Seasonal and inter-annual variability in wetland methane emissions simulated by CLM4Me′ and CAM-Chem and comparisons to observations

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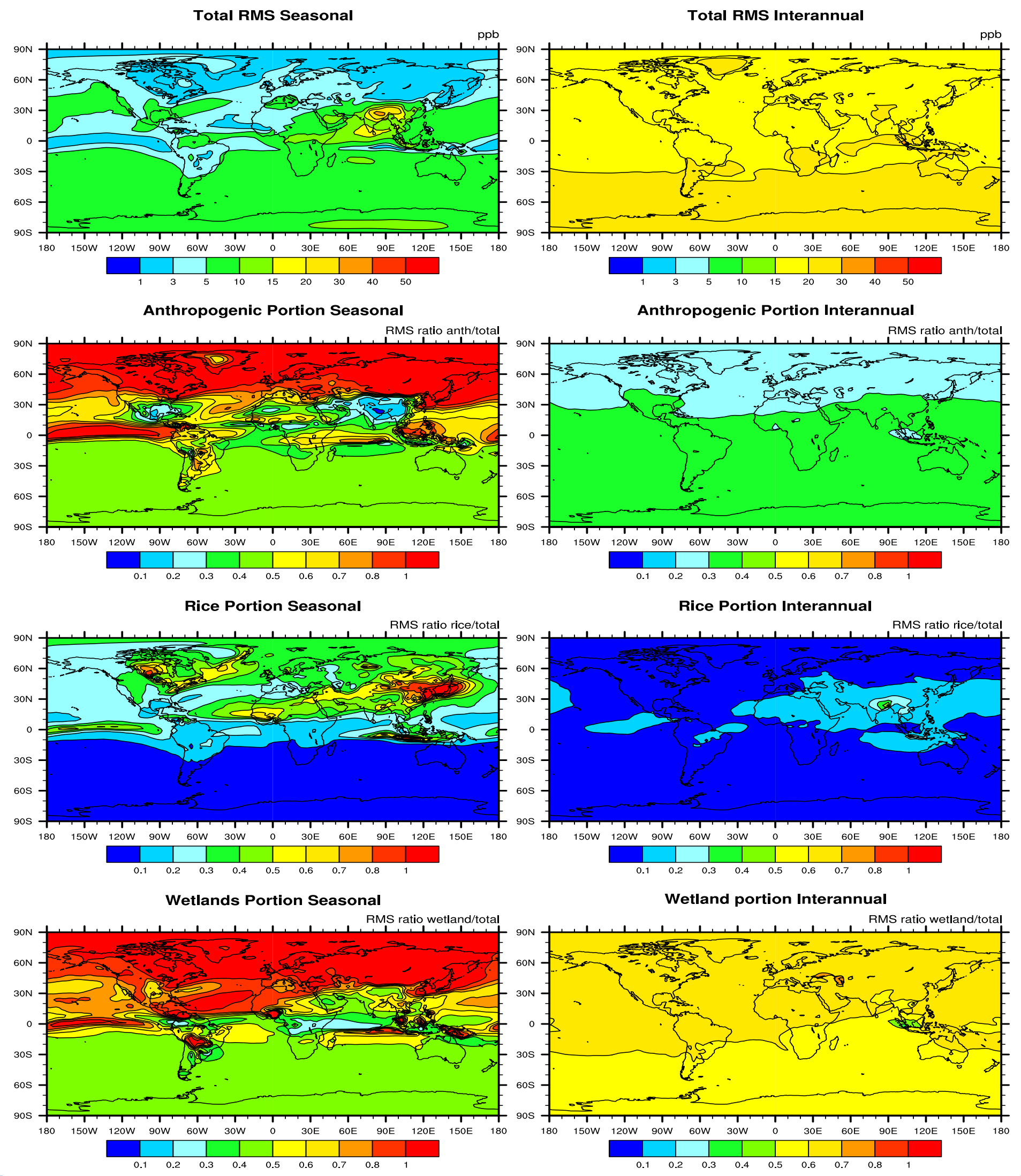
Abstract:
Understanding the temporal and spatial variation of wetland methane emissions is essential to the estimation of the global methane budget. We examined and evaluated the seasonal and inter-annual variability in wetland methane emissions simulated in CLM4Me′, a process-based methane biogeochemical model. We also conducted simulations of the CAM-Chem model using CLM4Me′ methane emissions along with other methane sources and compared CAM-Chem simulated atmospheric methane concentration with observations. The simulated and observed concentrations were used to improve the magnitude of methane simulated from wetlands in our model. Our analysis suggested that wetland methane emissions peaked in 1994 and decreased since then in the period of 1990-2005. The largest decrease in wetland emissions occurred in the tropics due to the decrease in inundated area, as observed in satellite retrievals. In CLM4Me′, the largest seasonal variation was present between 30N and 50N in mid-latitude. The seasonal variation in high latitudes was small in magnitude due to the overall low emissions. CAM-Chem model simulations suggested that both prescribed anthropogenic and predicted wetlands methane emissions contributed substantially to seasonal and inter-annual variability in atmospheric methane concentration. Rice paddies had an important contribution in seasonal variability of atmospheric methane concentration in parts of Asia and North America. This study confirms the significance of tropical wetlands in constraining global wetland methane fluxes and suggests that changes in the growth rate of methane may be strongly driven by changes in tropical methane fluxes.



