Interdecadal Variability and Change in Global Precipitation During the Satellite Era (1979-2015)

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Objectives:

(i) Quantify global precipitation variability/change on interdecadal-long-term/trend time scales during the post-1979 period; (ii) Investigate physical mechanisms for observed precipitation variability/change by comparing satellite/ground based measurements with climate model outputs; (iii) Assess the capabilities of current climate models in simulating/reproducing observed global precipitation variability/change.

Data Sets:

(1) Satellite based monthly precipitation from the Global Precipitation Climatology Project (GPCP; Version 2.3):

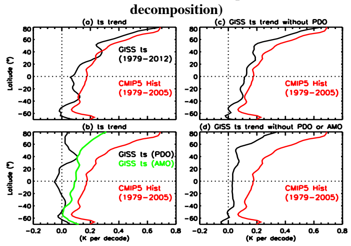
- Data resources: Infrared-based rain-rate estimates, microwave-based rain-rate estimates (after June 1987), and rain-gauges over global land
- Time coverage: 1979-present
- Spatial resolution: 2.5°×2.5°

(2) CMIP5 precipitation outputs:

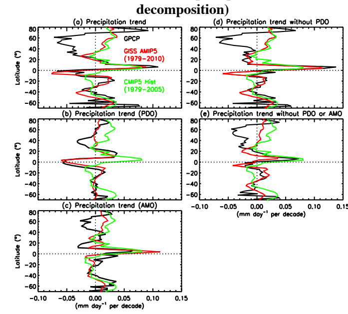
- AMIP-type simulations from NASA/GISS ModelE and multiple CMIP5 models (driven by observed SST and ice extent, and historical radiative forcings)
- Coupled historical simulations: (i) historical full radiative forcings (Hist All), and (ii) green-house-gas-forcing only (HistGHG)

I. Decomposing Interdecadal Variability/Trends in Global Precipitation

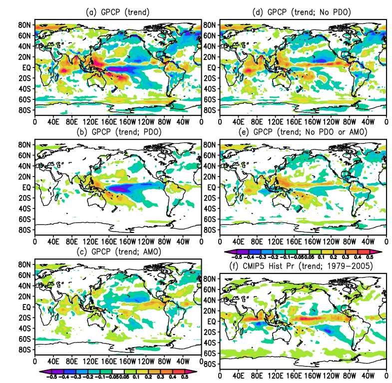
Trends in zonal mean surface temperature (and decomposition)



Trends in zonal-mean precipitation (and decomposition)



GPCP precipitation trends and decomposition, and CMIP5 precipitation trend (Hist All)



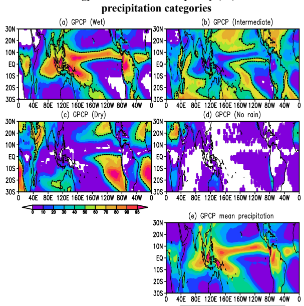
Methodology: Using multiple linear regression to estimate the contributions of both the Pacific Decadal Oscillation (PDO) and Atlantic Multidecadal Oscillation (AMO) and then decompose precipitation and surface temperature trends

Conclusion:

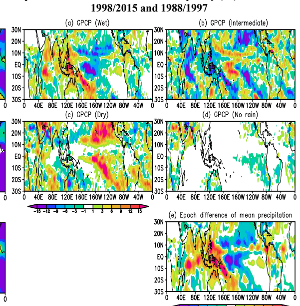
- PDO (and possibly AMO) may have contributed to surface temperature trends and to long-term precipitation changes/trends specifically in the deep tropics;
- Spatial features of GPCP precipitation trends with the effect of PDO (and AMO) removed tend to be more similar to those simulated by CMIP5 historical simulations.

II. Interdecadal Variability/Change in Tropical Wet and Dry Zones

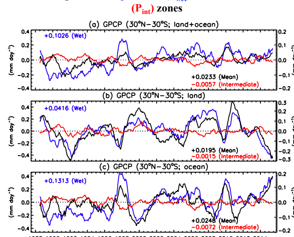
Climatology of Occurrence Frequency (%) for four precipitation categories



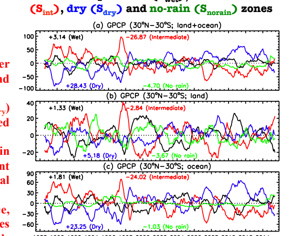
Epoch differences of occurrence frequency (%) between 1998/2015 and 1988/1997



Tropical mean precipitation (P_{mean}), and precipitation averaged over tropical wet (P_{wet}) and intermediate (P_{int}) zones



Sizes of tropical wet (S_{wet}), intermediate (S_{int}), dry (S_{dry}) and no-rain (S_{norain}) zones



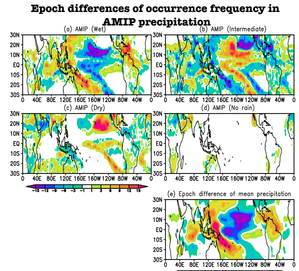
Methodology:

(1) Define four precipitation categories based on monthly percentiles (pct) and classify the tropical (30°N-30°S) domain into four distinct zones for each month:

- Wet ($P \geq P_{Pct=70th}$),
- Intermediate ($P_{Pct=70th} > P \geq P_{Pct=30th}$),
- Dry ($P_{Pct=30th} > P \geq P_{Pct=5th}$),
- No rain ($P_{Pct=5th} > P \geq P_{pct=0th}$)

(2) Compute frequency of occurrence for each precipitation category at grids, sizes of the four tropical zones (S_{wet}, S_{int}, S_{dry}, and S_{norain}),and precipitation averaged over the wet and intermediate zones (P_{wet} and P_{int})

Epoch differences of occurrence frequency in AMIP precipitation

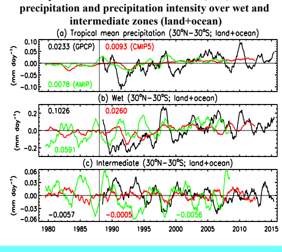


- Decadal changes in GPCP including both mean precipitation and anomalies in precipitation occurrence frequency for the four precipitation categories are in general reproduced in AMIP;
- Similar as for GPCP, P_{wet} has stronger positive trend than P_{mean} for both AMIP and CMIP5, while the trends in P_{mean} and P_{wet} for them tend to be weaker;
- Negative trend in P_{inter} appears as well for AMIP and CMIP5, though it is very weak for CMIP5;
- AMIP has similar interdecadel variations/trends in S_{wet}, S_{inter}, and S_{dry};
- CMIP5 shows similar trends especially for S_{wet}, though the magnitudes in S_{inter} and S_{dry} are smaller;
- These tend to confirm the combined impact from anthropogenic forcings and internal variability such as the PDO.

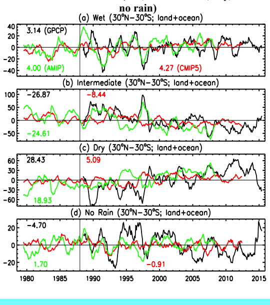
Conclusion:

- P_{wet} shows stronger positive trend than P_{mean} over both land and ocean, while P_{int} has negative trend over land and ocean;
- The sizes of wet and dry zones (S_{wet} and S_{dry}) increase over both land and ocean, accompanied by decreasing S_{int} and S_{norain};
- There is an evident decadal shift around 1998 in both S_{int} and S_{dry}, especially over ocean, coincident with the phase shift of the Pacific decadal Oscillation (PDO).
- Decadal changes exist in their appearance, measured by the corresponding epoch differences of occurrence frequency between two time periods (1998/2015 and 1988/1997);
- Spatial patterns of occurrence frequency differences for "wet" are similar as for mean precipitation, and also tend to be opposite to those for "intermediate";
- Increases in occurrence frequency for "dry" appear in the east half of subtropical Pacific, accompanied by the reductions in "intermediate" and "wet".

Comparisons with AMIP and CMIP5 (Hist): Mean precipitation and precipitation intensity over wet and intermediate zones (land+ocean)



Comparisons with AMIP and CMIP5 (Hist): Sizes of four distinct zones (wet, intermediate, dry, and no rain)



SUMMARY:

- Decadal/inter-decadal scale oscillations specifically the PDO might have played an essential role not only in temperature changes/trends during the post-1979 period, but also in precipitation changes/trends in particular their spatial distributions;
- In addition to the effect on temperature, the impact of the anthropogenic-related radiative forcing (mostly GHG) on global precipitation changes is also discernible in observed precipitation (GPCP), in spite of the PDO effect on regional scales.
- Decadal changes exist in the occurrence of the four precipitation categories; Changes in the occurrence of "wet" are similar as for mean precipitation, and tend to be opposite to those for "intermediate"; Also, large increases in the occurrence of "dry" appear in the east half of subtropical Pacific, accompanied by the reductions in the occurrence of "intermediate" and "wet";
- Precipitation averaged over wet zone (P_{wet}) shows stronger positive trend than the mean precipitation (P_{mean}) over both land and ocean; Negative trend is generally found for precipitation over the intermediate zone (P_{int}). This tends to confirm "wet-get-wetter, dry-get-dryer" especially over tropical ocean;
- Sizes of wet and dry zones (S_{wet} and S_{dry}) increase over both land and ocean, accompanied by reduced S_{int} and S_{norain}; Also, an evident decadal shift exists around 1998 in S_{int} and S_{dry}, especially over tropical ocean, likely confirming the impact of internal variability such as the PDO;
- Comparisons with AMIP and CMIP5 outputs further confirm the combined effects of anthropogenic forcings and internal variability including the PDO during the time period.

References:

Gu, G., R. F. Adler, and G. J. Huffman, 2016: Long-Term Changes/Trends in Surface Temperature and Precipitation during the Satellite Era (1979-2012). *Climate Dynamics*, **46**, 1091-1105, doi:10.1007/300382-015-2634-x.

Gu, G., and R. F. Adler, 2013: Interdecadal Variability/Long-Term Changes in Global Precipitation Patterns during the Past Three Decades: Global Warming and/or Pacific Decadal Variability? *Climate Dynamics*, **40**, 3009-3022. doi: 10.1007/s00382-012-1443-8.