School of Earth and Environment

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A systematic approach to model evaluation, using a global aerosol model

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Science Question

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- Multi-model ensembles tell us about diversity
- More complex more models don't always perform better
- Do more complex models have greater explanatory power or do parameter uncertainties dominate?

Why do models give such diverse results? Which processes are being affecting model output?

The Approach

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- Understand the effects of parameter uncertainty in individual models
- Compare important processes between different models

Carry out a sensitivity analysis to identify the most important parameter uncertainties

Sensitivity analysis of complex computer codes

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- Use variance-based sensitivity analysis, Saltelli (2000)
- To quantify the sensitivity of output to model parameters need to include interaction effects in a non-linear model
- Need to study output given simultaneous parameter changes
- The number of runs required is too high for complex environmental models

Solution: Emulation

Emulation

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- Estimate the output given every possible parameter combination conditioned on a few model runs – an emulator
- Carry out the sensitivity analysis with the emulator (Oakley and O'Hagan, 2004)
- Here, the Gaussian process emulator is used

The Gaussian Emulation Machine for Sensitivity Analysis
(Kennedy, 2004)
http://ctcd.group.shef.ac.uk/gem.html

A 1-dimensional GP emulator

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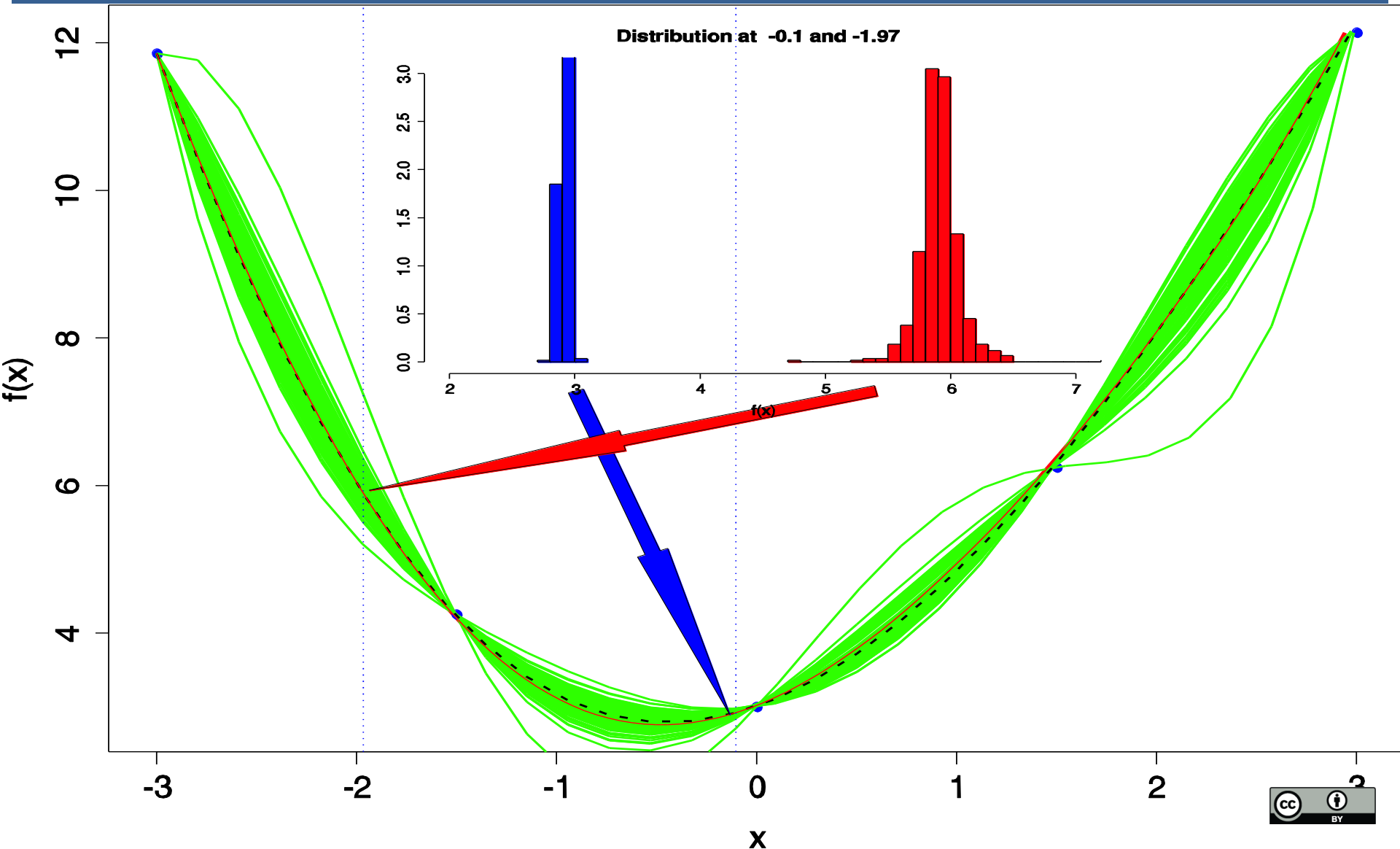

