P4.3 QUALITY CONTROLLED SURFACE VISIBILITY OBSERVATIONS USED TO VALIDATE PREDICTED SURFACE AEROSOL CONCENTRAION FOR SOUTHWEST ASIA

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1. INTRODUCTION

Aerosol modeling and measurements in the last two decades have made significant strides as the importance of atmospheric aerosols in climate change, air pollution, radiative transfer and numerical weather prediction are being realized. Challenges exist and continue to emerge in both depicting and understanding the distribution (vertical and horizontal) and evolution of aerosol species (e.g., chemical and photochemical reactions, local source identification, land surface characterization). Relating aerosol model output to surface sensible parameters (e.g., horizontal visibility) still remains an issue due to the aforementioned challenges and difficulty in deriving aerosol vertical distribution from remotely sensed observations (e.g., the Total Ozone Mapping Spectrometer (TOMS)). The implications of skillfully predicting atmospheric visibility are profound given the fact that many military and civilian operations are exclusively dependant on observed visibility.

There are several shortcomings in using reported visibility observations that must be considered in determining what type of comparison or computation can be made against a predicted quantity. Surface station visibility reports are inherently subjective as visibility can be defined as a minimum detectable contrast by an observer's eyes or through several different “visibility meters” on the market. The resultant distance can be related to the intensity of attenuation of radiation by the suspended particles (i.e., directly related to the horizontal extinction coefficient at the surface). Reported visibilities suffer from errors due to coarse reporting bins, difficulties in judgment beyond 10 km (when the horizon is unobscured), and the qualitative nature of the observation. In addition, differences in reporting exist between World Meteorological Organization (WMO), National Oceanic and Atmospheric Administration (NOAA), and U.S. Navy protocols.

Despite the aforementioned shortcomings, visibility reports are globally abundant and can be related successfully to surface extinction (N'tchayi Mbourou et al. 1997, Husar et al. 2000).

It is the aim of this paper to select a few quality-screened surface stations that will be used for validation of aerosol model predictions of aerosol surface concentration. This station visibility database may also be used for developing an operational statistical regression model for converting the predicted surface aerosol concentrations to a more usable surface horizontal visibility value.

2. DATA & METHODOLOGY

Model-predicted surface aerosol concentrations are computed by the Navy Aerosol Analysis and Prediction System (NAAPS), which is a modified form of a hemispheric sulfate aerosol model developed by Christensen (1997). NAAPS utilizes global meteorological fields from the Navy Operational Global Atmospheric Prediction System (NOGAPS) (Hogan and Rosmond 1991). The current NAAPS is run twice daily in a test mode at the Naval Research Laboratory (NRL), with output produced at 6-hour intervals out to a 5-day forecast. The global 1°×1° fields are computed at 24 levels for three aerosol species. Additional information on NAAPS can be obtained at http://www.nrlmry.navy.mil/aerosol/.

Surface synoptic reports are operationally received and decoded by Fleet Numerical Meteorology and Oceanography Center (FNMOC). Reports typically come in on a 6-hour basis from airports, civilian stations, and merchant and navy ships. In addition to reporting horizontal visibility, most stations also report past and present weather conditions, winds, temperature, and dew point temperature that are in accordance with the WMO international codes (WMO 2001). For this study, a two-year sample (2001-2002) of station reports were collected in the Southwest Asia region (i.e., 10°N-40°N, 30°E-70°E). Several criteria were used to screen out stations whose reporting practice, consistency, or quality was in question.

The first screen employed eliminates reporting stations where the frequency of observation is less than 4 times per day. This subjective criteria ensures that only operationally maintained stations are included in the final data set while eliminating ships or some stations that may use a protocol other than the WMO standard.

