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}

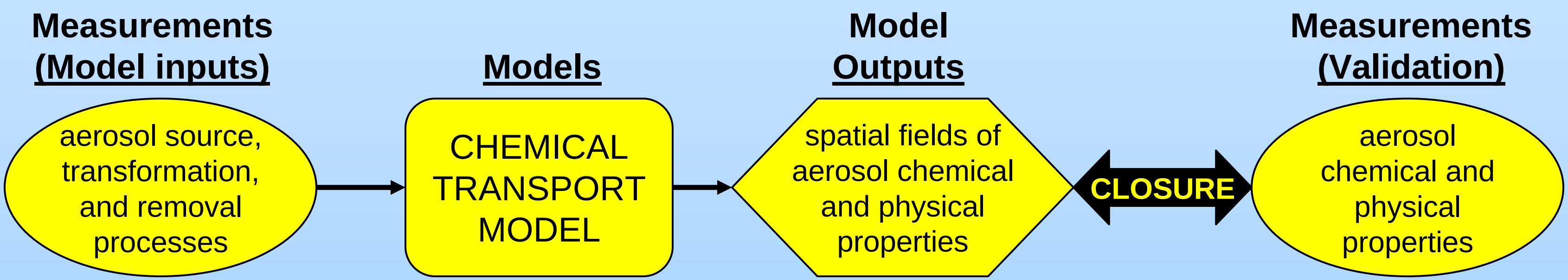
TOA: net change in energy budget due to backscattering and absorption of solar radiation

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; $\tau_a = 0.3$

Interactions of Aerosol Measurements and Models for Radiative Forcing



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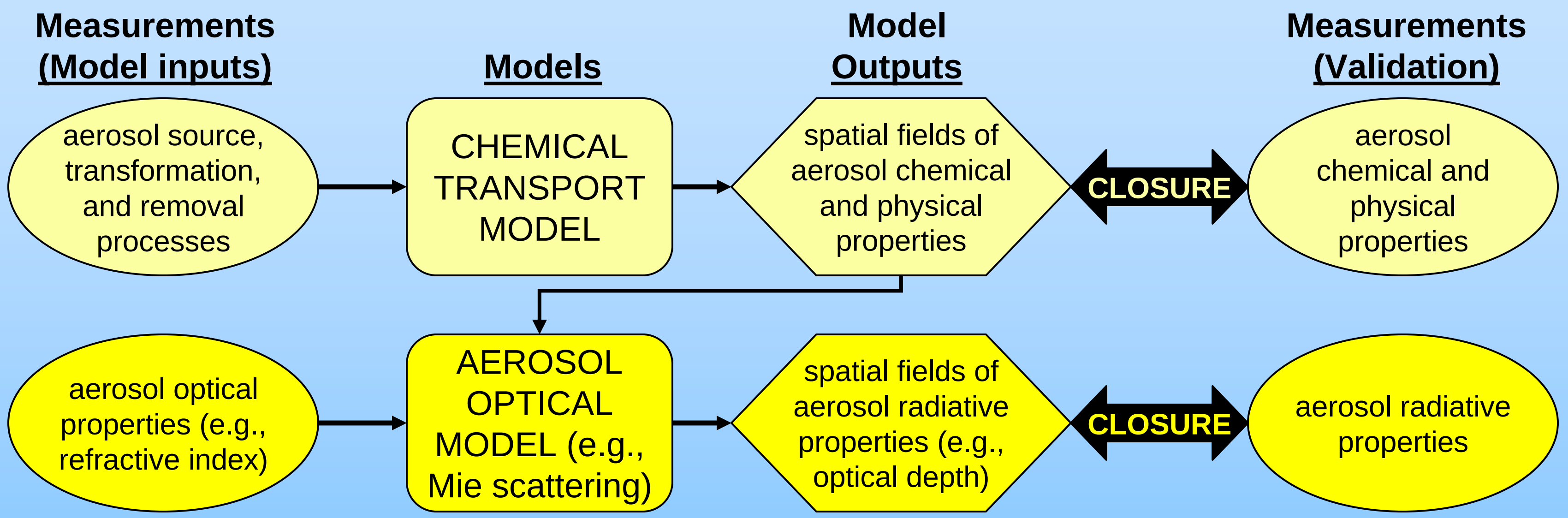

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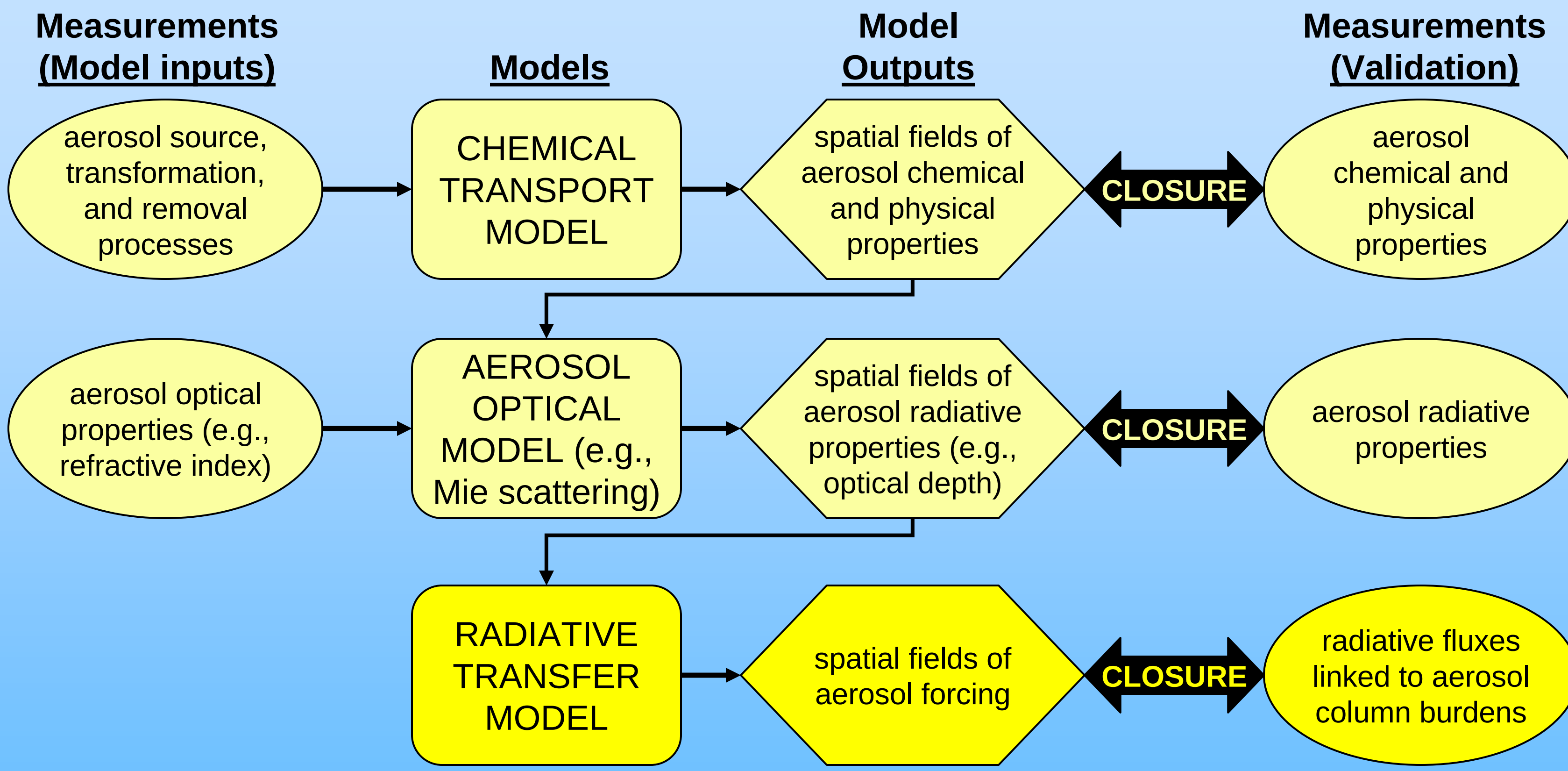

