Aerosol-Monsoon Water Cycle Interaction

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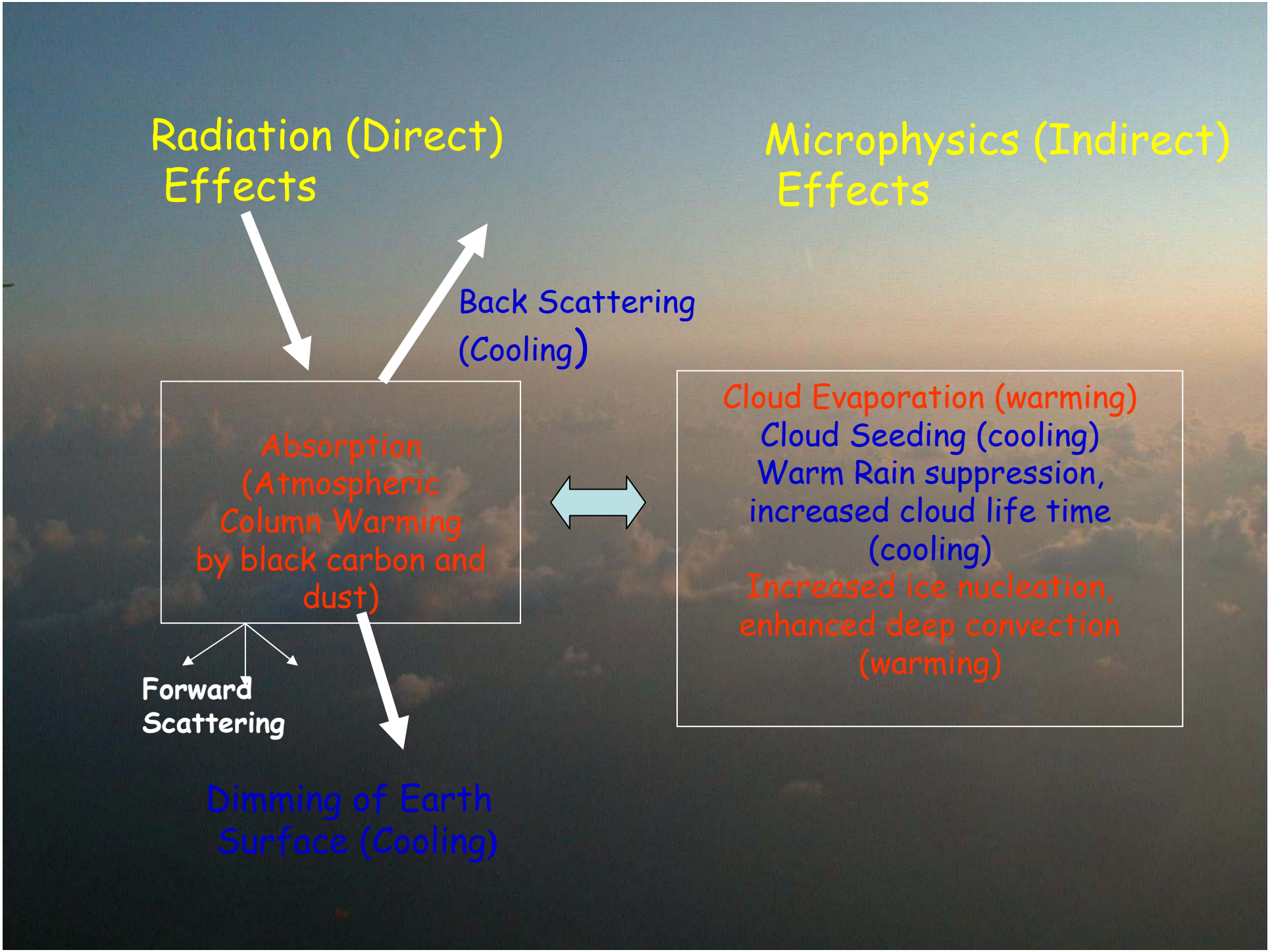
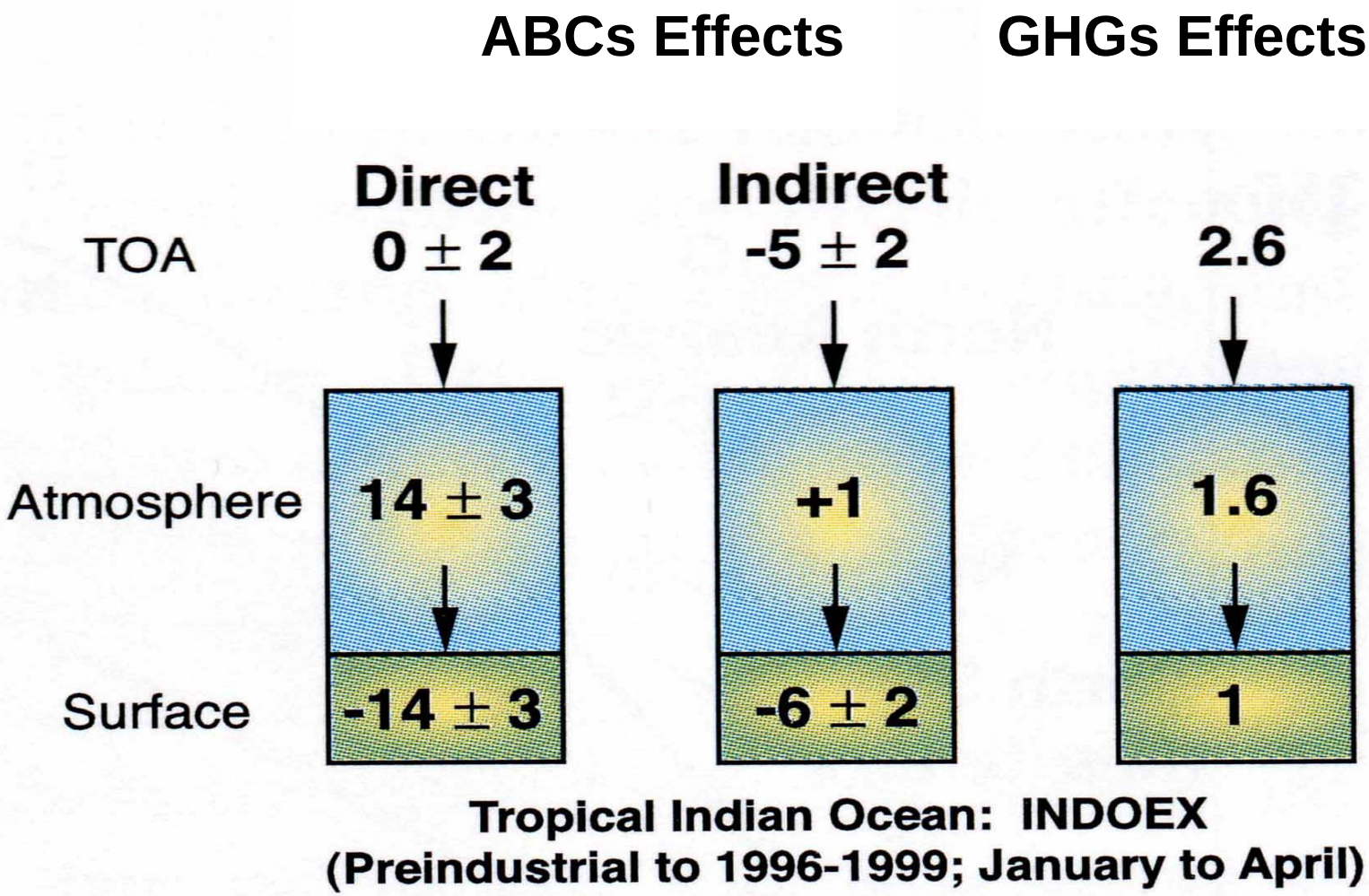
Why do we need joint aerosols-monsoon studies?

