ECHAM/ECMWF tracer forecasts for the NASA GTE/TRACE−P experiment

Martin G. Schultz, Hans−Stefan Bauer, and Johann Feichter
Max Planck Institut für Meteorologie, Hamburg
24 April 2001

TRACE−P (Transport and Chemistry Experiment − Pacific) is the latest in the GTE (Global Tropospheric Experiment) series of aircraft campaigns to study the chemical composition and chemical evolution of tropospheric trace gases and aerosols. The experiment took place in the Western Pacific in spring 2001 (25 February − 9 March) and was operated out of the two base stations Hongkong, China, and Yakota, Japan. The objectives of TRACE−P were:

- to determine the chemical composition of the Asian outflow over the Western Pacific in spring in order to understand and quantify the export of chemically and radiatively important gases and aerosols, and their precursors, from the Asian continent
- to determine the chemical evolution of the Asian outflow over the Western Pacific in spring and to understand the ensemble of processes that control this evolution.

In order to meet these objectives, two aircraft, the NASA DC−8, and the NASA P−3B, performed over 100 flight hours each, sampling air over the Pacific ocean from as low as 250 m to a maximum altitude of 12 km (DC−8) and 8 km (P−3B). They encountered a wide range of pollution conditions from pristine tropical air to heavily polluted outflow from China and Japan.

The Max Planck institute for meteorology, Hamburg, supported the TRACE−P experiment by providing daily forecasts of chemical tracer fields and meteorological parameters to the experimentalists in the field. We ran a beta version of the new ECHAM5 general circulation model, nudging the climate model towards the forecast products from ECMWF. The model was run in T42 resolution (due to technical difficulties, we could not run in T106 resolution as originally planned) with 19 vertical levels, and it contained a description of emissions, chemical sources and sinks and transport of 11 "tagged" carbon monoxide (CO) tracers. Tagging was done with respect to emission region (Figure 1) and type (anthropogenic or biomass burning). While the tagged tracers have the respective emissions as their only source, the total CO concentration carries a major contribution (up to 35ppbv) from the chemical oxidation of methane (CH4).

The ECHAM5 model forecasts were executed in Reading and were triggered automatically after 144 hours into the daily 12Z forecast (typically around 10:30 pm). The necessary nudging data (vorticity, divergence, surface pressure, and sea surface temperature) were then extracted from the MARS archive and interpolated to the ECHAM T42 horizontal grid and the orography and vertical resolution of the ECHAM model. Each day, a 1−day run that was nudged with the most recent analysis data available was performed to produce a restart file, then a 5−day run nudged with the 12Z ECMWF forecast data followed. The results were automatically processed (including the generation of various figures), and the data were automatically transferred to Hamburg, from where they were downloaded to the field sites, as well as archived on the ECFS. Interpolation and postprocessing was done on the ecgate1, and the model runs were performed on the VPP5000. With the T42 resolution, the 5−day forecast was typically ready by about 1:30am Z, so that an up−to−date 36 hour forecast was available in the field by 9am or 10am local time in Hongkong and Yakota, respectively.

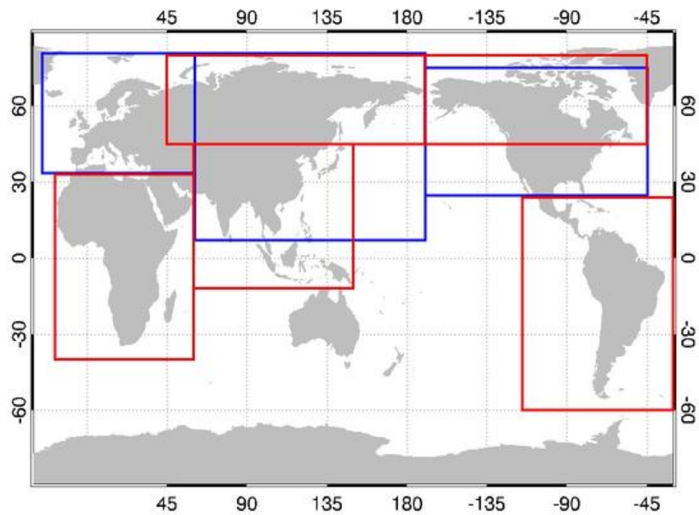

Figure 1: Emission regions used for tagging of the CO tracer in the TRACE−P forecast runs. Blue: anthropogenic emission regions, red: biomass burning emission regions

