THE DOE ATMOSPHERIC SCIENCE PROGRAM

Highlights from the 2008 Science Team Meeting

And

THE DOE CLIMATE "GRAND CHALLENGE" WORKSHOP

Stephen E. Schwartz - ASP Chief Scientist

Ashley Williamson - DOE Program Manager for ASP

Climate Change Science Program

Atmospheric Composition Interagency Working Group

April 8, 2008

Washington, DC

- ***Reconfigured in 2004***.
- Aerosol processes affecting radiative forcing of climate change.
- Field measurements, instrumentation, laboratory and theory, modeling.
- Second solicitation 2007.
- 35 Science projects: DOE National Labs, other federal agencies, universities, private sector.
- ***Major field projects***:

  MArine Stratus Experiment (MASE) – California coast, 2005.

  Megacity Aerosol Experiment–MEXico City (MAX-MEX) – 2006.

  Cumulus Humilis Aerosol Processing Study (CHAPS) – OK, 2007.

  Indirect and Semi-Direct Aerosol Campaign (ISDAC) – North Slope Alaska, 2008.

  VAMOS Ocean-Cloud-Atmospheric-Land Study (VOCALS) – Chile coast, 2008.

OVERVIEW

The need to ***reduce uncertainty in aerosol forcing***.

Aerosol processes that must be understood and represented in climate models.

Some highlights of recent research in DOE's Atmospheric Science Program – emphasis ***carbonaceous aerosols***.

Representing aerosols in global chemical transport models and global climate models.

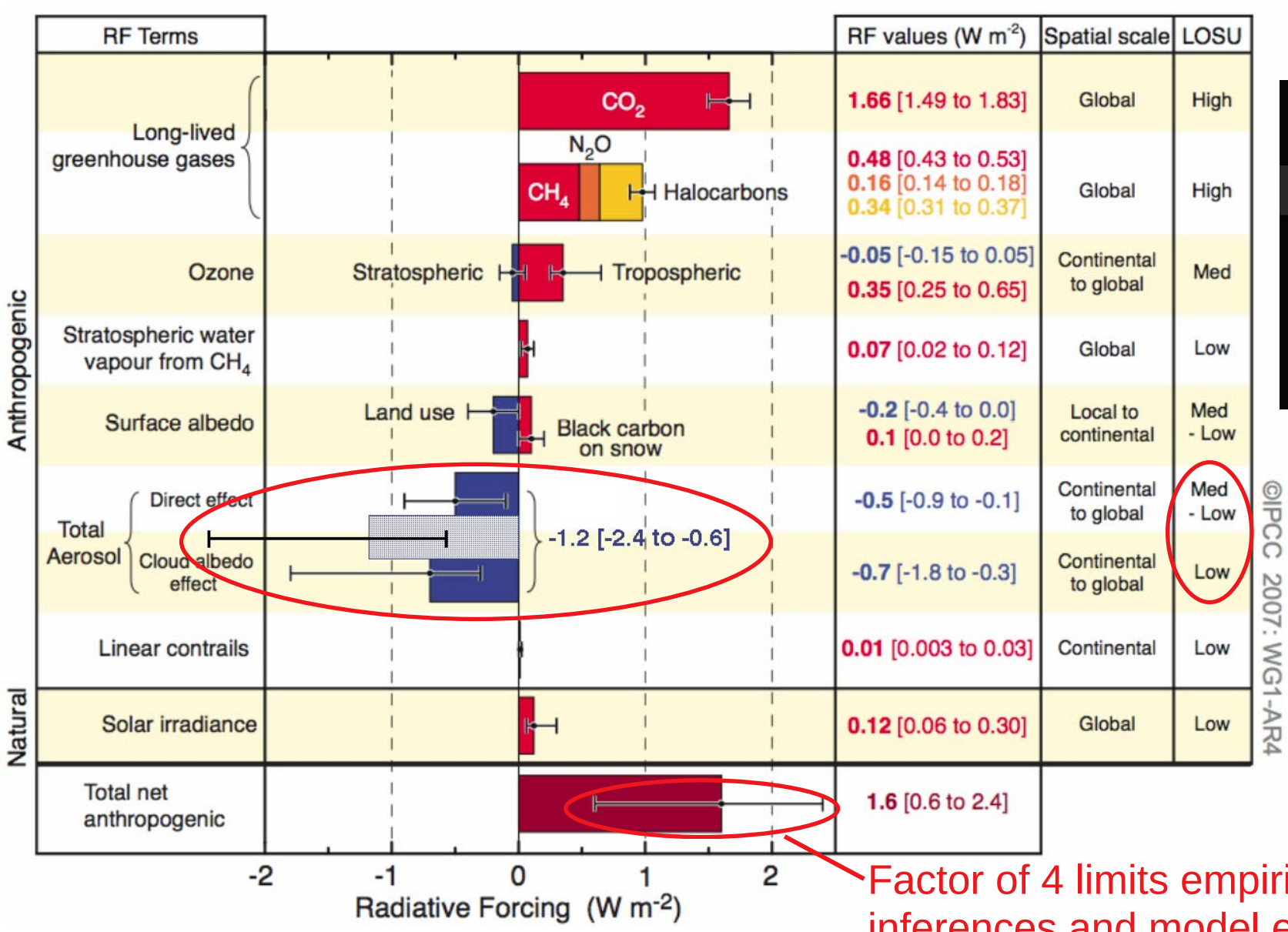
Summary.

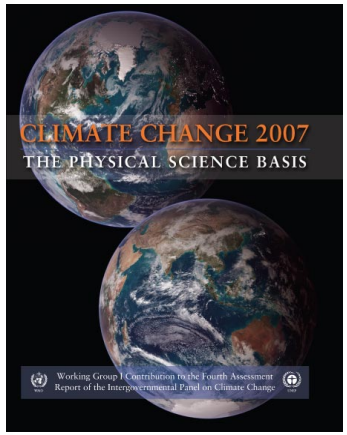
DOE workshop on "grand challenges" in climate science.

THE NEED TO REDUCE UNCERTAINTY IN AEROSOL FORCING

GLOBAL-MEAN RADIATIVE FORCINGS (RF)

Pre-industrial to present (Intergovernmental Panel on Climate Change, 2007)





©IPCC 2007: WG1-AR4

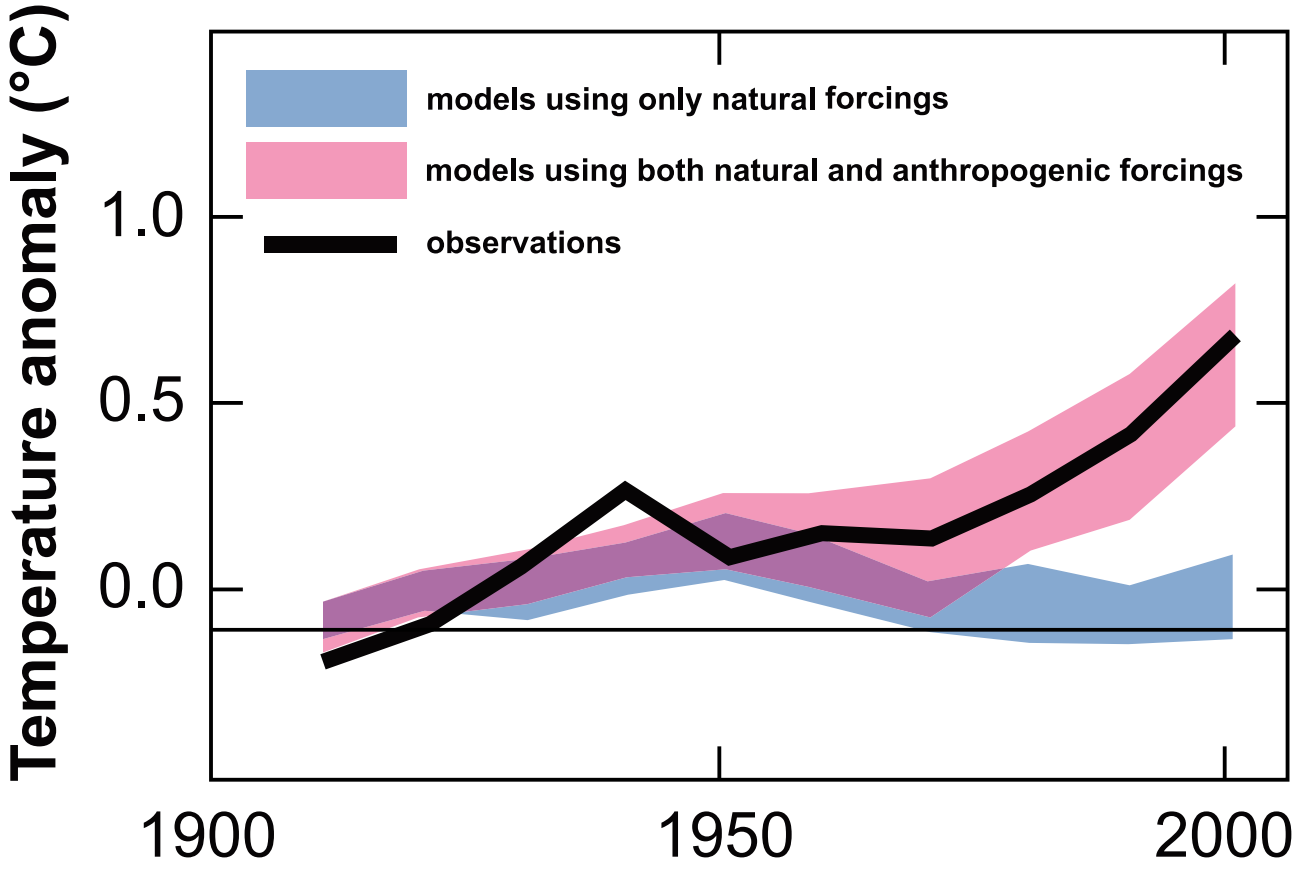
Factor of 4 limits empirical inferences and model evaluation.

LOSU denotes level of scientific understanding.

Uncertainty range: 5 - 95%.

