AEROSOLS AND LAND USE INTERACTIONS

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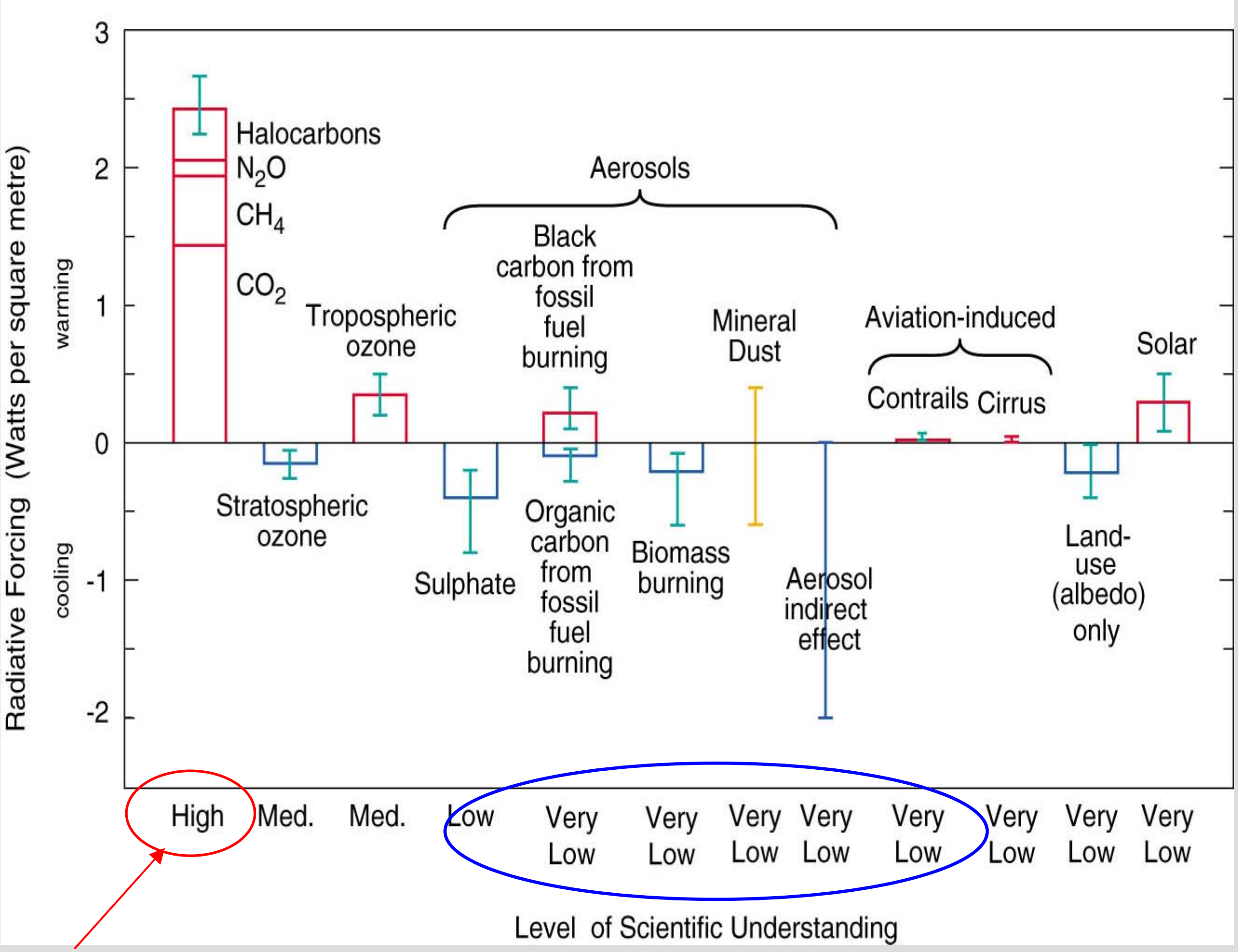
Climate radiative forcing of atmospheric aerosols can enhance or rival warming caused by GHGs

Intergovernmental Panel on Climate Change (IPCC, 2001)

