Economic Impacts of Atmospheric Rivers in the Transportation Sector: Methodology and Case Studies

working to advance road weather information systems technology

tech transfer summary

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RESEARCH PROJECT TITLE
Economic Impacts of Atmospheric Rivers in the Transportation Sector: Methodology and Case Studies

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The Aurora program is a partnership of highway agencies that collaborate on research, development, and deployment of road weather information to improve the efficiency, safety, and reliability of surface transportation. The program is administered by the Center for Weather Impacts on Mobility and Safety (CWIMS), which is housed under the Institute for Transportation at Iowa State University. The mission of Aurora and its members is to seek to implement advanced road weather information systems (RWIS) that fully integrate state-of-the-art roadway and weather forecasting technologies with coordinated, multi-agency weather monitoring infrastructures.

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Institute for Transportation

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This project developed a methodology to estimate the impacts of atmospheric rivers on traffic flow, crashes, and road closures; applied the methodology in five case studies in California, Colorado, and Utah; and provided direct cost estimates of these transportation impacts.

Goal

The goal of this project was to develop a better understanding of the impacts of atmospheric rivers (ARs) on road safety and mobility outcomes at test sites in California, Colorado, and Utah.

Problem Statement

ARs can decrease the safety of roadways by bringing heavy rainfall, winds, ice, and snow, which can increase crashes, road closures, travel delays, and travel time. However, there have been no comprehensive studies that quantify the costs of AR impacts on the road transportation system.

Background

ARs are long, narrow bands in the atmosphere that transport water vapor from the tropics to the mid-latitudes, like rivers in the sky (Zhu and Newell 1998). When an AR makes landfall, it releases this water vapor as rain or snow. Weak and moderate atmospheric rivers can be beneficial, replenishing water supplies, while extreme ARs can have significant negative impacts (Ralph et al. 2019). In recent decades, flooding due to ARs caused an average of $1.1 billion in damages annually throughout the western US (Corringham et al. 2019).

Project Objectives

- Develop a methodology that links data on AR occurrence and intensity to state department of transportation (DOT) traffic flow and road safety data
- Develop statistical analyses to quantify the impacts of ARs on traffic flow and road safety outcomes
- Quantify the impacts of AR occurrence and intensity on traffic flow rates on I-5 in California
- Quantify the impacts of AR occurrence on traffic incidents, crashes, road closures, and delay times at five sites in Colorado and Utah
- Quantify the economic costs associated with AR impacts at the case study locations
- Propose ways in which operational AR forecasts of varying lead times could be used to mitigate the impacts of ARs on road transportation systems

Project Description and Research Methodology

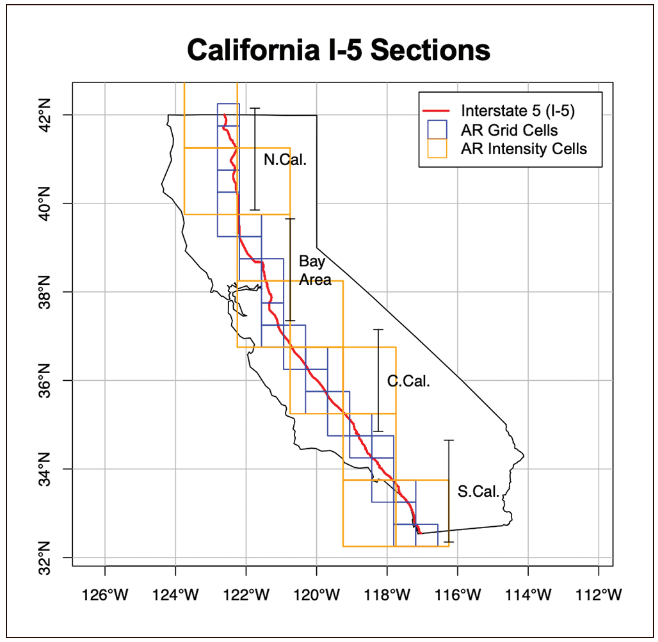
This project included a literature review; acquired and processed AR and transportation data; developed a methodology to estimate the impacts of ARs on traffic, crashes, and road closures; applied the methodology to test sites in California, Colorado, and Utah; provided estimates of the direct costs of these impacts; and discussed potential areas for future research.

