Storm Tracks and their Influence on North American Precipitation in the Boreal Winter

Storm tracks can have a profound impact on the climate by influencing the variability in cyclonic activity in the mid-latitudes. This study uses 6-hourly Climate Forecast System Reanalysis (CFSR) data to investigate the behavior of Northern Hemisphere (NH) winter storm tracks and their relation to surface precipitation in North America. Storm tracks are described by isentropic potential vorticity (IPV) within a Lagrangian framework. The two most prominent storm tracks in the NH, the Pacific and North American-Atlantic (NAA) storm tracks, are analyzed to discern their impacts on North American weather and climate. First, the main properties of the storm tracks are discussed, including their mean intensities, or average strengths, and small-scale regions of cyclogenesis and cyclolysis. The majority of storms identified from IPV are likely those where deep convection dominates because the isentropic level used here resides in the mid- to upper troposphere and potentially misses low-level shallow convection.

Much of the reanalysis precipitation produced by storms occurs in regions where the storm tracks are strongest, indicating that storm tracks identified from IPV values leave a strong footprint in surface precipitation, especially over the oceans. Even the weaker portions of the storm tracks over land are shown to leave a signal in precipitation. An analysis was also performed using daily precipitation accumulations from the Global Precipitation Climatology Project (GPCP). The results show that the observed precipitation associated with IPV storm tracks occurs in nearby regions as the storm precipitation from the reanalysis. The magnitudes of both observed and reanalysis patterns over the Pacific Ocean are similar; however, the reanalysis appears to overestimate precipitation over the western coast of North America and in the western North Atlantic Ocean.

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Outline

- Motivation and Objectives
- Methodology
- Storm Track Properties
- Storm-related Precipitation
  - Reanalysis vs Observations
- Summary

Motivation

- Large narrow bands of extratropical cyclonic activity (*i.e.*, *storm tracks*) impact the climate by contributing to shifts in tropospheric jets, altering global atmospheric flow patterns.
- Storm tracks can influence the climatological intensities and spatial distributions of quantities like precipitation.

Objectives

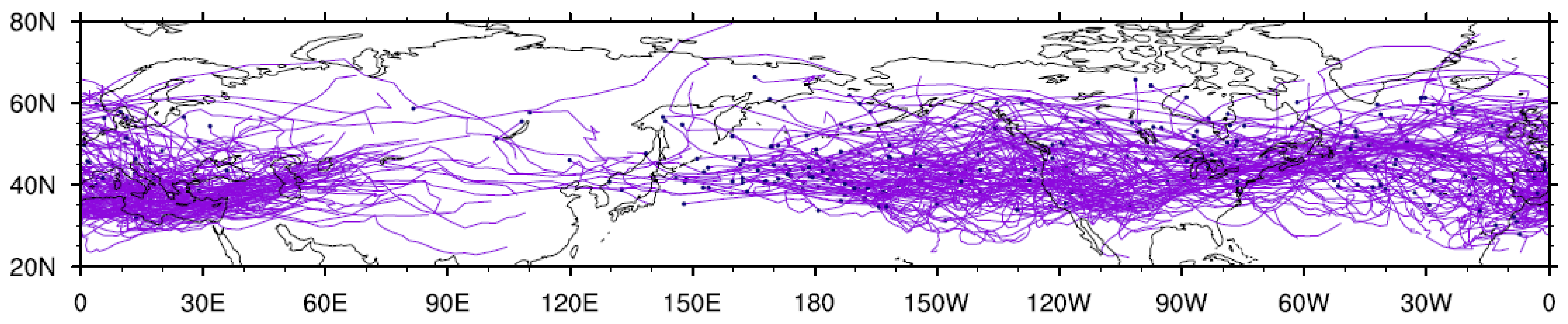
By analyzing Northern Hemisphere mid-latitude storm tracks and their influences on winter precipitation, we hope to provide guidance in seasonal forecasting and to further the development of climate prediction in conjunction with the mission of NOAA's Climate Prediction Center (CPC).

Methodology

A cyclone-tracking approach is used to identify and track individual storms from Potential Vorticity (PV) anomalies on the θ=320K surface, with a minimum cyclogenesis intensity threshold of 0.5 PVU, where 1 PVU is equivalent to 10^{-6} K m^2 kg^{-1} s^{-1}.

- PV acts as a dynamical tracer for storms because parcels (i.e., cyclones) conserve PV and θ in an adiabatic frictionless flow, so they must propagate along isocontours of isentropic PV.

