Perspectives from across Sciences Road: What atmospheric chemistry research can tell us about the Earth’s surface* (and vice versa)

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& many collaborators from UOW and beyond!

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*as defined by an atmospheric chemist…
What goes on across the road in the Centre for Atmospheric Chemistry?


(as of 2012)
Why do we care about the stuff in the atmosphere?

**HEALTH**

Outdoor air pollution deaths, 2008

**CLIMATE**

World Health Organization, 2011

Intergovernmental Panel on Climate Change, AR5, 2013
How are the atmosphere and surface related — from an atmospheric chemist’s perspective?

Anthropogenic + Chemical → Natural

Industry, Agriculture, Transport

Ocean, Fires, Vegetation, Volcanoes, Dust
How can we study this complicated system?

Surf

Aircraft

Satellite

Data and models work best together!
What kind of “model” do I use?

GEOS-Chem: chemical transport model

Global, gridded 3D model with:

- **Transport**: “assimilated meteorology” — aka external winds, temperature, etc.
- **Chemistry**: solves simultaneous gas-phase and particulate chemistry for >100 species
- **Sources**: from external inventories or process-based parameterisations
- **Sinks**: wet and dry deposition, exchange with surface reservoirs

Represents the community’s best current understanding of sources & processes
Where have I been looking?

**ARCTIC**
Apr./Jul. 2008 field campaign

**SOUTHEAST US**
Aug.-Sep. 2013 field campaign

**AUSTRALASIA**
Current work
Part 1: when models & data disagree

What explains elevated mercury in the Arctic atmosphere & ocean?
Mercury in the Arctic is an ecological and health concern

Mercury is a **neurtoxin** that **bioaccumulates** in marine food webs.

Some of the highest amounts have been found in **Arctic wildlife**.

**Traditional diets** include these species.

**Atmosphere-ocean cycling** is complex and uncertain.
The Arctic mercury cycle (simplified*)

* no chemistry! no terrestrial exchange!
Arctic atmospheric mercury has a unique seasonal cycle

Observations

Can we explain this using our current understanding (i.e., the model)?
We use the model to test hypotheses, pushing parameters to the limits of their uncertainties.

“Traditional” explanations (atmospheric transport, snowpack processing, ocean chemistry) cannot explain the summer peak.
We use the model to test hypotheses, pushing parameters to the limits of their uncertainties.

With a large source from Arctic rivers & coastal erosion, the model comes much closer to the observations — our working hypothesis!

Fisher et al., 2012
With this working hypothesis, we can use the model to probe drivers of change.

Over the last 30 years…

- **Hg emissions growth: 1979-2010**
- **Air temperature change: 1979-2010**
- **May sea ice extent trend: 1979-2010**

Streets et al. (2011)

![Graphs showing changes in Hg emissions, air temperature, and sea ice extent]

What are the implications for past — and future — variability in Arctic Hg?
With this working hypothesis, we can use the model to probe drivers of change.

GCMs predict future ↑ cloudiness & ↓ spring-summer ΔT → less Hg may be added to the Arctic Ocean in future!

Fisher et al., 2013
What influences atmospheric composition in Australasia?
Australasia is influenced by distant sources

Satellite observations: October 2003

Known influence from fires, especially African & South American

But what about other sources? human activity? vegetation?

How much do local vs distant sources matter?
We can track source influence with carbon monoxide (CO)

Mix of sources (fires, fossil fuel, vegetation)

Lifetime of weeks to months

Measured in Australasia:


GEOS-Chem (2009)

CO Column, $10^{18}$ molecules/cm$^2$

Month
The model provides a realistic picture, so we can use it to run “experiments”, and extrapolate in time/space

Test the influence of emission source types (or regions):

**Impact on this region:**

![Map of Australia and New Zealand](image)

**Fossil fuels**

**Summer (DJF) 2009**

![Graph showing CO concentrations](image)
The model provides a realistic picture, so we can use it to run “experiments”, and extrapolate in time/space.

Test the influence of emission source types (or regions):

Impact on this region:

![Diagram showing the impact of Fossil fuels and Wildfires on CO levels in the atmosphere during Summer (DJF) 2009.]
The model provides a realistic picture, so we can use it to run “experiments”, and extrapolate in time/space.

Test the influence of emission source types (or regions):

**Impact on this region:**

- **Summer (DJF) 2009**
  - CO [ppbv]
  - Altitude [km]

- **Fossil fuels**
- **Wildfires**
- **Vegetation*”**

*mostly*
The model provides a realistic picture, so we can use it to run “experiments”, and extrapolate in time/space.

Test the influence of emission source types (or regions):

**Impact on this region:**

- **Summer (DJF) 2009**

- **CO [ppbv]**
  - 0
  - 10
  - 20
  - 30
  - 40
  - 50

- **Altitude [km]**
  - 0
  - 2
  - 4
  - 6
  - 8
  - 10
  - 12

- **mainly from Australia**
- **mainly from Africa & South America**

[Diagram showing CO concentration and altitude with arrows pointing to regions labeled as mainly from Australia and mainly from Africa & South America.]
The model provides a realistic picture, so we can use it to run “experiments”, and extrapolate in time/space

Test the influence of emission source types (or regions):

Impact on this region:

![Map of Australia](image)

Summer (DJF) 2009

But these vegetation sources & their chemistry remain very poorly understood!
Part 3: when we need more data

What are the atmospheric consequences of biogenic emissions?
The Southeast US is a hotspot for “biogenics” (compounds emitted from vegetation)

HCHO
(biogenic proxy)

Aug

Sep

2006
2007
2008

D. Jacob & L. Zhu (Harvard), J. Reid (NRL)
The Southeast US is a hotspot for “biogenics” — with air quality consequences!

D. Jacob & L. Zhu (Harvard), J. Reid (NRL)
But we don’t understand the atmospheric chemistry in this region at this time of year.

![Graph showing observed and multiple model ozone data with a mean bias of 7.2 ppb and a correlation coefficient of 0.61.](Image)

*Fiore et al., 2009*
We needed more data - with unprecedented chemical detail

Studies of Emissions & Atmospheric Composition, Clouds, & Climate by Regional Surveys (SEAC⁴RS)

August-September 2013 (Houston, TX)
We needed more data - with unprecedented chemical detail.

DC-8 Exterior

DC-8 Interior

DC-8 Wing & Probe

ER-2 Flightsuit

Learjet

Photos: Houston Daily News
Modellers do fieldwork, too!

Biogenic (vegetation) emissions: 1 Aug - 22 Sep

GEOS-Chem nested domain

Southeast Region

atoms C/cm²/s
After months of work, model results look promising. Now the real analysis can begin…

Most extensive sampling of Southeast US atmosphere + new high-resolution model will greatly enhance our understanding of biogenic sources, chemistry, & impacts - stay tuned!
Take-home messages

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4. Model-observation agreement facilitates “experiments” we couldn’t otherwise run
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4. Model-observation agreement facilitates “experiments” we couldn’t otherwise run

There are lots of unanswered questions at the atmosphere-surface interface — let’s keep options open for Chemistry-SEES collaboration!
Collaborators:
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