NOAA Award Number: NA11OAR4310099 (GC number: GC11-289)
Project Title:
Observational constraints, diagnosis and physical pathways for precipitation and extreme event processes in next-generation global climate models
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Final Report (October 2015, after No-Cost Extension)
Award Period: 08/01/2011 - 07/31/2014; NCE 08/01/2014 - 07/31/2015
Reporting period 08/01/2011 - 07/31/2015

Publications From the Project:

<u>Refereed publications:</u>

1. Lintner, B. R., C. E. Holloway and J. D. Neelin: Column water vapor statistics and their relationship to deep convection and vertical horizontal circulation, and moisture structure at Nauru. *J. Climate*, 24, 5454-5466, doi: 10.1175/JCLI-D-10-05015.1.

2. Stechmann, S. and J. D. Neelin, 2011: A stochastic model for the transition to strong convection *J. Climate,* **68**, 2955-2970, doi:10.1175/JAS-D-11-028.1.

3. Ruff, T. W., and J. D. Neelin, 2012: Long tails in regional surface temperature probability distributions with implications for extremes under global warming, Geophys. Res. Letts, **39**, L04704, doi:10.1029/2011GL050610.

3Sup. Reviewed online supplement to [3], 3pp., 1 Figure, 1 table.

4. Sahany, S., J. D. Neelin, K. Hales, and R. Neale, 2012: Temperature-moisture dependence of the deep convective transition as a constraint on entrainment in climate models. *J. Atmos. Sci.*, **69**, 1340-1358, 2012.

5. Langenbrunner, B. and J. D. Neelin, 2013: Analyzing ENSO teleconnections as a measure of model fidelity in simulating precipitation. *J. Climate*, **26**, 4431-4446, doi:10.1175/JCLI-D-12-00542.1.

6. Neelin, J. D., B. Langenbrunner, J. E. Meyerson, A. Hall, and N. Berg, 2013: California winter precipitation change under global warming in the Coupled Model Intercomparison Project 5 ensemble. *J. Climate*, **26**, 6238-6256, doi:10.1175/JCLI-D-12-00514.1.

7. Sheffield, J., A. Barrett, B. Colle, R. Fu, K. L. Geil, Q. Hu, J. Kinter, S. Kumar, B. Langenbrunner, K. Lombardo, L. Long, E. Maloney, A. Mariotti, J. E. Meyerson, K. Mo, J. D. Neelin, Z. Pan, A. Ruiz-Barradas, Y. L. Serra, A. Seth, J. M. Thibeault, and J. C. Stroeve, 2013a: North American climate in CMIP5 experiments. Part I: Evaluation of 20th century continental and regional climatology. *J. Climate*, **26**, 9209-9245, doi:10.1175/JCLI-D-12-00592.1.

8. Sheffield, J., S. J. Camargo, R. Fu, Q. Hu, X. Jiang, N. Johnson, K. B. Karnauskas, J. Kinter, S. Kumar, B. Langenbrunner, E. Maloney, A. Mariotti, J. E. Meyerson, J. D. Neelin, Z. Pan, A.

Ruiz-Barradas, R. Seager, Y. L. Serra, D.-Z. Sun, C. Wang, S.-P. Xie, J.-Y. Yu, T. Zhang, and M. Zhao, 2013b: North American climate in CMIP5 experiments. Part II: Evaluation of 20th century intra-seasonal to decadal variability. *J. Climate*, **26**, 9247-9290, doi:10.1175/JCLI-D-12-00593.1.

9. Maloney, E., S. J. Camargo, E. Chang, B. Colle, R. Fu, K. L. Geil, Q. Hu, X. Jiang, N. Johnson, K. B. Karnauskas, J. Kinter, B. Kirtman, S. Kumar, B. Langenbrunner, K. Lombardo, L. Long, A. Mariotti, J. E. Meyersony, K. Mo, J. D. Neelin, Z. Pan, R. Seager, Y. Serra, A. Seth, J. Sheffield, J. Stroeve, J. Thibeault, S.-P. Xie, C. Wang, B. Wyman, , and M. Zhao, 2013: North American climate in CMIP5 experiments: Part III: Assessment of 21st century projections. *J. Climate*, **27**, 2230-2270, doi:10.1175/JCLI-D-13-00273.1.

10. Loikith, P. C., B. R. Lintner, J. Kim, H. Lee, J. D. Neelin, and D. E. Waliser, 2013: Classifying reanalysis surface temperature probability density functions over North America with cluster analysis. *Geophys. Res. Lett.*, ***40***, 3710–3714, doi:10.1002/grl.50688.

