The Cloud-Radiative Forcing of the U.S. landfalling Atmospheric Rivers

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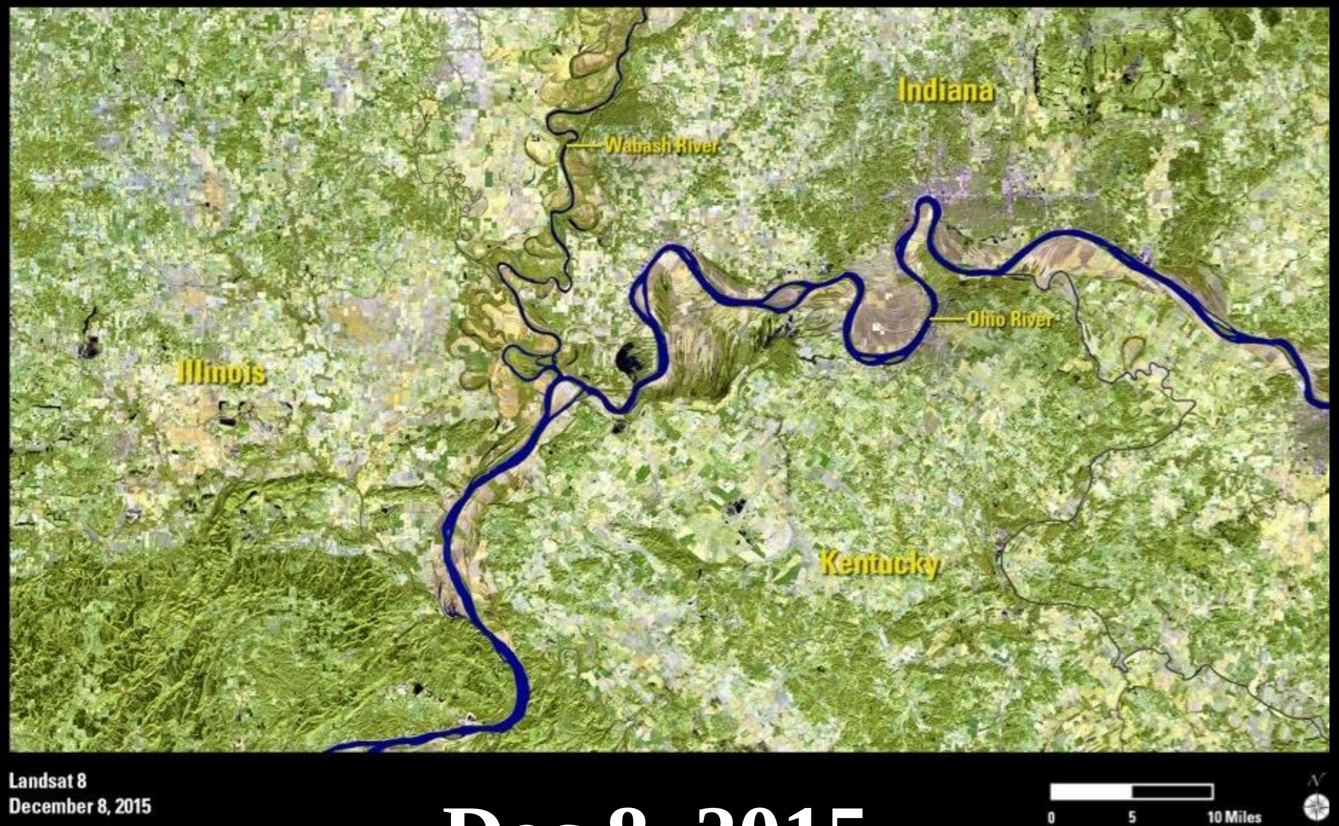
[1] Q. Luo and W.-w. Tung, 2015: Case study of moisture and heat budgets within atmospheric rivers, *Mon. Wea. Rev*., DOI: 10.1175/MWR-D-15-0006.1
[2] Q. Luo and W.-w. Tung, 2016: The Cloud-Radiative Forcing of the Atmospheric Rivers on the US continents: an observational climatology study, *in preparation*

