

# On the Resonances and Teleconnections of the North Atlantic and Madden-Julian Oscillations

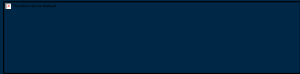
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EGU, May 4, 2020



# Outline

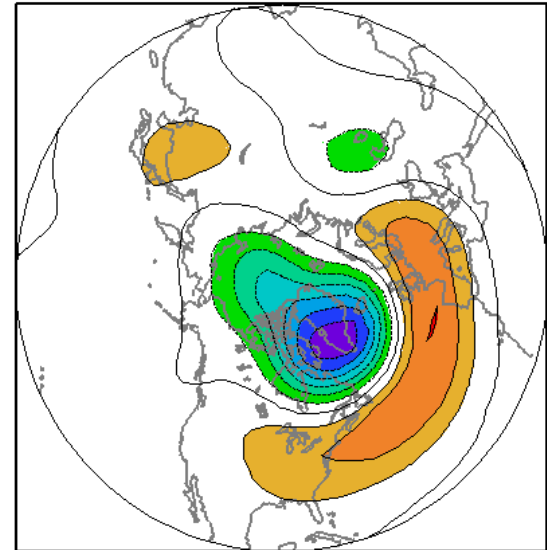
- Introduction
- Three ways to identify the NAO as a normal mode with resonant behavior
- Conclusion



# Introduction

- What is the dynamical interpretation of the North Atlantic Oscillation (NAO)?
- The NAO: a normal mode? If yes then it should resonate at its natural frequency in well-tought numerical experiments and in the observed atmosphere.
- Words of caution: normal mode thinking is based on linear and weakly nonlinear GFD theory.

A definition of the NAO:  
2<sup>nd</sup> REOF of monthly Z500

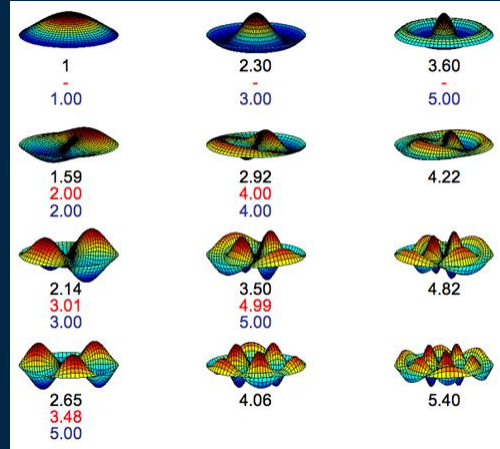


# Three ways to identify the NAO as a normal mode

- 1) Solving normal mode differential equations for steady atmospheric flows;
- 2) An EOF analysis using wave activities (i.e. conservation laws);
- 3) To identify the NAO as a resonant pattern for a given periodic forcing in time.



Basic State



Normal Modes

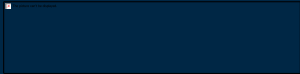
Montreal Jazz Festival 1982



Buddy Rich

# Way 1: Solving a normal mode partial differential equation for a steady atmospheric flow

- Frederikson and Lin (JAS, 2013):  
Tropical–Extratropical Interactions of Intraseasonal Oscillations
- They have identified a 34-day normal mode with a NAO-MJO teleconnection signature.