Many of the surface station reports that are retrieved and decoded by FNMOC via the Global Telecommunication System (GTS) do not include or

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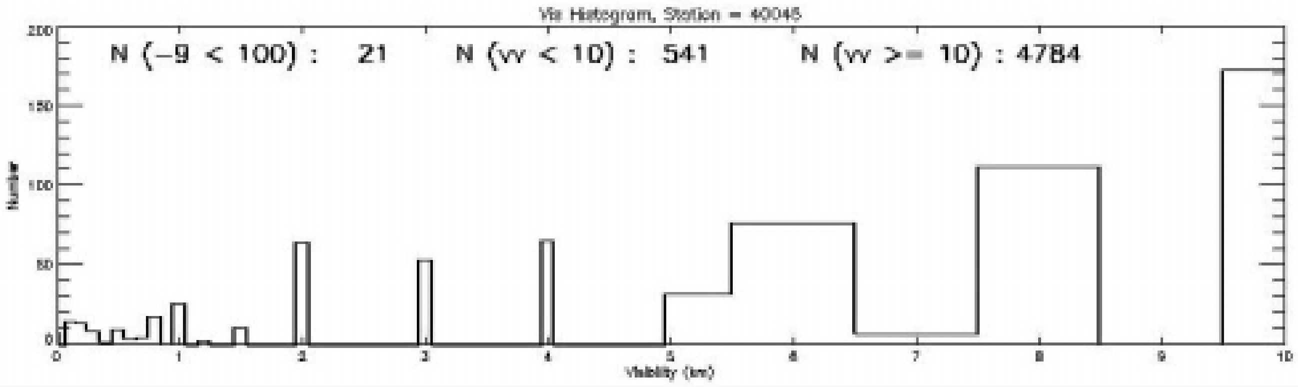

Figure 1: Sample horizontal surface visibility (km) frequency histogram for station 40045 (Dayr Az Zawr, Syria, 35.2°N, 40.1°E).

infrequently include visibility estimates. We impose a criteria whereby each station must not have more than 100 missing reports during the two-year study period.

3. RESULTS

Care was taken not only in screening surface stations, but also in looking at the reporting practices of individual and blocks of stations. For example, some countries use a different unrestricted visibility category than others, while some stations with automated instruments show more granularity beyond 10 km visibility that is difficult for the human observer to gauge.

A total of 1367 unique stations were reporting within the predefined Southwest Asia domain. Of this total, 72.5% (991) were ships that reported on the order of 10 to several 100 times during the 2-year study period. The first screening of stations reporting less than 4 four times daily eliminated all ship reports and reduced the number of stations to 13.5% of the original sample (185 stations). The second criteria that retains stations with less than 100 missing visibility reports further reduced the number of stations by 31 (or 11.3% of original sample).

A randomly chosen surface station histogram of visibility distribution is shown in Figure 1. For this case, the station is located in the desert of Eastern Syria. The frequency pattern of this particular station is more typical of visibility reports using the WMO standard of reporting bins that are in 0.1 km bins (from 0-5 km) but only using such discrimination in severely restricted visibility conditions of less than 1 km. As with most screened stations, the reporting times are at 3-hourly increments with the exception of four stations in northwest Iran whereby about an equal number of reports came in one hour ahead of the three-hourly report.

The characteristic typical distribution of reported visibility (not shown) reveals a "default" unrestricted visibility category at 10 km for 74% of the filtered stations. These stations are reporting 10 km visibility 78 % of the time. Exceptions to the 10 km unrestricted visibility bin appear in Syria (20 km "default"). Outside of Syria, the most frequently reported visibility categories other than 10 km are reported on average 55% of the time. These include instrumented stations (e.g., Bahrain and Doha, Qatar) that have visibility bin maximum frequencies of less than 35%.

