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Synopsis of article given below is provided by the study's authors and was originally posted (April 21, 2011) on the Climate Science Website of Roger Pielke Sr. http://pielkeclimatesci.wordpress.com/2011/04/21/guest-post-atlantic-multidecadal-oscillation-and-northern-hemisphere%E2%80%99s-climate-variability-by-marcia-glaze-wyatt-sergey-kravtsov-and-anastasios-a-tsonis/

"Atlantic Multidecadal Oscillation And Northern Hemisphere's Climate Variability" by Marcia Glaze Wyatt, Sergey Kravtsov, And Anastasios A. Tsonis

Climate is ultimately complex. Complexity begs for reductionism. With reductionism, a puzzle is studied by way of its pieces. While this approach illuminates the climate system's components, climate's full picture remains elusive. Understanding the pieces does not ensure understanding the collection of pieces. This conundrum motivates our study.

Our research strategy focuses on the collective behavior of a network of climate indices. Networks are everywhere – underpinning diverse systems from the world-wide-web to biological systems, social interactions, and commerce. Networks can transform vast expanses into "small worlds"; a few long-distance links make all the difference between isolated clusters of localized activity and a globally interconnected system with synchronized [1] collective behavior; communication of a signal is tied to the blueprint of connectivity. By viewing climate as a network, one sees the architecture of interaction – a striking simplicity that belies the complexity of its component detail.

Considering index networks rather than raw three-dimensional climate fields is a relatively novel approach, with advantages of increased dynamical interpretability, increased signal-to-noise ratio, and enhanced statistical significance, albeit at the expense of phenomenological completeness. Climate indices represent distinct subsets of dynamical processes. One could consider these indices – the nodes of our network – to be climate oscillators, each node, by itself, an intrinsic, self-sustaining system. When coupled with other self-sustaining oscillators of the network, the collective choreography of interlinked nodes generates a hemispherically spanning, propagating teleconnection signal – our "stadium wave" – an atmospheric and lagged oceanic teleconnection sequence that communicates an Atlantic-born climate signal of multidecadal warming and cooling (superimposed upon longer-time-scale temperature trends) across the Northern Hemisphere. Significantly, a warm North Atlantic generates a decadal-scale lagged cooling hemispheric response; a cool Atlantic generates a warming one.

The devil is always in the detail. What are the mechanisms linking one node to the next? And what is the statistical significance of low-frequency alignment of a collection of regional climate time series, considering we are working with only the 20th century instrumental record in this study – a matter of only one hundred years? The bulk of our paper is devoted to these matters.

Using the network approach, data – raw variables such as sea-surface-temperature (SST) and sea-level-pressure (SLP), etc. – are compressed into indices, or into a subspace of dynamically and geographically distinct indices [2]. Our selection of indices was guided by extensive literature review regarding proxy records, instrumental data, and climate-model studies. We first tested eight indices (AMO, AT, NAO, NINO3.4, NPO, PDO, ALPI, and NHT). They represent a variety of oceanic and atmospheric processes, each of which, upon preliminary examination, appeared to have a multidecadal component, albeit not simultaneously timed. To these indices, we applied Multichannel Singular Spectrum Analysis (M-SSA) – a method well suited to identify a propagating signal. A leading pair of modes, well separated from all others, was considered to be our climate signal. We later added seven complementary indices to generate a larger, fifteen-member network. Our M-SSA results remained unchanged with this expanded network.

Statistical-significance testing showed the leading M-SSA pair – our climate signal – to be unlikely due to random temporal alignment of uncorrelated red-noise indices, the chance for such being less than three percent. It is not uncommon for geophysical time series to possess a strong low-frequency component – red-noise. This is due to slowly varying factors within geophysical systems that build in inertia, conveying a "memory" that manifests as a spurious low-frequency oscillatory temporal signal. Such red noise can contaminate a possible "real" low-frequency signal. This caveat can be minimized if a coherent spatial structure, distinct from noise, characterizes a quasi-periodic signal. Our stadium-wave signal, present in a set of indices representing geographically diverse regions – i.e. a coherent spatial structure – minimizes the likelihood the signal will reflect contamination. Separation of signal from noise, therefore, is more robust.

Using the identified climate signal as our spatiotemporal filter, normalized reconstructed components (RCs) were generated for all indices, each reflecting a multidecadal signal that centers on ~64 years. The long time scale suggests involvement of ocean dynamics. A substantial fraction of variance dominates AMO, AT, PDO, and NHT. AT is an atmospheric index. Its strong variance in the low-frequency spectrum speaks to an atmospheric response to ocean-induced multidecadal variations. Numerous studies cited in our paper address this less-well-known phenomenon of decadal-scale and longer forcing of the atmosphere by the oceanic heat flux. This phenomenon, most pronounced in the boreal winter – the interval of our focus – is believed to play a strong role in the stadium-wave teleconnection sequence [3].

