ESRL Research on Aerosol Direct Radiative Forcing of Climate

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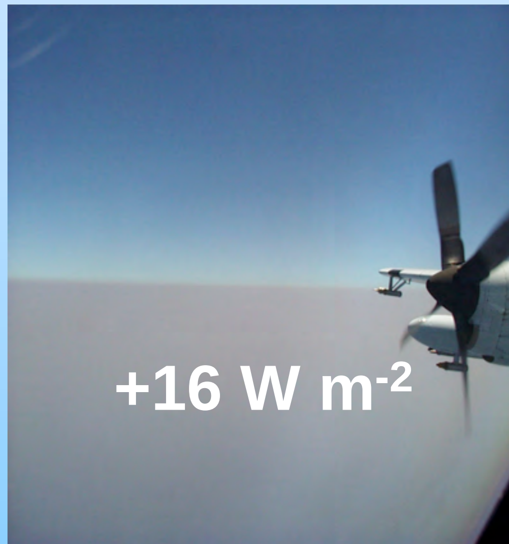
Clear-sky Aerosol Radiative Forcing over North Indian Ocean

-7 W m^{-2}

Photo shows pollution layer over Indian Ocean



-23 W m^{-2}

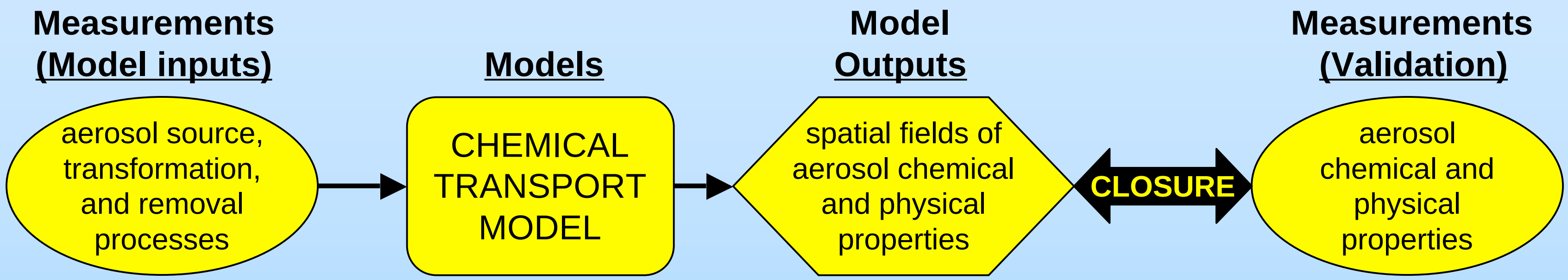
TOA: net change in energy budget due to backscattering and absorption of solar radiation

Atmosphere: heating due to aerosol absorption of sunlight

Surface: cooling due to aerosol absorption and backscattering

Source: Ramanathan et al., J. Geophys. Res., 2001
average for Jan - March, 1999; 0 - 20°N; τ_a = 0.3

Interactions of Aerosol Measurements and Models for Radiative Forcing



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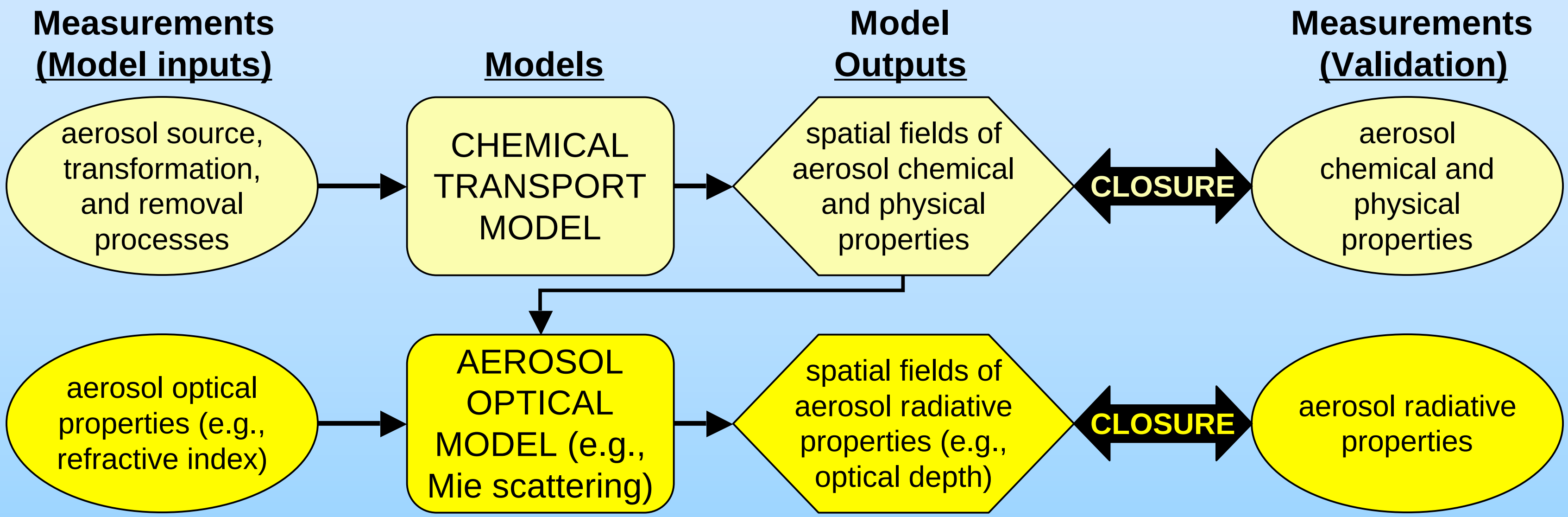

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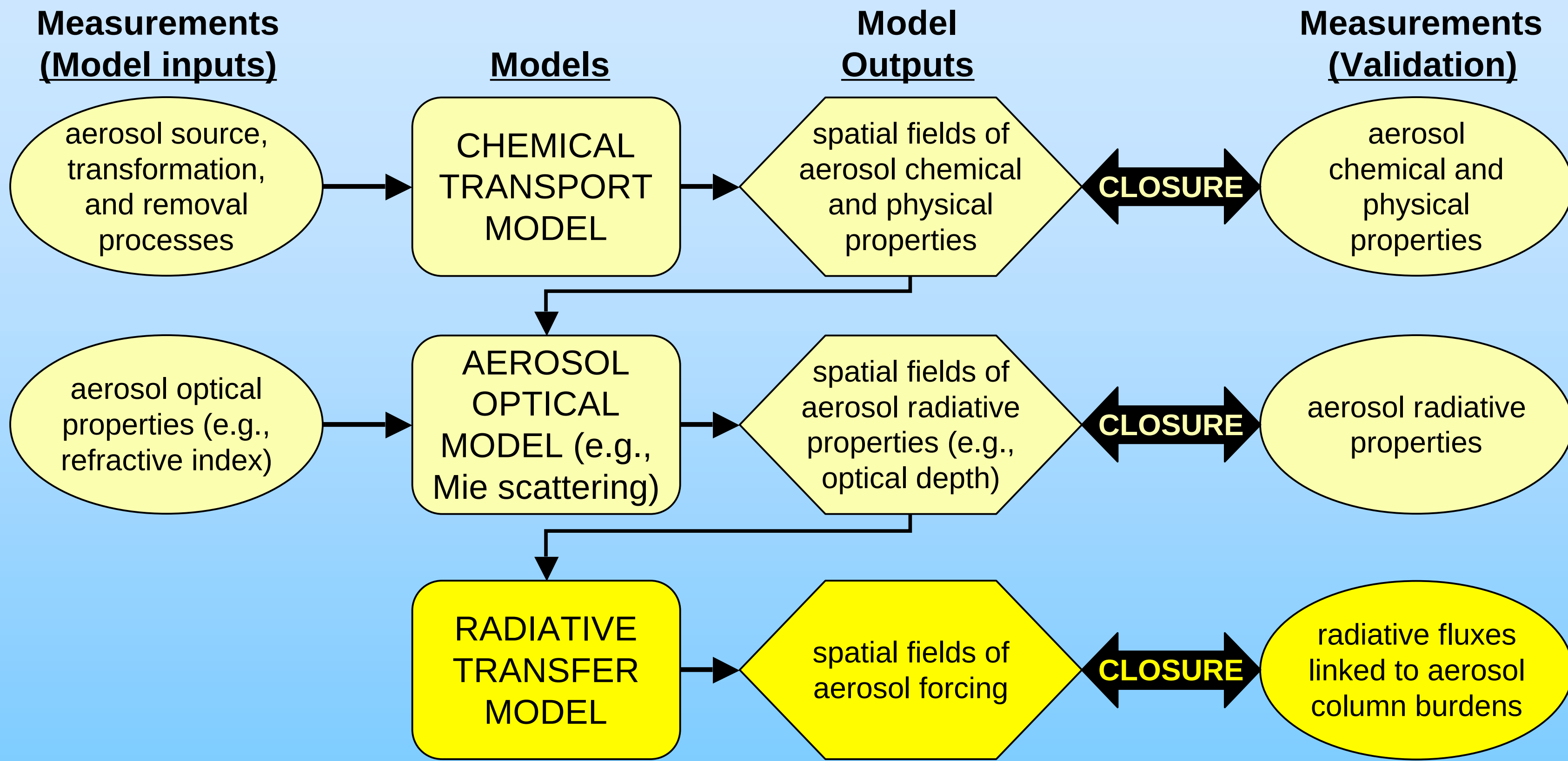