GLOBAL MEAN TEMPERATURE CHANGE

Ensemble of 58 model runs with 14 global climate models

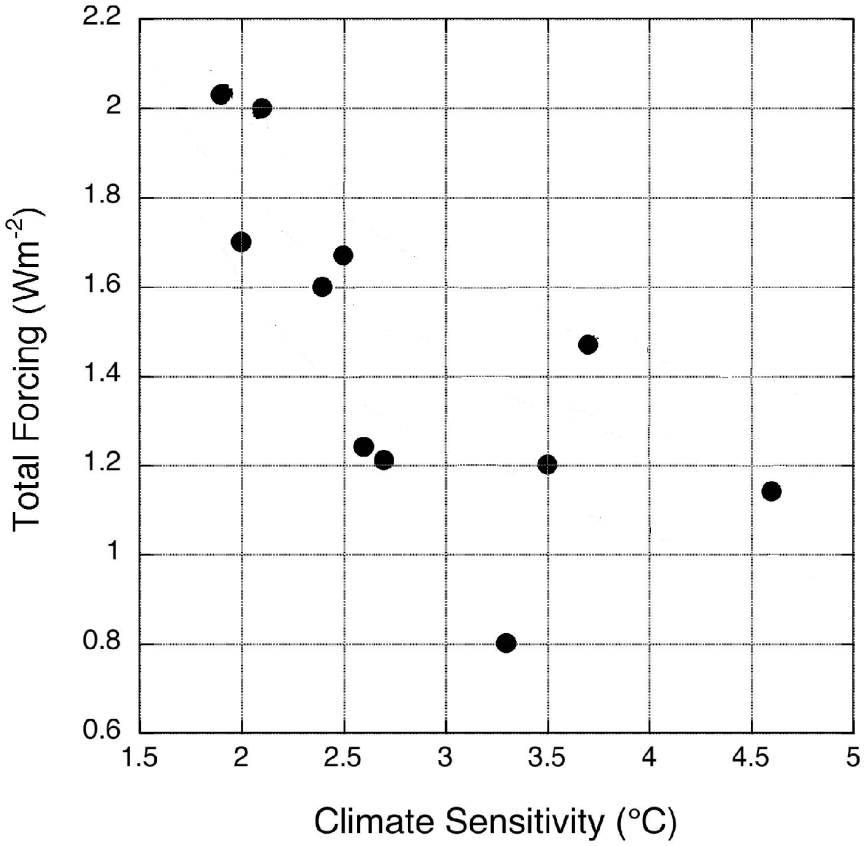


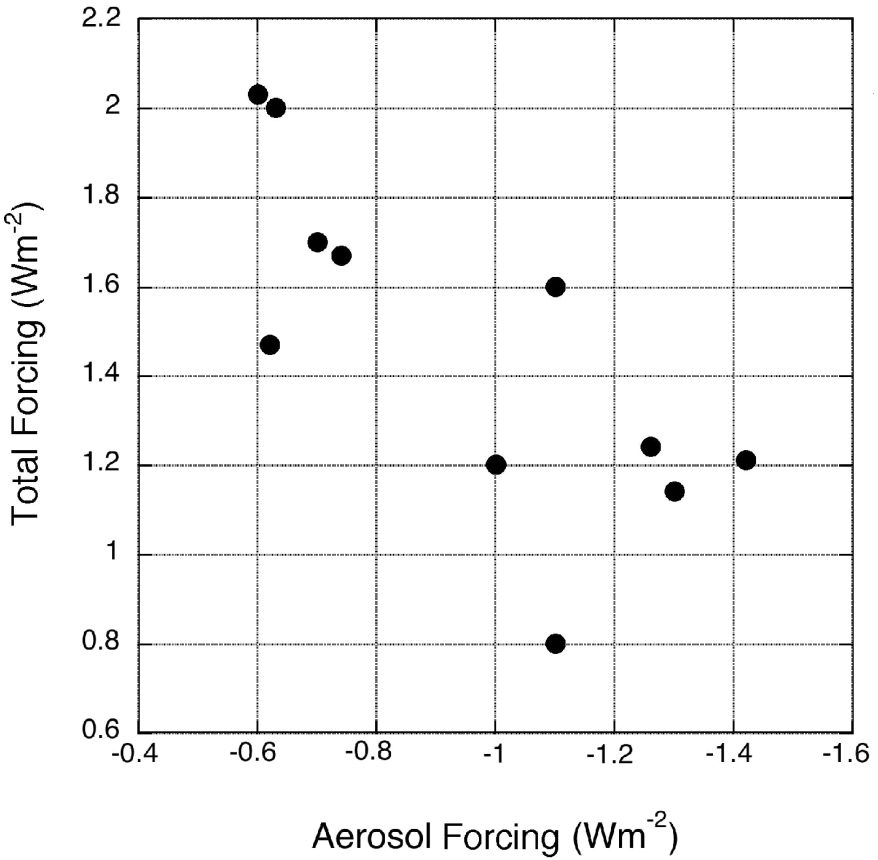
“ Models can … simulate many observed aspects of climate change over the instrumental record. One example is that the ***global temperature trend over the past century … can be modelled with high skill when both human and natural factors that influence climate are included***.

IPCC AR4, 2007

CORRELATION OF AEROSOL FORCING, TOTAL FORCING, AND SENSITIVITY IN CLIMATE MODELS

Eleven models used in 2007 IPCC analysis





Modified from Kiehl, GRL, 2007

Climate models with higher sensitivity have lower total forcing.

Total forcing decreases with increasing (negative) aerosol forcing.

IMPLICATIONS OF UNCERTAINTY IN CLIMATE SENSITIVITY

Uncertainty in climate sensitivity translates directly into . . .

- Uncertainty in the amount of ***incremental atmospheric*** $\mathbf{CO_2}$ that would result in a given increase in global mean surface temperature.
- Uncertainty in the amount of ***fossil fuel carbon*** that can be combusted consonant with a given climate effect.

At present this uncertainty is more than a factor of 2.

Reduction in uncertainty in aerosol forcing is essential to reducing uncertainty in climate sensitivity.

DEPARTMENT OF ENERGY ATMOSPHERIC SCIENCE PROGRAM SCIENCE TEAM MEETING

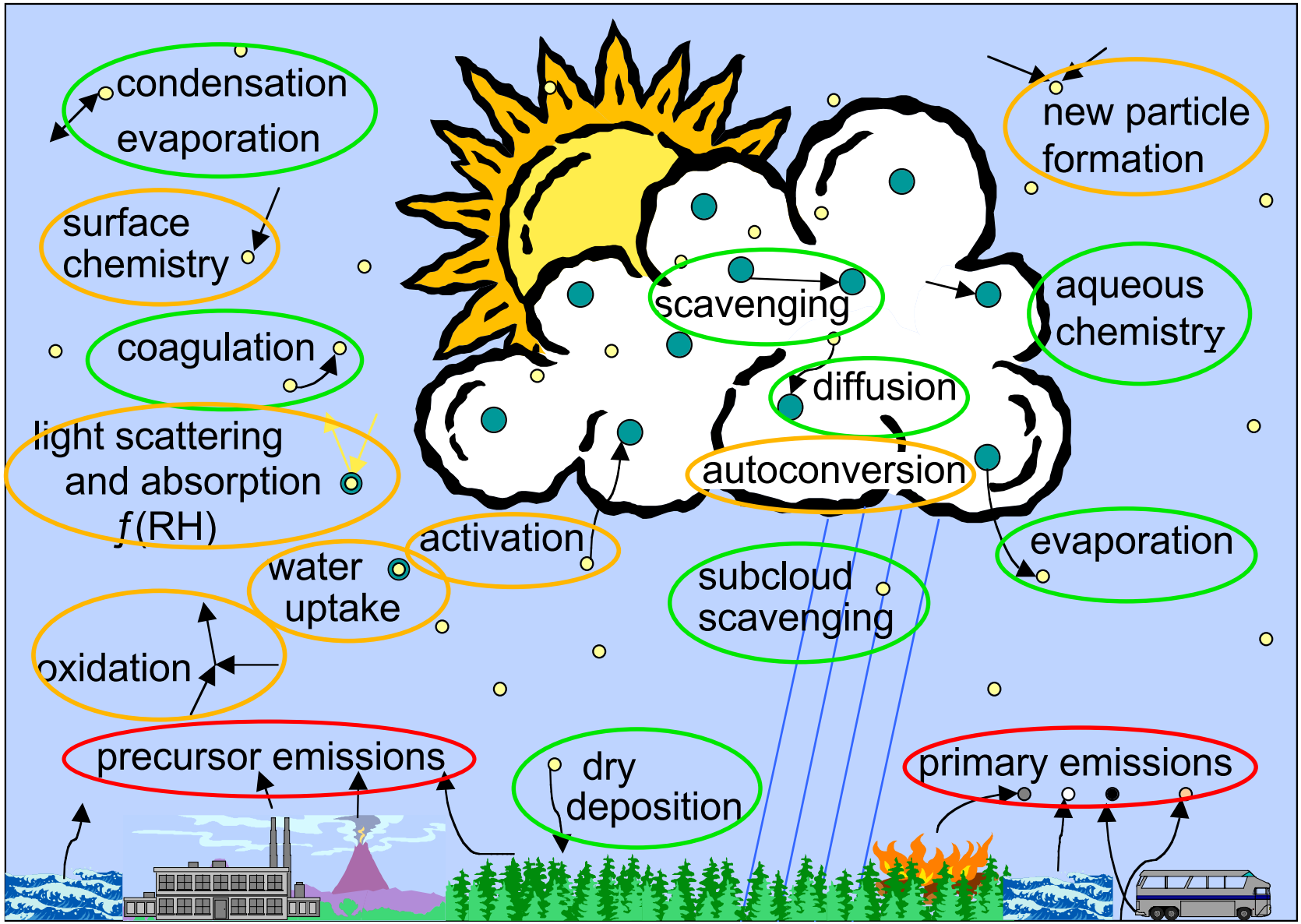
February 25-27, 2008

Annapolis MD

Presentations available at www.asp.bnl..gov

AEROSOL PROCESSES THAT MUST BE UNDERSTOOD AND REPRESENTED IN CLIMATE MODELS

AEROSOL PROCESSES THAT MUST BE UNDERSTOOD AND REPRESENTED IN MODELS

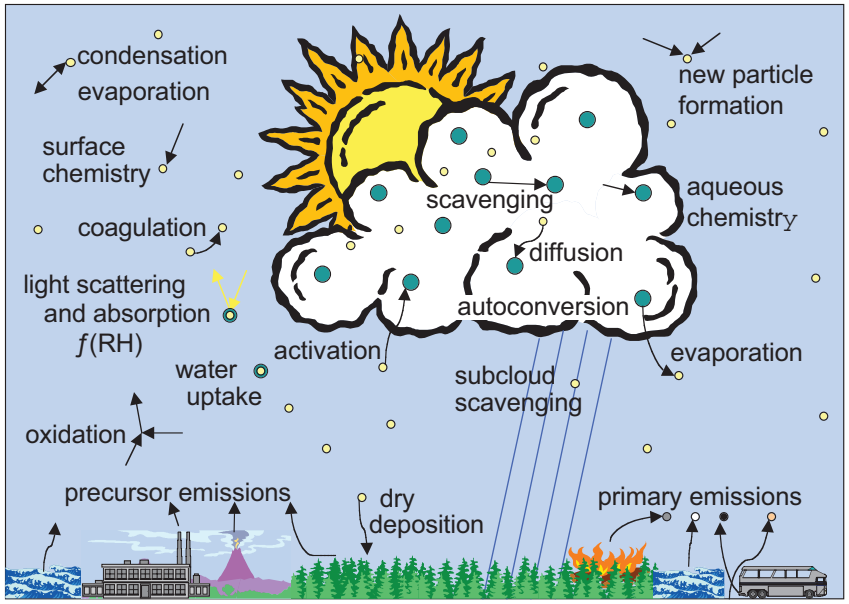


Ghan and Schwartz, Bull. Amer. Meterol. Soc., 2007

Well understood Current research portfolio Missing

APPROACH TO DETERMINE AEROSOL FORCING

Numerical simulation of physical processes



Isomorphism of processes to computer code

Modeling aerosol processes requires understanding these processes, developing and testing their numerical representations, and incorporating these representations in global scale models.