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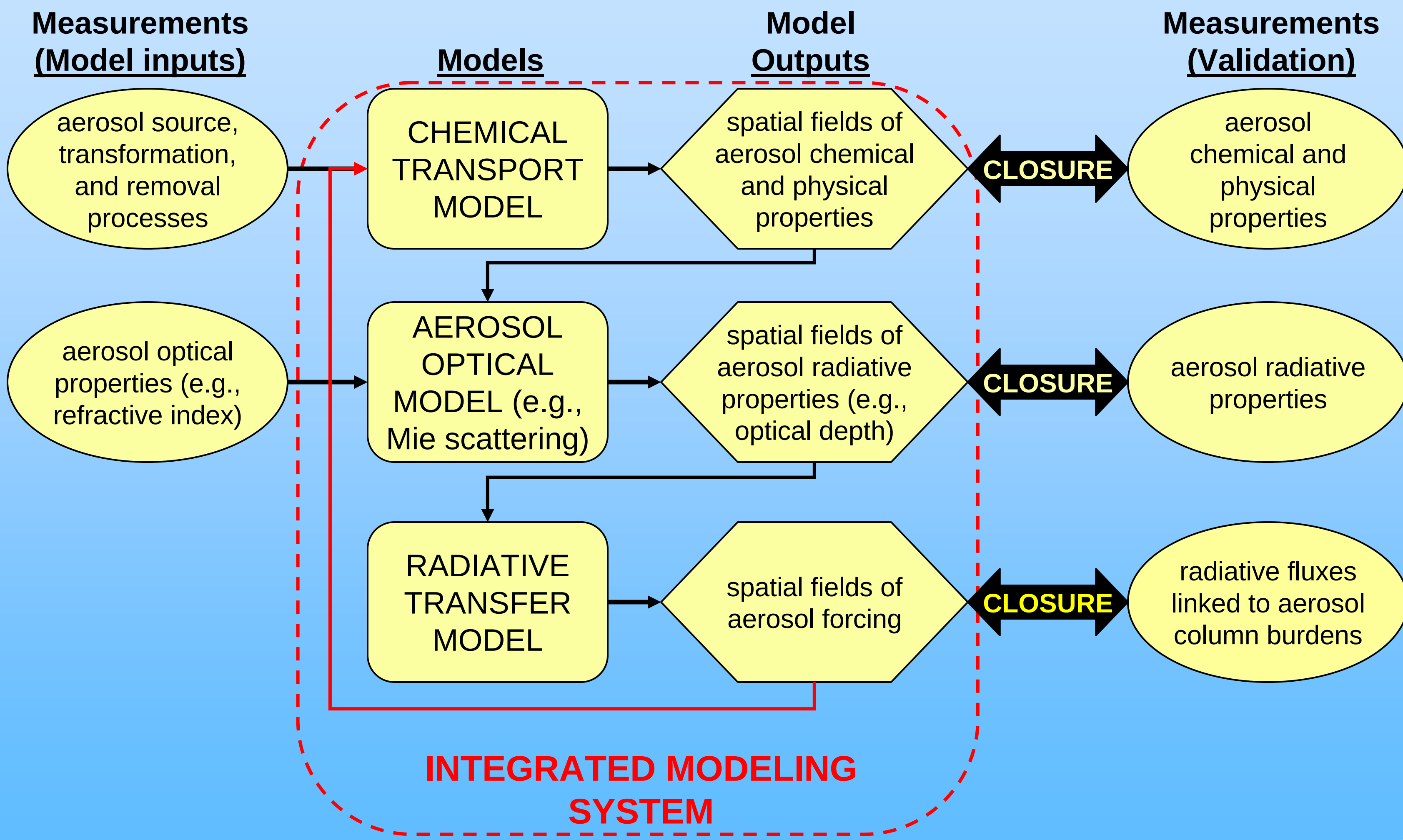

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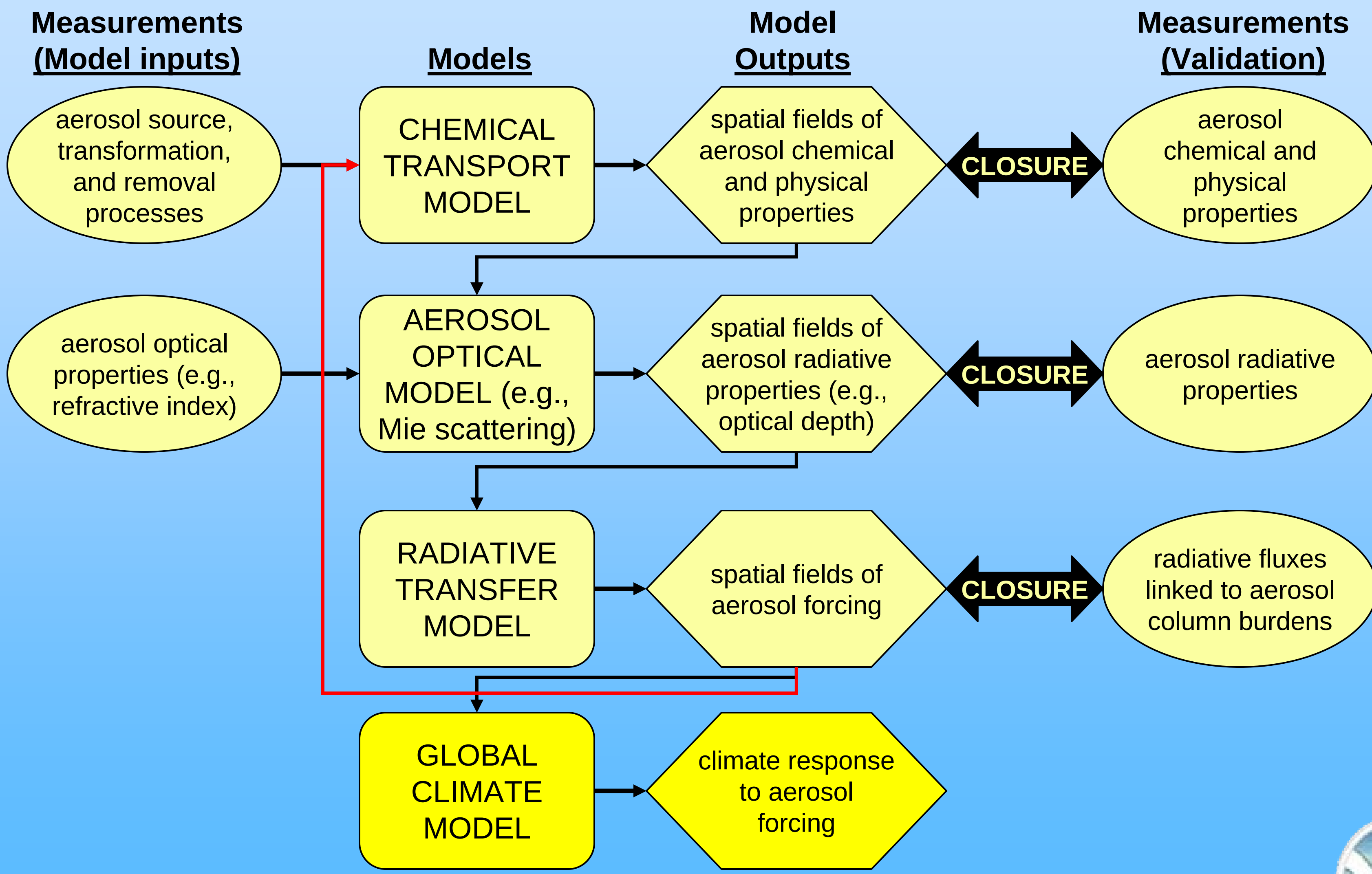

