GLOMAP: A Global Model of Aerosol Processes

Ken Carslaw, Dominick Spracklen,

Kirsty Pringle, Martyn Chipperfield,

Graham Mann

Institute for Atmospheric Science

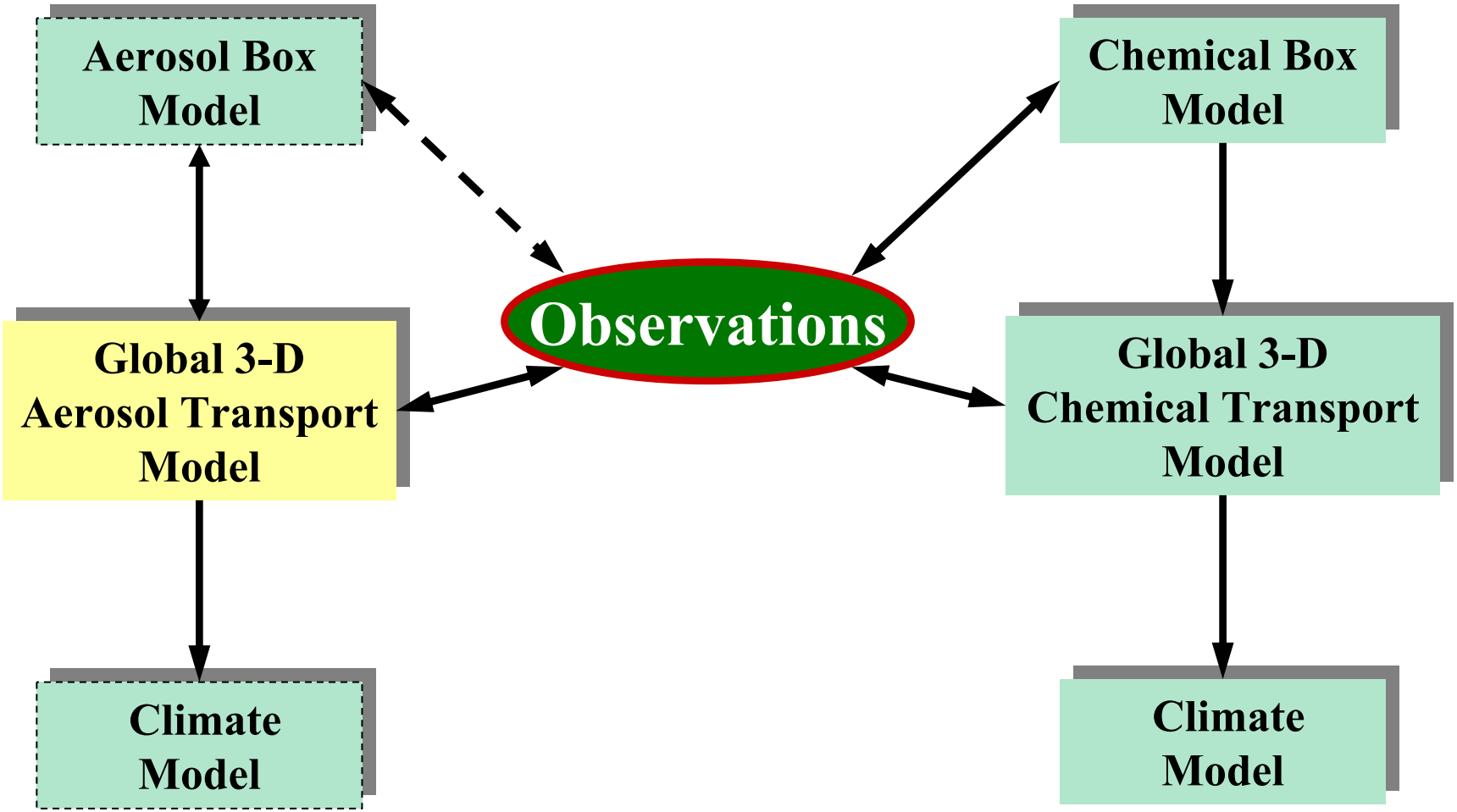
University of Leeds, UK

Funded by NERC (UGAMP)

Talk Structure

- Motivation for development
- Model description
- Comparison with observations
- Future Applications

Motivation for Development



Introduction to GLOMAP

Aerosol Size Distribution

- **Two moment** scheme: aerosol number and mass
- Variable number of geometrically spaced bins
- **Moving centre, fixed grid** (*Jacobson, 2000*)
  - Bin edges are fixed
  - Bin centre moves to represent average mass

Introduction to GLOMAP

Aerosol Composition

- Currently carry sulfate and sea salt in a single distribution
  - Baseline model: compare with other schemes
- Aim to have a multi-component version by summer 2004, including:
  - Sulphate
  - Sea salt
  - Dust
  - Black and organic carbon

TOMCAT

- 3D Offline CTM
- Forced by ECMWF Winds
- Convective transport
- Convective and resolved rain

GLOMAP

- Aerosol size spectrum (~ 1 nm – 24 μm)

Sources

Emissions
- Anthrop + volcanic SO_2 emissions
- DMS emissions from wind stress and DMS sea surface concentration
- Sea salt aerosol generation function

Sulphur Chemistry
- 8 sulphur species, 8 sulphur reactions
- Aqueous phase chemistry
- Oxidants from full chemistry run

Microphysics

Nucleation and Condensation
- Binary H_2SO_4/H_2O nucleation
- Condensational growth

