Using observations and modelling to quantify mercury biogeochemical cycling in the Australian Context

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SUMMARY

The GEOS-Chem biogeochemical mercury model (like every other major mercury model) has historically been developed and evaluated using observations from the northern hemisphere, which are significantly more abundant than observations in the southern hemisphere. A recent evaluation of GEOS-Chem against a global database of Hg observations found significant biases in simulation of Hg in the southern hemisphere; however, only three southern hemisphere sites were included and none were in Australia.

Model performance in Australia was evaluated against recent gaseous elemental mercury (GEM) observations at Cape Grim (Tasmania) and Gunn Point (Northern Territory).

Sensitivity simulations were used to determine the influence of different emission sources to concentrations of atmospheric mercury. We find that both sites are sensitive to ocean Hg^0 exchange, there is a latitudinal gradient across Australia (with higher values towards the equator) and that the model is most sensitive to contributions from soil and anthropogenic emissions.

This work provides the first evaluation of GEOS-Chem over Australia, paving the way for model development that will improve Hg simulation in this part of the world.

MODEL DESCRIPTION

- GEOS-Chem Hg model (v11-01)
- GEOS-FP assimilated meteorology.
- 2° x 2.5° resolution.
- 2013-2016 (+ 5 year spin-up).

AIMS

- To evaluate the performance of the GEOS-Chem mercury model against Australian based observations.
- To use sensitivity simulations to determine how effectively different sources contribute to Australian atmospheric mercury.
- To evaluate if Australia acts as a net sink or a net source for atmospheric mercury.

SIMULATIONS

FULL SIMULATIONS

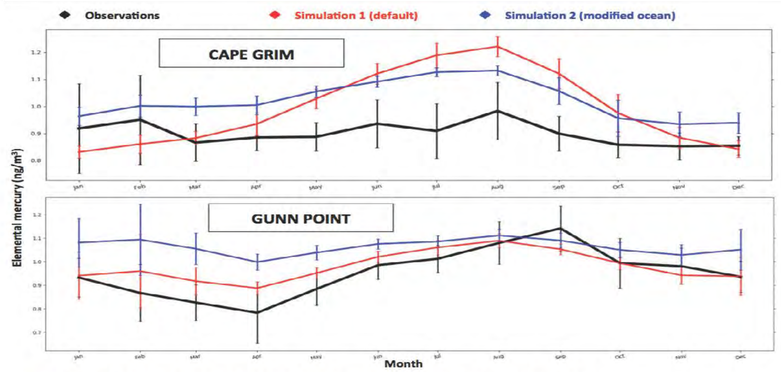
- **Simulation 1:** uses the standard parameters for ocean mercury cycling in GEOS-Chem
- **Simulation 2**: uses the optimized configuration for ocean mercury cycling described in Song et al., (2015). The configuration is optimized through Bayesian inversion methods that combine GEOS-Chem simulations with GEM observations from a number reference sites (none are in Australia). This configuration was found to improve simulation performance at mid-latitude sites in the northern hemisphere.

SENSITIVITY SIMULATIONS

The sensitivity simulations start with the InvOcean simulation and then had one component changed (e.g. a single emissions source was excluded from each simulation).

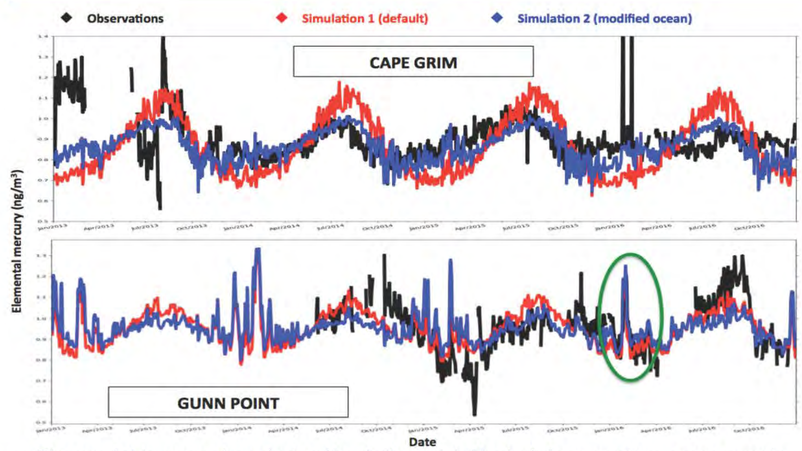
- **Anthro:** no emissions are included from anthropogenic sources at the global scale.
- **Soil:** no emissions are included from soil sources at the global scale.
- **Biomass:** no biomass burning emissions are included at the global scale.