Absolute RMS variability (in ppb) from 1991-2004 of atmospheric CH_4 concentration. The left panel shows seasonal RMS variability and the right panel indicates inter-annual RMS variability. From the top to the bottom are total RMS variability, anthropogenic contribution to total RMS variability, rice contribution to total RMS variability, and wetland contribution to RMS variability. Note that portional RMS variability of anthropogenic sources, rice paddies, and wetlands add up to >1 when cancellation among component tracers occurs in the summing of total CH_4.

Selected Bibliography:
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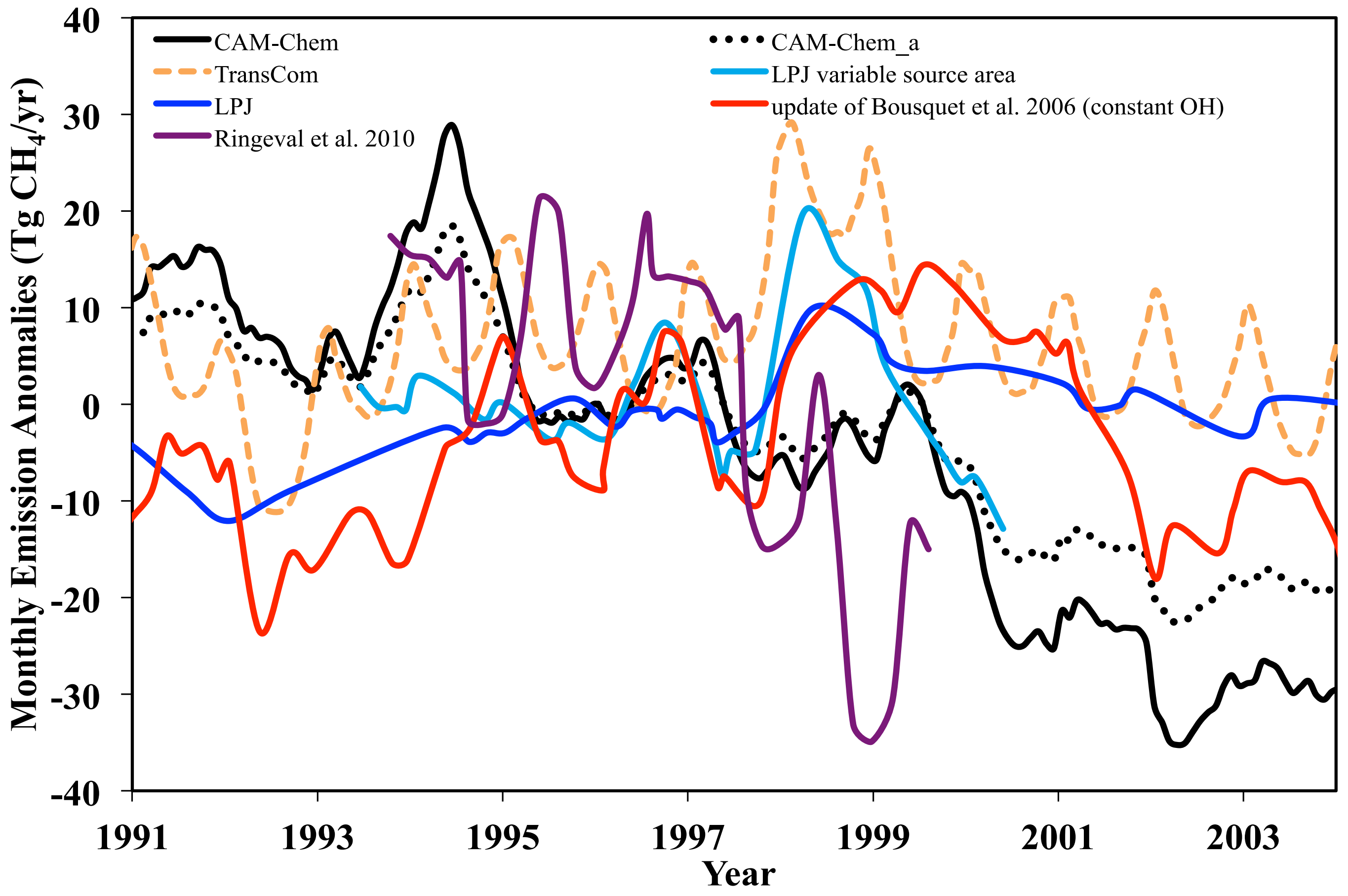
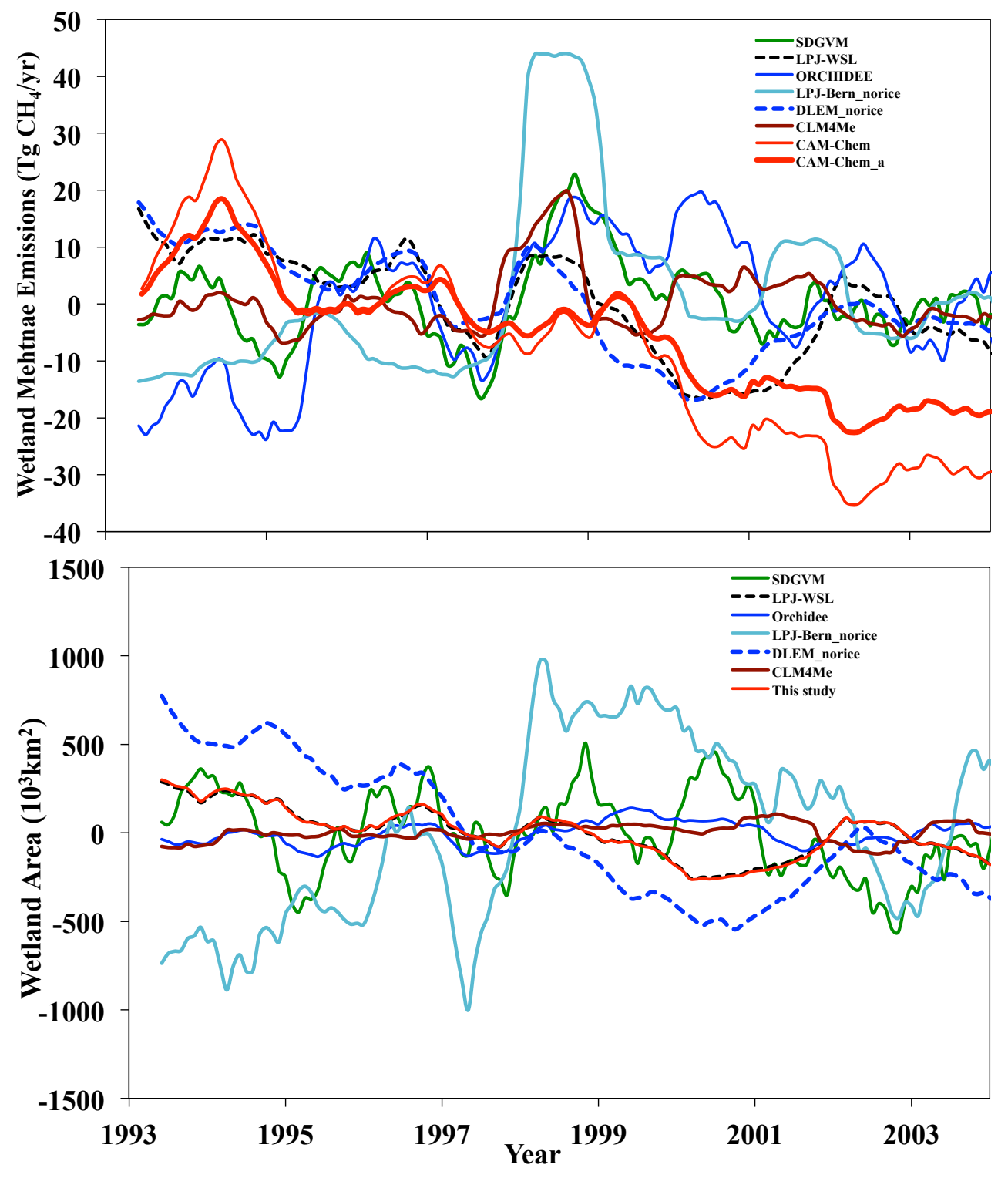
Melton, J.R. et al., 2013. Present state of global wetland extent and wetland methane modelling: conclusions from a model inter-comparison project (WETCHIMP). Biogeosciences, 10(2): 753-788.
Meng, L. et al., 2012. Sensitivity of wetland methane emissions to model assumptions: Application and model testing against site observations. Biogeosciences: 9, 2793-2819, doi:10.5194/bg-9-2793-2010.
Prigent, C., Papa, F., Aires, F., Rossow, W.B. and Matthews, E., 2007. Global inundation dynamics inferred from multiple satellite observations, 1993-2000. Journal of Geophysical Research-Atmospheres, 112, D12107,doi: 10.1029/2006JD007847(D12). Papa, F. et al., 2010. Interannual variability of surface water extent at the global scale, 1993-2004. Journal of Geophysical Research-Atmospheres, 115, D12111, doi: 10.1029/2009JD012674: -.
Riley, W.J. et al., 2011. Barries to predicting changes in global terrestrial methane fluxes: Analysis using CLM4ME, a methane biogeochemistry model integrated in CESM. Biogeosciences, 8: 1925-1953, doi: 10.5194/bg-8-1925-2011.
Ringeval, B. et al., 2010. An attempt to quantify the impact of changes in wetland extent on methane emissions on the seasonal and interannual time scales. Global Biogeochemical Cycles, 24, GB2003, doi: 10.1029/2008gb003354.

