REAL-TIME SO_2 FORECASTING SYSTEM WITH COMBINED ETA ANALYSIS AND CALPUFF MODELING

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INTRODUCTION

Avoiding violations is a daily challenge for many plants which emit pollutants in amounts that cause no problem under most meteorological and operational conditions, but occasionally lead to excessive concentrations in their surroundings. Timing particularly polluting operations during favorable periods and reduced emissions during unfavorable weather can be greatly helped by a forecasting dispersion modeling system.

In this paper, we describe an online forecast-warning system that has been developed to help predict periods when meteorological conditions could lead to high sulfur dioxide (SO_2) concentrations in the vicinity of a smelter-power plant facility in North America.

The key to the warning system is to use online synoptic weather forecasts issued by the National Centers for Environmental Prediction (NCEP) as a driver for the CALPUFF dispersion modeling system, issue hourly predictions of 30-minute averaged SO_2 concentrations for a full load and reduced load scenarios, and report on source apportionment. The system is general in structure and can be coupled to other forecast models. The whole process is run automatically, without manual intervention.

The forecast system and an associated real-time system are described in the next section, followed by a description of the new "no observations" (NOOBS) version of the CALMET-CALPUFF system (*Scire et al*, 2000, a,b), evaluation and discussion.

FORECAST AND REAL-TIME SYSTEMS

Overview

An online forecast system has been developed to help detect periods when meteorological conditions could lead to exceeding sulfur dioxide (SO_2) guideline concentrations in the vicinity of a smelter-power plant facility in North America. The key to the warning system is to use online gridded synoptic weather forecast fields issued by the National Centers for Environmental Prediction (NCEP) as a driver for the CALPUFF dispersion modeling system, and issue hourly predictions of 30-minute averaged SO_2 concentrations for the next day.

SO_2 concentrations are computed by CALPUFF for a maximum load and several reduced load scenarios. Time series of SO_2 concentrations at the local monitors and of maximum SO_2 concentrations, as well as a source apportionment summary, are reported to the operators in a timely fashion. The forecast of SO_2 concentrations at two monitors, and on arcs of equidistant receptors, is updated 4 times daily (at 0, 6, 12 and 18 GMT), allowing reduction of emissions to be planned effectively. The whole process is run automatically, without manual intervention.

Additionally a real-time prediction system has been developed to update the SO_2 predictions on an hourly basis, using actual emission rates and local meteorological observations from a local 10-meter meteorological tower and SODAR system on site. This gives a real-time picture of the SO_2 plumes over the area and their likely impact at the monitors, which can be further compared with the observed concentrations at the monitors and with earlier forecasts to continuously update operational decisions.

The overview of the modeling system is shown in Figure 1, both for the forecast and real-time modes.

