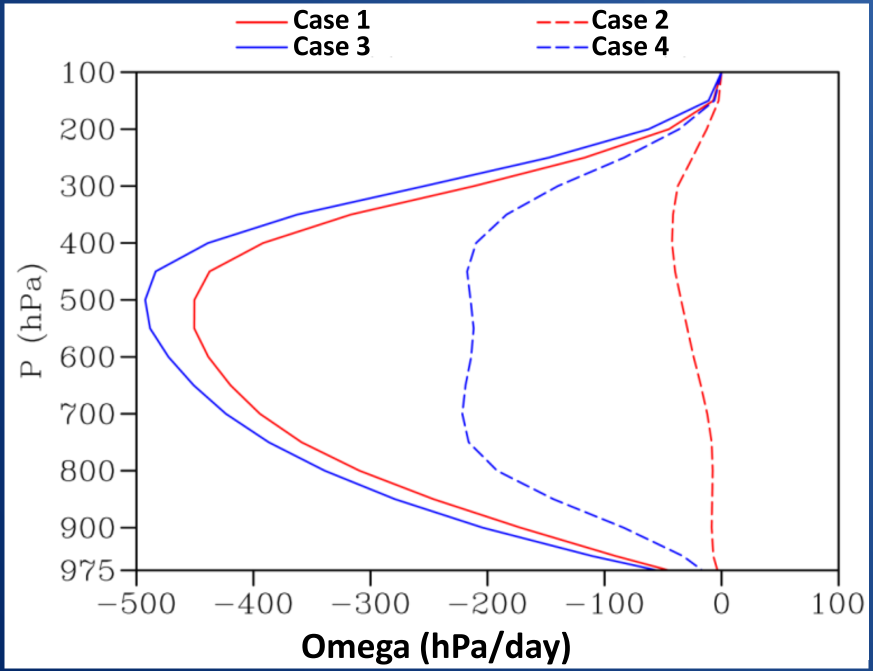


- Higher (lower) frequency of rain events in all SCAMs (GISS, GFDL AMs and ECMWF) than in observation.
- Mean intensity of rain events are much larger in daytime than in nighttime in GFDL AM3 and SCAMs.
- SCM-observation differences in frequency and mean intensity of rain events tend to compensate each other for most SCMs.

Scatter-plot of 500hPa omega and total precipitation







Four Cases:

Case 1: dPr<-20mm/day for all SCMs (Day)

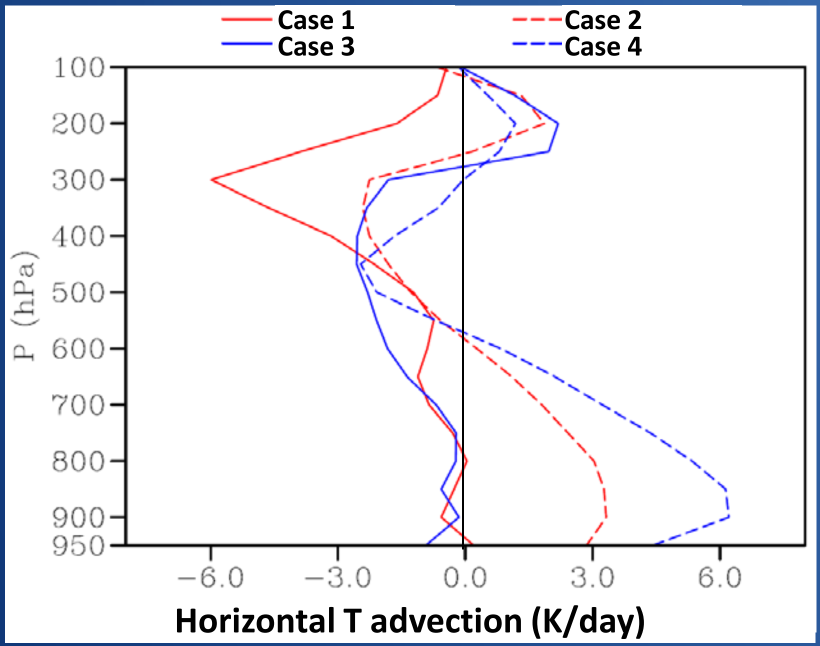
Case 2: dPr> 10mm/day for 5 SCMs (Day)