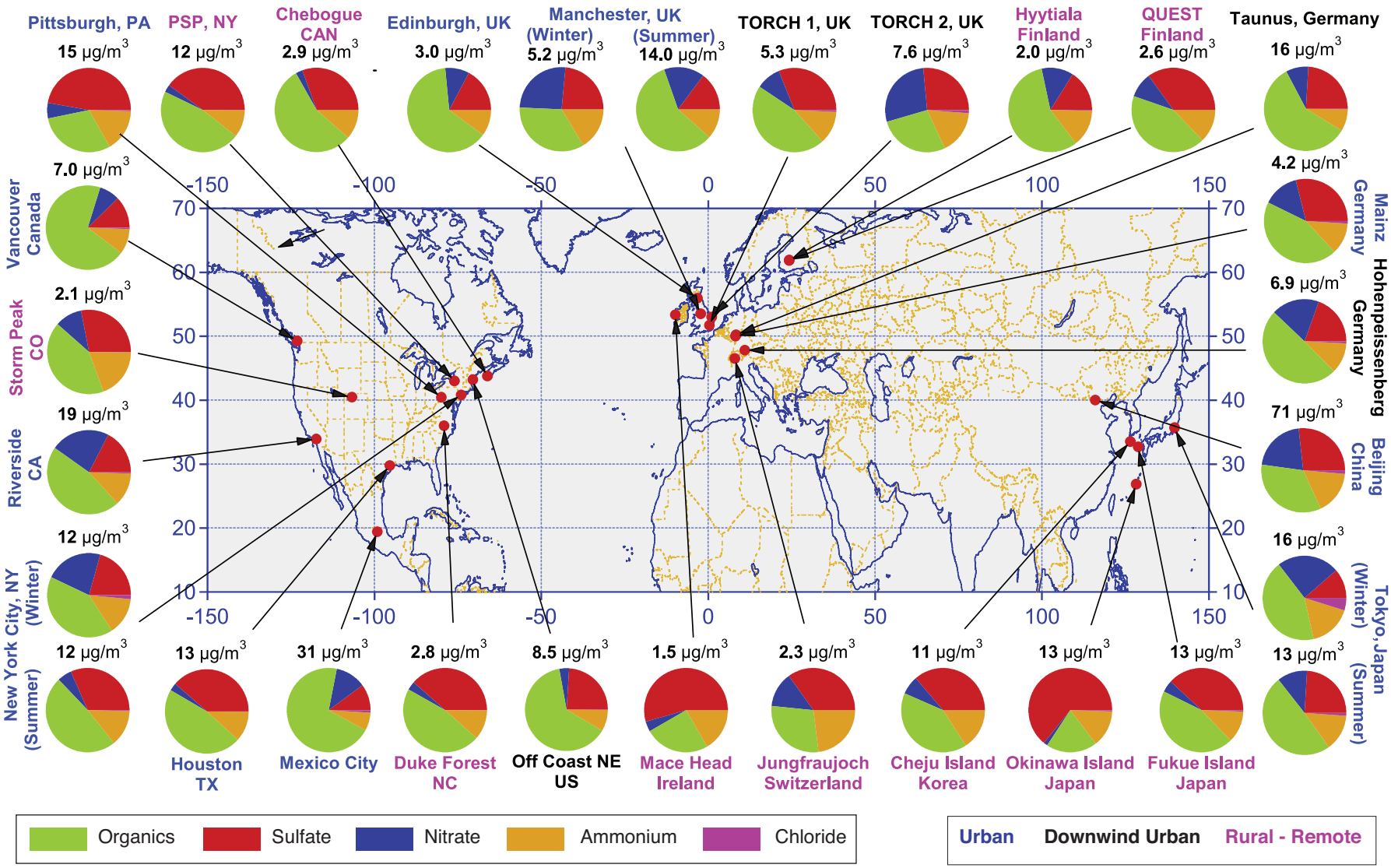
ATMOSPHERIC AEROSOL PROCESS RESEARCH

What's new?

Organics

DOMINANCE OF ORGANIC AEROSOL

Measurements by aerosol mass spectrometer

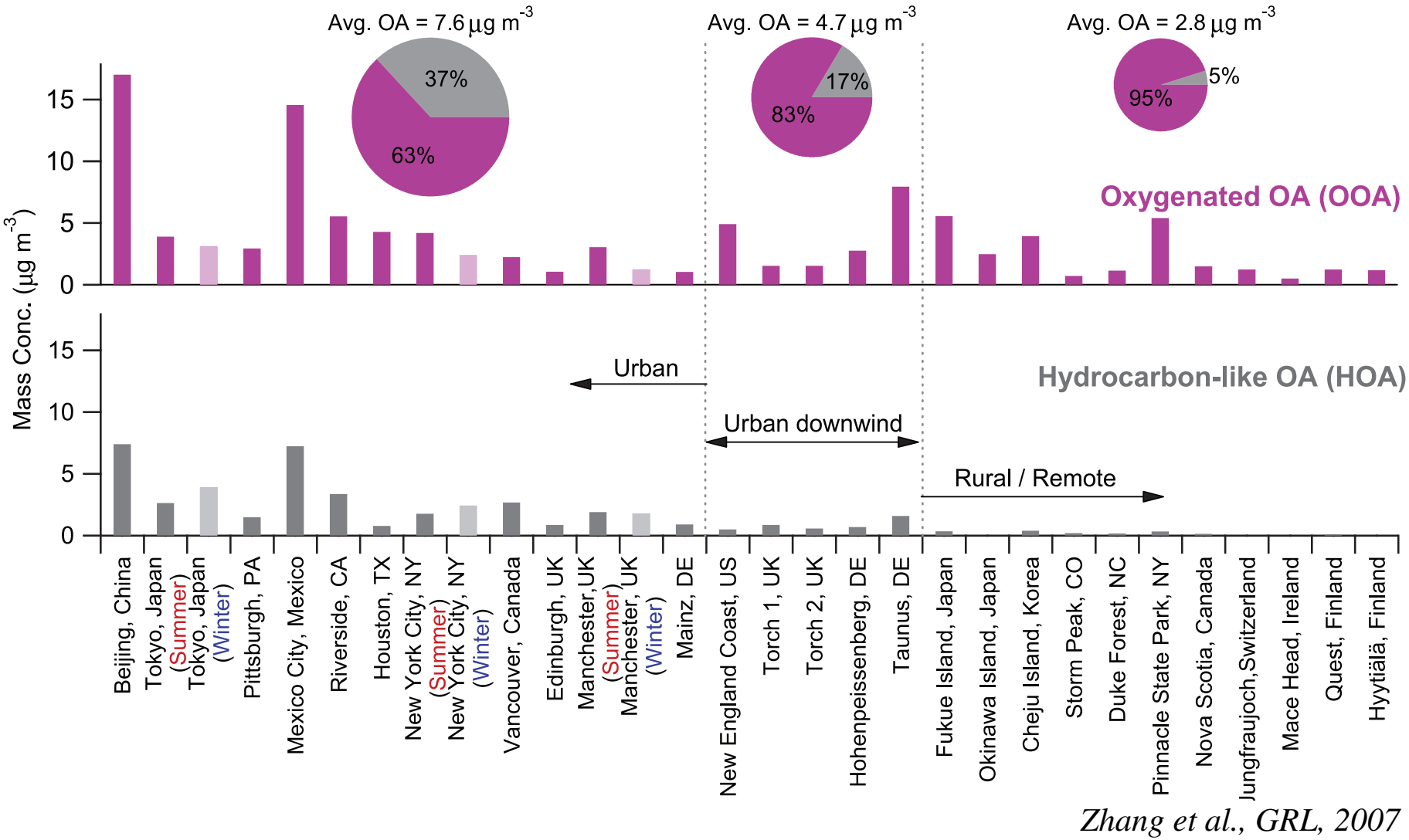


Zhang et al., GRL, 2007

Organic aerosol is major or dominant species throughout the anthropogenically influenced Northern Hemisphere.

PRIMARY AND SECONDARY ORGANIC AEROSOL BY LOCATION TYPE

Area of pie scaled to organic aerosol concentration



Zhang et al., GRL, 2007

Secondary fraction increases with increasing distance from urban sources.

AEROSOL IN MEXICO CITY BASIN

Photo credit Berk Knighton

AEROSOL IN MEXICO CITY BASIN

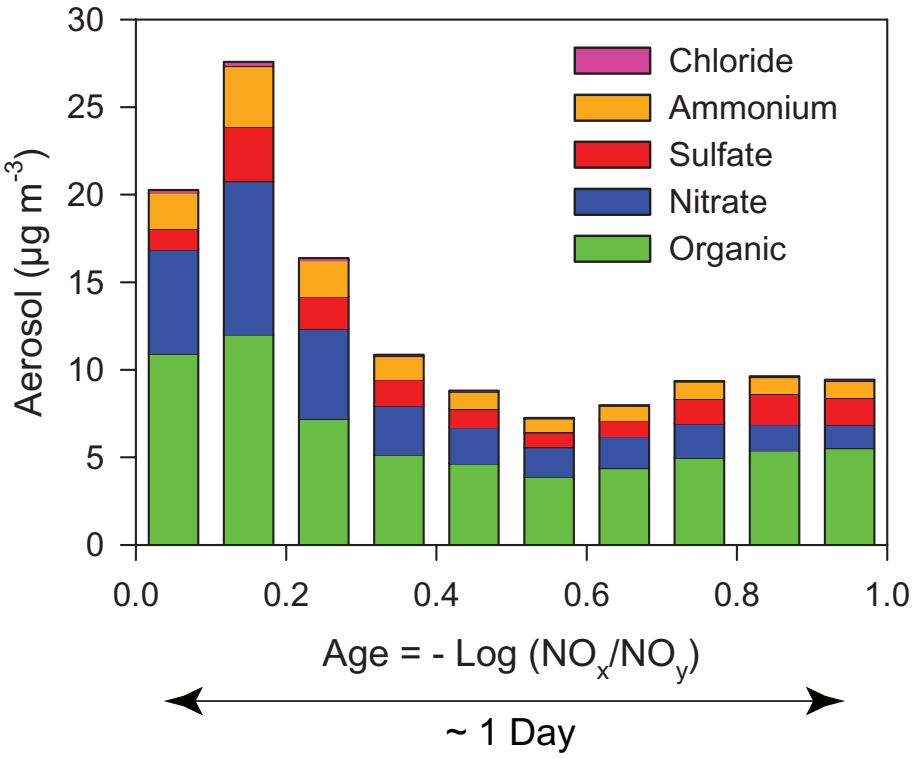
Photo credit Berk Knighton

Mexico City is a wonderful place to study aerosol properties and evolution.

