RESULTS OF IMPLEMENTING A SUB-GRID SCALE TERRAIN EFFECTS PARAMETERIZATION UPON EMISSIONS AND DRY DEPOSITION IN CAMX

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1. INTRODUCTION

The mathematical formulation of certain algorithms in any atmospheric and air quality models may be based on assumptions and simplifications that can lead to incomplete treatment of mass conservation (Byun, 1999a and 1999b; Odman and Russell, 2000). Air quality models combine emissions with meteorological fields to track the transport, transformation and removal of air pollutants. Problems of mass inconsistency or mass distribution in the air quality models arises due to

- Using inconsistent meteorological field generated by the meteorological model.
- Inconsistency in the otherwise correct meteorological fields introduced during translating the grid and time step to the air quality model.
- Terrain height discrepancies in the meteorological models due to numerical stability issues in the dynamics.

The mass inconsistency problem can be handled by modifying the wind and density field used or by using other mass adjustment methods or using a combination of these methods. But, the terrain height problem is not currently addressed in any operational meteorological, emission, or air quality model.

A project funded by Central California Ozone Study (CCOS) addressed that issue by implementing parameterized sub grid scale terrain effects on emission and dry deposition processes in CAMx air quality model.

Section 2 gives a brief description of the problem and the approach to solve it. Section 3 describes the modeling domain, time period and basis of the sensitivity analysis presented in section 4. The final section (5) summarizes the main findings of the study.

2. SUB GRID SCALE TERRAIN EFFECT

In search of sources of mass distribution problems, CAMx model formulations are examined to realistically simulate interactions with complex terrain such as found in California. Existing Baron Advanced Meteorological Systems (BAMS) tools show that when high-resolution United States Geological Survey (USGS) 30 arc-sec terrain data are averaged over 4km CCOS grid in CAMx, the standard deviation of the terrain height within the grid cells exceeds 200 m for most of the State of California, with a maximum of 515 m. Such differences in terrain height would have substantial impacts on model simulations. For example, emission sources and their plumes may be placed at a very different altitude in the model than the actual atmosphere. Again, deposition processes may be removing very different amounts of mass in the model than the actual atmosphere. This further implies, the volume of air subject to emission and dry deposition needs to be corrected to account for the sub-grid scale terrain effect.

The problem is approached from two perspectives.

- Sub-grid scale correction to effective stack height for point source plume rise. This will have substantial effect on emissions near static point sources and resulting air quality behavior.
- Devise a better sub-grid scale terrain parameterization. There are at least two different approaches available,

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the ‘naive’ approach and the ‘reference-mass-conservative’ approach described by Coats (2005).

The primary variables for the sub-grid scale terrain effects are the number of model layers PLAYS into which terrain is allowed to penetrate, and a 3-D array of layer fractions LFRAC, which gives the fraction of each layer of each horizontal grid cell in contact with the terrain. The details of correction approach are described in another accompanying paper (Coats et. al, 2007) in this conference. In brief, the sub grid scale terrain effects are parameterized via modified layer fraction (the fraction of each layer of each horizontal grid cell in contact with the terrain) and a stack height adjustment technique.

3. MODELING SETUP

The modeling domain for this exercise is shown in Figure 1 below.

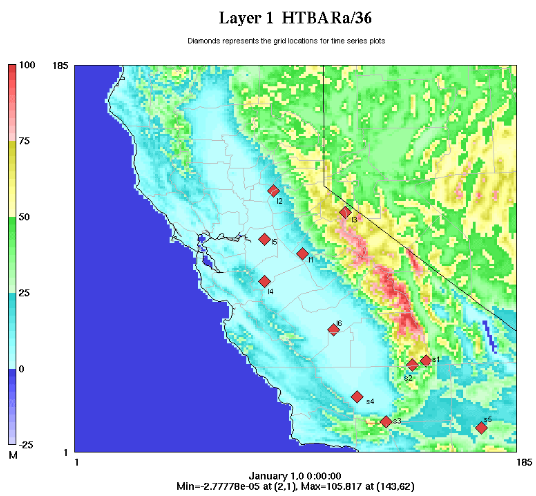

Figure 1: CCOS CAMx modeling domain with terrain height. The diamonds represent selected grid cells for which some detailed analysis are performed.

