Impact of Volcanic Heat Release on Local Weather for the 2006 Augustine Volcano Eruption

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1. INTRODUCTION

General Circulation Models (GCMs) have been used to study the effects of volcanic eruptions on climate. Studies show that large volcanic eruptions can affect both global and regional climate in a variety of ways, like increasing the land-sea temperature gradient (Robock and Mao 1992, 1995) as well as the general circulation in the lower and middle atmosphere (Kirchner et al. 1999, Robock 1996, 2000).

Volcanic eruptions (regardless of size) release ash, aerosols, heat and water vapor to the atmosphere. Research suggests that such emissions can lead to variation in microphysical processes, which lead to changes in atmospheric variables (i.e., temperature and precipitation; Mölders and Olson 2004).

On January 13 and 14 2006, the Augustine Volcano (located in the Cook Inlet of south central Alaska) erupted releasing a plume of ash, aerosols, heat, and water vapor into the atmosphere. The plume reached a nine kilometer height, extending to the north and northwest (AVO 2007). Though the eruption was not large enough to significantly affect global or regional climate, the small scale emissions could have affected the microphysics, which could alter local weather during the time of the eruption. Our study explores the impact of the aforementioned releases on local weather. In the following, we will focus on the impact of the heat released during the Augustine volcano eruption on local, mesoscale weather. These investigations are based on simulations with the Weather Research and Forecasting (WRF; Skamarock et al. 2005) model.

2. EXPERIMENTAL DESIGN

2.1 Brief model description

We use the Advanced Research version (Wang et al. 2004) of WRF. Our simulations use the National Centers for Environmental Prediction (NCEP) global final (FNL) analyses that have a 1.0^{o}x1.0^{o} degree and six hour resolution as initial and boundary conditions.

WRF was run using a four kilometer grid increment with 149x149 grid points and 31 vertical layers centered at 59.4^{o}N and 153.4^{o}W. This domain is centered over the St. Augustine Volcano on Augustine Island, Alaska which is located in costal terrain surrounded by the Pacific Mountain System. WRF was run for a period of twenty days, from January 10 to January 30, 2006.

2.2 Analysis

To evaluate WRF's performance, simulated data was compared with data from observing sites within the region. Data evaluated included hourly (cloud cover, wind speed, pressure, temperature, dew point, precipitation) and daily (precipitation, maximum temperature, minimum temperature) variables. Both qualitative and quantitative procedures were used.

To evaluate precision, trends of the observed and simulated data were plotted per station. Similar observed and simulated trend behavior indicates precise simulations. Accuracy is indicated by determining how close the simulated values are to the observed. To do this, skill scores were calculated for each atmospheric variable. Systematic errors were determined by calculating the bias, random errors are represented by the standard deviation of error (SDE), and the overall performance was determined by calculating the root mean square error (RMSE) in accord with Anthes (1983), Anthes et al. (1989), Narapusetty and Mölders (2005), and Zhong et al. (2005). To determine the accuracy for categorical atmospheric variables, like precipitation and cloud presence, threat and accuracy scores were also used (Anthes 1983, Zhong et al. 2005).

A second simulation (referred to as "heat" hereafter) was run introducing the heat released from the Augustine Volcano eruption. Heat released from the volcano during the eruption period was estimated using the NOAA Advanced High Resolution Radiometer (AVHRR) data provided by J. Dehn, Alaska Volcano Observatory (2007). The results of this simulation were compared with the observations, in the same way as indicated previously, and compared with the initial simulation. Improvements in the WRF performance between the reference ("no heat") and "heat" simulations may suggest that the addition of heat to the atmosphere from the volcanic eruption had an effect on local, mesoscale weather.

3. PRELIMINARY RESULTS

3.1 Model Evaluation: No Heat

In general, WRF overestimated temperature, wind speed, precipitation, and dew point; and underestimated cloud cover and pressure. Daily data was generally not as accurate as hourly (table 1). WRF showed excellent precision by capturing the trends of the observed data very well, but often deviated from the actual values, with bias scores ranging on the order of 0.01 to 2.

