Looking for Correlations between Dust Events and Weather at Observatories

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Abstract:
An important issue affecting ground-based observatories is the local conditions, especially dust in the atmosphere. Dust events can appear suddenly and without warning, and can be very detrimental to a telescope's optics. Due to these dust events, optics may be required to undergo cleaning and recoating which can cost the observatory a substantial amount of money, in addition to lost observing time. This research involves the statistical analysis of data obtained from the Apache Point Observatory, in Sunspot, New Mexico, which has similar weather conditions to the Magdalena Ridge Observatory site. The objective of this work is to find a correlation between dust events and certain weather effects, such as changes in pressure, humidity, wind speed, and wind direction. It is the goal of this research to predict dust events by identifying weather effects that precede them. This work is supported through grant money from LANL to NMT for the Magdalena Ridge Observatory.

Introduction:
The goal of this project is to find a way to predict dust events in order to protect an observatory's optics. Dust particles can damage the coating on a mirrored lens and increase light scattering. If the surface of the mirror has dust built up on it from a dust event, then when moisture reacts with this dust, it causes a chemical reaction which triggers the rapid erosion of the mirror.[1] Dust can also scratch the surface of a mirror during periods of high winds. Weather data from the Apache Point Observatory (APO) was examined to look for possible correlations between documented dust events and other possible weather precursors. The APO has a meteorological weather station which includes a dust monitor, and all of this data is available online.

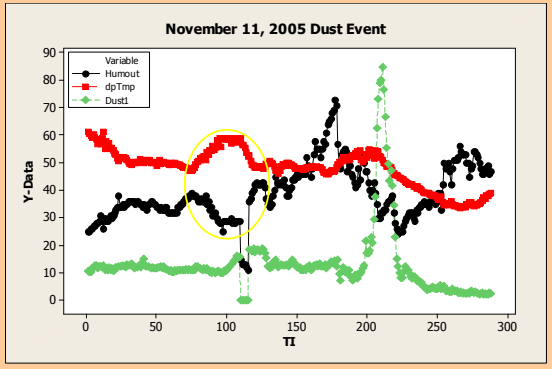
Magdalena Ridge Observatory (MRO):
The Magdalena Ridge Observatory project is an international scientific collaboration between New Mexico Tech (NMT), the University of Cambridge (UK), and an observatory consortium which include the Los Alamos National Laboratory (LANL). The Magdalena Ridge Observatory project is run by NMT with oversight by the Office of Naval Research (ONR). The observatory is primarily intended for astronomical research and will be composed of two facilities, a fast-tracking 2.4m telescope and an array of optical/infrared telescopes called an interferometer.[2] MRO is located on the main ridge of the Magdalena Mountains at an elevation of 10,600 ft. (3231 m.) above sea level, 30 miles west of the NMT campus in Socorro, NM.

Apache Point Observatory (APO):
APO is located in the Sacramento Mountains at Sunspot, NM, which is 18 miles south of Cloudcroft, NM at an elevation of 9,147 ft. (2788 m.) above sea level, and is privately owned and supported by the Astrophysical Research Consortium (ARC). Their mission is to operate the observatory to further astronomical research by the scientists and students of its member institutions. Those institutions are the Institute for Advanced Study, University of Chicago, University of Colorado-Boulder, Johns Hopkins University, New Mexico State University, Princeton University, and University of Washington. NMSU operates the observatory site for the Consortium. The observatory consists of The Astrophysical Research Consortium's 3.5-meter telescope, the Sloan Digital Sky Survey 2.5-m telescope with a 20" photometric telescope, and New Mexico State University's 1.0-m telescope.[3]

Weather Data Comparison at MRO and APO:
The weather at these two observatories is very comparable because of their similar altitudes, close proximity to each other, and because they are both located next to desert settings. The weather data from APO is almost identical to the data from MRO, except that some of the events are slightly staggered because of the difference in longitude and latitude of the observatories. A study was made comparing the weather data from several years from these two sites which found that their weather is very similar.[4] We used the APO data because it has simultaneous dust monitoring on site, and because MRO doesn't have a dust monitor in place yet.

Dust Events:
Dust events occur when there is a readily observable amount of particulate matter in the surrounding air. Some observatories use a flashlight to see how dusty it is outside and whether they should close their observatories down. Others use quantitative scientific devices to determine the amount of dust in the atmosphere. The APO site uses the Met One 227B particle counter.

Dust events occur seasonally at various levels. There are three different seasons for dust events at APO.[5] The first one is in the spring, from May to June, the second is during New Mexico's monsoon season (July through September), and the final one is from October through December.[4] The amount of dust events diminishes as we pass through the year.



Dust Monitoring at APO:
The APO's Met One model 227B dust counter is mounted in a weather-tight area about 50 feet above the ground on the APO weather tower. This places the instrument in free air flow, away from the effects of most human activities.[4] It operates by drawing air through a tube into the counter, where photodiodes measure the light transmitted by an infrared (wavelength) laser and scattered by the dust particles. The air pump draws 0.1 cubic foot of air per minute through the counter which is automatically run every 15 minutes for one minute. Data is collected with two different channels which measure the number of dust particles bigger the 0.3 microns and the number of particles bigger then 1.0 microns.


227a / 227b Handheld Airborne Particle Counter

Cleaning and Recoating Mirrors at an Observatory:
After a dust event is noticed, most observatories will then close down until the event has passed to further protect their optics. Some observatories will clean the mirrors immediately after a dust event, to keep the particles from causing any further damage. Others choose to recoat the mirrors annually, or at another set time interval, to keep the optics from degradation. Either option can cost a substantial amount of money and observing time. If these dust events could be predicted, then the observatory could close down right before they occur, and thus the major damage might be avoided.