The Model

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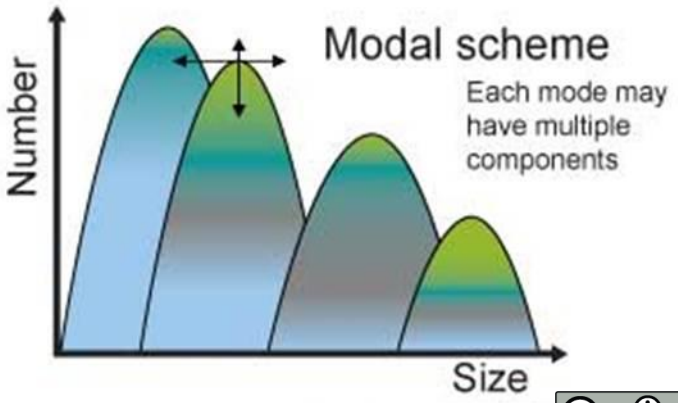
- The sensitivity analysis is applied to the GLOMAP model (Mann, 2010)
- The Global Model of Aerosol Processes
- Part of AEROCOM
- Simulates the evolution of global aerosol
- This includes sulphate, sea-salt, dust, black carbon and particulate organic matter
- Concentrating on the output cloud condensation nuclei (CCN)

GLOMAP
Global Model of Aerosol Processes

http://researchpages.net/glomap/



Emulation of GLOMAP

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- Study CCN sensitivity to 8 GLOMAP parameters
- Include emission factors and model parameters

Have 80 runs of GLOMAP chosen by a space-filling Latin Hypercube

- With same 80 GLOMAP runs build different emulators for different regions and altitudes
- What is the primary source of uncertainty in CCN?