11. Lee, S.-K., C. Mechoso, C. Wang, and J. Neelin, 2013: Interhemispheric influence of the northern summer monsoons on southern subtropical anticyclones. *J. Climate*, 26, 10193–10204.

12. J.-L. F. Li, W.-L. Lee, D. E. Waliser, J. D. Neelin, J. P. Stachnik and T. Lee: 2014 Cloud-Precipitation-Radiation-Dynamics Interaction in Global Climate Models: A Snow and Radiation Interaction Sensitivity Experiment. *J. Geophys. Res*., **119**(7), 3809–3824, doi:10.1002/2013JD021038.

13. Su, H., J. H. Jiang, C. Zhai, T. J. Shen, J. D. Neelin, G. L. Stephens and Y. L. Yung, 2014: Weakening and Strengthening Structures in the Hadley Circulation Change Under Global Warming and Implications for Cloud Response and Climate Sensitivity. *J. Geophys. Res.*, doi:10.1002/2014JD021642, **119**, 5787–5805, doi:10.1002/2014JD021642.

14. Stechmann, S. and J. D. Neelin, 2014: First-Passage-Time Prototypes for Precipitation Statistics. *J. Atmos. Sci.*, **71**, 3269-3291, doi:10.1175/JAS-D-13-0268.1.

15. Sahany, S., J. D. Neelin, K. Hales and R. B. Neale, 2014: Deep Convective Onset Characteristics in the NCAR CCSM and Changes Under Global Warming. *J. Climate*., **27**, 9214–9232. doi:10.1175/JCLI-D-13-00747.1.

16. Loikith, P. C., D. E. Waliser, H. Lee, J. Kim, J. D. Neelin, B. R. Lintner, S. McGinnis, C. A. Mattmann and L. O. Mearns, 2015: Surface Temperature Probability Distributions in the NARCCAP Hindcast Experiment: Evaluation Methodology, Metrics and Results.. *J. Climate*, **28**, 978-997, doi:10.1175/JCLI-D-13-00457.1.

17. Anderson, B. T., Lintner, B. R., Langenbrunner, B., Neelin, J. D., Hawkins, E. and Syktus, J., 2015: Sensitivity of terrestrial precipitation trends to the structural evolution of sea surface temperatures. *Geophys. Res. Lett*., 42: 1190–1196. doi: 10.1002/2014GL062593.

18. Langenbrunner, B., J. D. Neelin, B. R. Lintner, and B. T. Anderson, 2015: Patterns of precipitation change and climatological uncertainty among CMIP5 models, with a focus on the midlatitude Pacific storm track. *J. Climate*, revised.

Published Abstracts:

Neelin, J. D., S. Stechmann, and Tyler Ruff, 2011: Informing stochastic parameterization: threshold processes, tails, simple prototypes and observations. NG32B-02 Invited talk at 2011 Fall Meeting, AGU, San Francisco, Calif., 5-8 Dec.

Neelin, J. D., S. Sahany, K. Hales, R. B Neale, 2011: The onset of tropical deep convection: observational metrics for climate models and the role of entrainment. A31H Invited talk, at 2011 Fall Meeting, AGU, San Francisco, Calif., 5-8 Dec.

Langenbrunner,B., J. D. Neelin, and J. E. Meyerson, 2011: Analysis of precipitation teleconnections in CMIP models as a measure of model fidelity in simulating precipitation. Poster session, presented at 2011 Fall Meeting, AGU, San Francisco, Calif., 5-8 Dec.

Sahany, S., J. D. Neelin, K. Hales, and R. B. Neale, 2012: Temperature-Moisture Dependence of the Deep Convective Transition As a Metric for Intercomparison of Climate Models. 92nd Annual Meeting, 24th Conference on Climate Variability and Change, Amer. Meteorol. Soc., New Orleans, LA, Jan. 20-24, 2012, Abstract 5B.1

Neelin, J. D., 2012: Sensitivity of precipitation processes in climate models, Abstract A32D-06, 2012 Fall Meeting, AGU, San Francisco, Calif., 3-7 Dec.

Neelin, J. D., B. Langenbrunner and J. E. Meyerson, 2012: Interpreting the rich-get-richer effect in precipitation change under global warming: issues at monsoon scales, Abstract GC34A-01, 2012 Fall Meeting, AGU, San Francisco, Calif., 3-7 Dec.