Statistical results address only co-variability among nodes within the climate-index network, not causality. Interpretation of our results relies on a diverse collection of observational and modeling studies. Our paper details these studies, which suggest mechanisms that include: i) the ocean forcing the atmosphere throughout the troposphere on decadal and longer timescales, ii) stability changes in the tropical thermocline, and iii) latitudinal shifts in the Intertropical Convergence Zones of the Atlantic and Pacific.

In addition to evaluating multidecadal behavior – the stadium wave – in a climate network, we also considered interannual-to-interdecadal-scale variability. For this, we evaluated the collective behavior of higher-frequency variability of the residual signal in the fifteen indices, from which the multidecadal signal had been removed. This line of inquiry was motivated by related previous research of Tsonis et al. (2007) and Swanson and Tsonis (2009), whose work identified five intervals throughout the 20th century during which certain high-frequency indices synchronized. Three of these five intervals coincided with multidecadal hemispheric climate-regime shifts, which were characterized by a switch between distinct atmospheric and oceanic circulation patterns, a reversal of NHT trend, and by altered character of ENSO variability. Our results provide a more detailed picture of these "successful" (~1916, ~1940, and ~1976) and "unsuccessful" (~1923 and ~1957) synchronizations among the higher-frequency indices. While a conclusion is far from clear, it appears the "successful" synchronizations tend toward a more symmetrical contribution from both the Atlantic and Pacific sectors. PNA participates in all synchronizations. It is intriguing to note a shared rhythm among the following: successful synchronizations of high-frequency indices, shifts between periods of alternating character of interannual variability, and the stadium-wave's multidecadal tempo. This similar pacing suggests possible stadium-wave influence on synchronizations of interannual-to-interdecadally-varying indices within the climate network. Future research is required to determine the exact significance of these episodes.

In closing, results presented in our paper suggest that AMO teleconnections, as captured by our stadium-wave, have implications for decadal-scale climate-signal attribution and prediction. Potential mechanisms underlying the stadium-wave and related interdecadal variability are topics of active and controversial research, reliant upon technological leaps in data retrieval and computer modeling to advance them toward consensus.

Index Profile of the Stadium Wave:

- Atlantic Multidecadal Oscillation (AMO) – a monopolar pattern of sea-surface-temperature (SST) anomalies in theNorth Atlantic Ocean.
- Atmospheric-Mass Transfer anomalies (AT) – characterizing direction of dominant wind patterns over the Eurasian continent.
- North Atlantic Oscillation (NAO) – reflecting atmospheric-mass distribution between subpolar and subtropical latitudes over theNorth Atlanticbasin.
- NINO3.4 – a proxy for El Nino behavior in the tropical Pacific Ocean.
- North Pacific Oscillation (NPO) – the Pacific analogue for theAtlantic's NAO.
- Pacific Decadal Oscillation (PDO) – an SST pattern in the North Pacific Ocean.
- Aleutian Low Pressure Index (ALPI) – a measure of intensity of the Aleutian Low over the Pacific Ocean mid-latitudes.
- Northern Hemisphere Temperature (NHT) – anomalies of temperature across the Northern Hemisphere.

The “Stadium Wave”:

-AMO → (7 years) → +AT → (2 years) → +NAO → (5 years) → +NINO3.4 → (3 years) → +NPO/PDO → (3 years) → +ALPI → (8 years) → **+NHT** → (4 years) → **+AMO** → (7 years) → -AT → (2 years) → -NAO → (5 years) → -NINO3.4 → (3 years) → -NPO/-PDO → (3 years) → -ALPI → (8 years) → **-NHT** → (4 years) → -AMO

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[1] The term synchronization is not synonymous with the term synchronous. Synchronization refers to the matching of rhythms among self-sustained oscillators; although the motions are not exactly synchronous (or simultaneous). If two systems have different intrinsic oscillation periods, when they couple, they adjust their frequencies in such a way that cadences match; yet always with a slight phase shift (lags).

[2] The original eight indices include: AMO, AT, NAO, NINO3.4, NPO, PDO, ALPI, and NHT. Please refer to explanation of indices at article’s end. It details the dynamical profile of each index.

[3] Refer to stadium-wave sequence and associated lags between indices after profile of indices.