Previous Work:
Many researchers have sought to find a correlation between dust events and weather, but their results were inconclusive. In a previous study at MRO, they found no interdependence between weather characteristics and dust events.[5] Another study preformed at the Italian Galileo telescope (TNG) found no correlation between dust content and humidity and wind direction.[6] Research preformed at the VLT Observatory of Cerro Paranal found no relation to the wind direction and dust events. These scientists concluded that the dust events were not from local phenomena, like a nearby mine. They proposed that the notable increase of particle density during the warmer, humid months of the year was due to whirlwinds, a thermal phenomenon particular to the desert areas.[7]

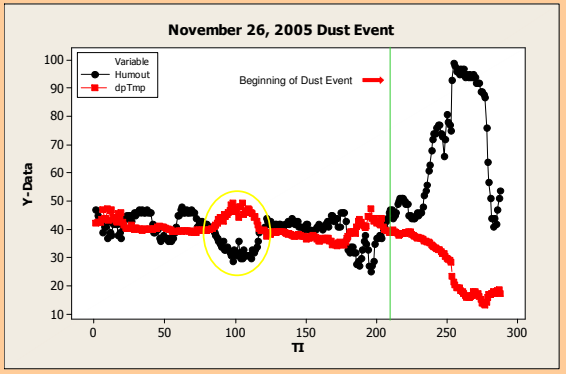
Data Analysis:
We looked graphically at twenty dust events which occurred over several months of data from June to December 2005. All of these events occurred when the levels of particles larger then 1.0 microns exceeded the accepted value for the APO shutdown criteria, which is 300 particles per cubic foot. We looked for trends that occurred previous to a dust event by hours, or days. We analyzed different combinations of weather phenomena, such as temperature and pressure, and dew point and wind speed. We were looking for a set of two or more changes in meteorological measurable quantities which precede every dust event, over a certain period of time, nominally 24 hours.

Results:
After plotting these twenty dust events, we found there was one pair of meteorological measures which changed together in a similar fashion, occurring 85% of the time before a dust event. We found that preceding most dust events at 28.6±6.7 hours, the humidity will drop on average by 26.1 percent over an average time interval of 14.2 hours and the dew point temperature will raise on average 12.2 °F over an average time interval of 14.2 hours. Examples of this are shown in the figures below. Our results are in the table to the right.

Looking for a reason for what type of weather phenomena could cause this to happen, we turned to our local meteorologist. This was his response:

"In order for the dew point to rise with the humidity falling the entire time, it would have to be a situation where warm air was flowing over the area. If there was more moisture in the incoming air than what it replaced the dew point would rise, but that would cause a rise in relative humidity. To counteract that, the warmth of the incoming air would have to be high enough to counteract the increase in moisture, thereby lowering the relative humidity. That scenario isn't one you would encounter often, but with the atmosphere many, MANY things are possible. It was probably a surge of warm air...possibly from the southeast (away from the western deserts) where the air is more likely more moist."[8]

Future Analysis:
Presently we plan on studying several more months of data to see if this trend continues. We are considering automating the search process to determine if there are any other measurable weather occurrences which go with it. We are trying to analyze why this doesn't occur for the other 15% of the dust events. We also want to see where the jet stream was during these dust events, to figure out what is causing the dust levels in the atmosphere to get stirred up and fall to ground level. We want to further investigate why these dust events are not caused by local weather and instead by something in the upper atmosphere.



Conclusions:
Dust event prediction is very important to observatories in order to maintain the cleanliness of optics and their operating schedules. The cost of recoating the mirrors and the time lost by shutting down an observatory due to dust can be very high. We have analyzed several months of data from APO to determine if there are a set of events that preceded any dust event. Initial conclusions show that humidity will drop while the dew point temperature rises almost one day previous to the dust event. Future research should hopefully show that this trend continues on indefinitely, and therefore can be used as part of an observatories shutdown criterion.

Acknowledgments:
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Number	Date of dust event and two days previous	Rise in dew point temperature	Period of rise	Drop in humidity	Period of drop	Time to dust event
		Degrees F	Hours	Percent	Hours	Hours
1	5/31-6/02/05	15	14.5	20	8.8	26.0
2	6/13-6/15/05	*	*	*	*	*
3	6/23-6/25/05	25	23.3	20	23.5	26.5
4	6/25-6/28/05	19	17.3	39	16.3	38.8
5	6/25-6/28/05	20	20.3	32	16.3	38.5
6	7/07-7/09/05	18	13.8	21	16.3	25.5
7	7/16-7/18/05	6	8.3	26	7.3	26.8
8	7/27-7/29/05	14	13.8	29	9.5	42.5
9	8/10-8/12/05	11	9.5	33	8.8	20.0
10	8/16-8/19/05	14	12.0	43	17.0	31.5
11	8/18-8/20/05	15	17.8	51	21.3	27.0
12	8/19-8/21/05	6	6.0	20	6.0	26.8
13	8/21-8/23/05	14	23.5	42	23.3	29.5
14	11/9-11/11/05	12	11.3	14	11.5	23.0
15	11/24-11/26/05	10	8.8	17	13.3	25.0
16	11/30-12/02/05	14	13.8	15	14.3	21.8
17	12/01-12/03/05	10	21.8	8	19.5	20.8
18	12/10-12/12/05	*	*	*	*	*
19	12/24-12/26/05	*	*	*	*	*
20	12/29-12/31/05	5	6.8	14	8.5	36.3
Standard Deviation:		5.3	5.6	12.2	5.6	6.7
Mean:		13.4	14.2	26.1	14.2	28.6

* Unknown cause of dust event