- Over 60% of world population live in monsoon regions
- Monsoon related droughts and floods, and aerosols are the two most severe environmental hazards in monsoon regions, e.g. Asia and West Africa
- The monsoon water cycle is driven by atmospheric heating, through the dynamical interaction of wind, moisture, clouds and rainfall.
- Sea surface temperature, and land surface processes alter monsoon water cycle, through generation of surface heating gradients and atmospheric heat sources and sinks.
- Suspended particles (aerosol, clouds, precipitation) in the atmosphere regulate and interact with heat sources and sinks, and alter the monsoon water cycle


Radiation (Direct) Effects
Microphysics (Indirect) Effects
Back Scattering (Cooling)
Absorption (Atmospheric Column Warming by black carbon and dust)
Cloud Evaporation (warming)
Cloud Seeding (cooling)
Warm Rain suppression, increased cloud life time (cooling)
Increased ice nucleation, enhanced deep convection (warming)
Forward Scattering
Dimming of Earth Surface (Cooling)

ABCs and GHGs: Impact on Regional Radiation Budget

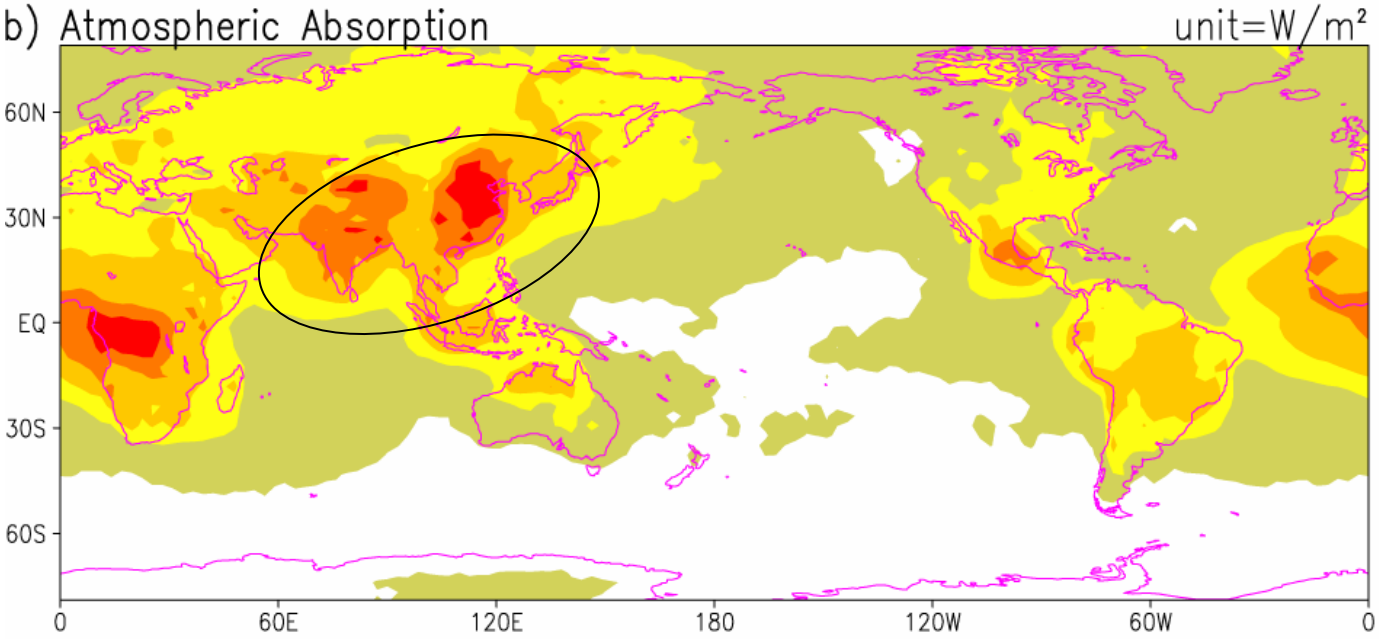


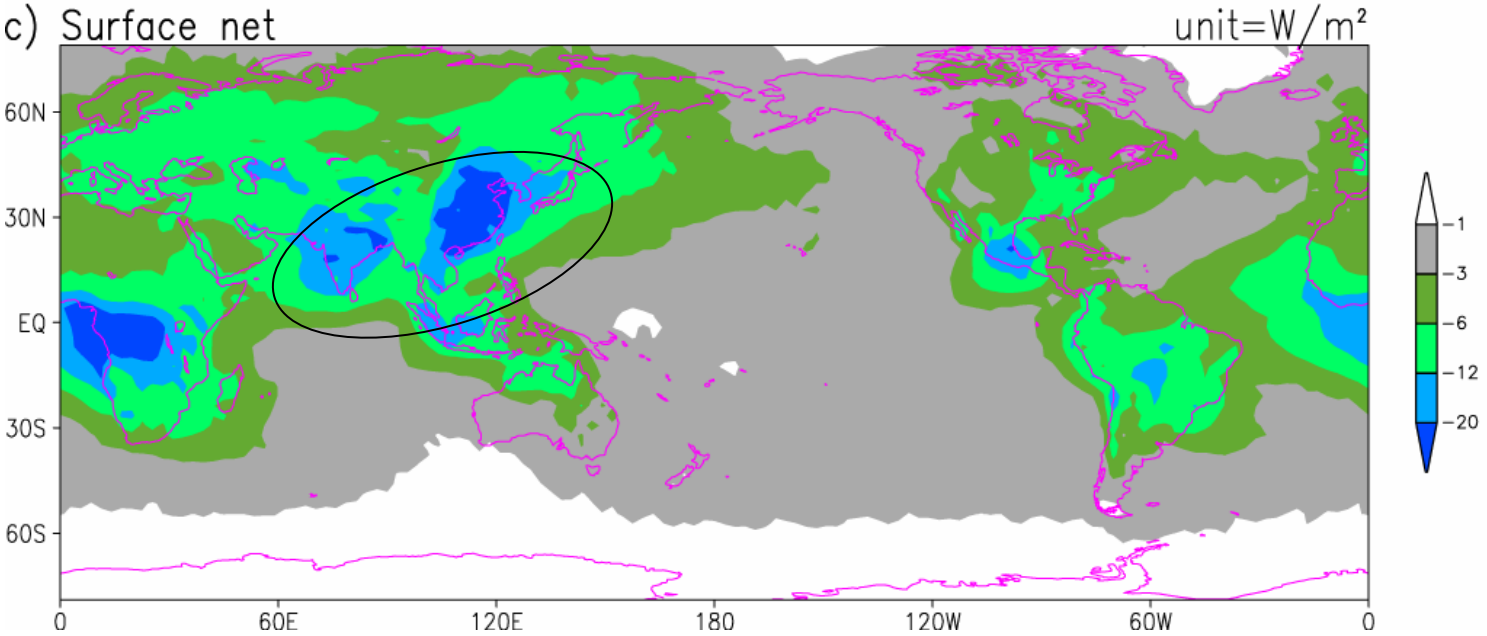
Ramanathan et al, Science 2001

Ramanathan et al 2005 suggested weakening of the Indian monsoon by aerosol solar dimming (direct effects)

