On the benefits of using high resolution transport and fluxes to simulate atmospheric CO2 variability

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Abstract

The interpretation of observed variability of CO_2 in the atmosphere depends on the accurate representation of transport and surface fluxes by models. The Copernicus Atmosphere Monitoring Service (CAMS) 9-km CO_2 forecast has high skill in representing the day-to-day variability of atmospheric CO_2 because it relies on the ECMWF state-of-the-art Numerical Weather Prediction (NWP) model. To assess the benefit of the high resolution, the simulations at 9 km are compared with lower resolution simulations (80 km) commonly used in meteorological re-analysis (e.g.ERA-Interim) and chemical transport models. The results show how the transport accuracy improves with model resolution, resulting in up to 1-day gain in the forecast lead time. The resolution of surface fluxes can also have an additional impact on the representation of the atmospheric CO_2 variability. The benefit of the high resolution is further highlighted by using tagged carbon tracers from anthropogenic, land ecosystems, ocean and biomass burning sources. These tagged tracers show the plumes emanating from the different sources. The plumes are used to assess the overlap of the atmospheric signal associated with separate sources during a 5-day forecast. Finally, the high resolution forecast also allows to assess the small-scale (¡ 100 km) variability of atmospheric CO_2 observed by in situ and satellite observations, which cannot be represented by coarser-grid transport models. As these high resolution CAMS CO_2 forecasts are provided in real time, they can be used as boundary conditions for regional modelling studies and for planning field experiments.

Global atmospheric CO_2 simulations

✓ Cyclic forecasts initialized on 1 January 2014 with GOSAT analysis [4] are performed for a month to test the impact of different resolutions:

- ✗ Forecast is re-started daily at 00 UTC with meteorology from operational ECMWF analysis.
- ✗ Transport from operational C-IFS model at ECMWF [3].
- ✗ Most fluxes are prescribed, while the biogenic fluxes are modelled online [1][2].
- ✗ Atmospheric CO_2 is cycled from one forecast to the next (i.e. free running).

✓ Different resolutions are used for the fluxes and the model transport:

- ✗ **HR**: Transport at 9 km, 137 vertical levels and surface fluxes at 9km.
- ✗ **LR**: Transport at 80 km, 137 vertical levels and surface fluxes at 80km.

Impact of horizontal resolution on CO2 transport

Model resolution has an impact on the global transport of CO_2:

✓ Reduction of wind speed root mean square error (RMSE) at all forecast days.

✓ Reduction of surface daily mean CO_2 RMSE at all forecast days.

