P-15 The Projection of Northern Hemisphere Flow Regime Transitions Using Integrated Enstrophy.

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Introduction

- The work of Lorenz (1963) implied the Northern Hemisphere (NH) flow vascillates between two quasi-equilibrium states. Charney and DeVore (1979) postulated the NH flow may possess multi-equilibria, including those that represent blocking.
- Dymnikov et al. (1992) introduces a quantity called integrated Enstrophy (IE), which in a barotropic atmosphere correlates highly to the positive Lyapunov exponent in the NH.
- Jensen et al. (2017) and references therein show that IE may be useful for identifying block onset and decay, as well as flow regime transition.

Motivation/Objective/Goal

- Ensemble models have been used to improve model performance and mitigate the issue of sensitive dependence on initial conditions.
- It may be possible to use IE to anticipate a change in the prevailing NH flow regime and/or the onset or decay of blocking.
- Thus, IE in conjunction with ensemble modelling may be used to improve local and/or regional weather prediction in the 6-21 day time frame. http://weather.missouri.edu/naefs/IRE-NAEFS-MU.html

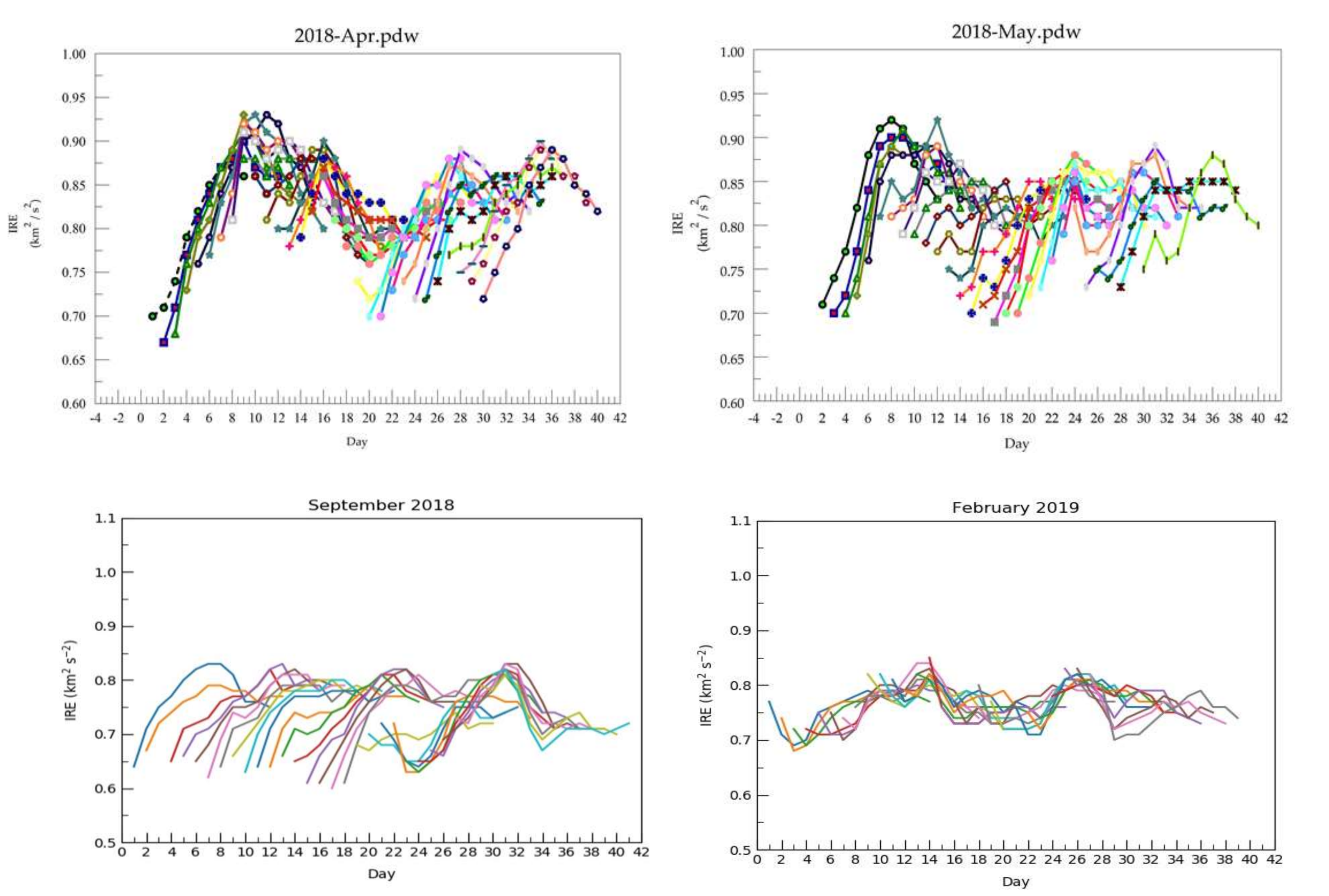

Figure 1. The April 2018 (top left), May 2018 (top right), September 2018 (bottom left) 2018, and February 2019 (bottom right) daily mean GEFS Ensemble IE derived from the NH 500 hPa height field. Each plume shows the 10-day forecast in 24 h increments.