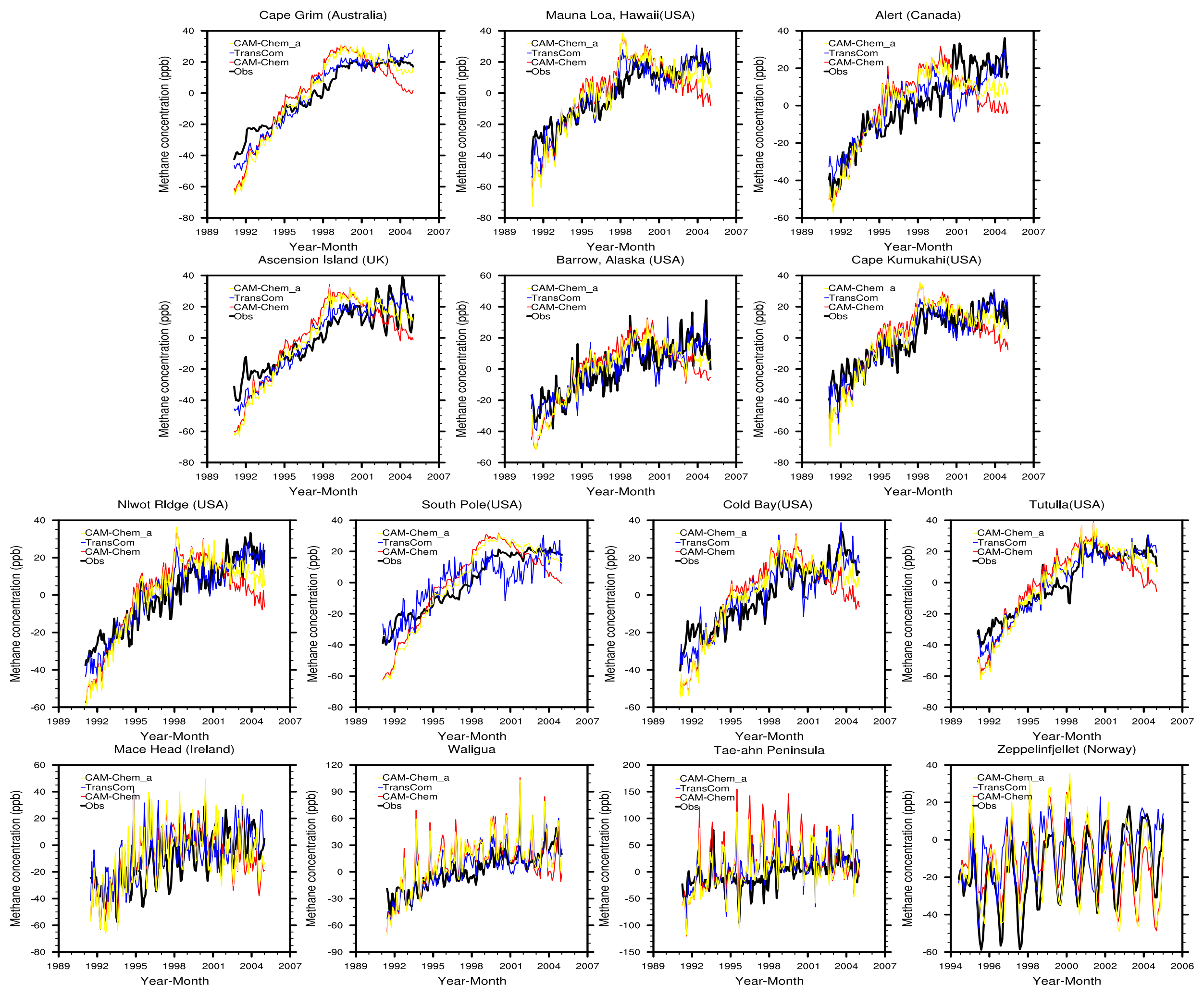
In the CLM-Me' simulations used here, there is a strong decrease in tropical methane emissions, more so than seen in most other simulations. This is largely driven by the inundation dataset (e.g. also seen in Ringeval et al), but also driven by the model's predictions of decreased hetereotrophic respiration after 2000. Our model results also have a stronger decrease across 2000 than the models than were included in the WETCHIMP methane flux intercomparison.