Coagulation
- Semi implicit fast numerical solution

Hygroscopic Growth
- Equilibrium size given by solution of Kohler equation

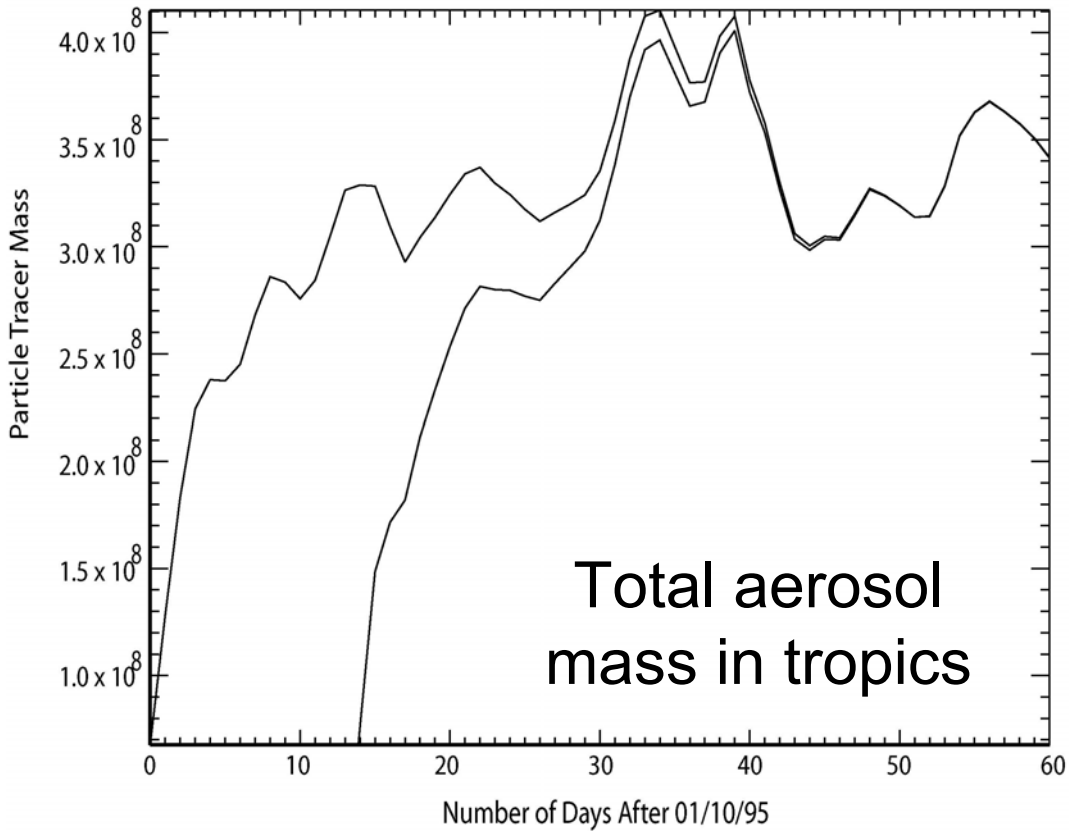
Removal

Dry Deposition
- Dry deposition of aerosol

Clouds
- Convective and frontal rain
- In-cloud nucleation scavenging
- Below cloud scavenging
- ISCCP observed low-level clouds for cloud processing

Simulating a Global Aerosol Distribution

Spin-up from an **aerosol-free** atmosphere



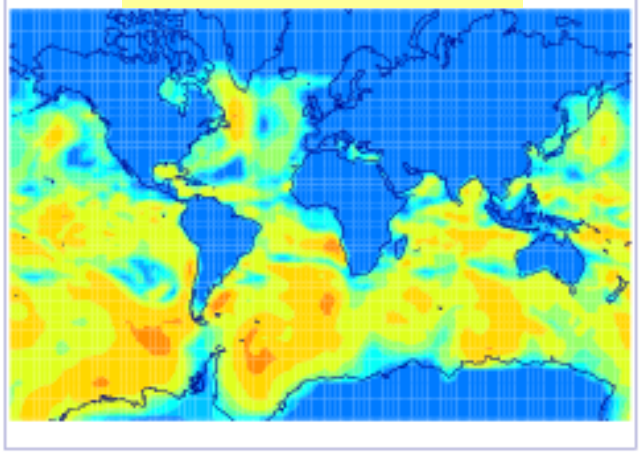
After 30 model days particle tracer mass is independent of the number of days after initiation

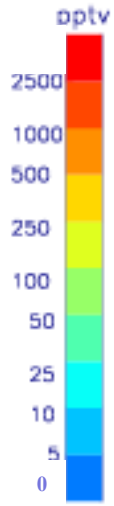
Simulating a Global Aerosol Distribution

- October 1995 (after 1 month spin up)
- T42 resolution (2.8^{o} x 2.8^{o}), 31 vertical levels
- Sulphate and sea salt aerosol only
- 20 aerosol bins (2 nm – 25 μm)

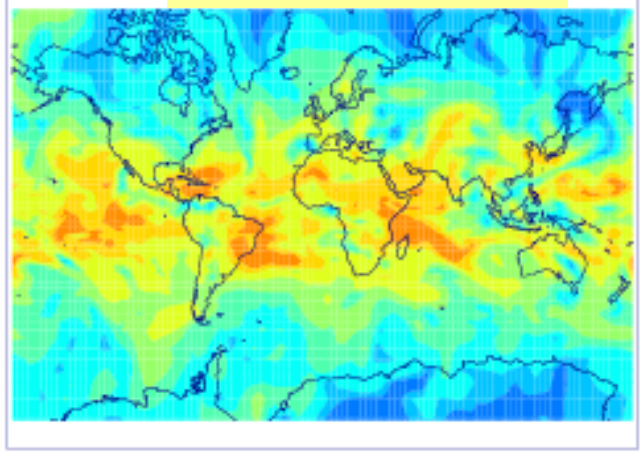
Sulphur Species (Surface)

