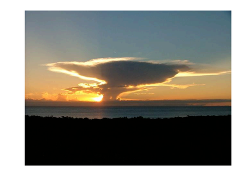
MJO Structure in an AMIP-style Simulation Using the CSU Superparameterized CAM



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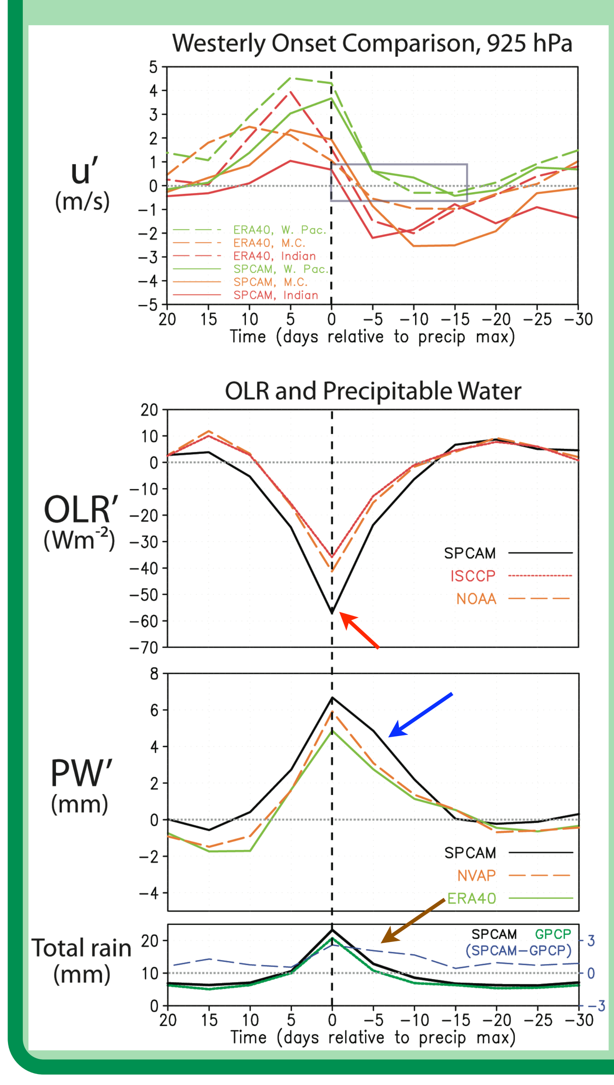
1. Background

Intraseasonal (20-90 days) atmospheric variability is poorly simulated in many conventional **GCM**s. It has been demonstrated (Khairoutdinov et al., 2008 **JC**) that the **CSU MMF**-GCM more accurately depicts tropical intraseasonal variability compared to the **NCAR CAM**. The MMF is a model set-up in which conventional cloud parameterizations are replaced by a string of small-domain cloud-resolving models (**CRM**; often called "super-parameterization") that are embedded within each GCM grid column to more explicitly depict clouds and their effects. A 19-year **AMIP**-style simulation was conducted using the CSU MMF and observed monthly SSTs. From this dataset, we select and composite **MJO**-like disturbances based on rainfall. The MJO composite results are compared to a host of observation-based datasets, including **GPCP** rainfall, **NVAP** precipitable water, **ISCCP** and **NOAA OLR**, and many **ERA40** fields.