global mean radiative forcing (W/m2): 2000 relative to 1750

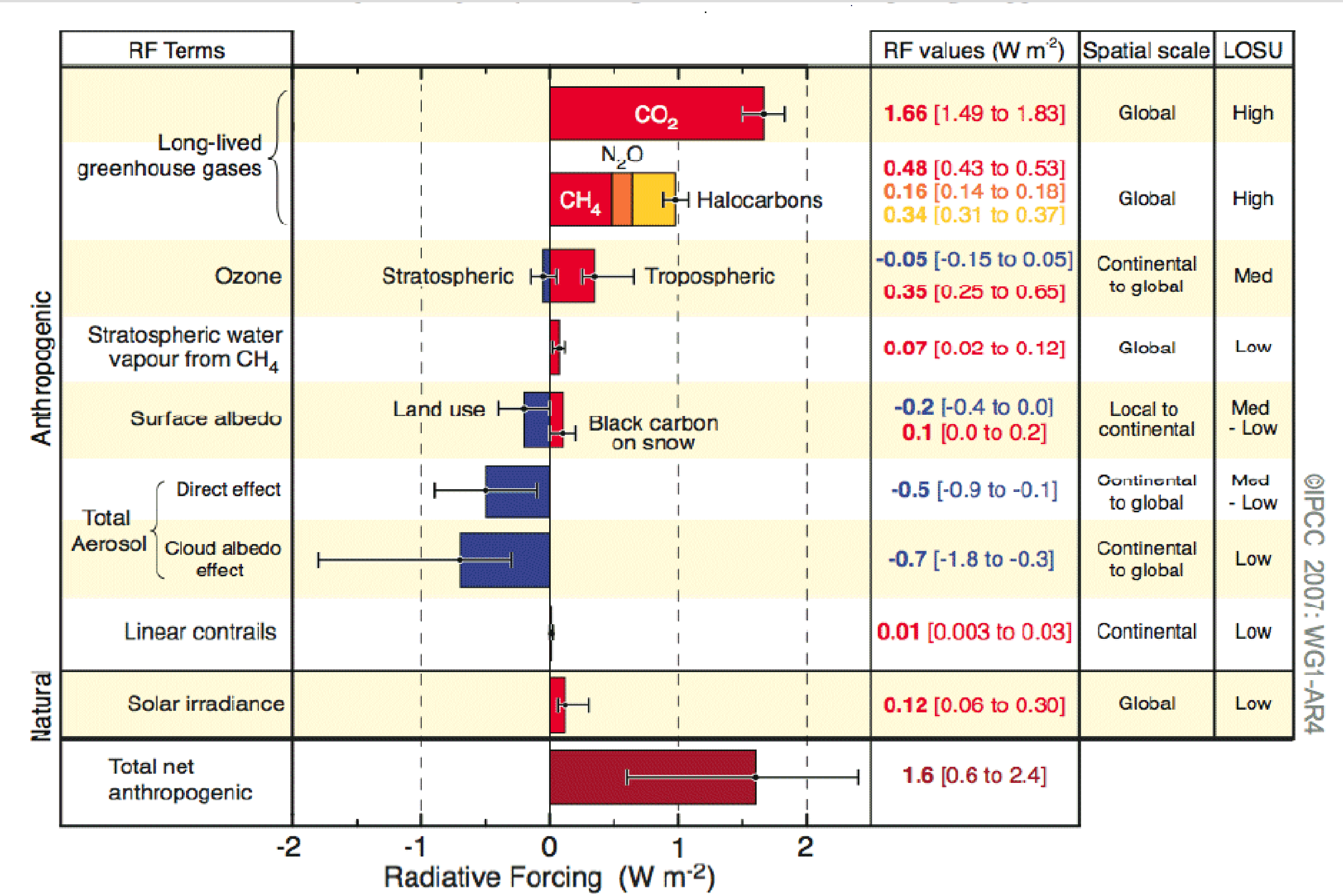


Need to know concentrations

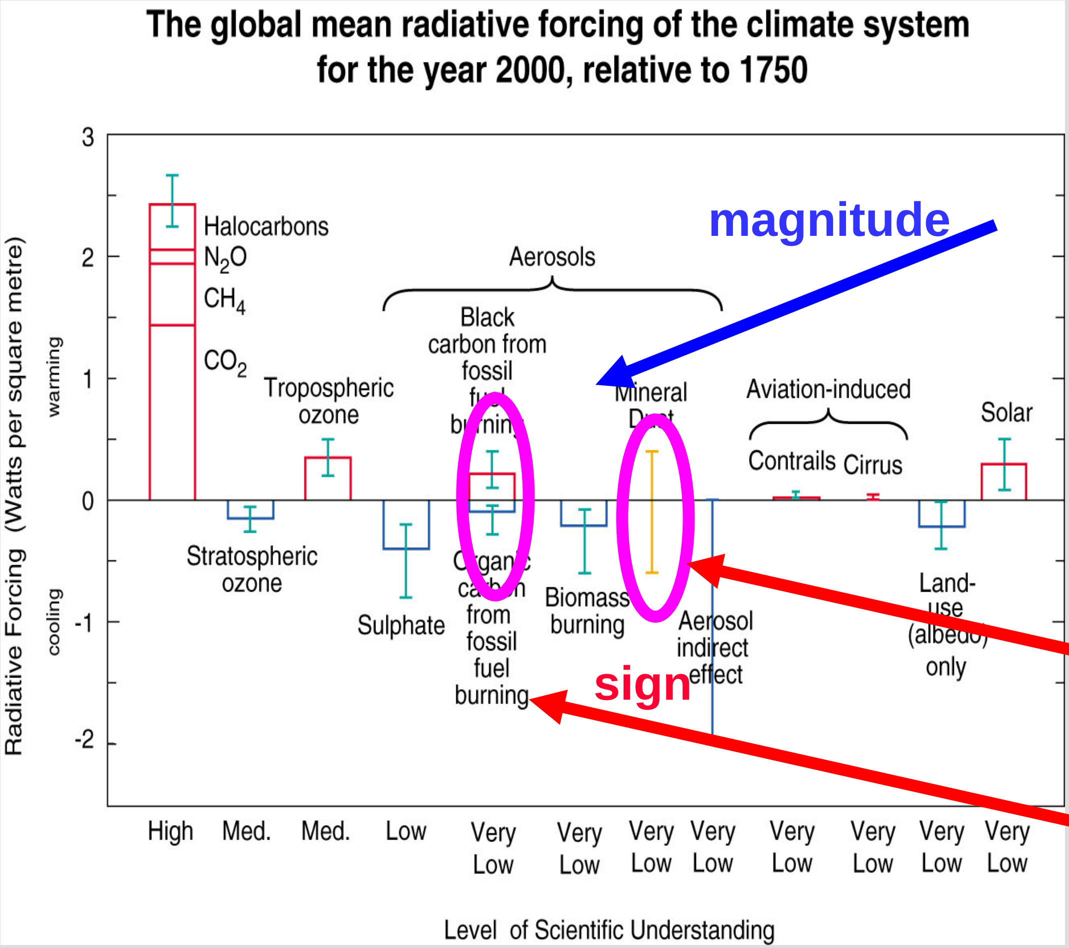
Complexity of aerosols:

- **different types (distinct sources and differing physical and chemical processes)**
- **short lifetime (up to about 2 weeks)**
- **heterogeneous distribution of sources**
- **ageing (changes during transport)**
- **anthropogenic vs. natural aerosols**

IPCC (2007): Summary for Policymakers



HOW TO IMPROVE THE PREDICTION OF RADIATIVE FORCING BY AEROSOLS



***Key questions*:**

- **Total aerosol loading**
- **Anthropogenic fraction**
- **Light absorption by dust**
- **OC/BC ratio in carbonaceous aerosols**

…BUT… AEROSOLS (DUST and SMOKE) CAUSE OTHER IMPORTANT RADIATIVE IMPACTS

Impacts	**Importance**
Direct radiative impacts	
Cause the radiative forcing at the top of the atmosphere	**Affect energy balance of the Earth's climate system (warming or cooling depending on the aerosol types and environmental conditions)**
Alter the energy balance at the surface	**Affect surface temperature and surface-air exchange processes**
Cause radiative heating or cooling within aerosol layers in the atmosphere	**Affect temperature profile and atmospheric dynamics and thermodynamics**
Affect visibility	**Decrease visibility and degrade air quality**
Indirect radiative impacts	
Serve as ice nuclei	**Affect the properties and amount of ice and water clouds and hence their radiative effects**
Serve as cloud condensation nuclei	
Promote or suppress precipitation	**Affect the lifetime of clouds and hence their radiative effects**
Alter actinic flux	**Alter the abundance of radiatively important atmospheric gases (e.g., O3) via photo and heterogeneous chemistry**
Absorb chemically important gases	
Provides particle surfaces for heterogeneous chemical reactions	

Emissions gap

All GCMs rely on the “static” emission inventories (e.g., particular year)

A need for new approaches to develop dynamic emission algorithms based on process-oriented description of land ecosystems dynamics and climate change

(A new iLEAPS-GEIA initiative on process-based emission models)

The FLAMES Project

Fire-Land-Atmosphere Modeling and Evaluation System for Mainland Southeast Asia

Personnel

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Collaborators

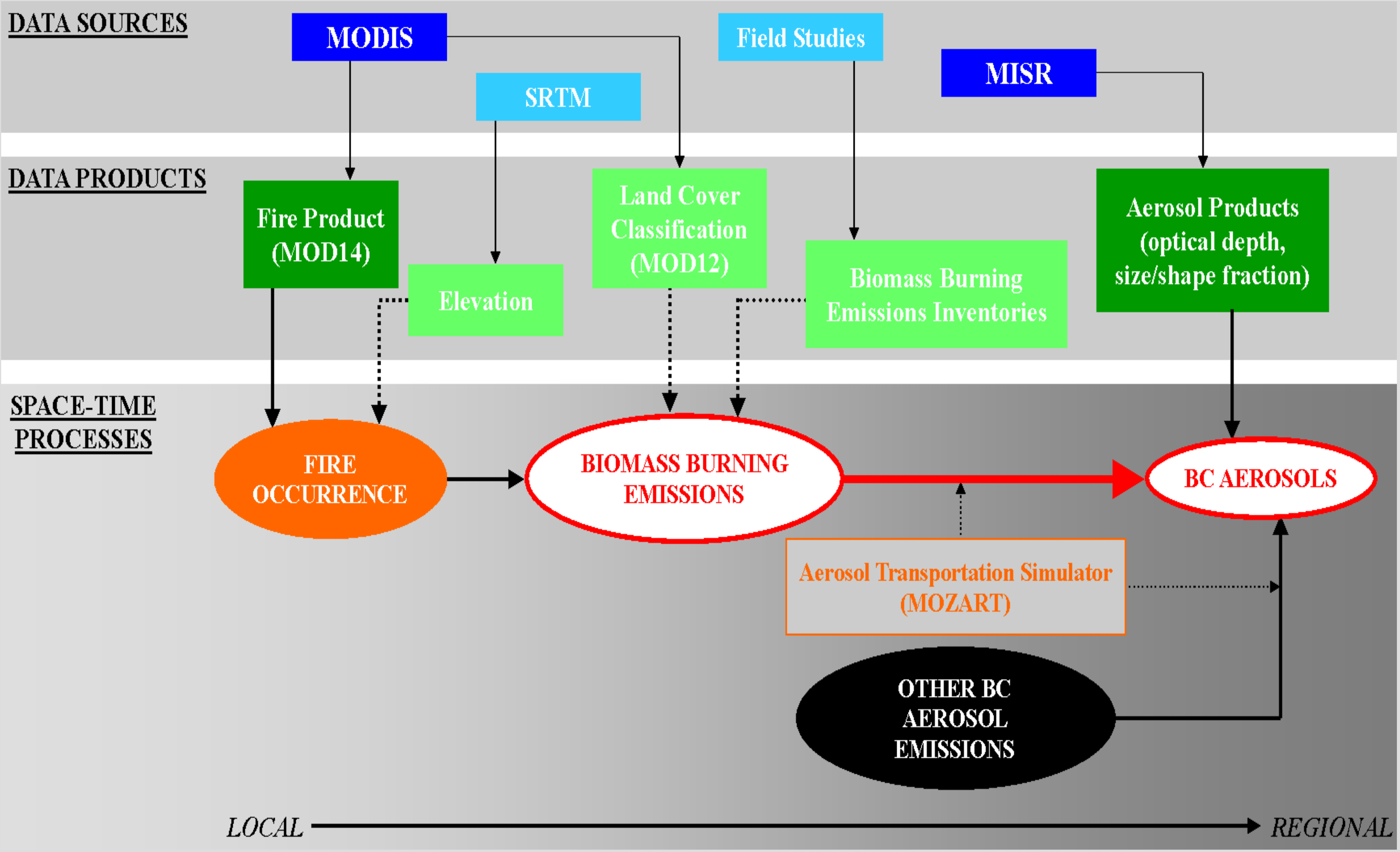
Louisa Emmons (NCAR), Jeff Fox (East-West Center), Ralph Kahn (Jet Propulsion Laboratory), Gabriele Pfister (NCAR), Phil Rasch (NCAR)