The time period of interest is July 29, 2000 to August 02, 2000. The horizontal resolution is 4 km and the temporal resolution is 1 hour. The time stamps in CAMx runs are local standard time, which in our case is Pacific Daylight Time (PDT). For this analysis, only layer 1 ozone (PPM) is considered. Table 1 below describes the base case and scenario case runs that have been made.

Table 1: List of model runs for CCOS

Case	***Description***
Base	Default Version, this is the reference case
Lfrac_em	Introduce layer fraction with emission effects only
Lfrac_dif	Introduce layer fraction with deposition consideration only
Lfrac	Introduce layer fraction with both emission and deposition consideration
Stk	Introduce stack height adjustment
Lfrac_stk	Introduce layer fraction and stack height adjustment together

4. RESULTS OF THE SENSITIVITY ANALYSIS

The base case layer ozone varies from near 0 to 0.267 PPM with a definite diurnal pattern in it. A plume is found to develop around 11 AM local time at and near grid cell (147, 52) every day from 07/29/ 2000 to 7/31/2000 (see Figure 2).

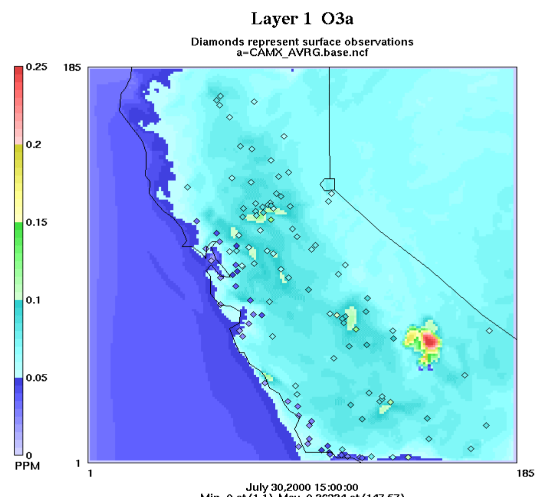

Figure 2: July 30, 2000 3:00 PM surface ozone simulation with surface observation overlay. No surface observation is available to support the hot plume in the southeastern section of the modeling domain.

The plume has a NNE to Northerly movement which disperses by 6 to 8 PM local time. On 7/31, 8/1 and 8/2 some more activity is also noted in the central valley region. The introduction of layer fraction with emission only does not seem to affect the simulation, but the introduction of layer fraction with deposition, affects the result significantly. Figures 3 a-c depicts the effect for July 30, 2000 3:00 PM simulation.

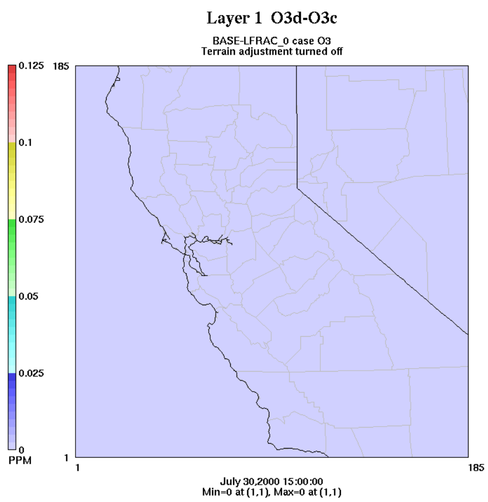

Figure 3a: No Correction applied, the reference.