Aerosol Induced Dimming: 2002

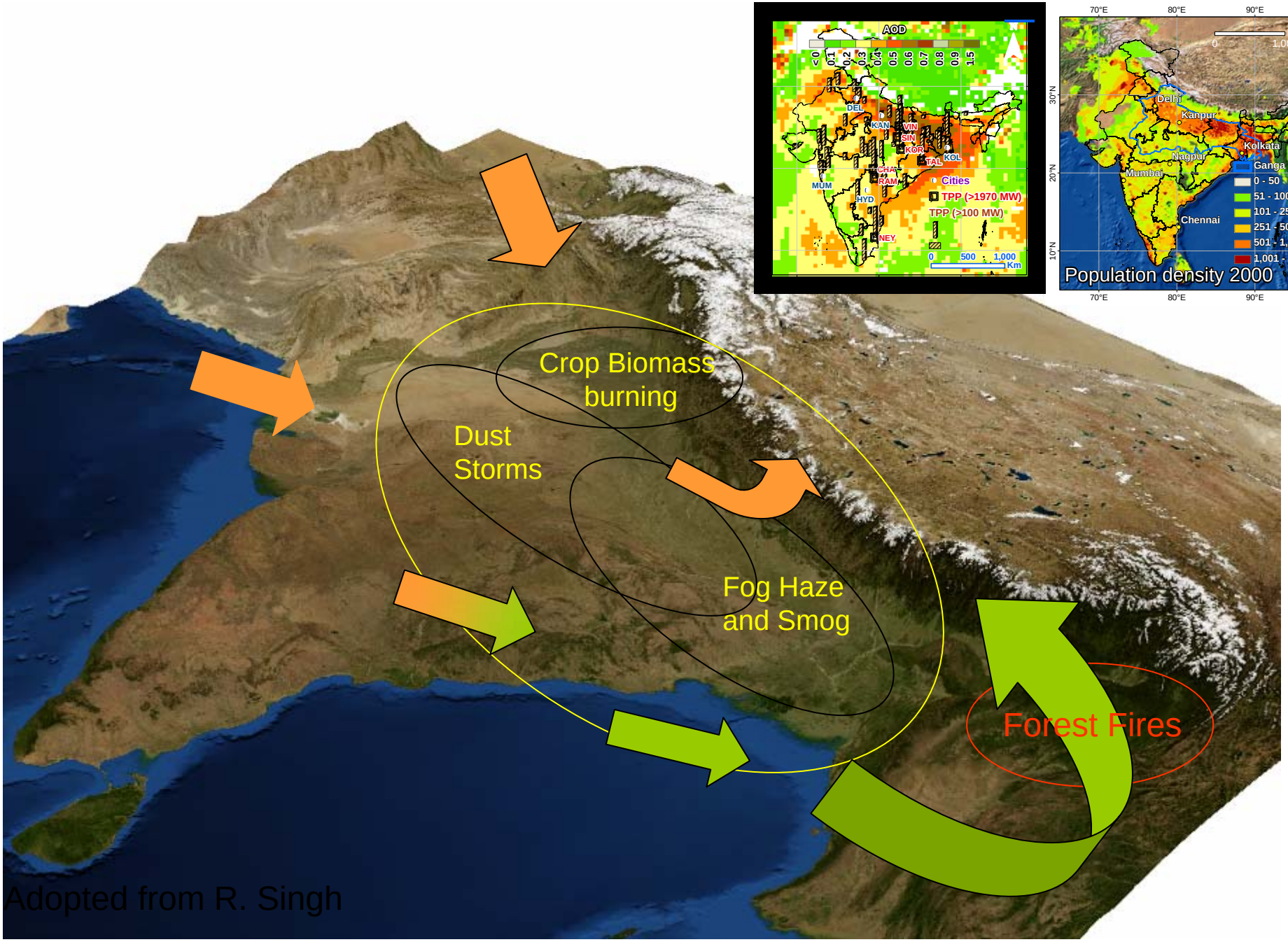
{A Synthesis of ground and satellite observations}





Integration of MODIS/CERES/ISCCP/ TOMS; Ace-Asia; INDOEX; AERONET/ ABC/GEBA/ GOCART/ MACR

Chung, Ramanathan, Kim, Podgorny,2005


AOD
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KAN
VIN
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Cities
TPP (>1970 MW)
TPP (>100 MW)
0 500 1,000 Km
70°E 80°E 90°E
30°N 20°N 10°N
0 1,000 Km
Delhi
Kanpur
Kolkata
Nagpur
Mumbai
Chennai
Ganga Basin
0 - 50
51 - 100
101 - 250
251 - 500
501 - 1,000
1,001 - 122,755
Population density 2000
Crop Biomass burning
Dust Storms
Fog Haze and Smog
Forest Fires
Adopted from R. Singh

Goddard Space Flight Center

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FEATURE

Hot Dust and Moisture Collide to Fuel Asian Summer Rainy Season **09.07.06**

Who would think that something like dust in the air could trigger rain? According to a new NASA study, this is just what's happening over South Asia's Tibetan Plateau. Very small dust particles called aerosols blow in from desert regions and collect in the atmosphere over the plateau's slopes early in the region's monsoon season, helping trigger rainfall.

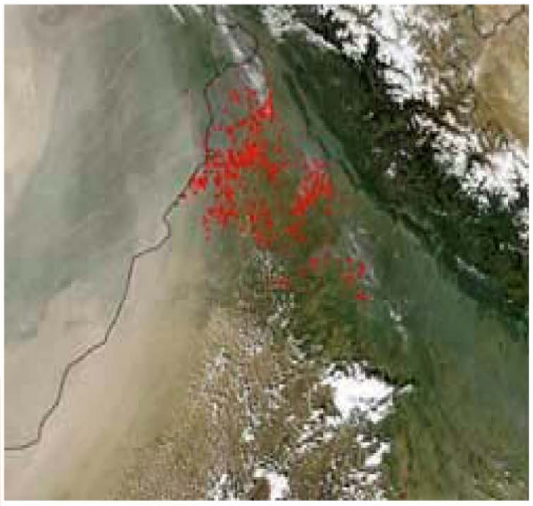


Image right: Dust and smoke from fires (red points) over northwestern India/Pakistan may contribute to a change in rainfall patterns over the region. **Click image to enlarge.** Credit: NASA