2. Timeseries Composites of the MJO

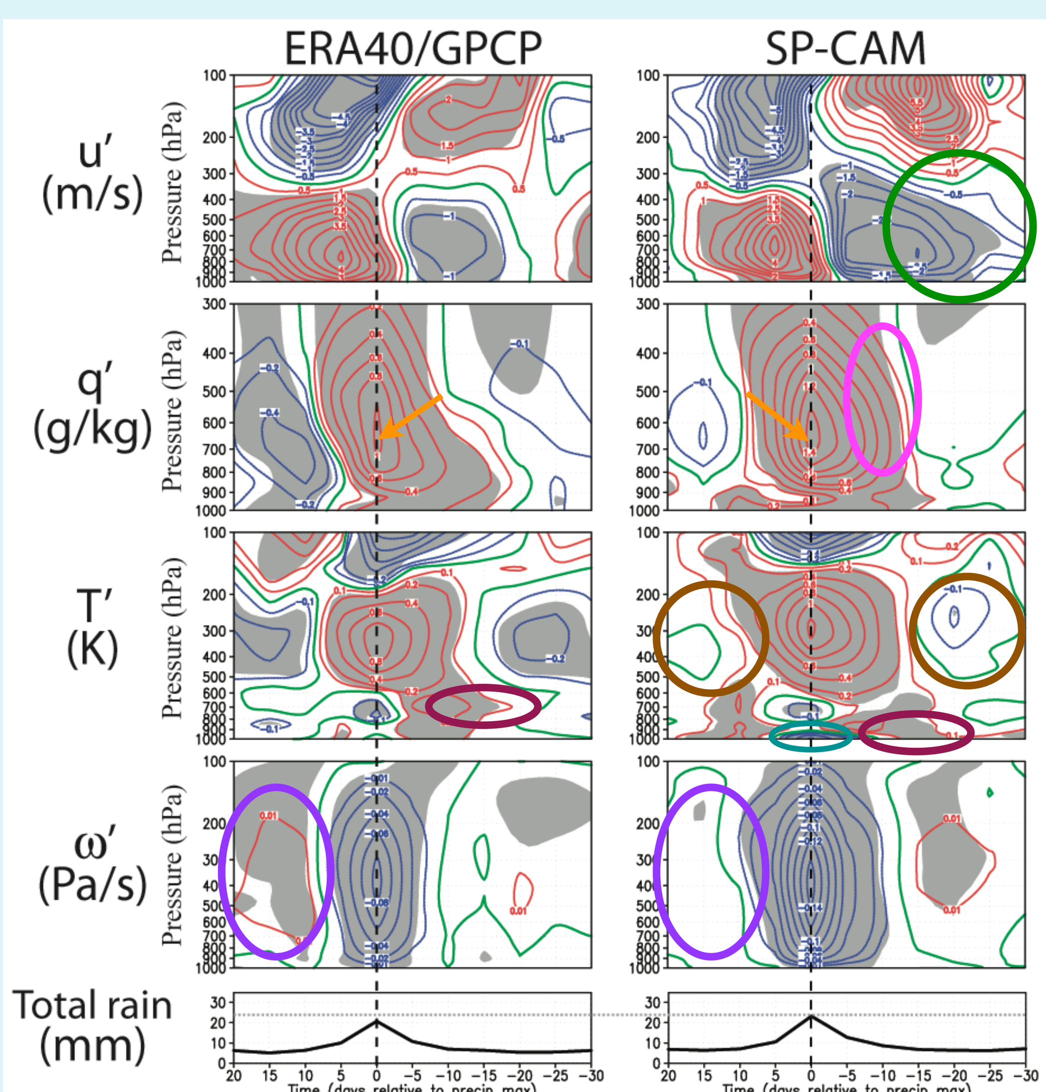


- **Geographical differences in westerly wind onset**: The pool of 50 MJO events was subsetted based on where max rainfall occurred (Indian Ocean, Maritime Continent, West Pacific). As indicated within the gray box, the **SPCAM** accurately depicts the tendency for *earlier* westerly onset relative to heaviest rainfall as MJO-related convection moves from the Indian to Pacific Ocean.

- **OLR and Precipitable Water anomalies**: Compared to ISCCP and NOAA satellite products, the SPCAM has a strong tendency to overestimate OLR magnitude during the MJO lifecycle (35% on Day 0 when rainfall is most intense). Integrated column moisture is also overdone by SPCAM, particularly in the week preceding heaviest rainfall. Not surprisingly, the SPCAM also has a higher amount of accumulated rainfall 1-2 weeks leading up to peak rainfall.