IPV storm trajectories of highest 20% intensity, DJF 1980-2010

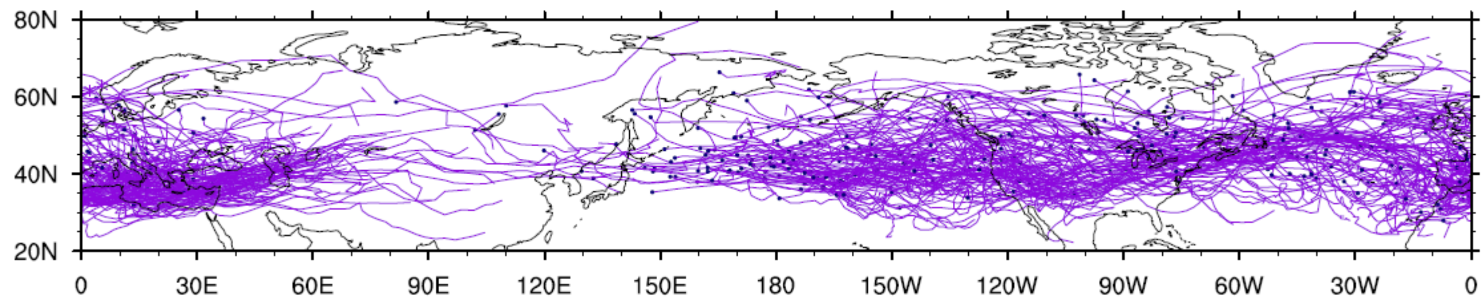


CFSR

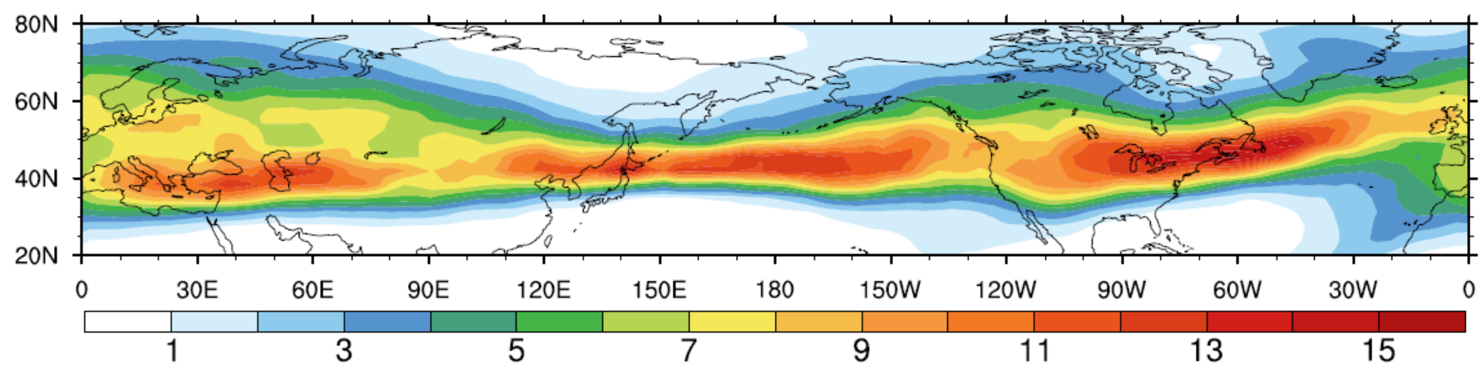
Methodology

- Storm tracks are represented by the track density of all identified cyclones that last at least 2 days and travel farther than 1000 km.
- Small-scaled features are captured.
- Cyclones and anticyclones are differentiated.

Storm Trajectories of Highest 20% Intensity



Storm Track Density 1980-2010



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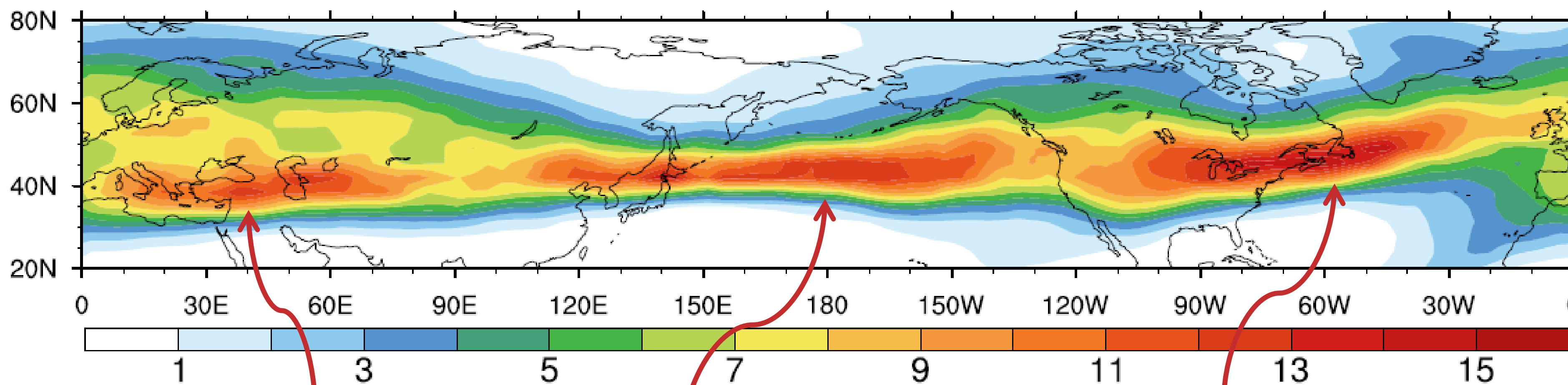
Storm Track Properties

Three storm tracks are easily identified.

Storm Track Density 1980-2010



Mediterranean Storm Track

Pacific (PAC) Storm Track

North American-Atlantic (NAA) Storm Track

Contour interval: 1.0 cyclone per 10^6 km^2 per month.

