Publications


4. MacDougall, A. H., M. Eby, and A. J. Weaver, 2013: If anthropogenic CO₂ emissions cease, will atmospheric CO₂ concentration continue to increase? *J. Climate*, 26, 9563-9576.


Abstract
The recent quantification of the reservoir of carbon held in permafrost soils has rekindled the fear that the terrestrial biosphere will transition from a carbon sink to a carbon source during the 21st century. This dissertation is a compilation of four modelling studies that investigate the permafrost carbon cycle feedback, its consequences for the projected future behaviour of the carbon cycle, and the origins of the proportionally between cumulative CO2 emissions and near surface temperature change.

Permafrost soils contain an estimated 1700 Pg of carbon, almost twice the current atmospheric carbon pool. As permafrost soils thaw due to climate warming, respiration of organic matter within these soils will transfer carbon to the atmosphere, potentially leading to a positive feedback. In this work a coupled global climate model is used to quantify the magnitude of the permafrost carbon feedback. The additional surface warming created by the feedback is independent of the emissions pathway followed in the 21st century and is estimated to be between 0.15 to 1.7 °C by 2300. The upper bound for the strength of the feedback is reached under the less intensive emissions pathways. This counterintuitive characteristic is a consequence of the higher radiative efficiency of a unit of CO2 at lower background atmospheric CO2 concentrations. These results suggest that the climate system may already be committed to significant warming from the permafrost carbon feedback.

If anthropogenic CO2 emissions were to suddenly cease, the evolution of the atmospheric CO2 concentration would depend on the magnitude and sign of natural carbon sources and sinks. In a scenario of zeroed CO2 and sulphate aerosol emissions, I assess whether the warming induced by specified constant concentrations of non-CO2 greenhouse gases could slow the CO2 decline following zero emissions, or even reverse this trend and cause CO2 to increase over time. I find that a radiative forcing from non-CO2 gases of approximately 0.6 W m−2 results in a near balance of CO2 emissions from the terrestrial biosphere and uptake of CO2 by the oceans, resulting in near-constant atmospheric CO2 concentrations for at least a century after anthropogenic emissions are eliminated. The transient climate response to cumulative CO2 emissions (TCRE) is a useful metric of climate warming that directly relates the cause of climate change (cumulative carbon emissions) to the most used index of climate change (global mean near surface temperature change). My analysis reveals that TCRE emerges from the diminishing radiative forcing from CO2 per unit mass being compensated for by the diminishing ability of the ocean to take up heat and carbon. The relationship is maintained as long as the ocean uptake of carbon, which is simulated to be a function of CO2 emissions rate, dominates changes in the airborne fraction of carbon.

Overall, the addition of the permafrost carbon pool alters model behaviour in ways that if representative of the nature world will make stabilizing climate more difficult than has previously been foreseen.

Awards, Scholarships, Fellowships
2013 UVic President's Scholarship
2013 Michael Smith Foreign Study Supplement
2011 –2013 NSERC Alexander Graham Bell Canadian Graduate Scholarship, Doctoral-2
2010 Graduate Fellowship, Masters
2008 – 2010 NSERC Post Graduate Scholarship, Masters
2008 Professor D.J. MacNeil Memorial Award
2007 Keating Memorial Award
2007 NSERC Undergraduate Research Award
2004 – 2008 Canadian Scholarship
2004 Canadian Cadet Scholarship
2004 – 2008 Nova Scotia Power Scholarship

Presentations
2. A.H. MacDougall, C.A. Avis, A.J. Weaver “The strength and timing of the permafrost carbon feedback as simulated by the UVic Earth system climate model.”, AGU Fall Meeting 2012 (Oral).
3. A.H. MacDougall, A.J. Wevaer, M. Eby “Will atmospheric CO2 concentration continue to increase if anthropogenic CO2 emissions cease?”, AGU Fall Meeting 2013 (Poster).