Surface CCN main effects

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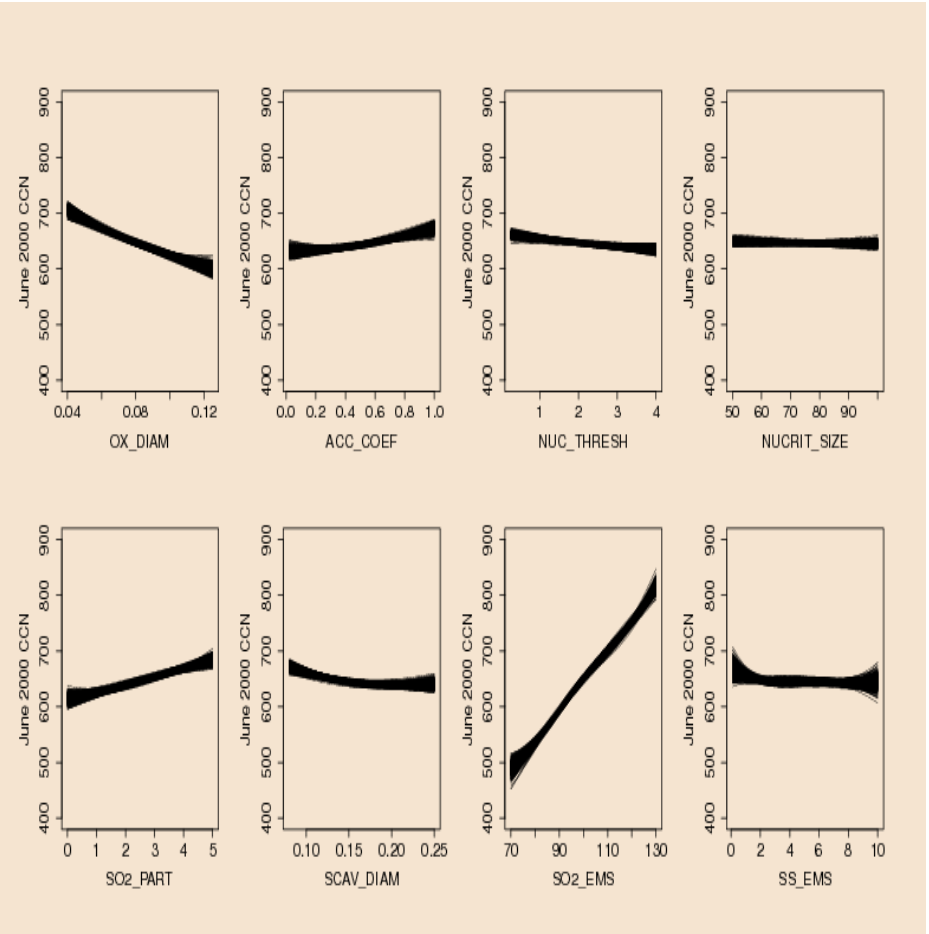
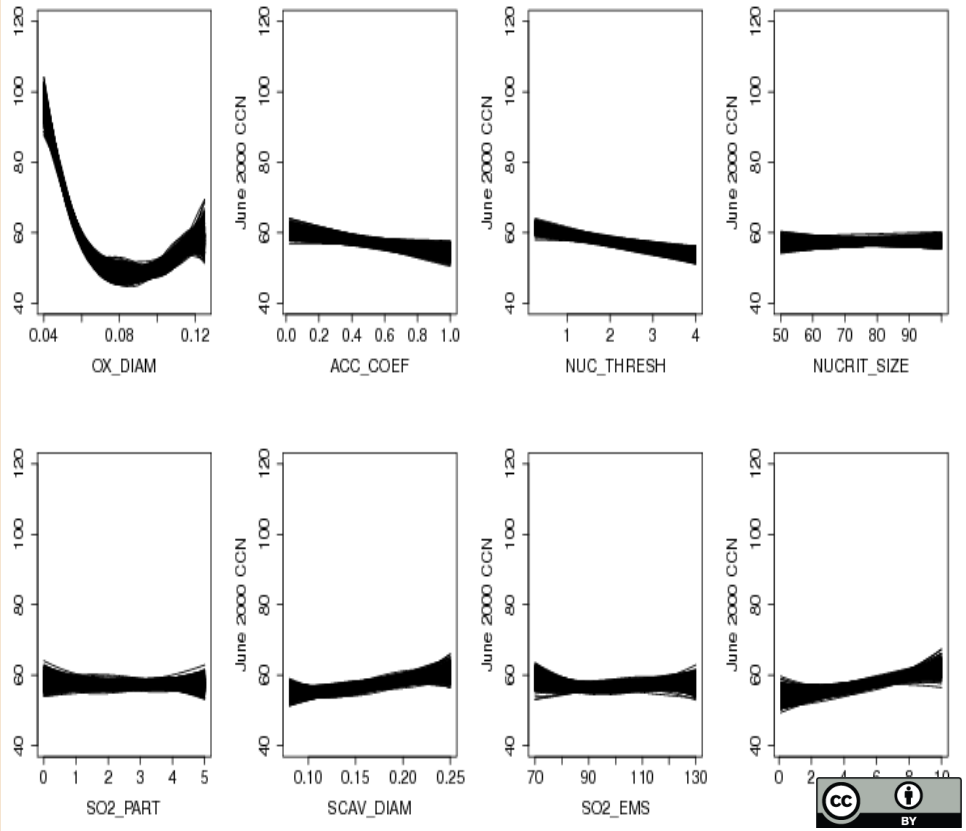
- Emulator built with June 2000 surface CCN in London and Pacific and parameter perturbations for 80 GLOMAP runs