Table 1. All NH blocking events from 1 April – 20 May 2018 using the Wiedenmann (2002) blocking criterion. All definitions for sector or block intensity (BI) are found in the reference or at http://weather.missouri.edu/gcc. All durations are in days.

Sector	Duration	Onset	Termination	BI	Onset Location
Pac.	9	1200 UTC 30 April	1200 UTC 8 April	4.24	170° W
Atl.	12.5	1200 UTC 10 April	0000 UTC 23 April	3.94	10° E
Pac.	10	0000 UTC 13 April	0000 UTC 23 April	3.67	160° E
Atl.	7.5	1200 UTC 28 April	1200 UTC 5 May	2.21	30° E
Atl.	14	0000 UTC 1 May	0000 UTC 15 May	3.79	-40° W
Cont.	9	0000 UTC 3 May	0000 UTC 12 May	3.78	130° E
Cont.	7	1200 UTC 13 May	1200 UTC 20 May	2.15	120° E

Acknowledgements

- Thanks to Missouri EPSCOR for partially funding this work, NSF Award IIA-1355406. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of NSF.

Data and Methods

- The 500 hPa daily height (m) provided by the National Centers for Environmental Prediction (NCEP) / North American Ensemble Forecast System (NAEFS) and the Global Ensemble Forecast System (GEFS) were used for the period of August 2018 to March 2019.
- The observed four-times daily 500 hPa re-analyses provided by the NCEP / National Center for Atmospheric Research (NCAR) were also used.
- The 500 hPa height for each ensemble member is used to calculate geostrophic vorticity which is integrated across the NH to 70° N. The IE is:
- $Integrated\ Enstrophy\ (IE) = \int_A \zeta_g^2 dA \ \ (1)$

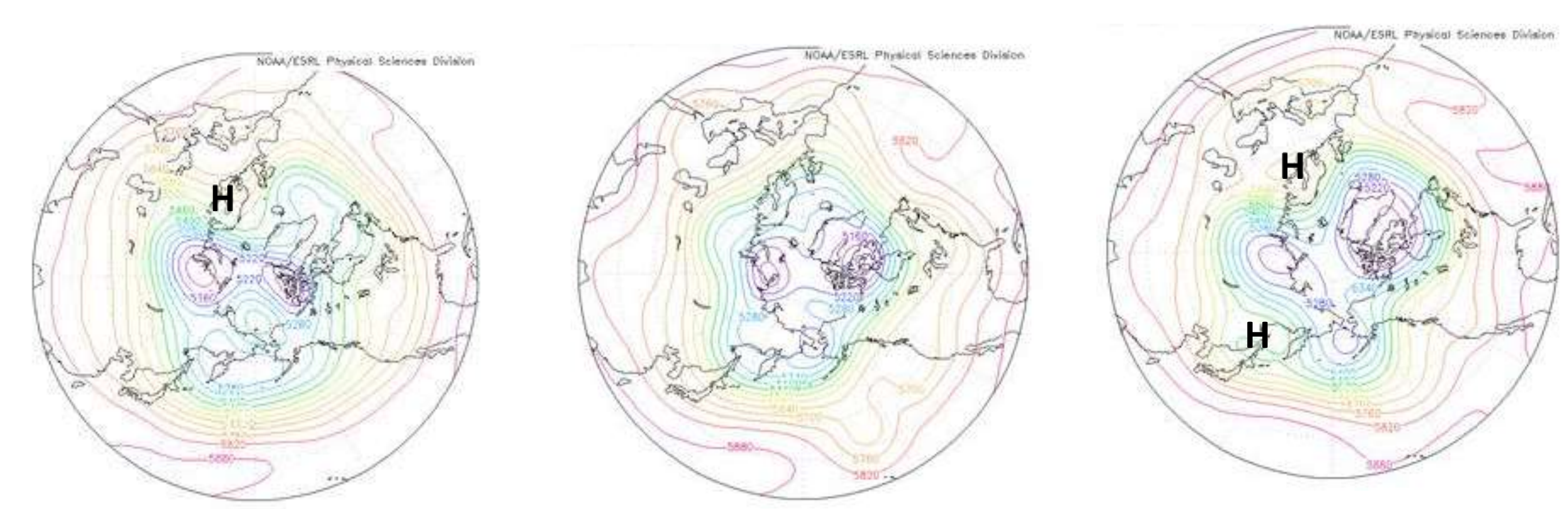

Figure 2. The observed 500 hPa height for 13 – 23 April (left), 24 April – 2 May (middle), and 2 – 15 May 2018. A black 'H' represents regions where blocking was prevalent.