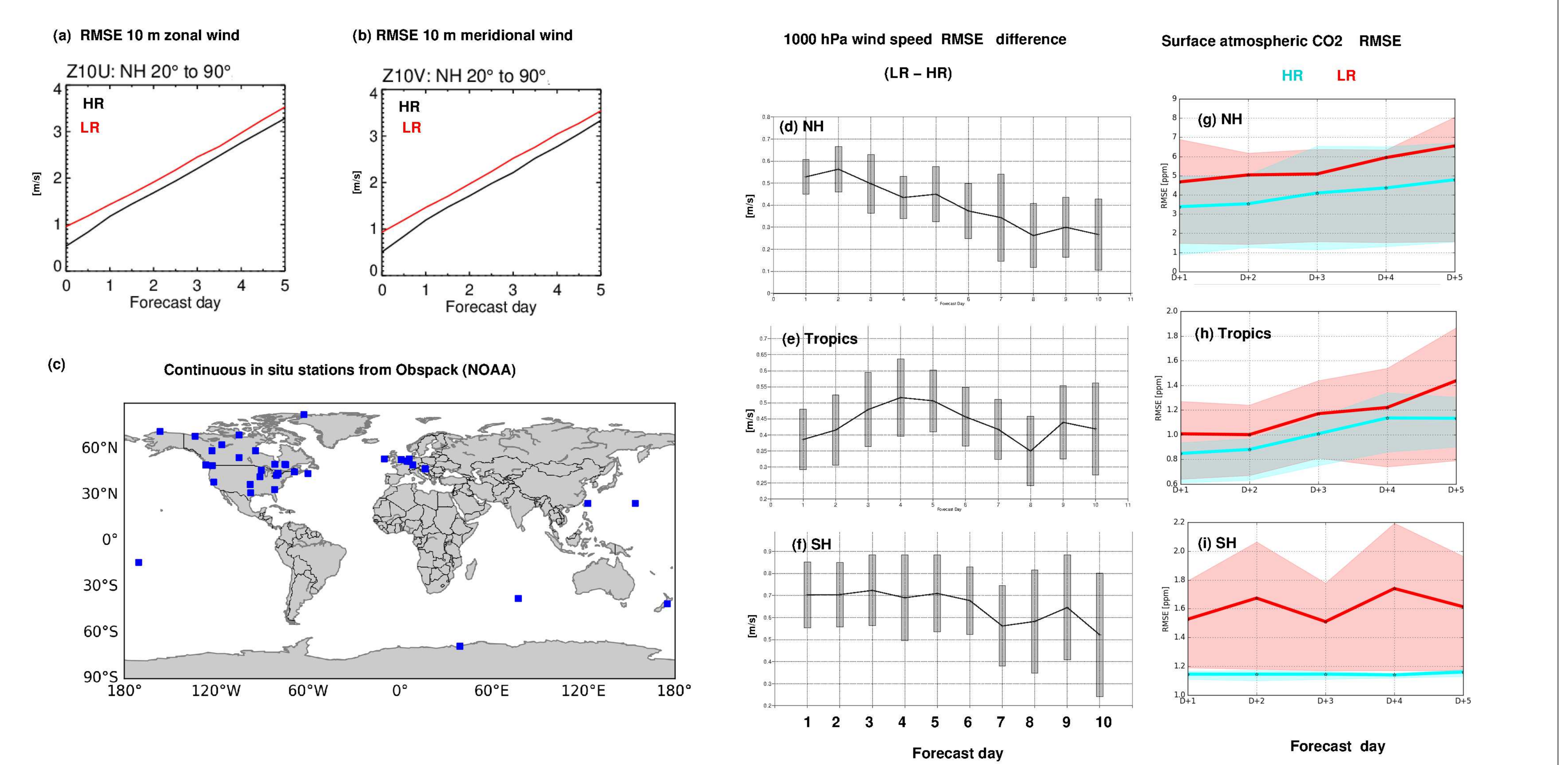

Figure 1: (a,b): RMSE of 10-m zonal and meridional wind speed [m/s] with respect to the ECMWF operational analysis; (c) Map of in situ surface and tower stations from the NOAA Obspack dataset [5] used to evaluate CO_2 forecast; (d,e,f): Difference in 1000 hPa wind speed RMSE between high (HR) and low resolution (LR) forecasts where RMSE is computed with respect to radiosonde observations and positive values mean that LR has larger RMSE than HR; (g,h,f) RMSE of CO_2 forecast [ppm] with respect to surface and tower in situ observations at sites in (c) shown by the mean of all stations (solid line) and the 20 to 80 percentiles (shaded area) for the LR (red) and HR (cyan) forecasts at different forecast days. All the statistics are computed for January 2014.

Tagging CO_2 tracers to sources/sinks

Tagged tracers give an indication on the atmospheric CO_2 change associated with the different CO_2 source/sink components. The anthropogenic plumes associated with the passage of weather systems are collocated with the plumes of biogenic origin. Overall, these biogenic plumes have a larger signal at synoptic scales, except for the region of the western Pacific, where the anthropogenic plume emanating from SE China dominates.

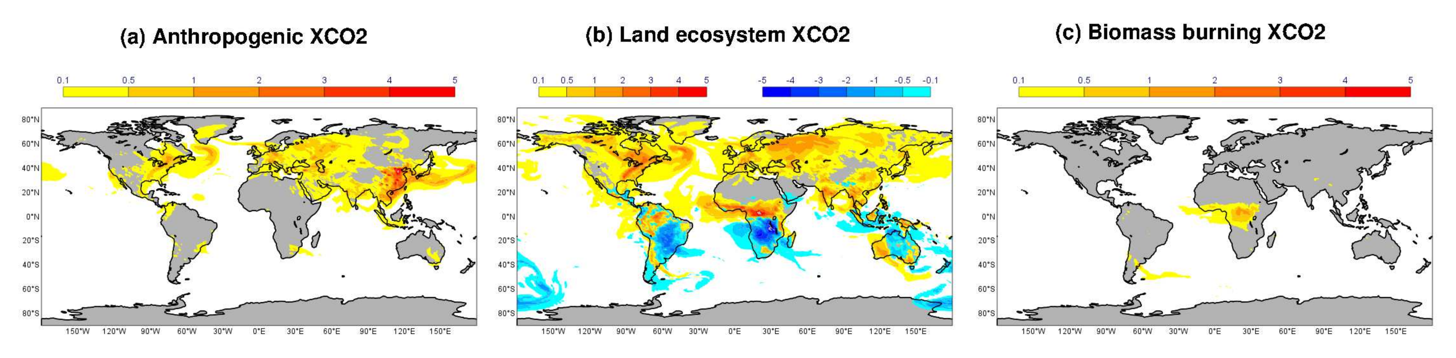

Figure 2: Enhancement/reduction of atmospheric CO_2 [ppm] associated with (a) anthropogenic emissions, (b) land vegetation sources/sinks; (c) biomass burning during after a 5-day forecast initialised on 9 January 2014.

CO2 subgridscale variability

The largest impact of high resolution is expected in regions where there is small-scale variability. Subgridscale variability (σ) of total column mean dry molar fraction within 1x1 degree grid can be computed from the high resolution forecast (HRL137TransHRFlx):

✓ Largest values of small-scale variability ($\sigma > 0.5$ ppm) can be found in the tropics and also in regions with emission hotspots and complex topography.

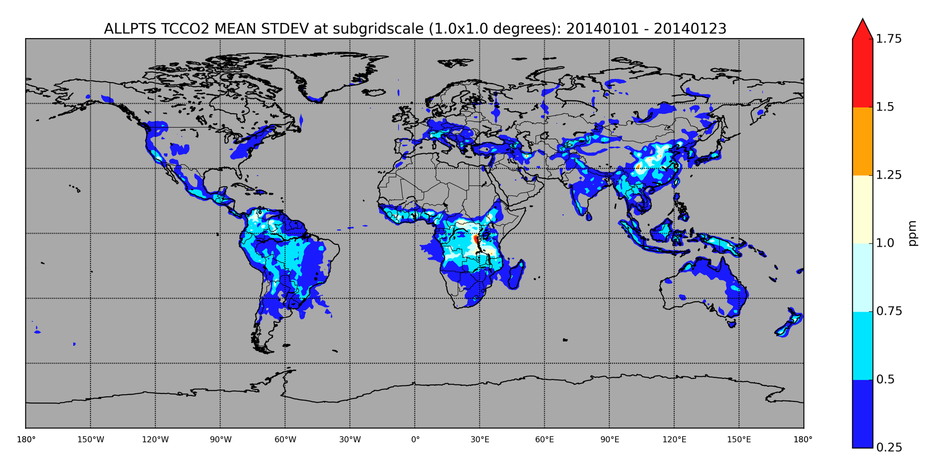

Figure 3: Standard deviation of total column mean dry molar fraction X_{CO2} [ppm] within a 1x1 degree cell for January 2014.

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