London profile CCN sensitivities

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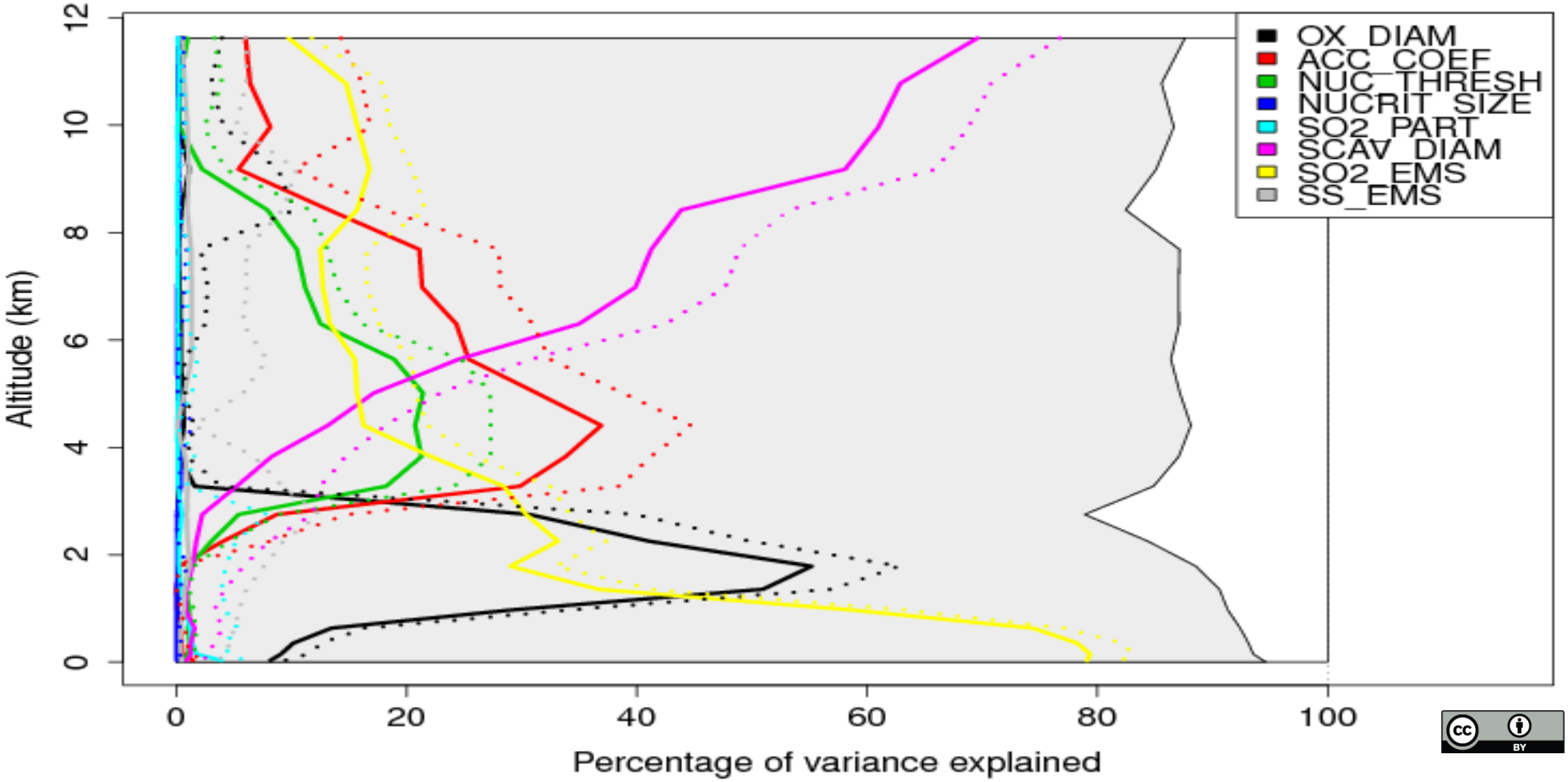
- Separate emulator for London CCN at each model level – variance in CCN partitioned to 8 sources