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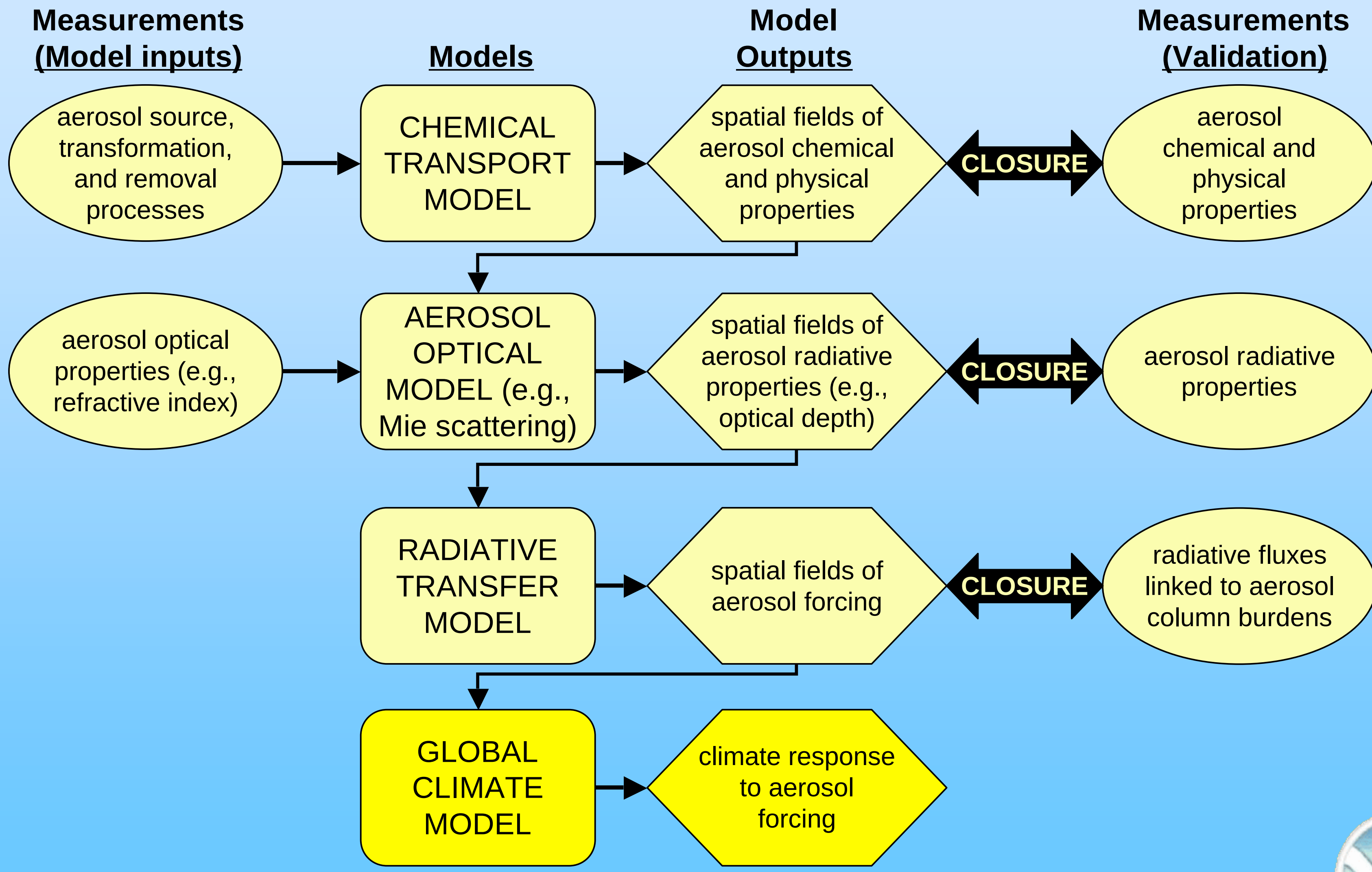

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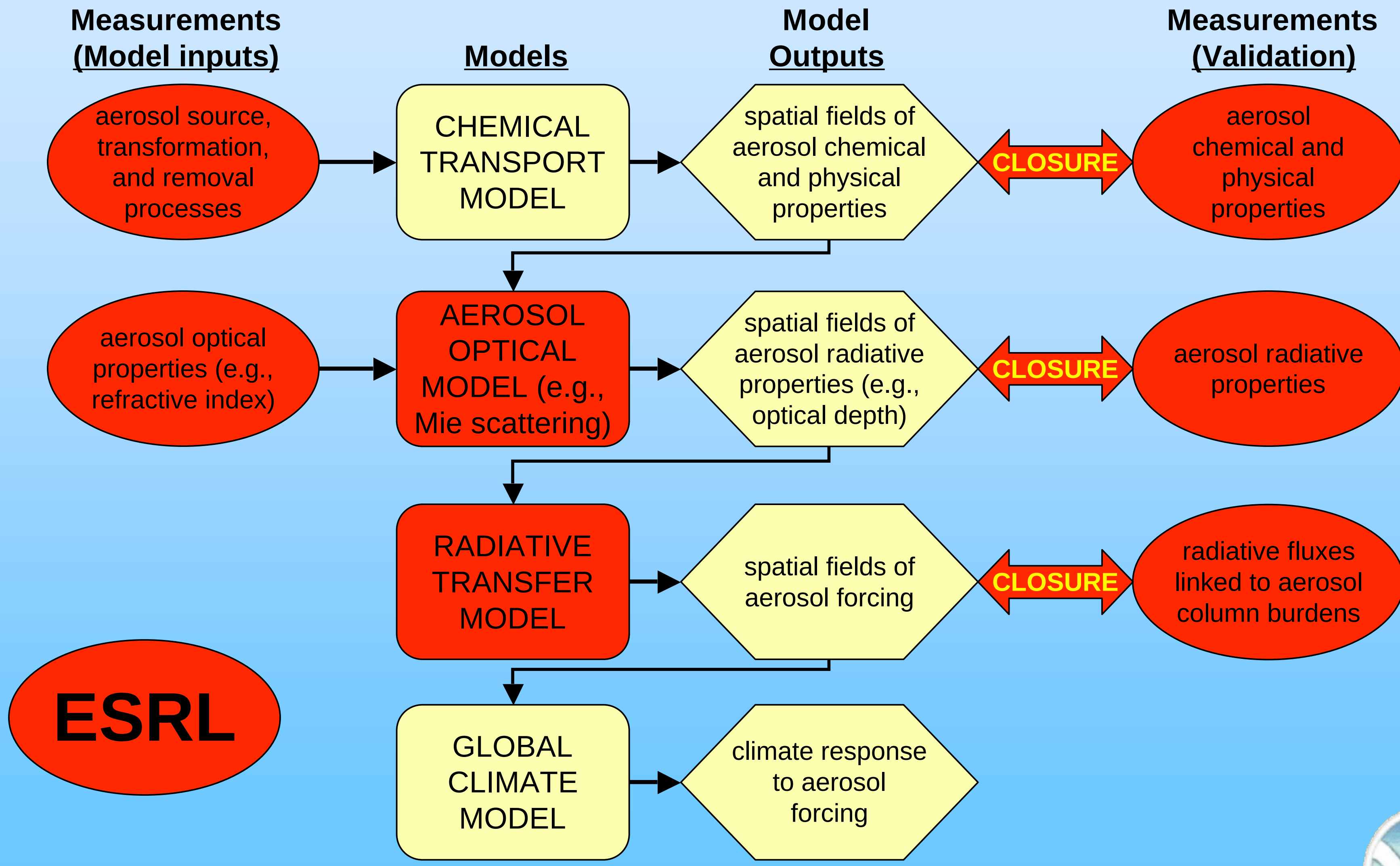

