Convective process diagnostics in relation to parameter sensitivity in CESM

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Coordinate:

1. Global change hydrologic cycle parameter sensitivity
   CESM1 historical & RCP 8.5 runs, 30 min output
2. Convective transition statistics parameter sensitivity
3. Precip event size (accumulation) distribution:
   reasonably robust to parameters

Global warming: rare large events above historical cutoff increase dramatically in probability

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1. CESM1 Precip change under RCP8.5 global warming scenario (standard param values)


Runs & analysis: D. Bernstein; CESM1.0.5, Branch run methodology
Stippled for T-test at 5% level; 1 of 15 ensemble members; CAM5.1.1 at 1.9° x 2.5°, POP ~1°)
1. CESM1 param. sensitivity of RCP8.5 prec. change

i.e. difference in JJA Prec. Anom. 2071-2090 – 1976-1995 for values of deep convective adjustment time across case 240 min minus case 30 min

(Zhang-McFarlane-Neale-Richter convection scheme)
1. CESM1 param. sensitivity of RCP8.5 prec. change

i.e. difference in JJA Prec. Anom. 2071-2090 – 1976-1995 for values of entrainment across case at 2 km\(^{-1}\) minus case 0

PRECET rcp8.5(2071-2090)-hist(1976-1995) cesm1.0.5, >5% stipple

Bernstein & Neelin in prep
Stippled for T-test at 5% level
1. CESM1 param. sensitivity of RCP8.5 prec. change


entrainment for narrowed range: case at 1.5km$^{-1}$ minus case 0.5

PRECT rcp8.5(2071-2090)-hist(1976-1995) cesm1.0.5, >5% stipple

Bernstein & Neelin in prep

Stippled for T-test at 5% level

Entrainment parameter dmpdz
How is strong sensitivity of RCP8.5 precipitation change $\Delta P^{**}$ distributed in params $\mu$? Identify “dangerous ranges*”. CESM1 $\Delta P (\mu)$ projected on spatial pattern of $\Delta P$ diffc across range

*very sensitive, nonlinear range

- e.g. of 2 parameters with large sensitivity
- 1 has highly sensitive “dangerous range”
- suggests target for uncertainty reduction if can exclude

**2081-2100 relative to 1986-2005

Bernstein & Neelin, in prep
2. Transition to strong convection: Background.
CAM*, 0.5° compared to observations (TMI**) (Sahany et al. 2014, *J Clim.*)

Model onset of deep convection comp. to obs. within uncertainty

Sahany et al. (2014, *J Clim.*)

Details on μwave onset stats cf. Neelin et al. 2009; caution re high prec rate retrieval;


*Community Atmos. Model 3.5; **TRMM Microwave Imager
Background 2: statistics for observed precipitation

Precip. onset/termination dependence on column water vapor*;
Occurrence probability for precipitating points
Event size distribution at Nauru (DOE ARM optical gauge)
(*normalized $w/w_c$ for 4 $T$ values est. from TMI, ERA-40)

Background for 3. Precip. event size distribution

- Nauru Atmospheric Radiation Measurement Program site optical gauge measurements

*Community Atmospheric Model 5 (FV, 1.9°x2.5°) Jan 1979-Dec 1982 (obs. SST) W. Pac. (15S-15N, 150-180E)

- good approx. to obs power law range (slope -1.3); large-event cutoff sensitive
- event size = integral of precip, i.e., accumulation (over event of P>0.4 mm/hr)

Nauru obs. vs. CAM5

ARM obs. Neelin et al. 2008; CAM analysis S. Sahany

see also Peters, Deluca, Corral, Neelin and Holloway, 2010, J. Stat. Mech. for all ARM sites
2. Deep Convective Transition stats: Manaus observed*

**Frequency of Occurrence:** all/precip’g pts

**Fraction precipitating times:** prec/fit

**Precip binned by CWV:** prec/fit

*15 min. gauge Precip, Column Water Vapor (CWV) from radiometer at GoAmazon DOE ARM Site. Analysis: K. Schiro, Y.-H. Kuo*
Convective transition: CESM1* standard params.

Frequency of Occurrence: all/prec/conv.