AR data were obtained from two catalogs based on work by Guan and Waliser (2015, 2019).

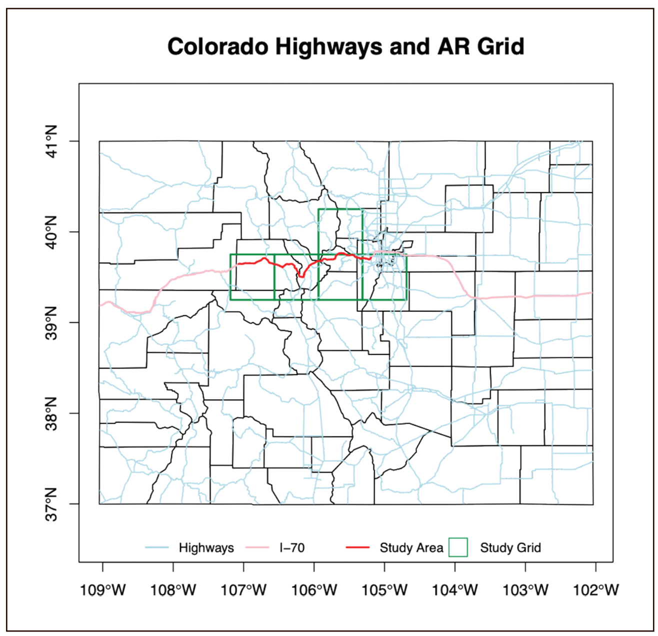
- The first catalog applies the Guan and Waliser (2015) AR detection algorithm to a gridded global weather reanalysis dataset and determines the presence or absence of AR conditions at a given location on a given day.
- The second catalog applies an updated AR detection algorithm (Guan and Waliser 2019) that provides integrated vapor transport (IVT) values at each grid cell. IVT measures the amount of moisture traveling through the atmosphere at a given location and is a standard measure of AR intensity. The IVT data allow for analyses of the effects of AR intensity on road safety and mobility outcomes.

Transportation data were acquired from the state DOTs in California, Colorado, and Utah.