Christmas Week 2015 in Midwest

Before



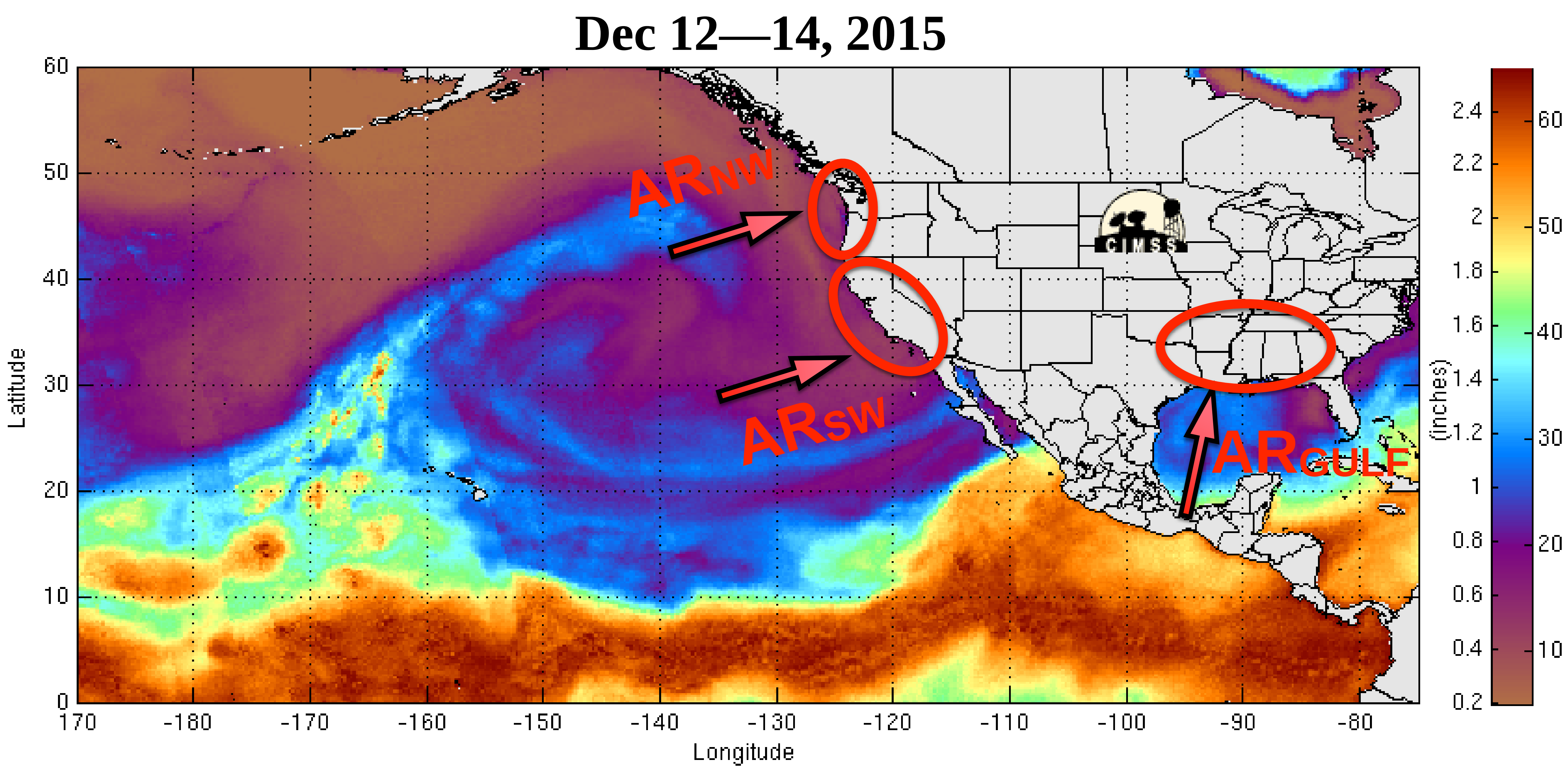
Dec 8, 2015

After

Jan 1, 2016

http://landsat.usgs.gov/

Atmospheric River (AR): redistribute moisture globally



Integrated Water Vapor (mm)

http://tropic.ssec.wisc.edu/real-time/mimic-tpw/epac/main.html

Current knowledge

1. **Winter ARs arrive at the West coast** (Neiman et al., 2008) **and Central-Eastern US** (Lavers and Villarini 2013)
2. **The impacts of ARs on Atmospheric energy budget through Cloud-Radiative Forcing has only been preliminarily established in weather-cases studies** (e.g., Luo 2013; Luo and Tung 2015).

Research Question

What are the sufficient conditions for extensive CRF induced by ARs over the continental U.S.?

Data for Nov—Mar, 2000–2008

1. **ECMWF ERA-Interim Reanalysis**

   (Dee et al., 2011)

   Global, daily, 1.5°×1.5° horizontal grids at 37 pressure levels from 1000 to 1 hPa, and at the surface

2. **Clouds and the Earth's Radiant Energy System SYN1deg** (CERES, Wielicki et al., 1996)

   Global, daily, 1°×1°

3. **Global Precipitation Climatology Project One-Degree Daily Precipitation** (GPCP, Huffman et al. 2001)

   Global, daily, 1°×1°

Methods

1. ARs during Nov—Mar, 2000–2008:

- Used indices from Dettinger et al. (2011) for AR_{SW} (60 cases) and AR_{NW} (60 cases)
- Constructed index for AR_{GULF} 0—3 days <u>after</u> AR_{SW} (35 cases) and AR_{NW} (16 cases), modified after Lavers and Villarini (2013)

2. Computed variables from ERA-Interim:

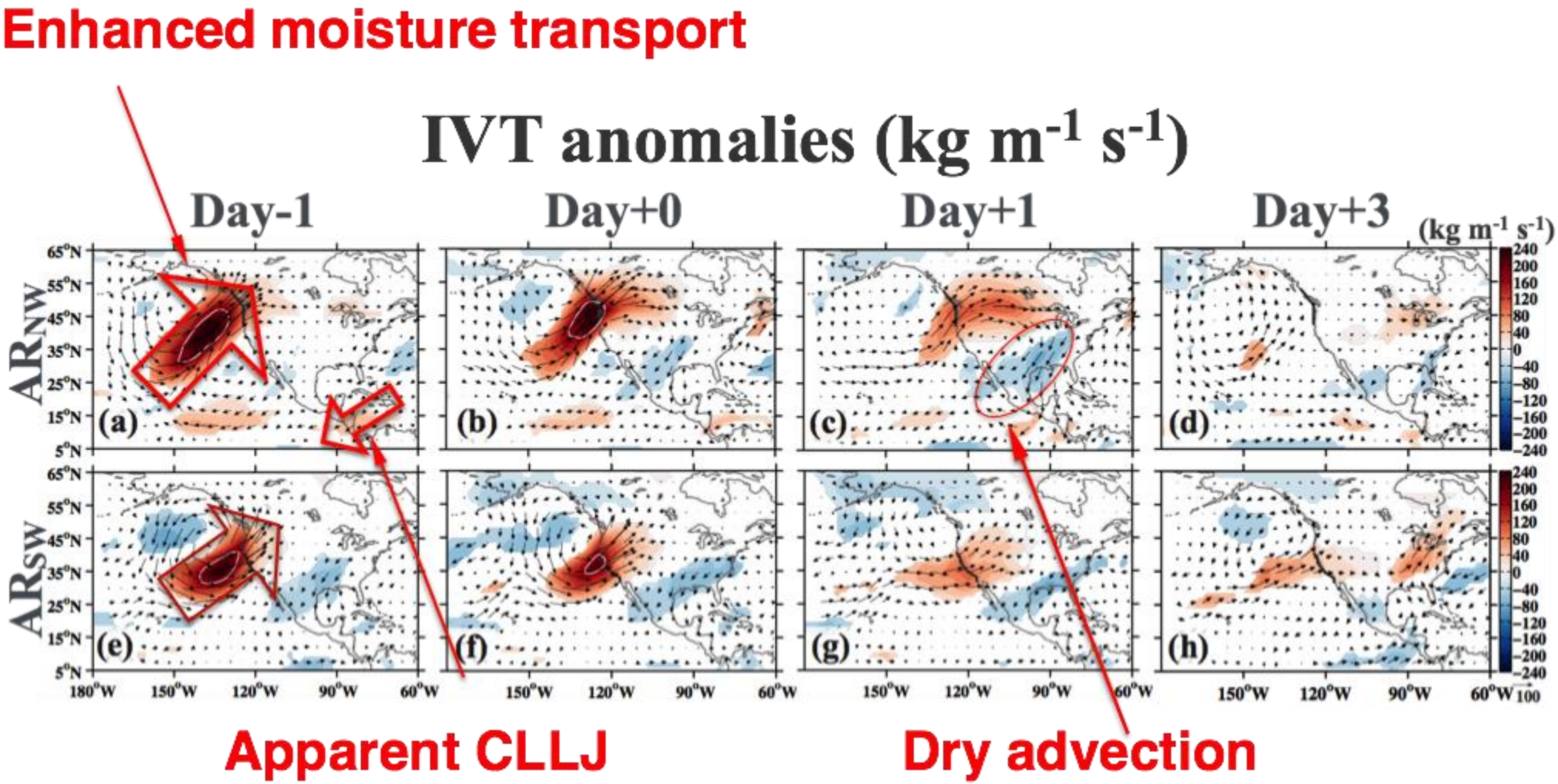
- Integrated horizontal water vapor transport (IVT, Neiman et al., 2008) = $\frac{1}{g}\int_{P_{sfc}}^{300\ hPa} qV\,dp$;
- Apparent heat source (Q_1) & Apparent moisture sink (Q_2, Yanai et al. 1973; Luo and Tung 2015)