The ECHAM/ECMWF model product was extensively used for flight planning. Figures 2−5 show a series of horizontal cross sections for various model levels that were produced for planning of a local flight out of Yakota on 21 March 2001. The red and green line represent the ground tracks of the DC−8 and P−3B aircraft, respectively. Highest CO concentrations (locally exceeding 1 ppmv) were predicted for the lower boundary layer, and in particular in the Yellow Sea region (Figure 2). At the (nominal) 850 hPa level, a distinctive plume with concentrations up to 300 ppbv is seen that originates from mainland China, and a strong North−South gradient was predicted seperating the outflow from clean subsiding air (Figure 3). These features are still present in the 700 hPa cross section, but maximum CO concentrations were predicted to have decreased by a factor of two. As the tagged tracers (and also the black carbon tracer) show, this outflow is dominated by biomass burning emissions from South East Asia (Figures 6 and 7). At the 500 hPa level (Figure 5), outflow takes place further to the North across the Japan Sea (note the different color scale). In addition to the horizontal maps, series of vertical cross sections at several longitudes and latitudes were produced as well as 3−dimensional animations with the Vis5D program (not shown).

A comparison of the model forecasts with observed CO concentrations has only recently begun as the observational data are still being evaluated. Ad−hoc observations during the mission indicate that the model had good skills in predicting the location and relative magnitude of lower level outflow, but seriously underpredicted higher−level outflow. In part, this was caused by an error in the convection routine, but it appears that this holds also for frontal lifting conditions. In−flight observations showed CO concentrations in the 300 ppbv range up to altitudes of about 7 km, whereas the model never predicted more than about 100 ppbv at this altitude.

Figure 8 shows the differences in total CO between two forecasts for 7 March 2001 at the nominal 700 hPa model level. The 66 hour forecast, which had been used for flight planning, shows a somewhat more confined pollution plume compared to the 18 hour forecast which was retrieved while the two aircraft were flying. The 18 hour forecast shows elevated CO concentrations closer to the south−eastern leg of the DC−8 (red line) which were indeed sampled during the flight (absolute concentrations were underpredicted by a factor of two, though).

For the near future, we plan to rerun our model after fixing the bug in the convection routine and further tests. In order to have better defined initial conditions, we will start the run in January 2000 and run through the complete TRACE−P period using the ECMWF analysis data. For selected flight days, we will also repeat the forecast runs and compare the results of different forecast initialisations with the analysis run and with the observations. If time and resources allow, we will furthermore run the model in higher resolution (T106) and evaluate the differences.

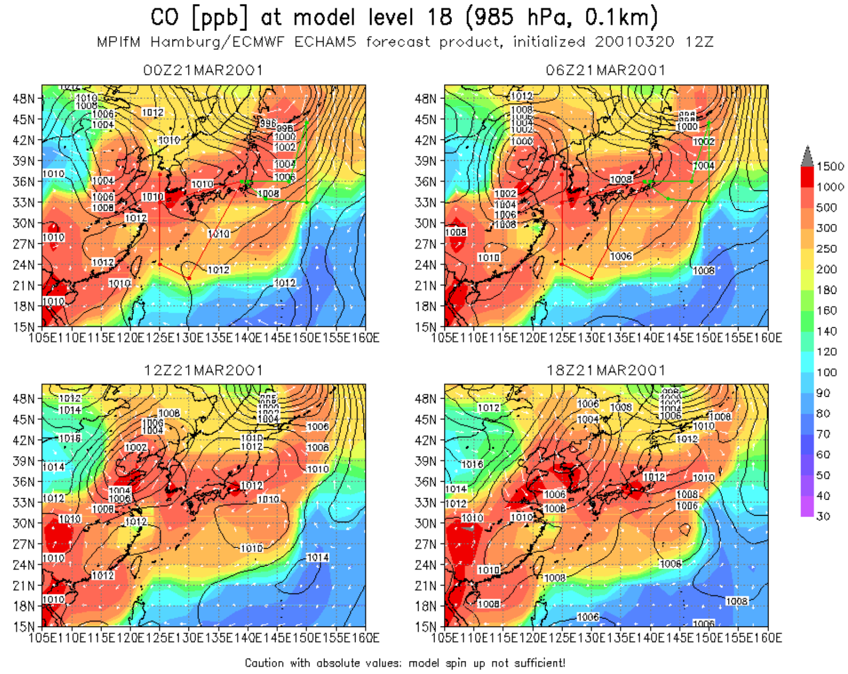

Figure 2: Horizontal cross section at the nominal model level of 985 hPa of the 36−54 hour forecasts of the total CO tracer and the wind field for 21 March 2001

