Precipitation issues in CMIP5 global warming and ENSO teleconnection simulations

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- Basics: quick view of climatological precipitation simulation, inter-model agreement on precipitation change, multi-model ensemble mean
- global/tropics as context for North American region
- ENSO teleconnections as test for precip processes
- agreement on sign despite issues on spatial pattern
- North American West Coast: Precip increases in CA?
- [Not today: changes in deep convection onset statistics]

**Observed (CMAP) and CMIP5 coupled models**

4 mm/day precip. contour

**Coupled simulation climatology** (20th century run, 1979-2005)

December-February precipitation climatology

June - August precipitation climatology

Coupled Model Intercomparison Project (CMIP5)

Analysis: J. Meyerson
Observed (CMAP) and CMIP5 coupled models
4 mm/day precip. contour (N. America)

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Coupled Model Intercomparison Project (CMIP5)

Analysis: J. Meyerson
CMIP5/IPC 5th Assessment report models

- Representative Concentration Pathway RCP 8.5 (akin to CMIP3 A2 scenario) for greenhouse gases, aerosol forcing


Analysis: J. Meyerson
NCAR Community Climate System Model
CMIP5/IPCC 5th Assessment report models

JJA Prec. Anom.

BCC rcp8.5 JJA Pra(2070-99) (61-90 clim)

(mm/day)
CMIP5/IPCC 5th Assessment report models

JJA Prec. Anom.
Multi-model Ensemble Mean (14 model)

JJA Prec. Anom.

ENS14 rcp8.5 r1 JJA Pra(2070-99) (61-90 clim)

Red line: climatological 4 mm/day contour

CMIP5
Multi-model Ensemble Mean (14 model)

DJF Prec. Anom.

ENS14 rcp8.5 r1 DJF Pra(2070-99) (61-90 clim)

Red line: climatological 4 mm/day contour

CMIP5
CMIP5 Intermodel disagreement on regional precip. change

Taylor plots of the precipitation change pattern for RCP8.5 2081-2100*. Angular direction: Average of the spatial correlation of a given model precipitation change pattern to each of the other members of the ensemble. Radial direction RMS amplitude (for the tropics, 25S-25N). Amplitude of ensemble mean & correlation to each member shown in red.

Multi-model ensemble mean substantially lower amplitude than the mean of each model’s amplitude

Analysis: B. Langenbrunner; *relative to 1961-1990; for tropics
How do the models do for ENSO?

Observed Nino3.4 rank correlations (Dec.-Feb., CMAP)

CMAP ERSST Nino3.4 DJF rank corr (1979 - 2005)

CPC Merged Analysis of Precipitation

Compare to CMIP5 atm. models with obs. SST

Analysis: B. Langenbrunner
CMIP5 models nino3.4 rank corr. AMIP runs (Dec.-Feb.)
Regional scale disagreement on ENSO teleconnections: poor model performance by some measures but some hope

Taylor plot of CMIP5 AMIP*-run ampl. & spatial correlation with observed ENSO teleconnection pattern (regression on Niño 3.4 index); unimpressive---despite observed SST!

*AMIP= Atmospheric Model Intercomparison Project style runs with observed sea surface temperatures

Langenbrunner et al., 2012
Modeled teleconnection amplitude for 4 regions

CMIP3/5 AMIP*-run spatial rms of ENSO teleconnection pattern normalized by obs.

Thin bars: 2*sdev within individual model ensembles; wide bars for all

Multi-model ensemble mean (red dots) systematically underestimates the amplitude

*AMIP= Atmospheric Model Intercomparison Project style runs with observed sea surface temperatures

Langenbrunner et al., 2012
Regional scale disagreement on ENSO teleconnections: poor model performance by some measures but some hope

Number of models that agree on drying signal with:
Top: multi-model ensemble mean
Bottom: observed
Top does reasonable job predicting agreement with observed (even where regr. not at 95%)

High numbers = agreement on negative precip change; Low numbers = agreement on positive precip change

Langenbrunner et al., 2012
Statements of regions where models agree on the sign of the trend: ENSO case supports usefulness.

CMIP5 Number of models with negative JJA precipitation change for RCP8.5 2081-2100 (relative to 1961-1990). Similar to CMIP3.

