The effect of storm direction on precipitation chemistry in southeastern New York

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Introduction

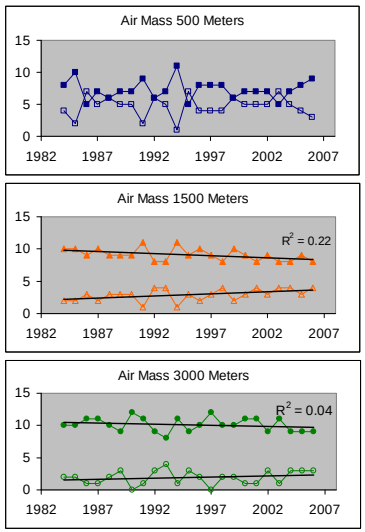
Climate change predictions for the northeast US are for increased precipitation, an increase in nor'easters, increase in winter precipitation that falls in the form of rain, & possibly an increase in tropical storms. An increase in precipitation, particularly storms that come from the east, (i.e., tropical storms & some nor'easters) can affect precipitation chemistry in unexpected ways. In this paper we examine the effect of increasing easterly storms on precipitation chemistry. We predict what we might expect in the future and how this could alter our efforts to reduce acid rain precursors.

Methods

- We ran 24-hour back trajectories using the NOAA ARL HYSPLIT model* for air masses at 500, 1500 and 3000 meters for one randomly selected precipitation event per month at IES (1984-2006).
- We ran back trajectories* for a subset of events that had pH>4.7 (1984-2006).
- Estimated volume-weighted mean concentrations of acidic components with and without events from the east with pH>4.7 to determine whether the increase in number of these storms has changed the slope of the decreasing trends in acid rain components.
- Using the relationship between the number of easterly storms & the difference in H^+ concentration the easterly storms makes, estimated how many easterly events it would take to bring our precipitation pH to 5.2, the approximate pH of 'normal' precipitation.

* Draxler, R.R. and Rolph, G.D., 2003. HYSPLIT (HYbrid Single-Particle Lagrangian Integrated Trajectory, Model access via NOAA ARL READY Website http://www.arl.noaa.gov/ready/hysplit4.html

Are Easterly storms increasing?

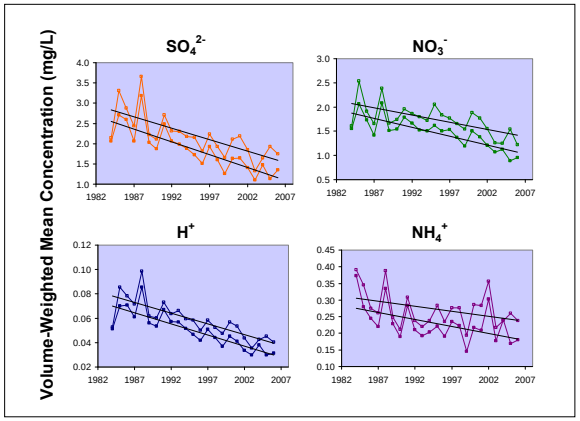


Volume-weighted mean concentrations (mg/L)		
	Easterly events	Westerly events
H^+	0.02370	0.05865
SO_4^{2-}	0.87	2.11
NO_3^-	0.66	1.98
NH_4^+	0.10	0.29

An increase in the number of easterly events (open symbols) with a concomitant decrease in westerly events (closed symbols) is apparent for 1500 meter air masses; 1500 meters is cloud height.

Concentrations of acid rain components in westerly events is roughly 2-3x that of easterly events.

How do easterly storms with pH>4.7 affect precipitation chemistry?

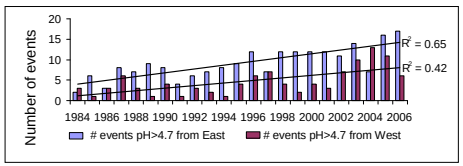


Regression line slopes		
	with	without
H^+	-0.0018	-0.0017
SO_4^{2-}	-0.0631	-0.0563
NO_3^-	-0.0365	-0.0298
NH_4^+	-0.0042	-0.0030

When events from the east with pH>4.7 were excluded (open symbols) concentrations were consistently higher than when these events were included (closed symbols) indicating that easterly events consistently reduce average concentrations of acid rain components.

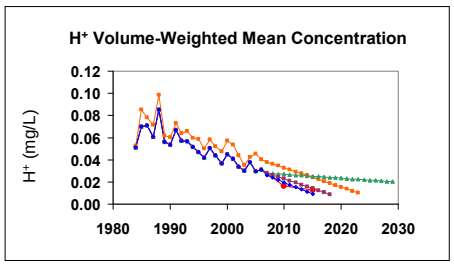
The slope of concentration decreases was greater when these events were included, indicating that the increase in easterly events has caused more of a downward trend in acid rain components than expected based on emissions reductions.

Are Events with pH>4.7 increasing?



The number of events with pH>4.7 is increasing from the east and from the west, but easterly events are greater in number and increasing at a faster rate than westerly storms.

Possible Scenarios for the Future



Year precipitation would reach 5.2 under 4 different scenarios		
■-1-■	No events from the east with pH>4.7, emissions reductions at the current rate	2025
▲-2-▲	No additional reductions, 1 additional easterly event / year with pH>4.7	2068
■-3-■	Current emissions reduction rate, 12 easterly events with pH>4.7 per year	2019
♦-4-♦	Current reduction rate, 1 additional easterly event with pH>4.7 per year	2016

Conclusions

- Events from the east are increasing
- Events with pH>4.7 from the east and from the west are increasing
- Events with pH>4.7 are increasing from the east at a faster rate than from the west
- Events with pH>4.7 from the east dilute acid rain components
- Trends in acid rain components are decreasing at a faster rate because of the increasing number of easterly events with pH>4.7
- The contribution toward reducing acid rain from emissions reductions far outweighs the contribution from easterly events with pH>4.7
- Continuing the current reductions in acid rain precursor emissions is necessary.