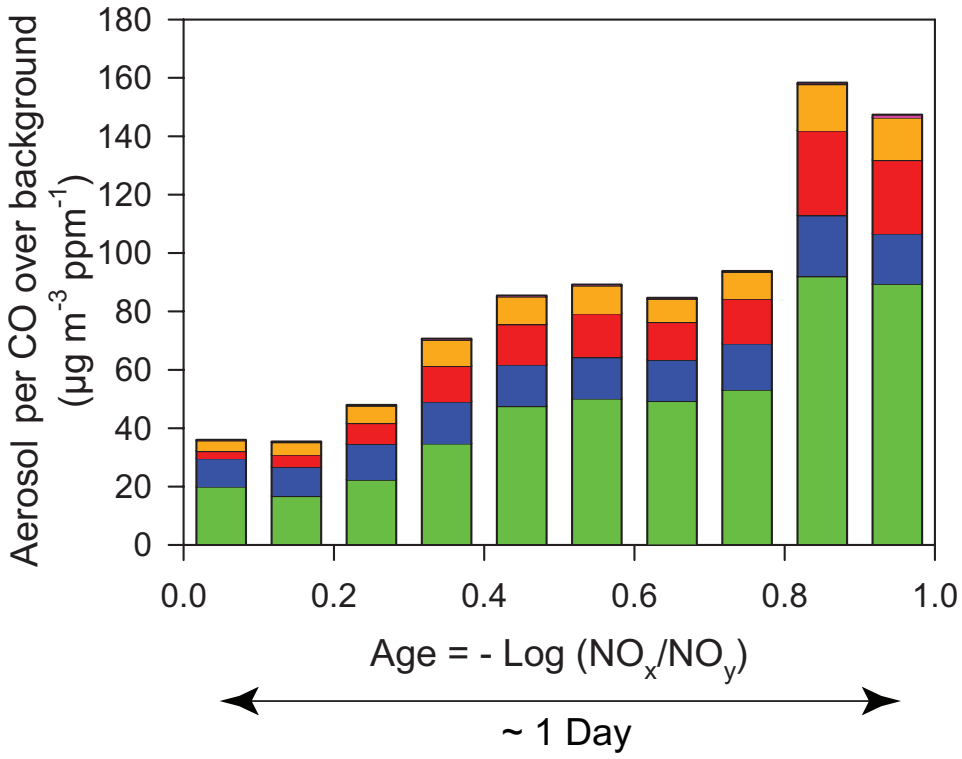
SECONDARY AEROSOL PRODUCTION

Parcel age measured using - Log(NO_x/NO_y) as clock

Concentration



Normalized concentration



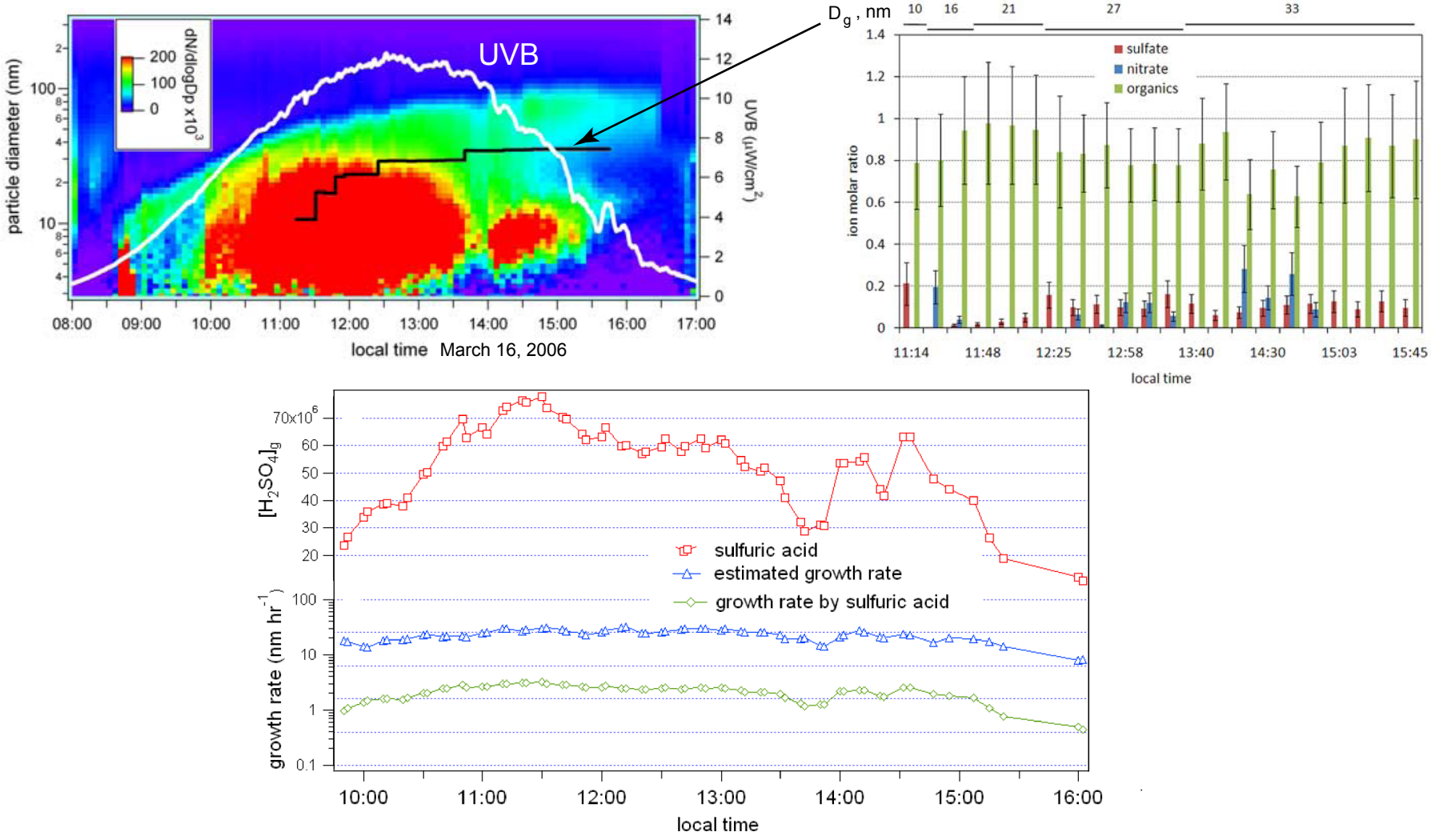
Kleinman et al, ACP, 2008

Dilution is accounted for by normalizing aerosol concentration to CO above background.

~5 × *increase* in organic aerosol.

Measured increase in organic aerosol exceeds modeled based on laboratory experiments and measured volatile organic carbon ***tenfold***.

Following the growth of particles formed from nucleation at Tecamac, Mexico



Sulfate accounts for only ~10% of particulate mass.

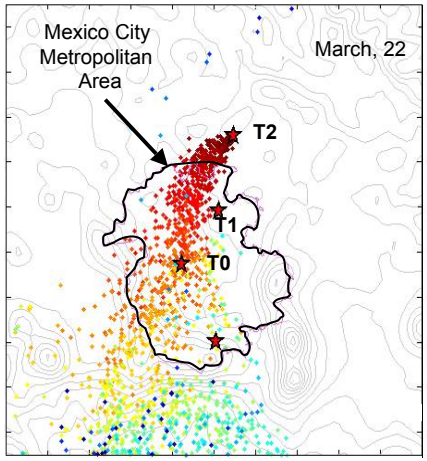
Growth rate exceeds that from sulfuric acid by order of magnitude.

