Wintertime weather regimes over North America and their predictability from submonthly reforecasts

International Research Institute for Climate and Society
Earth Institute | Columbia University

N. Vigaud, A.W. Robertson, M.K. Tippett and J. Yuan

1) Data & Methods

Objective: stratify wintertime weather using a reduced-order weather regime (WR) view and examine regime reproducibility in submonthly reforecasts with starts in October-March

Methodology: *k-means* clustering (*Michelangeli et al*, 1995) of daily 500hPa geopotentials (Z500) from re-analyses and subseasonal-to-seasonal (S2S) reforecasts (*WMO*, 2013)

Data: Oct-Mar MERRA-1 re-analyses (1982-2014) and 11-member ensemble mean ECMWF week-1 (day 0-6) reforecasts (1996-2015) with 2016 Thursday starts. Skill is then examined from ECMWF week-1 to week-4 reforecasts ([*d*;*d*+6] to [*d*+21;*d*+27] for a forecast on day *d*)

2) Recurrent wintertime regimes

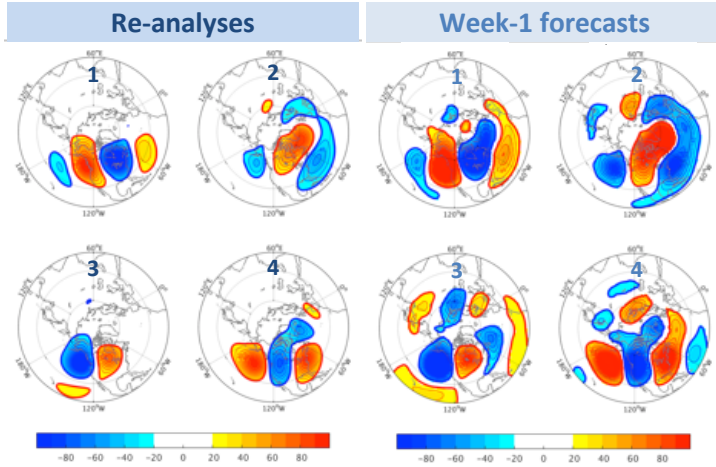
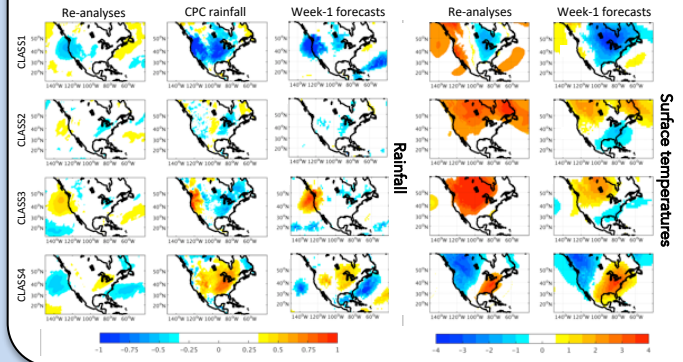


Fig.1: Mean MERRA (left) and ECMWF week-1 (right) Z500 anomaly patterns for each weather regimes identified over the 1982-2014 and 1996-2015 periods, respectively

Maximum classifiability of daily Z500 MERRA re-analyses (not shown) for a 4-cluster partition (Fig. 1 left panels) with patterns similar to earlier studies (*Strauss and Molteni*, 2004; *Stan and Strauss*, 2007; *Strauss et al*, 2007)

Three regimes resemble Rossby wavetrains (1, 3 & 4) and one regime (2) is related to the NAO



All WRs are well reproduced in ECMWF week-1 forecasts (Fig. 1, right panels), as well as associated rainfall and surface temperature anomalies (Fig. 2)

Fig.2: MERRA/CPC and ECMWF week-1 rainfall anomalies for the respective MERRA and ECMWF regimes (left), alongside corresponding MERRA and ECMWF surface temperature anomalies (right)

3) Predictability from submonthly reforecasts

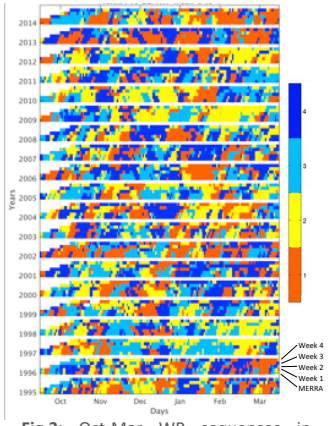


Fig.3: Oct-Mar WR sequences in MERRA and ECMWF week-1 to week-4 when projected onto MERRA WRs