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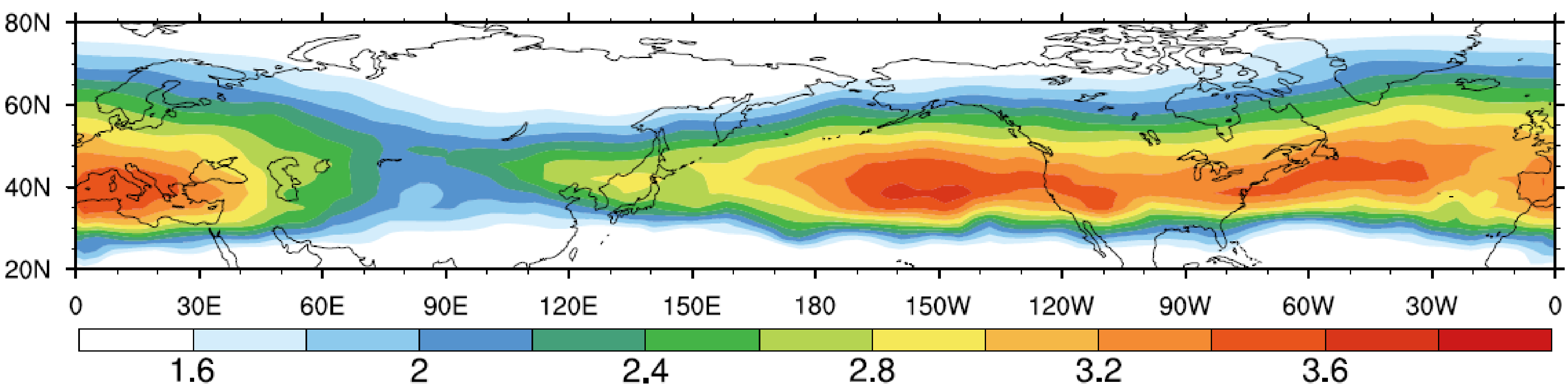
Storm Track Properties

Storm tracks are strongest over large water basins.

Mean Storm Intensity 1980-2010

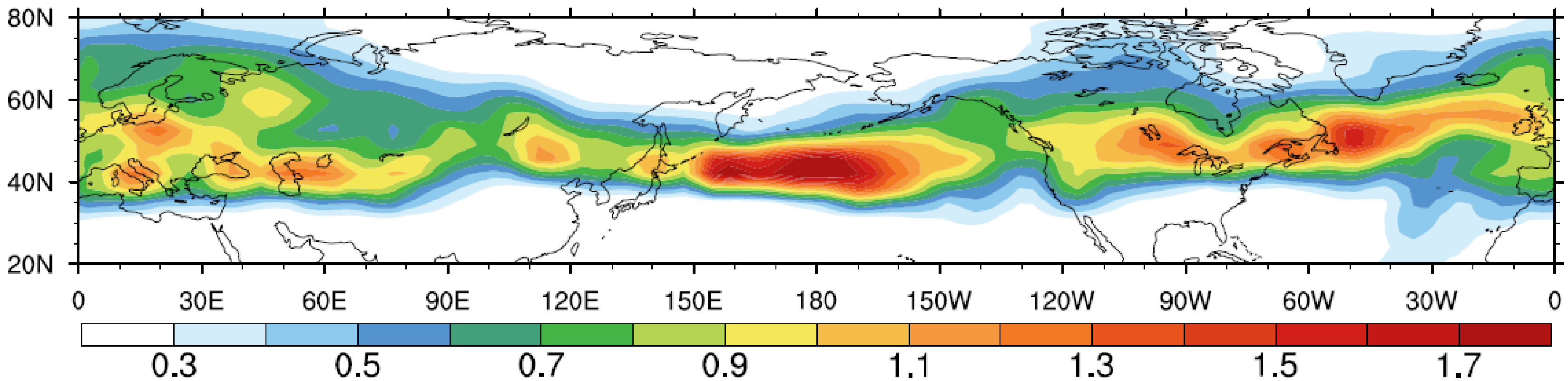


Contour interval: 0.2 PVU.