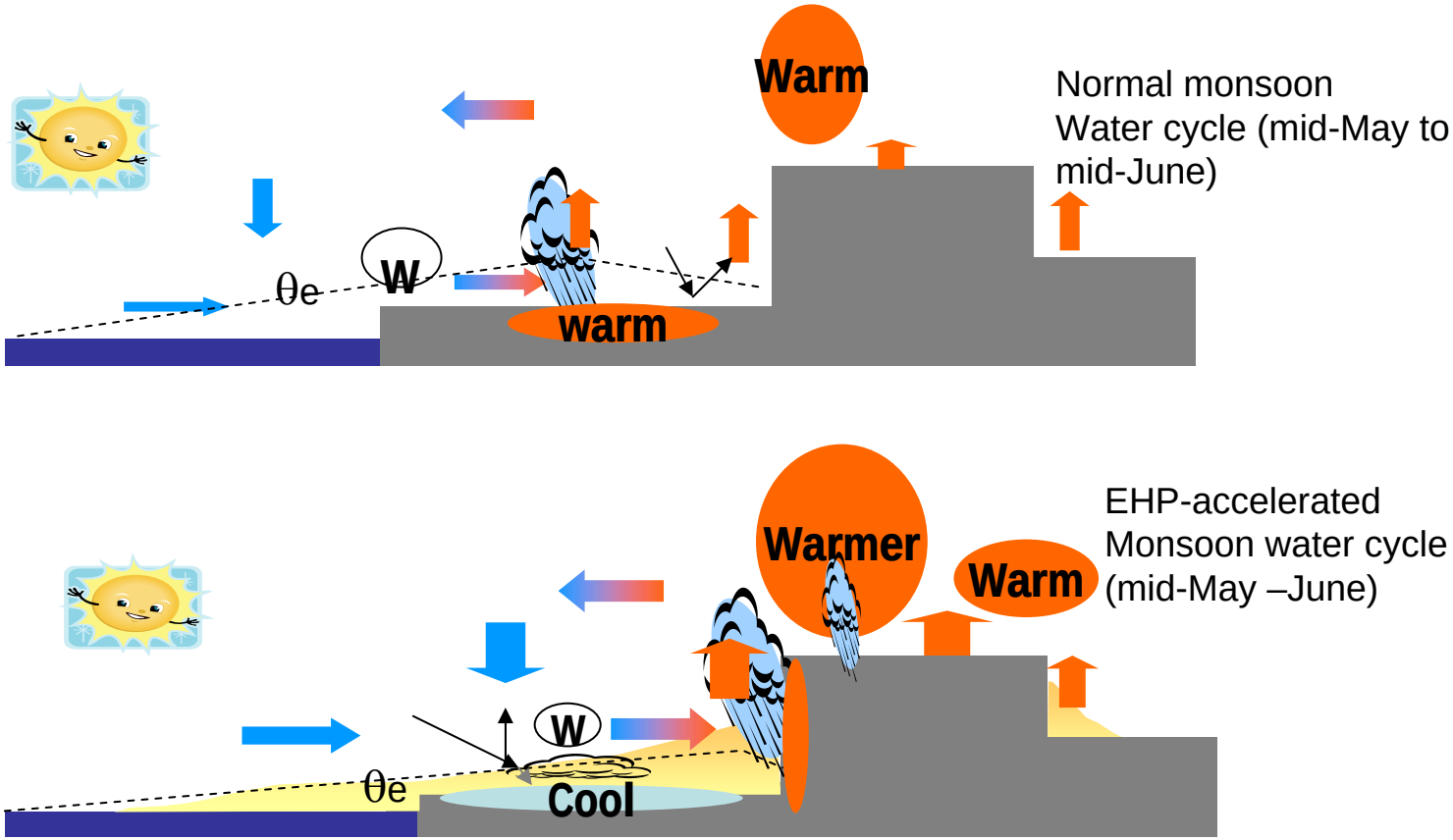
A monsoon is a seasonal shift in wind direction that alternately brings very wet and then very dry seasons to India and much of Southeast Asia.

William Lau, research scientist at NASA's Goddard Space Flight Center, Greenbelt, Md. and his team studied the aerosols using computer models. They found aerosols in the form of dust lofted from the desert surface and transported to the monsoon region can heat the air by absorbing the sun's radiation, altering the Asian monsoon water cycle. Black carbon particles from industrial emissions, bio-fuel burning and forest fires can add to this warming effect by absorbing the sun's radiation and heating the air currents transporting those aerosols. In some instances, black carbon coats the dust amplifying the heating effect because black carbon absorbs solar radiation more efficiently than dust. Rains from this annual weather cycle are a lifeline to over 60 percent of the world's population. Up to now, scientists have understood very little about how aerosols interact with the atmosphere to influence monsoons.

Lau's computer simulations indicate both of these light-absorbing and heat emitting aerosols, when mixed together with warm air currents and moisture, cause a heating effect in the air, triggering the rainy season

Lau et al., 2006: Effects of aerosols on Asian monsoon anomalies: The role of the Tibetan Plateau. *Climate Dynamics*.
Lau and Kim, 2006: Observational relationship between aerosol and Asian monsoon rainfall and circulation, *GRL*

The Elevated Heat Pump (EHP) hypothesis (Lau et al. 2006, Lau and Kim 2006)

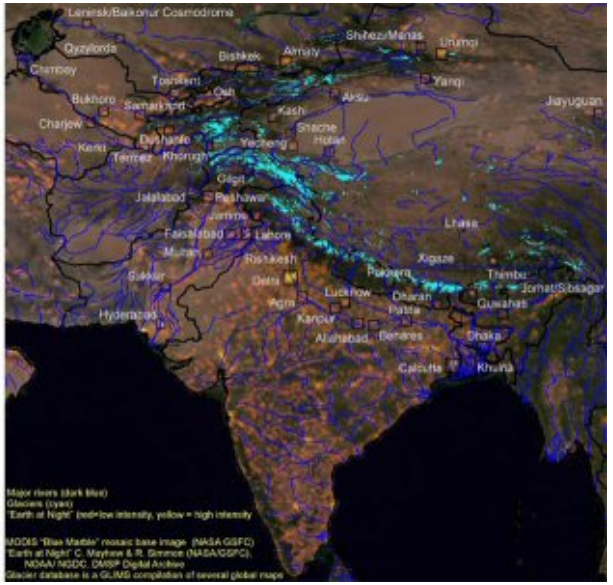


EHP postulates: a) an advance of the rainy season in northern India/Napal region in May-June
b) In July-August, the increased convection spreads from the foothills of the HImalayas
to central India, resulting in an intensification of the Indian monsoon.