3. Time-height Composites of the MJO

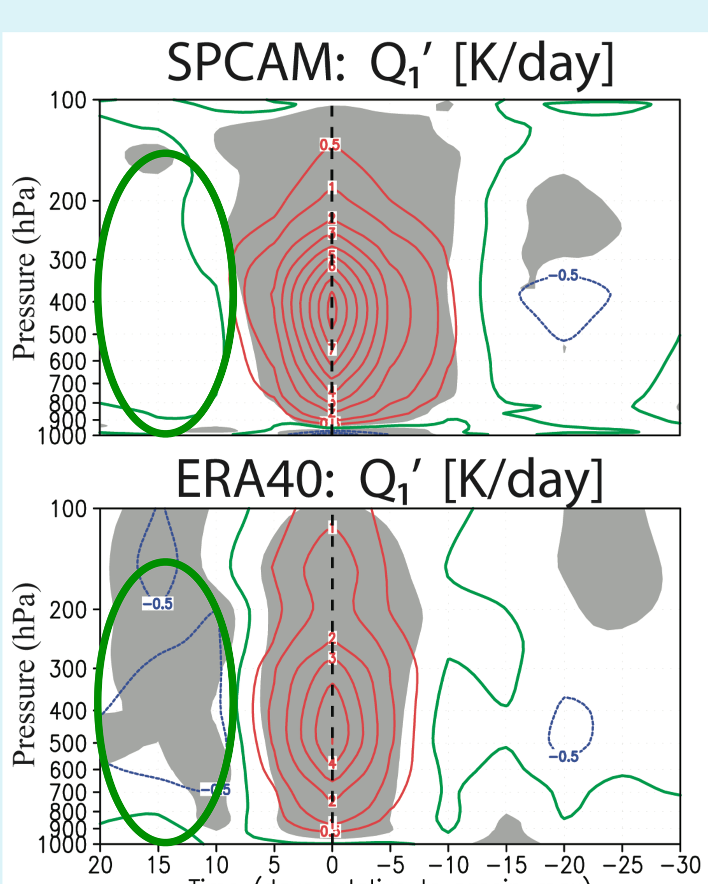
50 MJO events were selected in the 19 yrs of SPCAM output, and 46 events were found in observational data between 1984-2001 (18 yrs). At right, contours (blue < 0, green = 0, red > 0) are departures from calendar-day means, and gray shading is 90% significant.



- **Zonal wind**: Basic baroclinic structure well simulated, although easterly anomalies prior to heaviest MJO-related rainfall are too strong and extensive (this is true for events across all longitudes).

- **Water vapor**: SPCAM moisture deepens too rapidly—to the upper troposphere—10-15 days prior to max rain. Peak vapor anomalies on Day 0 are ~40% larger for SPCAM, and insufficient dryness noted both before and (particularly) after heaviest rainfall.

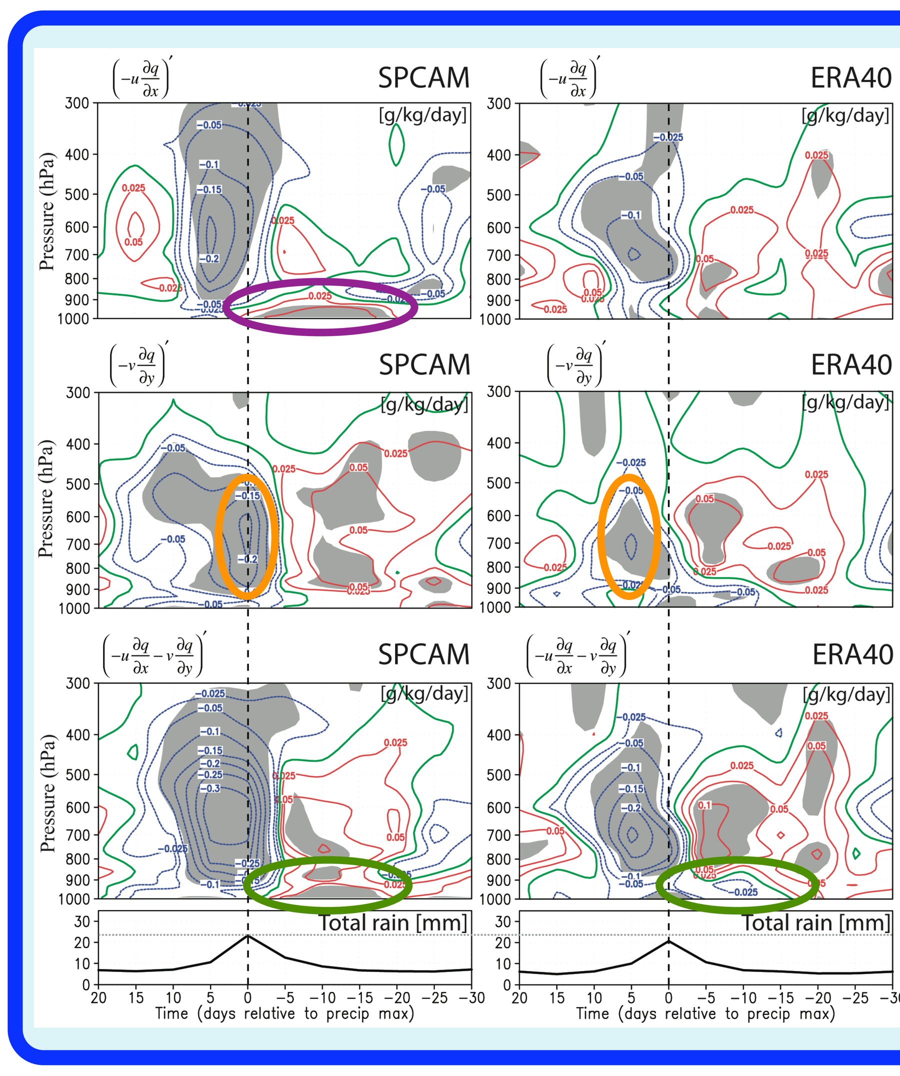
- **Temperature**: Insufficient mid-troposphere cooling before and after deep convection in SPCAM, too-warm mid-troposphere during max rain. SPCAM warms first near surface, ERA40 at 700 hPa; stronger SPCAM cold pool, possibly due to higher vertical resolution.