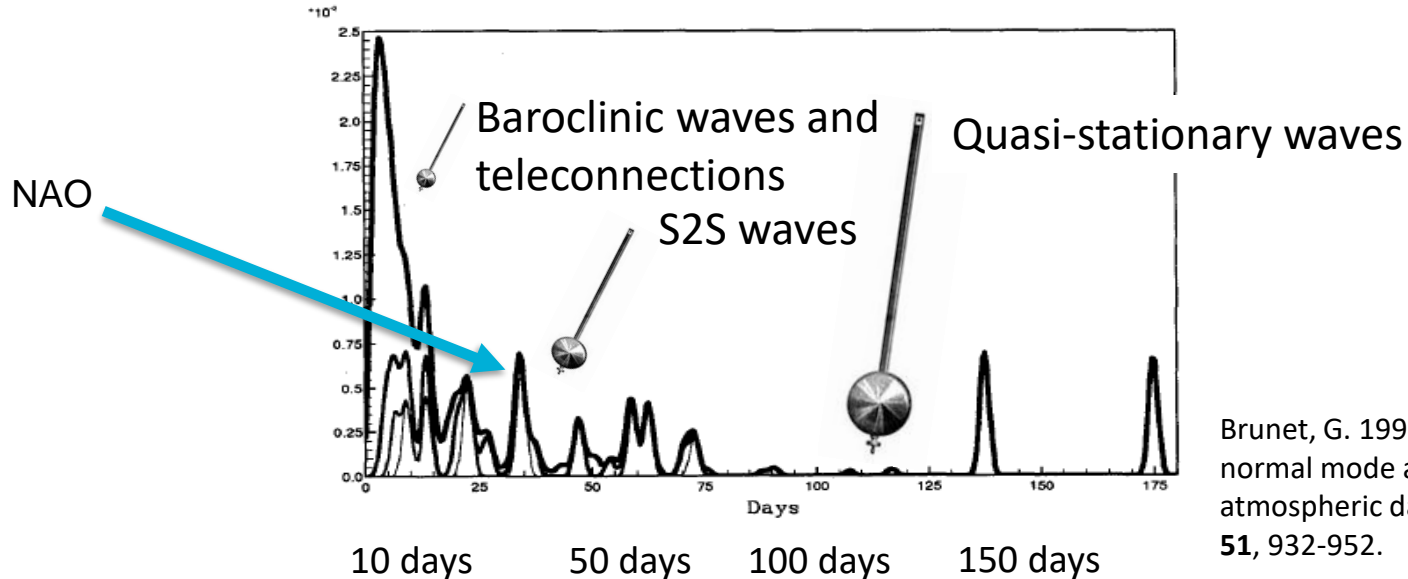


Way 2: An EOF analysis using wave activities (i.e. conservation laws)



# Wave Activity on the NH 315K isentropic surface for 24 winters

- Cumulative wave activity in function of calculated ENM resonant time period



Brunet, G. 1994 Empirical normal mode analysis of atmospheric data. J. Atmos. Sci., **51**, 932-952.

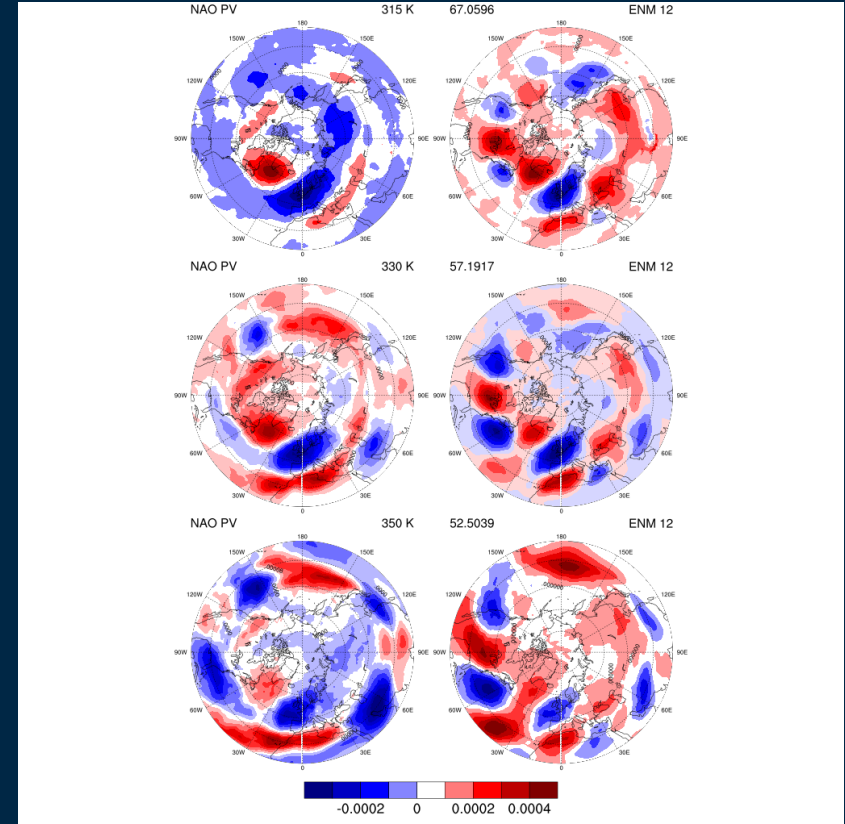
Continuous spectrum (80%)