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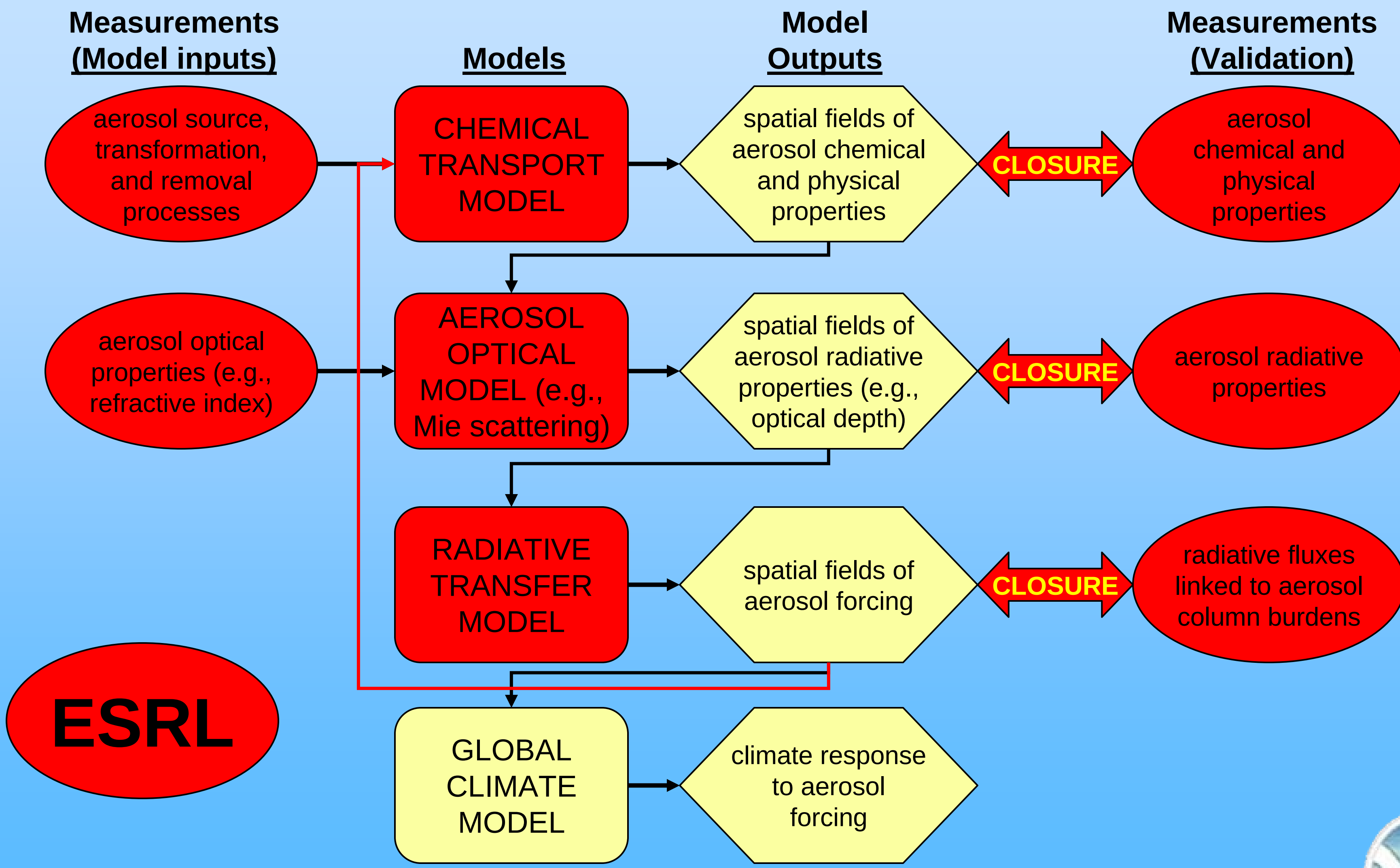