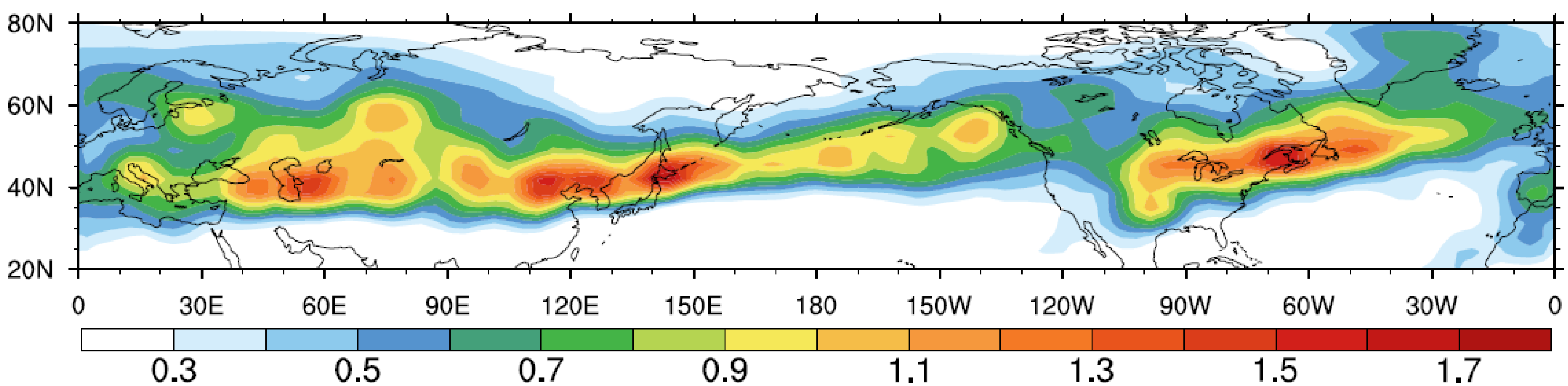
Storm Track Properties

Regions of cyclogenesis and cyclolysis are revealed.

Cyclogenesis Density 1980-2010



Cyclolysis Density 1980-2010



Contour interval: 0.1 cyclone per 10^6 km^2 per month.

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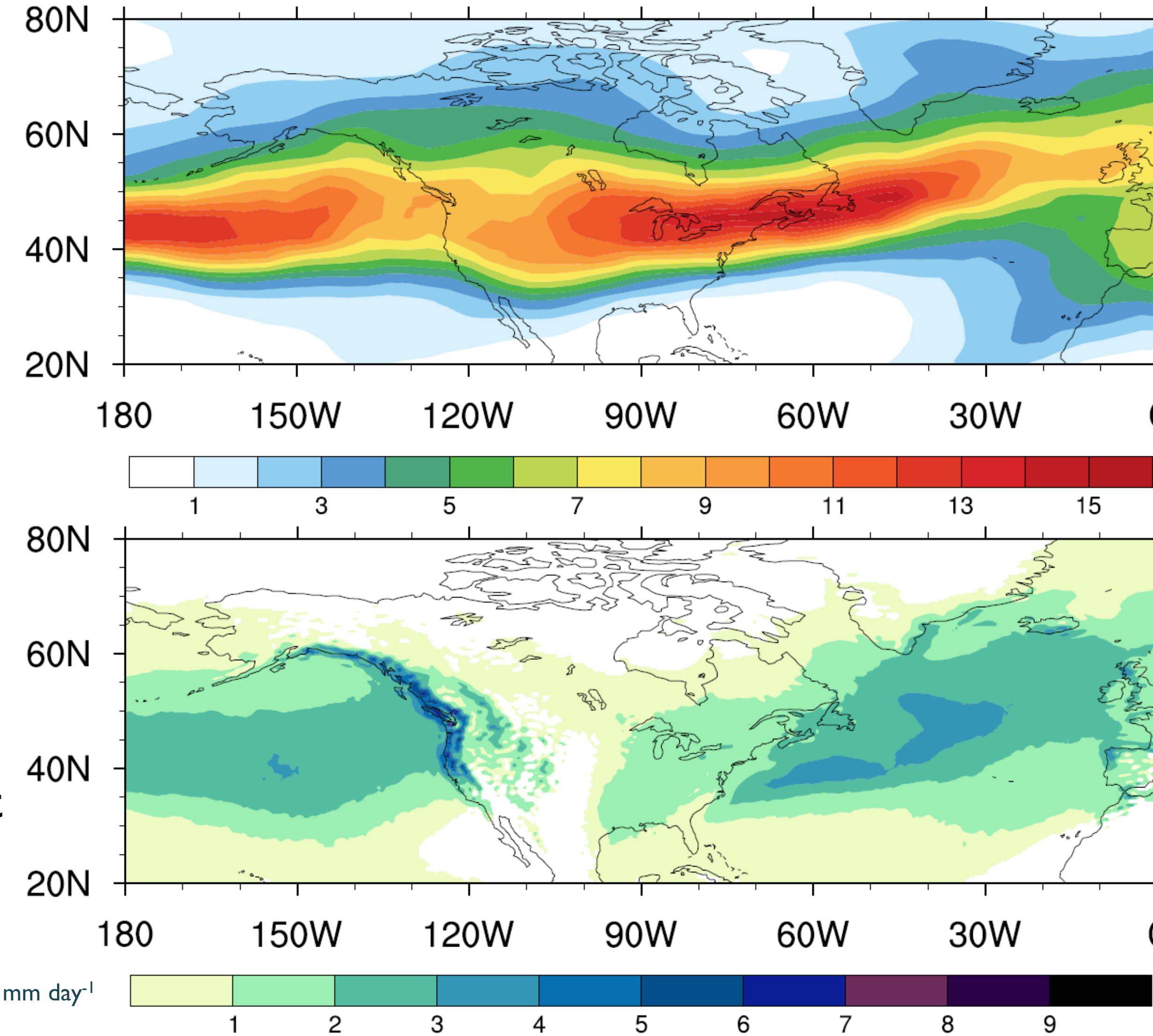
Storm-related Precipitation

1980-2010

Storm tracks leave strong precipitation footprints over the Pacific and Atlantic Oceans.

Precipitation from eastward propagating Pacific storms shows an enhanced signal over the west coast of North America due to orographic effects.