Pacific profile CCN sensitivities

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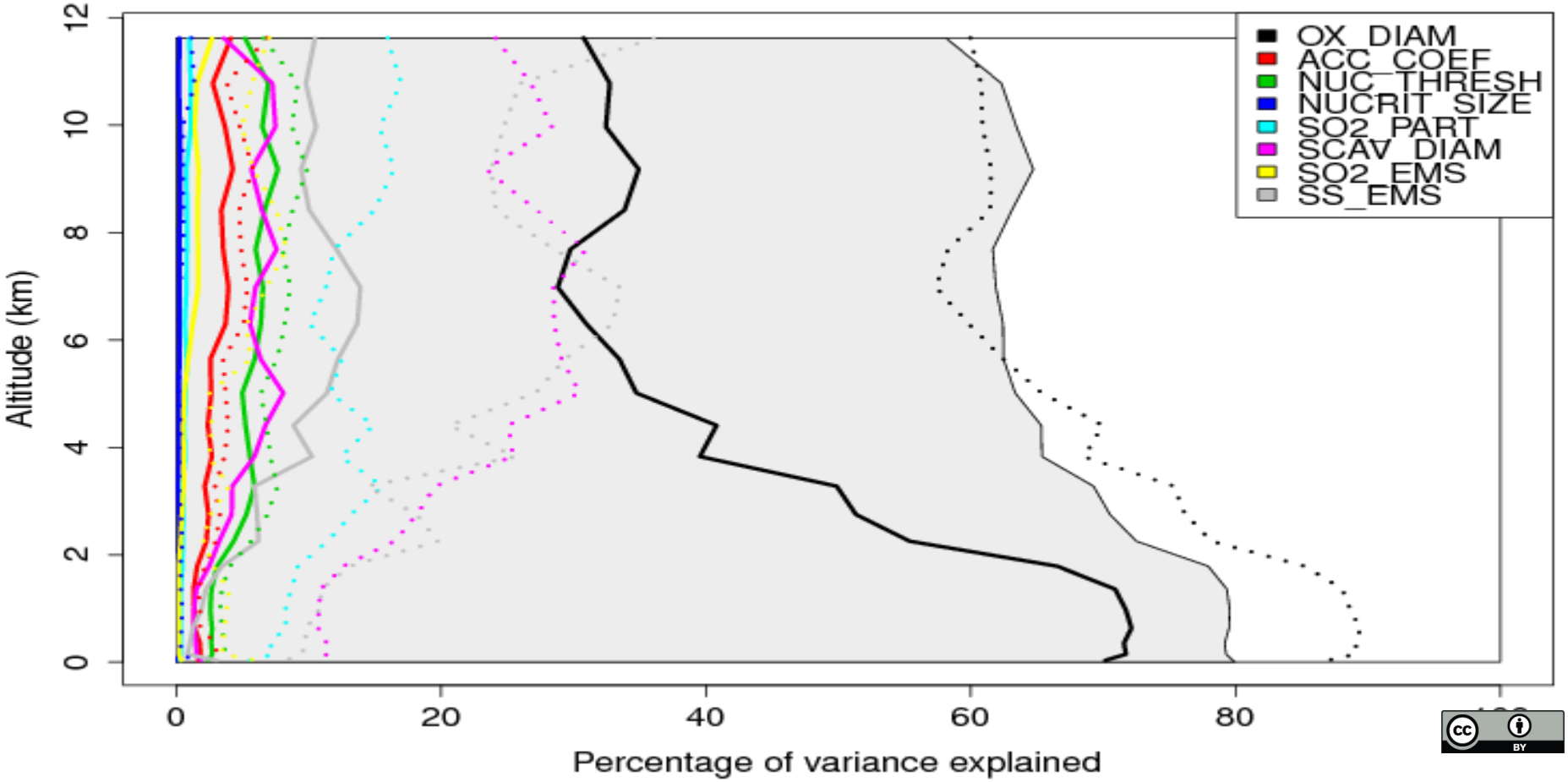
- More interactions apparent here



Summary

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- Shown how a few model runs can be used to produce multiple analyses and comprehensively evaluate a model
- Shown how parameter uncertainties can affect model output – a ranked list
- Research can be focussed on improving the important uncertainties
- Sensitivities between models can be compared to help understand diversity
- Model complexity required can be studied using parameter sensitivities

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References

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Aerosol model

http://researchpages.net/glomap/

- Mann, G., Carslaw, K., Spracklen, D., Ridley, D., Manktelow, P., Chipperfield, M., Pickering, S., and Johnson, C. (2010). Description and evaluation of GLOMAP-mode: a modal global aerosol microphysics model for the UKCA composition-climate model, Geoscientific Model Development, 3, 519–551.
- Spracklen, D., Pringle, K., Carslaw, K., Chipperfield, M., and Mann, G. (2005). A global off-line model of size resolved aerosol microphysics: II. Identification of key uncertainties, Atmos. Chem. Phys., 5, 3233–3250.

Statistics www.mucm.ac.uk/toolkit

- Bastos, L. and O'Hagan, A. (2009). Diagnostics for Gaussian Process Emulators, Technometrics, 4, 425–438.
- O'Hagan, A. (2006). Bayesian analysis of computer code outputs: A tutorial, Reliability Engineering and System Safety, 91, 1290–1300.
- Oakley, J. and O'Hagan, A. (2004). Probabilistic sensitivity analysis of complex models: a Bayesian approach, Journal of the Royal Statistical Society: Series B, 66, 751–769.
- Kennedy, M. (2004). The GEM software project, Tech. Rep. http://www.ctcd.group.shef.ac.uk/gem.html, Centre for Terrestrial Carbon Dynamics (CTCD).