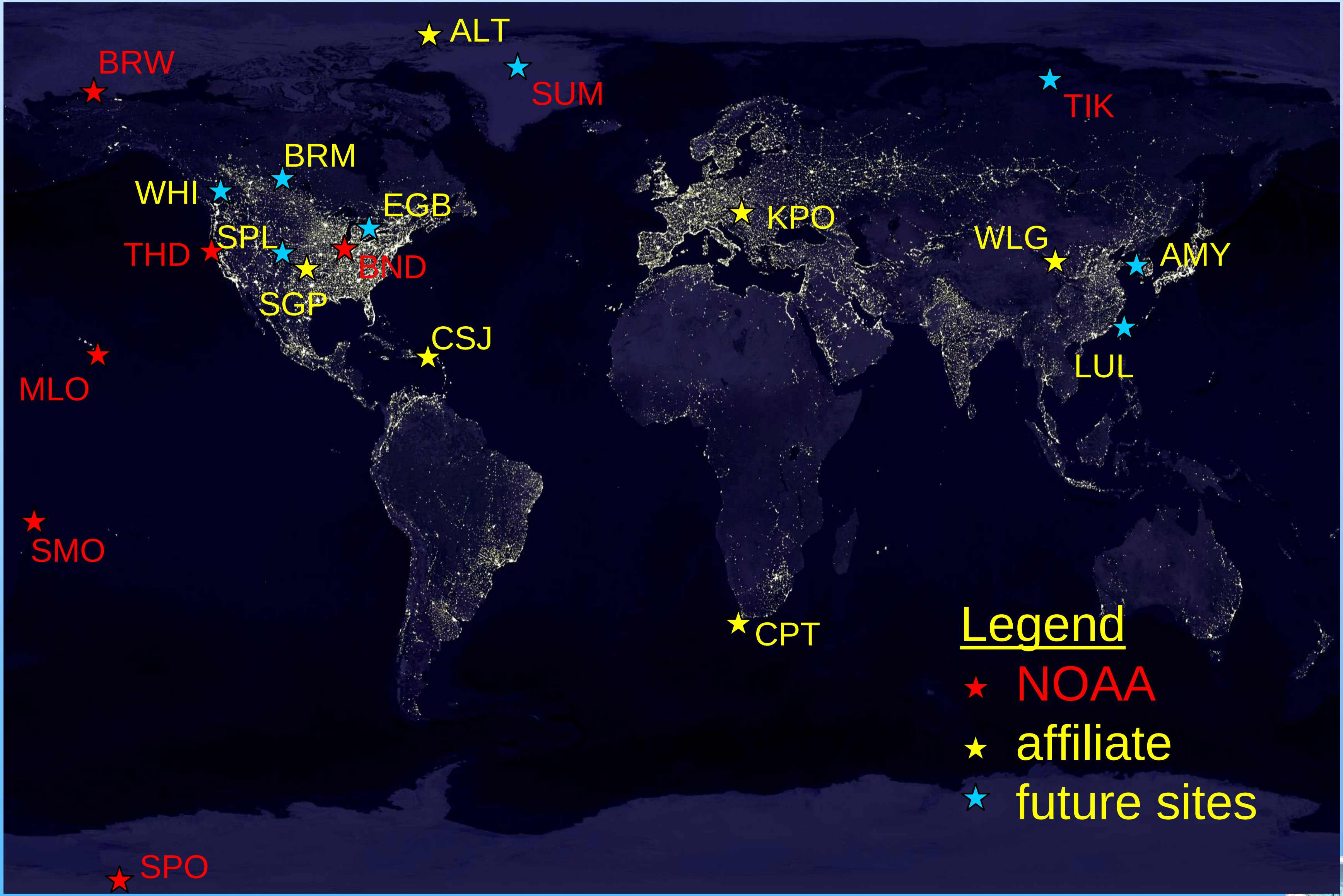
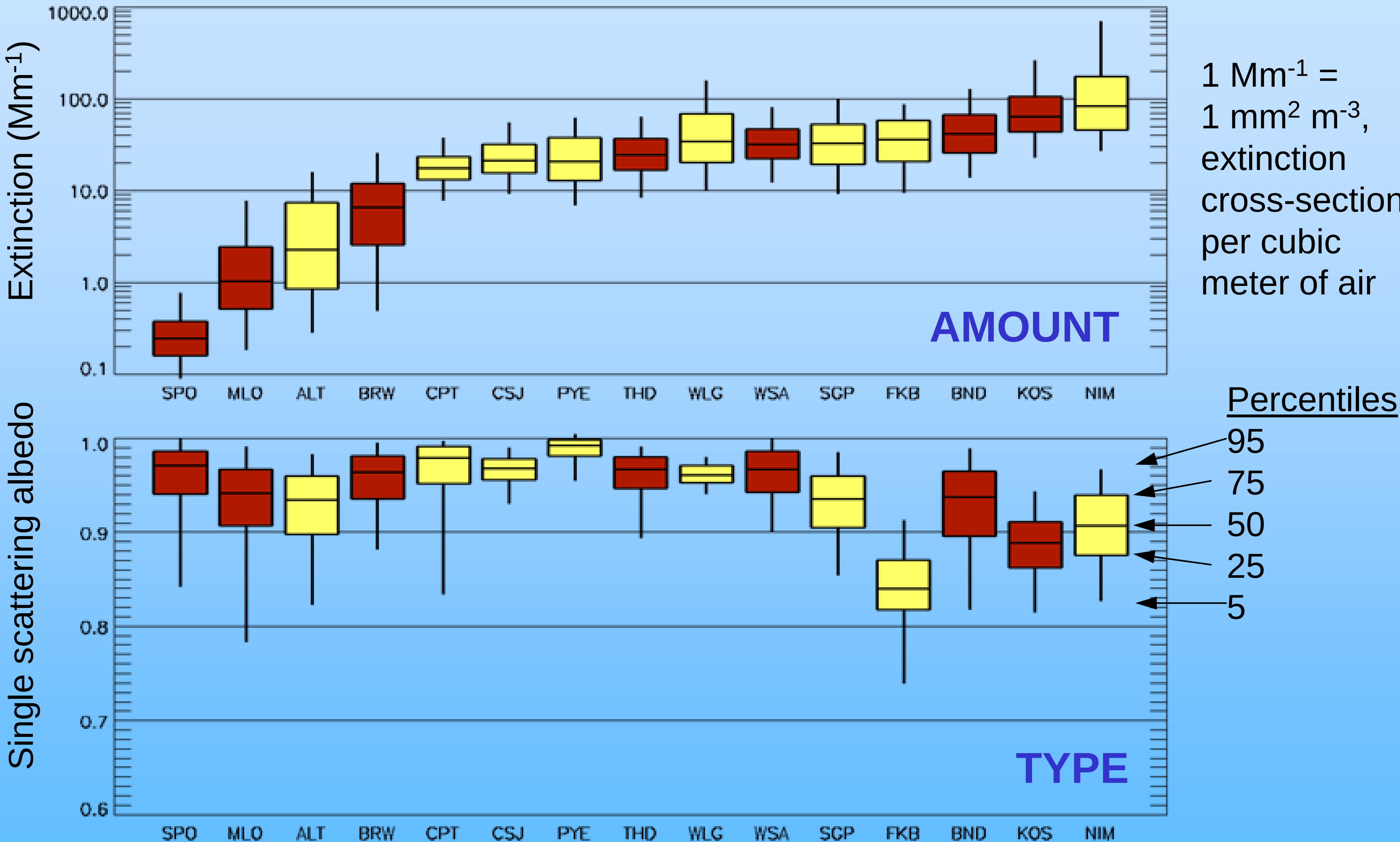