- **Vertical motion**: Subsidence, particularly after deepest convection, too weak in model; max rising motion in model stronger than ERA40.

- **Rainfall**: Compared to GPCP-based observations, SPCAM overestimates rain by about 20% on Day 0.

- **Convective heating**: Weak evidence of tilted heating structure in SPCAM, although values during max rain are too strong compared to reanalysis. Insufficient cooling (presumably radiative, see Sec. 2) following deep convective heating.



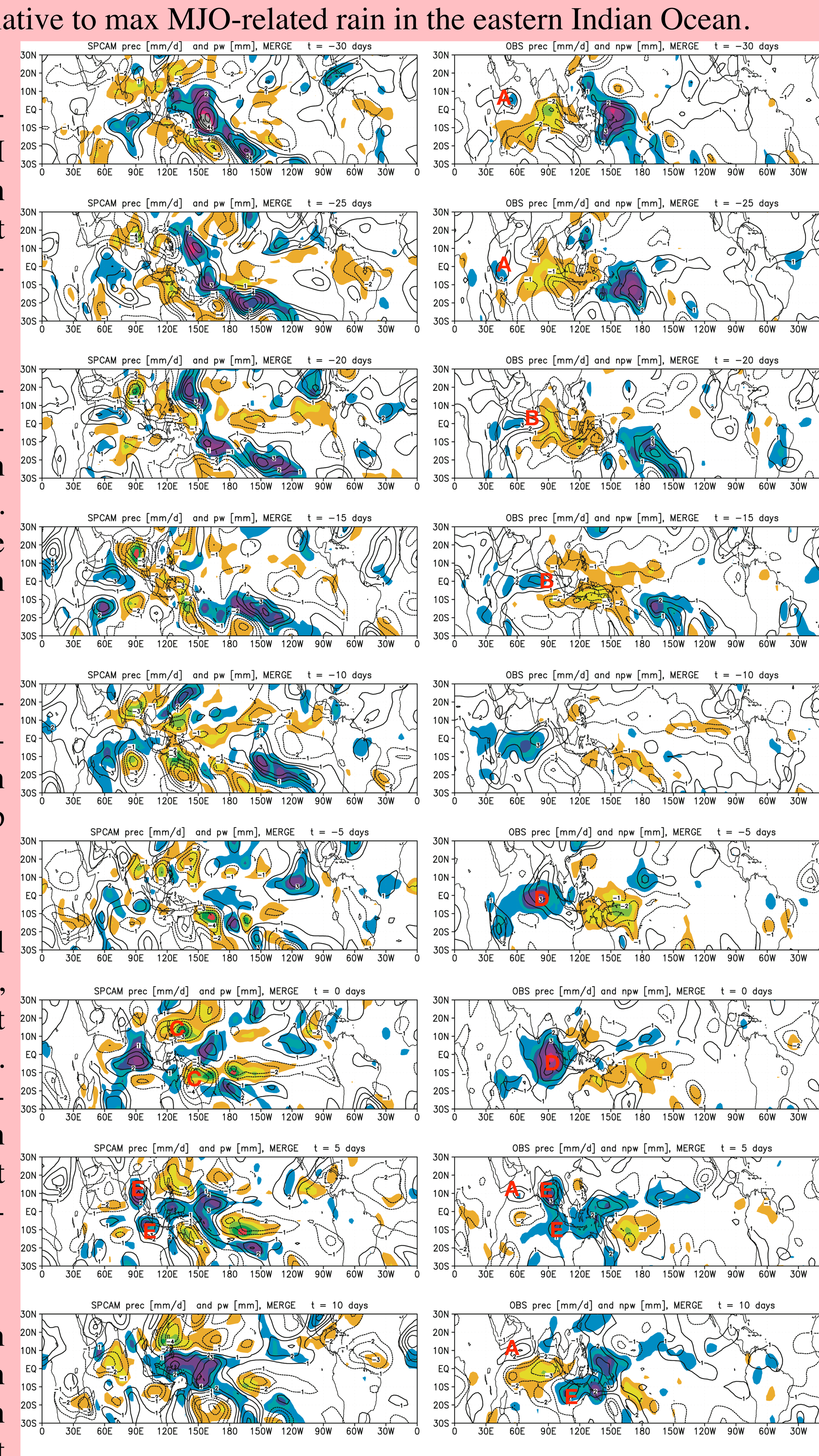
- **Zonal moisture advection**: Maximum advective drying occurs 5 days following deepest convection in model and reanalysis. Notable feature is statistically-significant boundary layer moistening in SPCAM in the 3 weeks leading up to max rainfall.