MEAN SEASONAL VARIATION



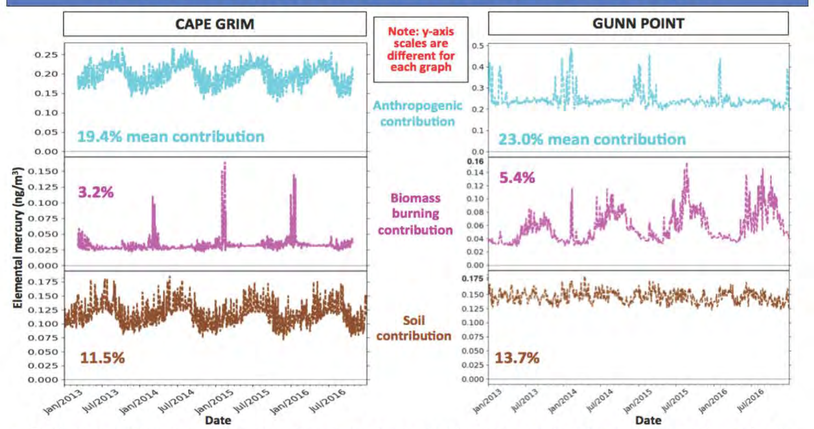
- Better representation at Cape Grim, particularly simulation 2.
- Both simulations miss the wet season drawdown at Gunn Point. Due to soil emissions/scavenging?

DAILY VARIABILITY



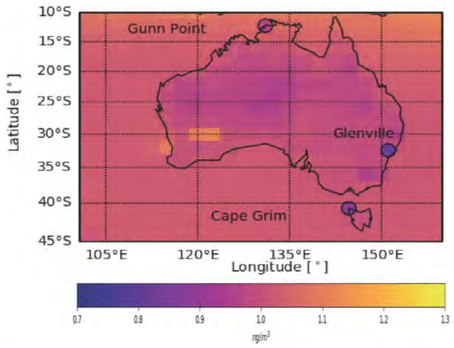
- The model is poor at capturing the daily variability, but does capture some events.

CONTRIBUTIONS FROM DIFFERENT SOURCES



- Soil and anthropogenic emissions make contributions to background levels at both sites.
- Biomass contributes to background at Gunn Point and events at both sites.
- Biggest events caused by anthropogenic emissions at Gunn Point.

SIMULATED DISTRIBUTION OF ATMOSPHERIC GEM



- The location markers represent observed multi-year mean GEM concentrations.
- The Glenville site was excluded as it has a lot of missing data and so we don't expect it to be representative of the wider region.
- Observed and simulated values indicate the presence of a latitudinal gradient in GEM concentrations across Australia.
- Australia is a net sink for atmospheric mercury: ~ 5.1 Mg/yr

CONCLUSIONS

1. GEOS-Chem can reproduce the observed seasonal cycle GEM at Australian sites and some large events, but tends to overestimate GEM concentrations.
2. GEOS-Chem has a poor ability to simulate the daily variability at Australian sites. This could be improved by using a finer resolution for simulations and customizing emission factors for soil and vegetation to improve representation of Australian conditions.
3. Australian sites are primarily influenced by oceanic, anthropogenic and soil sources, with smaller influences resulting from biomass burning.
4. Australia may act as a net sink for atmospheric mercury.

FURTHER RESEARCH

Future work will specifically target:

1. Customization of emissions factors for Australian soils and vegetation.
2. Scavenging of atmospheric mercury in tropical regions;
3. Moisture limitation for GEM emissions from tropical soils; and
4. Investigation of chlorine chemistry in the marine boundary layer.

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ACKNOWLEDGEMENTS

This research was undertaken with the assistance of resources provided at the NCI National Facility systems at the Australian National University through the National Computational Merit Allocation Scheme supported by the Australian Government.

The GEOS5-FP data used in this project have been provided by the Global Modeling and Assimilation Office (GMAO) at the NASA Goddard Space Flight Center.

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