ECMWF skill in predicting yearly and daily counts of WR occurrences (Fig. 3) decreases with increasing lead (Figs. 4 and 5)

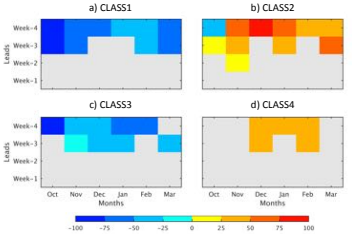


Fig.4: Differences in yearly counts (in days) between MERRA and ECMWF

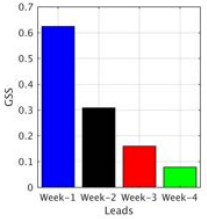


Fig.5: Gerrity skill score (GSS) for daily occurrences

Skill is limited for weekly counts after 2 weeks (Fig. 6) with maximum MJO relationships (Fig. 7) between 5-15 days, i.e. the time-scales of MJO influence on extra-tropics and NAO to establish (*Jin and Hoskins*, 1995; *Lin et al*, 2007), and for phases 3 and 6, consistent with MJO dipole favoring extratropical teleconnections (*Lin et al*, 2009, 2010; *Lin and Brunet*, 2018)

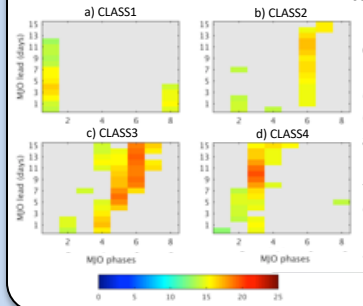
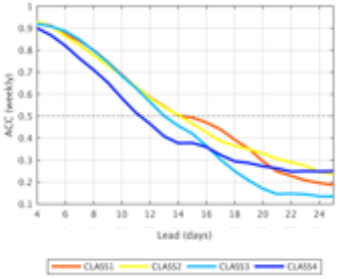


Fig.6: Anomaly Correlation Coefficients (ACC) for ECMWF as a function of lead (in *days*) for weekly targets (i.e., the period [*d*-3;*d*+3] for a lead of *d* days)

Fig.7: Percentage of WR occurrences per MJO phases (*x*-axis) in MERRA re-analyses as a function of lead time (*y*-axis, in *days*)



4) Conclusions

Four recurrent wintertime weather regimes are identified over North America through a *k-means* clustering applied to MERRA re-analyses 500hPa geopotential heights. These resemble Rossby wavetrain patterns, except one regime related to the NAO. The 4-cluster partition and associated rainfall/surface temperature anomalies are well reproduced in ECMWF week-1 reforecasts, however, the skill in forecasting daily regime occurrences and weekly regime counts is largely limited to two weeks with MJO relationships suggesting potential opportunities for skillful predictions.

REFERENCES: Jin, F., and B. Hoskins (1995) The direct response to tropical heating in a baroclinic atmosphere, *J. Atmos. Sci.*, 52, 307–319; Lin, H., and G. Brunet (2009) The influence of the Madden-Julian Oscillation on canadian wintertime surface air temperature, *Mon. Wea. Rev.*, 137, 2250–2262; Lin, H., and G. Brunet (2018) Extratropical response to the MJO: Nonlinearity and sensitivity to the initial state, *Mon. Wea. Rev.*, 75, 219–234; Lin, H., G. Brunet, and J. Derome (2009) An observed connection between the North Atlantic Oscillation and the Madden-Julian Oscillation, *J. Climate*, 22, 364–380; Lin, H., G. Brunet, and R. Mo (2010) Impact of the Madden-Julian Oscillation on wintertime precipitation in Canada, *Mon. Wea. Rev.*, 138, 3822–3839; Michelangeli, P., R. Vautard, and B. Legras (1995) Weather regime occurence and quasi-stationarity, *J. Atmos. Sci.*, 52, 1237–1256; Strauss, D., S. Corti, and F. Molteni (2007) Circulation regimes: Chaotic variability versus SST forced predictability, *J. Climate.*, 20, 2251–2272; Stan, C., and D. Straus (2007) Is blocking a circulation regime?, *Mon. Wea. Rev.*, 135, 2406–2413; Straus, D., and F. Molteni (2004) Circulation regimes: Results from large GCM ensembles, *J. Climate*, 17, 1641–1656; World Mondial Organization (2013) Sub-seasonal to Seasonal prediction, *Research Implementation plan report*, Geneva, pp. 63