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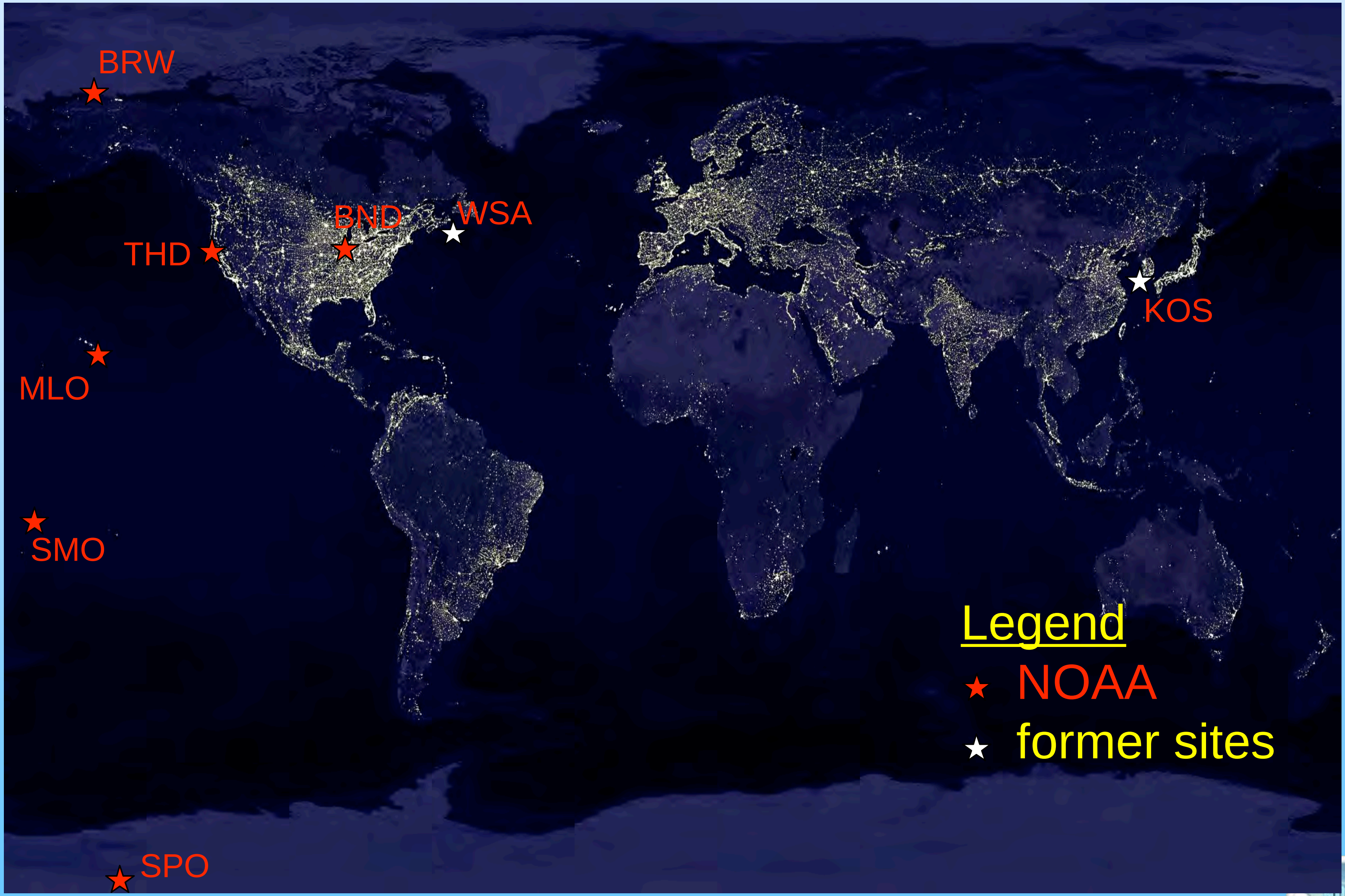
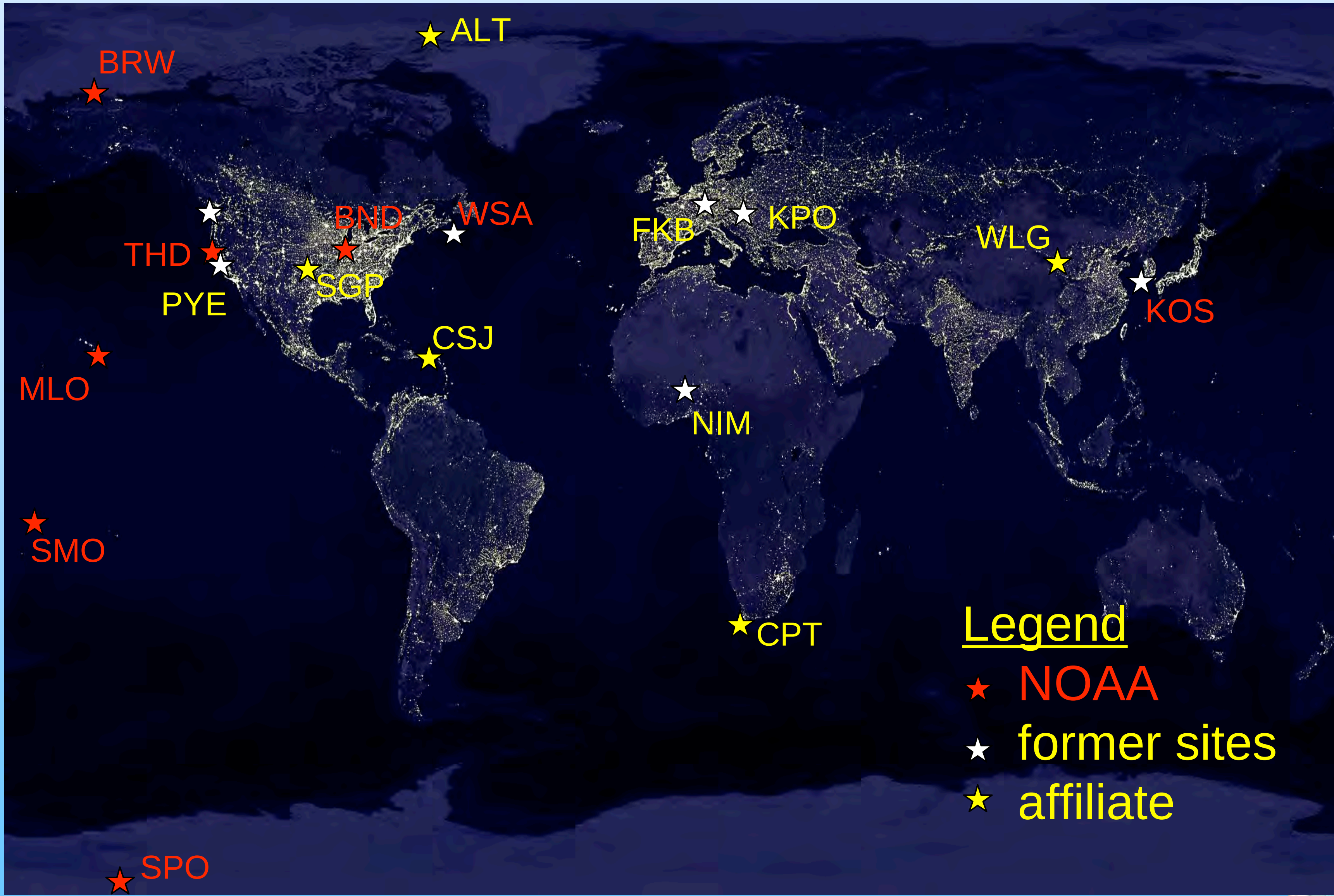
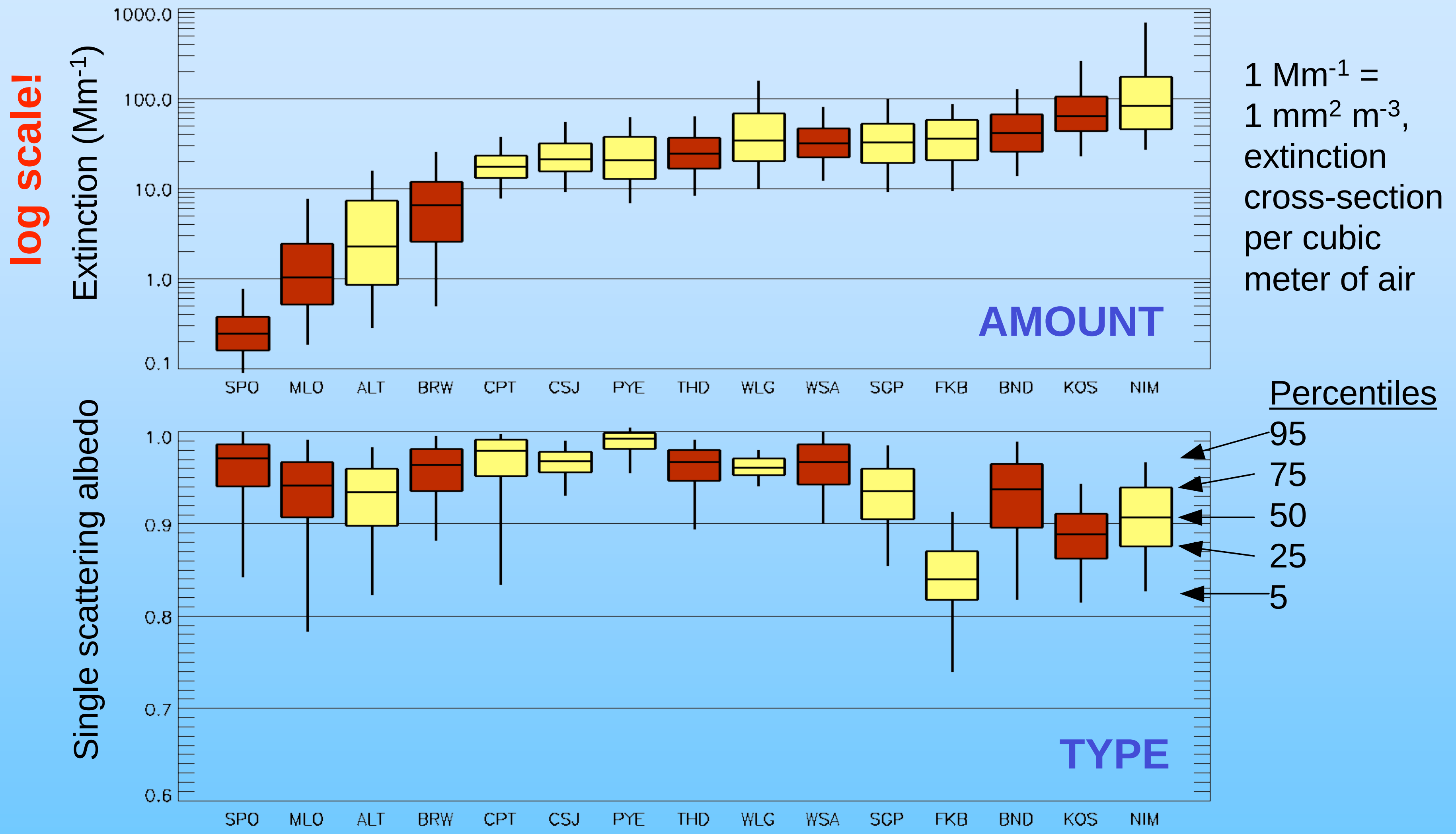
ESRL Long-term In-situ Aerosol Network