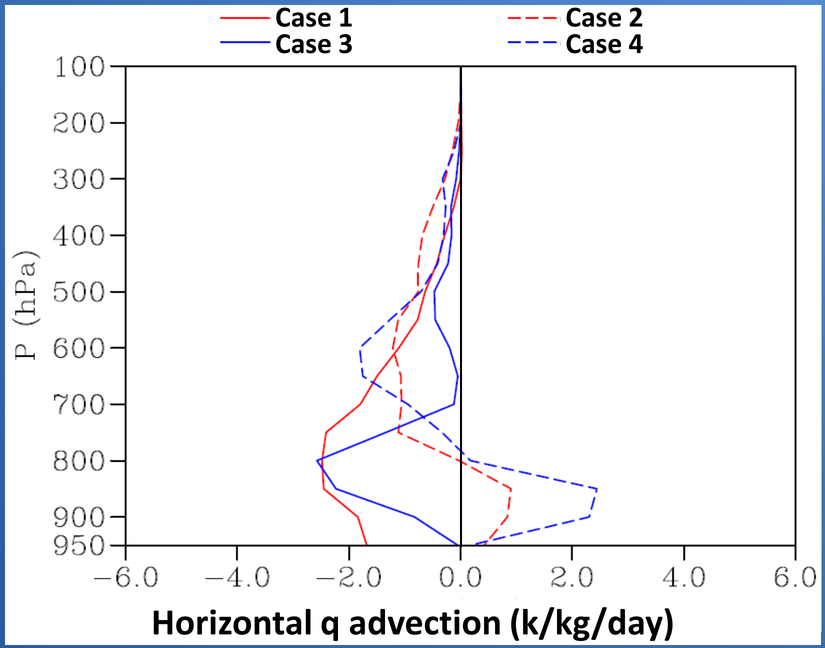
Case 3: dPr<-20mm/day for all SCMs (Night)

Case 4: dPr> 10mm/day for 4 SCMs (Night)

- Model underestimation cases occur in the strong ascending regimes.
- Model overestimation case (5 SCMs) in daytime occurs in the weak vertical motion condition with convective precipitation dominated.
- Model overestimation case (4 SCMs) in nighttime occurs in the moderate ascending regimes.