Possible consequences/signals of the "Elevated Heat Pump" effect

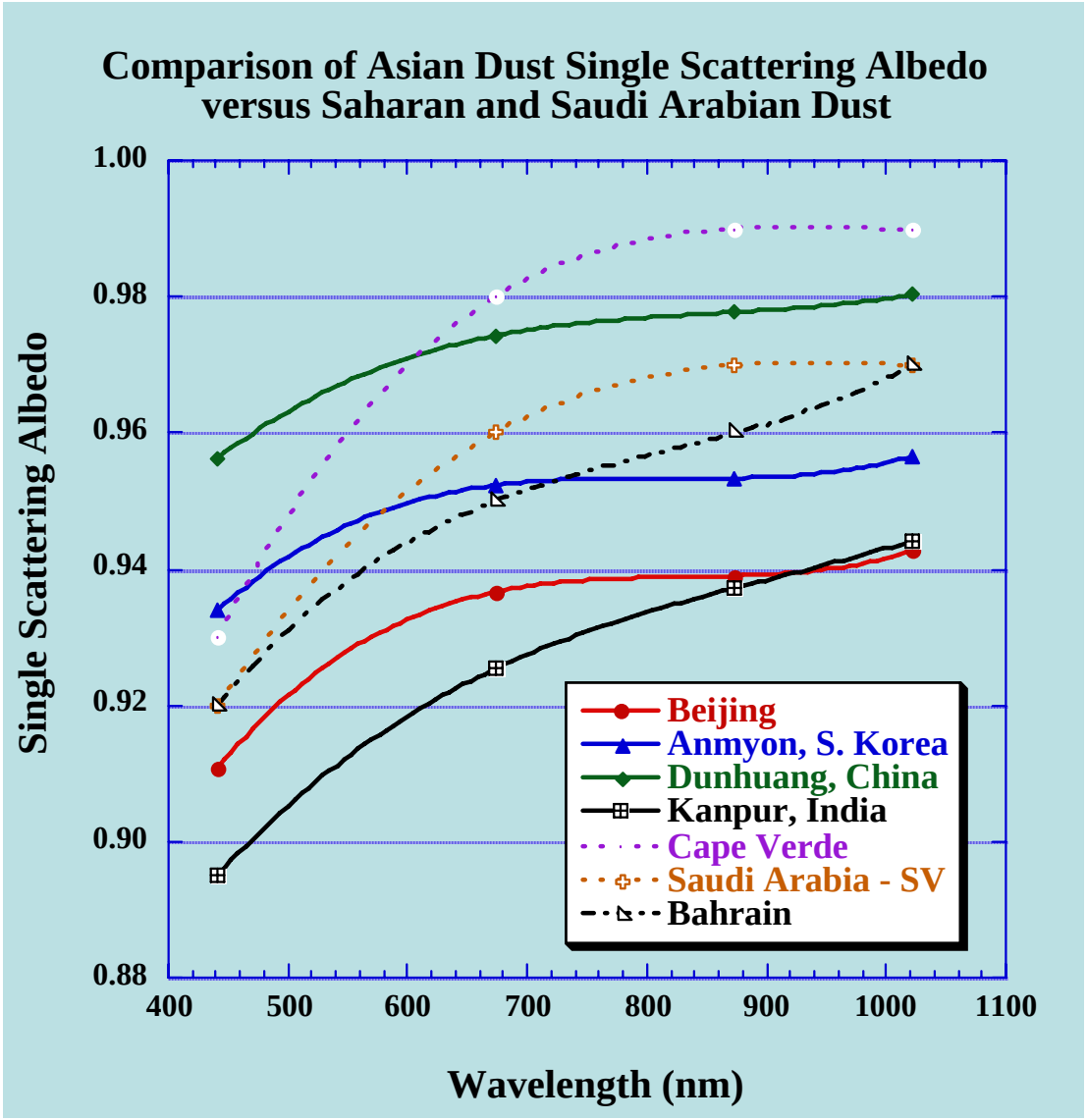
After major dust storm and/or as a long-term (decadal) trend:

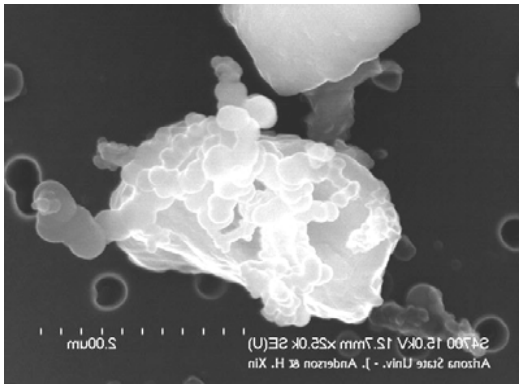
- Increased deep convection in the southern part of the TP, leading up to the monsoon onset
- Advance of monsoon rainy season, more rain in northern India/Nepal region in May-June; strengthening of Indian monsoon in June-July
- Weakening of the East Asian monsoon (Mei-yu rainfall), through large scale dynamical adjustment to EHP heating associated with a westward shift of the West Pacific subtropical high
- Accelerate the melting of mountain glacier→ expose land surface →surface warming → increased sensible heat flux → increased EHP
- Increased water vapor in the upper troposphere, and lower stratospheric, increased trend of stratospheric ozone hole over TP

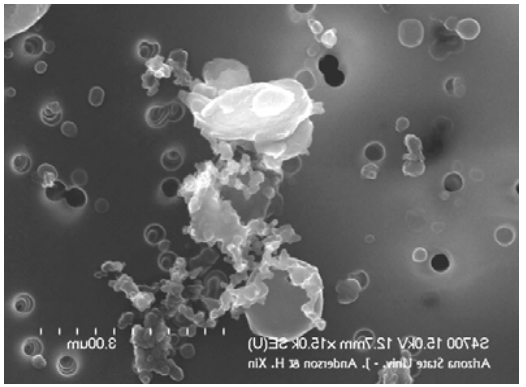


Dusts over big industrial cities are more absorbing (solar radiation)

More absorbing







Micrographs of soot coating and aggregate on mineral dust from Asian dust (courtesy of J. Anderson)

T. Eck et al 2004

Key findings of the Workshop on "Effect of elevated aerosols on radiation and dynamics of the Asian monsoon" July 31-August 4, 2006, Xining/Lhasa, China. (Sponsored by GEWEX/CEOP, NSFC/MOST, CAS)

- Aerosol-Monsoon interaction is an extremely complex, multi-scale, physical/chemical/hydrological interactions
- It may be the key to better understand and prediction of climate variability and change, *particularly in monsoon land regions*
- Aerosol and monsoon research communities need to work closer together
- International coordination, leveraging on national plans is essential

Joint Aerosol-Monsoon Experiment (JAMEX), 2007-2011

- *A 5-year (2007-2011) plan derived from grass-root planning, with the objective to unravel the physical, chemical and multi-scale interactions associated with aerosol-monsoon water cycle in the Asian Indo-Pacific region aiming at better understanding of climate change impacts and improved prediction of the Asian monsoon*

JAMEX will address the key science question: How do aerosols (natural and anthropogenic) affect the Asian monsoon water cycle?