Methods

3. Other Statistical analysis:

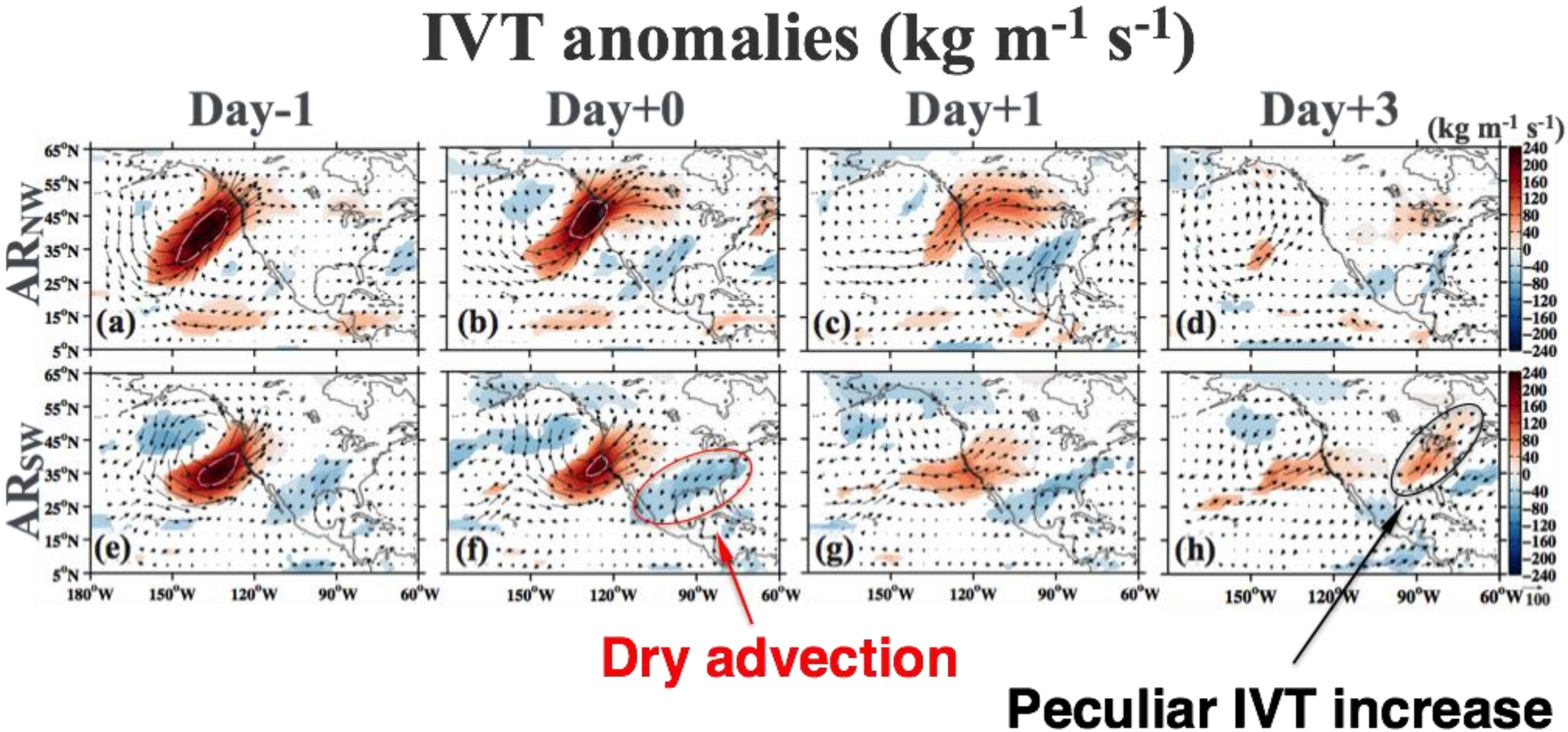
- Singular Value Decomposition (SVD) on CERES SWCRF and LWCRF
- Probability Density Functions
- Correlational Analysis

AR_{NW}: enhanced moisture transport on Day-1~+1



Anomalies = Original data - All winter average

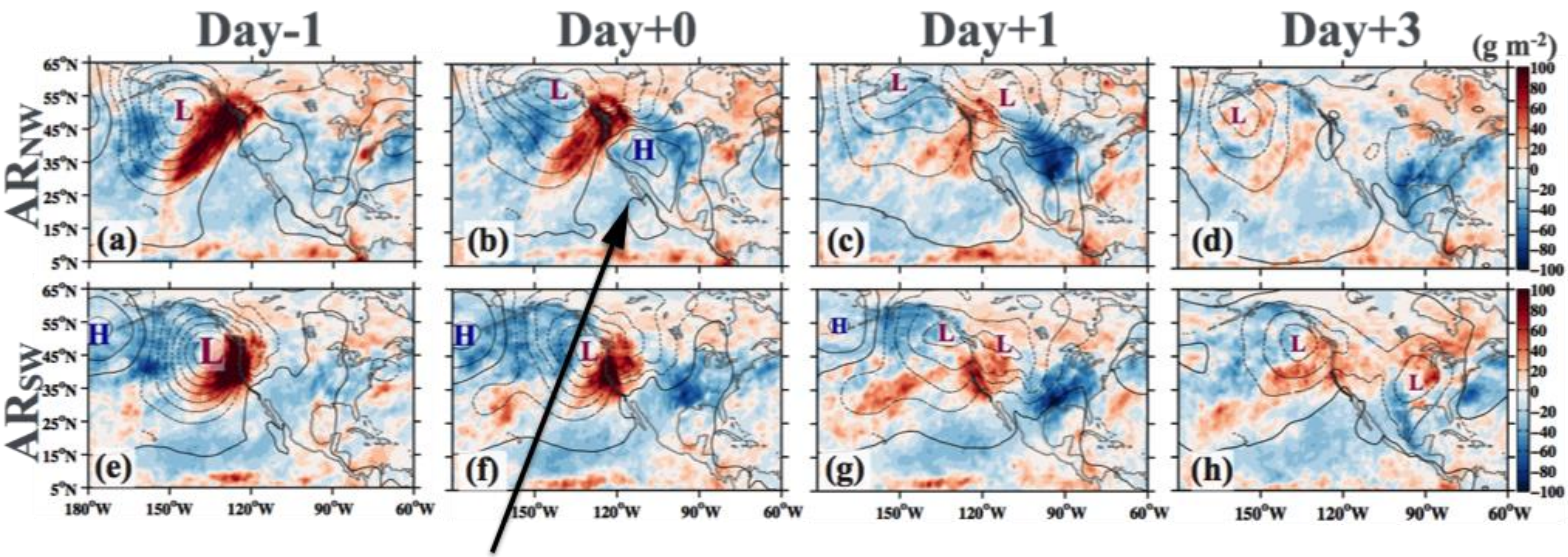
AR_{SW}: weaker yet prolonged moisture transport