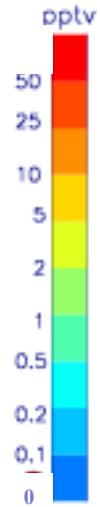
DMS



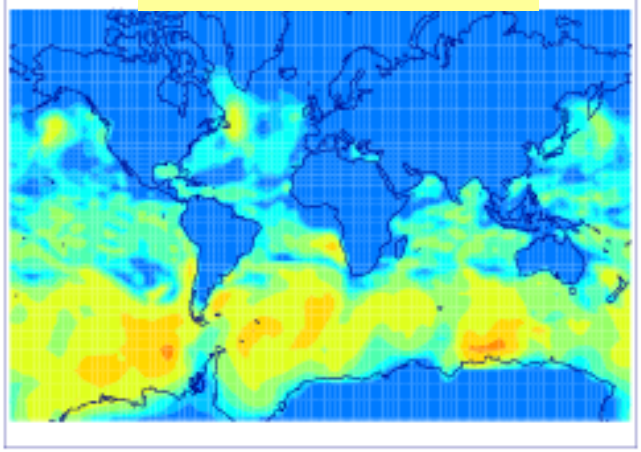


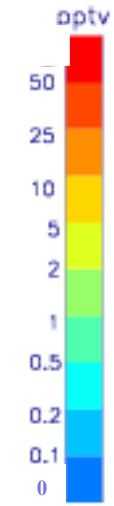
H_2SO_4



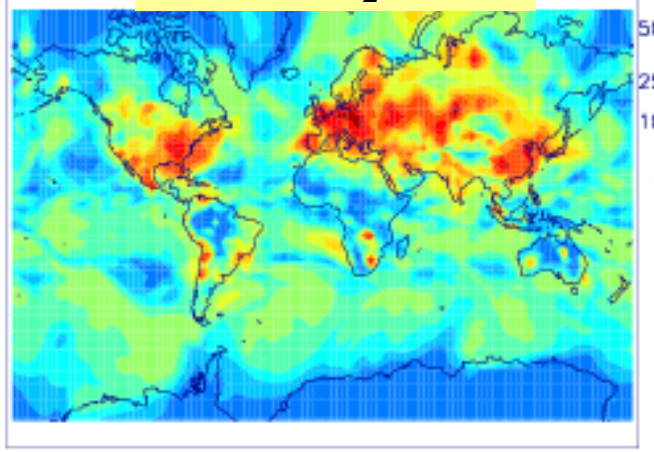


DMSO

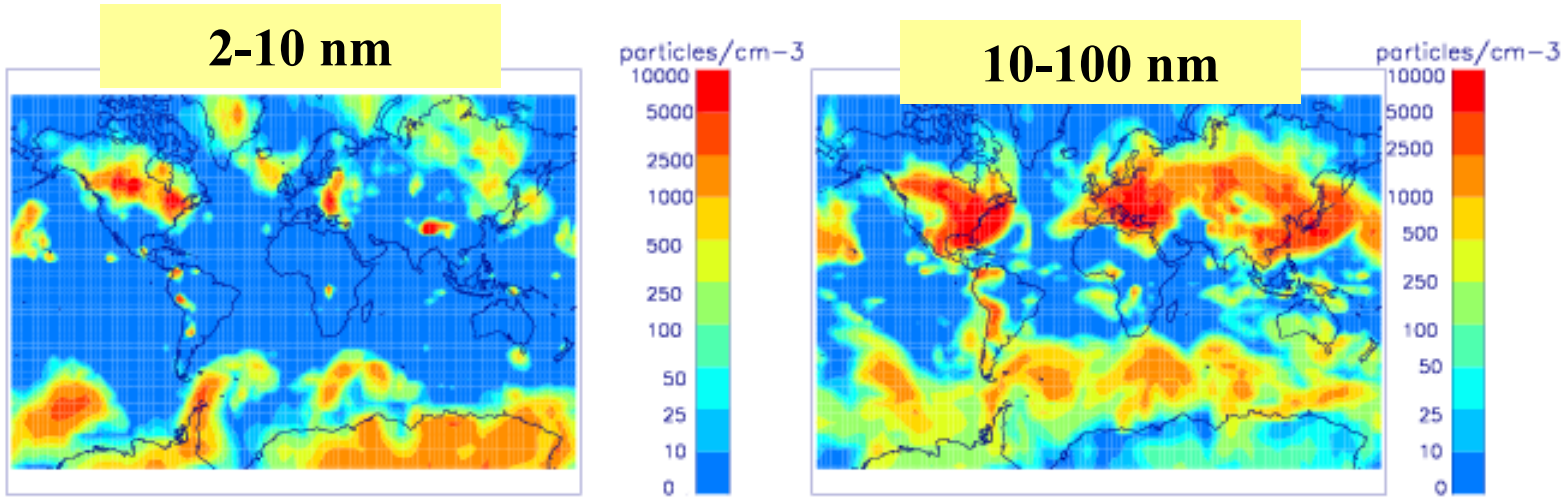




SO_2



Aerosol Spatial Distribution (Surface)