The spatial distribution of horizontal visibility reports of less than 10 km (Figure 2) gives a sense of the climatology of reported visibility during the 2001-2 period. Note that the percent of time with reduced visibility is a maximum at Bandar Abbas (27.1°N 56.2°E), Iran (86%). Several regions emerge as areas typically observing reduced visibility: Northern Iran near the Caspian Sea coastline, Israel and Western Jordan, the northern Persian Gulf, and the Hormuz Strait region. Several reasons other than weather phenomena can reduce visibility in these regions. For example in the Persian Gulf region, industrial pollution related to the oil industry and haze that may have emanated from dust sources hundreds of kilometers away will reduce visibility. On average, the frequency of reports of less than 10 km for the filtered station set is 13.5% of the time (roughly 50 days per year).

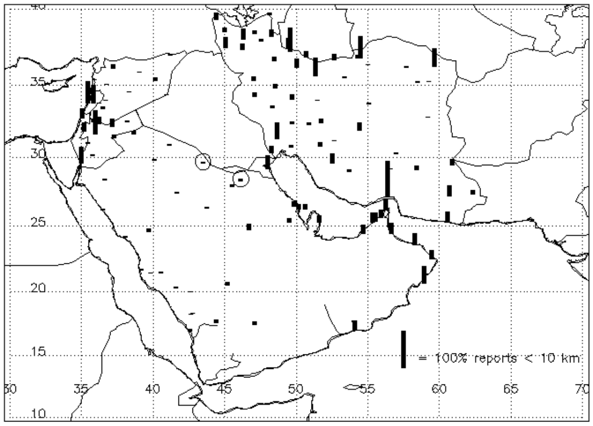

Figure 2: Southwest Asia surface station climatology of horizontal visibility less than 10 km for the period 2001-2002. Length of bar at each station site corresponds to percent of reports as indicated by key in lower right of image.

As a first step in gauging the relationship between the NAAPS predicted aerosol surface concentration and that observed by a surface station, the two fields are plotted as a function of time during a particularly strong synoptic event over Southwest Asia (Figure 3). The location of the two selected stations are circled on the map in Fig. 2. The surface concentration from the model is in units of µg/m^3 while surface horizontal visibility is observed in kilometers. Time series from two stations reveal that the relationship is not inversely proportional in a strict sense. Rather, there appears a lag in which model surface concentrations are greatly diminished even though visibility observations are still small (< 4 km). This appears in both stations of Fig. 3 following a severe dust outbreak across most of Iraq and Northern Saudi Arabia on 25 March 2003.

Other station-model trend comparisons similar to Fig. 3 showed the variable nature of station visibility observations, but all show the model's ability to capture the onset of a strong synoptically-forced event, such as that of 25 March 2003.