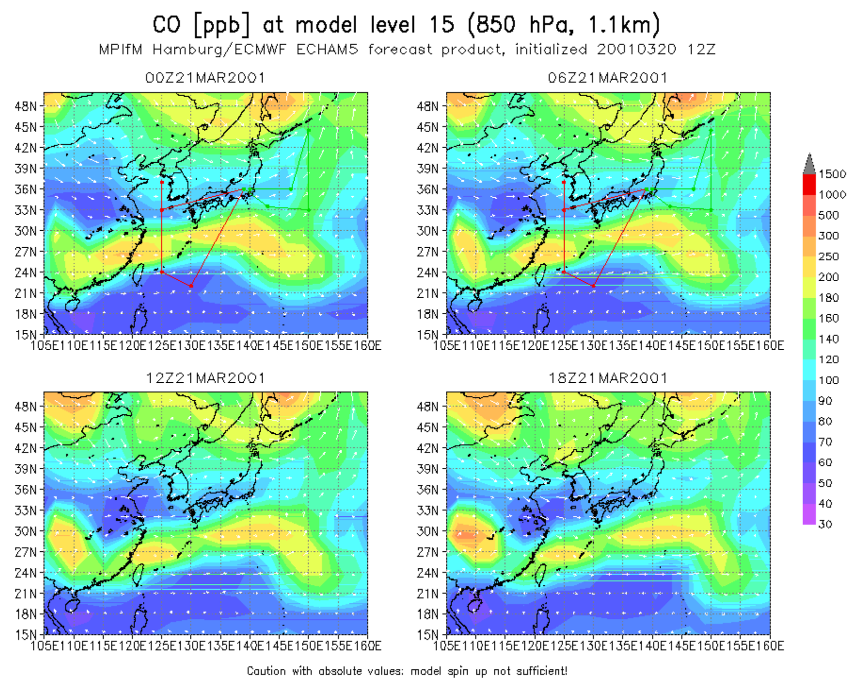

Figure 3: dto. for 850 hPa

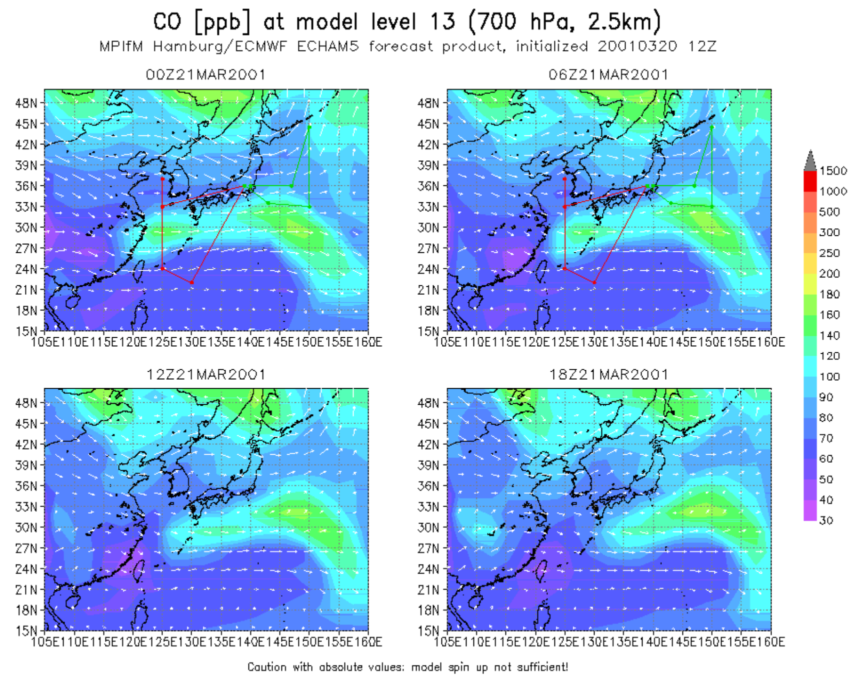

Figure 4: dto. for 700 hPa

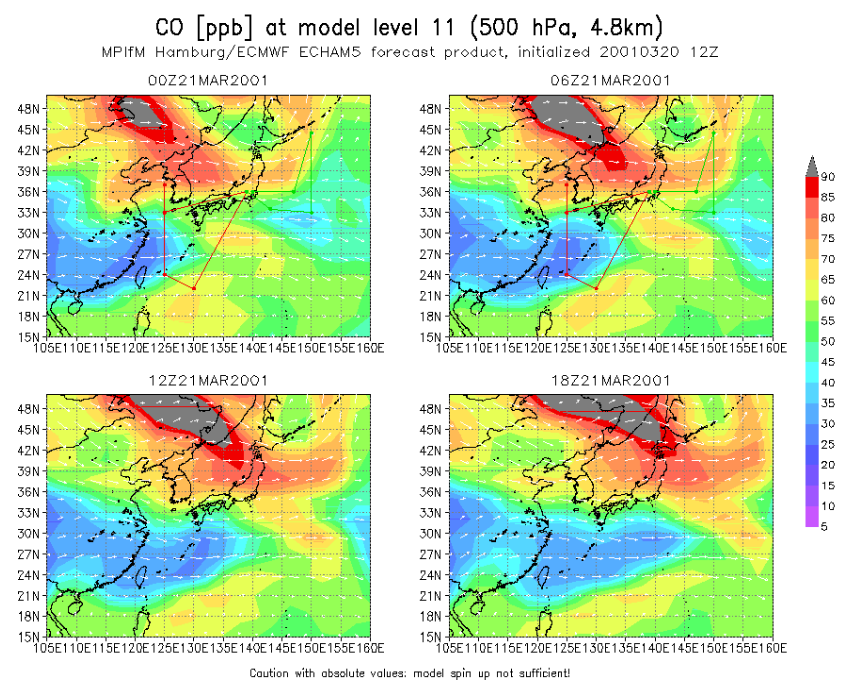

