SYNOPTIC SCALE CO_2 VARIABILITY SIMULATED WITH GLOBAL HIGH RESOLUTION ATMOSPHERIC TRANSPORT MODEL

S. Maksyutov[1,2], R. Onishi[1], G. Inoue[1], P.K. Patra[2], H. Akimoto[2] and T. Nakazawa[3,2]

[1]*National Institute for Environmental Studies, Tsukuba 305-8506, Japan;*
shamil@nies.go.jp, onishi.ryo@nies.go.jp, inouegen@nies.go.jp

[2]*Frontier Research Center for Global Change/JAMSTEC, Yokohama 236-0001, Japan;*
prabir@jamstec.go.jp, akimoto@ jamstec.go.jp

[3]*Graduate School of Science, Tohoku University, Sendai 980-8578, Japan;*
nakazawa@mail.tains.tohoku.ac.jp

ABSTRACT

We present a new version of the global atmospheric tracer transport model driven by analyzed meteorology with diurnally varying mixing in the boundary layer capable of running globally at resolutions up to quarter degree longitude-latitude or higher. The impact of the higher resolution model can be visible in resolving city plumes, airmass boundaries, diurnal cycle, fronts and synoptic scale events often observed in continuous CO_2 monitoring site data.

MATERIALS AND METHODS

Higher spatial resolution is beneficial for atmospheric CO_2 transport simulation, because it provides better accounting for surface flux heterogeneity, sharper contrast between polluted and relatively clean areas and air masses. These properties provide a base for treating the short term (hour to weeks) variability as signal rather than noise in the inverse model analysis of the global and regional surface CO_2 exchange with the atmosphere. However, the problem of the atmospheric CO_2 transport simulation at high resolution globally is computationally and data intensive. For the preliminary tests we decided to use lower resolution winds interpolated to higher resolution. The approach is justified by the fact that typical horizontal correlation radius for meteorological conditions is in the order of 100 km. In our study, NCEP operational analyses wind data (1x1 degree, 26 levels) are used together with higher resolution fossil fuel emissions data to simulate CO_2 transport globally at horizontal resolutions of 2, 1, 0.5, 0.25 degree with a new version of the offline NIES transport model [*Maksyutov and Inoue*, 2001]. The new model algorithms are same as in the original model with some changes limited to temporal and spatial resolution. An effort has been made to adapt the model to run on massively parallel computer systems, including NEC SX series with vector processors. Parallelization is achieved by splitting the global data into latitude domains, allowing each processing element to work independently of others, with minimum of communications. In our program, all the wind data preprocessing, flux data interpolations and output processing are done within each domain for that domain only, thus achieving independent operation by each processor, and limiting inter-node communications to only those that are necessary by transport algorithm. Tests on NEC SX computers show the performance per processor on 60 domains remains at the level of 70% of that for the single processor at resolutions from 1 to 0.125 degree globally.

The surface CO_2 fluxes used in this study are seasonally varying oceanic flux [*Takahashi et al.*, 2002], a Sib2 diurnally varying terrestrial ecosystem fluxes [*Law et al*, 2005], and fossil fuel emissions [*Marland et al.*, 2003]. Higher resolution anthropogenic CO2 emissions are synthesized from 1x1 degree emission inventory enhanced with 2.5 min global population map data (CIESIN, 2000), and combined with lower resolution terrestrial ecosystem and oceanic flux data. The population map shows good performance in isolating the large megacities (although not in every country), but is not expected to produce a good job in refining the location of large point sources, such as power plants. The vertical resolution is enhanced to 47 levels in order to resolve better the mixing processes in a boundary layer, driven by 3-hourly PBL height data by ECMWF. The lowest layer has thickness of about 80 m, which is probably not thin enough to resolve diurnal cycle. The layer thickness increases from about 12 hPa near surface to 25 hPa in the troposphere.

RESULTS

The enhancement in horizontal resolution potentially isolates mega city plumes, provides better match with observed amplitude of CO_2 spikes often observed in the continuous monitoring data over continents. However when synoptic scale variability in summer over continent is considered, the simulations with various resolutions from 2 x 2 degree to 0.25x0.25 degree show very similar results when the flux signal is dominated by diurnally varying ecosystem fluxes. Figure 1 shows one example for simulating a synoptic scale event at Pt. Barrow (data by NOAA/CMDL). The synoptic scale variability is captured by model in a similar way regardless of the resolution, and the simulated time series match observed variability better at higher resolution. This calls for further enhancement in both resolution of the surface fluxes and meteorology, including diurnal cycle of mixing. In the presence of diurnally varying surface flux signal the city plumes of the anthropogenic origin are only visible a sufficiently high resolution and above surface level where diurnal cycle amplitude is lower. In many sites located within 300 km of the metropolitan areas, the increase of the resolution from 2 to 0.5 degree does produce significant impact on annual average concentration by simulating a better contrast between polluted urban and clean countryside areas.

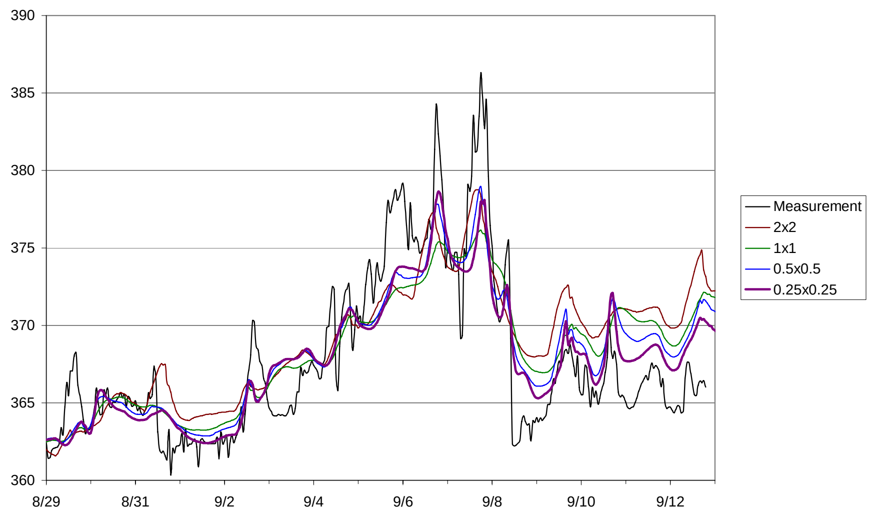

Figure 1 shows the time series (observed and modelled) of CO_2 concentrations at Pt. Barrow simulated at 4 resolutions (0.25, 0.5, 1, and 2 degrees).

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