CI: 1.0 mm day^{-1}

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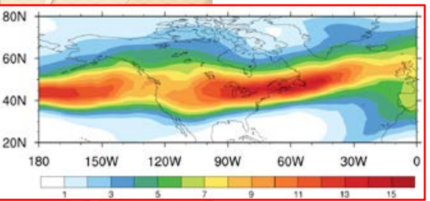
Storm-related Precipitation

1980-2010

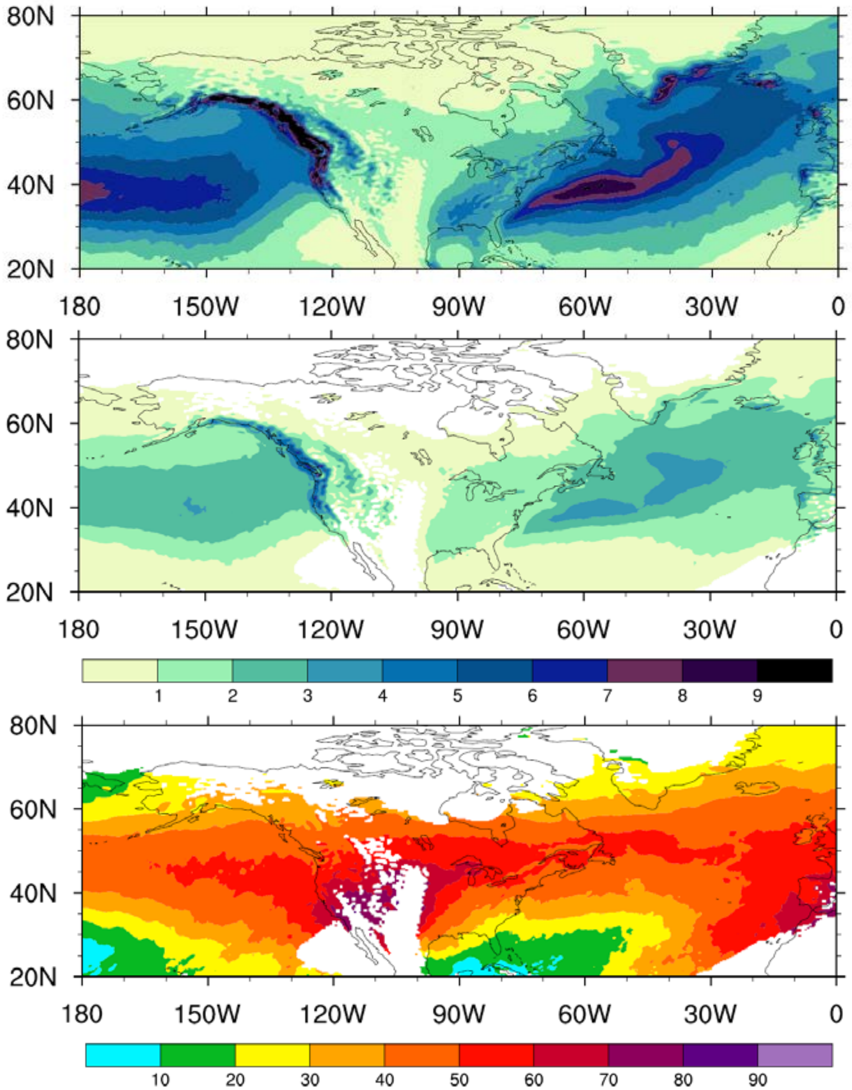


Storms produce 40-50% of the total precipitation over the oceans, and 50-60% in North America.

Total PR

Storm PR

PR %



CI: 1.0 mm day^{-1}

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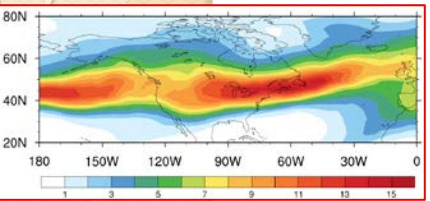