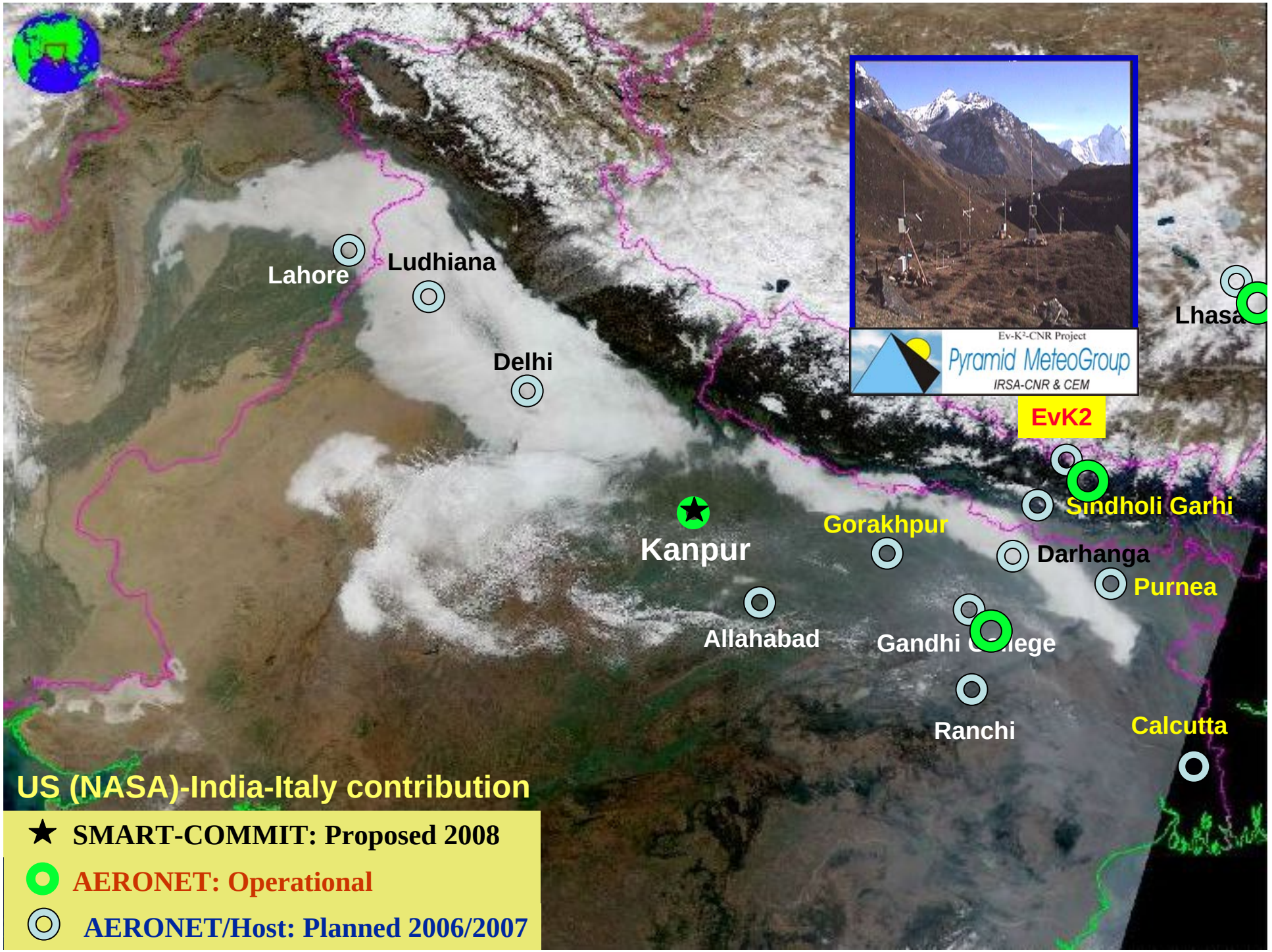
- "Solar dimming" effect on land and ocean surface, may weaken the Indian monsoon (Ramananthan et al 2005…)
- "Elevated Heat Pump" effect may strengthen the Indian monsoon in May-June, but weaken the East Asian monsoon (Lau et al 2006, Lau and Kim 2006).
- Transport of dusts, soot from deserts, semi-arid regions to monsoon regions
- Microphysics effects on clouds and rainfall from natural sources (dust storms and biomass burning) mixing with anthropogenic aerosols (soot, sulphate)
- Coupled atmosphere-land hydrology effects: feedback from melting of dirty snow and mountain glaciers in high mountain terrains e.g. Nepal, Pakistan, Qinghai-Tibet Plateau
- Coupled Ocean-Atmosphere effects (e.g. SSTA from El Nino) on aerosol forcing and response

JAMEX calls for the establishment of a multi-national science working group to:

- Identify key uncertainties in natural and anthropogenic aerosol forcing and impacts in monsoon regions
- Coordinate joint aerosol-monsoon long-term observation platforms, with a Special Observing Period in 2008-9 to measure winds, temperature, moisture, aerosols physical, chemical and transport processes
- Develop a strategy for aerosol-monsoon dynamical system investigations to stimulate collaboration among national and international monsoon observational, modeling programs, and operational centers.
- Promote greater synergism between Asian regional aerosol and monsoon research programs through more efficient use of limited resources

Potential contributors/partners to JAMEX

- Asia and Indo-Pacific Ocean (AIPO) Project, China (poc: GX Wu)
- Aerosol Research Project (ARP), China (poc: X. Zhang)
- Continental Tropical Convergence Zone (CTCZ), STORM, India (poc: D. Sikka/S. P. Rao)
- MAHARSRI, Japan (poc: J. Matsumoto)
- Atmospheric Brown Cloud (ABC) (poc: V. Ramanathana)
- Pacific Aerosol-Cloud-Dust Experiment (PACDEX) (poc: J. Stitch, V. Ramanathan)
- East-AIRE, US(DOE)-China (poc. Z. Li, U. Md)
- Stations at High Altitude for Research on the Environment of Asia (SHARE-Asia), Italy (poc. G. Tatari)
- Radiation, Aerosol Joint Observation – Monsoon Experiment over the Gangetic Himalayas Area (Rajo-Megha) (poc. S. C. Tsay, NASA)
- Monsoon Asia Integrated Regions Studies (MAIR) (poc: C.B. Fu, China)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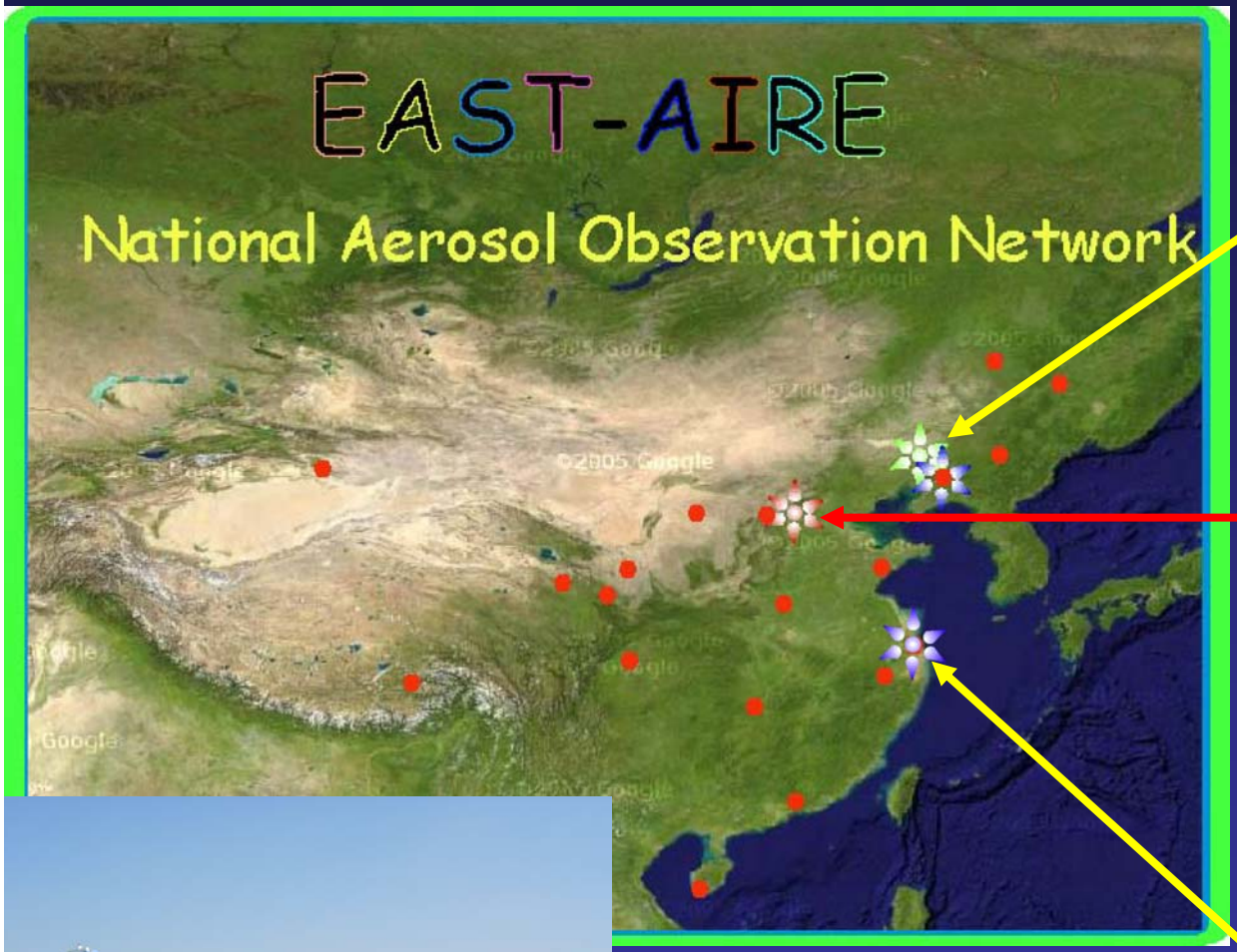
Lhasa
Sindholi Garhi
EvK2
Ev-K²-CNR Project
Pyramid MeteoGroup
IRSA-CNR & CEM
US (NASA)-India-Italy contribution
SMART-COMMIT: Proposed 2008
AERONET: Operational
AERONET/Host: Planned 2006/2007