Affiliated Long-term Aerosol Network

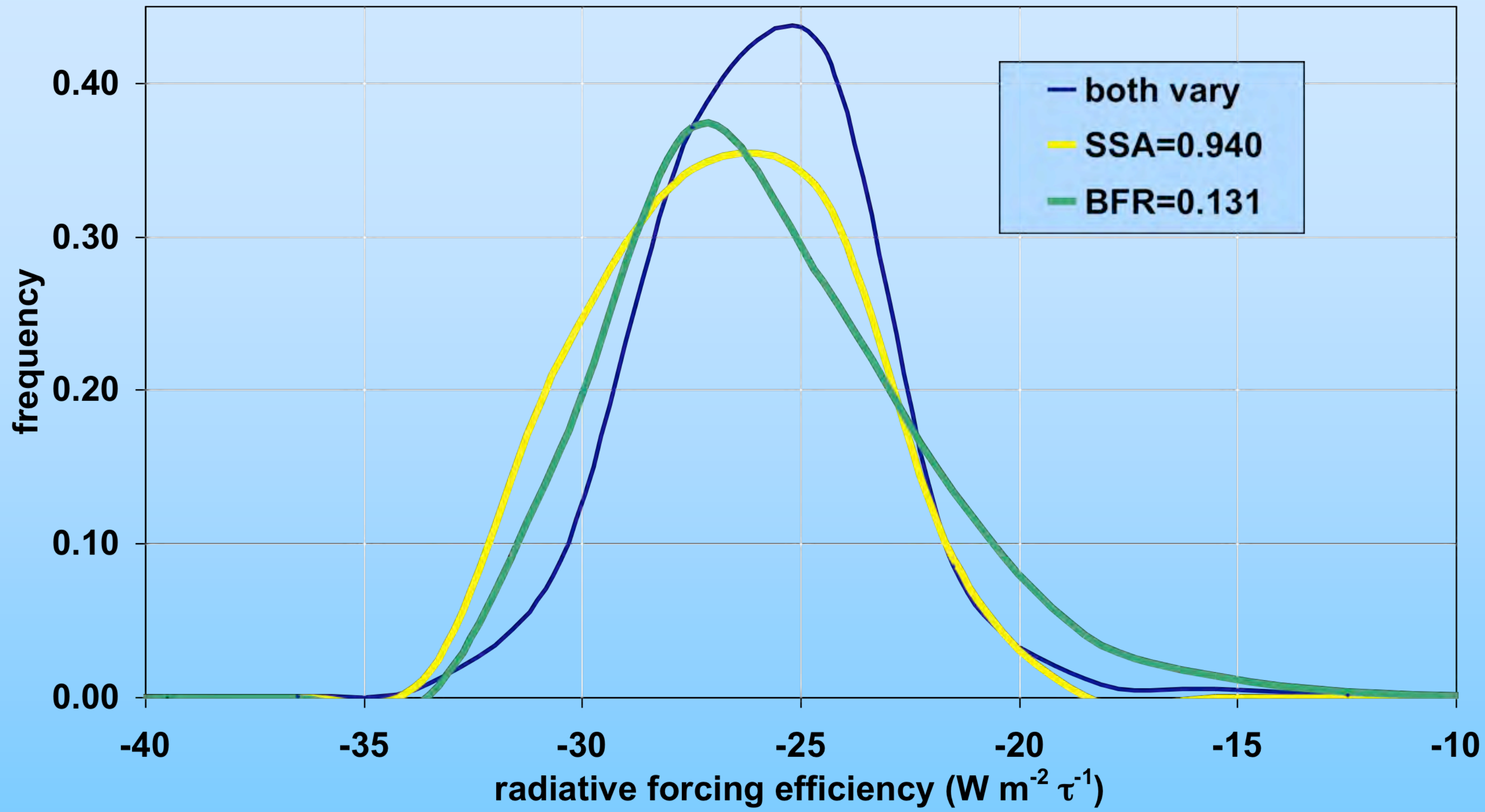


Variations in Aerosol Amount and Type



A rich data set for evaluating chemical transport models

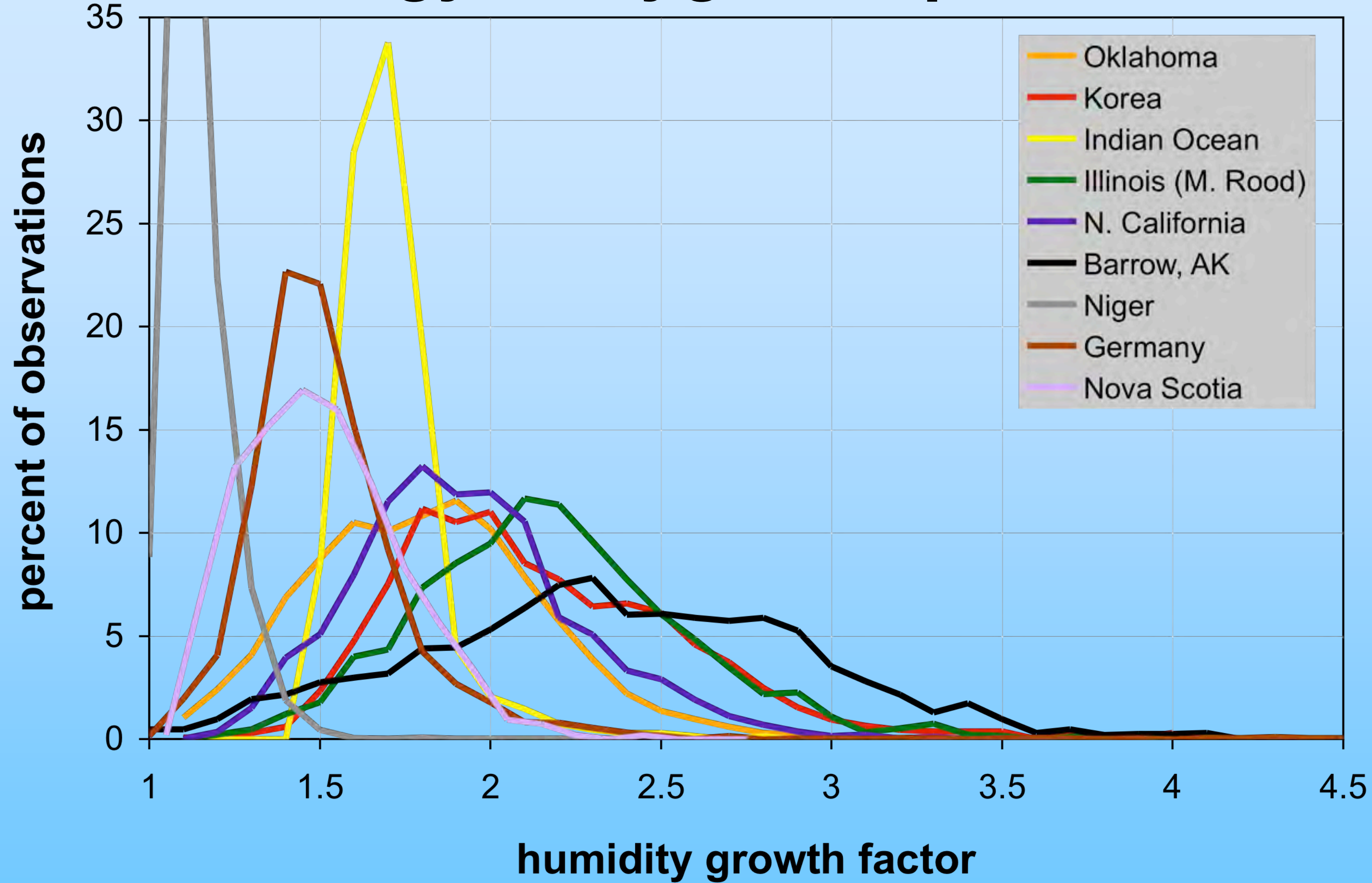
Variability of Radiative Forcing Efficiency



Forcing per unit optical depth (RFE) is calculated from in-situ measurements of aerosol single-scattering albedo (SSA) and backscatter fraction (BFR). SSA and BFR co-vary, so that total variability is less than what would be expected from individual variabilities.