Langenbrunner, B., J. D. Neelin and J. E. Meyerson, 2012: Using ENSO teleconnections in AGCMs to gauge the fidelity of the CMIP5 ensemble in modeling past and future precipitation changes, Abstract A53L-0323 2012 Fall Meeting, AGU, San Francisco, Calif., 3-7 Dec.

Zamboni, L., R. L. Jacob, V. R. Kotamarthi, I. Held, M. Zhao, T. J. Williams, J. C. McWilliams, J. D. Neelin and M. Wilde, 2012: Cloud processes' impact on precipitation: sensitivity and uncertainty, Abstract A53J-0273, 2012 Fall Meeting, AGU, San Francisco, Calif., 3-7 Dec.

Meeting abstracts (not formally published)

B. Langenbrunner, J. David Neelin, J. Meyerson, 2012: ENSO teleconnections in CMIP5 AMIP runs as a measure of model fidelity in simulating precipitation. WCRP CMIP5 abstract - Honolulu meeting, March 5-9.

Neelin, J. D., B. Langenbrunner, J. Meyerson, S. Sahany, K. Hales, R. B. Neale, 2012: Precipitation response under global warming: The tropics and western North America in CMIP5. WCRP CMIP5 abstract - Honolulu meeting, March 5-9, 2012

A. Mariotti, S. Nigam, J. Sheffield, E. Maloney, J. Kinter on behalf of the MAPP CMIP5 Task Force participants, 2012: CMIP5 Task Force Overview. WCRP CMIP5 abstract - Honolulu meeting, March 5-9, 2012.

Neelin, J. D., B. Langenbrunner, J. Meyerson, S. Sahany, C. Chou, and S. N. Stechmann, 2013: Precipitation change under global warming and interpreting the rich-get-richer effect: issues at regional scales and large event sizes. 19th Conference on Atmospheric and Oceanic Fluid Dynamics, AMS. Newport, RI.

Neelin, J. D., M. Chekroun, A. Bracco, Hao Luo, J. C. McWilliams, D. Kondrashov, M. Ghil, S. Sahany and R. Neale, 2013: Fundamentals of parameter sensitivity in climate models. 2013 Joint Mathematics Meeting, American Mathematics Society. San Diego, Calif.

Niznik, M. J., B. R. Lintner, B. Langenbrunner, J. D. Neelin, 2013: Circulation, moisture, and precipitation relationships along the South Pacific Convergence Zone in reanalyses and CMIP5 models. 2013 Fall Meeting, AGU. San Francisco, Calif.

Neelin, J. D., S. Stechmann, and S. Sahany, 2013: Convective onset statistics and event size distributions as process-oriented diagnostics in climate models. 2013 Fall Meeting, AGU. San Francisco, Calif.

Su, H., J. H. Jiang, C. Zhai, J. D. Neelin, G. L. Stephens, Y. L. Yung, J. T. Shen, 2013: High Climate Sensitivity Suggested by Multi-satellite Observations: the Role of Circulation and Cloud Feedback. 2013 Fall Meeting, AGU. San Francisco, Calif.

Langenbrunner, B., J. D. Neelin and B. T. Anderson, 2013: Principal uncertainty patterns in precipitation among CMIP5 models: Dominant modes of intermodel disagreement in precipitation climatologies and projected change patterns. 2013 Fall Meeting, AGU. San Francisco, Calif.

Loikith, P., D. E. Waliser, J. Kim, H. Lee, B. R. Lintner, J. D. Neelin, S. A. McGinnis, C. A. Mattmann, and L. O. Mearns, 2013: Surface Temperature Probability Distributions and Extremes in the NARCCAP Hindcast Experiment: Evaluation Methodology and Metrics, Results, and Associated Atmospheric Mechanisms. 2013 Fall Meeting, AGU. San Francisco, Calif..

Neelin, J. D., B. Langenbrunner, J. E. Meyerson, C. Chou, S. Sahany, D. N. Bernstein, L. Zamboni, and R. B. Neale, 2013: What will it take to bring down uncertainty in predictions of precipitation change? 2013 Fall Meeting, AGU. San Francisco, Calif.

Lee, S.-K., C. R. Mechoso, C. Wang, and J. D. Neelin, 2014: Interhemispheric Influence of the Northern Summer Monsoons on the Southern Subtropical Anticyclones. 94th Annual Meeting, AMS. Atlanta, Georgia.