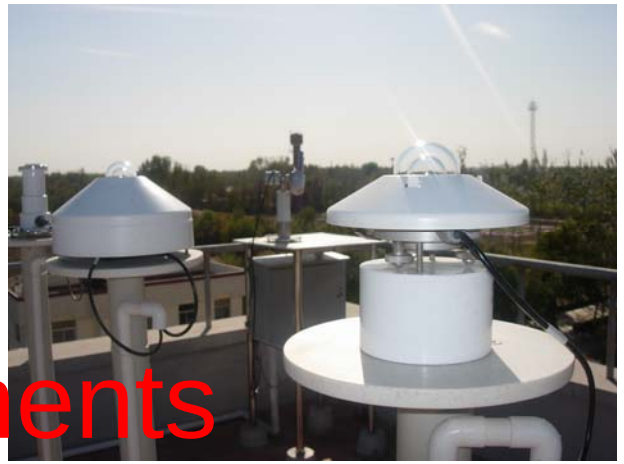
EAST-AIRE Observational Activates



US(DOE)-China contribution

http://www.atmos.umd.edu/~zli



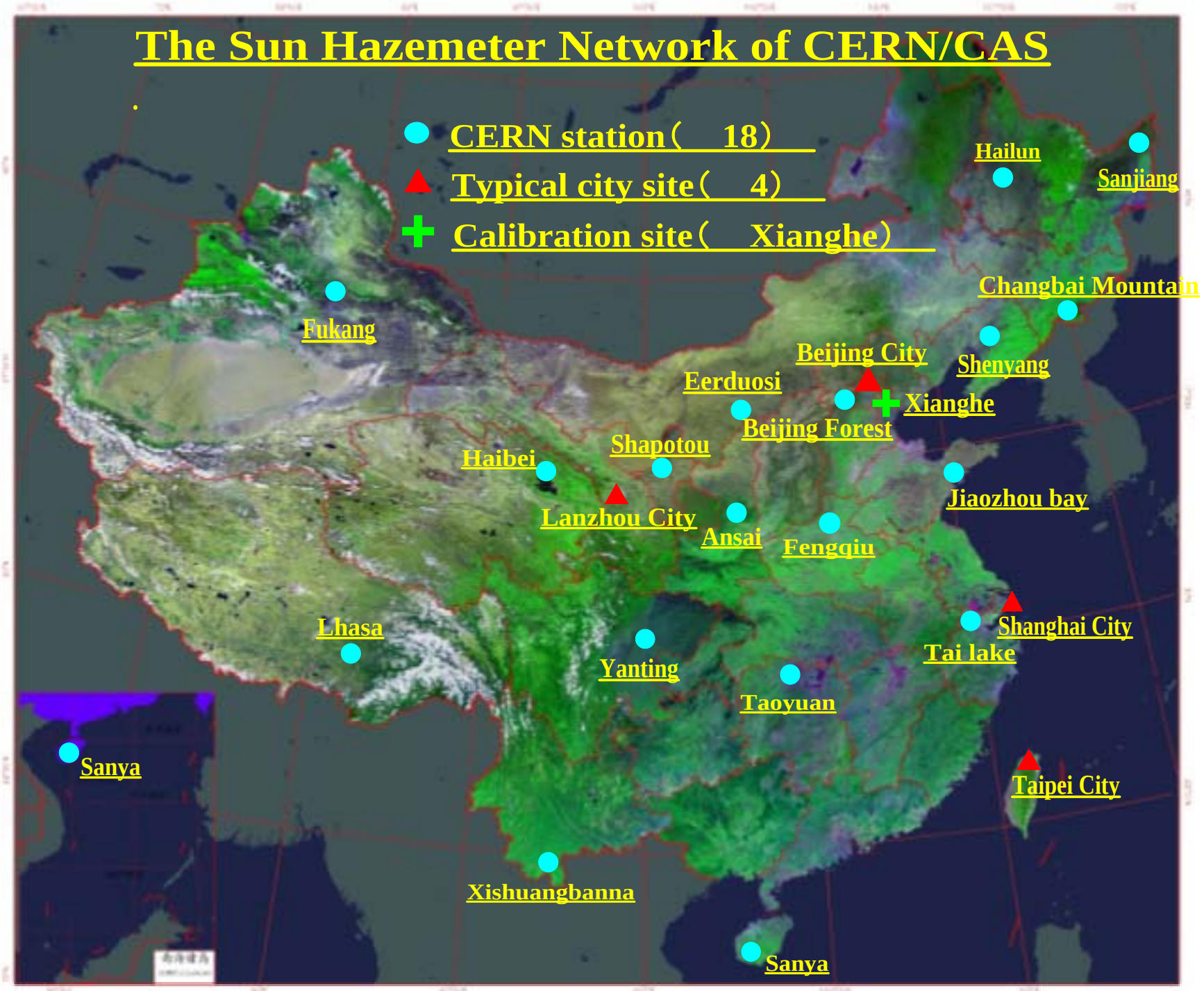


Radiation Instruments

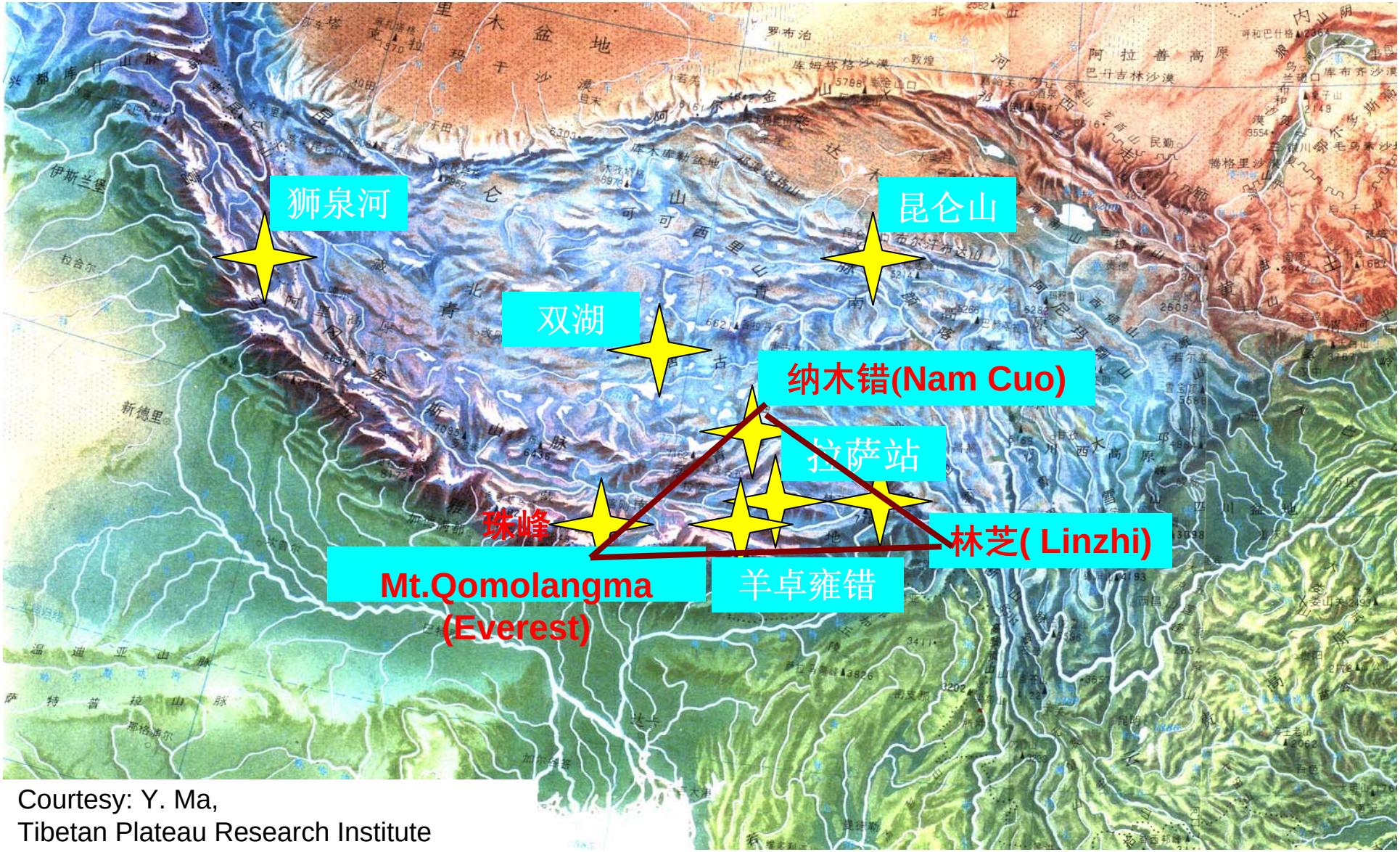

Aerosol Instruments



Cloud Instruments


The Sun Hazemeter Network of CERN/CAS
CERN station（ 18）
Typical city site（ 4）
Calibration site（ Xianghe）
Hailun
Sanjiang
Changbai Mountain
Fukang
Beijing City
Shenyang