Figure 5: dto. for 500 hPa

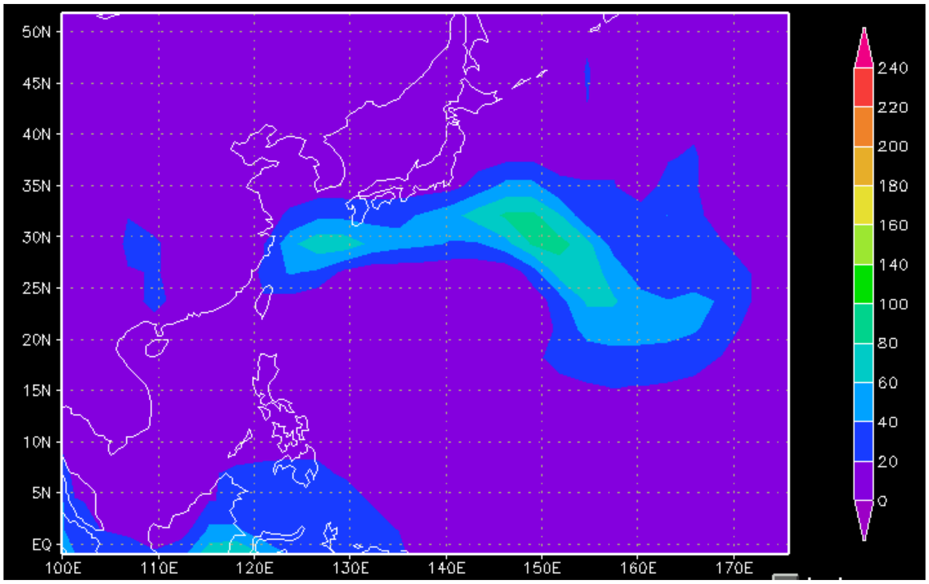

Figure 6: Same as figure 4b, but for the tagged CO tracer representing the contribution from Southeast Asian biomass burning