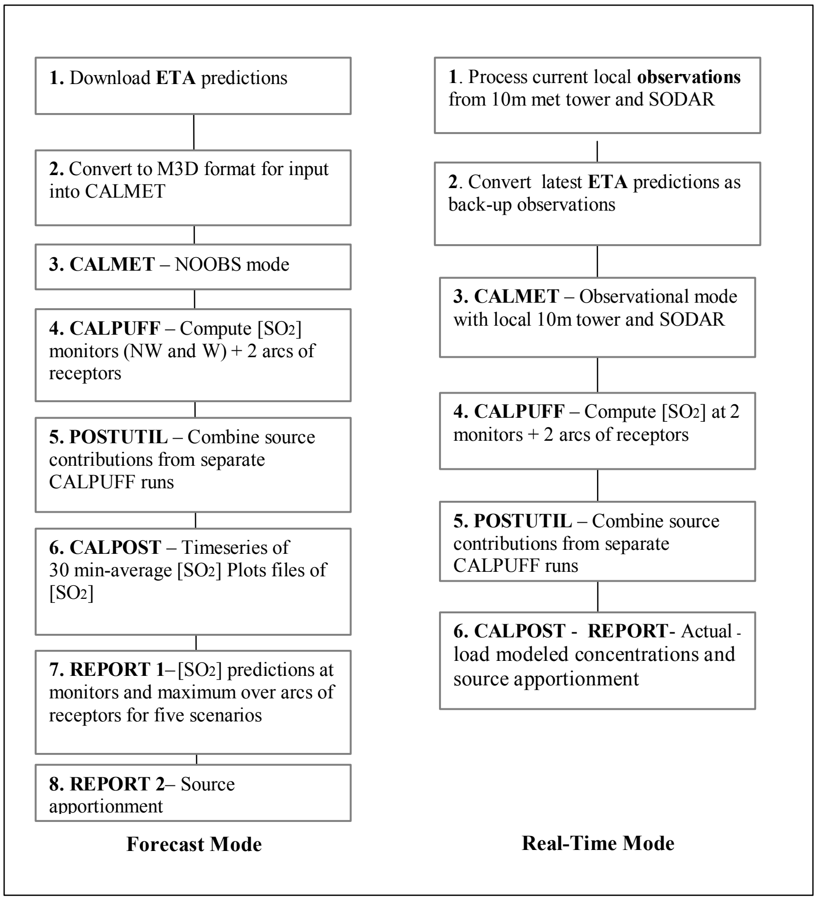


Figure 1. Flow Charts for the forecast and real-time modeling systems.

Meteorological Modeling

A newly developed version of CALMET allows the CALPUFF modeling system to run in the absence of actual observations, provided large scale weather predictions, such as ETA or MM5 gridded prognostic 3D output, are available to steer the meteorological modeling. This is the so-called NOOBS mode of CALMET.

In the current forecasting system, three-hourly ETA predictions at 40-kilometer (km) resolution (ETA grid 212) are interpolated in time (1 hour) and space (200 m) by CALMET over the 10 by 10 km CALPUFF computational domain. The winds are refined for any land use and terrain effects and other meteorological variables, such as stability classes and mixing heights, are computed by CALMET.

In the real-time system, actual surface wind observations from the 10-meter meteorological tower, SODAR upper air winds, and precipitation observations, are incorporated into CALMET, along with vertical temperature profiles, relative humidity and cloud coverage and ceiling heights derived from the ETA forecast. As a back-up, ETA wind forecasts are also formatted as pseudo-observations and used as a back-up to insure that the real-time system runs continuously even in the event of missing on-site meteorological data.

Dispersion Modeling

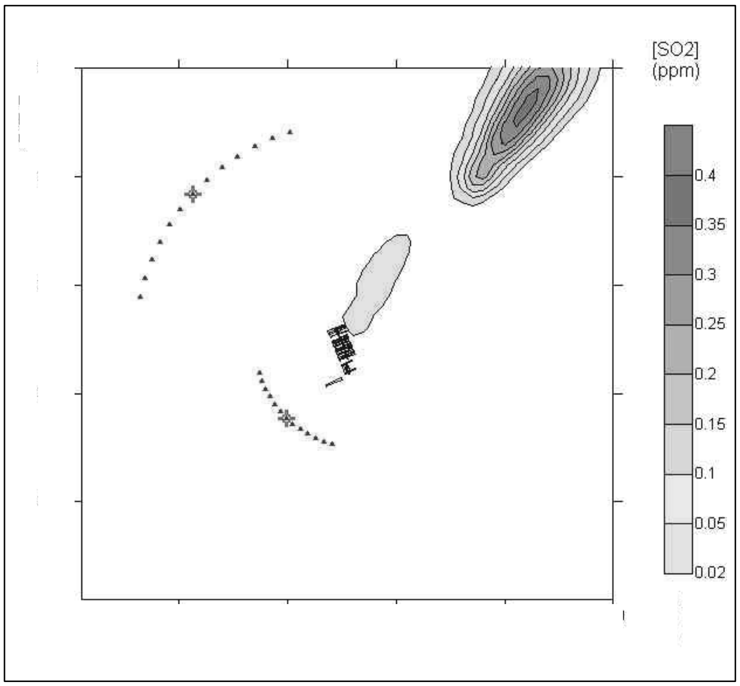


Figure 2. Locations of the 2 existing monitors and rings of equidistant receptors.

The current operational plant set-up is simulated with CALPUFF, as well as 5 reduced load scenarios. The sources are divided into nine source groups to provide a better understanding of the source apportionment.