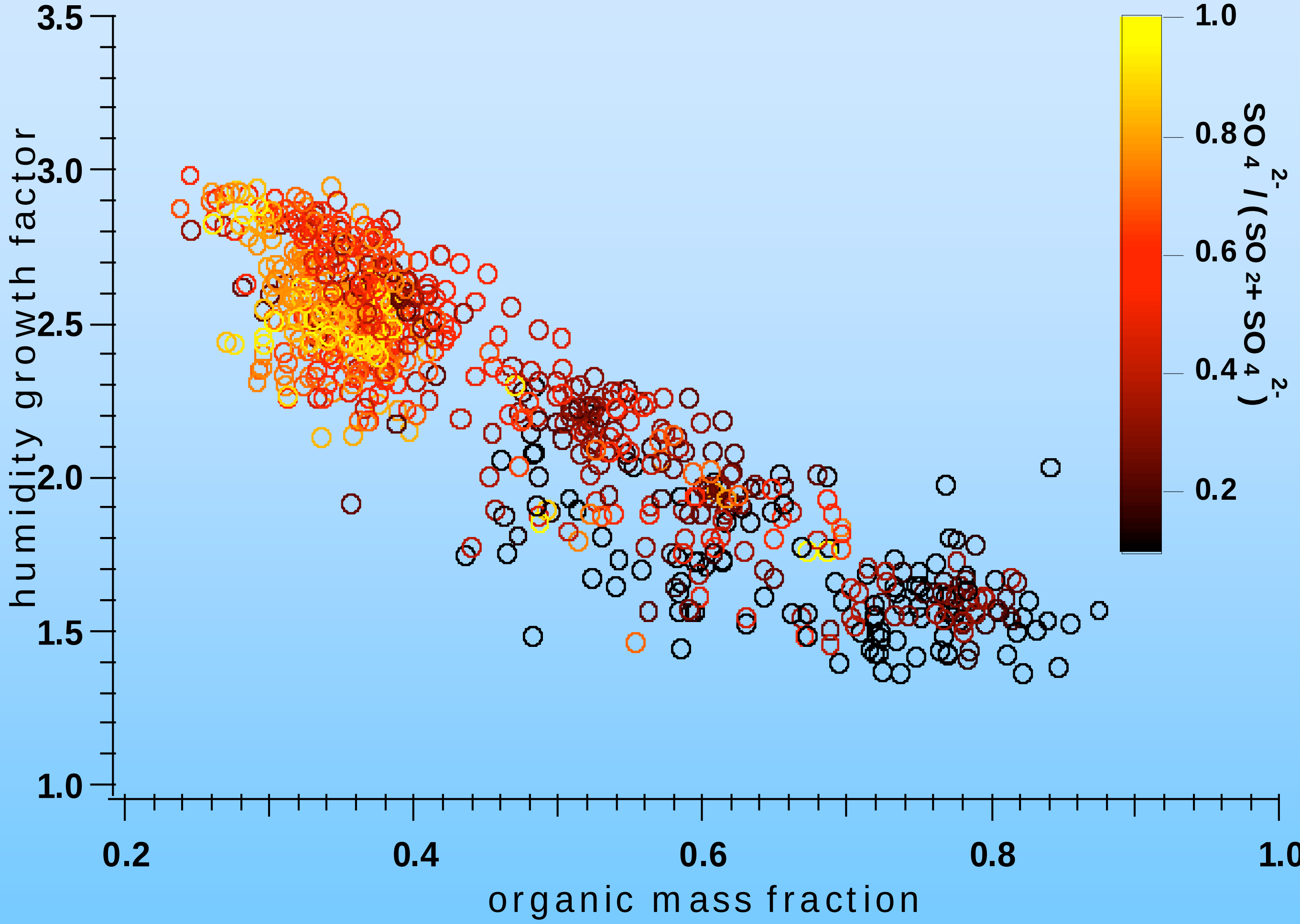
Daily averages, 1996-2005, for DOE/ARM site in Oklahoma (SGP)

Climatology of Hygroscopic Growth



Climate models must represent water uptake by aerosols to calculate radiative forcing. Measurements from ESRL long-term network allow evaluation of model performance for a wide range of conditions.

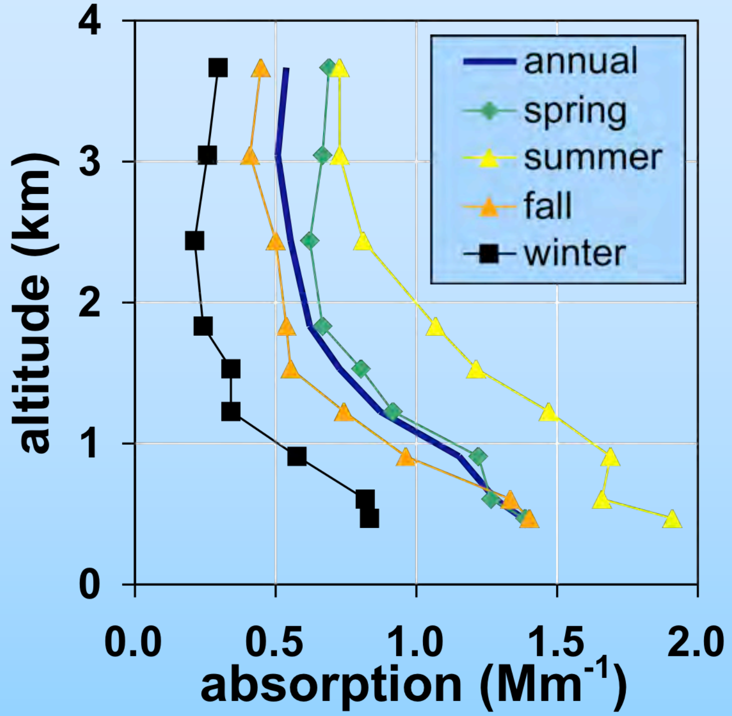
Chemical control of hygroscopic growth



Process studies provide predictive understanding of water uptake by aerosols. This can be parameterized in climate models and compared with results from long-term network.

In-Situ Aerosol Profiling

- Objective: Obtain a statistically-significant data set of vertical distribution of aerosol properties relevant to radiative forcing
- Measurements: emphasize aerosol scattering and absorption above a similarly instrumented surface site
- Oklahoma: 807 flights since 2000
  Illinois: 205 flights since 2006
- Key Results
  - aerosol properties at surface represent statistics in lower 2-km layer, which dominates forcing
  - clear seasonality seen in profiles
  - RFE fairly constant throughout lower 5km



