The Impact of Meteorological Analysis Uncertainties on the Spatial Scales Resolvable in CO_2 Model Simulations

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The evolution of CO_2 is governed by the species transport equation and thus may be considered to be perfectly predictable if the advecting winds are perfectly known. However, this is never the case. In this work, we study the predictability of CO_2 in order to better understand the contribution of uncertain meteorological analyses to CO_2 transport error. Specifically, we identify the spatial scales resolvable in CO_2 simulations given that advecting winds are imperfectly known. A newly developed coupled meteorological and greenhouse gas transport model based on Environment and Climate Change Canada's operational weather and environmental prediction models are used for this purpose. With posterior fluxes from Earth Systems Research Laboratory Global Monitoring Division's (ERSL/GMD) CarbonTracker, CO_2 simulations compare well to observations assimilated by CarbonTracker (surface continuous) as well as to independent observations (TCCON and ERSL/GMD aircraft profiles). This coupled model is then used to show that the predictability of CO_2 is much shorter than that of the temperature field but is commensurate with that of the wind fields. When broken down into spatial scales, CO_2 has predictability at the very largest scales (wave numbers less than 10 near the surface) due to long time scale memory in surface CO_2 fluxes as well as in land and ocean surface forcing of meteorological fields. The predictability due to the land and ocean surface is most evident in boreal summer when biospheric uptake produces large spatial gradients in the CO_2 field. Predictability errors provide an upper limit for errors arising solely from the use of uncertain meteorological analyses. When considering meteorological analysis errors, CO_2 can be simulated well only on large scales (see Figure 1). Thus, there is a spatial scale below which information cannot be obtained simply due to the fact that meteorological analyses are imperfect.

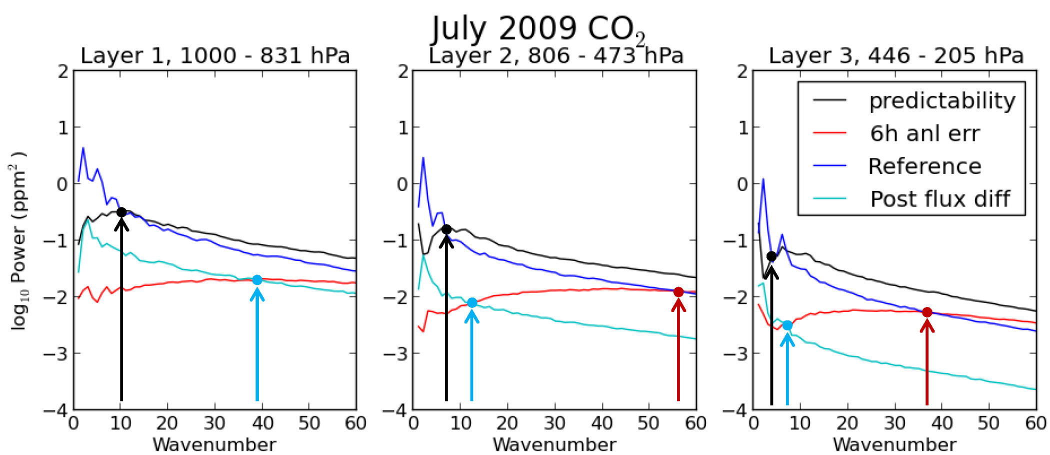

Figure 1. Spectra of various fields as a function of total wavenumber. Spectra are averaged over one month for July 2009 and over 12 model levels. The lower and upper model levels averaged are indicated above each frame in approximate pressure. The CO_2 reference state spectra (blue curves), predictability error (black curves), error due to a 6-h shift in analysis fields (red curves) and differences due to the use of different posterior fluxes (CT2010 or CT2013B) (cyan curves) are shown. Wavenumbers smaller than the black arrows are theoretically predictable. Wavenumbers smaller than the red arrow are definable in the presence of meteorological analysis errors. The scales for which the difference in CO_2 resulting from two different posterior fluxes exceed CO_2 errors due to uncertain meteorology are to the left of the cyan arrows.