Anomalies = Original data - All winter average

AR_{NW}: AR-storm quickly dissipated

Anomalous
Total Cloud Ice Water Path (g m^{-2})
Sea-level Pressure (hPa)

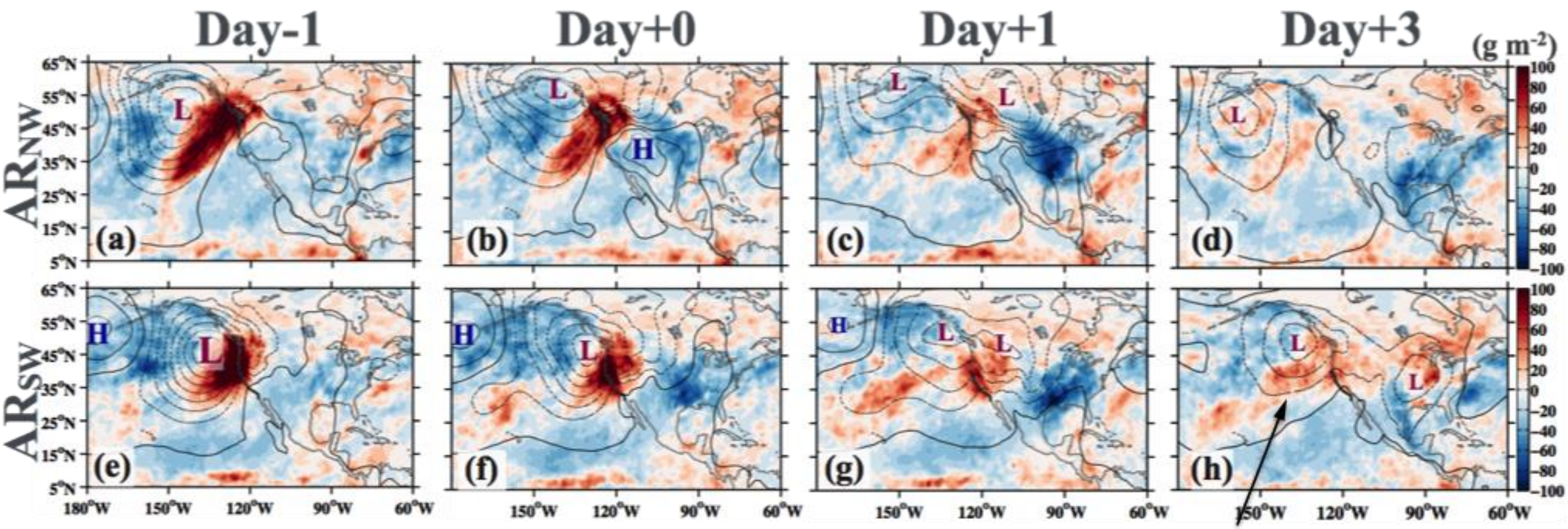


Strong Pacific High

Anomalies = Original data - All winter average

ARsw: eastward propagating AR-storm

Anomalous
Total Cloud Ice Water Path (g m^{-2})
Sea-level Pressure (hPa)