Loikith, P. C., D. E. Waliser, J. Kim, H. Lee, B. R. Lintner, J. D. Neelin, S. A. McGinnis, C. Mattmann, and L. O. Mearns, 2014: Surface Temperature Probability Distributions and Extremes in the NARCCAP Hindcast Experiment: Evaluation Methodology and Metrics, Results, and Associated Atmospheric Mechanisms. 94th Annual Meeting, AMS. Atlanta, Georgia.

Sahany, S., J. D. Neelin, K. Hales, and R. B. Neale, 2014: Climate Processes in CMIP5: Deep Convective Onset Statistics as Process-Oriented Diagnostics for Climate Models. 94th Annual Meeting, AMS. Atlanta, Georgia.

Li, J.-L. F., W. L. Lee, D. E. Waliser, J. D. Neelin, E. J. Fetzer, J. Stachnik, S. Wong, and Q. Yue, 2014: Cloud-Precipitation-Radiation-Dynamics Interaction in Global Climate Models: A Snow and Radiation Interaction Sensitivity Experiment. Abstract 11B.6, 31st Conference on Hurricanes and Tropical Meteorology, AMS, San Diego, California, 30 Mar. – 04 Apr.

Neelin, J. D., S. Sahany, S. N. Stechmann, and D. N. Bernstein (2014) Changes in Large Precipitation Events Under Global Warming, Abstract A14F-03 presented at 2014 Fall Meeting, AGU, San Francisco, Calif., 15-19 Dec.

Su, H., J. Jiang, C. Zhai, J. Shen, J. D. Neelin, G. Stephens, and Y. Yung, 2014: Weakening and Strengthening Structures in the Hadley Circulation Change Under Global Warming and Implications for Cloud Response and Climate Sensitivity. Abstract AS49-A011, AOGS 11th Annual Meeting, Sapporo, Japan, 28 Jul - 01 Aug.

Su, H., J. H. Jiang, C. Zhai, T.-P. J. Shen, J. D. Neelin, G. Stephens, and Y. L. Yung, 2014: Weakening and strengthening structures in the Hadley Circulation change under global warming and implications for cloud response and climate sensitivity. Abstract 9259-4, 2014 SPIE Asia-Pacific Remote Sensing, Beijing, China, 13-16 Oct.

Loikith, P. C., D. E. Waliser, H. Lee, J. D. Neelin, J. Kim, B. R. Lintner, S. A. McGinnis, and L. O. Mearns, 2015: Temperature Extremes and Associated Large-Scale Meteorological Patterns in NARCCAP Regional Climate Models: Towards a framework for generalized model evaluation. Abstract 546, 27th Conference on Climate Variability and Change. AMS, Phoenix, Arizona, 04-08 Jan, 2015.

Results and Accomplishments:

Numbers do not precisely correspond to those in the publication list because papers with related themes are grouped together.

1) Lintner et al (2011) examines the origin of long tails in the probability distribution of water vapor that are associated with intense convective events. In previous work with microwave satellite retrievals, we had noted that there was a Gaussian core in the water vapor distribution for precipitating points, occurring just below the onset of strong convection, and serving as a quantification of quasi-equilibrium convection assumptions. However, at high water vapor, in the strongly precipitating regime, the probability of a given water vapor occurring did not fall nearly as quickly as would have been extrapolated from the Gaussian. Instead, there was a long, approximately exponential tail, implying that strong precipitation events occur much more frequently than would be expected from Gaussian statistics. A mathematical prototype for this was found in the physics and applied mathematics literature that suggested that such Gaussian core/exponential tail distributions can arise from passive tracer advection problems with the maintained gradient and certain flow characteristics. In Lintner et al. (2011) These relationships are examined in in situ data at the Atmospheric Radiation Measurement Project site at Nauru, which has a variety of instrumentation and in which radiosonde data can be used to look at the vertical structure and to confirm the important role of vertical advection in the physical processes producing the long tails.

2) Stechmann and Neelin (2011) creates a stochastic model with the aim of capturing as much as possible in a simple prototype of the set of observed properties of the transition to deep convection that we have been assessing. It proves possible to capture not only Gaussian core and exponential tail properties of the water vapor distribution across the convective transition, but also the power law autocorrelation and power law distribution of rainfall event sizes. Having the relatively simple model permits one to compare, for instance, roles of a Markov jump process for convective initiation and Wiener processes for both the amplitude of precipitation sink and the driving by dynamical processes, in controlling various properties. This is done both numerically and by seeking analytic solutions of the Fokker-Planck equation in in limiting regimes. For example, the probability density function of precipitating points has a significant dependence on the Markoff onset process on one side of the transition but not on the other, suggesting which aspects of the climate model solution would be strongly affected by convective initiation that is not slaved to large-scale thermodynamic variables. Overall this work sets the groundwork for assessing the impact of potential modifications of convection schemes in climate models, and for understanding the observed distributions that lead to extreme precipitation events.