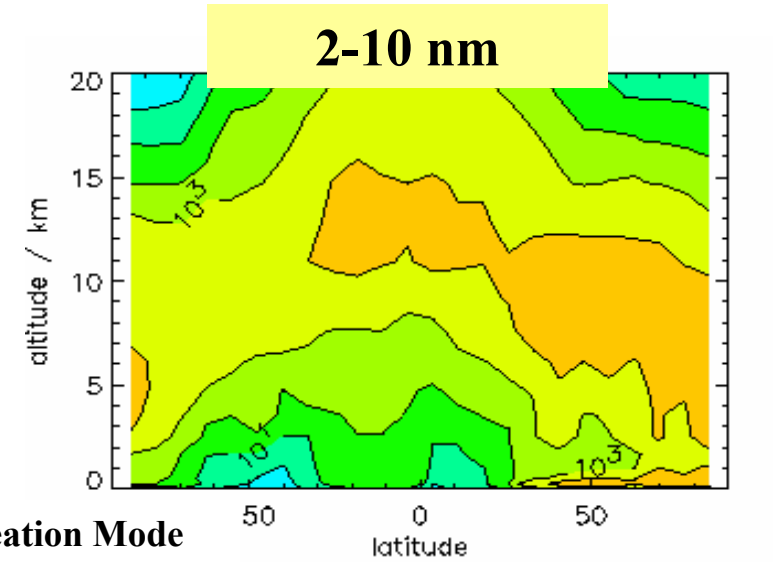
Nucleation Mode

Aitken Mode

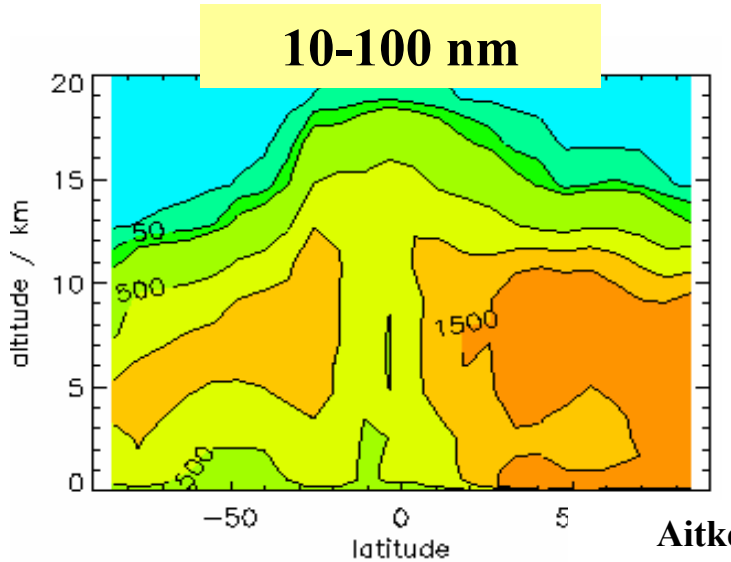
Accumulation Mode

Coarse Mode

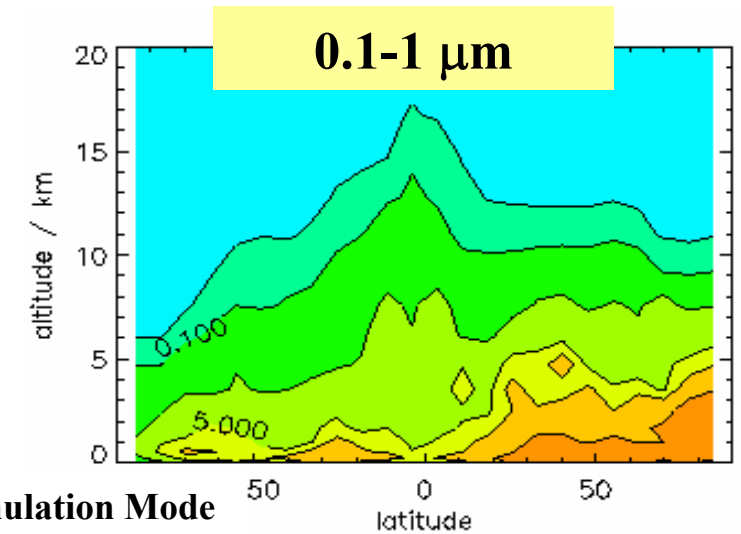
Aerosol Spatial Distribution (Profile)