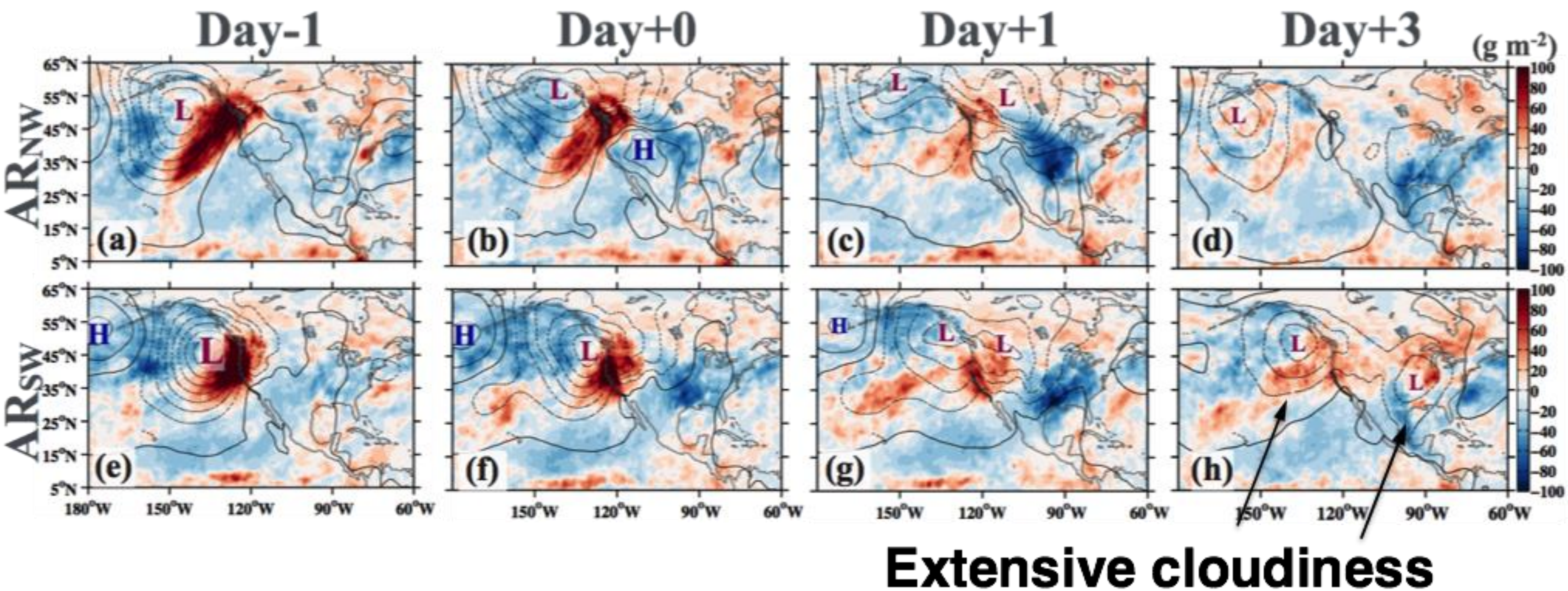


Persistent Low offshore

Anomalies = Original data - All winter average

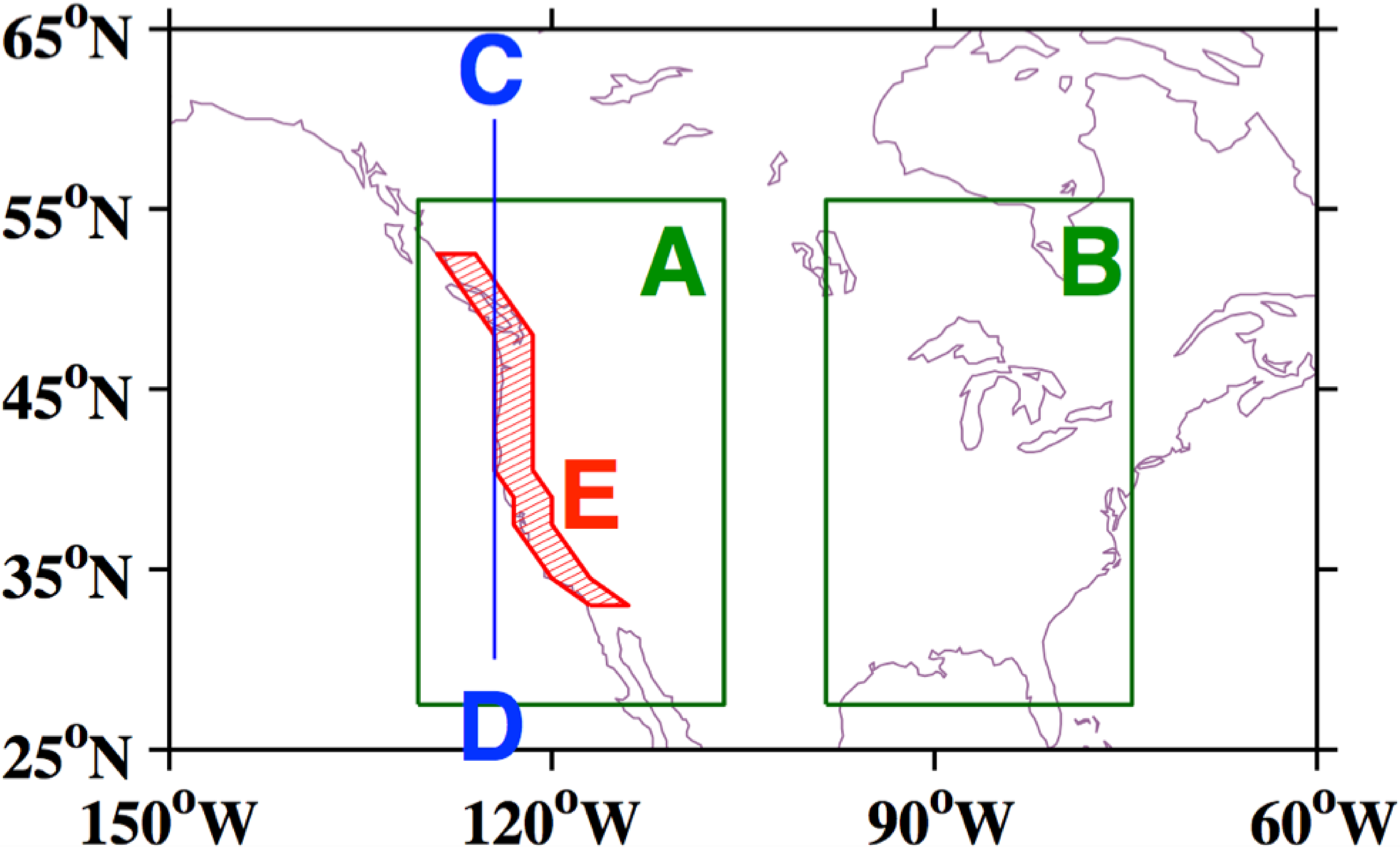
AR_{SW}: prolonged mixed-phased clouds

Anomalous
Total Cloud Ice Water Path (g m^{-2})
Sea-level Pressure (hPa)



Anomalies = Original data - All winter average

To study cloud properties & impacts:



Q_1 and Q_2 suggest

- Convection associated with the **AR_{NW}** was strongest in the landfalling regions on **Day-1**, yet it **quickly decayed**.
- In contrast, AR_{SW} generated **persistent** heating/drying along the West Coast. **From Day+0 onward**, the heating/drying was **stronger** than that produced by the AR_{NW}.