3) If long tails are common in distributions of water vapor — and other atmospheric tracers, as noted in our earlier work — and having established the importance of advection across the maintained gradient, it is natural to hypothesize that similar long tails might occur in distributions of surface temperature. Ruff and Neelin (2012) shows that this is indeed common in observed surface air temperature traditions for daily average, daily minimum and daily maximum temperatures. The potential importance of this for the rate of increase of temperature extreme events above a given threshold under global warming is also demonstrated, indicating that it is important to assess climate models for these aspects of the simulated temperature distribution before making quantitative statements regarding the shifts of such distributions under global warming.

4) Sahany et al (2012) examines a quantitatively very important feature of the transition to strong deep convection in the tropics: the physics that determines the onset boundary in a water vapor-temperature thermodynamic plane. This curve separates strongly convecting from non-convecting regions of the thermodynamic plane, and has been determined empirically in prior work. Here we show: 1) a high resolution version of a recent revision of the Community Atmosphere Model does a reasonable job at capturing this onset boundary compared to observations; 2) that the physics of

conditional instability in entraining plumes, such as it is included in the model parameterization, can capture this boundary — but only if the lower tropospheric entrainment lies within a certain range. This thus helps to set constraints for the representation of entrainment in climate models.

5) Langenbrunner and Neelin (2013) evaluates the remote impacts on precipitation teleconnections of El Niño/Southern Oscillation in the Coupled Model Intercomparison Project Phase 5 (CMIP5) ensemble, comparing the simulation quality to the earlier CMIP3 ensemble. Furthermore, it uses the simulation of this natural phenomenon for which we have observations to evaluate the type of statistics that are applied to global warming assessment. Although the model performance at the detailed spatial distribution of the teleconnection precipitation signal is far from perfect, the amplitude is reasonably well reproduced by the mean of the ensemble amplitudes (*not* the amplitude of the ensemble mean). And furthermore high agreement on sign is an impressively accurate predictor of the sign of the teleconnection signal.

6) Neelin et al. (2013) evaluates an important aspect of North American precipitation change under global warming in CMIP5 simulations. One of the main features that has changed between the earlier CMIP3 and CMIP5 is the estimated change of precipitation in Central and Northern California, associated with a change in the storm tracks coming onto the coast (this feature also continues inland). The precipitation increases significantly in the current CMIP5 ensemble (at the 96% level for a T-test for independent means). Even more interestingly this difference is a property of most of the individual models, not just of the ensemble itself (T-test for dependent means for models with both a CMIP3 and a CMIP5 version significant at the 99% level). Physically, this feature is associated with an extension of the Pacific jet onto the California coast. The jet extension increases winter storm rainfall onto the coast in the manner consistent with similar steering of storms that occurs during El Niño (although in the global warming case the jet change is not driven from the tropical Pacific). The model representation of rainfall changes in interannual variability validates reasonably well against observations, bolstering confidence in the models ability to simulate a significant step in this pathway. Overall, this should be viewed as identifying a significant contributing mechanism that can alter the location of the boundary between subtropical drying and mid-latitude precipitation increases. Other aspects of the hydrological cycle, including snowmelt and evapotranspiration changes must also be taken into account in assessment of regional impacts.

7) Sheffield et al. (2013a,b) and Maloney et al. (2013) summarize the performance of the CMIP5 models for current climate compared to observations over North America and their projections of climate change. Our group contributed to this MAPP program coordinated effort particularly in aspects regarding the hydrological cycle and projections of precipitation change.

8) The Loikith et al. (2013, 2014) collaboration sets up a framework for evaluating the regional properties of surface temperature probability density functions, including longer-than-Gaussian tails such as had been identified in Ruff and Neelin (2012), described in the previous progress report. By using cluster analysis, Loikith et al. (2013) seek geographic regions that have similar PDFs, permitting compact comparison over regions in which the distribution is governed by similar dynamics. These distributions are evaluated in reanalysis products including the North American Regional Reanalysis, setting a target for model assessment. This paper was in preparation in the last reporting period and is now published. The Loikith et al. (2014) paper evaluates the characteristics of daily surface temperature pdfs in a six-member regional climate model (RCM) hindcast experiment against the same analysis in the reanalysis data sets. Some features including temperature skewness are reasonably well simulated by most RCMs, especially in the winter, suggesting confidence in the use of these models to simulate future temperature extremes. Aspects in which the models exhibit bias are also identified.