Department of Geography[1]
Department of Statistics[2]

Objectives

- Hierarchical Bayesian process-based statistical modeling
  - Formally account for sources of uncertainty and missing data
  - Synthesize data, observed at different spatial resolutions and temporal scales
- Modeling aerosol dispersion, given atmospheric circulation, using an aerosol transport simulator
- Synthesizing the effects of recent land-use changes, biomass burning and regional aerosol concentrations in Southeast Asia
- Conducting policy scenario and sensitivity analyses of biomass burning at a regional (sub-continental) level
  - Interactive, web-based tools

Statistical Framework



Carbonaceous aerosols from biomass and fossil fuel burning

Increasing frequency of biomass burning

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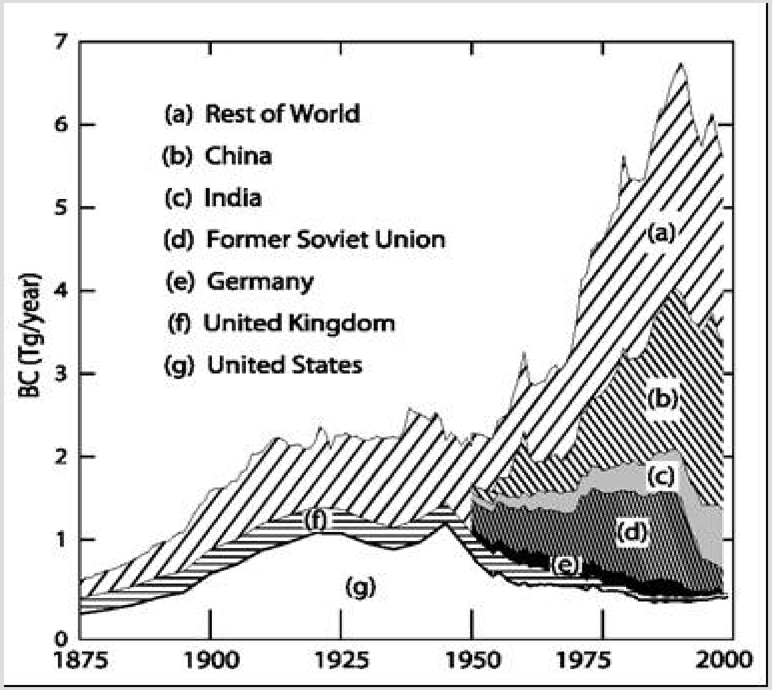
Higher emissions of trace gases (CO_2, CO, etc) as well as carbonaceous aerosols => integrated approach for gases and particulates

Regional emissions of black carbon from fossil fuel burning (Novakov et al., 2003)



Control of fossil-fuel particulate black carbon and organic matter, possibly the most effective method of slowing global warming (*Jacobson et al*.)

Climate Warming Due to Soot and Smoke? Maybe Not (*Penner et al*.)

Slow down of the hydrological cycle (*Ramanathan et al*.)

UNDERSTANDING THE ROLE OF CHANGES IN LAND USE/LAND COVER AND ATMOSPHERIC DUST LOADING AND THEIR COUPLING ON CLIMATE CHANGE IN THE NEESPI STUDY DOMAIN DRYLANDS

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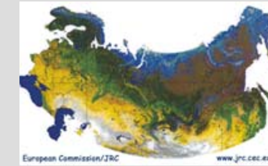
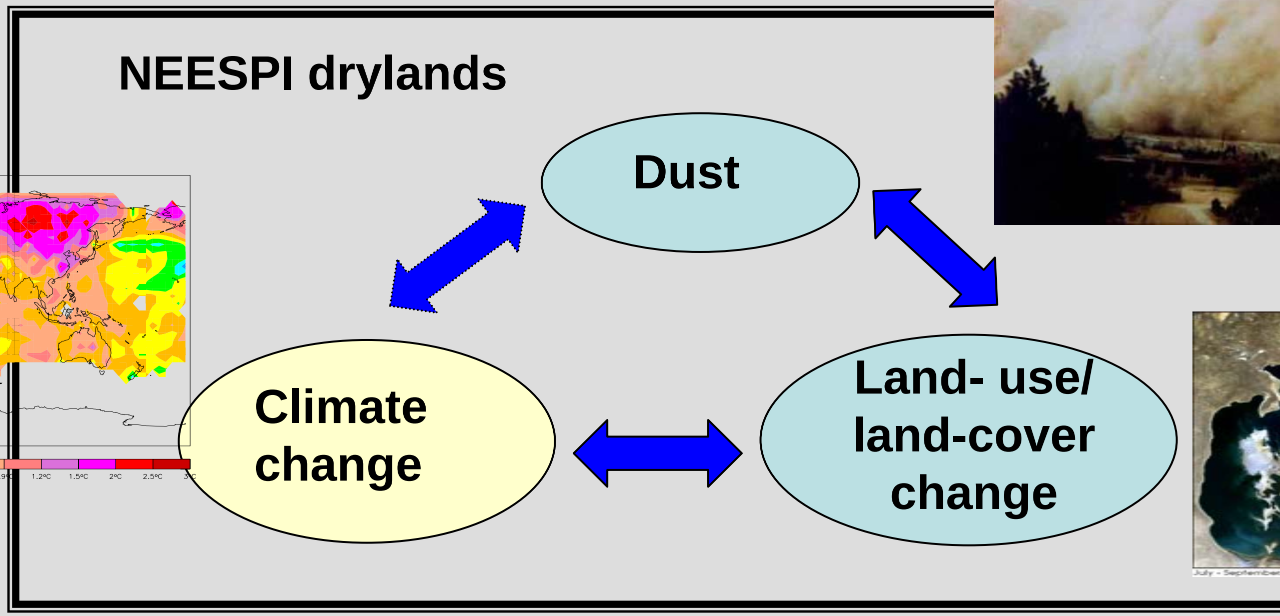
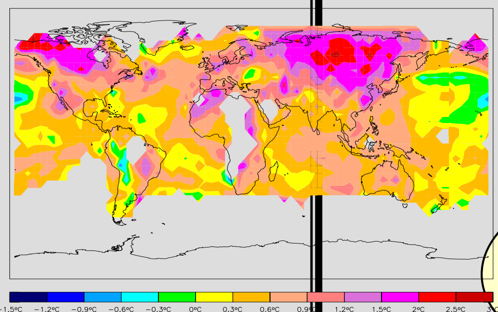
The main goal is to investigate how and to what extent land-use/land cover changes and varying dust loadings and their interactions have been affecting climate of drylands in the NEESPI study domain over the past 50 years.

Modeling approach:

NCAR WRF + DuMo + land model





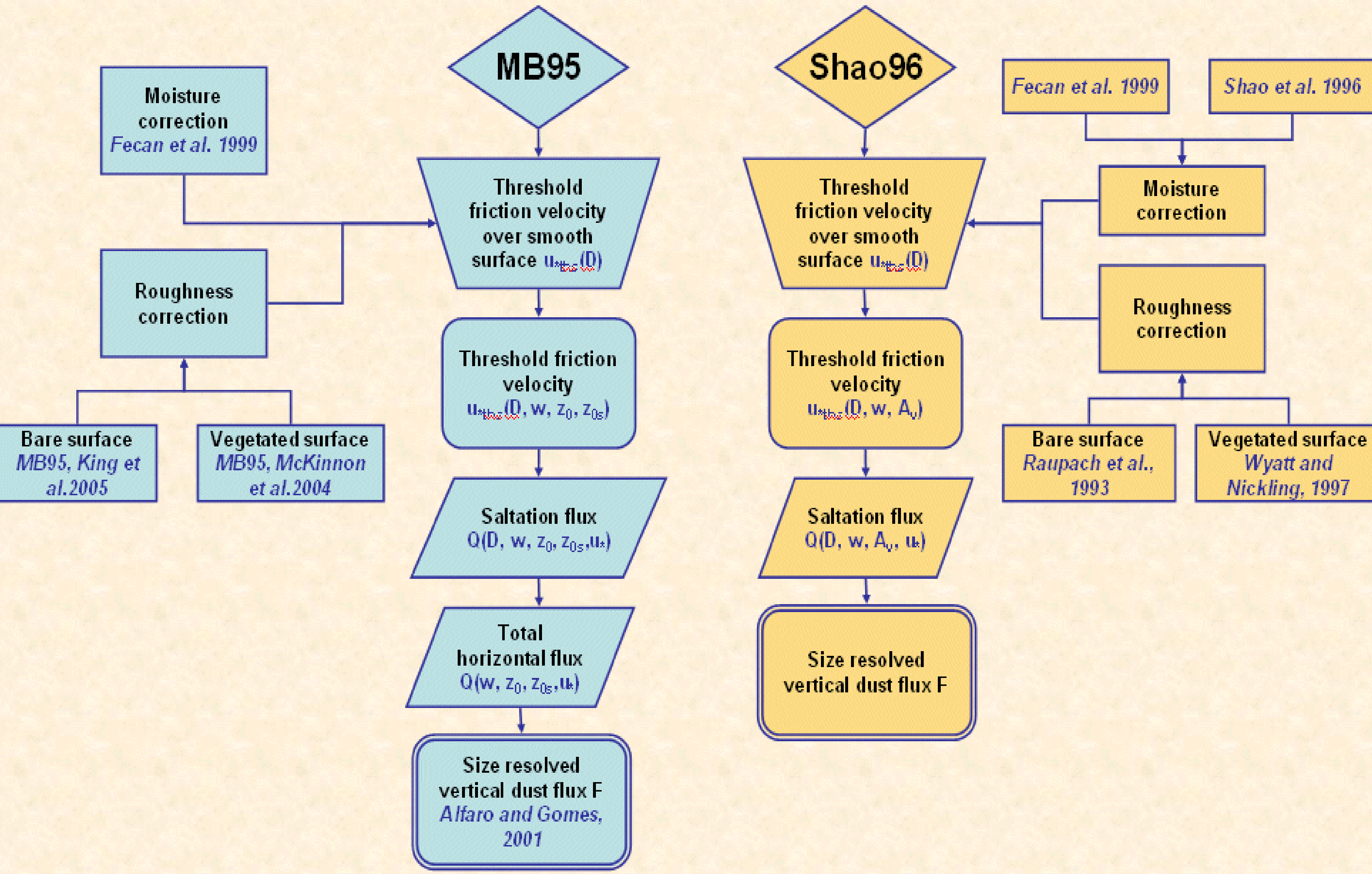


Objectives:

Development of a suite of the process-based models.

Development of Asian Dust Databank: 50-years climatology of dust events, climatic variables and land-use/land cover changes in Central and East Asia by merging available data from satellite, weather and monitoring stations, and historical records.

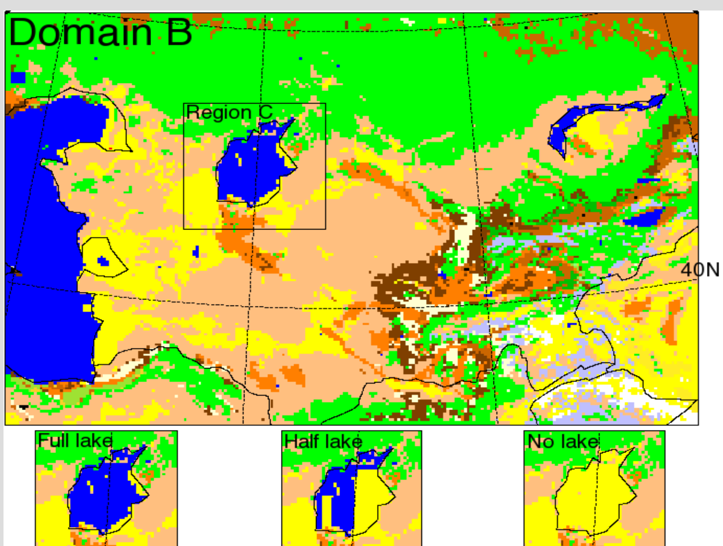
State-of-the-art dust emission module tailored for Central and East Asia



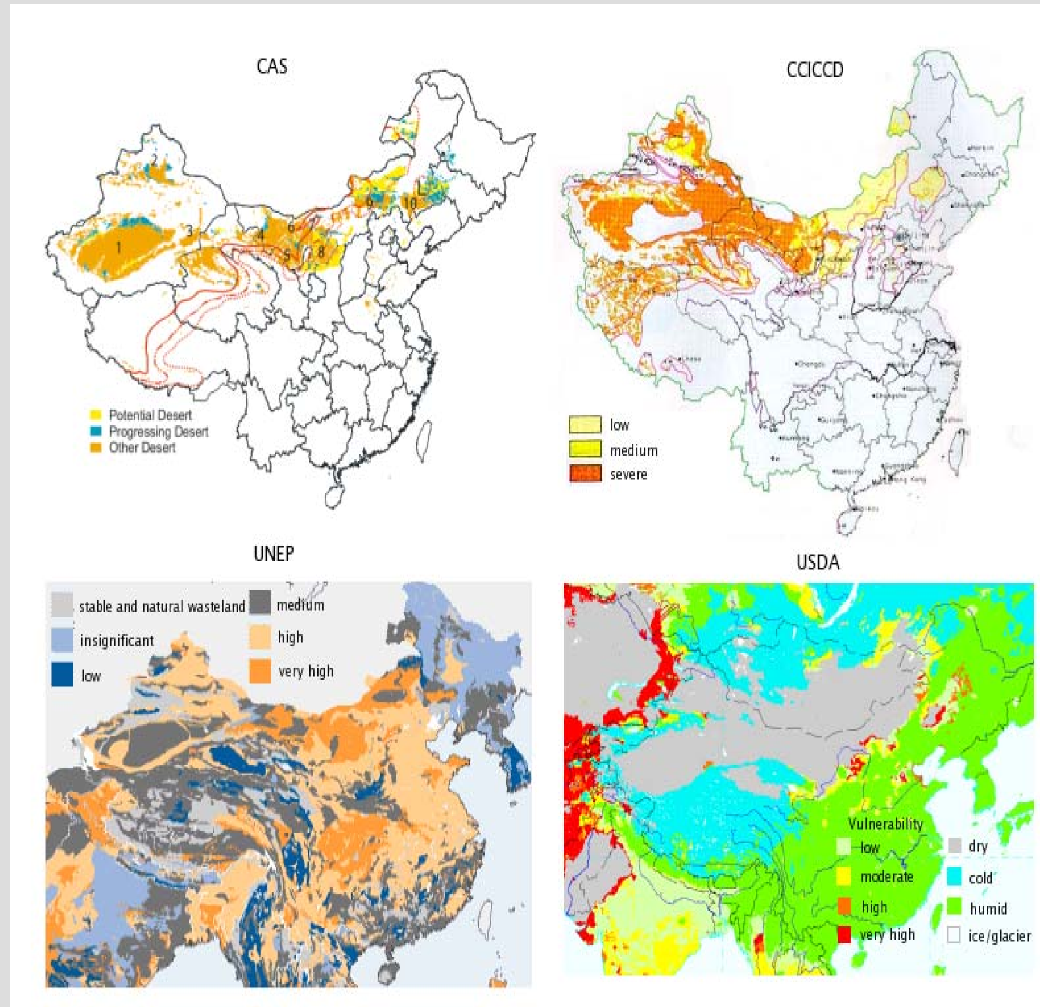
Anthropogenic vs. natural dust: Need better linkages between dust emission and land-cover/land-use change

Study	Estimated anthropogenic dust fraction
Sokolik and Toon 1996	~ 20 %
GCMs estimates	
Tegen and Fung 1996	30 - 50 %
Mahowald et al. 2003	14 - 60 %
Tegen et al. 2004	< 10 %
Mahowald et al. 2004	0 - 50 %