Reanalysis vs Observed

1999-2010

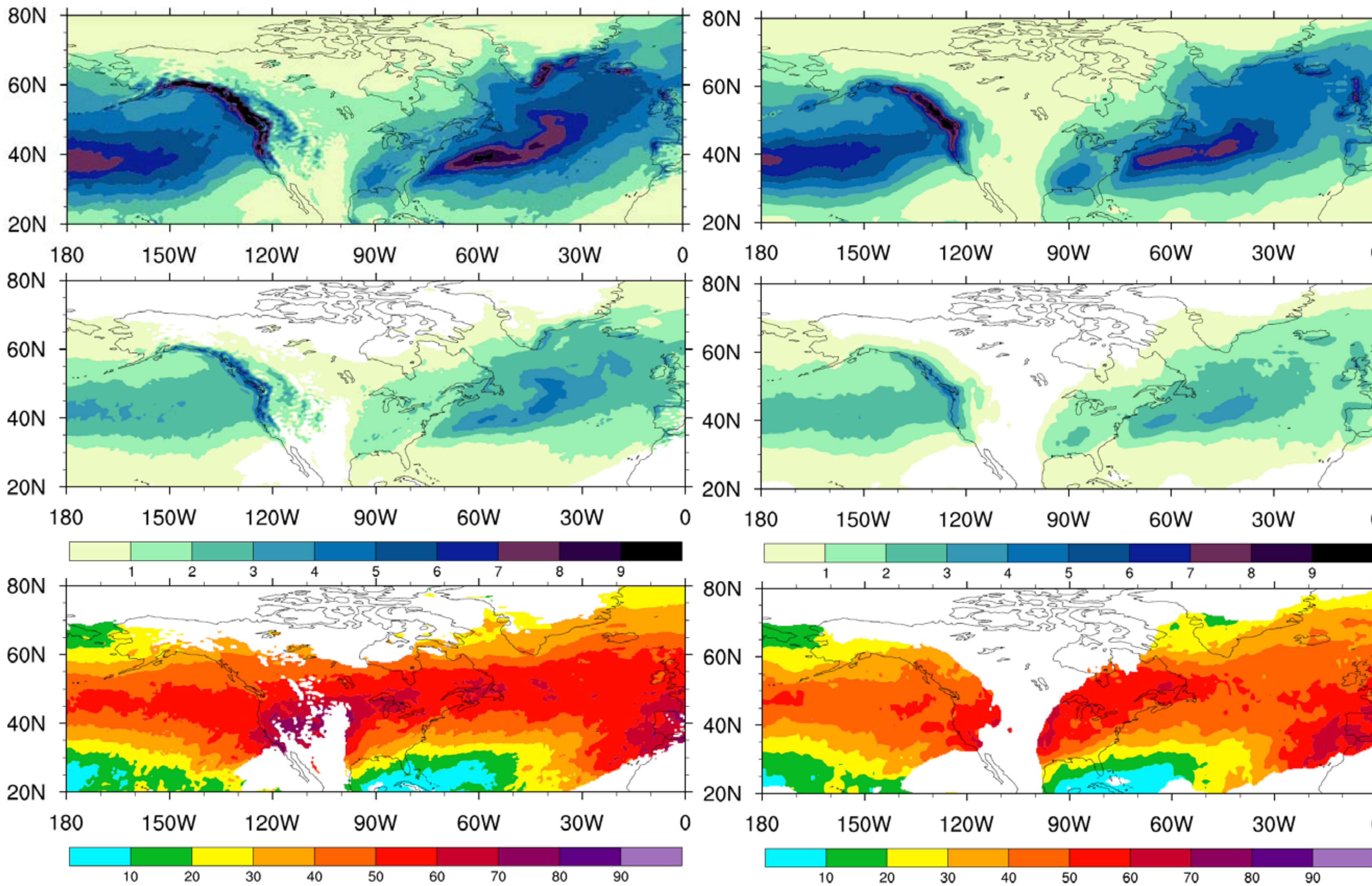
CFSR

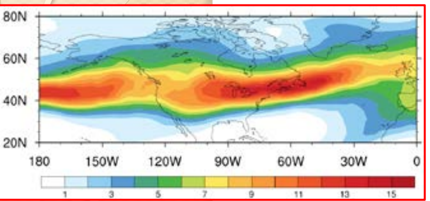
GPCP

Total PR

Storm PR

PR %





Reanalysis vs Observed

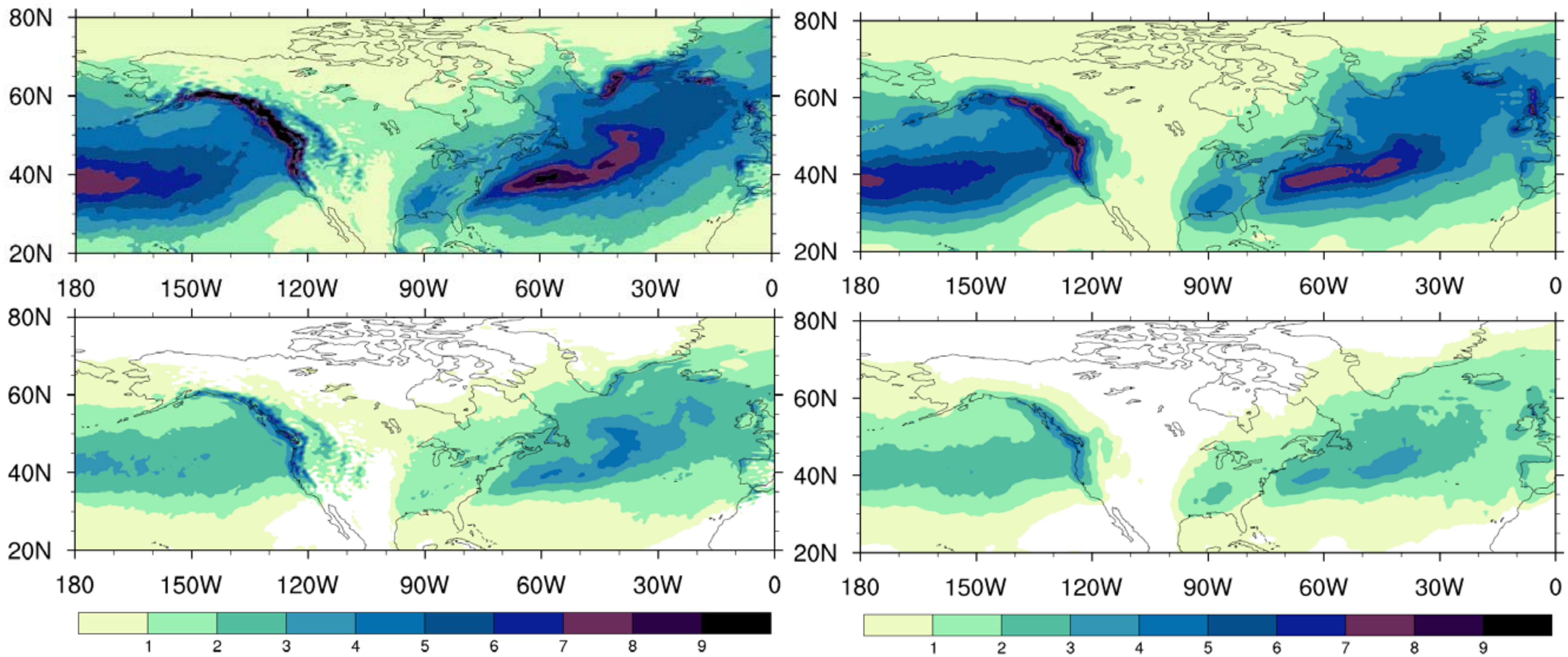
1999-2010

CFSR

GPCP

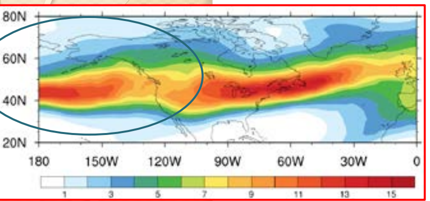
Total PR

Storm PR



Total and storm-related precipitation generally agree over the oceans and in North America.

- However, the reanalysis is noticeably more intense than observations, particularly