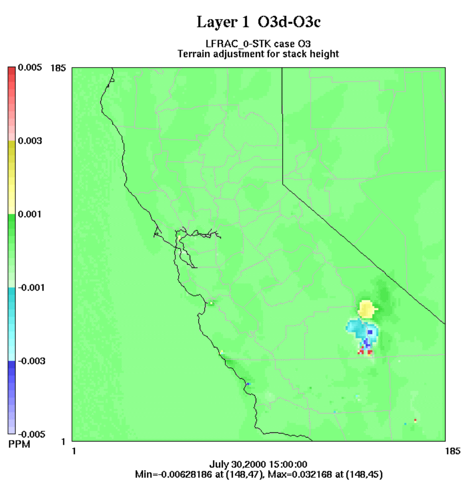

Figure 3b: Effect of introducing stack height adjustment

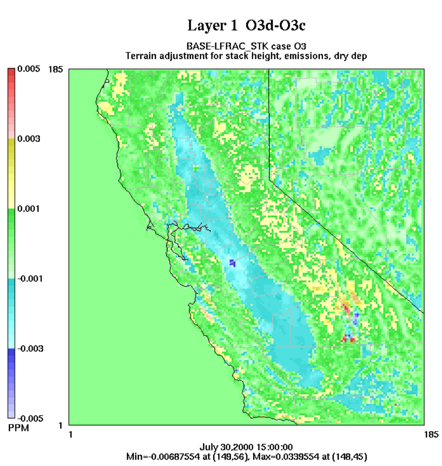

Figure 3c: Effect of introducing layer fraction and stack height adjustment

The stack height adjustment effect (Figure 3b) is pronounced only near a significant point source. But as, the layer fraction correction is introduced, more widespread effects are noted (Figure 3c) mainly due to corrected deposition. The effects are more pronounced over and close by mountains and very less to negligible in the plain valley.

In order to assess, the performance of these simulations, the model output is compared against surface observation. Diamonds in Figure 2 shows the locations of some of the surface ozone monitoring sites in California. For the performance analysis the entire domain is split in 3 windows. The Northern window covers 38.8° N, 122.8°W to 40.0° N, 121.8° W. The Central window covers 37.7° N , 122.3° W to 38.7°N, 121.4°W; and the Southern window covers 37.1°N, 120.6°W to 37.4°N, 119.7°W. For each window the model and observation pairs are selected for morning hours between 8 to 10 AM local time and evening hours between 4 to 6 PM local time. These 6 cases are marked as NM, NE, CM, CE and SM, SE cases respectively. The effect of different scenario case simulation is assessed via the improvement (or deterioration) of the correlation coefficient between model and observation with respect to base case run. Figure 4 shows a bar plot with improvements in correlation coefficient for different scenario cases with respect to the base case run. Negative numbers indicate the correlation is improved towards 1.0 and positive numbers indicate correlation worsens away from 1.0.

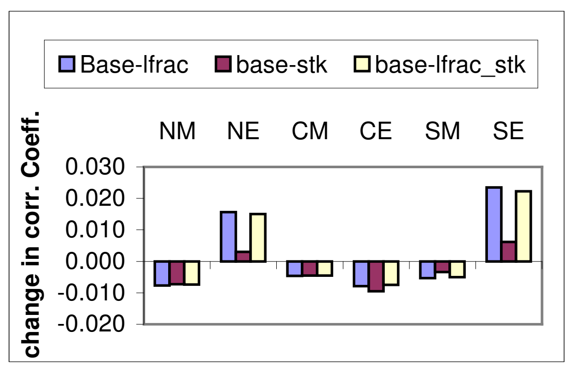

Figure 4: Bar plot for improvements in correlation coefficient

It is observed the layer fraction correction has significant impact in both southern and northern window in the evening. The central part does not show any significant change.

To investigate further how different adjustments impact over the base case, a time series analysis is performed over selected grid cells. 11 points are selected (see Figure 1).

The time series analysis show, the lfrac correction seem to smooth the temporal gradient of the field particularly around the evening hours. For locations in the plain valley, l5 and l6, (see figure 1) the effects are negligible (Figures 5 and 6).