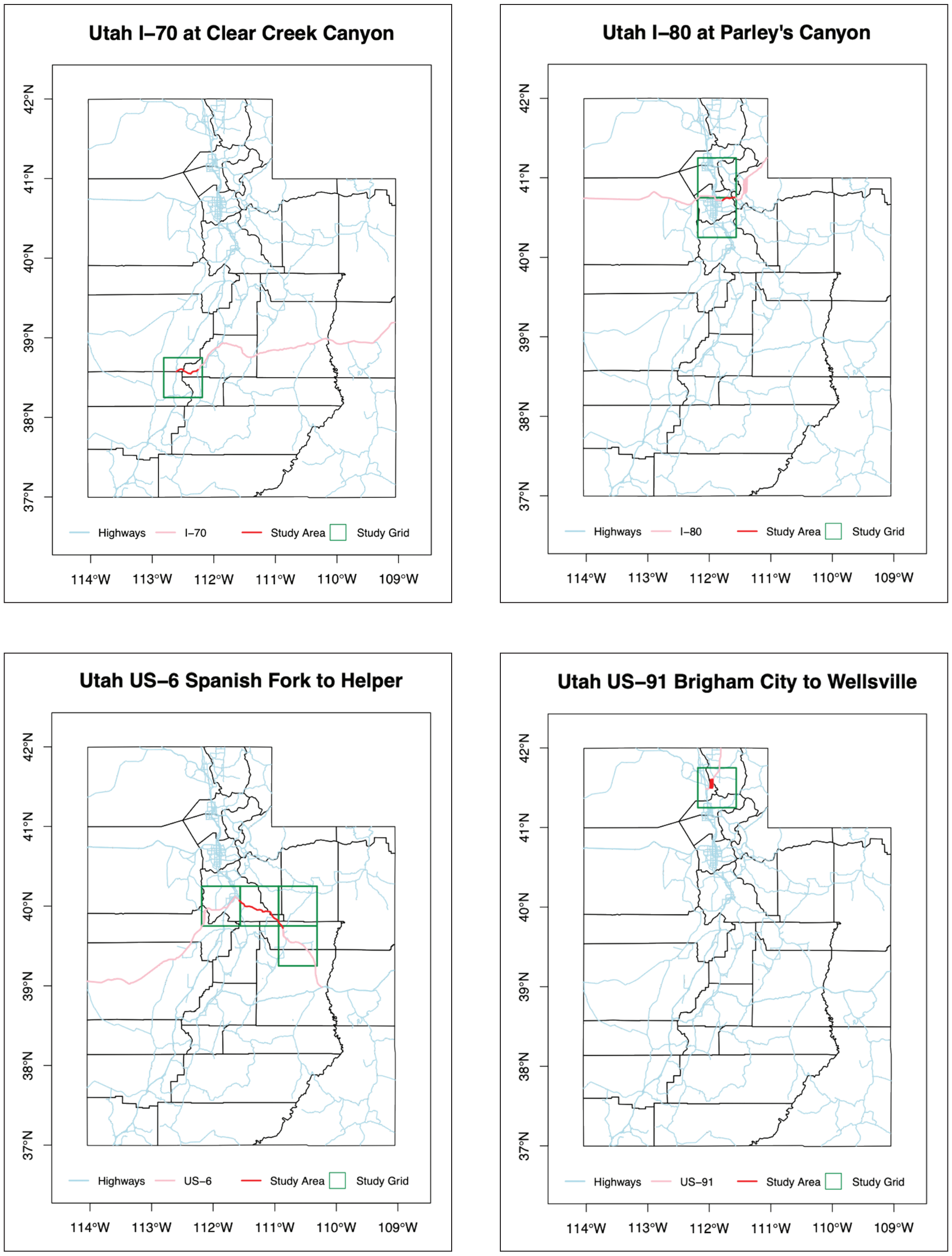
- Data on traffic volumes were obtained from the California DOT (Caltrans) Performance Measuring System (PeMS). The project dataset covers the period of January 1996 to December 2019 and consists of observations taken from traffic census substations from San Diego to the California-Oregon border.
- Data on crashes, road closures, delays, and traffic volumes were obtained from CDOT for the month of March 2019 on I-70 west of Denver from Wolcott to Idaho Springs. March 2019 was chosen because of the historic avalanche cycle that has affected the region over that period.
- Utah DOT data included information on crashes, road closures, and delays from 2012 to 2019 at four sites of key concern to road managers: I-70 at Clear Creek Canyon, I-80 at Parley's Canyon, US 6 from Spanish Fork to Helper, and US 91 from Brigham City to Wellsville.



California I-5 road network, AR grid cells, and study regions



Colorado road network, AR grid cells, and study region

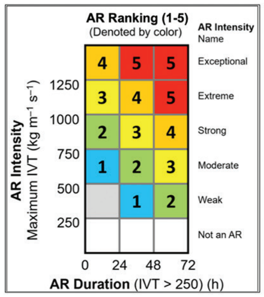


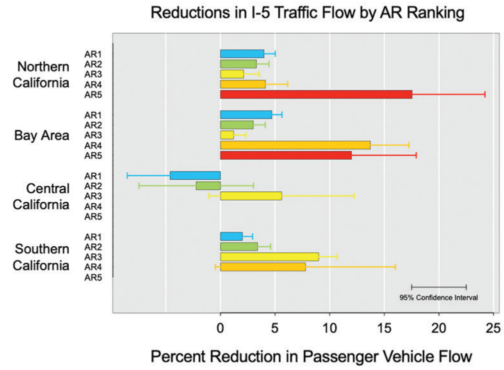
Utah road network, AR grid cells, and study regions