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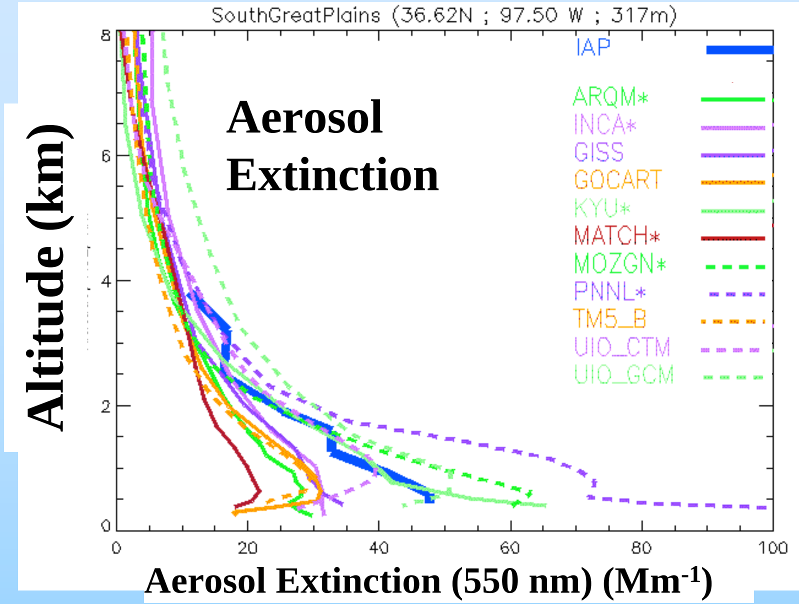
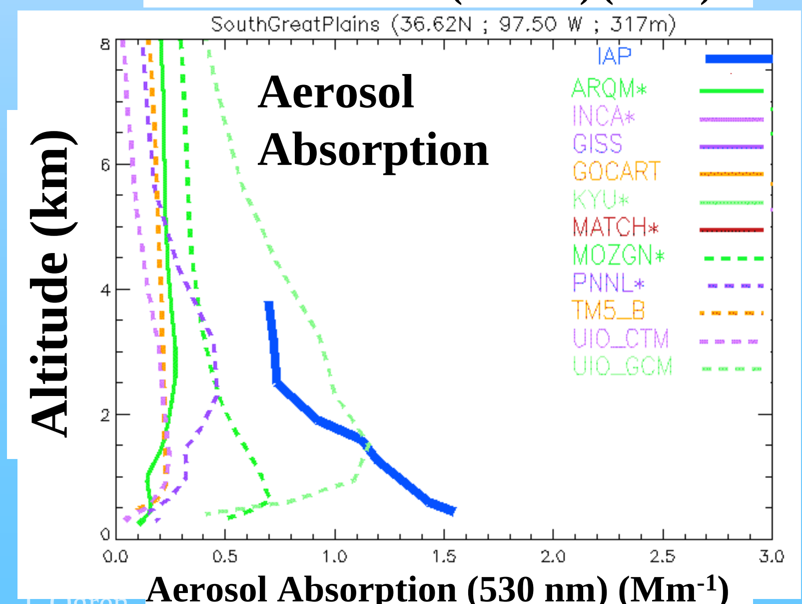
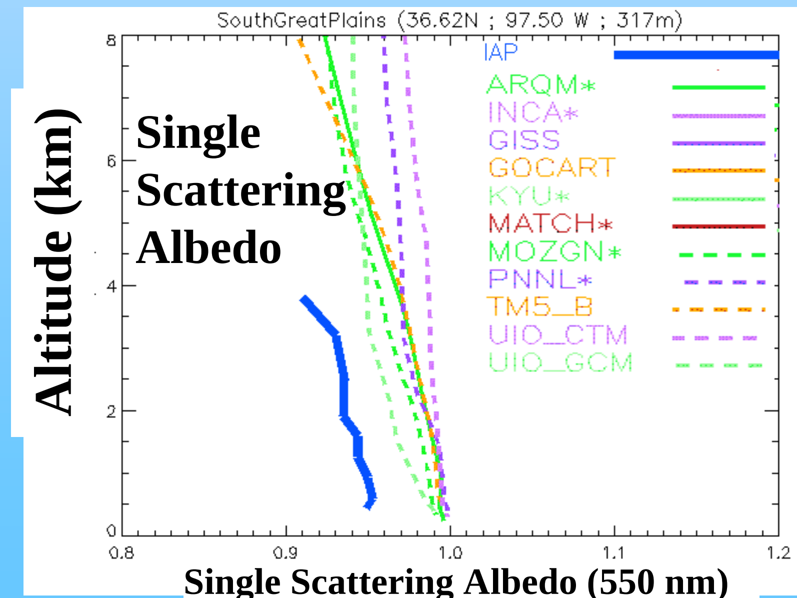
Evaluating models with data



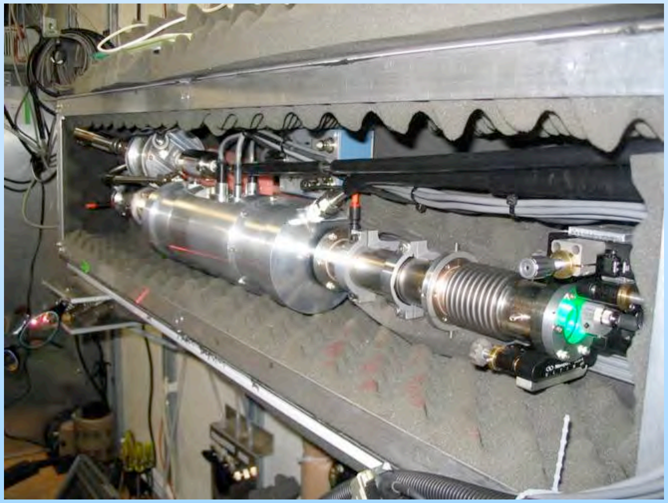
- **Daytime measurements 2-3 times/week**
- **Primary measurements**
  - aerosol scattering and absorption
- **Derived properties**
  - single-scattering albedo
  - aerosol optical depth
- **AEROCOM profile comparisons**
  - general agreement in aerosol extinction
  - models generally show less absorption
- **Acknowledgement: R. Ferrare, NASA**

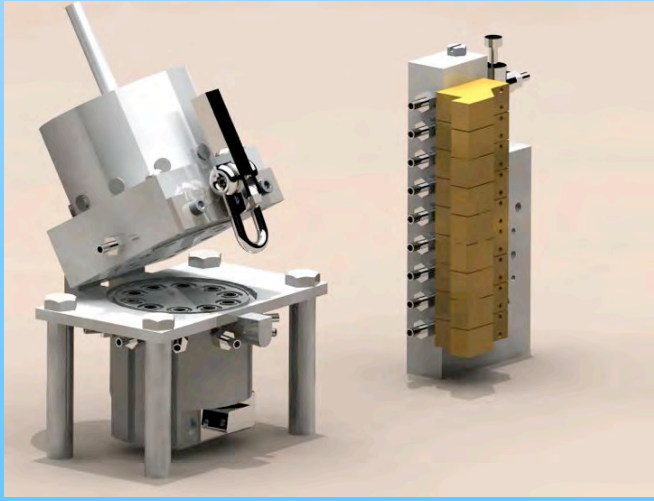


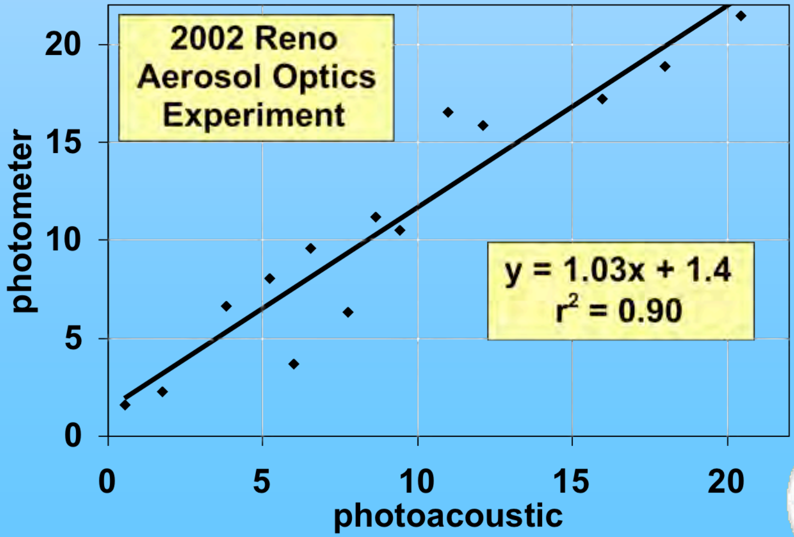


Absorption Method Development

- **Photoacoustic (right)**
  - Costly to build and run
  - Improved accuracy
- **Photometer (below)**
  - Method in widespread use
  - Affordable for global network
  - Known interferences
- **Calibrate photometer with photoacoustic (lower right)**