Aral Sea

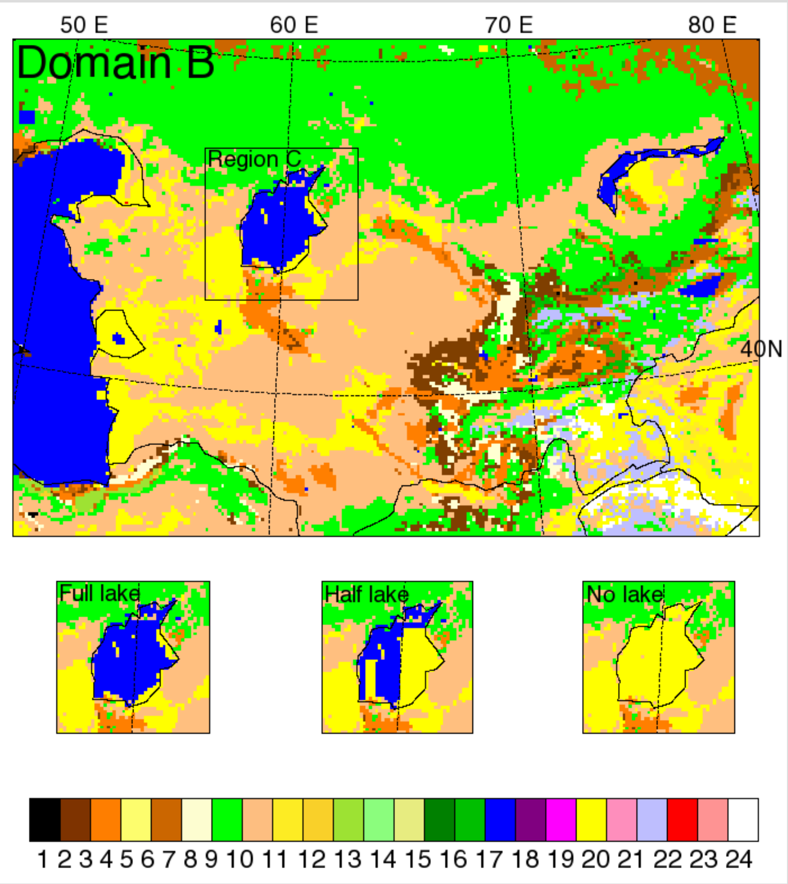


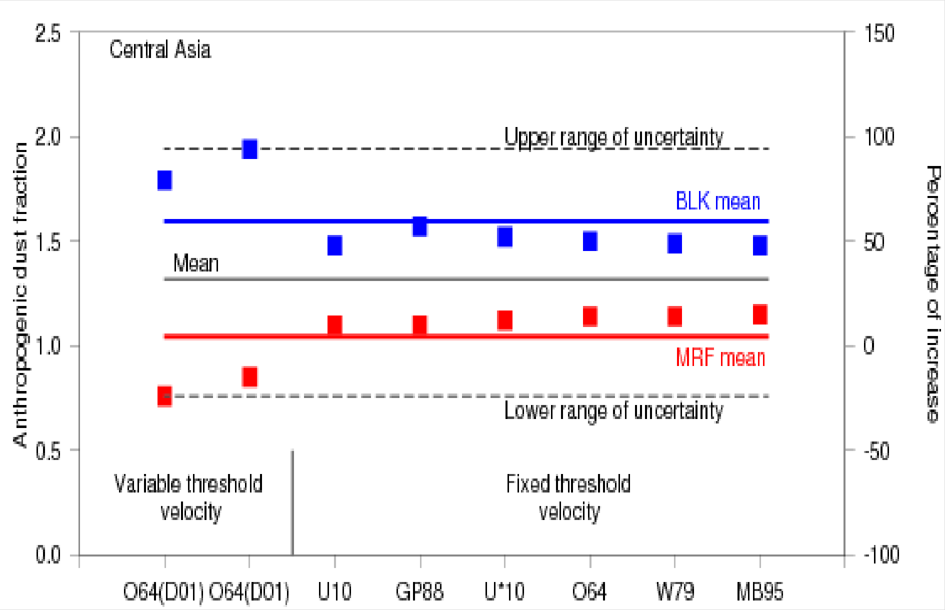
Desertification in China



Assessment of the anthropogenic dust fraction in Central Asia

Darmenova and Sokolik (2007)

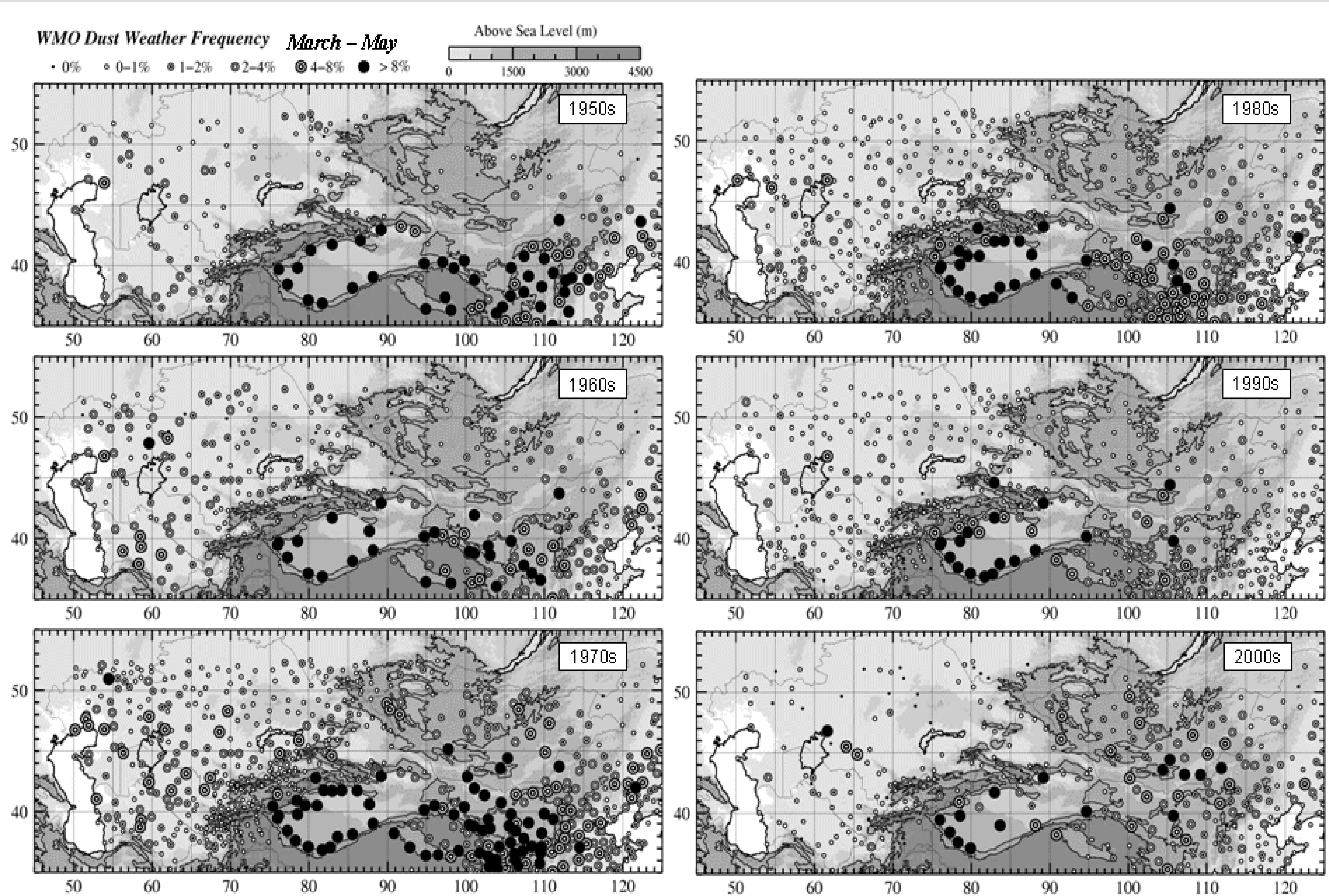




The estimation of the anthropogenic dust fraction depends on the choice of PBL parameterization and dust production scheme

The anthropogenic dust fraction in the Aral Sea region depends on the combined effects of wind changes inside and outside the lake bed, the threshold velocity selected for dust production and the increase of source area.