Table 2. The probability of detection for the ensemble model to detect flow regime changes at Day 1, 4, 7, 10 from August 2018 – February 2019. The ability of the model to detect these above the noise is (d') = z(POD) – z(FAR) = 0.7895 (significant at the 80% confidence level).

Forecast	POD	MISS	FAR	MEAN	STDEV
10-day	0.38	0.62	0.59	-1.5	1.4
7-day	0.85	0.15	0.12	+0.1	1.1
4-day	0.79	0.21	0.21	+1.0	1.4
1-day	0.90	0.10	0.10	+0.4	1.6

Two Case Studies – Hit and Miss

- Miss case August 21, 2018. Mean temperature across MO – 25.3 °C (+0.0° C), rain observed during 60% of days before the miss (49 mm). Following the date 25.0 C +0.8 °C), rain observed during 45% days after miss (51 mms).
- Hit Case 14 February 2019. Mean temperature across MO - -0.5 °C (-1.5 °C), rain observed on 60% of days (42 mm), no snow (T). Following the date: -2.0° C (-3.5 °C), well below normal and snow at all sites (5 – 30 cm) and 24.6 mm precipitation.

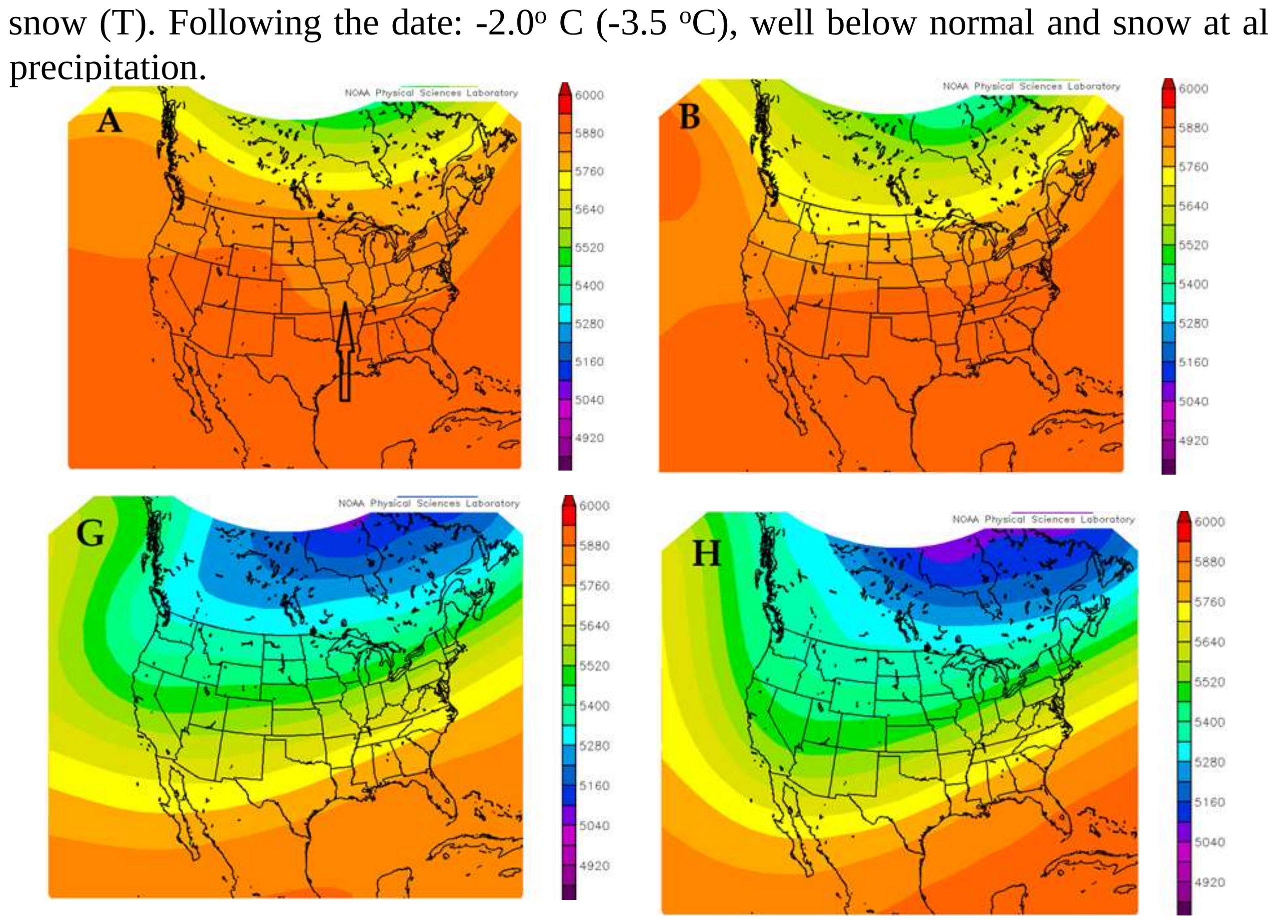

Figure 4. As in Fig. 2, except for 11 – 20 August 2018 (top left), 21 – 30 August 2018 (top right), 5 – 14 February 2019 (bottom left), and 15 – 24 February 2019 (bottom right).

What is Integrated Enstrophy (IE)?

- Entrophy is the square of the relative vorticity (ζ^2). Therefore, all enstrophy values will be positive, whether a circulation is cyclonic or anticyclonic. For example, if we consider the case of an area with a strong blocking anticyclone, and significant cyclones immediately adjacent, we would expect relatively large values of negative and positive vorticity, respectively. Therefore, that region will also feature significant integrated enstrophy values.
- A positive trend in IE suggests more and/or stronger circulations over a region and may portend a regime change toward low index flow (Fig. 3).