AR_{SW}: less moisture but stronger CRF in Western US

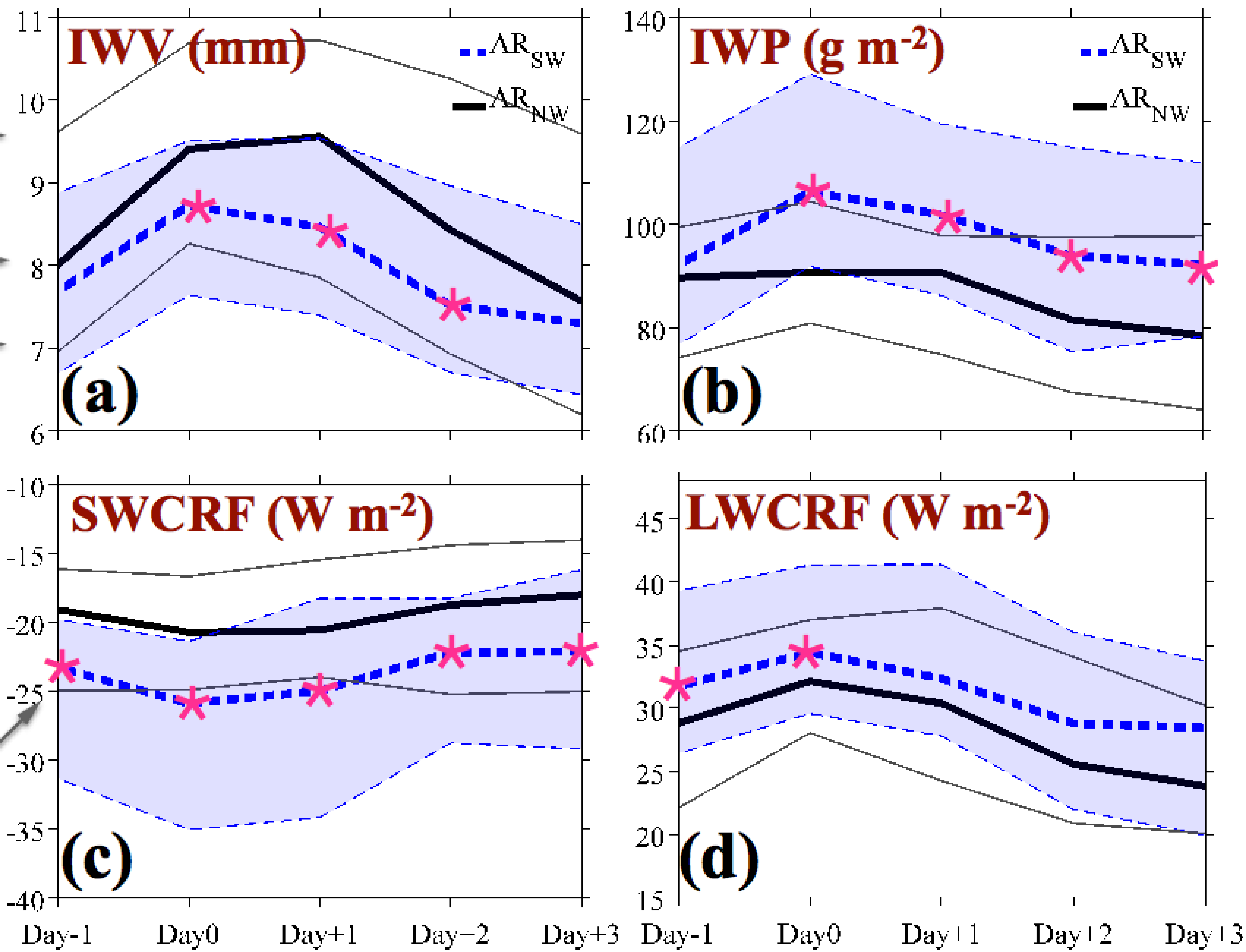
A

75th →

Median →

25th →

Pass the one-sided Wilcoxon ranksum test at 5% significance level

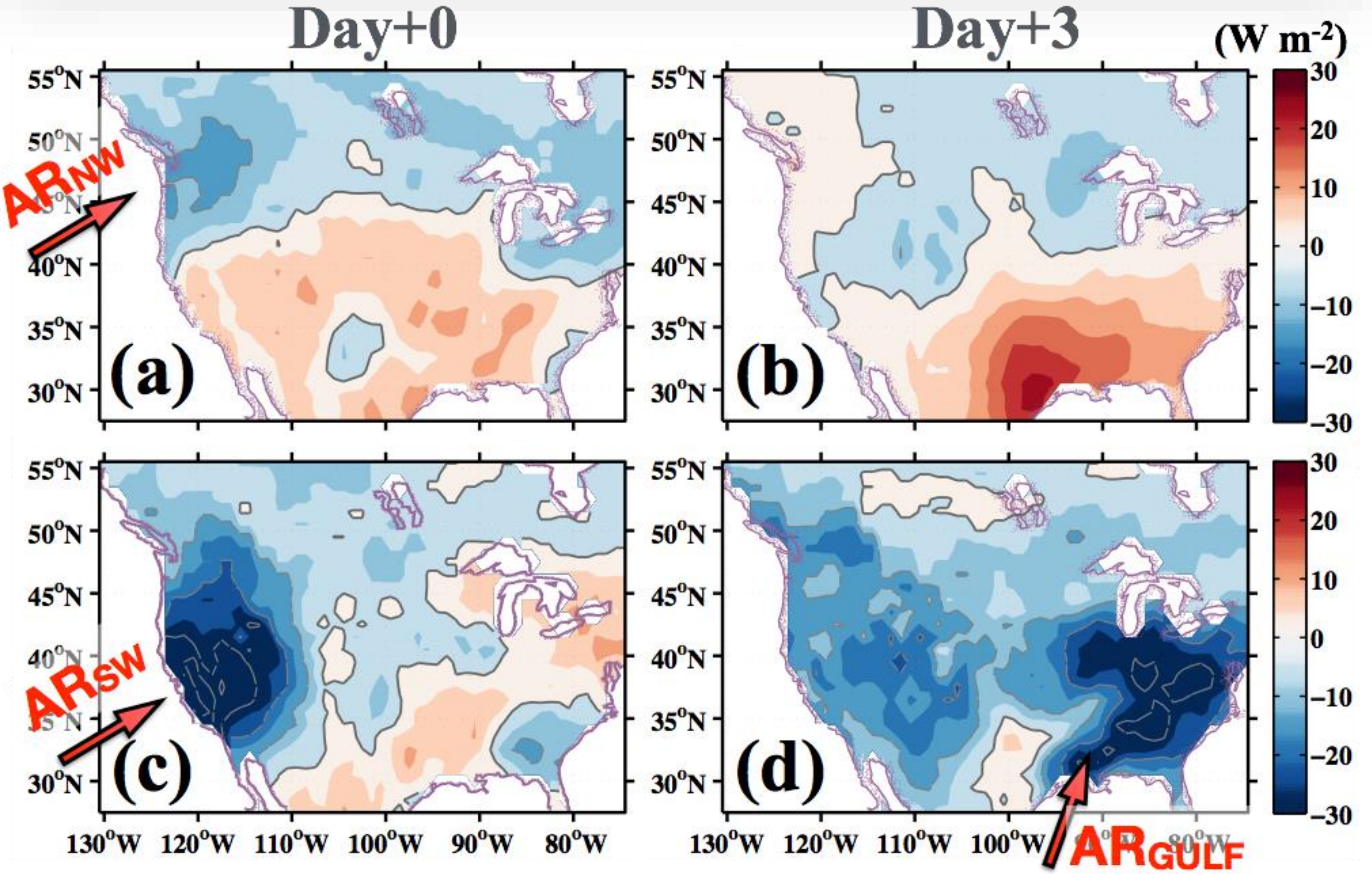


SVD and Reconstruction

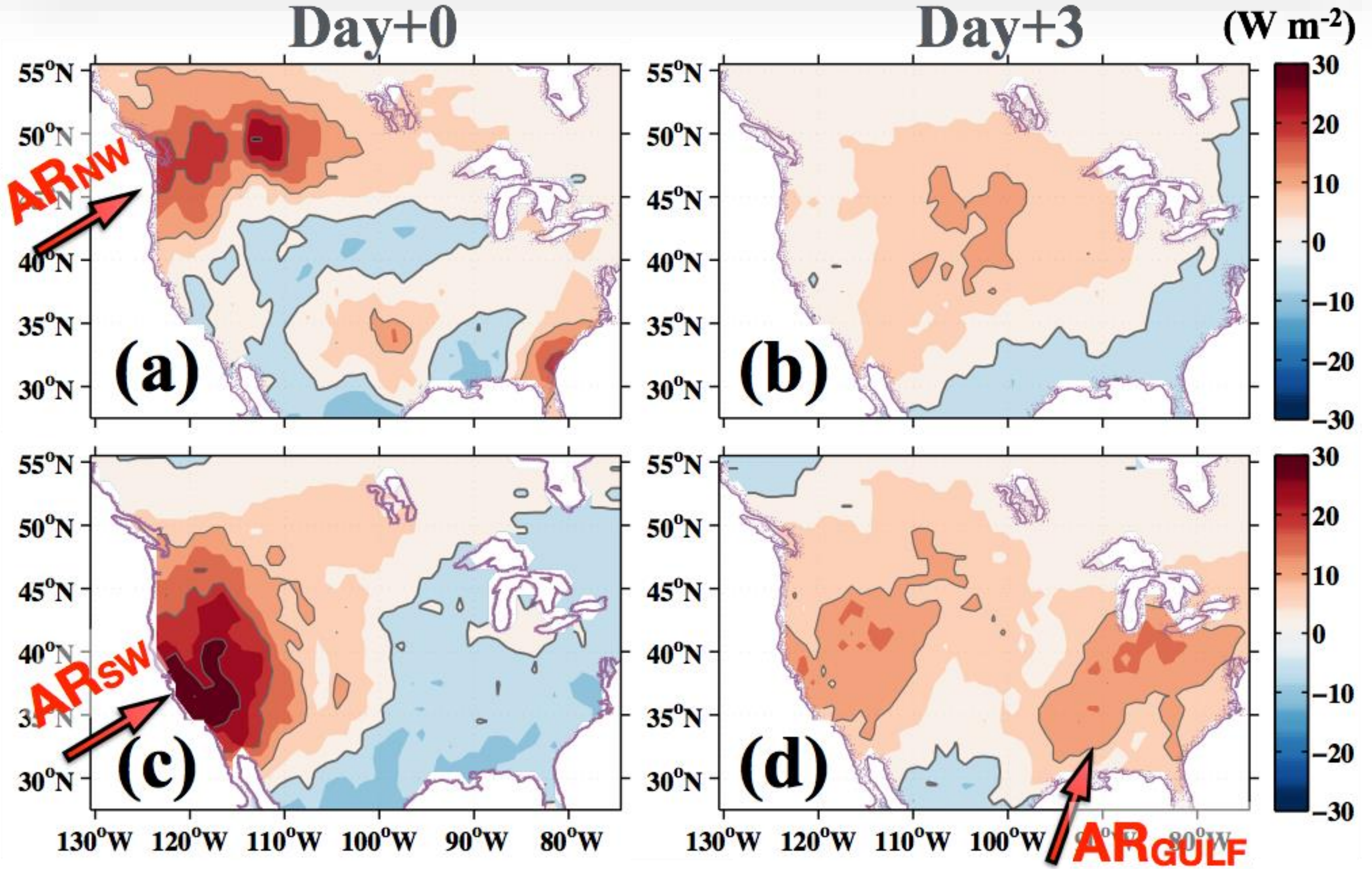
SWCRF, LWCRF variances EOFs PCs eigenvalues

- $$X = U \Lambda V^T$$
- **Reconstructed X such that:** $$\frac{\sum_{i=1}^{k} \lambda_i}{\sum_{i=1}^{M} \lambda_i} \geq 50\%$$
- **Computed time mean for time steps when:** $$\frac{\|PC\| - E[\|PC\|]}{\sigma(\|PC\|)} \geq 0$$