9) The Li et al. (2014) collaboration combines sensitivity experiments in the NCAR CCSM with observational and CMIP analysis. The changes associated with the effects of precipitating hydrometeors on radiation, typically omitted in model convective parameterizations, exhibit a number differences consistent with biases in CMIP3 and CMIP5.

10) Loikith et al. (2015) sets up a framework for evaluating the regional properties of surface temperature probability density functions, including longer-than-Gaussian tails such as had been identified in Ruff and Neelin (2012), described in a previous progress report. The Loikith et al. (2015) paper evaluates the characteristics of daily surface temperature pdfs in a six-member regional climate model (RCM) hindcast experiment against the same analysis in the reanalysis data sets. Some features including temperature skewness are reasonably well simulated by most RCMs, especially in the winter, suggesting confidence in the use of these models to simulate future temperature extremes. Aspects in which the models exhibit bias are also identified.

11) Su et al. (2014) looks at global warming changes in cloud quantities, water vapor and of the Hadley circulation in the CMIP5 models. The change of the Hadley Circulation exhibits meridionally varying weakening and strengthening structures, physically consistent with the cloud changes. Measures of these in current climate help distinguish among models.

12) Stechmann and Neelin (2014) leverages the related 2012 work, described previously, to establish theory for precipitation event size distributions, including controls on the probability of very large events. This helps to explain the nature of these distributions in initial observations, and sets up coherent targets for evaluation and understanding of these important extreme event measures in models.

13) Sahany et al. (2014) looks at fast timescale measures of convective onset in the NCAR CCSM compared to observations and examines how these change under global warming. The onset boundary under global warming changes in a manner that is consistent with convective conditional instability for an entraining plume. The model's favorable comparison to observations in these measures helps to boost credibility of its simulation of changes under global warming, including the simulated increase in frequency of occurrence of events in the strongly precipitating supercritical range.

14) Anderson et al. (2015) and Langenbrunner et al. (2015) address issues in quantification of the regional precipitation uncertainty in CMIP5 model projections of climate change. Principal Component Analysis and Maximum Correlation Analysis across the multi-model ensemble are used to identify spatial patterns and relationships among climate fields contributing to the leading sources of precipitation uncertainty, which commonly occur at the margins of major precipitation features. In the Pacific mid-latitude storm tracks, there is a coherent region of intermodel uncertainty in the precipitation where storms arrive at the West Coast of North America. This is closely related to changes in the jetstream in this region, highly consistent with a physical pathway involving the steering of storms, with the changes in the jet being set of very large-scale, despite the local scale of the precipitation impact. This work for projection of future rainfall is also coordinated with other NOAA funding on quantifying biases in current climate, in which similar patterns are found.

Highlights of Accomplishments:

- Identification of physical mechanisms producing the long tails in the probability distribution of water vapor that are associated with intense convective events and producing a mathematical prototype for these

- Establishing that long tails exist in the distribution of surface air temperature in observations, quantifying potential implications for changes in temperature extreme events under global warming and evaluating regional distributions in current climate
- Investigation of a high-resolution climate model simulation to show that it captures the onset boundary of strong deep convection with reasonable accuracy and that this accuracy depends critically on representation of entrainment
- Identifying physical pathways for the California precipitation change in the Coupled Model Intercomparison Project (CMIP) 5 under current climate and global warming scenarios.
- Validation of CMIP5 ENSO teleconnections, including simulated amplitude of precipitation change in the main teleconnection regions and spatial distribution of the sign of the precipitation change
- Contributions to evaluation of North American climate change and validation of CMIP5 models for North American current climate as part of the MAPP CMIP5 Task Force.
- Adding to the set of observations that help distinguish associations of deep convective circulations and hydrometeor/cloud contributions to both global warming change and current climate bias in CMIP5 models
- Showing how measures of deep convective onset in observations, described previously, can help constrain a climate model convective parameterization, including in the range of allowable entrainment values, and add to confidence in simulated change of precipitation strong event statistics associated with long tails in the water vapor distribution for precipitating points.
- Adding to understanding of the precipitation event size distribution, including controls on the frequency of very strong events.
- Identifying key patterns of intermodel uncertainty in regional precipitation, especially impacting the US Pacific coast, and the association with other climate variables and physical pathways