Measurement-based determination of aerosol forcings at ARM sites: Proposed joint ASP-ARM study

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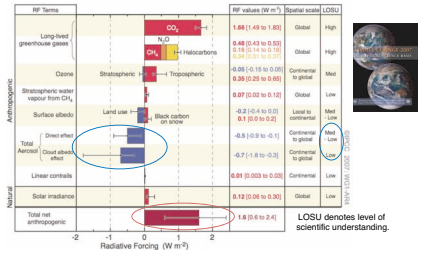
BACKGROUND

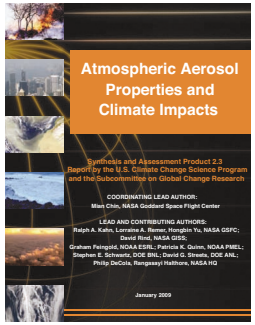
GLOBAL-MEAN RADIATIVE FORCINGS (RF)

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



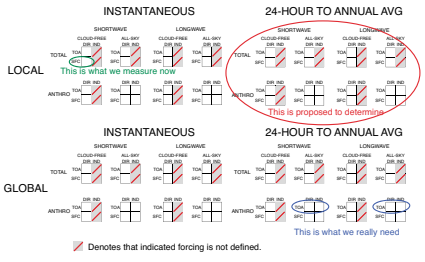
Uncertainty in aerosol forcing dominates uncertainty in forcing over industrial era.

There are many aerosol forcings!



www.climatescience.gov/Library/sap/sap2-3

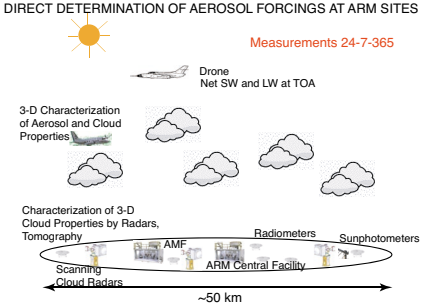
SEVEN DIMENSIONS OF AEROSOL FORCINGS



80 Distinct aerosol forcings

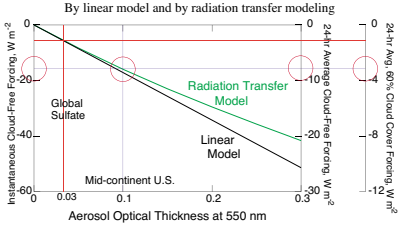
A MODEST PROPOSAL

DIRECT DETERMINATION OF AEROSOL FORCINGS AT ARM SITES



ESTIMATES OF AEROSOL DIRECT FORCING

By linear model and by radiation transfer modeling

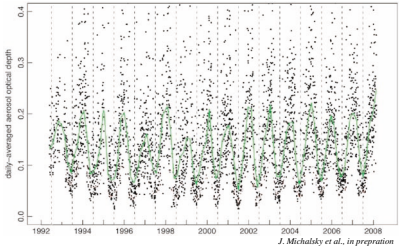


Global average sulfate optical thickness is 0.03: ***1 W m^{-2} cooling***.

In ***continental U. S.*** typical aerosol optical thickness is 0.1: ***3 W m^{-2} cooling***.

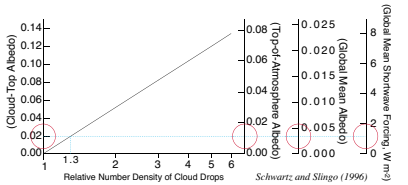
AEROSOL OPTICAL DEPTH AT ARM SGP

Fifteen years of daily average 500 nm AOD in North Central Oklahoma



Green curve is LOWESS (locally weighted scatterplot smoothing) fit.

SENSITIVITY OF ALBEDO AND FORCING TO CLOUD DROP CONCENTRATION



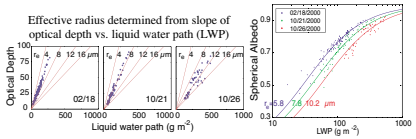
Indirect forcing is highly sensitive to perturbations in cloud drop concentration.

A 30% increase in cloud drop concentration results in a forcing of ~1 W m^{-2}.

CLOUD ALBEDO AND FORCING CALCULATED FROM MEASURED EFFECTIVE RADIUS AND LIQUID WATER PATH

North Central Oklahoma

Effective radius determined from slope of optical depth vs. liquid water path (LWP)



Cloud albedo is calculated for observed data and for average effective radius for each day. Forcing is calculated for indicated conditions relative to October 26.

Radiative forcing for solar zenith angle 60° and liquid water path 100 g m^{-2}

Date, 2000	Effective radius r_e μm	Optical Depth	Net flux at TOA W m^{-2}	Forcing relative to 10/26, W m^{-2}
10/26	10.2	15.1	293	
10/21	7.8	20.8	266	27
02/18	5.8	28.3	240	53

Kim, Schwartz, Miller, and Min, JGR, 2003

SUMMING UP

There are ***multiple aerosol radiative forcings***. Distinguishing them is essential to progress.

Direct determination of aerosol radiative forcings at ARM sites would be a ***stringent test of ability to determine these forcings***.

SGP would be a great place to start. Much needed instrumentation is in place. There would be plenty of signal!

Determining aerosol radiative forcings at a relatively small number of sites would ***lend confidence to extending this process globally***, from remote sensing and in-situ measurements.

Confident determination of aerosol radiative forcings at ARM sites would require ***substantial new effort and commitment***.

Next step is to ***systematically examine the feasibility and costs*** of such a direct determination.

Contact me if you might be interested.

See handout for more details

SOME SPECIFICS

APPROACH

Determine 3-D cloud field by ground based and remote sensing.

Determine 3-D field of aerosol amount, optical properties as f(RH), cloud nucleating properties, IFN properties, by in-situ measurement.

Attribute aerosol to natural and anthropogenic.

Calculate radiative fluxes at surface and TOA for observed aerosol.

Compare with measurements to assess accuracy.

Calculate cloud properties for natural aerosol.

Calculate radiative fluxes for alternative aerosol loadings: zero aerosol (direct only), natural aerosol.

Calculate radiative ***forcings***: total aerosol (direct only); anthropogenic aerosol; surface, TOA; shortwave; longwave; ...

CHALLENGES IN DETERMINING AEROSOL RADIATIVE FORCINGS

Determine ***anthropogenic contribution*** to aerosol.
- In-situ measurements
- Modeling

Determine aerosol ***optical properties*** (σ_{ep}, ω_0, g) including RH dependence as $f(x, y, z)$.

Determine $N_{ccn}(s)$ ***and*** N_{cd} for actual and natural aerosol as $f(x, y, z)$; s is supersaturation.

Determine ***3-D cloud morphology and microphysical structure***.

Measure radiative flux components at surface and TOA.

Calculate ***3-D Radiative transfer*** for observed atmospheric . Accuracy sufficient to lend confidence to modeling of difference due to anthropogenic aerosol

Consistency and error estimation from radiation measurements.

CHALLENGE TO ARM AND ASP

Determine aerosol radiative forcings at ARM site(s).

. . . with well specified definitions.

. . . with "known and reasonable uncertainties".

Deliver these radiative forcings regularly and systematically as an ARM VAP.

This is a necessary (not sufficient) element of determining anthropogenic aerosol forcing pertinent to climate change over the industrial period.

Developing these forcing products would be an enormous challenge to ARM and ASP requiring substantial resources.

Presented at Atmospheric Radiation Measurement Program Science Team Meeting, Louisville KY, March 30-April 2, 2009