AR_{SW}: extensive SWCRF cooling



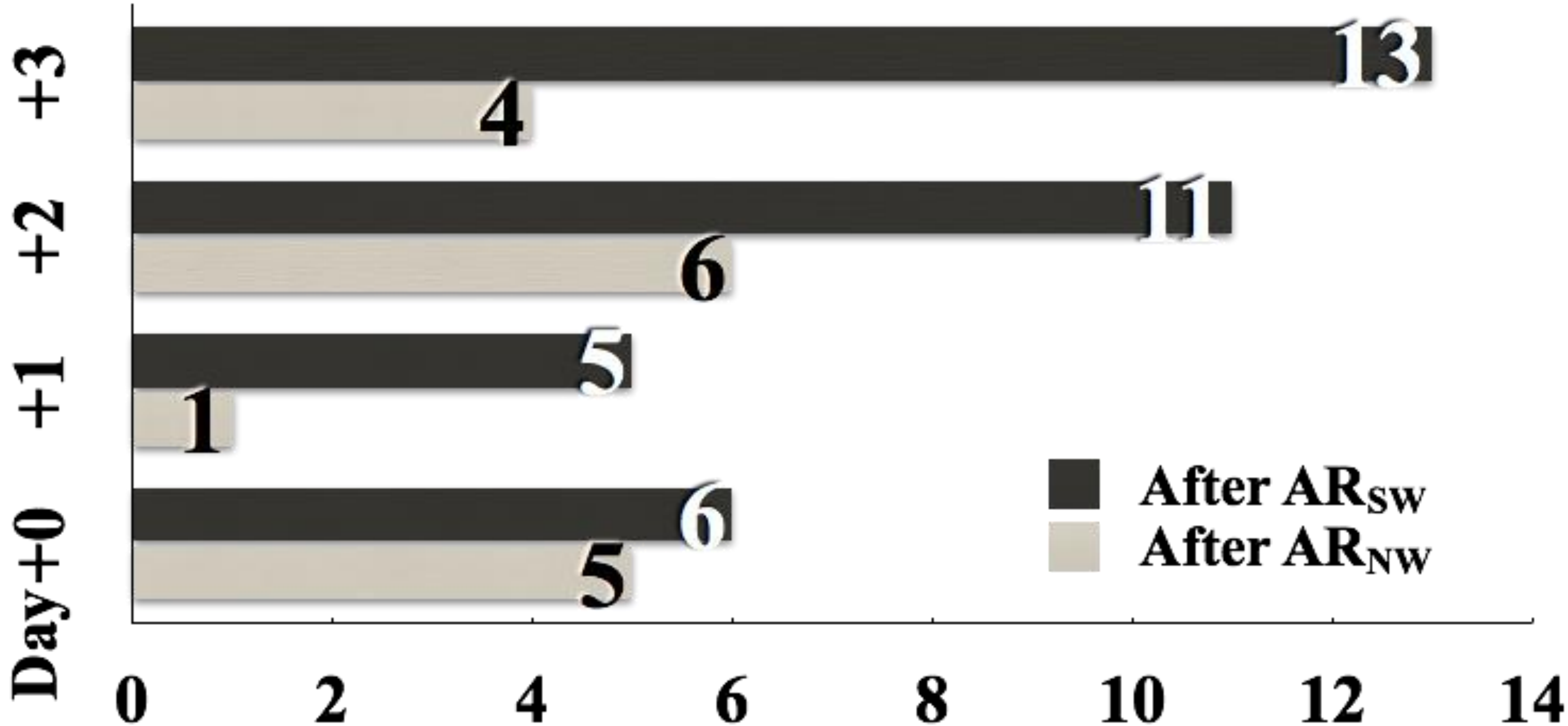
AR_{SW}: extensive LWCRF warming



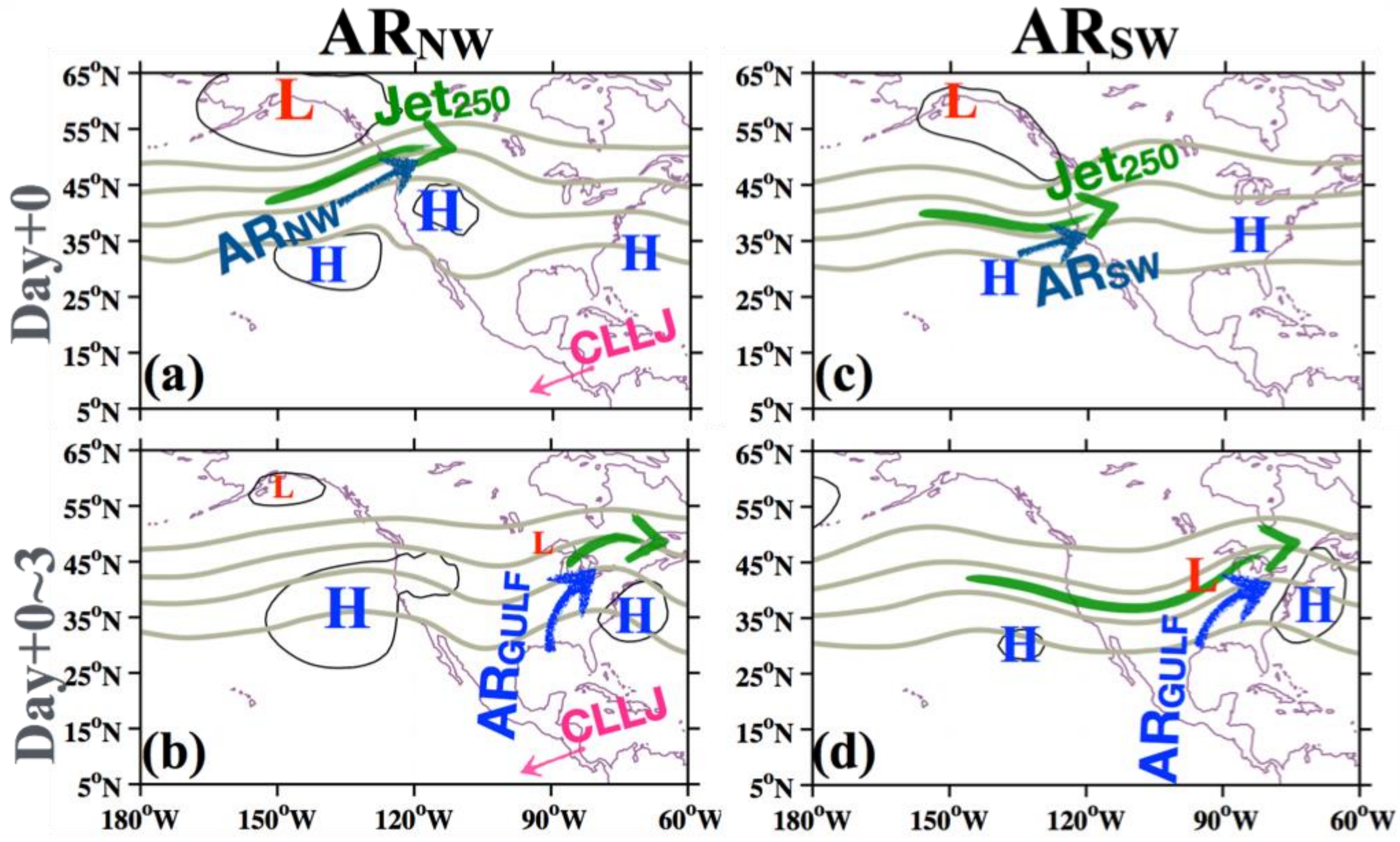
After AR_{SW}: More AR_{GULF}

Total # of AR_{GULF}:

- 35 after AR_{SW}
- 16 after AR_{NW}



After AR_{GULF}: Stronger AR_{GULF}



Key Conclusions

- **AR$_{SW}$ has <u>weaker</u> hydrological impacts but <u>extensive</u> CRF in the western US. The latter is induced by persistent Low pressure offshore.**
- **The <u>synergy</u> between the west-coast AR and the AR$_{GULF}$ resulted in spatio-temporal extensive cloud coverage therefore inducing apparent CRF.**
- **Such scenario is <u>more frequently</u> associated with AR$_{SW}$.**

Don't hesitate to contact me:

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