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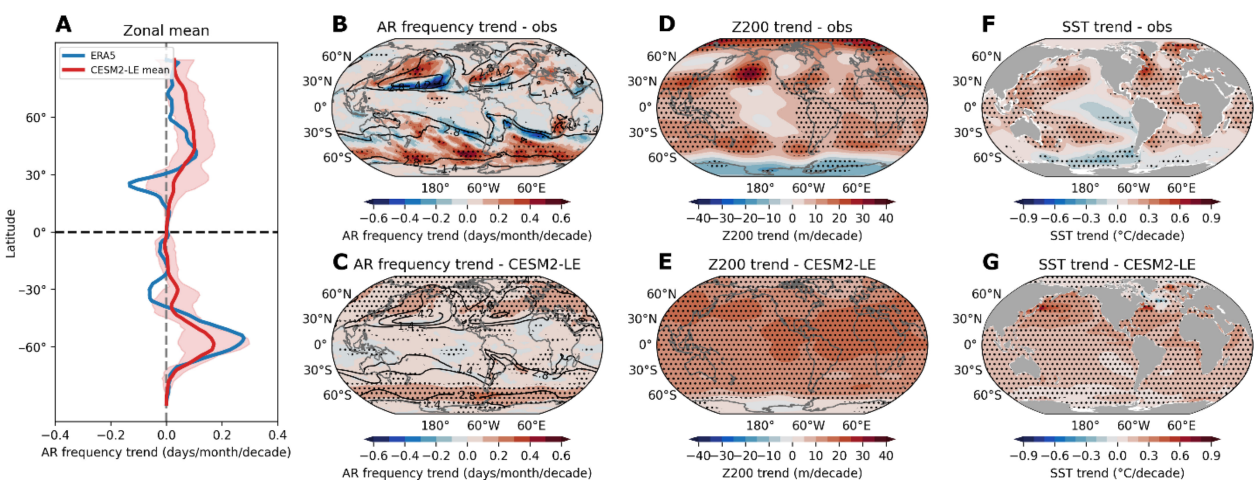
Sent: Tuesday, April 29, 2025 2:34 PM
To: Delta Council ISB <disb@deltacouncil.ca.gov>

Subject: Briefing: Global poleward shift of atmospheric rivers in DJF and implications for hydroclimate in California and the Southwest

Dear Delta Independent Science Board members,

Wanted to provide this summary of recent climate research, produced by giving some key papers to DeepSeek AI to summarize.

An October 2024 study in Science Advances by Zhe Li at UCAR and Qinghua Ding at UC Santa Barbara found a **global poleward shift of atmospheric rivers (ARs)** in December, January, and February from 1979-2022, with significant implications for California and Southwest North America and the 21st century megadrought. (Figure 1 reproduced under CC by NA)



Key findings and their regional impacts include:

1. **Poleward AR Shift**:

- AR frequency has **increased at 50°–60° latitudes** (e.g., North Pacific near Alaska, North Atlantic) but **decreased in subtropical regions near 30° latitudes**.

- This **10° poleward displacement** of AR activity means fewer ARs reach the subtropical zone, where California and Southwest North America (32°N–40°N) lie.

- The change in AR frequency is not captured by the Community Earth System 2 Large Ensemble model projections. CESM2-LE also fails to capture the observed pattern of warming in the Pacific.

- The magnitude of the observed trend in geopotential height at 200hPA (upper troposphere) is also not captured by CESM2-LE.

2. **Impact on precipitation**:

   - The **North Pacific**—a critical moisture source for California and the Southwest —shows a **strong AR frequency decline** in its historical peak region.

   - Reduced AR landfalls in California and the Southwest during **winter (DJF)**, a key season for snowpack and reservoir recharge, exacerbating drought conditions.

   - Findings extend the decreasing trend of -15% in ARs landfalling in California between 1951-2000 found by (Gershunov et al. 2019).