Discrete spectrum (dim. ~ 12, 20%)

- The low frequency variability (NAO, PNA, Atlantic blockings, MJO ...) controls significantly the distribution of high-impact weather (like the Atlantic storm track and wave guides).

# A 3D ENM analysis for four NDJFM (2013-17)

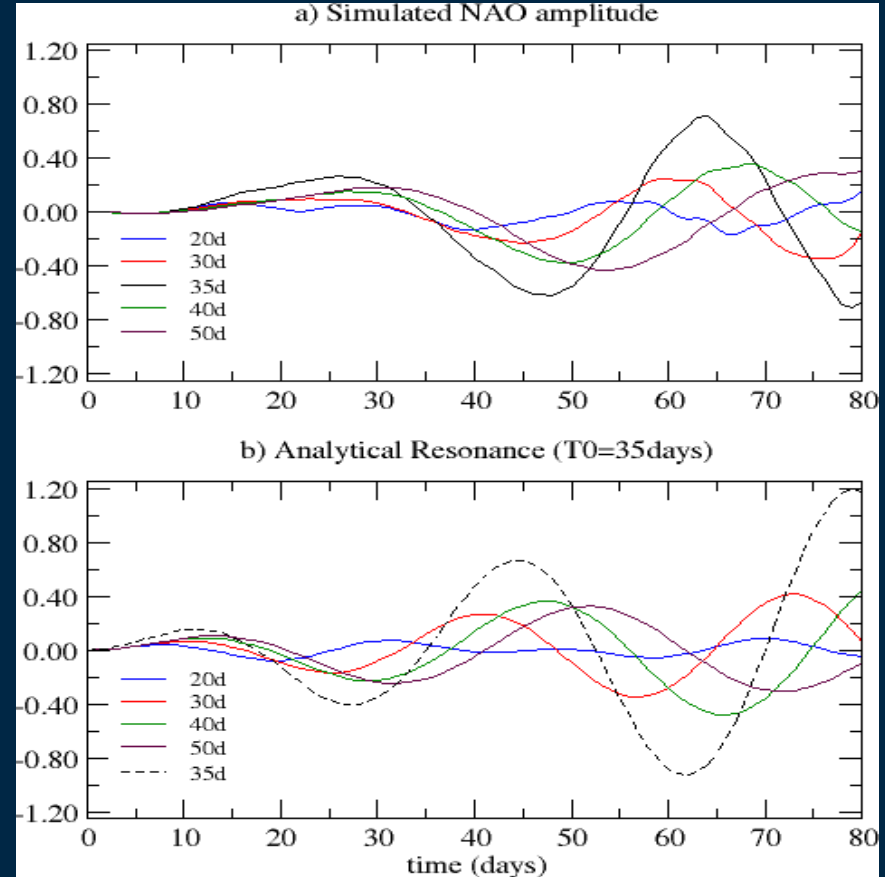
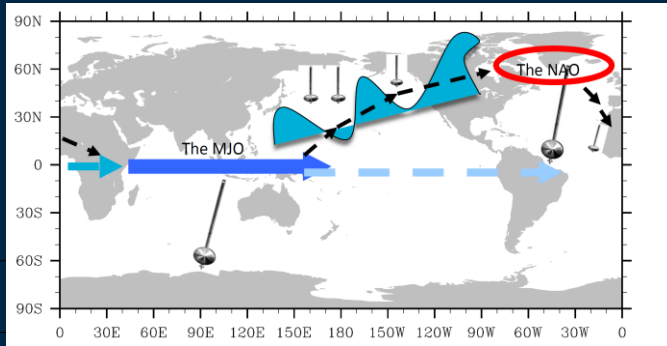
- ENM 12 shows the highest correlation with NAO PV.
- Resonant Period of ENM12 is 38 days.