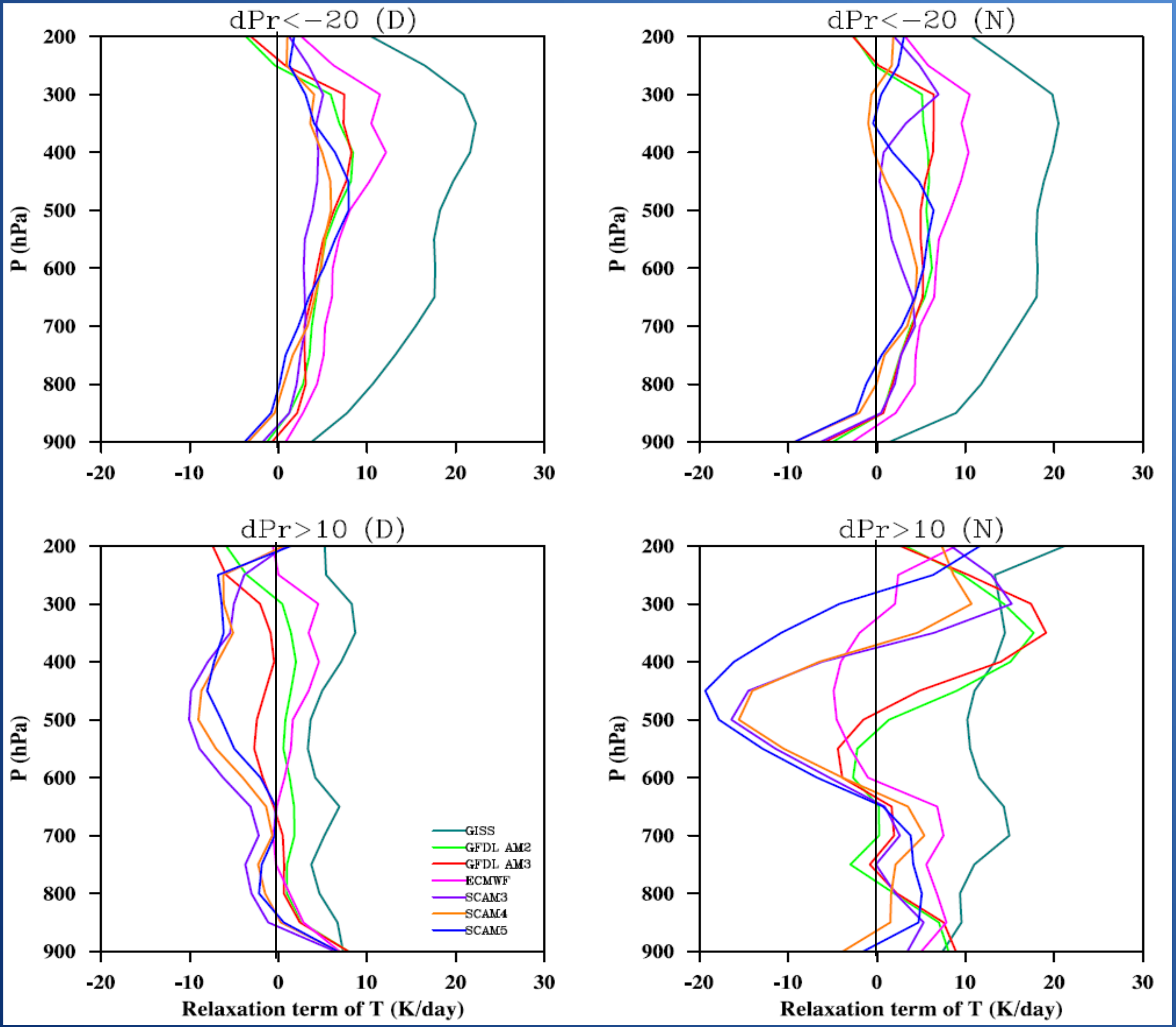
Large-scale horizontal advection terms of T and q



