Evaluating the Relationship between Inter-Annual Climate Variability and Nitrogen Wet Deposition in the United States

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Introduction

Human inputs of nitrogen into the atmosphere have increased dramatically as a result of fossil fuel emissions and fertilizer use. When this excess nitrogen deposits onto the Earth’s surface, it has many diverse and harmful effects, ranging from reduced drinking water quality to altered chemical composition of ecosystems.

Wet deposition rate of nitrogen is governed by precipitation amount and frequency and thus is influenced by large-scale climate. This study uses wavelet analysis to determine the relationship between nitrogen wet deposition and the following four indices of climate variability:

1. The El Niño Southern Oscillation (ENSO) is a climate cycle that can be measured by NINO3.4, an index quantified by the sea surface temperature in the area of 5S–5N latitude and 170–120W longitude. El Niño (positive phase of ENSO) winters are associated with warm, dry weather in the Pacific Northwest and cool, wet weather in the Southwest and Southeast US; the opposite is true of La Niña winters (negative phase of ENSO).

2. The Arctic Oscillation (AO) is an index defined by opposing atmospheric pressure patterns in northern middle and high latitudes. The positive phase of AO corresponds to low pressure over the polar region and high pressure at the mid-latitudes, which keeps the eastern US warmer than normal and brings drier conditions to the western US.

3. The Pacific/North American (PNA) teleconnection pattern is associated with above average temperatures in the western US and below average temperatures in the southeastern US in its positive phase; the opposite is true of the negative phase.

4. The North Atlantic Oscillation (NAO) is an index characterized by differences in pressure between a station on the Azores and one on Iceland. Positive phases of NAO are associated with above-average temperatures across the eastern US.

Objectives

• To identify inter-annual variability of total nitrogen (sum of ammonium and nitrate) wet deposition
• To evaluate the correlation between precipitation and nitrogen wet deposition
• To determine the correlation between dominant signals of climate indices and nitrogen wet deposition through wavelet transforms.

Data and Methods

• Nitrates (NO$_3^-$) and ammonium (NH$_4^+$) wet deposition data and precipitation data were collected for 79 stations across the United States from the National Atmospheric Deposition Program (NADP) and the National Trends Network in the range of 1979–2011. Selected stations all had at least 21 years of continuous data.
• Standardized anomalies were calculated by subtracting seasonal means from each seasonal value and dividing by the seasonal standard deviation in order to remove the annual cycles.
• Climate index data was obtained from the National Oceanic and Atmospheric Administration’s Climate Prediction Center.
• The wavelet analysis tool was used in order to decompose one or two time series into both time and frequency space.

Correlations of precipitation and total nitrogen wet deposition with each of the climate indices were determined based on the dominant mode of climate variability. For the ENSO cycle, the coefficients were calculated using the 2-6 year scale-averaged variance (band), which was found to be the dominant periodicity in the 1995-2012 data set based on the wavelet analysis. The correlations with other indices were calculated for the 0.5-2 year band. Results are shown here for both the NINO3.4 and the NAO with precipitation and combined NH$_4$ and NO$_3$ wet deposition. The red arrow indicates station FL41, which is used as an example for the wavelet transforms below.

Figure 1. a) Correlation coefficient ($R^2$) values for NINO3.4 and precipitation; b) $R^2$ values for NINO3.4 and N wet deposition; c) $R^2$ values for NAO and precipitation; and d) $R^2$ values for NAO and N wet deposition. All results shown are without considering lag time.

Continuous Wavelet and Cross Wavelet Transforms

Conclusions and Future Work

• The wavelet analysis tool makes it possible to determine the dominant periodicities of a time series and where in time these occur. The darker red colors indicate areas of high power, or areas where the variance is largest. The black contours display statistically significant variances at the 95% confidence level.
• As seen in both the time series and the continuous wavelet spectra, nitrogen wet deposition at FL41 has an area of significantly high variance around 1997, which corresponds to the strong El Niño event of 1997–1998.
• The cross wavelet transform reveals that the two time series share a period of high common power centered around 1997.
• The arrows represent the phase relationship, with right-pointing arrows representing in-phase and left-pointing representing out of phase. In this case, the arrows, which point roughly southeast, indicate that NINO3.4 leads N deposition by about 3-5 months.

References & Acknowledgements

1. National Atmospheric Deposition Program: http://nadp.sws.uiuc.edu

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