Discrepancy in the wind speed is higher at lower wind speeds due to varying extremely small scale microphysical processes. Precipitation showed a higher accuracy score for events with high amounts of precipitation (i.e., higher thresholds). This is because light precipitation events are difficult to accurately detect with rain gauges. Daily precipitation data was generally overestimated, but hourly data was slightly underestimated, which is evident from the bias scores in table 1.

3.2 Comparison of Heat verses No Heat

Introducing volcanic heat release to the WRF simulation did not affect the trends, but it did produce slightly different values. Similar to the "no heat" simulation, WRF generally overestimated temperature, wind speed, precipitation, and dew point; while underestimating cloud cover and pressure. Also, hourly data remains more accurate than daily. In the "no heat" simulation, precipitation was overestimated in the hourly data, but underestimated in the daily; the "heat" simulation shows an overestimation of daily data, but the hourly data shows negligible bias.

Table 2 gives the changes in skill scores, from the "no heat" simulation to the "heat" simulation. It is evident that some atmospheric variables improved (e.g. daily precipitation, daily minimum temperature, dew point, temperature and wind speed), while others did not; however, there is a clear overall improvement in the simulation. Discrepancy seen in the skill scores is likely due to station location. Stations in closer proximity to the volcano experienced more change than the stations further away.

4. CONCLUSION

In general, WRF captures the trends of observed data very well, but deviates slightly from actual values. It tends to overestimate temperature, wind speed, precipitation, and dew point temperature; but underestimates cloud cover and pressure. Overall, the hourly data is better than the daily because WRF tends to underestimate the width of the diurnal cycles.

Introducing the volcanic heat release from the 2006 eruption of the Augustine Volcano generally improved the simulation. Skill scores (tables 1 and 2) show how the RMSE, SDE, and bias changed from the first (no heat considered) to second (heat considered) simulation. Most values decreased indicating a more accurate simulation in terms of both systematic and nonsystematic errors.

Large volcanic eruptions have been shown to affect global and regional climate (Kirchner et al. 1999, Robock 1996, 2000, Robock and Mao 1992, 1995). However, small eruptions releasing heat to the atmosphere may affect local, mesoscale weather.

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Table 1. Shows skill scores for the two WRF simulations, No Heat (volcanic heat release not considered) and Heat (volcanic heat release considered).

	No Heat			*Heat*		
	RMSE	**SDE**	**Bias**	**RMSE**	**SDE**	**Bias**
Daily Max Temperature	4.05	3.49	0.07	4.04	3.49	0.10
Daily Min Temperature	5.59	4.75	2.36	5.47	4.77	2.14
Daily Precipitation	2.41	1.54	1.02	2.33	1.52	1.01
Cloud Existence	0.75	0.39	-0.09	0.75	0.40	-0.09
Dewpoint	0.86	0.85	0.03	0.72	0.72	0.06
Precipitation	0.01	0.01	-0.0001	0.01	0.01	0.00
Pressure	0.40	0.40	-0.03	0.40	0.40	-0.04
Temperature	0.83	0.83	0.01	0.72	0.72	0.03
Wind Speed	0.47	0.37	0.03	0.45	0.34	0.03

Table 2. Shows the difference between skill scores for the two WRF simulations, Heat (volcanic heat release considered) minus No Heat (volcanic heat release not considered).

	Difference		
	RMSE	**SDE**	**Bias**
Daily Max Temperature	0.01		-0.03
Daily Min Temperature	0.12	-0.02	0.22
Daily Precipitation	0.08	0.02	0.01
Cloud Existence		-0.01	
Dewpoint	0.14	0.13	-0.03
Precipitation			-0.0001
Pressure			0.01
Temperature	0.11	0.11	-0.02
Wind Speed	0.02	0.03	