3. **Connection to the Megadrought**:

   - The observed AR shift aligns with the **peak 21st century megadrought timeline (2000-2022)**, suggesting that declining AR-derived rainfall contributed to prolonged aridity.

- As ARs moved poleward, there was a decadal scale decrease in moisture delivery to California and Southwest North America, intensifying water scarcity and ecological stress.

In summary, the study underscores that **climate-driven AR redistribution** has starved California and Southwest North America of vital winter precipitation, playing a role in sustaining the region's megadrought. This trend highlights growing vulnerabilities for water resources and ecosystems under continued global warming.

Climate Model Biases in Capturing Observed SST Trends

The Li and Ding study suggests observed **La Niña-like Pacific SST trends** (accelerated western Pacific warming + muted eastern warming) and associated Walker circulation strengthening are critical drivers of AR shifts. However, climate models (CMIP5/6, LENS) systematically fail to replicate these trends, undermining their ability to project AR behavior.

1. Observed vs. Modeled SST Trends

- **Observed Trends**:
  - **Strengthened SST Gradient**: Since 1980, the equatorial Pacific has developed a stronger east-west SST gradient, consistent with La Niña-like conditions (Seager et al. 2019, 2022).
  - **Walker Circulation Intensification**: Trade winds and Pacific overturning circulation have strengthened (Li et al. 2019), counter to model projections.
- **Model Projections**:
  - CMIP5/6 models predict a **weakening SST gradient** (El Niño-like response) under greenhouse gas forcing, with a weaker Walker circulation.

    - Large ensembles (e.g., Wills et al. 2022) show observed trends are **extremely unlikely (<5% probability)** to arise from internal variability alone, pointing to model biases.

2. Implications for AR Projections

- **AR Dynamics**: The La Niña-like SST gradient influences jet stream positioning, steering ARs poleward. Models that fail to replicate this gradient **underestimate AR declines in the subtropics** (e.g., southwest North America).

- **Southwest Megadrought**: Model biases in SST trends likely lead to **overly optimistic projections** of AR-derived precipitation, masking the true drought risk.

3. Why Models Fall Short

- **Underestimated Forced Responses**: Models inadequately represent:

    - **Aerosol impacts**: Reductions in anthropogenic aerosols (e.g., sulfates) may drive eastern Pacific cooling, a mechanism poorly captured in CMIP6 (Hwang et al. 2024).

    - **Cloud-SST feedbacks**: Biases in simulating cloud cover and wind-evaporation-SST interactions distort tropical Pacific responses.

4. Consequences for Regional Climate Projections

- **Water Security**: Misrepresented SST trends lead to errors in projecting AR frequency and snowpack recharge, critical for drought-prone regions like California and the Southwest.

- **Policy Relevance**: Reliable AR projections require models to resolve Pacific SST trends. Current biases hinder adaptation planning for water resources and ecosystems.

Key Takeaways

- **Critical Gap**: The failure of climate models to capture observed La Niña-like SST trends and Walker circulation changes undermines their ability to project AR shifts and regional hydroclimate.

- **Urgent Need**: Improved representation of **aerosol impacts**, **ocean-atmosphere feedbacks**, and **regional SST variability** in models is essential to refine AR and drought forecasts.

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3. Seager, Richard, Naomi Henderson, and Mark Cane. 2022. "Persistent Discrepancies between Observed and Modeled Trends in the Tropical Pacific Ocean." *Journal of Climate* 35 (14): 4571–4584.

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6. Gershunov, Alexander, Tamara Shulgina, Rachel E. S. Clemesha, Kristen Guirguis, David W. Pierce, Michael D. Dettinger, David A. Lavers, et al. 2019. "Precipitation Regime Change in Western North America: The Role of Atmospheric Rivers." *Scientific Reports* 9, no. 1: 9944.

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Climate change, pandemics, and societal change from a complex systems perspective

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"We aren't just failing to address the growing climate crisis to come; we're unprepared even for the impacts already here—in part because they keep surprising us with their intensity and in part because we can't seem to fathom our genuine vulnerability." – David Wallace Wells

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