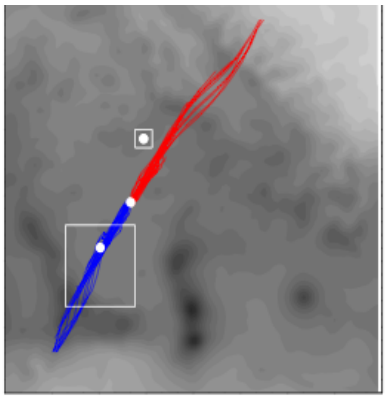
Smith, McMurry et al., GRL, 2008

AEROSOL TRANSPORT AND EVOLUTION

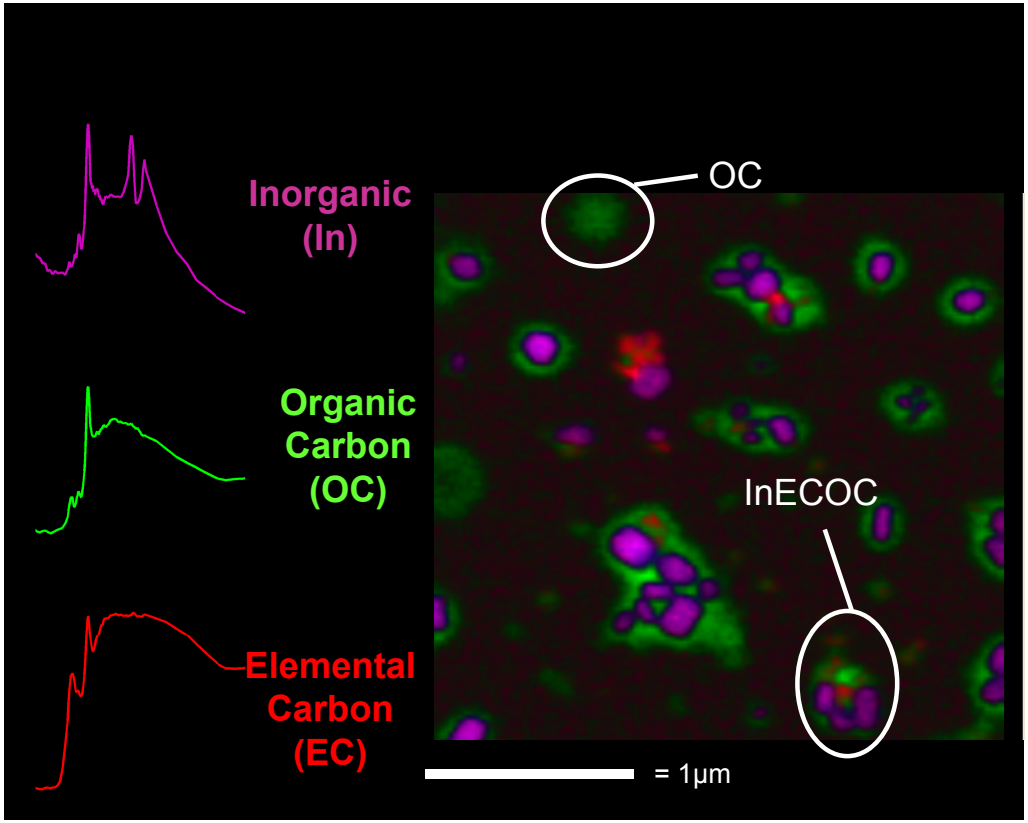
Mexico City, March 22, 2006

FLEXPART age and back trajectories

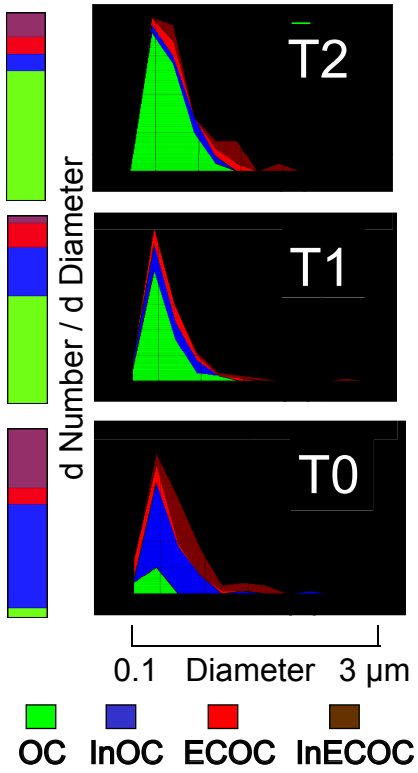




Component ID by scanning transmission electron microscopy



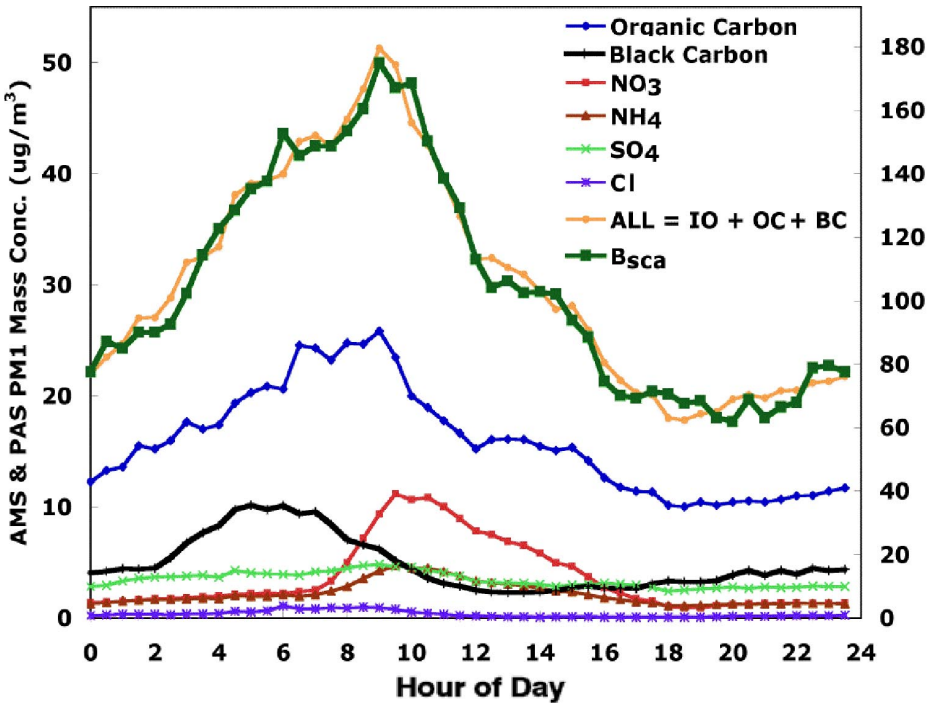
Number fraction and number size distribution

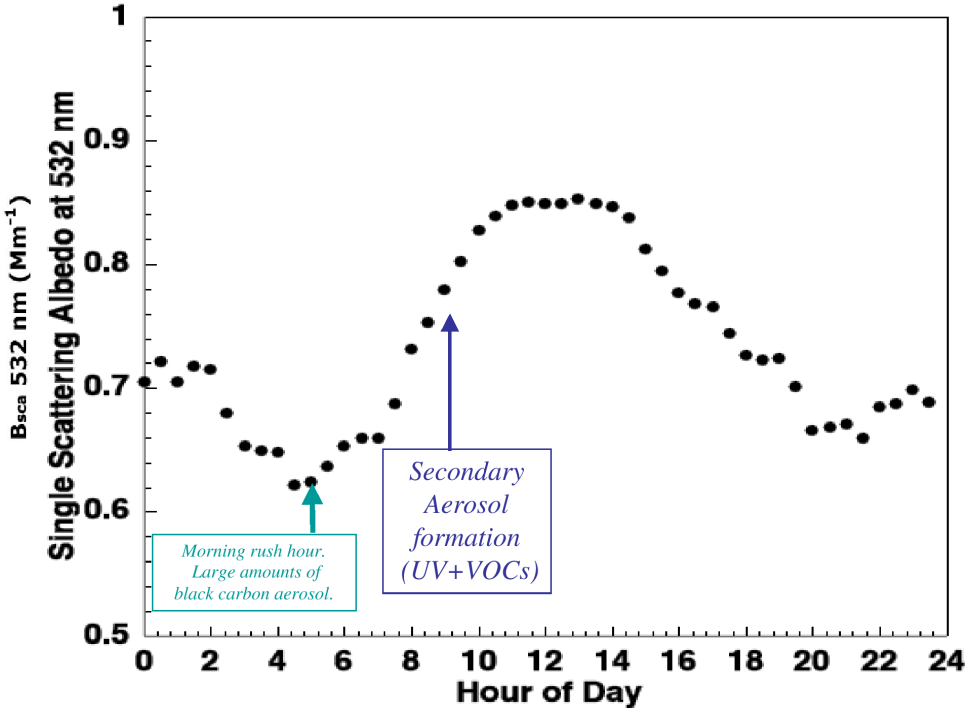


Moffet, Tivanski, Hopkins, Desyaterik, Fast, Barnard, Laskin, Gilles; PNNL, LBL

AEROSOL COMPOSITION AND OPTICAL PROPERTIES

Mexico City (T0 site), Project average, March 2006 – Low RH





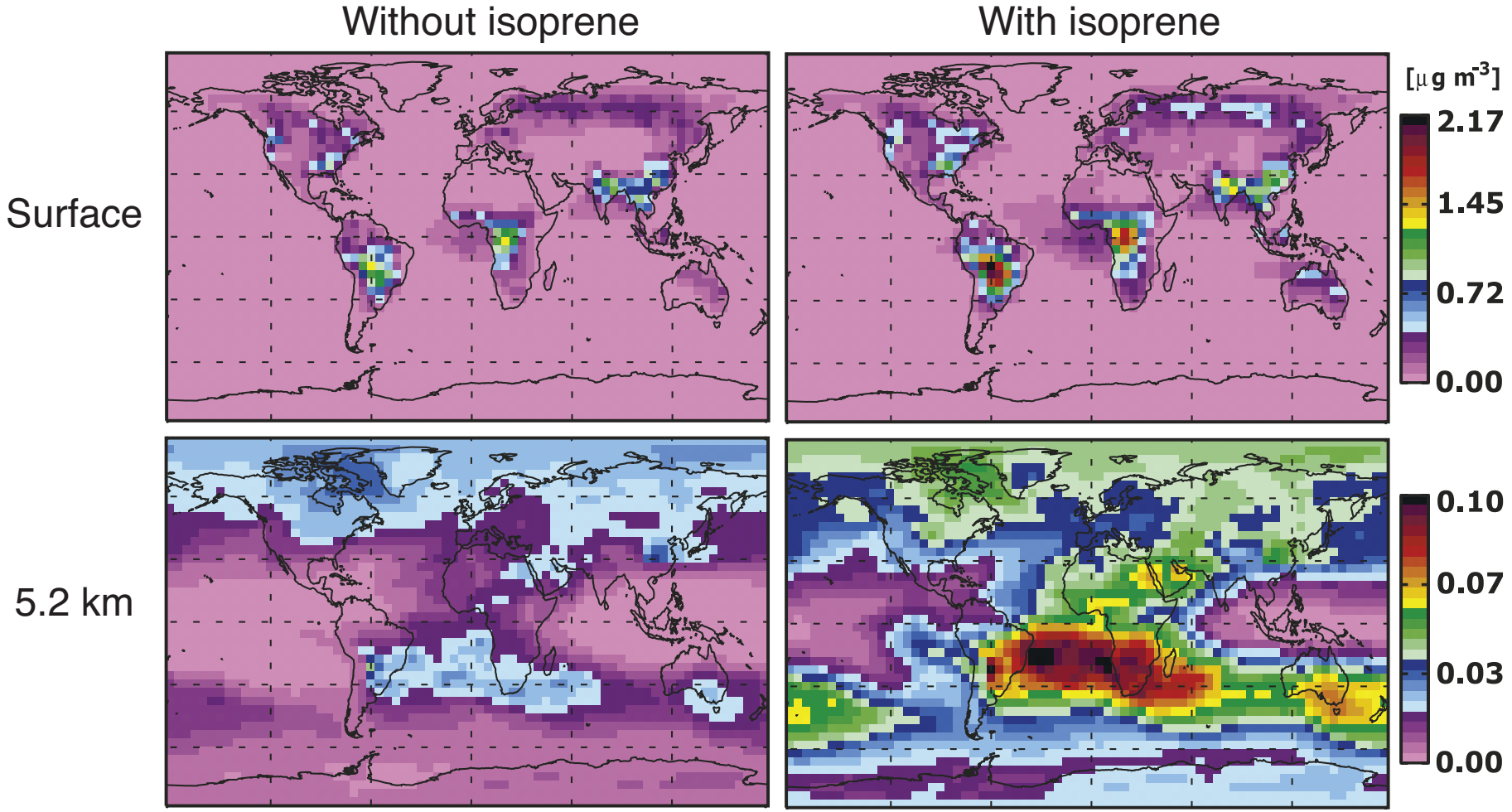
Aerosol mass spectrometry: Jose Jimenez, Allison Aiken; Optical properties: Pat Arnott, Lupita Paredes

Light scattering coefficient tracks mass concentration.