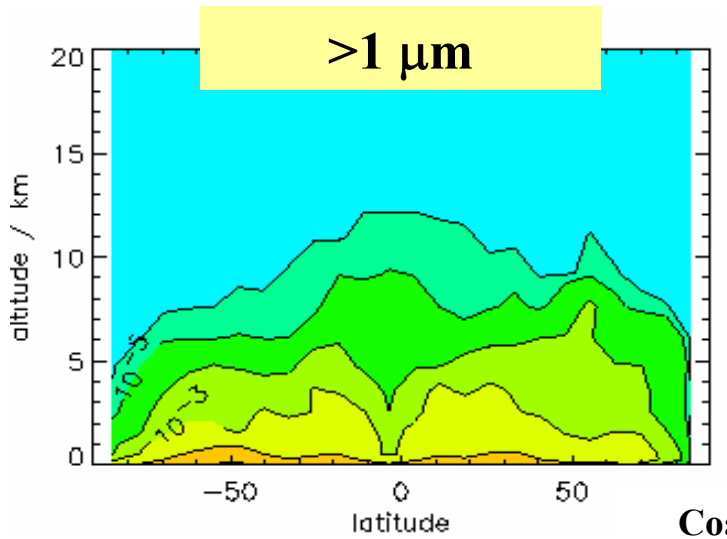
Nucleation Mode



Aitken Mode

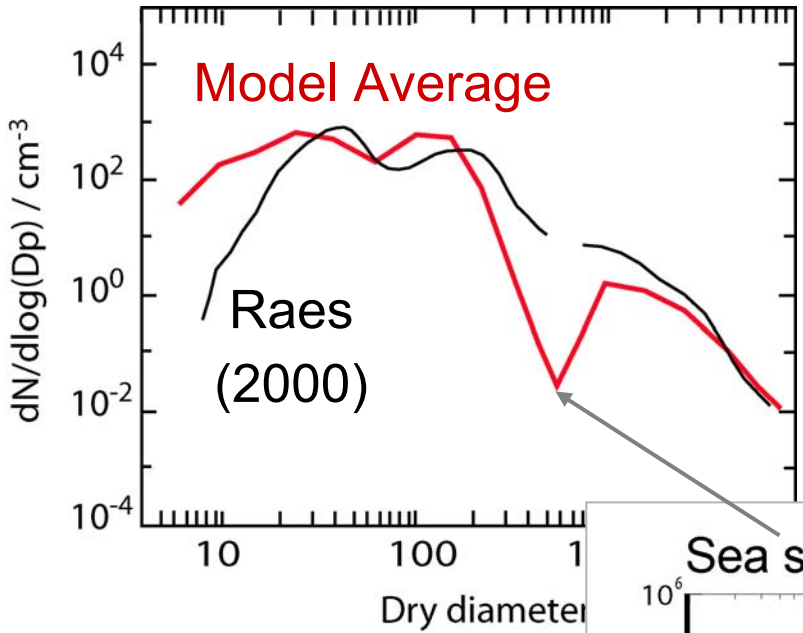


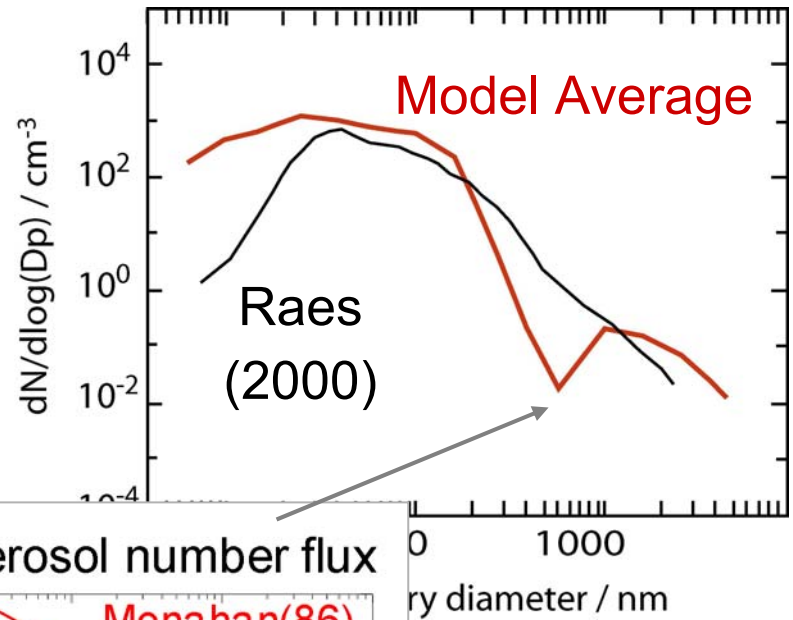
Accumulation Mode



Coarse Mode

Size Distributions: Remote N. Atlantic

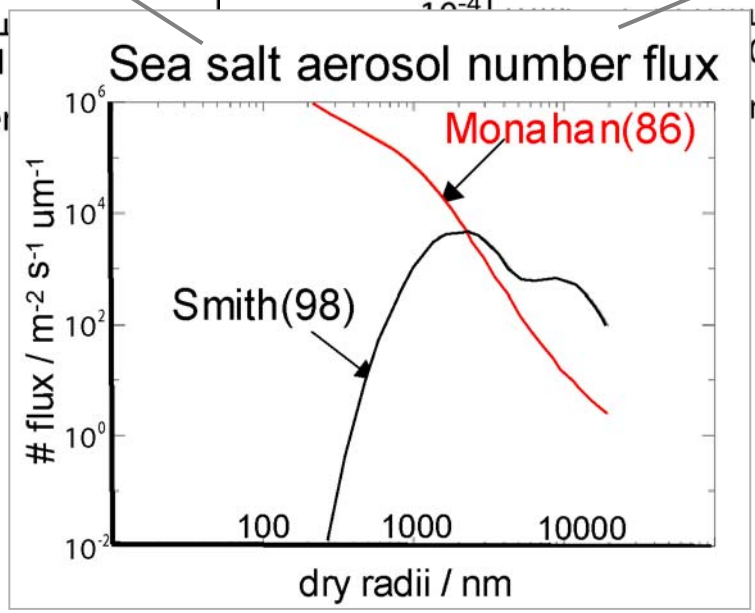




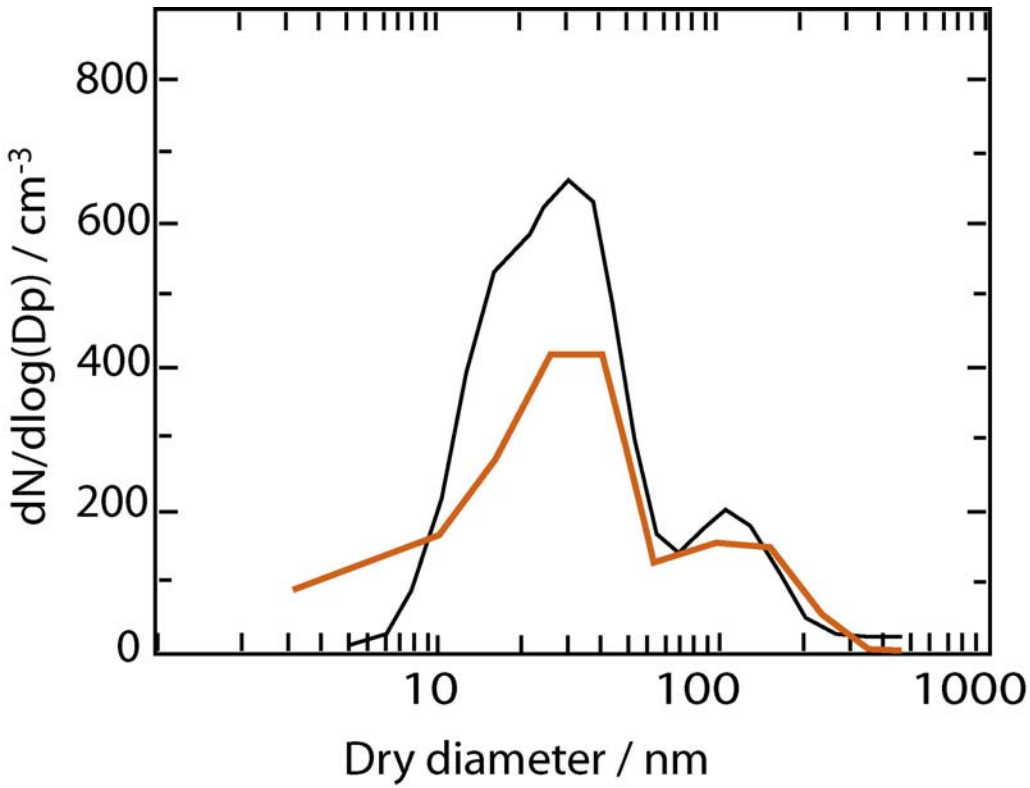
Surface

2.3km

Monahan parameterisation not valid for radii less than 400 nm



Aerosol Size Distributions



Southern Hemisphere Aerosol Characterisation Experiment

Model

ACE-1

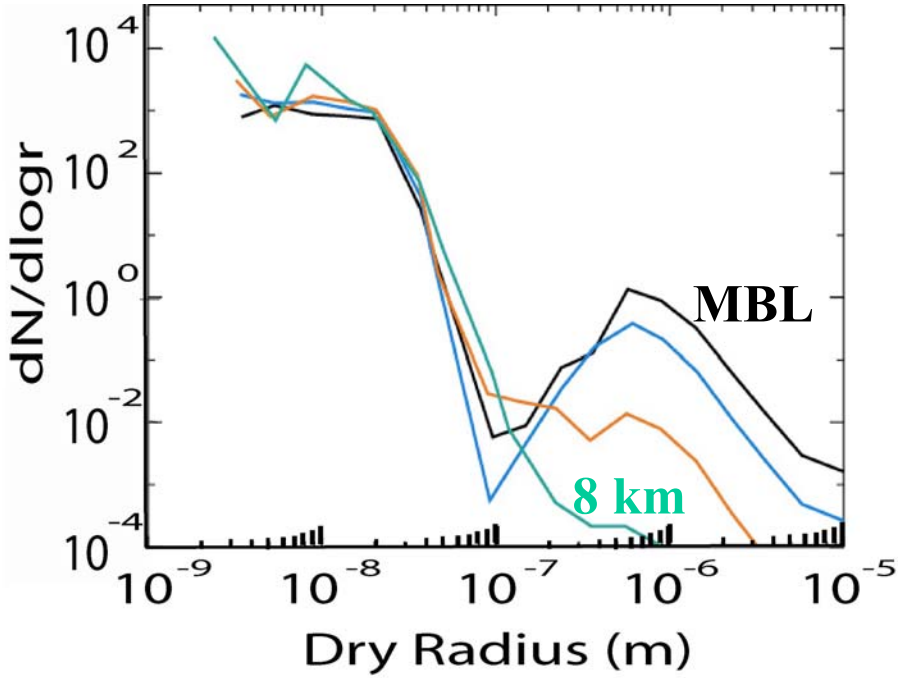
Average spectra over sampling sites, 15th November – 15th December 1995

GLOMAP Applications

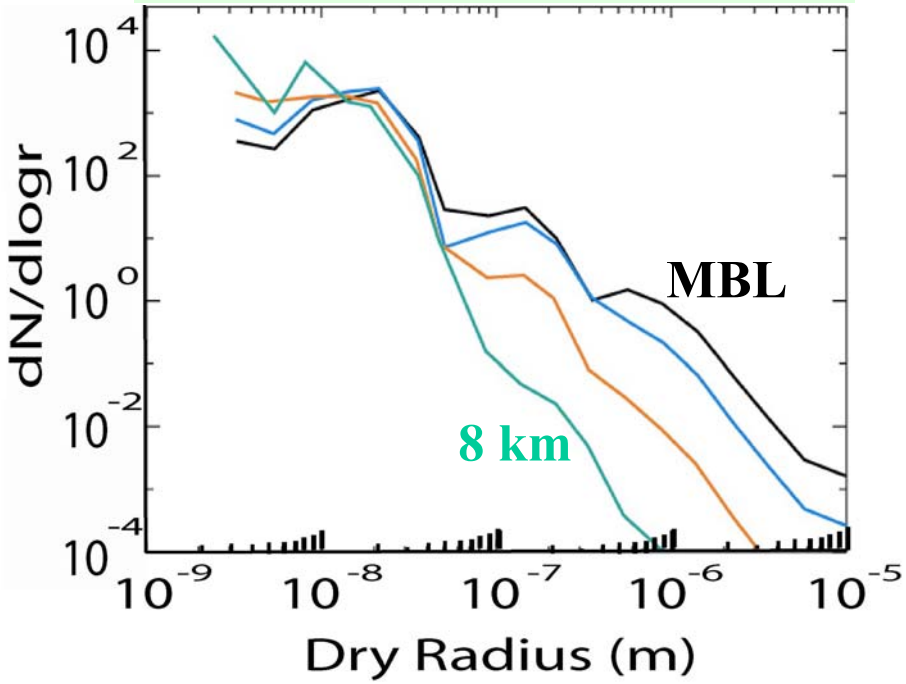
1. Understanding of natural and perturbed size and composition resolved global aerosol lifecycle
   - Routes to CCN formation + sensitivities
     - Link to cloud models
   - Aerosol interactions (e.g., BC+sulfate)
   - Fate of anthropogenic sulphur

The Fate of Anthropogenic Sulfur

Without Anthropogenic Sulfur



With Anthropogenic Sulfur



Aerosol number distributions averaged over the North Atlantic

GLOMAP Applications

1. *Understanding of natural and perturbed size and composition resolved global aerosol lifecycle*
   - *Routes to CCN formation + sensitivities*
     - *Link to cloud models*
   - *Aerosol interactions (e.g., BC+sulfate)*