in the North Atlantic Ocean and over the west coast of North America.

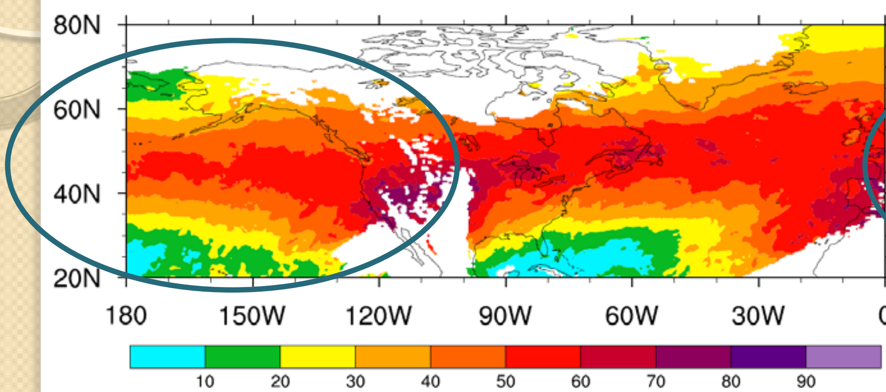


Reanalysis vs Observed

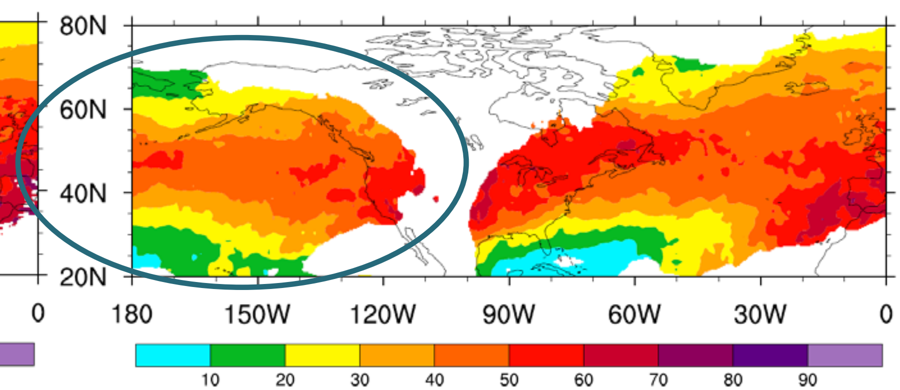
1999-2010

PR %

CFSR



GPCP



The **PAC storm track** yields:

- About 50% of the total reanalysis and 40-50% of the total observed precipitation over the North Pacific Ocean.
- 50-60% of the total reanalysis and 40-50% of the total observed precipitation over the west coast of North America.