Single scattering albedo reflects change in aerosol composition.

ISOPRENE ENHANCEMENT TO SECONDARY ORGANIC AEROSOL

Modeled SOA without and with isoprene at surface and 5.2 km



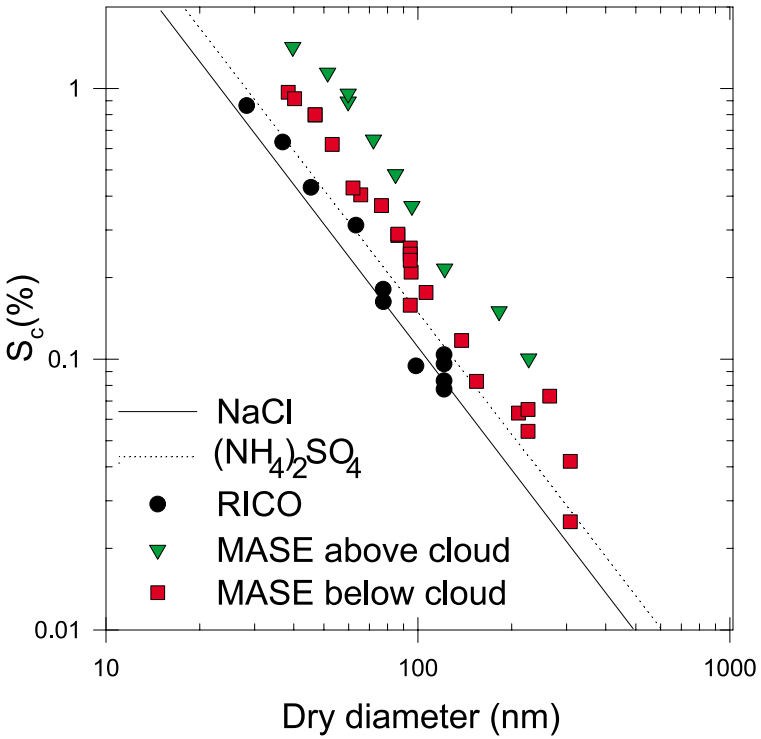
Henze and Seinfeld, GRL, 2006

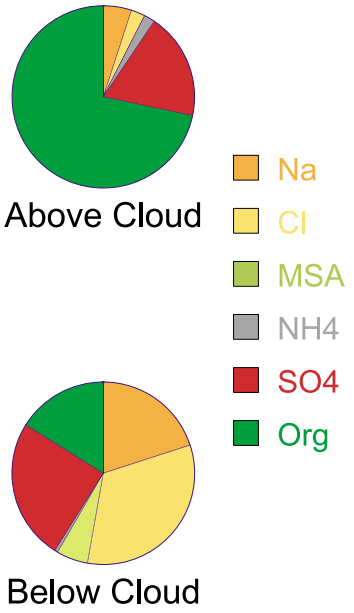
Isoprene increases global SOA by more than a factor of 2.

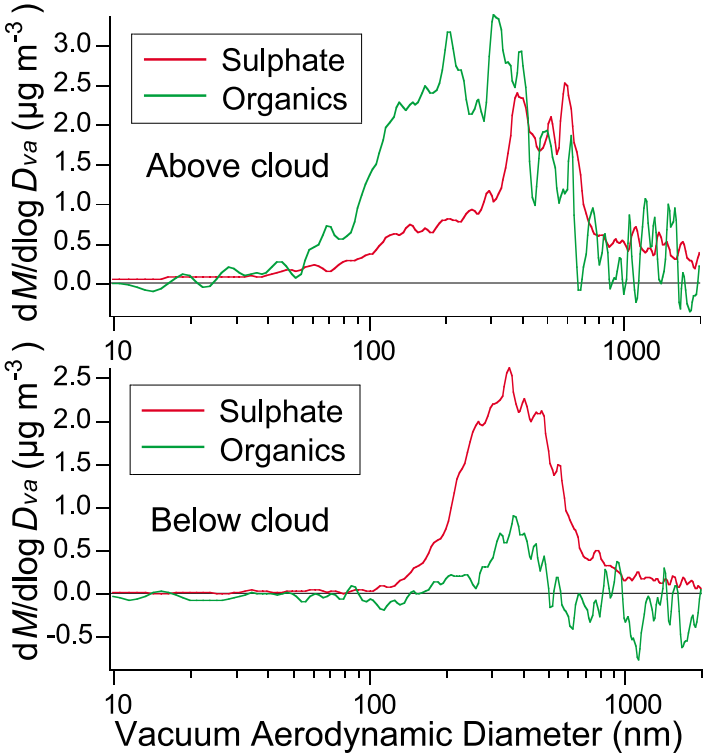
Relative enhancement is much greater in free troposphere (note different scales).

COMPOSITION MATTERS

Size dependent critical supersaturation of aerosol particles







J. Hudson, Y.-N. Lee, M. Alexander

Measurements below (110-170 m) and above (400-470 m) clouds off the coast of California, north of San Francisco, on July 25, 2005.

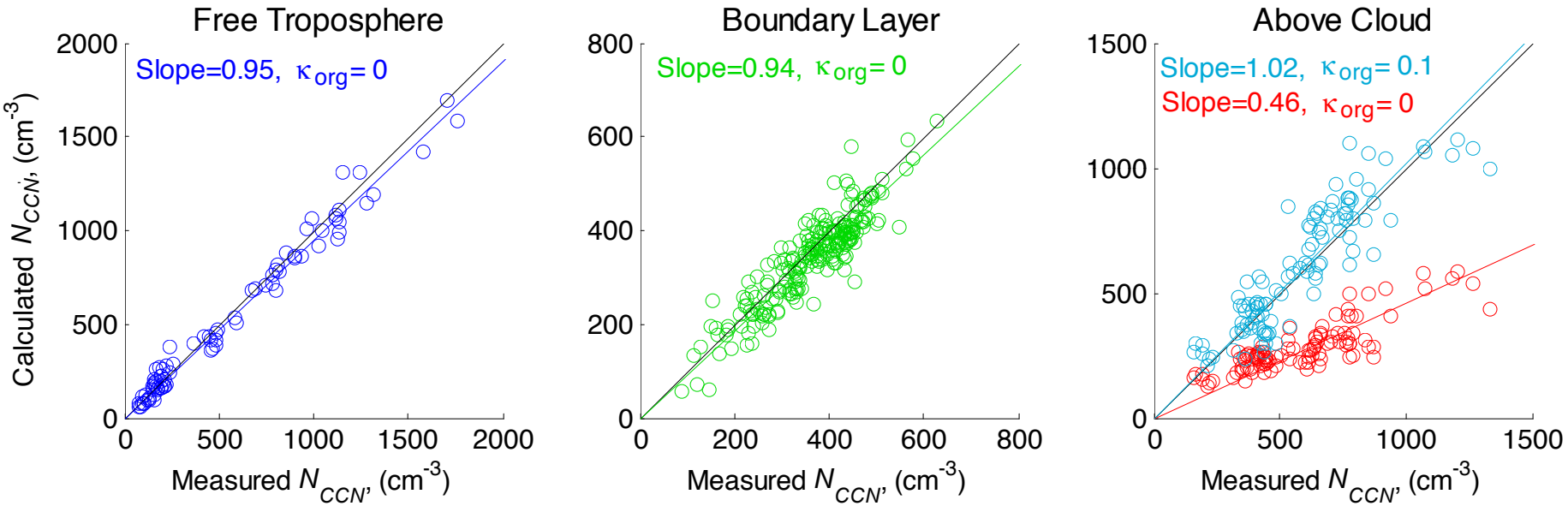
Higher supersaturation is required to activate particles with greater organic fraction.

Bulk composition determined by PILS (particle into liquid sampler).

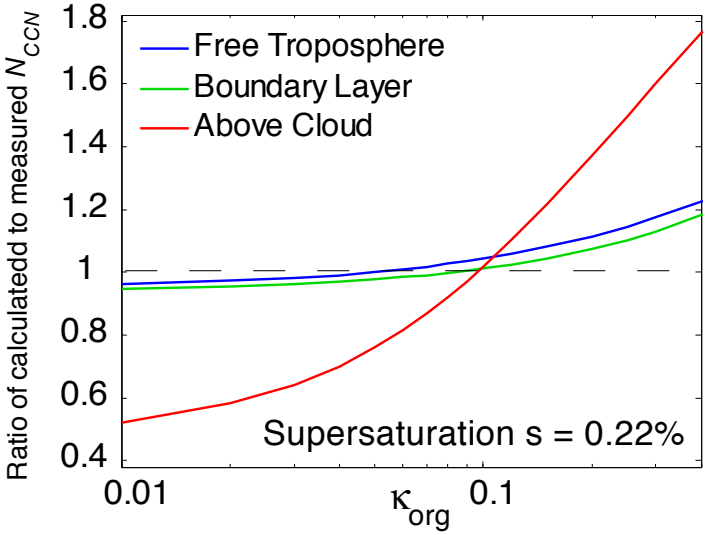
Size-dependent composition determined by aerosol mass spectrometer.

