IEAGHG Information Paper; 2013-IP25; Impact of N_2O on the greenhouse effect and ozone depletion

At the 44th ExCo meeting Helle Brit Mostad of Statoil referred us to a recent publication by the MIT Joint Program on the Science and Policy on Global Climate Change. You can find the link to the full paper published at: http://globalchange.mit.edu/news-events/news/news_id/309#.UlQO_dKkrDX

After carbon dioxide and methane, nitrous oxide (N_2O) is the third-largest contributor of greenhouse-gas emissions to the atmosphere. Not so well known to many is that N_2O has a major role in ozone depletion[1]. There is therefore a need to pay close attention to N_2O mitigation opportunities because of its dual role.

The majority of nitrous oxide emissions arise naturally from soil, where microbes break down nitrogen, releasing nitrous oxide as a by-product. Human activities such as farming, and the increased use of nitrogen based fertilizers, in particular, have increased nitrous oxide emissions over the last 35 years. Such a rise cannot be discounted as having contributed to the overall warming of the planet in the last few decades.

The Scientists in MIT's Centre for Global Change Science have developed a highly detailed model that simulates levels of N_2O emissions in different regions and ecosystems of the world. Based on local soil temperature and moisture content, some of the simulations were able to reproduce actual nitrous oxide measurements.

From their simulations, the researchers discovered a surprising pattern which was that:

- Regions around the world typically experience a decrease in N_2O emissions during El Niño events[2], which periodically create unusually warm waters in the Pacific Ocean, affecting temperature and rainfall patterns around the world.
- Conversely, they found that emissions rise during periods of La Niña[3], the opposing weather pattern, in which colder waters take over the Pacific.

The findings suggest a feedback mechanism in which N_2O not only contributes to global warming, but may also be affected by climate patterns.

The key conclusion is that researchers in the past have focused on the carbon cycle and the implications of CO_2 for instance on climate models. This work suggests that those researchers also need to include the nitrogen cycle in their modelling analyses.

To simulate N_2O emissions around the world, The MIT scientists' adapted a model of soil temperature and moisture content that is often used by hydrologists to track the movement of water through soil. They then added to this model a component that calculates how much N_2O is likely emitted from a region, given variables such as soil temperature and moisture. Then they simulated monthly global N_2O emissions from 1975 to 2008; to check that the model generated accurate calculations. This was achieved by simulating nitrous N_2O emissions in regions where actual nitrous oxide measurements were available, including 25 locations in the Amazon, North and Central America, Asia, Africa and Europe.

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[1] See foe example Stratospheric ozone depletion due to nitrous oxide: influences of other gases, Portmann et al, Philosophical Transactions of the Royal Society B: Biological Sciences at: http://rstb.royalsocietypublishing.org/content/367/1593/1256.full

[2] El Niño is a band of anomalously warm ocean water temperatures that occasionally develops off the western coast of South America and can cause climatic changes across the Pacific Ocean. There is a phase of 'El Niño–Southern Oscillation' (ENSO), which refers to variations in the temperature of the surface of the tropical eastern Pacific Ocean (El Niño and La Niña) and in air surface pressure in the tropical western Pacific.

[3] La Niña is a coupled ocean-atmosphere phenomenon that is the counterpart of El Niño as part of the broader El Niño–Southern Oscillation climate pattern

For many of the sites, the model's calculations agreed with observations, verifying its ability to accurately simulate nitrous oxide emissions. Looking at the variability of emissions from year to year, they noticed a dramatic correlation with the El Niño/La Niña climate pattern, particularly in tropical regions near the equator: N_2O emissions dipped during periods of El Niño, and spiked during La Niña events.

Prof Saikawa, the lead Scientist on the study, says this periodic seesaw in emissions makes sense. As El Niño warms the Pacific, rainfall increases to the east, causing flooding in parts of South America, and droughts in parts of South Asia. Since the largest sources of N_2O emissions arise from South Asia; Prof Saikawa observed that decreased soil moisture from El Niño led to a large dip in emissions from those regions, with the opposite effect from La Niña.

"We thought we would see some variability, but we didn't think it would be this significant, "Prof. Saikawa says. "There is a need for more research to really determine what the possible impacts from future climate change are."

Going forward, the MIT team will incorporate agricultural components into the model, to simulate the effect of certain fertilizers on nitrous oxide emissions. Many types of fertilizer introduce nitrogen to the soil — an ingredient that nitrogen bacteria thrive upon. The more fertilizer nitrogen there is in soil, the more bacteria break it down, releasing nitrous oxide as a by-product. Deforestation has also stirred up N_2O emissions, particularly in regions such as Brazil, where the Brazilian government, is exploring the increased production of biofuels, fertilizing croplands in place of forests. The implication could be that by making biofuels they could be causing increased N_2O and CO_2 emissions"

For me the take away lines from this are:

1. We are still developing our knowledge and the models of the impacts of different gases and global warming and ozone depletion.
2. Globally close attention needs to be paid to N_2O because of its warming effect but also because when we phase out F gases this will be the most significant contributor to ozone depletion.
3. We know from IEAGHG's earlier work[4] that globally the primary source of N_2O emissions is the agricultural sector.
4. We are locked into a cycle of increasing global population and the need to increase food production which is met principally by use of nitrogen based fertilisers.
5. We also know from our earlier work in this area that nitrogen based fertilisers are not spread efficiently but are effectively over used.
6. The over-fertilization of soil could be potentially quite damaging for the climate and also for the ozone layer.
7. Also the desire to reduce emissions in the transport sector may have unwanted consequences by increasing emissions from soils something that needs to be thought about seriously before widespread production of biofuels is introduced. We have already discussed in an earlier IP, the unforeseen consequences of the EU biofuels policy[5] on global GHG emissions.

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[4] PH4/25 Building the Cost Curves for the Industrial Sources of Non-CO_2 GHGs, April 2003
[5] IP 2013/1, Unintended Consequences of Low Carbon Policies