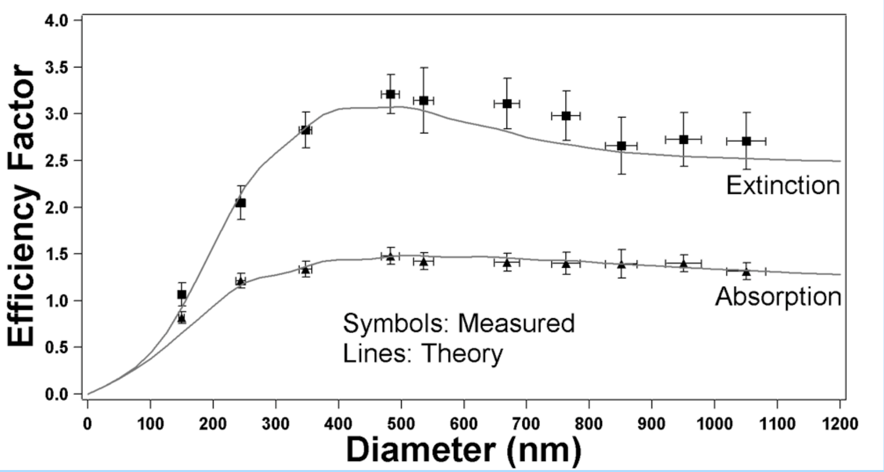


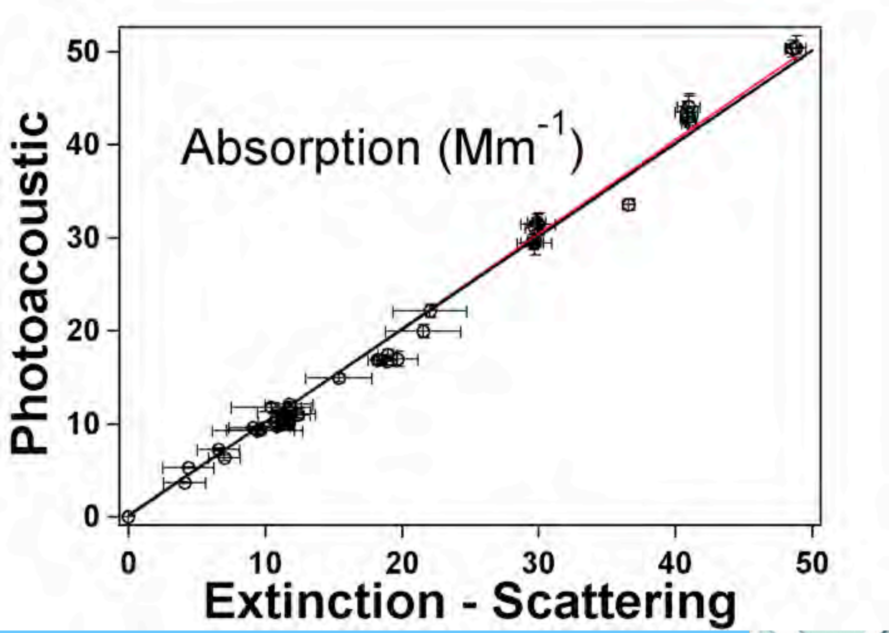




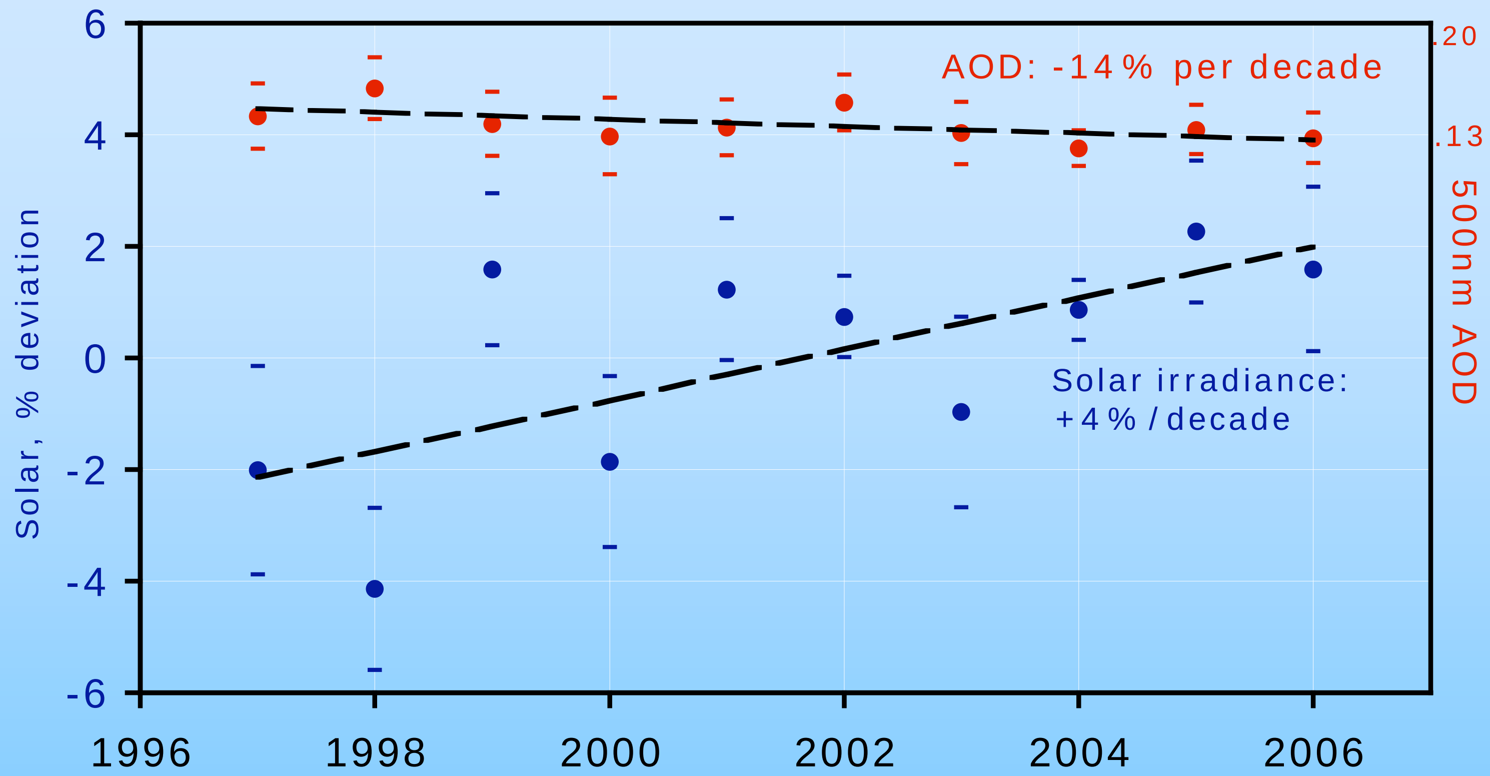
Optical Closure Studies

- Over-determined set of measurements provides rigorous assessment of measurement uncertainty
- Laboratory and ambient conditions
- Upper figure shows measured extinction and absorption cross-sections for cavity ringdown and photoacoustic instruments
- Lower figure compares photoacoustic absorption with difference between extinction and scattering



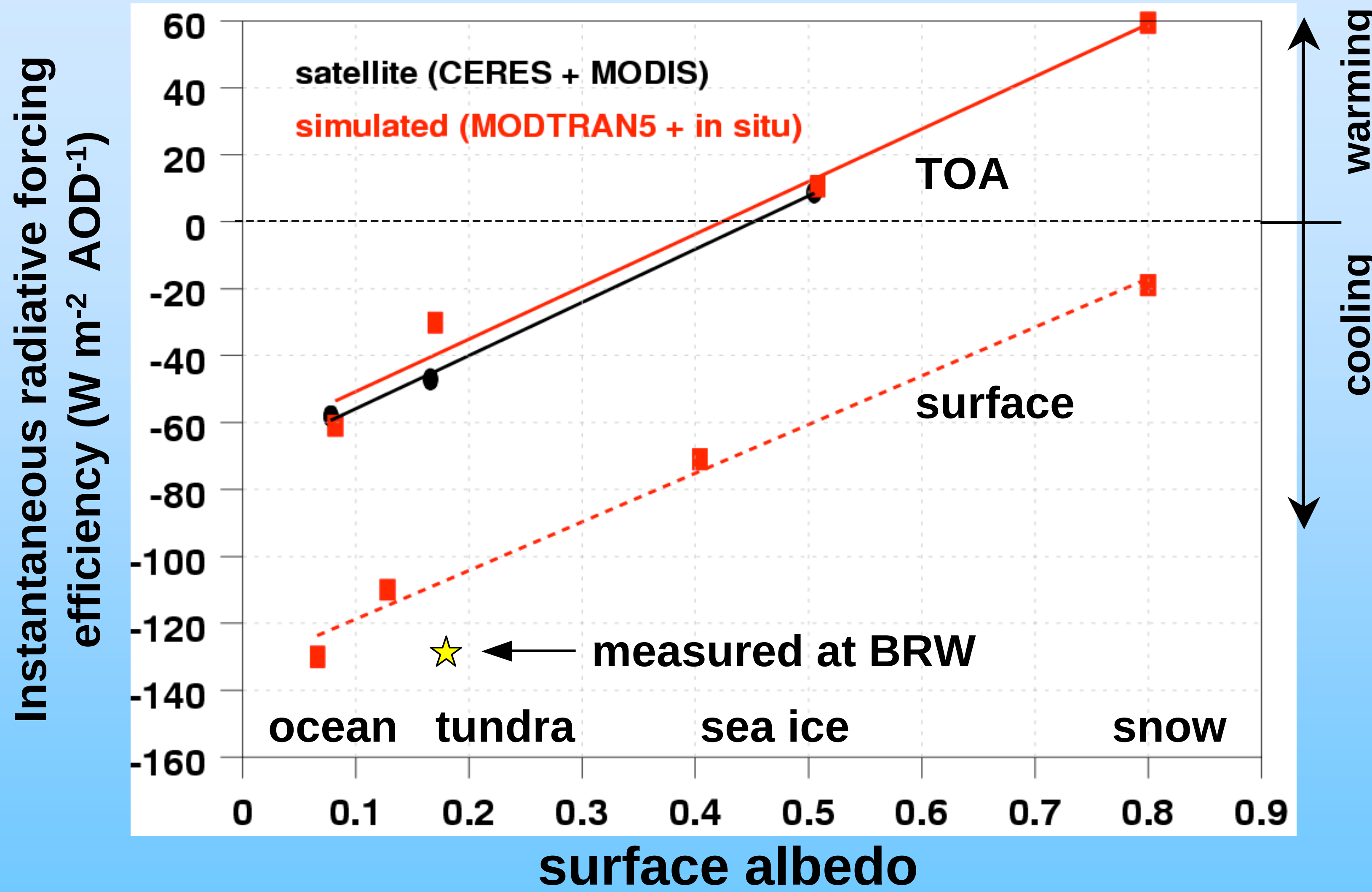


Aerosol optical depth over U.S.