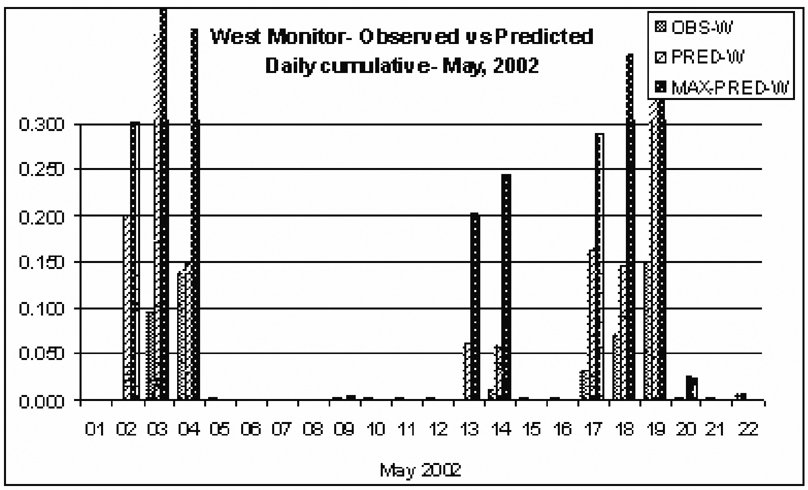
For the real time simulations, actual emission rates are fed into CALPUFF. The variable point source emission characteristics contain the current hour actual emissions, as well as the previous 2 hours of actual emissions for these sources. The 2 previous hours of emissions are needed to avoid startup under-estimates of SO_2.

CALPUFF computes hourly SO_2 concentrations at the two existing monitors (referred to as NW and W monitors), as well as over 2 arcs of receptors located at the same distance from the center of the sources as the actual monitors. The monitors and arcs of receptors are illustrated in Figure 2. The arcs span 30 degrees on each side of the monitors, to account for the fact that wind direction cannot be predicted perfectly and that high concentrations predicted anywhere on the arcs of receptors are as likely to occur at the monitors themselves. The warning system and response strategy should, therefore, make little difference between a predicted "hit" at the monitors, and a predicted "hit" at nearby receptors.

EVALUATION AND DISCUSSION

Evaluation of the modeling results was performed by comparing SO_2 forecasts at the monitors and maximum predicted SO_2 at the receptor rings with the observed SO_2 concentrations at the Northwest (NW) and West (W) monitors.

From January to May 2002, all observed hits, except for one, were predicted by the warning system. The timing of the events was very well predicted too, although sometimes with a couple of hours lag. Figure 3 shows daily cumulative and time-series of observed vs. predicted concentrations in May at one of the monitors.



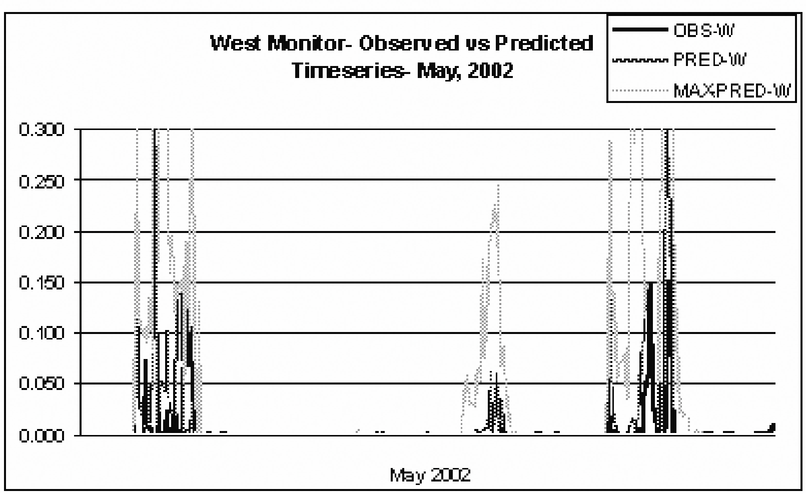


Figure 3. Daily cumulative and time-series of 30-minute average SO_2 concentrations at the West Monitor: observed vs. modeled vs. ring maximum (May 2002).

The magnitude of the impacts tends to be overpredicted by the warning system (i.e., the system is conservative), but the overestimates are often due to the fact that the actual emissions were reduced when the monitored concentrations started to increase, whereas the warnings from the modeling system were based on full-load impacts.

The warning system also issued several false alarms. These false alarms usually showed up on the extreme ring receptors and not on the monitors themselves. However when the occurrence of an impact was correctly predicted, its magnitude generally lied between the magnitude predicted at the monitor and the maximum predicted magnitude, thus highlighting the need for additional receptors away from the monitor itself to correctly assess the potential for violations. The span of receptor rings near a given monitor can be optimized to reduce the number of false alarms while correctly predicting the potential magnitude of the impact.

REFERENCES

Scire, J.S., F.R. Robe, M.E. Fernau and R.J. Yamartino, 2000a: User's Guide for the CALMET Meteorological Model, (Version 5.0), Earth Tech, Inc., Concord, MA.

Scire, J.S., D.G. Strimaitis and R.J. Yamartino, 2000b: User's Guide for the CALPUFF Dispersion Model, (Version 5.0), Earth Tech, Inc., Concord, MA