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Mechanisms of 20th Century Mediterranean drying: The role of external forcing versus natural variability

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The Mediterranean region experienced a downward trend in wintertime precipitation during the late 20th Century. The coupled models from the WCRP Coupled Model Intercomparison Project, CMIP3, robustly suggest that increasing greenhouse gases will cause a further reduction in much of this region's rainfall over the current century, resulting in a significant decrease in land surface water availability. Much of the observed winter drying from the 1960s to the '90s was influenced by the robust positive trend in the North Atlantic Oscillation (NAO), the dominant mode of atmospheric variability in the North Atlantic, leading to considerable debate as to the mechanisms responsible. Did rising CO2 and global warming play an important role, or were the strong trends predominantly a result of low frequency variability on interdecadal timescales? Model simulations and observations are used to quantify the probable relative roles of radiative forcing and internal variability in explaining the circulation trend that drove much of the precipitation change. Using a multi-model ensemble we assess how well the models can simulate multidecadal trends comparable in magnitude to those observed during the 20th Century, and apply signal-to-noise maximizing EOF analysis to obtain a best estimate of the models' sea level pressure (SLP) and precipitation responses to changes in radiative forcing. The observed SLP and Mediterranean precipitation fields are regressed onto the time series associated with the models' 20th Century externally forced pattern and the implied linear trend in both fields between 1960 and 1999 is calculated. It is concluded that the radiatively forced trends are a small fraction of the total observed trends. Instead it is argued that the robust trends in the observed NAO and Mediterranean rainfall during this period were largely due to multidecadal internal variability with a small contribution from the external forcing. In addition to the NAO, other key mechanisms for Mediterranean drying, such as 1) poleward expansion of the Hadley Cell and 2) thermodynamic changes associated with increasing atmospheric water vapor and changes in mean flow moisture divergence, are also examined. Through analysis of the moisture budget the three mechanisms are explored to determine the relative contributions from changes in specific humidity, mean circulation and transient eddy moisture fluxes. Ensemble average moisture fluxes are used to represent the radiatively forced component and are contrasted with the mechanisms of natural variability determined by forming moisture budget composites based on naturally varying NAO phases. This allows an assessment of whether the mechanisms for radiatively-forced drying and natural drying are distinct and distinguishable. The radiatively forced trends in circulation and precipitation are predicted to strengthen in the current century and this study highlights the importance of their contribution to future precipitation in the region. The above analysis will be applied to the newly-available CMIP5 model outputs and the radiatively-forced versus internal components of the Mediterranean rainfall variations in the 20th and 21st Centuries will be attributed. We will make comparisons of the CMIP3 and CMIP5 results in this presentation as well as comparison to 20th Century observations whenever possible. One of the expected improvements of the CMIP5 is the characteristics of the models' NAO spatial and temporal behavior. Another possible improvement is the horizontal resolution of the CMIP5 models that can more realistically represents the Mediterranean region's rainfall distribution. We hope to better address the question of how much of the recent Mediterranean rainfall decreases are due to anthropogenic climate change using the CMIP5 data in this presentation.