   - *Fate of anthropogenic sulphur*

2. **Baseline model** for development of **GCM** aerosol schemes – process reduction

   - NCAS collaboration

Development of a GCM Aerosol Scheme

The NCAS collaboration

The Remit: To develop an aerosol module to be implemented in the UK Met Office Unified Model

The Plan:

- Graham Mann: 3 year post-doctoral position
- Incorporate the existing UM sulfate/sea salt scheme into GLOMAP and compare
- Incorporate modal microphysical scheme into GLOMAP (evaluate against GLOMAP and observations)

GLOMAP Applications

1. *Understanding of natural and perturbed size and composition resolved global aerosol lifecycle*
   - *Routes to CCN formation + sensitivities*
     - *Link to cloud models*
   - *Aerosol interactions (e.g., BC+sulfate)*
   - *Fate of anthropogenic sulphur*

2. *Baseline model for development of GCM aerosol schemes – process reduction*

   - NCAS Collaboration

3. **Support of field campaigns** (e.g. ITOP July 2004)

Conclusions

- GLOMAP: A 3D sectional aerosol model currently carrying sulfate and sea salt
- Preliminary comparisons with observations are encouraging but more work is needed
- GLOMAP will be used to examine the fate of anthropogenic sulfur
- Work on the development of a GCM aerosol scheme, using GLOMAP is just starting