Inter-annual variability in wetland CH_4 emissions used in this study and in others. A centered 12-month running mean filter has been applied to smooth monthly output. Data for “LPJ variable source area”, “LPJ”, and “update of Bousquet et al. 2006 (constant OH)” were obtained from Spahni et al. 2011. “LPJ variable source area” indicates emissions anomalies for 1993-2000 calculated by using the observed monthly inundated area (Prigent et al. 2007). “LPJ” indicates global CH4 emission anomalies simulated by LPJ (natural ecosystem and rice agriculture) for scenario SC2 listed on Spahni et al. 2011. “update of Bousquet et al. 2006 (constant OH)” refers to global wetland emission anomalies derived from long-term atmospheric synthesis inversion updated from Bousquet et al. (2006). CAM-Chem_a refers to the reduced (by a factor of 0.64) wetland emissions used in CAM-Chem (please see Table 1 for the differences between CAM-Chem and CAM-Chem_a). TransCom refers to emission anomalies derived from the combined wetland and rice paddies emissions. Methane emissions in Ringeval et al. (2010) were estimated using the ORCHIDEE global vegetation model with a process-based wetland CH4 emission model. The wetland area was prescribed to the observed monthly inundated area (Prigent et al. 2007) in Ringeval et al. (2010). Please note that in this figure, “LPJ variable source area”, “LPJ”, and “update of Bousquet et al. 2006 (constant OH)” data were obtained from Spahni et al. 2011. The mean anomalies over 1993-2000 were adjusted to zero for the all data plotted on this graph.



Methane fluxes from wetlands but for the models that participated in WETCHIMP (Melton et al. 2013; Wania et al. 2013). Each model used a different wetland extent to estimate methane emissions (see Table 1 in Melton et al. 2013 for wetland determination scheme in each model). LPJ-WSL prescribed wetland area from monthly inundation dataset (Prigent et al. 2007, Papa et al. 2010). DLEM_norice prescribed the maximum wetland area from the inundation dataset with simulated intra-annual dynamics. SDVGM used the internal hydrological model to determine wetland locations. All other models parameterized wetland areas based on inundation dataset or land cover dataset that produced different inter-annual and intra-annual variability in wetland area. CAM-Chem and CAM-Chem_a used wetland emissions simulated by CLM4Me', which is different from CLM4Me. For the differences, please refer to Meng et al. (2012). Please also refer to Melton et al. (2013) for detailed description of each model (SDGVM, LPJ-WSL, Orchidee, LPJ-Bern_norice, DLEM_norice, CLM4Me).



Model simulations vs. Observations (Dlugokencky et al. 2005) for atmospheric concentrations. The climatological monthly mean was removed to focus on inter-annual variability in atmospheric CH_4 concentration at these stations. The observations and model show the change in the slope of the methane after 2000.

Growth rate:

In the model simulations of atmospheric concentration, the annual growth rate for 1993-2000 and 2001-2004 is 6.9 ppb/yr and -4.9 ppb/yr. The growth rate for the wetland portion is 4.0 ppb/yr and -5.0 ppb/yr for 1993-2000 and 2001-2004, respectively, thus the wetland methane growth rate changes in the model are a very large contributor to changes in the methane growth rate.
In our model this is due partly to inundation extent changes, derived from satellite, and partly from changes in hetereotrophic respiration, which are model derived. Our model tends to have a stronger tropical methane source than other models, which makes our model simulations of the growth rate changes more sensitive to wetland methane than previous studies.