ESRL Long-term Aerosol Network



Variations in Aerosol Amount and Type

log scale!

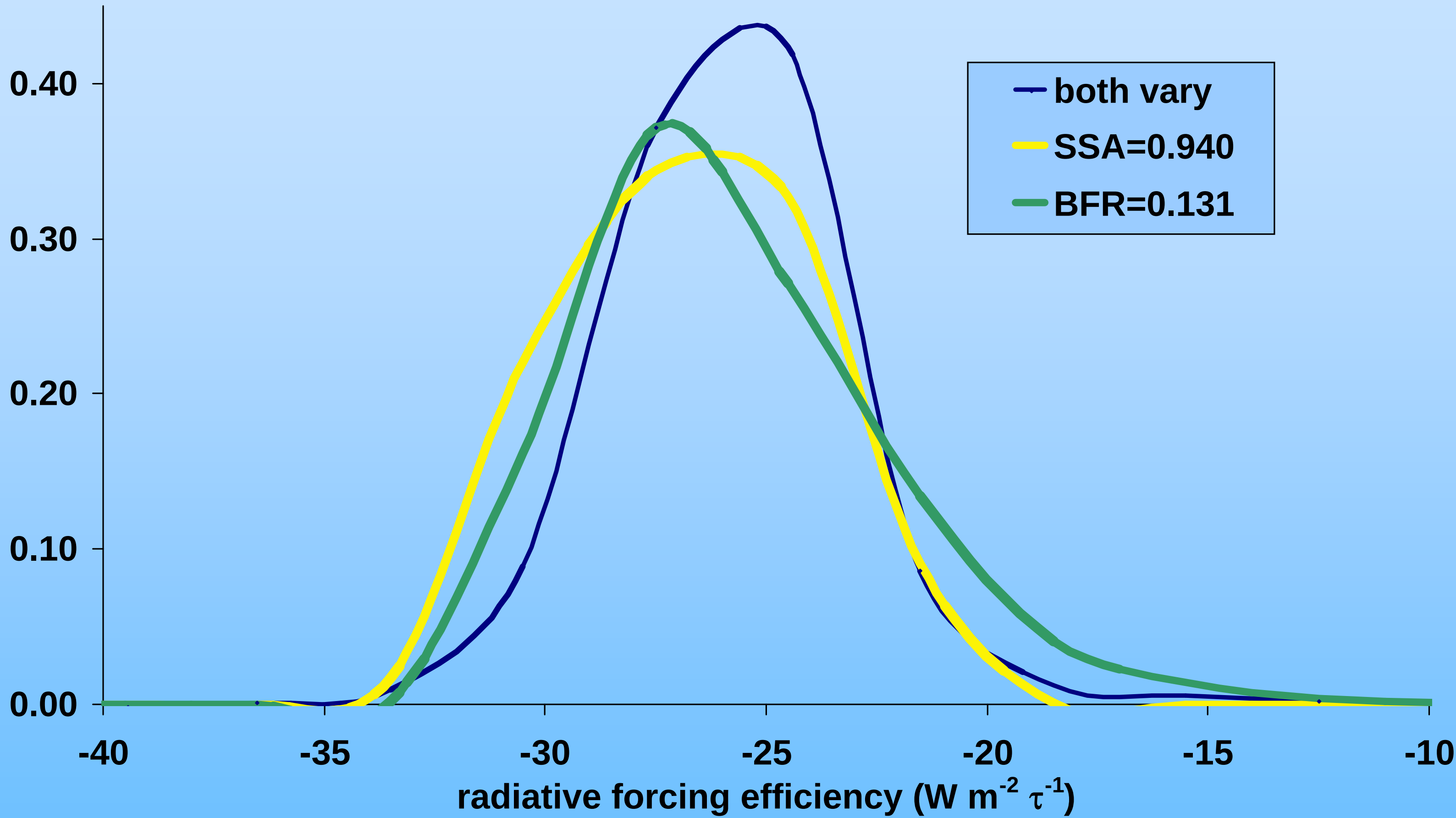


1 Mm^{-1} = 1 mm^2 m^{-3}, extinction cross-section per cubic meter of air

PRISTINE → POLLUTED

A rich data set for evaluating models

Variability of Radiative Forcing Efficiency

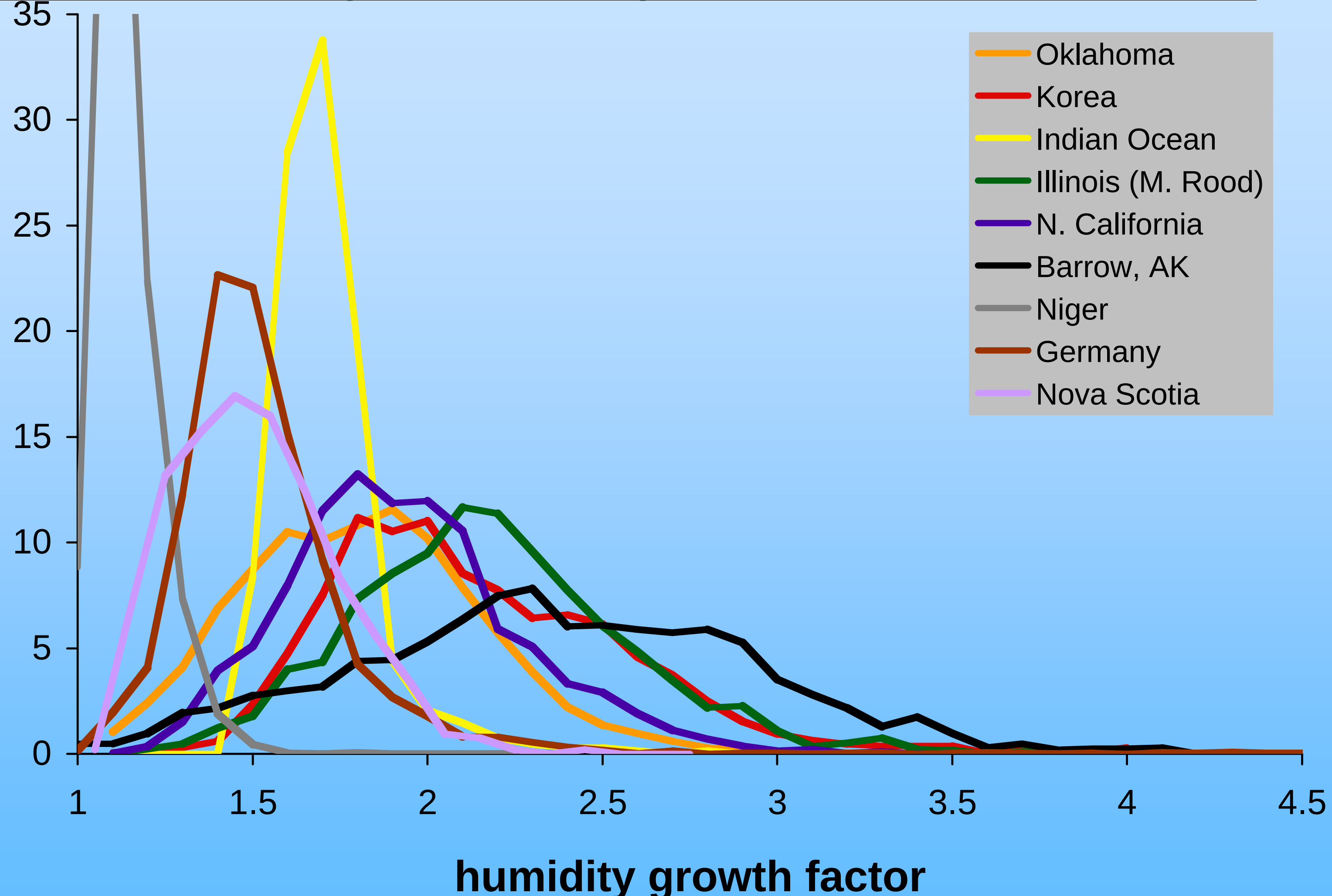


RFE = TOA Forcing / Optical depth

Calculated using a simple radiative transfer model and in-situ measurements of aerosol single-scattering albedo (SSA) and backscatter fraction (BFR).

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

Climatology of Hygroscopic Growth



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.