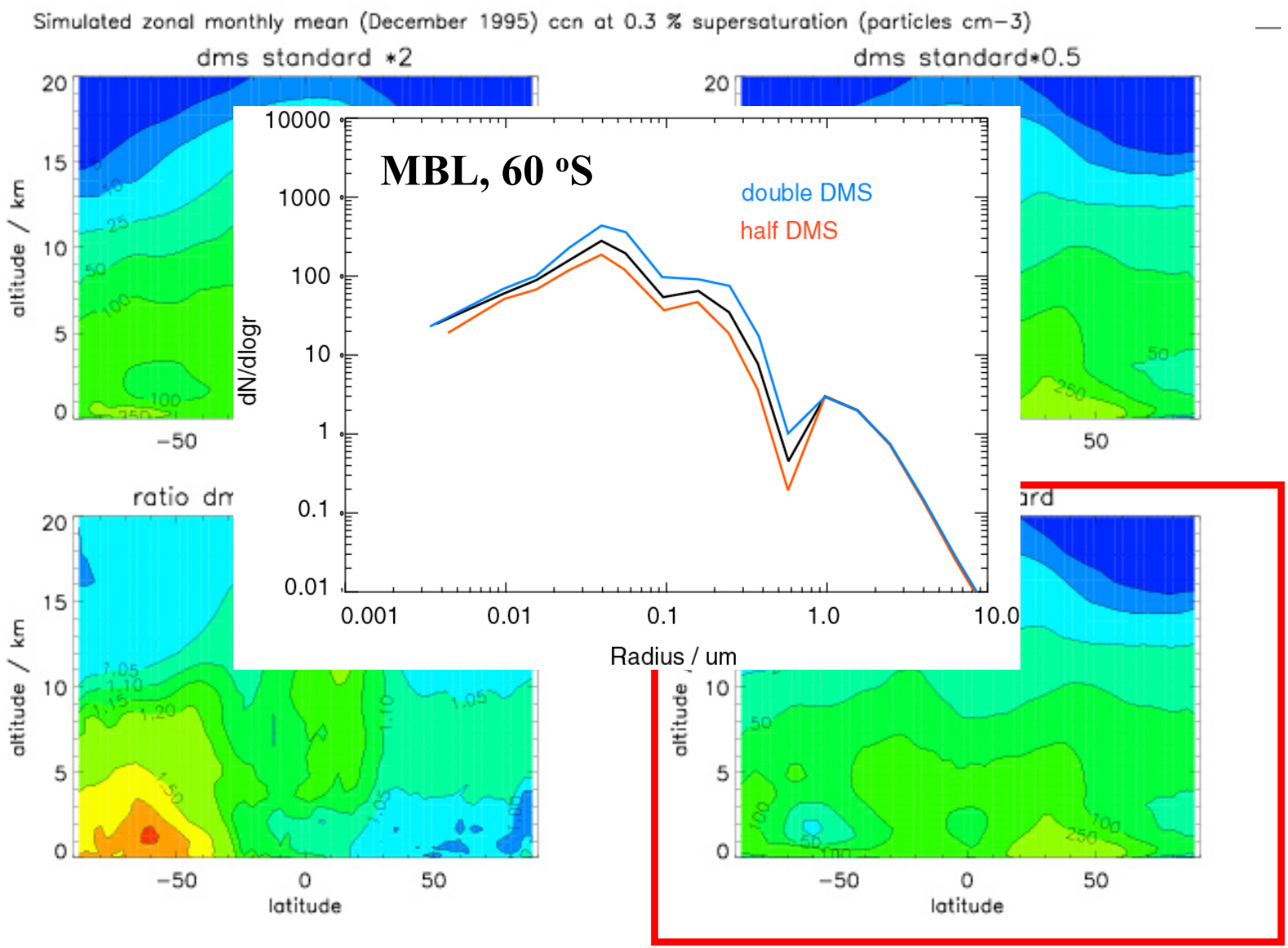
The Plan

1. Incorporate existing UM sulfate/sea salt scheme in GLOMAP and test
2. Incorporate modal microphysical scheme in GLOMAP
    1. Start with sulfate/sea salt and progressively add more components
    2. Evaluate against GLOMAP and observations
3. SOA scheme (ACMSU/UMIST)
4. CCN scheme (M. Smith)
5. Port to UM

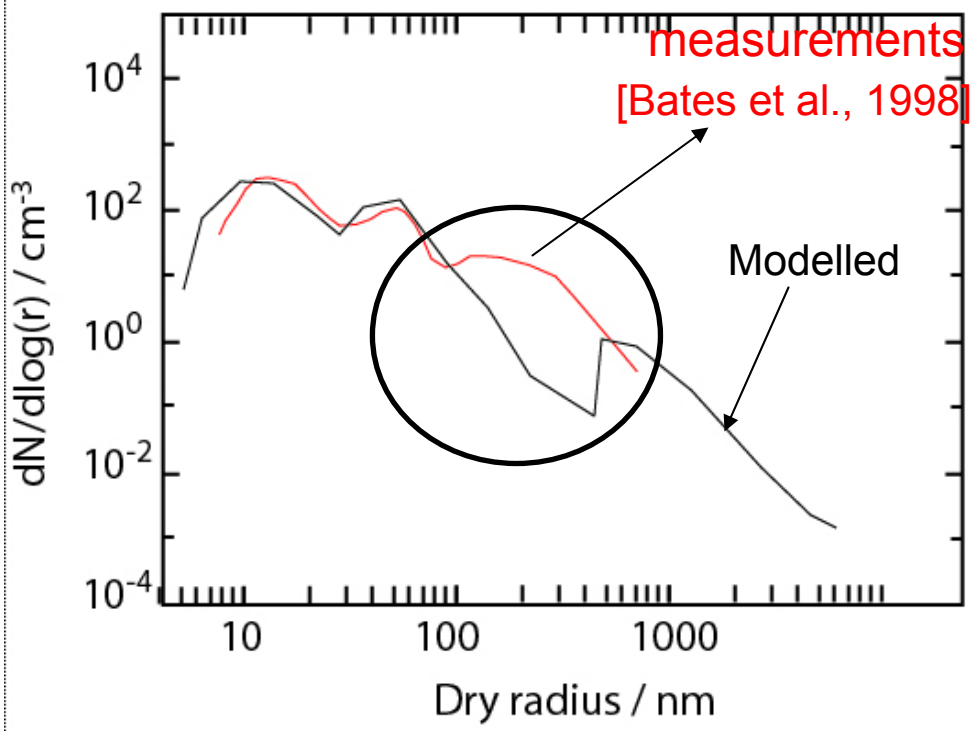
A Brief History of Aerosol Modeling..