- **Meridional moisture advection**: Similar structure, although drying earlier in model.

- **Horizontal moisture advection**: Overall, SPCAM replicates advective moisture tendencies. Most notable difference is shallow moistening up to 15 days prior to MJO-related deep convection.

4. Spatial Composites of the MJO

To investigate the spatial character of MJO events as they propagate eastward, a single composite event was created. Below, rain and precipitable water for the SPCAM composite (12 events) are compared to observations (19 events, GPCP rain and NVAP precipitable water). Lag day is time (in pentads) relative to max MJO-related rain in the eastern Indian Ocean.



Above, MJO composite based on SPCAM (observations) appears in the left (right) column. Time increases downwards. Shading is rainfall anomalies, contours are precipitable water anomalies.

Days -30 to -25: Deep convection in West Pacific, SPCAM much too moist in Indian Ocean. In observations, moist area (A) seen along east African equatorial coast.

Days -20 to -15: As MJO-related rain dissipates in central Pacific, new convection develops in central Indian. Along Equator, eastward nose of high moisture (B) leads rain in nature but not in SPCAM.

Day -10: Above normal moisture in model *lags* rain anomalies in Indian Ocean, *leads* in nature, although overall precip structure qualitatively similar.

Days -5 to 0: Off-equatorial drying in West Pacific (C), disorganized rain development Indian on Day -5 for SPCAM. Max rain in east Indian involves north-south elongation of precip area (D). Moist anomalies lead deep convection in West Pacific.

Days +5 to +10: East Indian convection splits north-south along Equator (E) as main rain area shifts to Pacific. Moist area (A) appears to be shed from East Indian convection and migrates westward (see Days -30 and -25). This feature is not clearly seen in SPCAM.

Discussion and Summary: Overall, several aspects of MJO-related rainfall and moisture patterns are well simulated by the SPCAM, including the eastward progression and timing of deep convection, the north-south split of heavy rainfall as it exits the east Indian Ocean, and the migration of rainfall along the **SPCZ**. Relationships between moisture and rainfall involving the MJO are not simulated as well. In observations, there is clear evidence that increased moisture precedes the arrival of heavier rain, although this could be a result of fewer MJO events in the model composite. We are currently investigating the moist westward return flow (A) and its possible role in reinitiating convection in the west-central Indian Ocean as part of the next MJO convective event.

LIST OF ACRONYMS

AMIP — Atmospheric Model Intercomparison Project
CAM — Community Atmosphere Model
CRM — cloud resolving model
CSU — Colorado State University
ECMWF — European Centre for Medium Range Weather Forecasts
ERA40 — ECMWF 40-year Reanalysis
GCM — general circulation (or climate) model
GPCP — Global Precipitation Climatology Project
ISCCP — International Satellite Cloud Climatology Project
JC — *Journal of Climate*
MJO — Madden-Julian Oscillation
MMF — Multi-scale Modeling Framework
NCAR — National Center for Atmospheric Research
NOAA — National Oceanic and Atmospheric Administration
NVAP — NASA Water Vapor Project
OLR — outgoing longwave radiation
SPCAM — Superparameterized Community Atmosphere Model
SPCZ — South Pacific Convergence Zone
SST — sea surface temperature