Analysis: B. Langenbrunner; Small numbers indicate agreement on positive precipitation change.
Multi-model Ensemble Mean (14 model)
for JJA Prec. change for 2070-99 minus 1961-90

Red line: climatological 4 mm/day contour; RCP 8.5; analysis J. Meyerson
Inter-model agreement on sign (13 model) for JJA Prec. change for 2070-99 minus 1961-90

Red colors: higher number of models (out of 13) agree on negative precip change; Blue colors imply agreement on a positive precip change. RCP 8.5. Colored gridpoints pass two-tailed t-test at 95% level. Analysis B. Langenbrunner.
Multi-model Ensemble Mean (14 model)

for DJF Prec. change for 2070-99 minus 1961-90

Red line: climatological 4 mm/day contour; RCP 8.5; analysis J. Meyerson

CMIP5
Inter-model agreement on sign (13 model) for DJF Prec. change for 2070-99 minus 1961-90

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CMIP5 Precipitation Change: ensemble anim.
Pacific-N. Amer. Dec-Feb; 2070-2099 avg minus 1961-90

BCC rcp8.5 DJF Pa(2070-99) (61-90)

Analysis: J. Meyerson
15 models plus multi-model ensemble mean
Red: 4 mm/day model climatology
CMIP5 Precipitation Change: ensemble anim.
Pacific-N. Amer. Dec-Feb; 2070-2099 avg minus 1961-90

ENSEMBLE(14mem) rcp8.5 DJF Pa(2070-99) (61-90)

Analysis: J. Meyerson
15 models plus multi-model ensemble mean

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**CMIP5 Intermodel agreement on regional precip. change**

Taylor plots of the precipitation change pattern for RCP8.5 2081-2100*. Angular direction: Average of the spatial correlation of a given model precipitation change pattern to each of the other members of the ensemble. Radial direction RMS amplitude (for North American West Coast). Amplitude of ensemble mean & correlation to each member shown in red.

North American West Coast in DJF: Relatively high pattern agreement
Precipitation CMIP5 1961-1990
Latitude section off US West coast (lon=230-235)
Precipitation CMIP5 RCP8.5 2070-2099
Latitude section off US West coast (lon=230-235)
Leading spatial pattern of inter-model uncertainty (14 model) for West Coast precipitation

DJF Precip. principal uncertainty pattern-1: 51% variance “amplitude mode”; second mode is “gradient mode”

PC analysis across ensemble; amplitude arbitrary. Analysis B. Langenbrunner
Summary

• Reduction of model uncertainty on precipitation change over large regions: slow (for climatology, global warming response, ENSO teleconnections, …)

• Leading issue in terms of decadal societal impact

• Fundamental questions on hydrological cycle sensitivity

• For North American sector:

  • Caribbean/Central American region has a well agreed upon drought as in CMIP3

  • North American West Coast has reasonable agreement on precip. increase in storm tracks coming onto central California. Leading mode of uncertainty is in amplitude not gradient

• [Extra: The onset of strong convection: Changes in statistics under global warming have a nontrivial relationship to saturation; shift in distribution]
• Extras after here
Transition to strong convection: High-resolution global model (CAM3.5, 0.5°) compared to observations (TMI)

Fit $P(w) = a(w-w_c) \beta$ above $w_c$; CAM use $\beta=1$

Sahany et al. 2012, JAS
Transition to strong convection: simulation of current conditions

Community Climate System Model 4 (CAM4, 1°) Historical run 1981-2000

**Conditionally avg. Precip P** for bins of Tropospheric bulk temperature $T$ (K)

CAM4 Instantaneous precipitation data: R. Neale, Analysis K. Hales
Transition to strong convection: simulation under global warming

Community Climate System Model 4 (CAM4, 1°)
Representative Concentration Pathway run RCP8.5 2081-2100

Conditionally avg. Precip $P$ for bins of Tropospheric bulk temperature $T$ (K)

CAM4 Instantaneous precipitation data: R. Neale, Analysis K. Hales
Transition to strong convection under global warming: CCSM4 convective onset boundary estimates for current climate and end-of-century (EoC; 2081-2100) under RCP 8.5

Onset boundary under warming: modified angle to saturation

CCSM4 Instantaneous precipitation data: R. Neale, Analysis K. Hales