Decadal frequency of dust weather

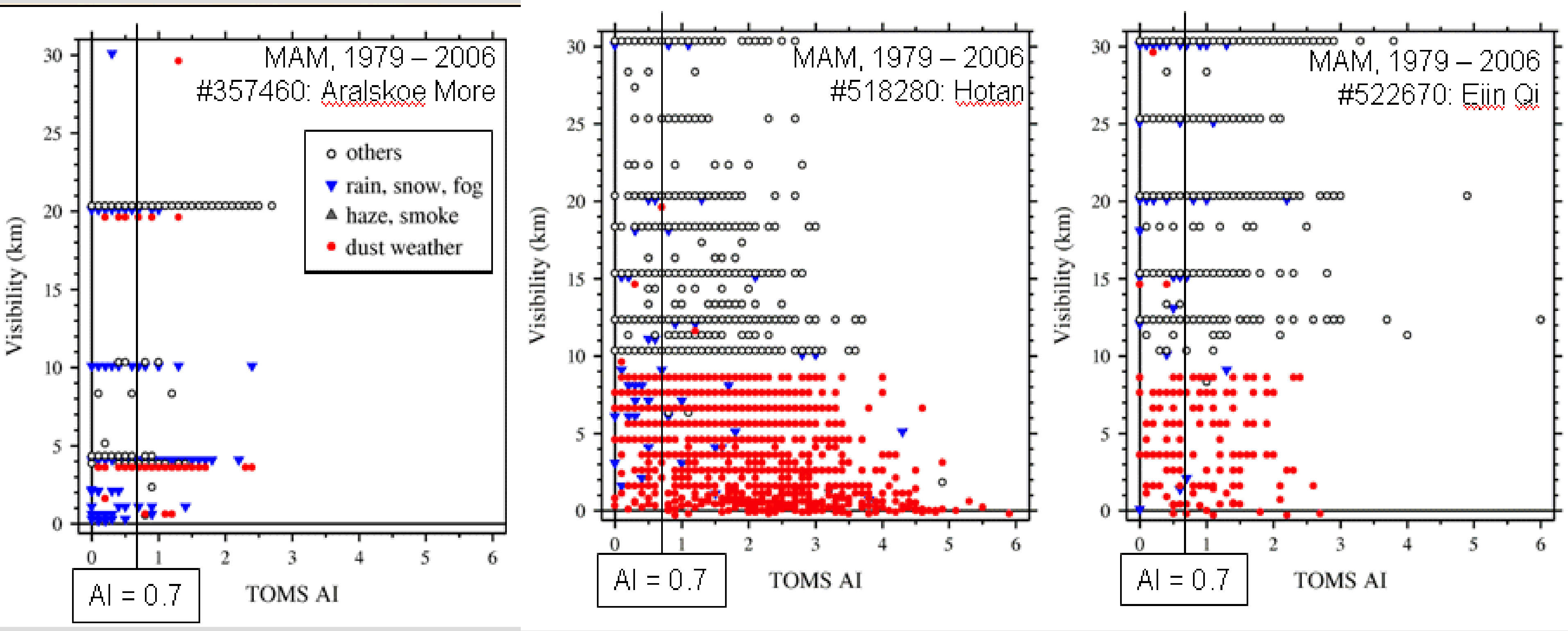


How to define a dust climatology

Visibility

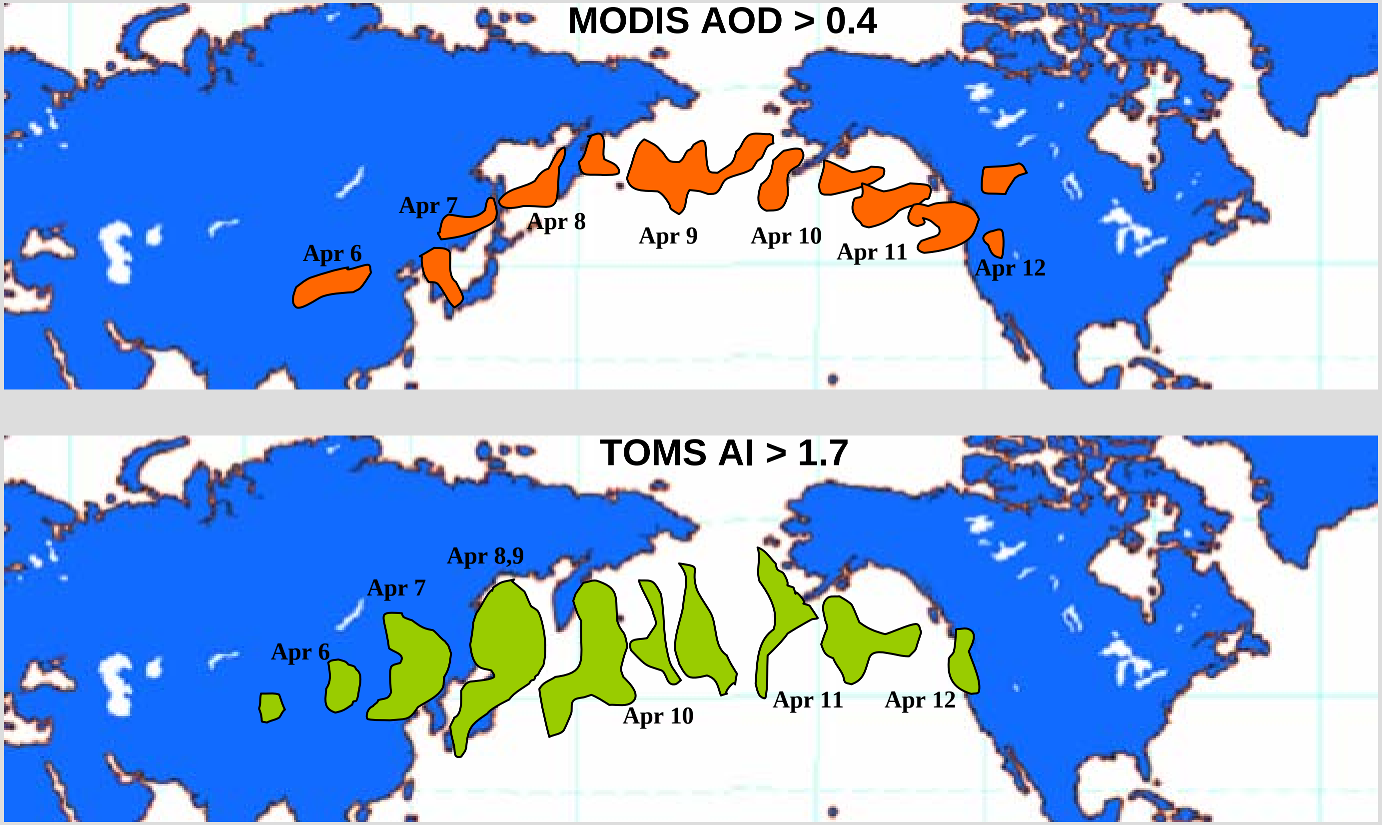
Dust weather (WMO)

TOMS/OMI Aerosol Index (Prospero et al., 2002 => AI > 0.7



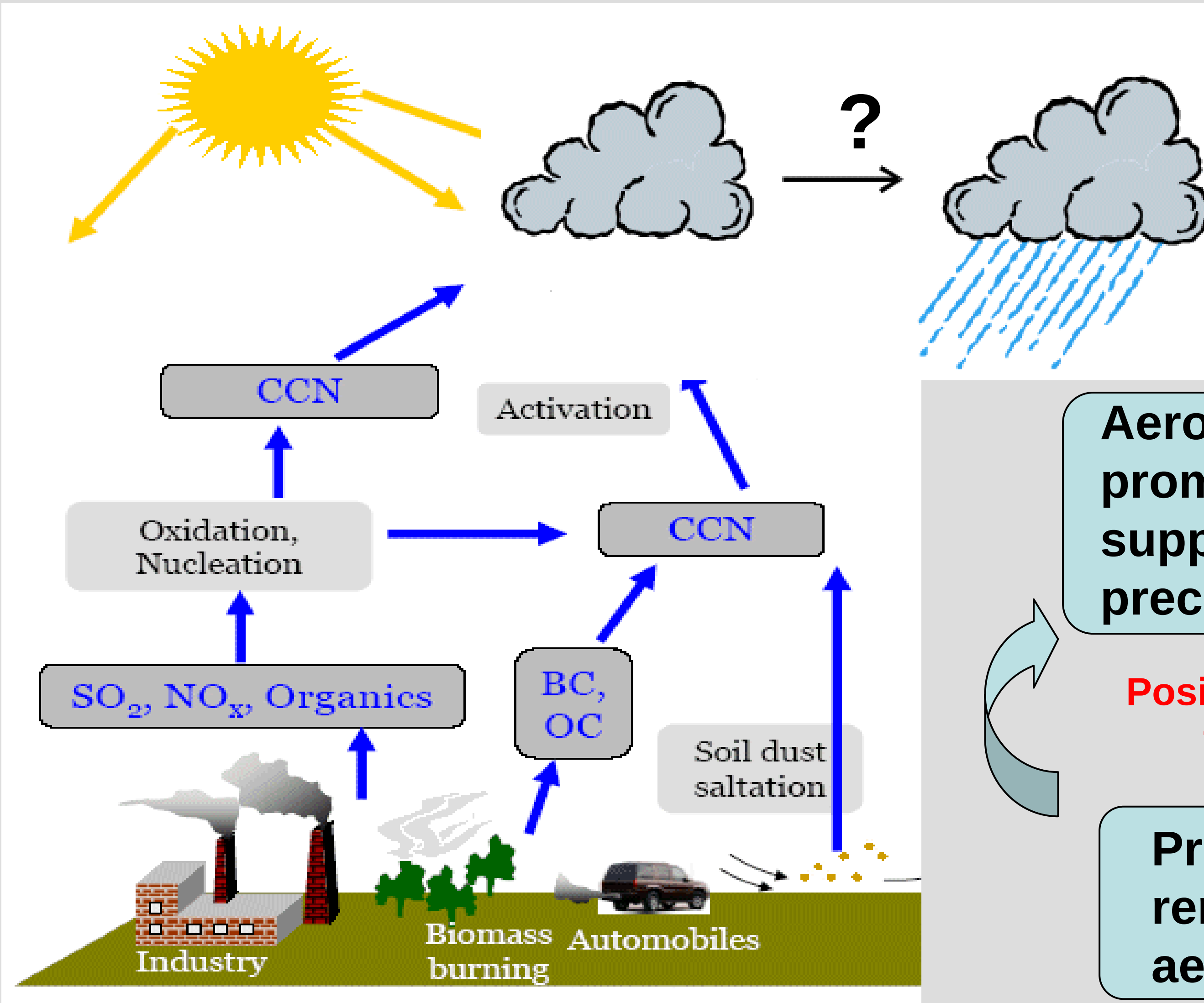
Long-range transport of Asian dust from TOMS AI and MODIS AOD

"The perfect dust storm" in 2001



The day-by-day coverage of the long-range transport obtained from TOMS AI and MODIS AOD shows broad agreement but there are various differences that hampers the validation of transport models and data assimilation

Aerosols- ecosystem-hydrological cycle linkages (via clouds)



Aerosols can promote or suppress precipitation

Positive or negative feedbacks?