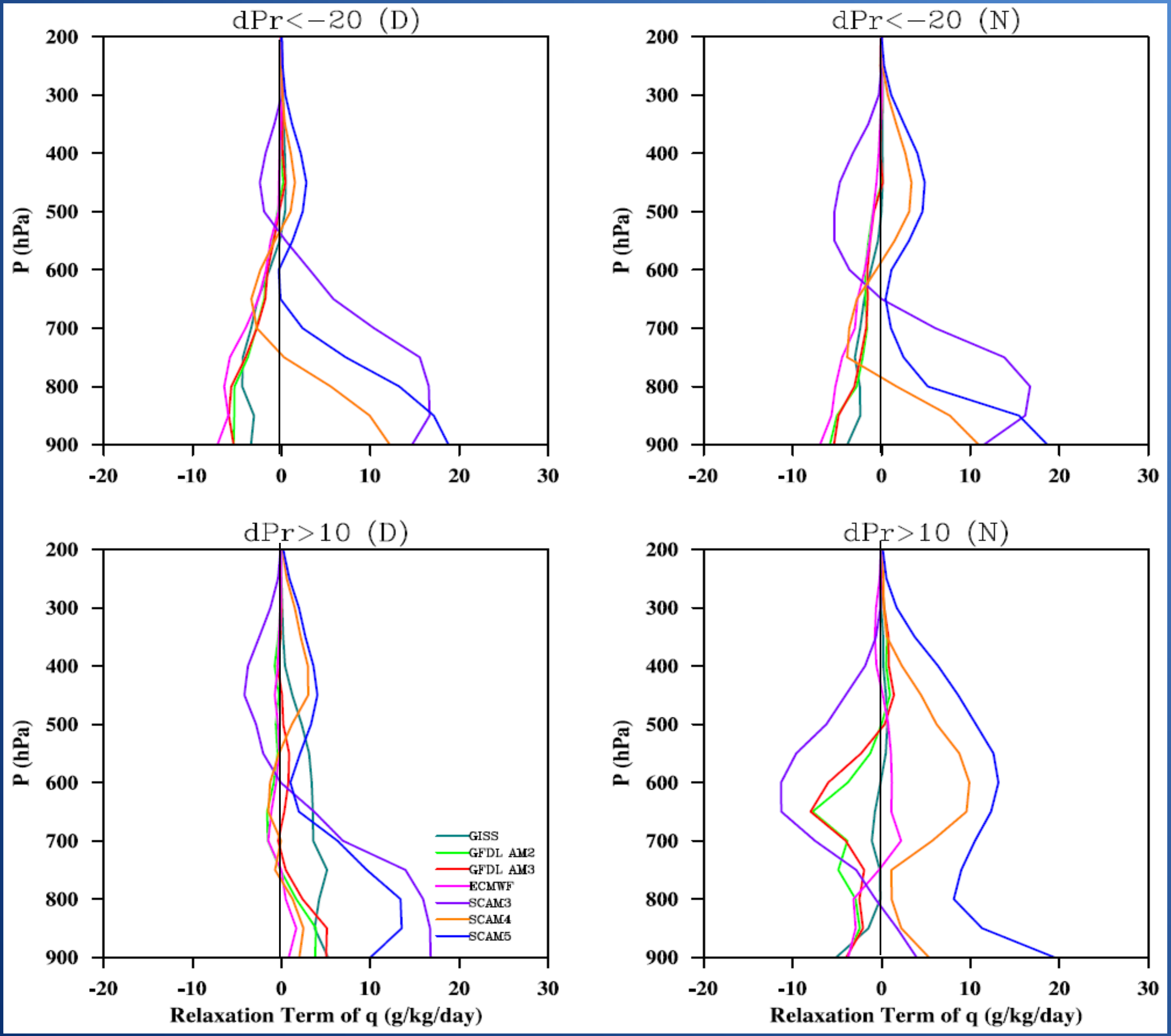


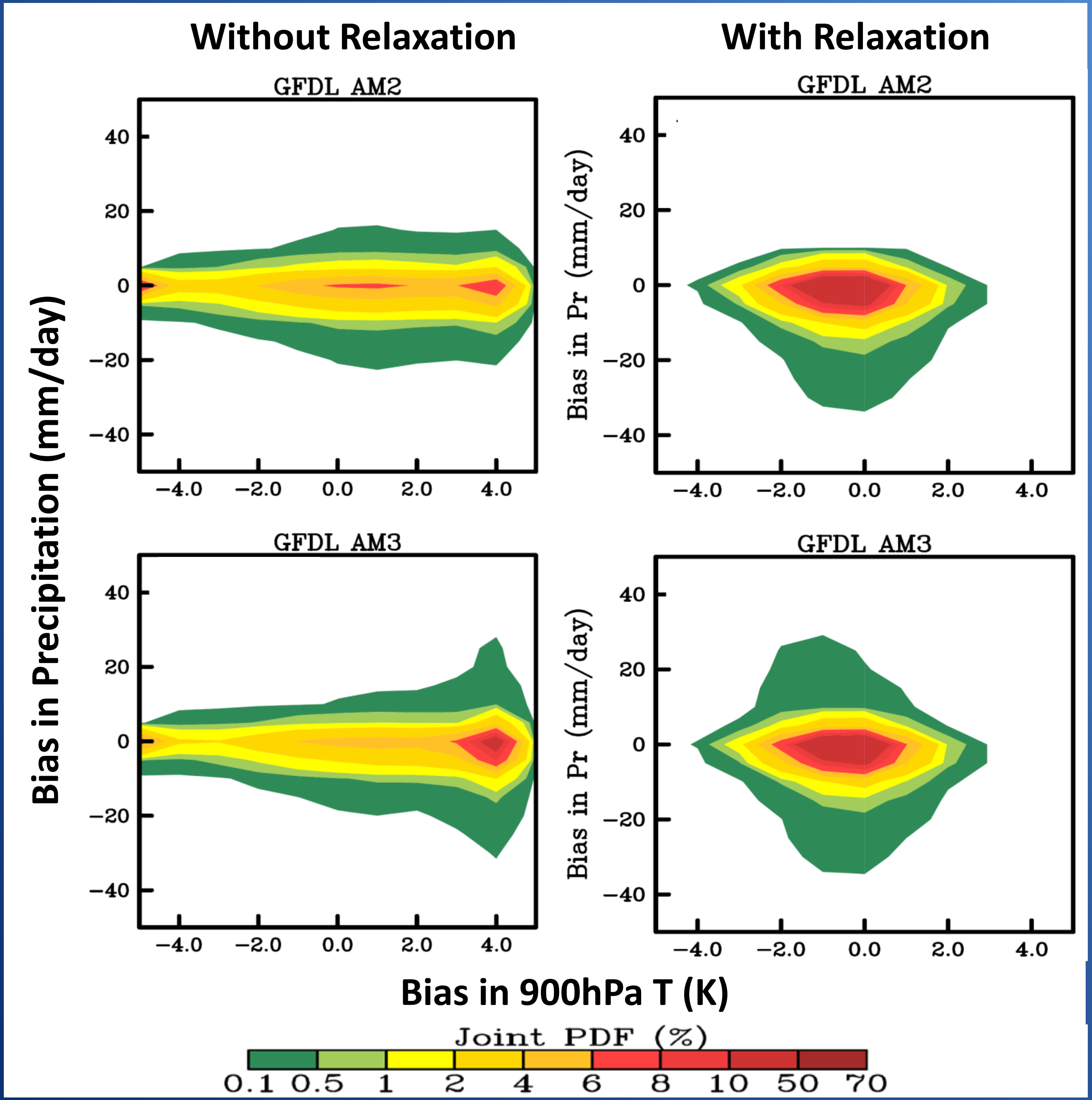
- Model underestimation cases: Weak negative large-scale horizontal T advection and low-level moisture divergence.
- Model overestimation cases: Strong low-level horizontal heating and moisture convergence, mid-level horizontal cooling and moisture divergence.