CLOSURE STUDY ON CCN CONCENTRATION

CCN concentration at 0.22% supersaturation for 9 flights during MASE, July 2005



$$S = \frac{D^3 - D_p^3}{D^3 - D_p^3\left(1-\kappa\right)} \exp\left(\frac{4\sigma_w M_w}{RT\rho_w D}\right) \qquad \kappa = \sum_i x_i \kappa_i$$



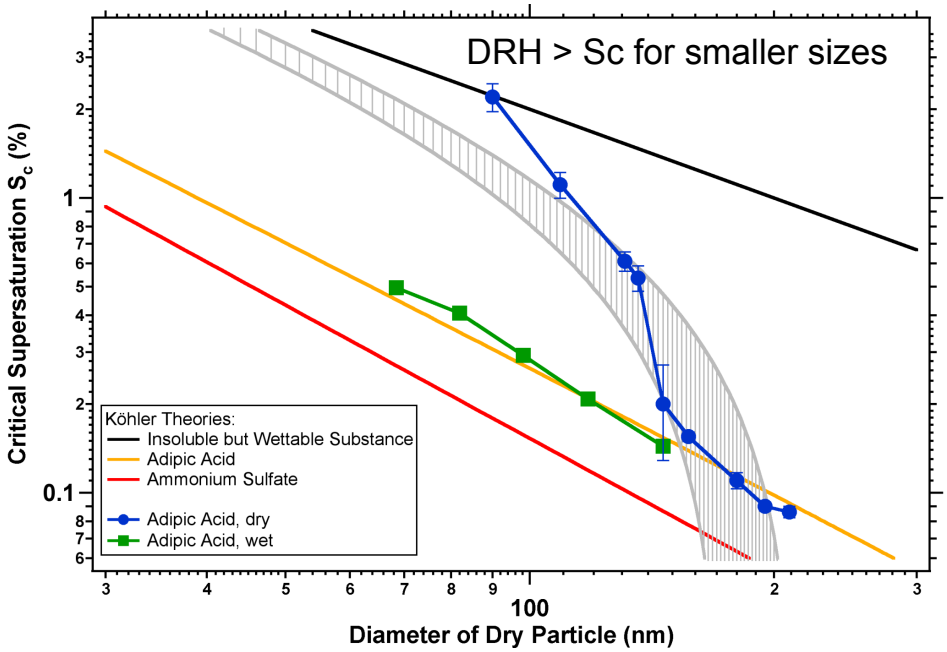
Strong dependence for above cloud aerosol because of high organic fraction, ~ 80%.

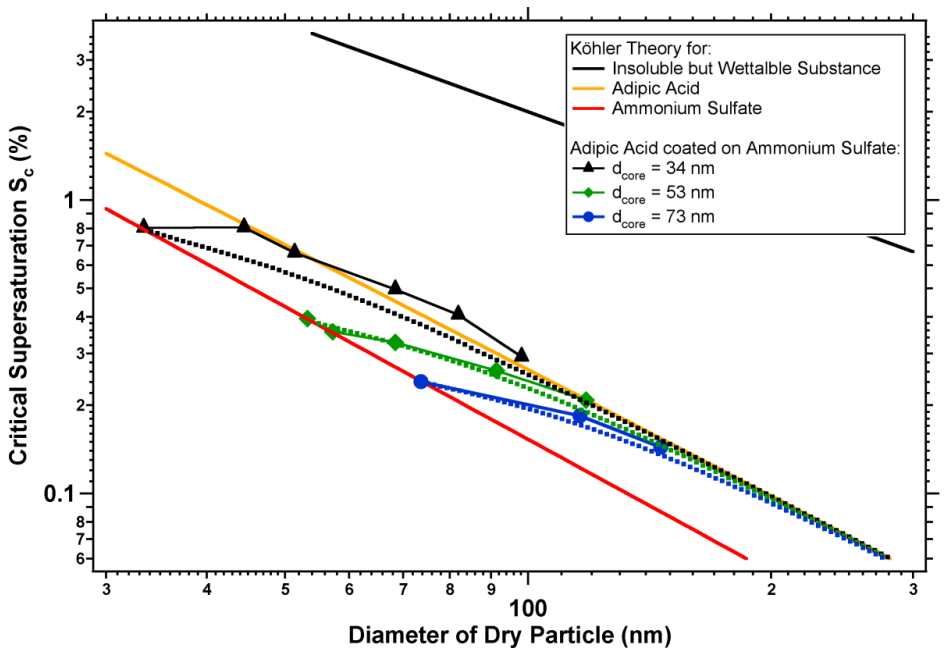
Weak dependence on κ_{org} for free troposphere and boundary layer aerosol because of lower organic fraction, ~ 50%.

Wang, Lee, Daum, BNL; Alexander, PNNL; Jayne, Aerodyne

LABORATORY STUDIES OF ACTIVATION OF MIXED ADIPIC ACID – AMMONIUM SULFATE PARTICLES

Sparingly soluble organic acid – soluble inorganic salt





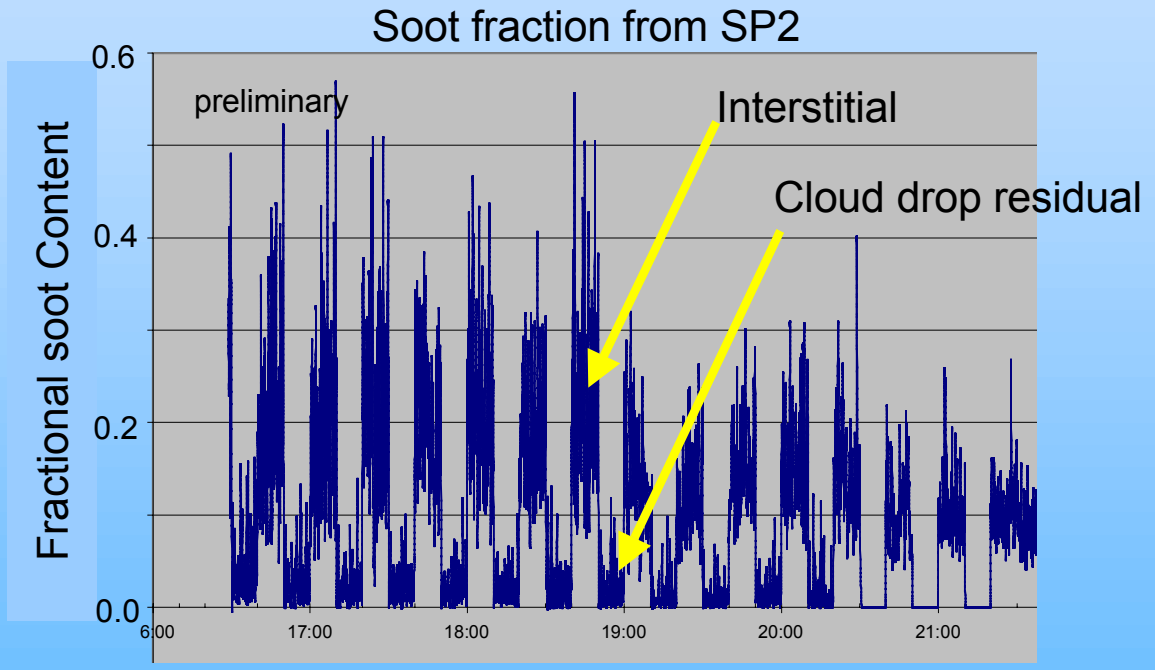
Koehler theory works well mixed adipic acid and sulfate particles.

For slightly soluble compounds initial particle phase is very important.

P. Davidovits, Boston Coll.; T. Onasch, Aerodyne, Inc., et al.

SOOT-CONTAINING FRACTION OF PARTICLES IN CLOUDWATER AND INTERSTITIAL AIR

Cloudwater virtual impactor measurements at Holme Moss, UK



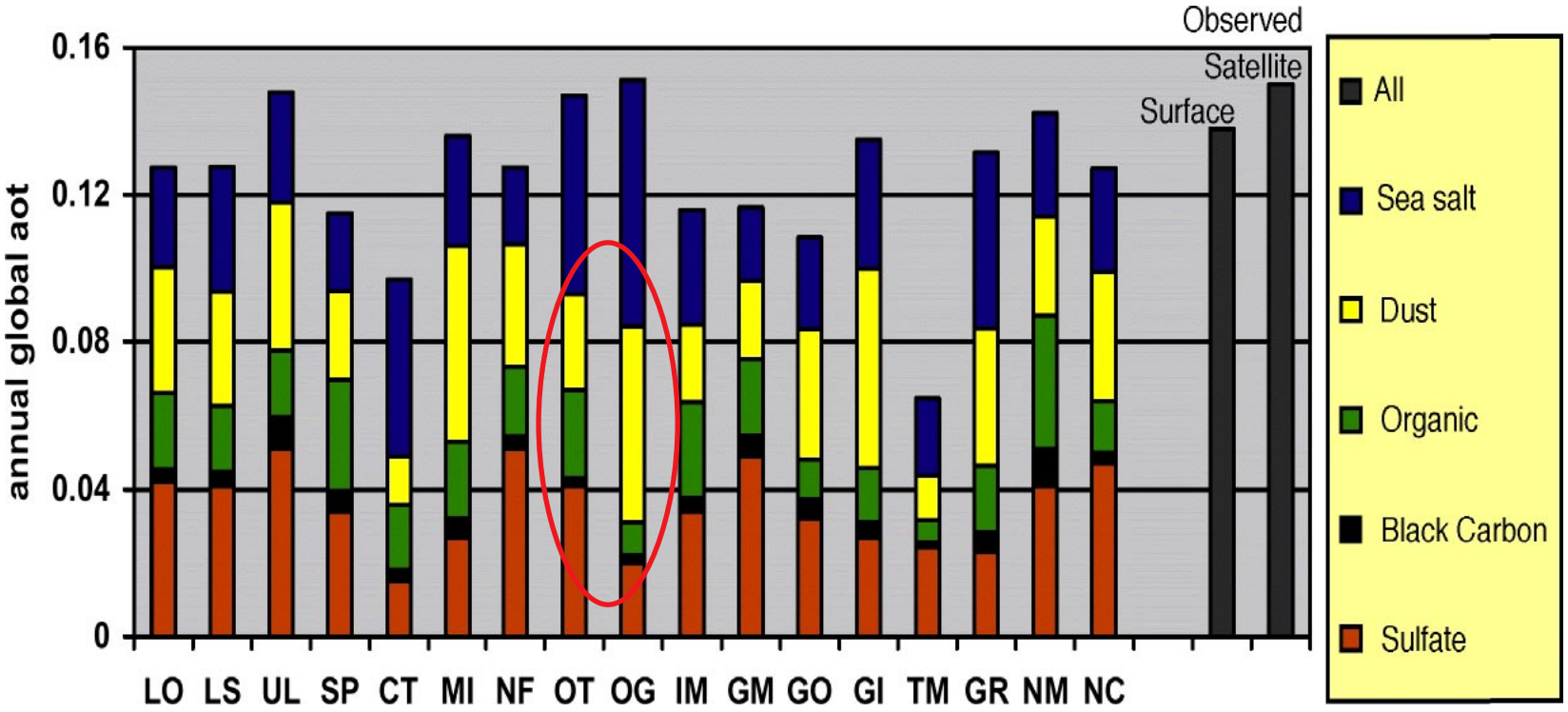
Soot-containing particles are less efficiently scavenged than particles not containing soot.

E. Andrews, J. Ogren et al., NOAA-ESRL; K. Bower, H. Coe et al., Univ. Manchester

REPRESENTING AEROSOLS IN GLOBAL CHEMICAL TRANSPORT MODELS

AEROSOL OPTICAL DEPTH IN 17 MODELS (AEROCOM)

Comparison also with surface and satellite observations



Kinne et al., ACP, 2006

Surface measurements: AERONET network.