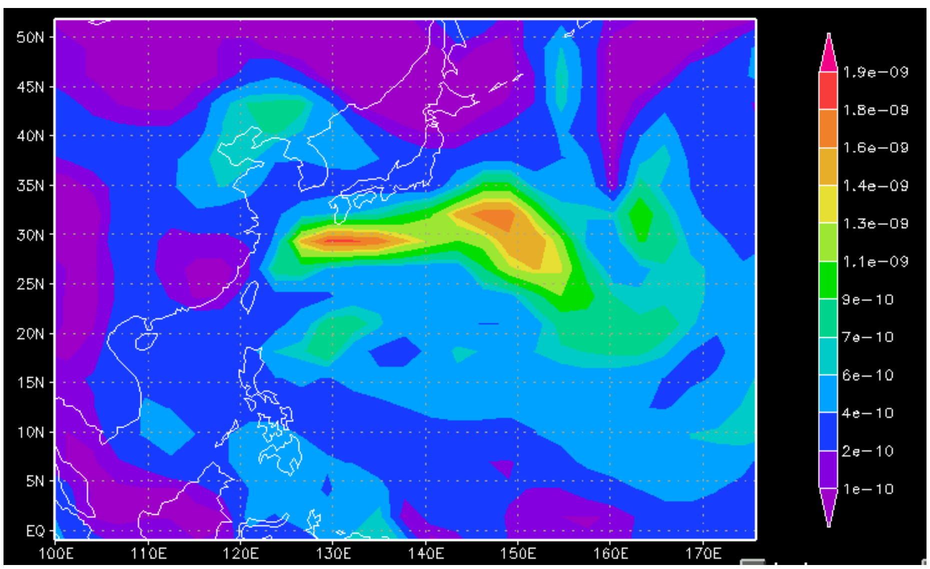

Figure 7: Same as figure 6, but for the hydrophilic black carbon concentration (kg/m3)

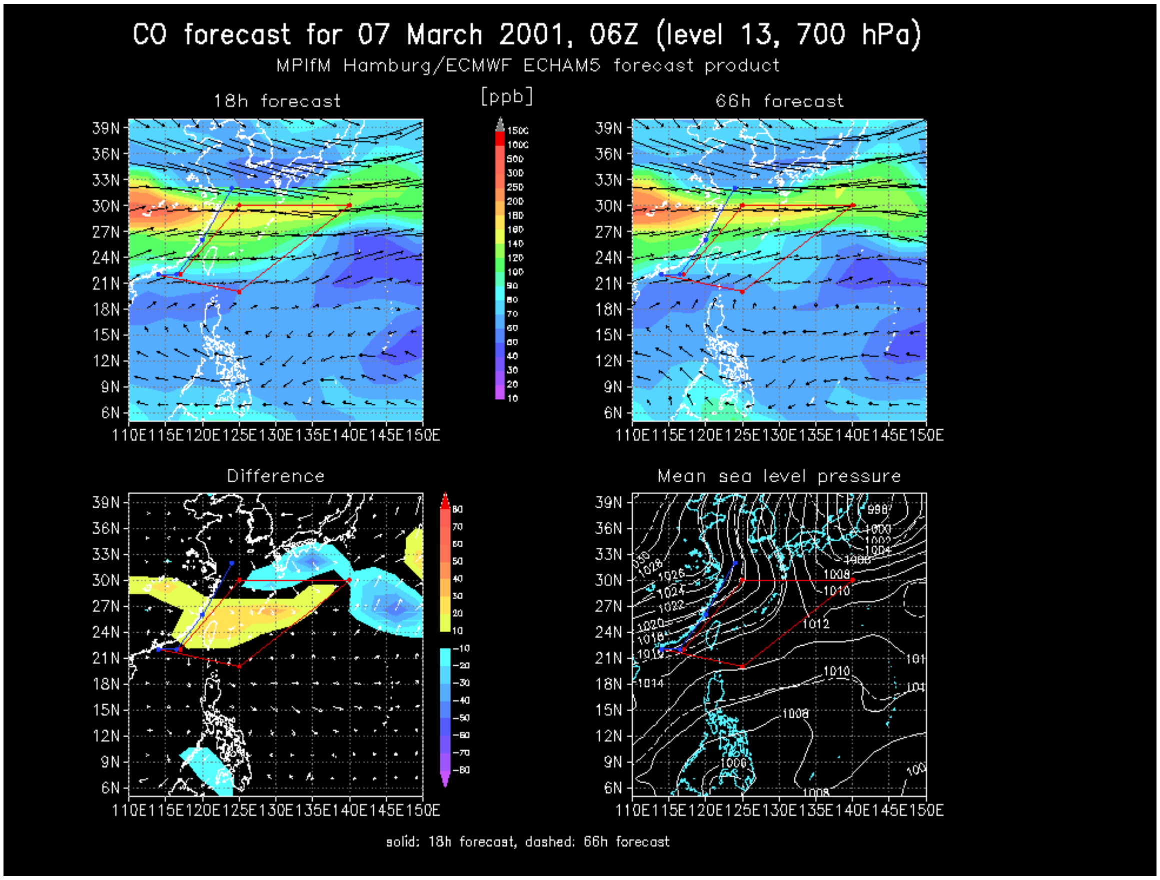

Figure 8: Difference between two forecasts for the same date