- Jensen et al. (2017) demonstrate that IE is related to Entropy (Kolmogorov-Sinai Entropy - KSE). Thus, IE can be thought of as a measure of predictability (higher values, less predictability). Relative maxima should be associated with flow regime transitions.

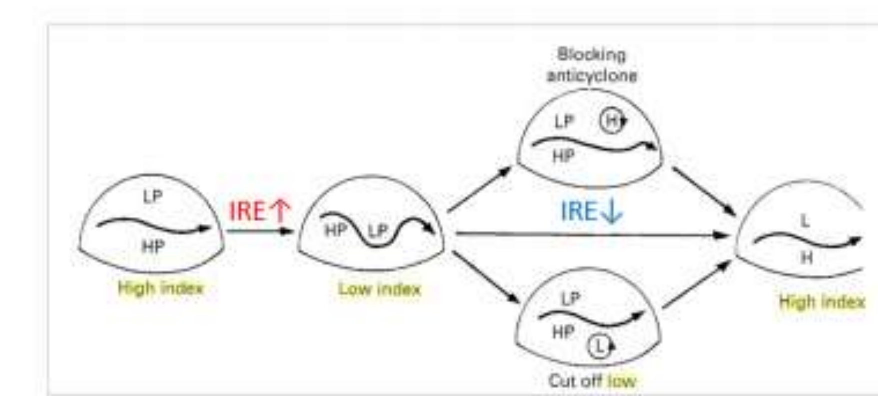

Figure 3. Schematic showing examples of periods when regional enstrophy should be increasing (IRE↑) and decreasing (IRE↓) with time. Modified from Robinson and Henderson-Sellers (1999).

Summary and Conclusions

- An automated system has been developed to download the 500 hPa height for the GEFS and NAEFS ensemble information for the NH, and is used to calculate IE.
- The ensemble mean IE is used to display day-by-day forecast values in 24-h increments out to 10 days. Daily forecasts are shown in order to check for model consistency.
- This system has been in place since February 2018, and the NH flow was examined here to demonstrate the efficacy of the IE method used in conjunction with ensemble models.
- The IE has utility in identifying regime transition as well as block onset and termination (see Jensen et al. 2017). Block onsets and terminations were identified for April and May 2018.
- The ability of the model to anticipate flow regime transition shows promise even out to 10 days. If all days are used the POD was greater than the number of FAR, and this was significant at greater than 80% confidence.
- When examining a MISS case, we can demonstrate that the weather regime in the Midwest USA was similar before and after the miss.
- When examining a HIT case, the weather regime before and after the regime change was significantly different.

Table 3. As in Table 2, except for the mean absolute error (forecast – observations = MAE), mean number of points for the forecast period (0.00 – 2.00), and skill score (0.00 – 1.00).

Forecast	MAE	Points	Skill
10-day	0.019	1.44	0.42
7-day	0.029	1.47	0.45
4-day	0.018	1.58	0.56
1-day	0.006	1.74	0.74
Climatology	0.064	1.03	0.00