- Mechanistic Aerosol Models
  - “Mechanistic Approach”
  - Explicit simulation of the processes that control the aerosol distribution
- Mass Only Aerosol Models
  - Predict aerosol mass
  - Empirical parameterisation of cloud droplet number
- Modal Aerosol Models
  - Size distribution approximated by one (or a number of) statistical functions
  - Aerosol processing treated

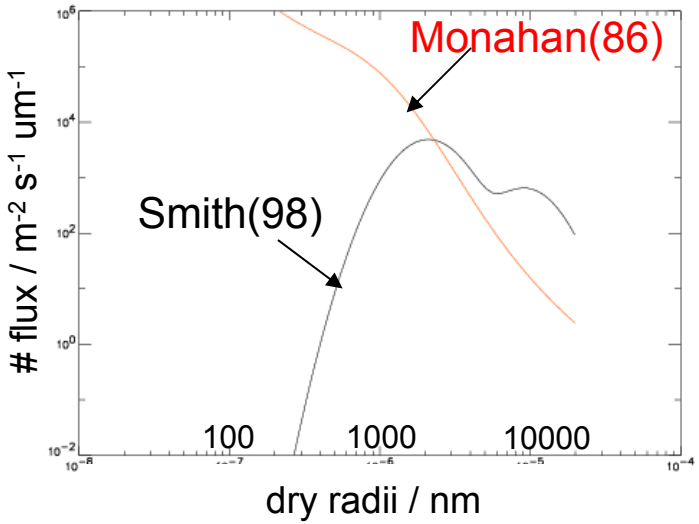
CLAW Hypothesis



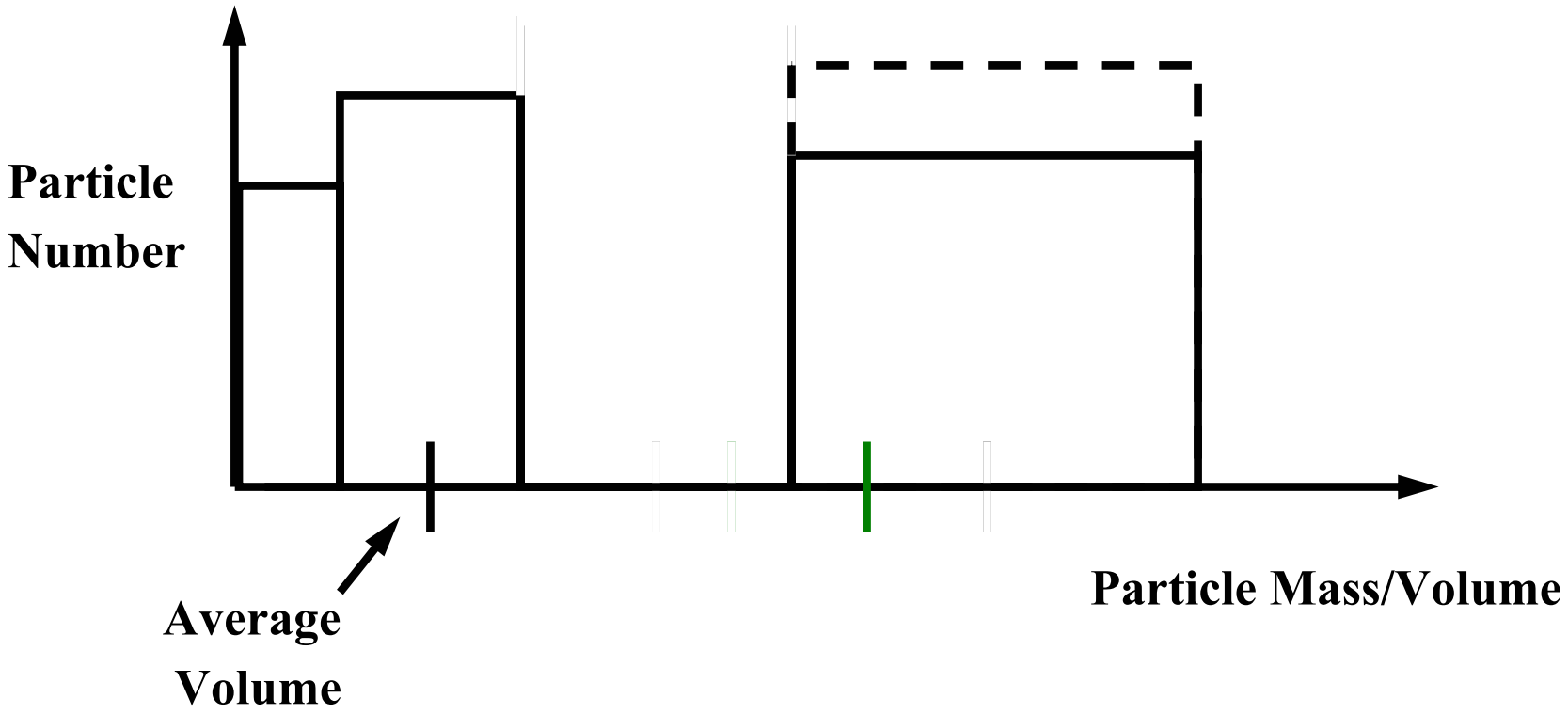
Comparison With Observations



Sea salt aerosol number flux



The Moving Centre Fixed Grid Method



- Minimises numerical diffusion.
- Maintains a fixed grid

GLOMAP Applications

- Understanding of natural and perturbed size and composition resolved global aerosol lifecycle
  - Routes to CCN formation + sensitivities
    - Link to cloud models
  - Fate of anthropogenic sulphur
  - Aerosol interactions (e.g., BC+sulfate)

Science

- Support of field campaigns
- Baseline model for development of GCM aerosol schemes – process reduction
- Biogeochemical cycling and atmospheric chemistry

Users