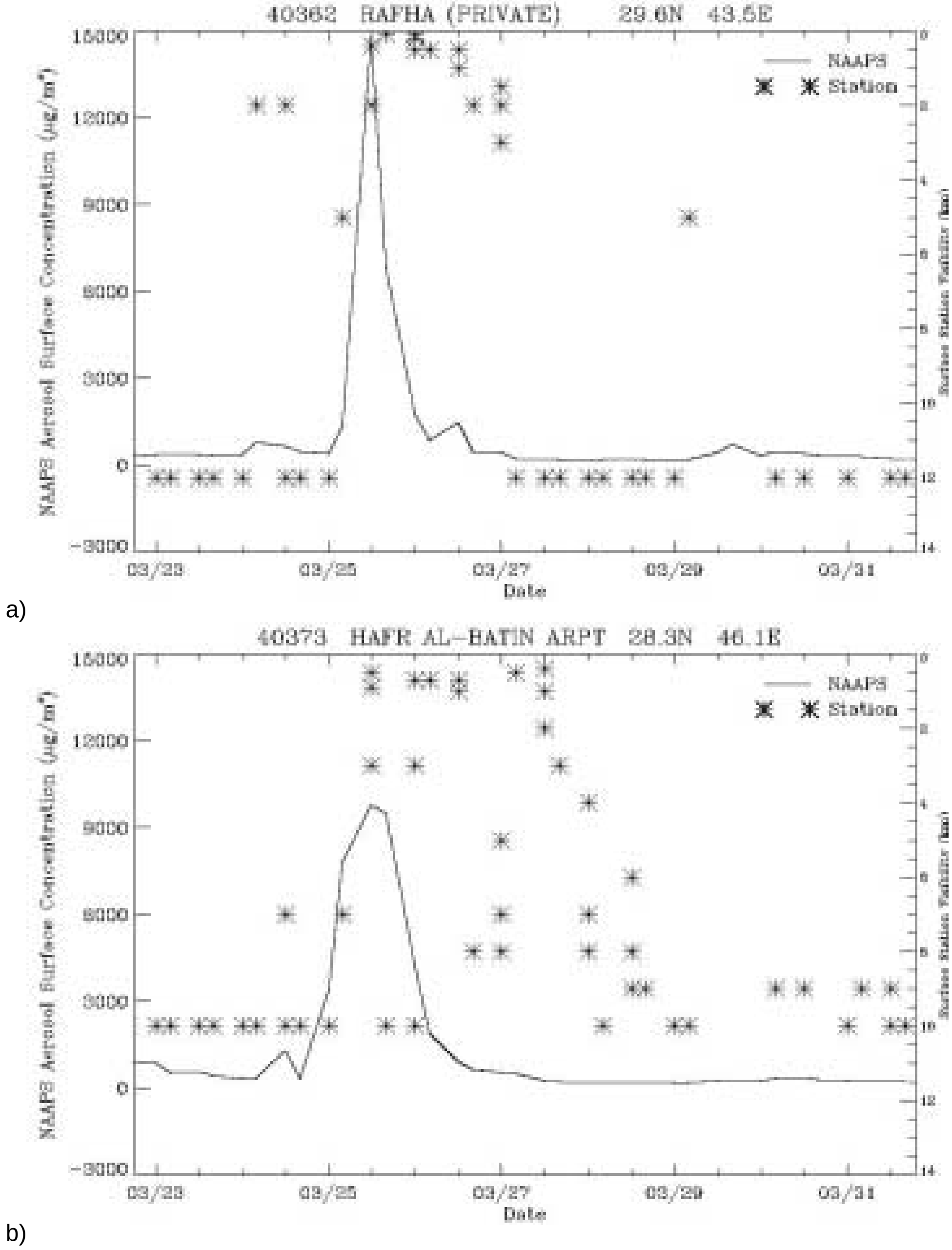

Figure 3: Time series of NAAPS aerosol surface concentration (line and left-hand scale in µg/m^3) and surface station horizontal visibility (asterisks and right-hand scale in km) for (a) Rafha, Saudi Arabia and (b) Hafr Al-batin Airport, Saudi Arabia.

4. SUMMARY AND FUTURE DIRECTION

A set of quality horizontal surface visibility observations is produced in hopes of using station reports as a tool to validate aerosol models. The first step towards that goal was to scrutinize the reporting characteristics of a 2-year sample of stations in Southwest Asia. A two-step filtering approach was employed that reduced the total number of reporting sites (including ships) by about 90%. Stations were removed from the original sample if they did not meet a frequency of reporting criteria or if "missing" was frequently reported vice a visibility number value. The resultant stations reported visibility less than 10 km about 50 days per year (13.5% of observations). Plotting model predicted surface aerosol concentration against station visibility shows a relationship between the two parameters that appears not well correlated which may be attributable to several different factors beyond the scope of the initial phase of this study. The onset of a severe dust event was captured well by the NAAPS model, although it tended to clear the air faster than was observed.

The goal of deriving a predictive relationship between model forecast surface concentrations and horizontal visibility will guide the direction of investigation. Comparing the raw output data from the model is only the first step in determining the value in using reported visibility to validate aerosol model surface forecasts. Further filtering of the station data will involve separating certain weather classes and determining how well correlated the aerosol model surface concentration forecasts and visibility observations are. Another approach will be to bin the visibility categories into intervals such that a binary success score (e.g., hit rate) from the model forecast can be calculated.

5. REFERENCES

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