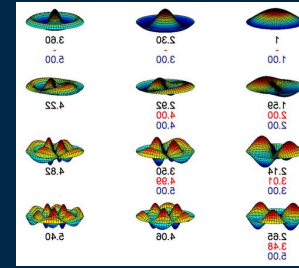


# Way 3: To identify the NAO as a resonant pattern for a given periodic forcing

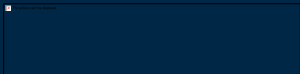
- Resonant numerical experiments using a simple general circulation model (Hall, 2000; Lin et al., 2010);
- Tropical forcing with an idealized small thermal forcing which is applied with different frequencies;
- An almost perfect fit is observed with a lag of 15 days.



# Conclusion

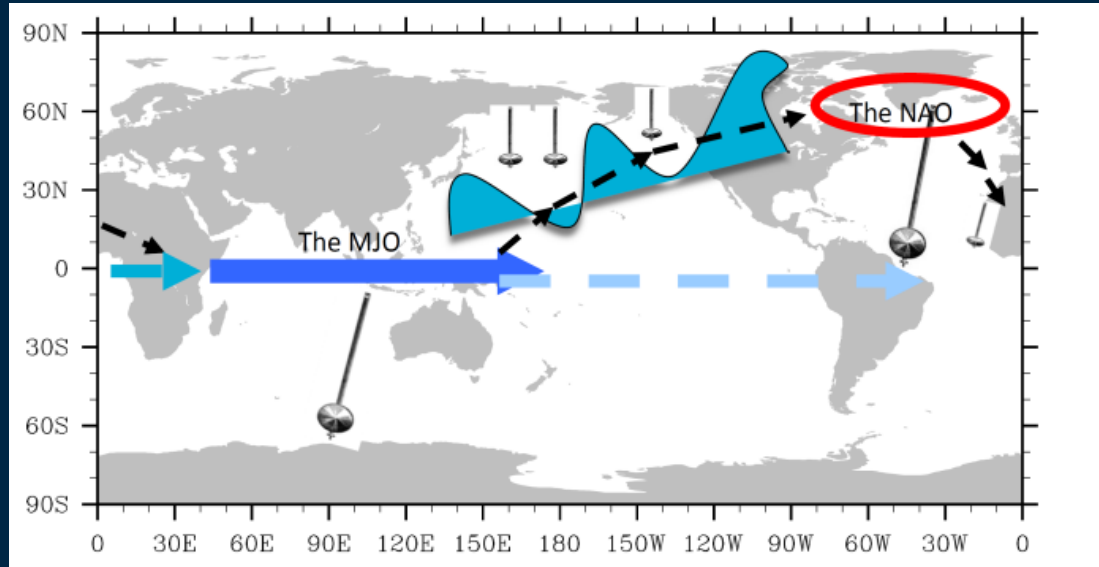


- Way 1: Frederikson and Lin (JAS, 2013) has identified a NAO-MJO 34-day normal mode;
- Way 2: Preliminary results for 2013-2017 NDJFs, the NAO PV pattern correlates relatively well with an 38-day ENM;
- Way 3: Small thermal perturbation numerical experiments with a simplified GCM show a NAO resonant behavior at 35 days.



# Conclusion (suite): and in the observed atmosphere?

- The NAO is similar to a resonance system whose variability can be amplified by the tropical MJO forcing which has a 30-50-day time scale that is close to the resonance frequency.



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.

Thank you.

Q&As