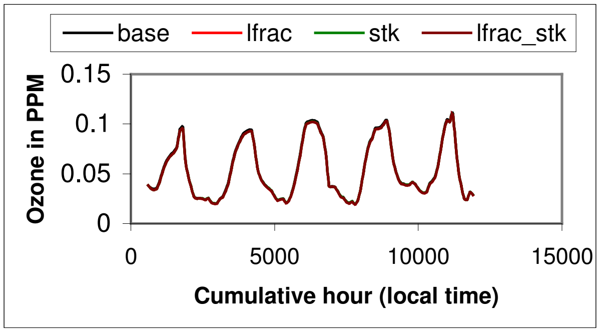

Figure 5: Time-series for grid cell l5

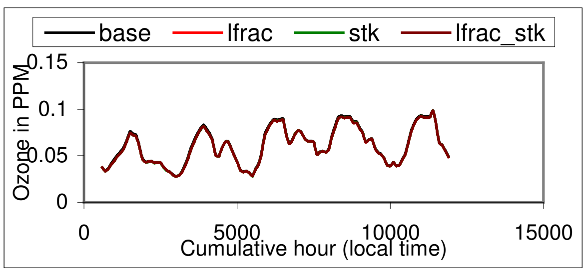

Figure 6: Time-series for grid cell l6

Some interesting features are noted during the time series analysis for grid cells s4 and s5, where there are significant effect of stack height correction. Again, those cells being on top or near mountains, the layer fraction effect is also quite pronounced. As a result, when both lfrac and stk are applied together, for point s4 (Figure 7), the opposite impacts are balanced out and in case of point s5 (Figure 8), similar impacts are added up resulting more temporal smoothing.

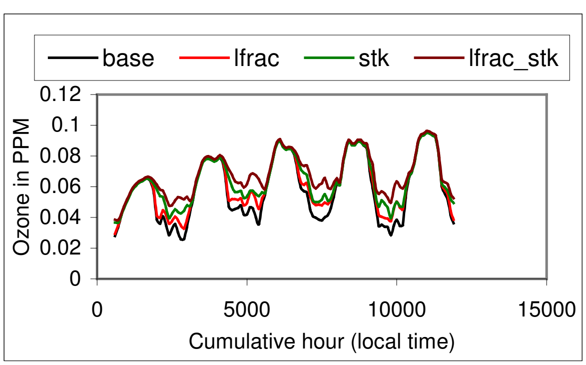

Figure 7: Time-series for grid cell s4.

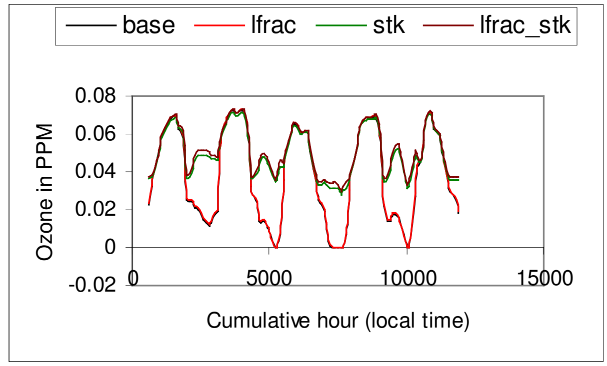

Figure 8: Time-series for grid cell s5.

5. SUMMARY

This paper discussed the result of applying sub-grid scale terrain correction to CAMx model in layer 1 ozone simulation over the State of California. It is found that adjusting stack height has significant but localized impact on air quality simulation near static point sources. It can be as high as 0.05 ppm at some locations. Introducing a layer fraction based terrain parameterization has a more wide spread effect, mostly near the mountains. The maximum effect noted is about 0.035 ppm. The valley region does not have much impact as expected due to flatter terrain.

6. REFERENCES

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