Ensemble Prediction and Predictability of Extreme Weather via Circulation Regimes

Control of Storminess over the Pacific and North America by Circulation Regimes

Enhances the upper and lower level storm tracks (Fig. 9b, c, respectively), while increasing the frequency of occurrence of atmospheric rivers (Fig. 9d) over this region. All of these indicators are consistent with a positive precipitation anomalies (Fig. 10c, d respectively) and an increase in the probability of having extreme precipitation in a relatively narrow region over the west coast (Fig. 10a).

In addition, the ridge centered over the Midwest and Northeast along with the dry air coming from Canada (Fig. 9a) cause a negative shift/normalized shift in precipitation over the Midwest (Fig. 10c, d, respectively) and cause intra-seasonal drought over the Midwest and Northeast (Fig. 10b). While our results show an increase in the frequency of extreme precipitation over southern Florida during this regime, there is no significant moisture flux or enhancement of atmospheric rivers over this region, although more active atmospheric rivers are seen just to the south of Florida. The extreme precipitation can be explained by the interaction of the extended upper level storm track (Fig. 9b) across the entire southern tier of North America with the high amount of background moisture in this region.

4.5 Arctic high

During this regime (Fig. 11a) a strong ridge centered over the Gulf of Alaska and a trough centered over central north Pacific direct the moisture in a broad swath from the central Pacific to the western US (see Fig. 12c, d). In the central North Pacific, the meridional gradient between the ridge and trough causes anomalous easterlies and thus a decrease in the frequency of atmospheric rivers (Fig. 11d) and weakened storm tracks in both upper and lower levels (Fig. 11b, 11e).

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Center for Ocean-Land-Atmosphere Studies
• Precipitation is one of the most poorly simulated and predicted quantities

• Models are generally skillful in simulating and predicting the large-scale large-scale circulation regimes.

• Patterns of storminess and extreme weather may be directly linked to circulation regimes

Can we use circulation regimes to extend predictions of extreme weather into the S2S time scales?
Circulation Regimes

- 500 hPa geopotential height
- k-means cluster analysis to group all states so that each 5-day running mean is assigned to one of the groups
- Each group of states is then associated with a characteristic map, called a circulation regime
- Principal Component Space (12 PCs) ~80% of the total space-time variance
Example: Applying k-means algorithm
Circulation Regimes Pacific – North America Region

Cluster Centroids
ERA–I 1980–2015 DJF
Z500 12_pcs (units: meters)
relationship of circulation regimes to storminess and extreme weather

4.3 Alaskan Ridge
During the Alaskan Ridge regime (Fig. 7a) a strong high-pressure system is dominant over the North Pacific and Gulf of Alaska, with low pressure extending from the northeast to the southwest of the continental US. Similar to the Arctic Low regime, this low-pressure configuration prevents the moisture flux anomaly from penetrating the west coast, except far north in Alaska (Fig. 8c, d). A weaker high-pressure system centered over southeast of the US directs the moisture flux anomaly from two different sources, the eastern Pacific and the Gulf of Mexico, to the southern states of the US (Fig. 8d). The enhanced moisture flux increases the atmospheric river frequency over the broad southern tier of the US (Fig. 7d), leading to a positive anomalies in precipitation further north (Fig. 8c, d) as well as a strong enhancement of the probability of extreme precipitation (Fig. 8a). The branch of moisture flux coming from the eastern Pacific is consistent with a southward shift in atmospheric river frequency (Fig. 7d), positive anomalies in precipitation over southern California (Fig. 8c, d) and an increase in the frequency of extreme precipitation over this region (Fig. 8a).

4.4 Pacific Trough
During the Pacific Trough regime (Fig. 9a), the low pressure center over the North Pacific directs enhanced moisture flux towards the west coast of the US (Fig. 10c, d) and...
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Control of storminess over the Pacific and North America by circulation regimes enhances the upper and lower level storm tracks (Fig. 9b, c, respectively), while increasing the frequency of occurrence of atmospheric rivers (Fig. 9d) over this region. All of these indicators are consistent with a positive precipitation anomalies (Fig. 10c, d respectively) and an increase in the probability of having extreme precipitation in a relatively narrow region over the west coast (Fig. 10a).

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Are Circulation Regimes Predictable?

Examples from S2S ECMWF reforecasts with 11 members: 1995-2014

Method:
- Project Forecast Z500 anomaly onto leading 12 EOFs from ERA-Interim for the appropriate period.
- In PC space, assign each forecast day to one of the 5 cluster centroids shown previously, using one of two methods:
  1. Match the forecast with the regime closest to its using Euclidean distance in PC space (same measure used to define clusters).
  2. Match the forecast with any regime with which it has a pattern correlation exceeding 0.40. *(Caveat: A forecast may be matched to more than one regime).*

On any given day, how many ensemble members are assigned the correct (verifying) circulation regime?
Forecasts Initialized: Dec 03 1997

- # members pattern corr with cluster >0.4
- # members assigned observed cluster
- Cluster assigned to each forecast
- Pattern correlation with cluster centroid

Graphs showing lead time (days) vs. number of members for different clusters:

- Arctic High
- Alaskan Ridge
- Pacific Trough
- Pacific Wave Train
- Arctic Low
Forecasts Initialized: Dec 31 2009

Cluster assigned to each analysis
Pattern correlation with cluster centroid

Arctic High
Alaskan Ridge
Pacific Trough
Pacific Wave Train
Arctic Low

Lead Time (Days)

# members pattern corr with cluster >0.4
# members assigned observed cluster
Cluster assigned to each analysis
Pattern correlation with cluster centroid
Forecasts Initialized: Dec 3 2010

# members pattern corr with cluster >0.4
# members assigned observed cluster
Cluster assigned to each analysis
Pattern correlation with cluster centroid

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Conclusions

• PNA Circulation regimes are related to extreme weather and storminess
• Evidence that ECMWF model can predict circulation regimes for some specific cases

Future Work

Advance the predictive capability of extreme weather on the S2S timescales, over the Euro-Atlantic and Pacific-North American regions, using reforecasts and forecasts from S2S, SubX, NMME