Precipitation removes aerosols

Dust effects on precipitation

REFERENCE	COMMENTS	CONCLUSION
Yin et al.(2002) Wurzler et al. (2000)	Air parcel modeling	dust promotes precipitation
Rosenfeld et al. (2001)	Case study of NOAA-AVHRR and TRMM data of Saharan dust	Dust suppresses precipitation
Rudich et al. (2002)	Case study of NOAA-AVHRR data of Aral dust	Aral dust promotes precipitation
Miller et al.(2004)	Modeling study using NASA GISS AGCM (resolution 4^0x5^0), considered only surface radiative forcing mechanism, no dust-cloud interactions	Dust promotes precipitation locally over desert regions

!!! Need to distinguish between dust impacts on warm and cold clouds

Analysis of precipitation trends in the Aral Sea region

__*Sokolik et al. (to be submitted to Science):*__

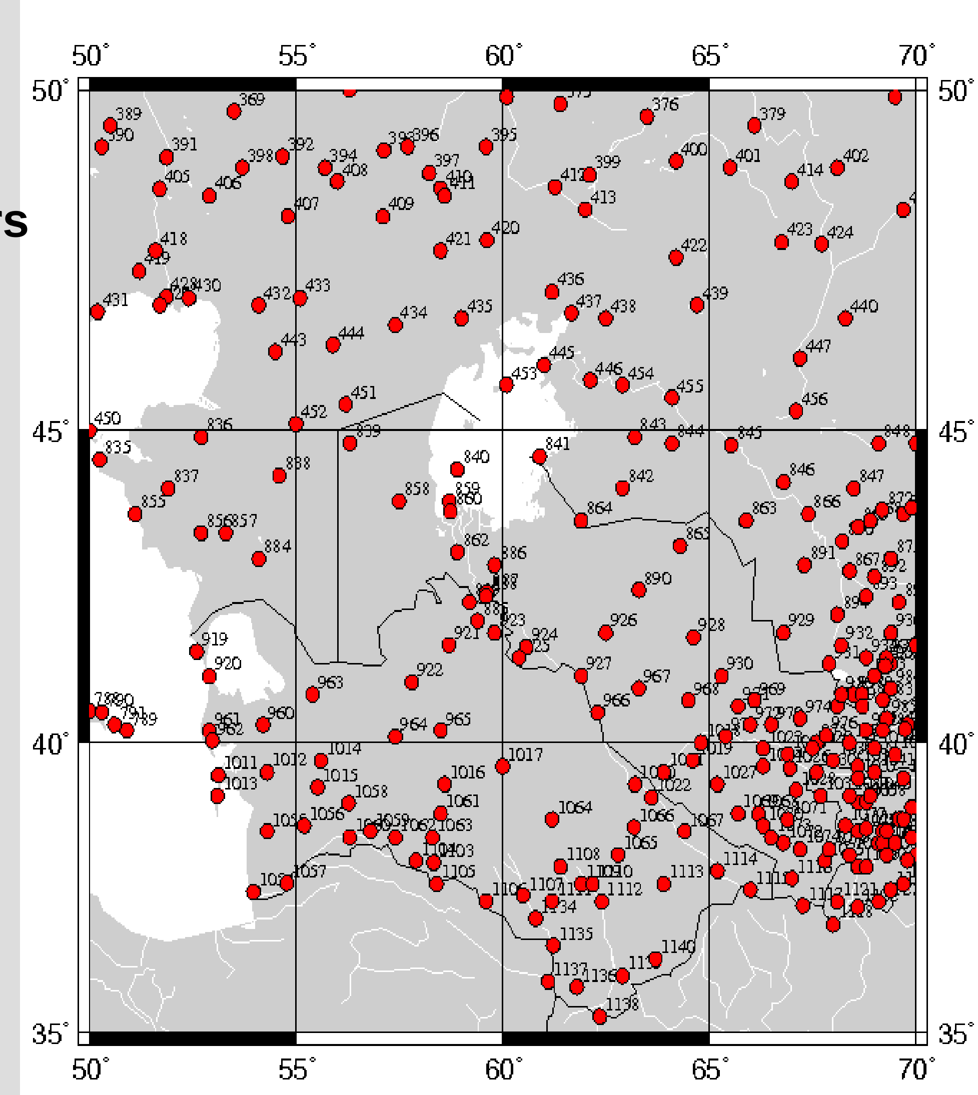
analysis of a new data set of

daily precipitation from

the surface stations for the 50-100 years

- ✓ **Did not find statistically significant changes in precipitation, though there are some indications that extreme precipitation increased over many locations in the Aral sea region.**

- ✓ **Rainfall observations do not provide clear evidence that Aral dust promotes precipitation. A number of other factors will need to be accounted for to establish the cause-effect relationships in precipitation changes.**



Suggested mechanism:

aerosol scattering increases diffuse component of PAR => increases CO2 sink

<u>Past studies</u>:

***Gu et al*.(2003): volcanic aerosols => increase in CO2 sink**

***Yamasoe et al*.(2006): biomass burning aerosol (Brazil) => increase in CO2 sink**

***Cohan et al*.(2002): anthropogenic aerosols (urban pollution) => increase, decrease or no change in CO2 sink**

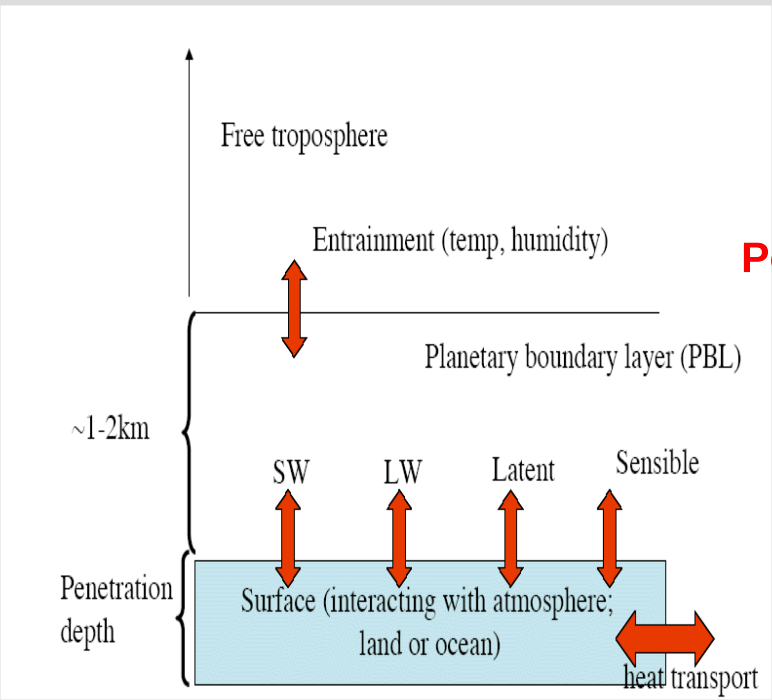
***Niyogi et al*.(2004): rural/continental (6 sites in US) => increase in CO2 sink for forest and crop lands, but decreases for grassland**

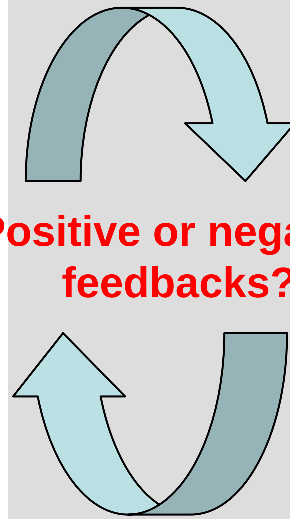
What is the effect of dust?