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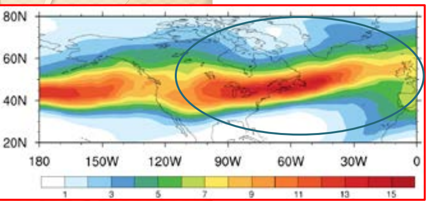
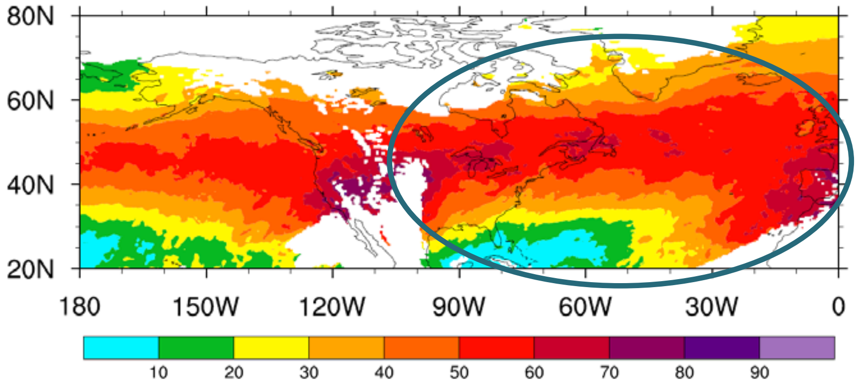


Reanalysis vs Observed

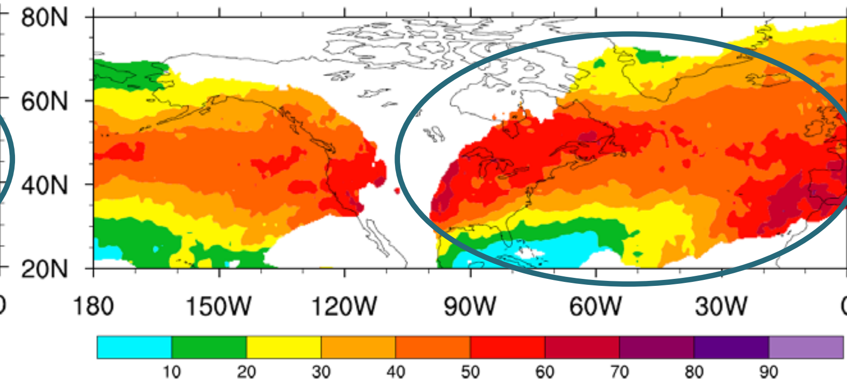
PR %

1999-2010

CFSR



GPCP



The **NAA storm track** yields:

- 50-60% of the total reanalysis and 40-50% of the total observed precipitation over the North Atlantic Ocean.
- 50-60% of the total reanalysis and about 50% of the total observed precipitation in eastern North America.

Summary

Three mid-latitude storm tracks are revealed following the evolution of PV perturbations.

Storm tracks leave conspicuous precipitation footprints where they are strongest (i.e., over the oceans), producing about half of the total precipitation there.

Storm tracks leave enhanced precipitation signals over the North American west coast in both reanalysis and observations.

The reanalysis overestimates the observed storm precipitation over the oceans and the North American west coast by 10%.

Thank you

Questions?

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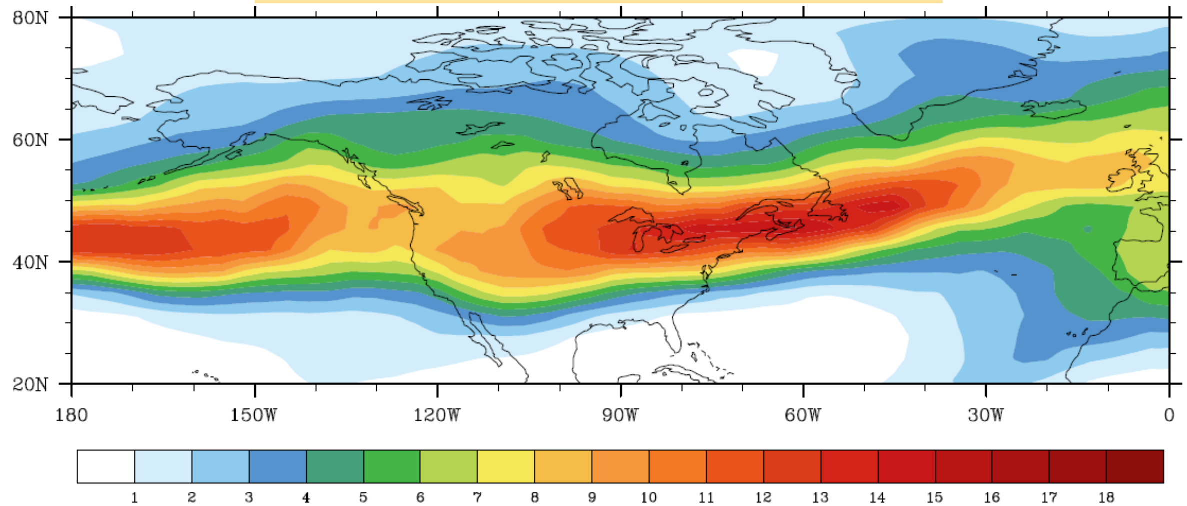
Key References:

Hawcroft, M. K., L. C. Shaffrey, K. I. Hodges, and H. F. Dacre, 2012: How much Northern Hemisphere precipitation is associated with extratropical cyclones? *Geophys. Res. Lett.,* **39**, L24809.

Hoskins, B. J., and K. I. Hodges, 2002: New perspectives on the Northern Hemisphere winter storm tracks. *J. Atmos. Sci.*, **59**, 1041-1061.

Supplemental Info

Storm Tracks DJF **1980-2010**



Storm Tracks DJF **1999-2010**