Integrated Observing Strategies for Atmospheric Rivers – Major Field Studies and Future Directions

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Scientific discourse on atmospheric rivers (ARs) has burgeoned over the last decade as extreme precipitation events from landfalling ARs have come into better focus through integrated observing systems and process modeling and analysis studies. An improved understanding of AR-related processes is needed to reduce uncertainties in weather predictions and climate projections of these high-impact events. This research has identified gaps in our understanding of ARs, including aerosol impacts on precipitation processes, that have motivated a series of intensive observing studies to examine the phenomena and linkages between the deep tropics and higher latitudes where they typically make landfall and lead to often beneficial but sometimes flooding rainfall.

This presentation provides an overview of recent major AR field campaigns and describes prospects for important future research directions. These experiments have addressed the AR observing challenge with a sophisticated array of facilities, strategies, and instruments including remote sensors and in situ measurements of meteorology, aerosols, and cloud microphysics. In 2011, the NASA Global Hawk (GH) Unmanned Aircraft System (UAS) conducted three long-endurance flights during the WISPAR (Winter Storms and Pacific Atmospheric Rivers) campaign surveying ARs in the eastern Pacific. As outcomes from this and the seminal CalWater studies in 2009-11, the CalWater 2 series of field campaigns were then proposed, planned, and conducted in winter 2014 and 2015 with four aircraft, a ship, and observations from the ground in near-shore regions of California and the eastern Pacific. CalWater 2014 examined AR dynamics with the NOAA Gulfstream-IV and its meteorology payload. CalWater 2015 brought all of the observing capabilities together with the NOAA G-IV, WP-3D, and NOAA Ronald H. Brown for an unprecedented examination of AR dynamics and aerosol-cloud-precipitation interactions both offshore and over land in California. DOE's Atmospheric Radiation Measurement (ARM) program contributed the Gulfstream-1 aircraft and ship-based facilities for the ARM Cloud Aerosol and Precipitation Experiment (ACAPEX) complementing CalWater

2015. With air-sea flux measurements and the ACAPEX observing system onboard, the RHB provided the first-of-its-kind observations of ARs offshore of California. The NASA ER-2 further complemented this observing scene with a payload of cloud and aerosol remote sensors. More recently, the Alpha Jet has performed three research flights along the U.S. West Coast demonstrating the potential to expand and enhance airborne observing capabilities of AR events with its meteorology and trace gas payload. The last flight in this series was conducted in coordination with the NOAA G-IV in March 2016 to examine tropical-extratropical interactions during the NOAA El Niño Rapid Response. Future prospects also include the use of UAS to study finer scale structure of AR-related processes in offshore environments.

Despite significant advancements in our understanding of ARs, key observing gaps remain: (i) quantifying the terms of the water vapor budget, including precipitation, evaporation, and convergence in ARs and (ii) assessing the impact of aerosols on the water vapor budget and precipitation in AR environments offshore and over land. These key observables will enable new model developments and parameterizations that lead to improved predictability for extreme precipitation events.