In California and Colorado, the latitude and longitude of each incident and census substation were obtained by matching DOT milepost locations to a U.S. Census Bureau dataset. The California and Colorado data were then matched to the nearest AR grid cells. The Utah incident data provided the latitude and longitude of each event directly. This location information was used to link the incident data to the nearest AR grid cells.

A set of spatially stratified multivariate regression analyses was used to estimate the impacts of AR occurrence and intensity on the road safety and mobility outcomes of interest, controlling for confounding factors such as the day of week or time of day.

The statistical methods were applied to the case study sites in California, Colorado, and Utah. In California, the impacts of ARs on total flow rates and vehicle miles traveled (VMT) on I-5 were quantified and translated into economic costs. In Colorado, the impacts of ARs on road closures on the I-70 case study site were quantified and translated into delay costs. In Utah, the impacts of ARs on crashes were quantified at four sites known to be impacted by adverse weather events, and the economic costs of additional crashes due to ARs were estimated.





Impact of ARs on I-5 traffic flow by AR intensity

Key Findings

- **California.** Weak to moderate ARs were associated with reductions in passenger vehicle traffic flow of approximately 2.5% in southern California and 5% in northern California and the Bay Area. Extreme and exceptional ARs caused reductions in traffic flow of approximately 8% in southern California and 15% in northern California. The costs associated with AR-related reductions in VMT on I-5 were estimated at $106 million per year, with a possible range of $67 million to $467 million per year, depending on assumptions about the sensitivity of road travel demand to the costs of VMT.

- **Colorado.** ARs increased the number of traffic events, spinouts, chain restrictions, full road closures, and closure durations during the significant avalanche month of March 2019. Decreased crashes and traffic events were observed on AR days, likely due to the closures and reduced flow rates, though these decreases were not statistically significant. Using observed traffic flow rates combined with closure durations, the delay costs to passenger vehicles and trucks associated with AR-related road closures were estimated to have exceeded $1.5 million over the corridor for the month.

- **Utah.** The increases in the number and duration of road closures that were associated with ARs at four sites in Utah from 2012 to 2019 were similar to those found at the Colorado study area. Additionally, the number of crashes increased significantly during AR conditions. The costs of AR-related increases in crashes were estimated to exceed $700,000 per year at the four sites.

Implementation Readiness and Benefits

This project developed a methodology to estimate the impacts of ARs on traffic, crashes, and road closures that ultimately could be extended to estimate AR transportation impacts over wider geographic regions, including a complete national analysis.

Recommendations for Future Research

- Applying the study methods over a wider area would provide road managers and policymakers a more complete picture of AR impacts on road networks across the US, allowing for improved response strategies and allocations of resources to mitigate the adverse impacts and outcomes.

- Additional data on traffic flows could be used to improve the cost estimates of AR impacts on traffic volume, speed, delay, and travel time. Broader economic costs of AR transportation impacts could be estimated, including those associated with reductions in consumer expenditures in urban areas and reductions in tourist activity in mountain areas that depend on open and clear freeways for access. Freight probe data combined with network modeling tools could be used to quantify the costs of ARs to freight transport networks.

- Recent improvements in AR forecast technology, including expanded observation networks and advances in dynamical modeling and machine learning capabilities, could be used to develop an operational AR transportation impacts index to enable transportation managers to better allocate resources during AR events and to mitigate against negative and costly outcomes. Further research could develop such tools and tailor them to the needs of transportation users and managers. Finally, projections of future changes in AR frequency, intensity, and spatial distribution could be used to inform long-term (i.e., decadal) planning and road infrastructure investment decisions.

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