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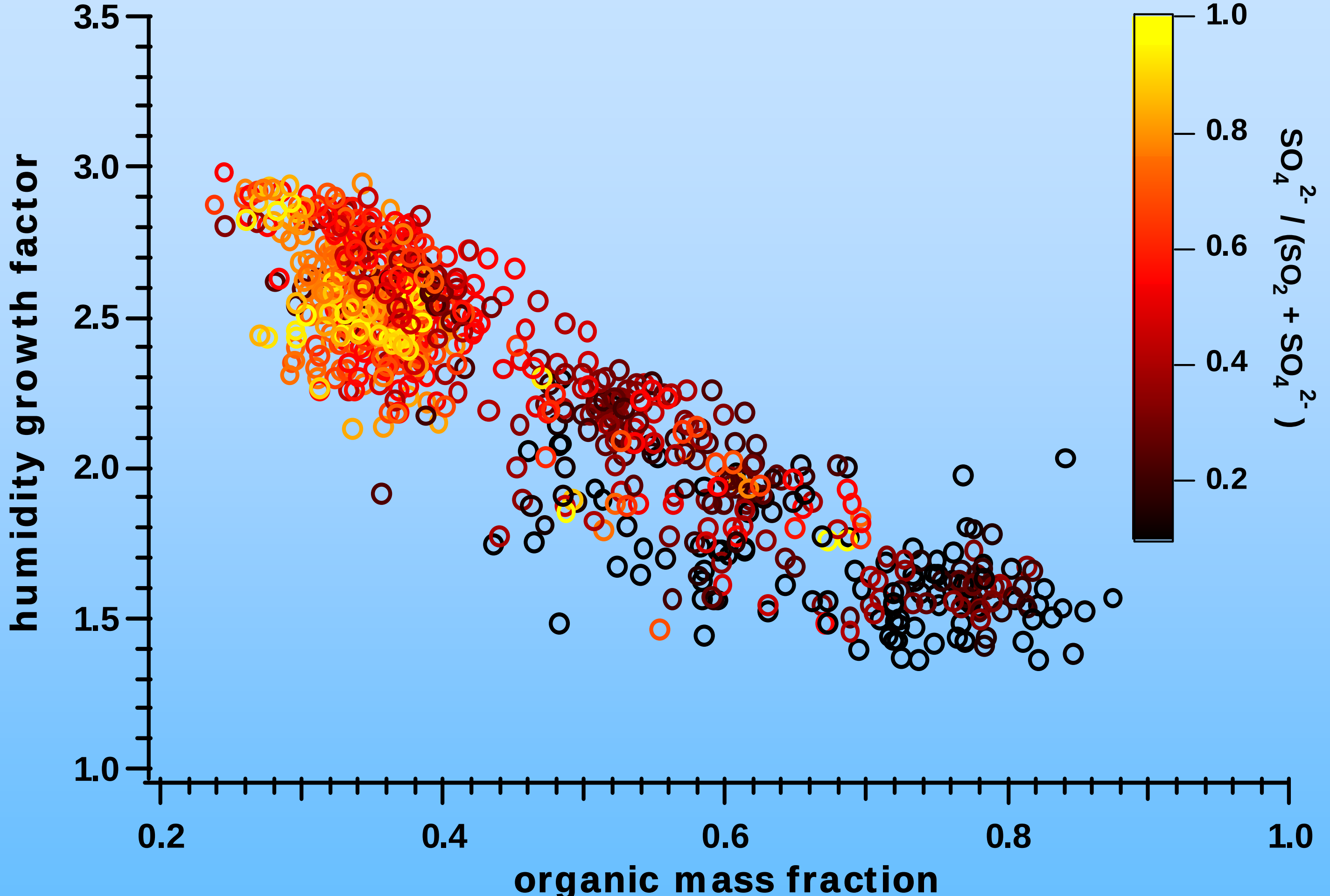
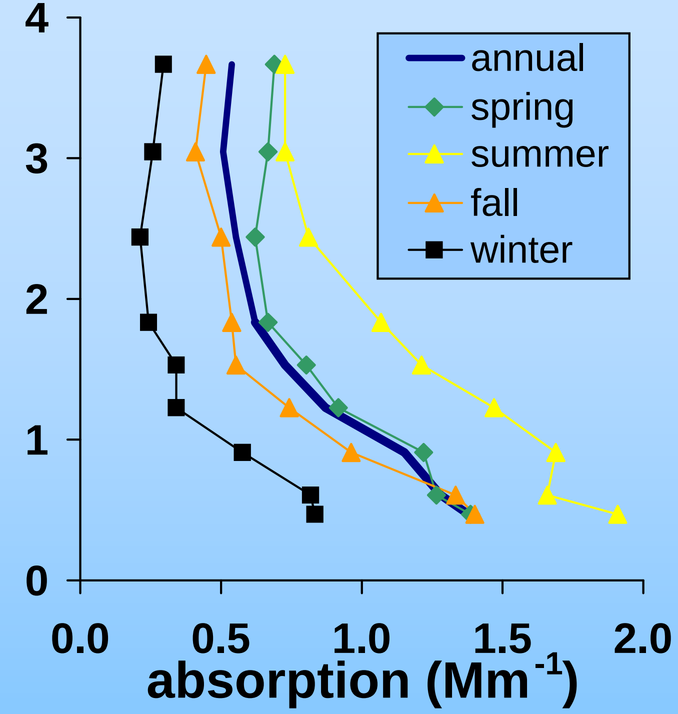
Chemical control of hygroscopic growth



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.

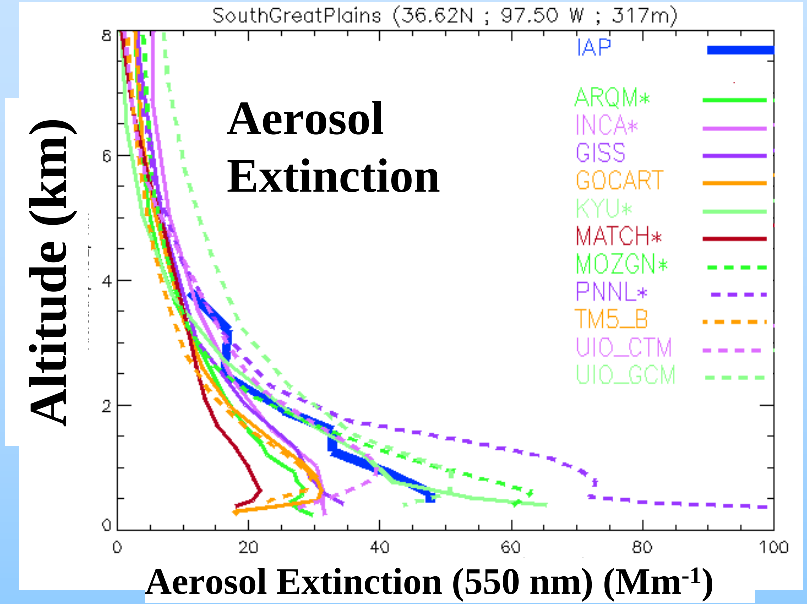
In-Situ Aerosol Profiling

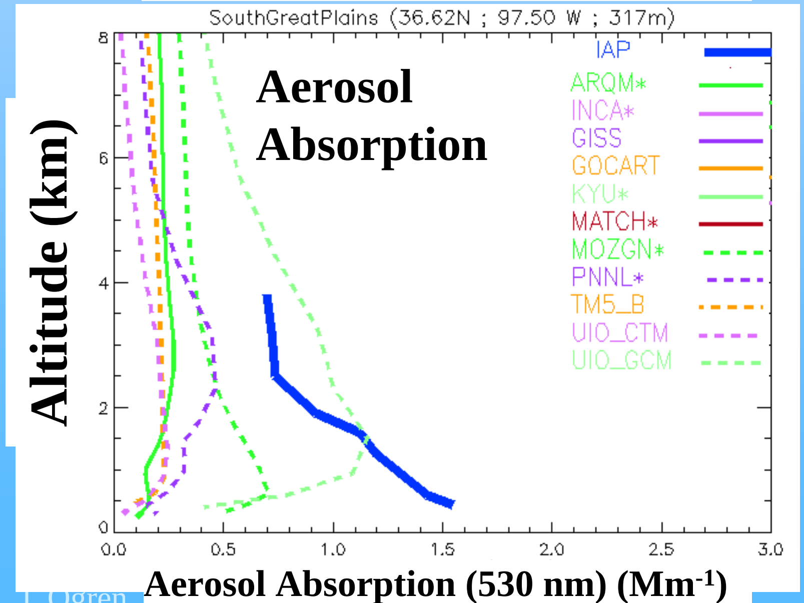
- Objective: Obtain a statistically-significant data set of vertical distribution of aerosol properties relevant to radiative forcing
- Measurements: emphasize aerosol scattering and absorption above a similarly instrumented surface site
- Oklahoma: 807 flights 2000-2007
  Illinois: **266** flights since 2006
- Key Results
  - aerosol properties at surface represent statistics in lower 2-km layer, which dominates forcing
  - clear seasonality seen in profiles
  - Radiative forcing efficiency fairly constant throughout lower 5km