Satellite measurements: composite from multiple instruments/platforms.

Are the models getting the "right" answer for the wrong reason?

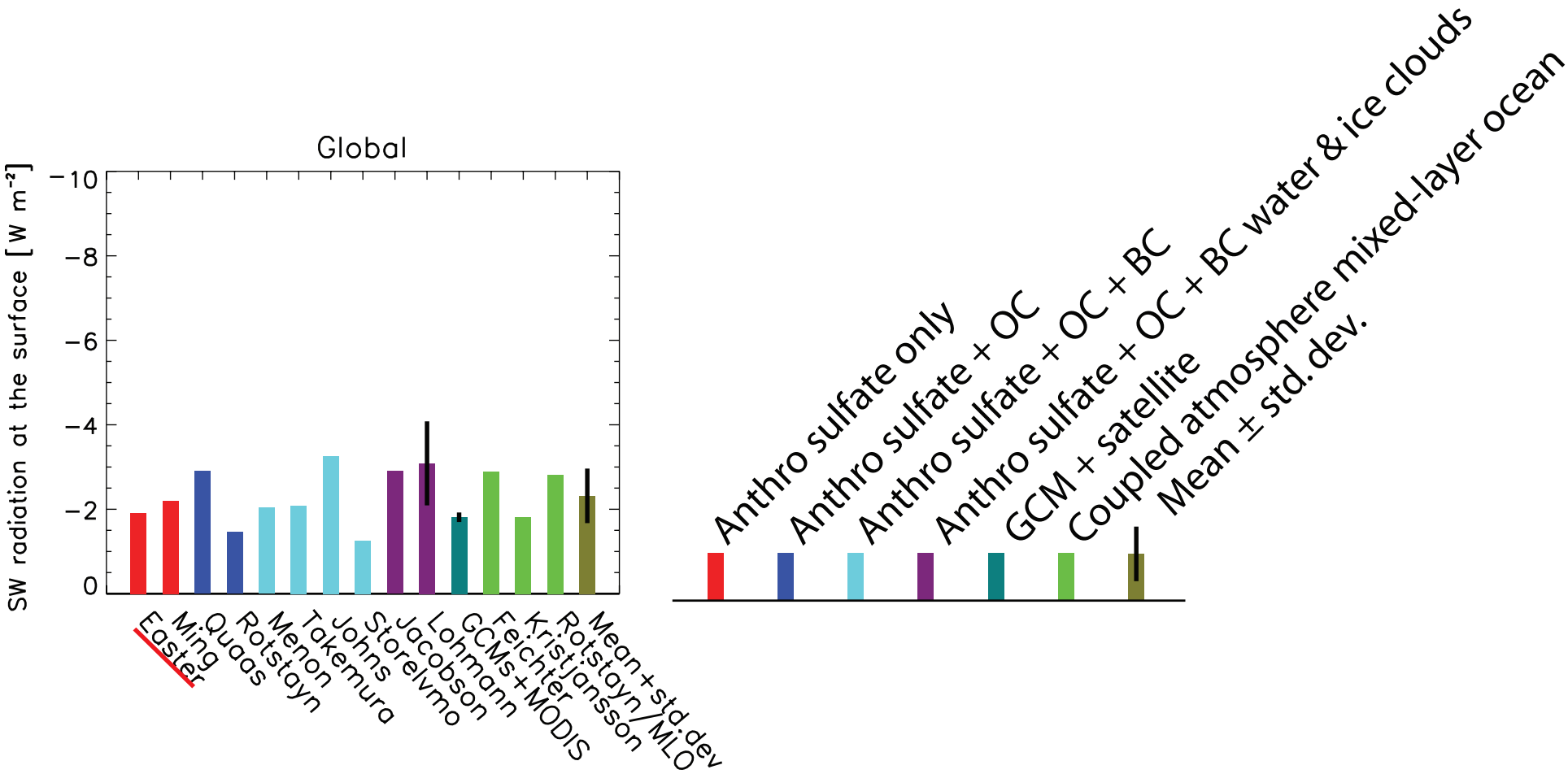
Are the models getting the "right" answer because the answer is known?

Are the satellites getting the "right" answer because the answer is known?

REPRESENTING AEROSOL FORCING IN CLIMATE MODELS

GLOBAL MEAN AEROSOL FORCING

Top of atmosphere forcing by direct, semi-direct, and indirect effects

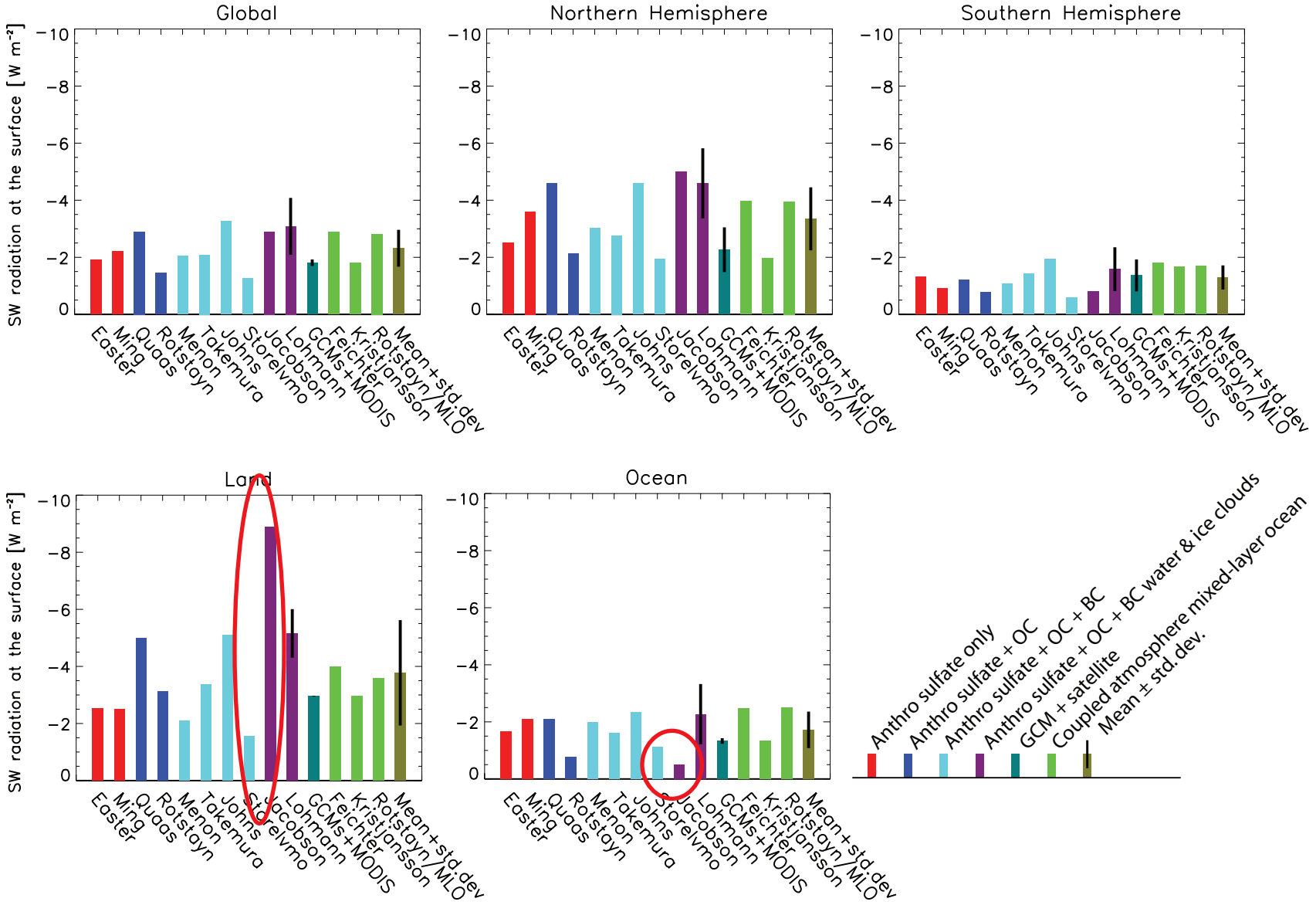


IPCC AR4, 2007

Forcings are comparable: -2 W m^{-2} ± 1 W m^{-2}. . .
despite different aerosol components and cloud types.

TOP OF ATMOSPHERE AEROSOL FORCING

Forcing by direct, semi-direct, and indirect effects



IPCC AR4, 2007

Many differences in detail.

SUMMARY

Aerosol forcing is substantial in the context of greenhouse gas forcing.

Uncertainty in aerosol forcing is substantial in this context.

This uncertainty greatly ***limits ability to evaluate performance of climate models*** over the twentieth century.

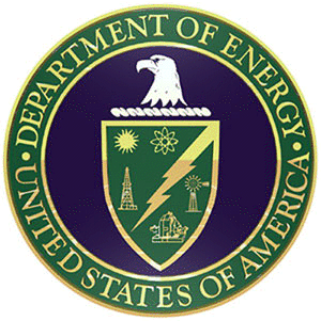
Exciting research. Important new findings. Much still at ***exploratory stage***.

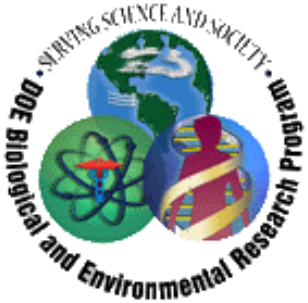
Modeling at ***sensitivity stage***.

A path forward exists to quantify aerosol forcing much better than at present.

Quantifying aerosol forcing would require substantial effort by U.S. and international partners.

Essential research elements are missing or under-represented in national and international portfolios.





Workshop on

IDENTIFYING OUTSTANDING GRAND CHALLENGES IN CLIMATE CHANGE RESEARCH:

GUIDING THE DEPARTMENT OF ENERGY STRATEGIC PLANNING

March 25-27, 2008

Arlington, VA

GRAND CHALLENGES IN CLIMATE SCIENCE

Charge to the Workshop

Under Secretary for Science
Washington, DC 20585
October 1, 2007

What are the grand challenges in . . .

1. Understanding ***Earth's past and present climate variability and forcing***;
2. Reducing uncertainty and improving confidence in projecting ***how the Earth's climate at regional to global scales may change in the future*** in response to natural and/or human-induced forcing;
3. Understanding and predicting the ***sensitivity and adaptability of managed and natural ecosystems to climate change***; and
4. ***Integrating data and knowledge*** from research and observations on climate and Earth system processes ***into climate and Earth system models and modeling***.