Relaxation term of T



Relaxation term of q

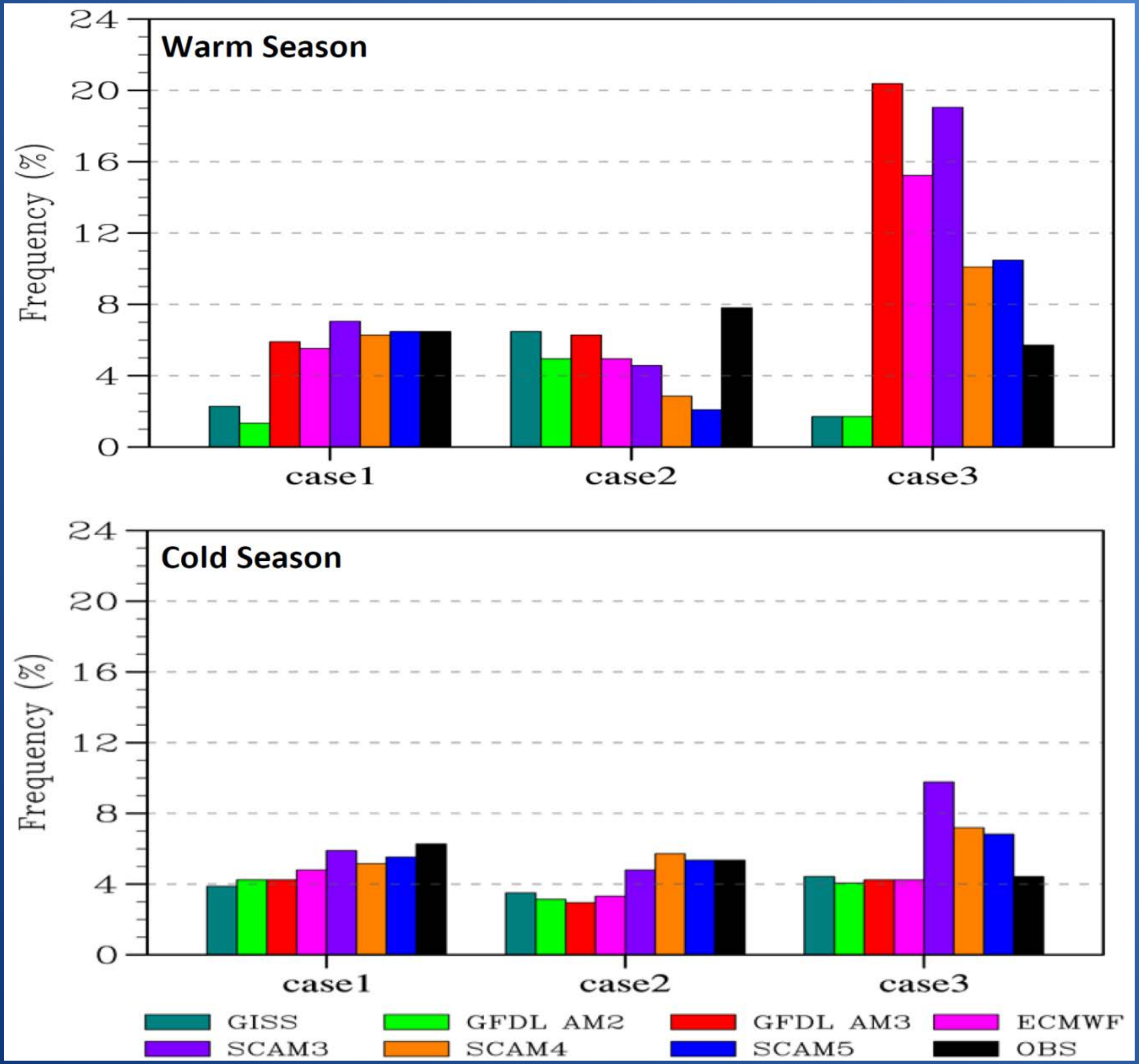



Without Relaxation
With Relaxation
GFDL AM2
GFDL AM2
GFDL AM3
GFDL AM3
Bias in Precipitation (mm/day)
Bias in Pr (mm/day)
Bias in 900hPa T (K)
Joint PDF (%)
0.1 0.5 1 2 4 6 8 10 50 70

Summary

- SCMs underestimate the observed precipitation amounts more often than they overestimate, with peak frequency in |dPr|<1mm/day.
- There are fewer (more) underestimation (overestimation) events in daytime than in nighttime in most SCMs.
- SCM-observation differences in frequency and mean intensity of rain events tend to compensate each other for most SCMs.
- Most SCMs have a precipitation peak in weak vertical motion regimes mainly in daytime, different from observation.
- Model underestimation cases occur in strong upward motion regimes with weak horizontal thermal advection and negative moisture advection.
- Model overestimation cases (for certain SCMs) occur in weak vertical motion regimes with low-level (mid-level) horizontal heating (cooling) and moisture convergence (divergence).
- Relaxation terms tend to stabilize (destabilize) the atmosphere for model underestimation (overestimation) cases in most SCMs.

Diurnal Cycle



Case 1: Pr (N)>10mm/day, Pr (D)>10mm/day, in the same day
Case 2: Pr (N)>10mm/day, Pr (D)<10mm/day, in the same day
Case 3: Pr (N)<10mm/day, Pr (D)>10mm/day, in the same day

Table 1. Summary of Participating SCMs and Main Related Parameterizations

Model	Convection Scheme	Microphysical Scheme	Resolution
GFDL AM2	Relaxed AS scheme Moorthi and Suarez 1992	One-moment Rotstayn 1997	L24, 30mn
GFDL AM3	Cumulus conv. scheme Donner et al. 2001	One-moment Rotstayn 1997	L24, 30mn
GISS ModelE v2	Bulk mass flux scheme Yao and Del Genio 1995	One-moment Del Geino et al. 1996	L40, 30mn
ECMWF IFS	Bulk mass flux scheme Tiedtke 1989	One-moment Tiedtke 1993	L91, 5mn
NCAR CAM3	Simplified AS scheme Zhang and McFarlane 1995	One-moment Rasch and Kristjansson 1998	L26, 20mn
NCAR CAM4	Simplified AS scheme Modified ZM, Neale et al. 2008	One-moment Rasch and Kristjansson 1998	L26, 20mn
NCAR CAM5	Simplified AS scheme Modified ZM, Neale et al. 2008	Two-moment Morrison and Gettelman 2008	L30, 20mn