Dust

Decrease surface SW radiation and increase LW radiation

Decrease or increase photosynthetically active radiation (PAR) (400-700 nm)



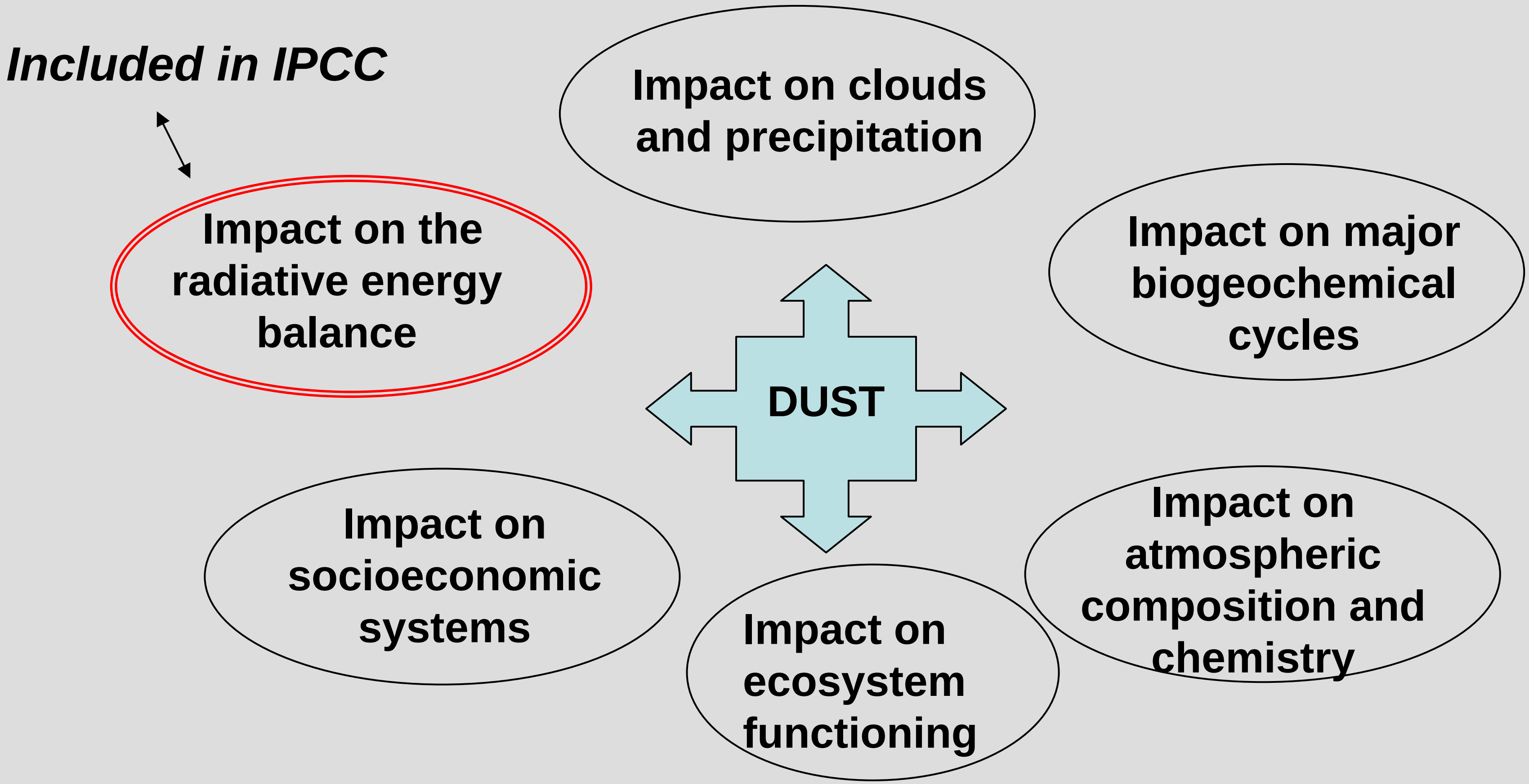


Positive or negative feedbacks?

What is missing: dust deposition on vegetation;
dust impact on ozone and rain acidity, etc.

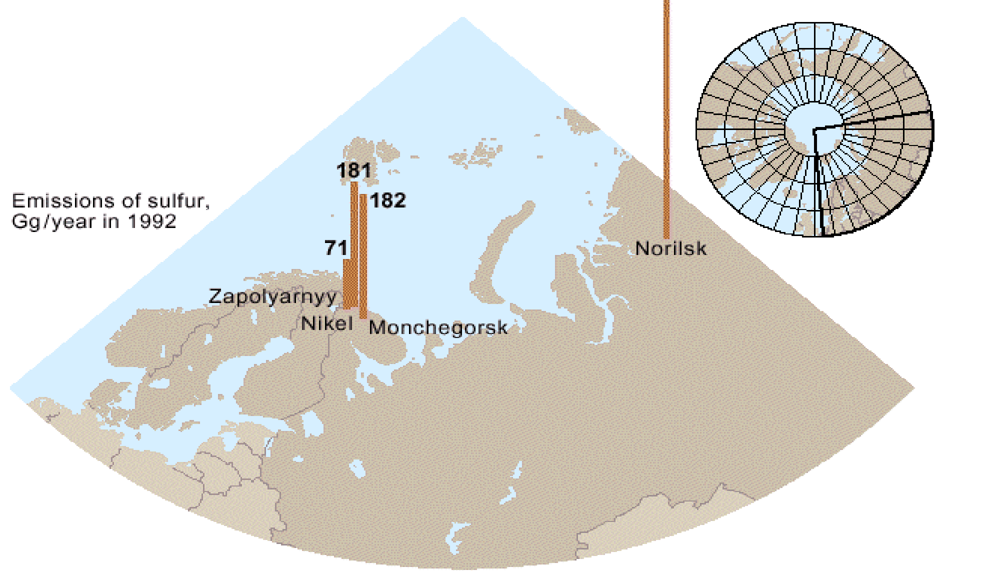
Systems Approach

Many challenges of "do-it- all" models



Air pollution – climate change linkages:

Emissions of sulfur dioxide have decreased considerably in North America and Europe after a peak in the late 1970s and early 1980s. This results from an interplay of political decisions to cut emissions, the replacement of 'dirty' fuels, and new technologies for removing sulfur from fossil fuel and for cleaning flue gases in power plants. Nonetheless, power generation and smelting remain major sources.



Less sulfates more warming?

***Andreae et al*., Nature 2005**

Summary

Climate change and population development in the 21th century are expected to cause increases in atmospheric aerosol concentrations. There is a clear need for improved knowledge of interactions between changing atmospheric aerosols and the Earth Systems to increase confidence in our understanding of how and why the climate and environment have changed and to develop improved predictive capabilities for integrative assessments of climate change in the future.

Why Northern Eurasia?

- The world's largest sources of major aerosol types and air pollutants => strong regional and global signals (via long-range transport, teleconnection)

- Distinct trends in sources and spatial and temporal variability (due to region-specific climatic, economical and political changes)

Focus of NEESPI

Aerosol- and air pollution-induced interactions and feedbacks in the land biosphere-atmosphere system and their role in climate change…

- ***What are the key aerosol- and air pollution-induced processes and feedbacks that have been affecting the energy, water and carbon fluxes over Northern Eurasia (their mechanisms, temporal and spatial scales)?***

- ***How will the future changes in terrestrial ecosystem dynamics, climate and human factors affect the above processes in Northern Eurasia?***

NEESPI FRC AAAP

- **Venue**:

  School of Earth and Atmospheric Sciences (EAS)
  Georgia Institute of Technology, Atlanta, USA

- **Leaders:**

  Irina Sokolik, Robert Dickinson, Judith Curry

- **Two-fold Objectives**:

✓ **Conduct, facilitate, and promote research aimed at improved understanding of interactions between changing aerosols, air pollutants and the Earth systems in Northern Eurasia**

✓ **Education and training**

Starting point for NEESPI FRC on Atmospheric Aerosol and Air Pollution

- **Facilitate and promote:**

- Establish dedicated web site (info on funded projects, research news, discussion forum, data and modeling tools)

- Upcoming Meetings: ESSP meeting, China, Nov. 2006

- Linkages with national and international programs

✓ ***IPY (International Polar Year)***

Endorsed IPY project:

Impact of aerosols on the hydrological cycle in Arctic

(funding: NSF?, NASA ROSES?, DOE ARM?)

✓ **IGBP: iLEAPS and IGAC**

!!!! Unlike GLP or GCP, there is no an Global Aerosol Program

The future of NEESPI:
considered for Integrated Regional Study (IRS) Program within IGBP