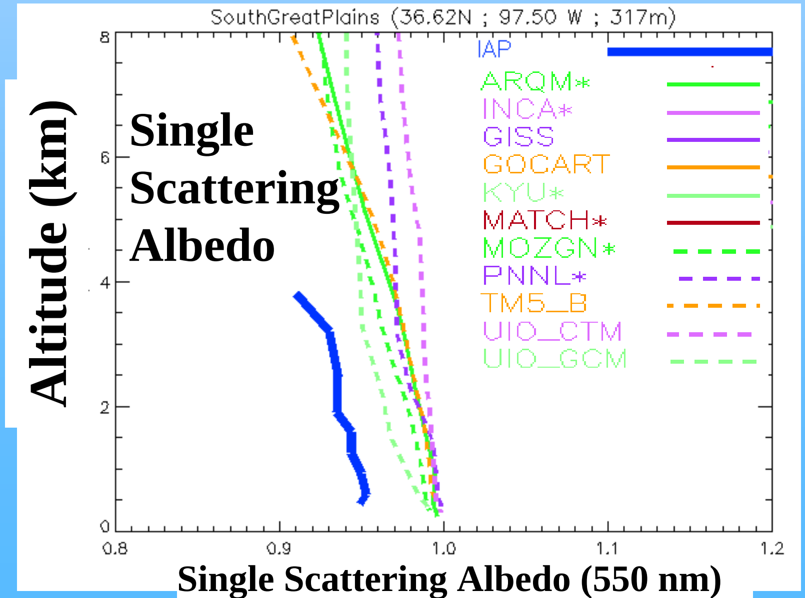


Evaluating models with data

- **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**

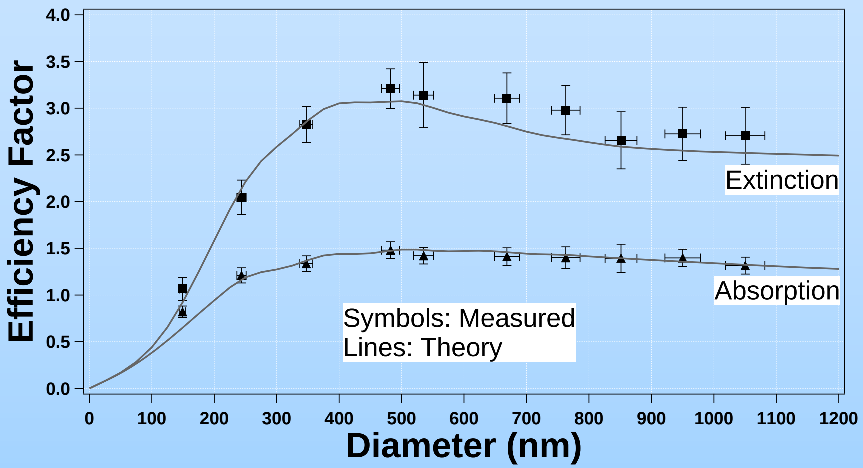


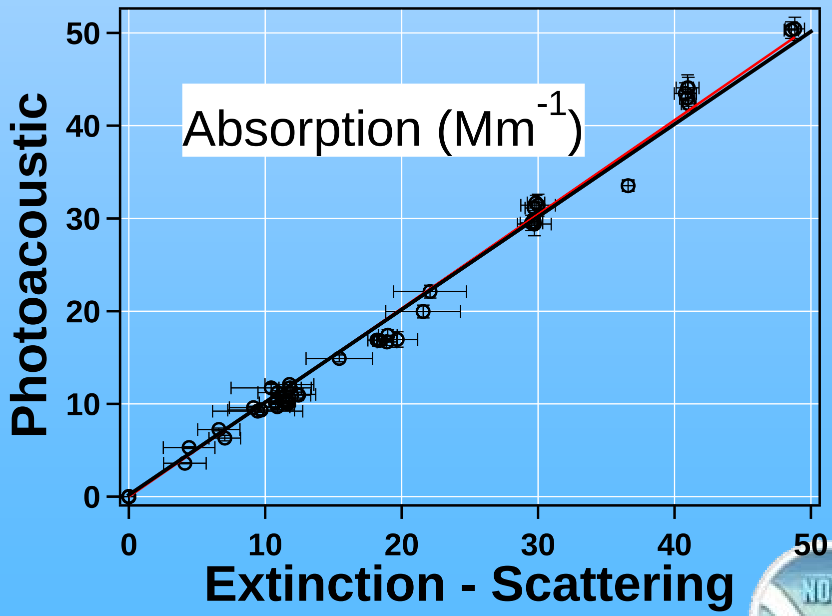




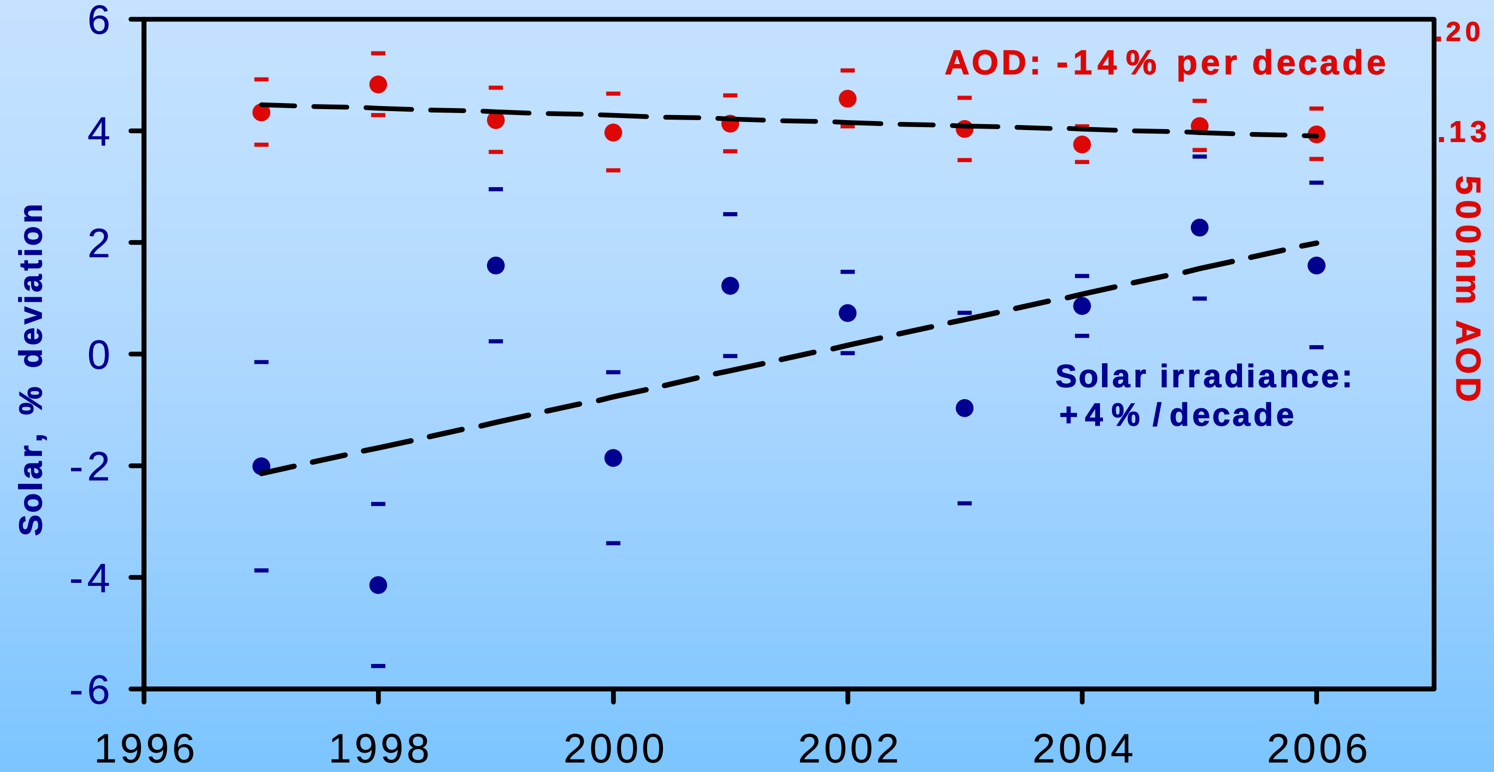
Optical Closure Studies

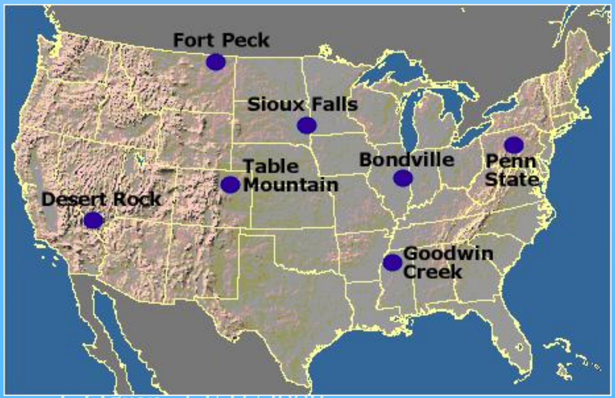
- Over-determined set of measurements provides rigorous assessment of measurement uncertainty
- Laboratory and ambient conditions
- Upper figure: Measurement vs. Theory
- Lower figure: Measurement vs. Measurement





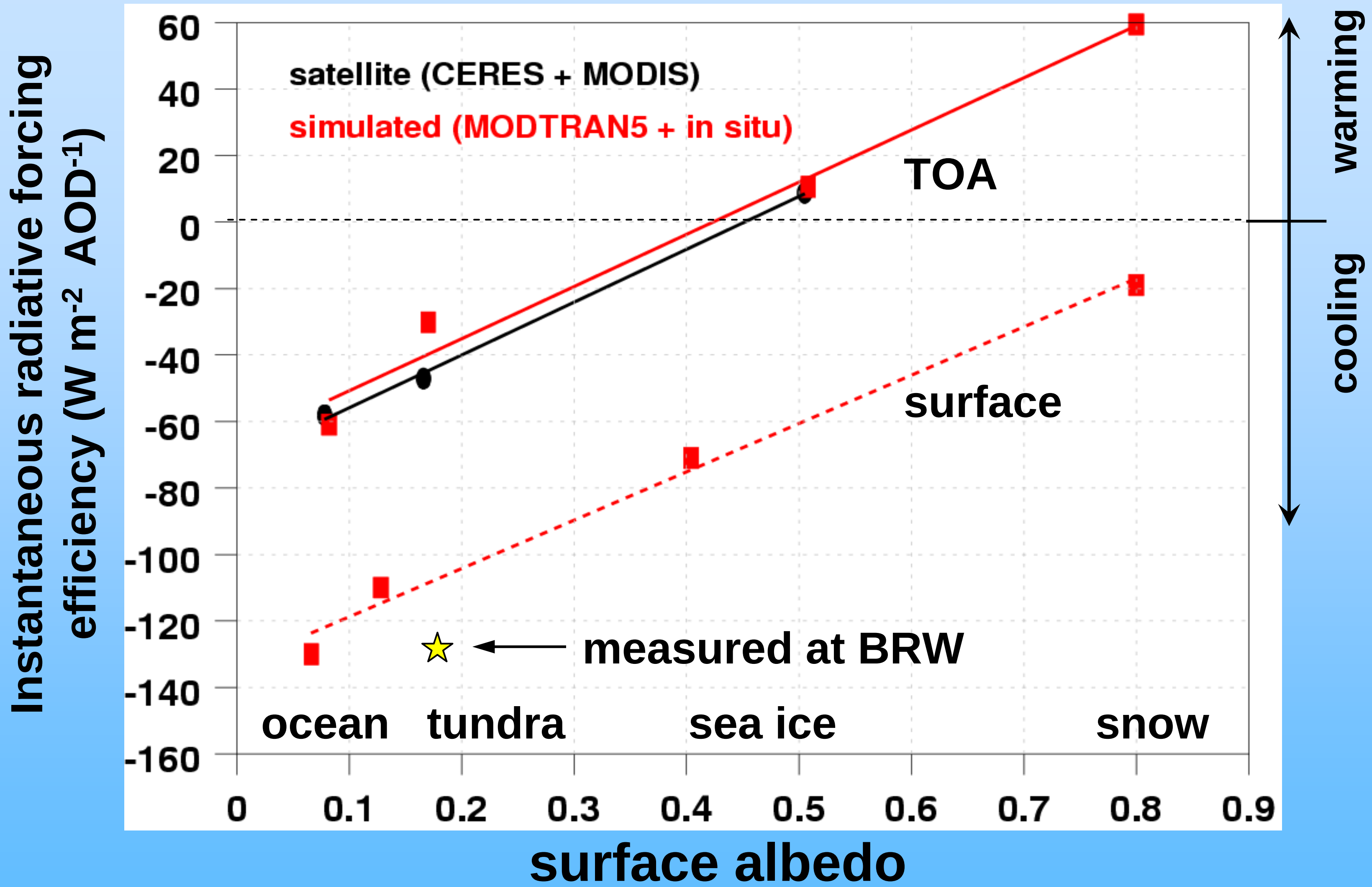
Aerosol optical depth over U.S.





- 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.

Conclusions

- **Results**
  - Aerosols cool the surface and heat the atmosphere
  - Sign and magnitude of TOA forcing depends on optical depth, absorption fraction, angular scattering, and surface albedo
  - ESRL measurements of these key aerosol properties provide a rich data set for evaluating models
- **Future directions**
  - Improved measurements of light absorption, measure humidity dependence
  - Expand global long-term network with additional collaborators and measurements
  - Evaluate models with measurements