Fraction precipitating times: prec/conv./fit

Precip binned by CWV: prec/conv./fit

Instantaneous Precip, Column Water Vapor (CWV)
At Manaus. (3 grid points). Analysis: Y.-H. Kuo
Fit is with simple stochastic ansatz \( (w-w_c+\xi)^+ \) where \( w= \text{CWV} \) & is \( \xi \) Gaussian

*Community Earth System Model 2°; 1975-2005 historical radiative forcing; standard parameter values
2. **Convective transition:** CESM1* high entrainment

- **Frequency of Occurrence:** all/prec/conv.
- **Fraction precipitating times:** prec/conv./fit
- **Precip binned by CWV:** prec/conv./fit

*Community Earth System Model 2°; 1975-2005 historical radiative forcing; dmpdz = 2

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Instantaneous Precip, Column Water Vapor (CWV) At Manaus. Analysis: Y-H Kuo
Convective transition: CESM1* a bit lower entrainment

Frequency of Occurrence: all/prec/conv.

Fraction precipitating times: prec/conv./fit

Precip binned by CWV: prec/conv./fit

Instantaneous Precip, Column Water Vapor (CWV)
At Manaus. Analysis: Y-H Kuo

*Community Earth System Model 2°; 1975-2005 historical radiative forcing; dmpdz = 0.5
2. Convective transition: CESM1* zero entrainment

Frequency of Occurrence: all/prec/conv.

Fraction precipitating times: prec/conv./fit

Precip binned by CWV: prec/conv./fit

Instantaneous Precip, Column Water Vapor (CWV) At Manaus. Analysis: Y-H Kuo

*Community Earth System Model 2°; 1975-2005 historical radiative forcing; dmpdz = 0
Instantaneous Precip, Column Water Vapor (CWV) At Manaus. Analysis: Y-H Kuo

*Community Earth System Model 2°; 1975-2005 historical radiative forcing; dmpdz = 0
Convective transition: CESM1 deep conv. timescale = 240m

Frequency of Occurrence: all/prec/conv.

Fraction precipitating times: prec/conv./fit

Precip binned by CWV: prec/conv./fit

Instantaneous Precip, Column Water Vapor (CWV) At Manaus. Analysis: Y-H Kuo

*Community Earth System Model 2°; 1975-2005 historical radiative forcing; dmpdz = 0
Reasonably robust to parameter changes: here entrainment & deep convective timescale

As long as has distinct transition to deep convection

zero entrainment (not shown) again differs strongly

Analysis: B. Langenbrunner
**Precip. event size** distribution – theory & CESM1

- First passage problem curves (top 3, smooth)
  \[ p_s(s) \sim C \exp\left(-\frac{s}{s_L}\right) s^{-\tau} \]

- Community Earth System Model 1 1976-2005; ensemble of 15

- good approx. to obs power law range (slope \(\sim -1.3\)); probability drops slowly until reach:

- large-event cutoff \(s_L\)

*event size=integrated precip over event \(P>0.4\) mm/hr

Neelin, Sahany, Stechmann and Bernstein, in prep.; simpler 1st passage pb Stechmann & Neelin 2014
• Historical 1976-2005
• + end-of-century (EoC) from 15 CESM1 RCP8.5 runs 2071-2100
• large-event cutoff $s_L$ indeed increases
• Modest increase in $s_L$ ⇒ large probability increase above cutoff

*event size=integrated precip over event $P>0.4$ mm/hr

Neelin, Sahany, Stechmann and Bernstein, in prep.
Ratio of the probability of a given event size under global warming RCP8.5 to the probability under current climate

Ratio useful for visualizing changes in the largest events relative to historic PDF, incr. roughly exponentially with event size

Essential physics is simple rescaling of distribution with cutoff

Bootstrap percentile

25\textsuperscript{th} – 75\textsuperscript{th}

5\textsuperscript{th} – 95\textsuperscript{th}

Bootstrap test 1000 replications from 15x30yrs in 2071-2100 & hist.
Summary

1. Global change hydrologic cycle parameter sensitivity
   - high sensitivity to convective parameters across feasible range—reduced if can exclude part of range

2. Convective transition diagnostics at fast timescale
   - clearly exclude most sensitive range for entrainment; likely to bring constraints for other parameters

3. Precip event size (accumulation) distribution:
   - reasonably robust to parameters
   - simple stochastic prototype explains form & predicts changes under global warming
   - confirmed in ensemble of 15 CESM runs: rare large events above historical cutoff increase dramatically in probability