- SURFRAD network of 7 stations
- Broadband solar irradiance shown as percent deviation from 10-year mean of 175 W m^{-2}
- Tick marks show standard error of mean
- Change in AOD explains less than 10% of modelled change in solar irradiance

Smoke aerosol radiative forcing in Arctic



Model parameters were constrained by observations of broadband solar irradiance, aerosol optical depth, single scattering albedo, and asymmetry parameter from the ESRL Barrow observatory.

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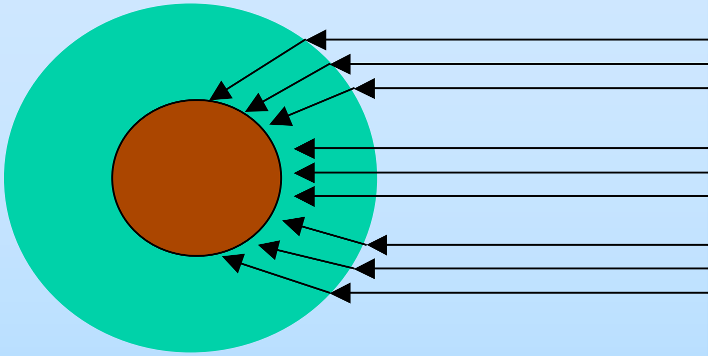
Future Directions

- **Continue and enhance current efforts**
  - Improved measurements of light absorption, measure humidity dependence
  - Expand global long-term network with additional collaborators
  - Arctic field studies 2008, California in 2010
- **Evaluate chemical transport models with measurements**
  - Regional models (e.g., WRF-Chem)
  - Global models (AEROCOM, IGAC/AC&C)

Aerosol Absorption and RH

- Absorption can increase by ~90% if an absorbing core is coated.
- VERY difficult to measure.
  - Filter-based methods won't work
  - Photoacoustic method looks promising (below)



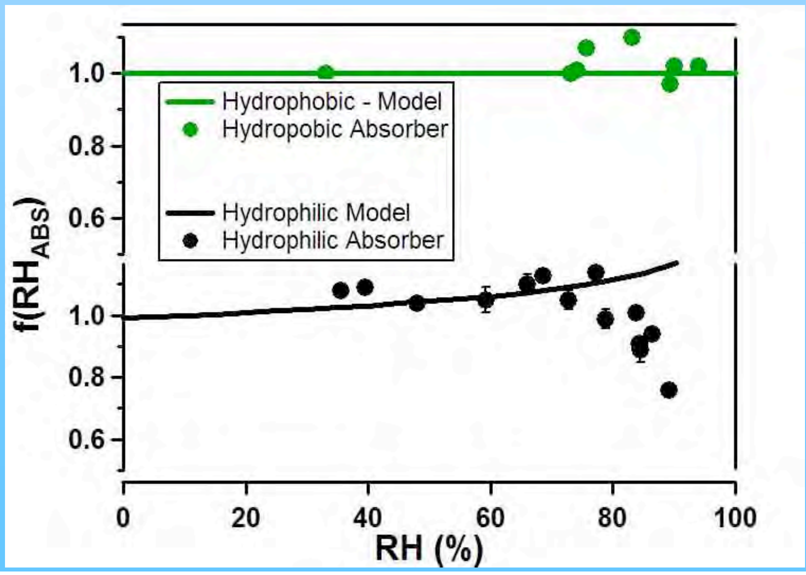
Laboratory:

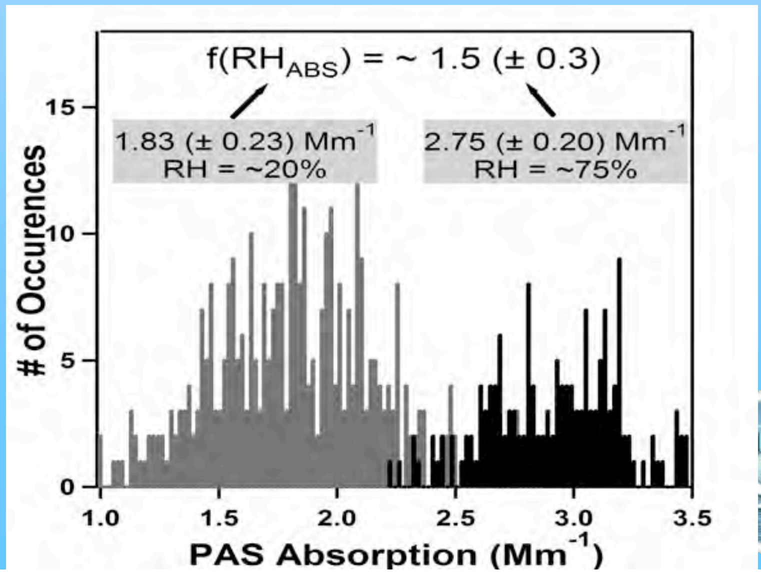
Can measure up to ~70% RH.

Field:

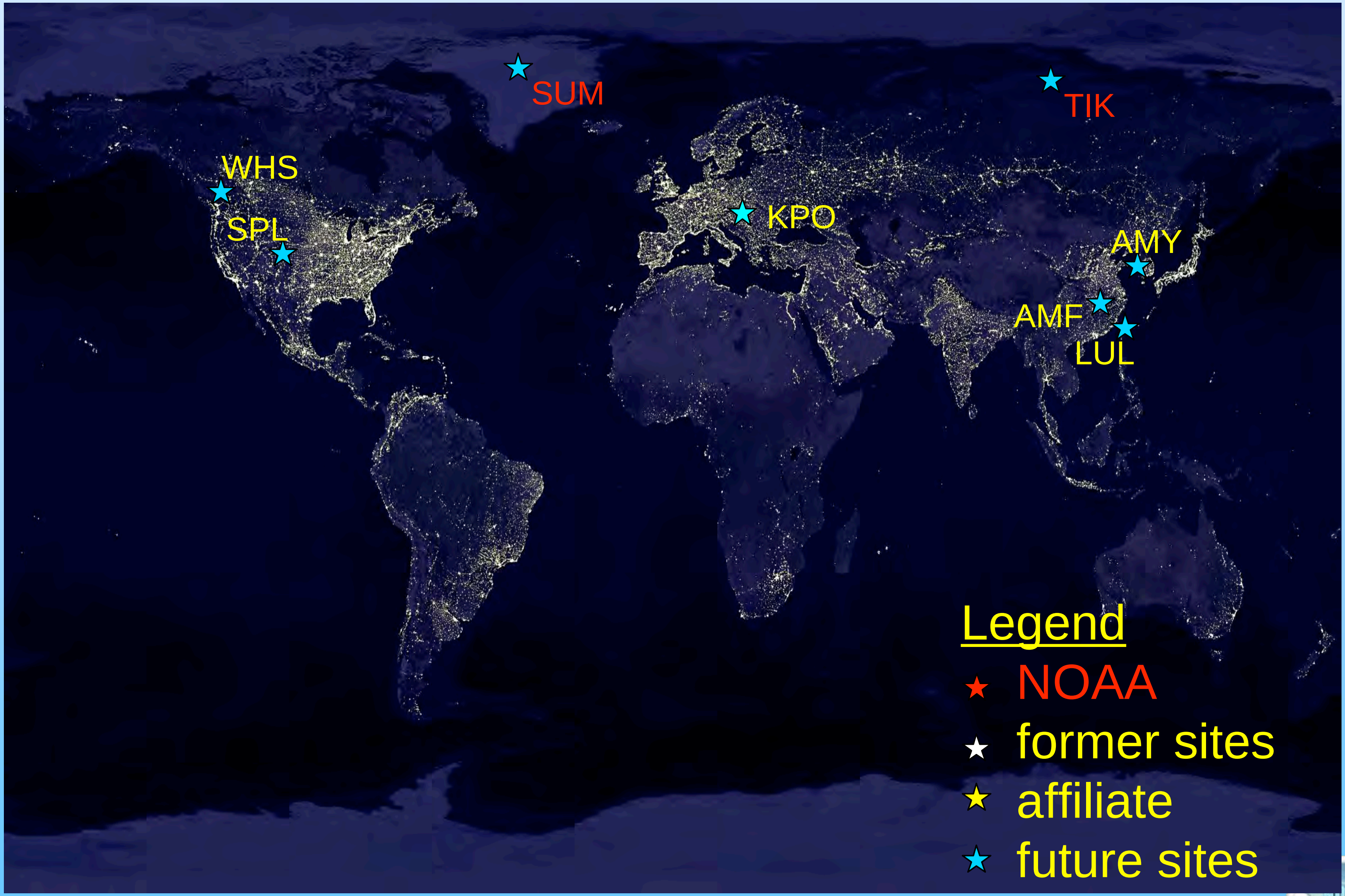
Saharan dust in Gulf of Mexico (75% RH).

Absorption increased by 50%.





Expanding Long-term Aerosol Network



Expanded Long-term Aerosol Network