Eerduosi
Xianghe
Beijing Forest
Shapotou
Haibei
Jiaozhou bay
Lanzhou City
Ansai
Fengqiu
Shanghai City
Lhasa
Tai lake
Yanting
Taoyuan
Sanya
Taipei City
Xishuangbanna
Sanya

MORP MOnitoring and Research Platform in Tibetan Area

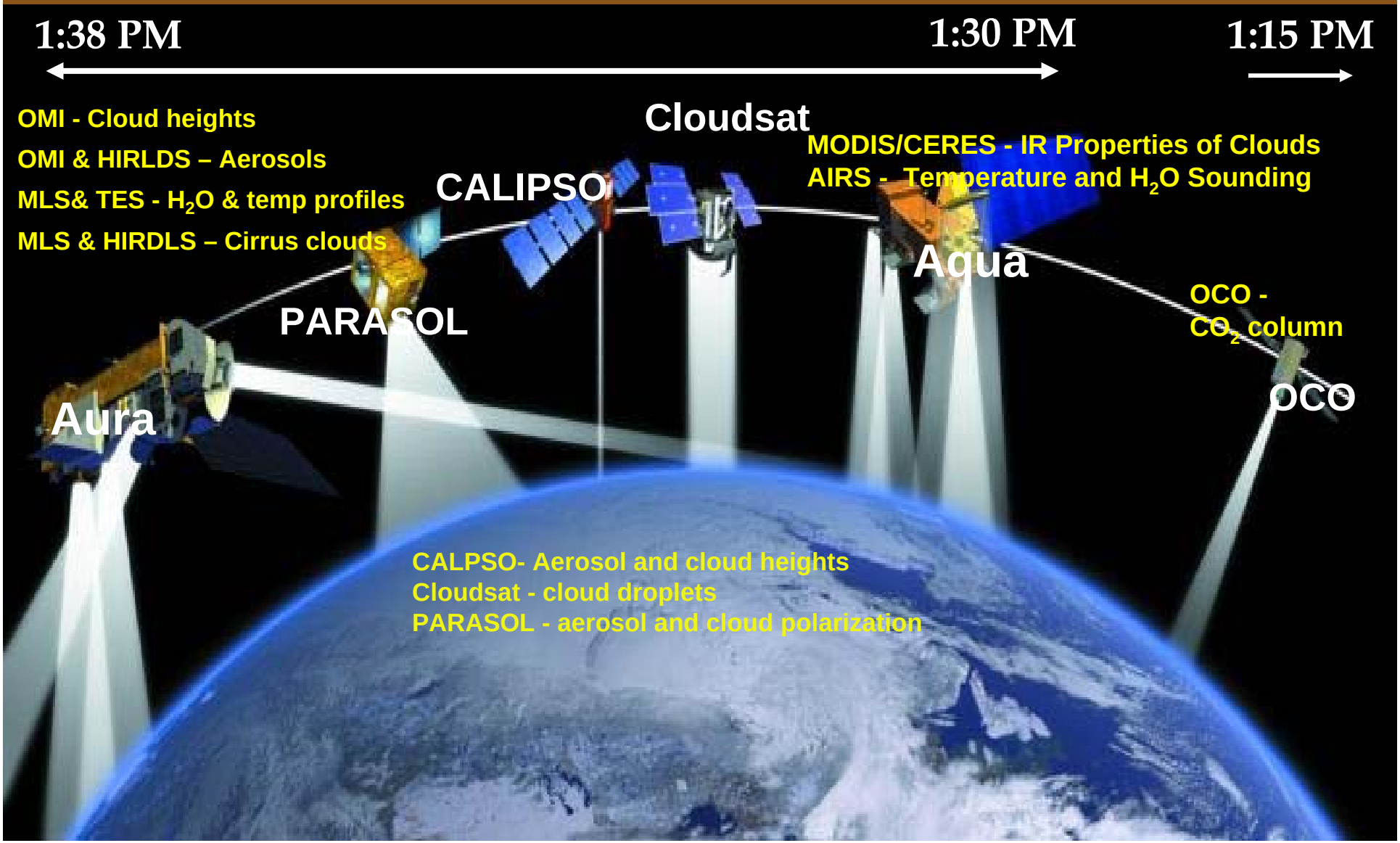


Courtesy: Y. Ma,
Tibetan Plateau Research Institute

SHARE – Asia Environmental Network

Courtesy G. Tartari, Ev-K2-CNR, Italy

Near Future Afternoon Constellation of the "A-Train"

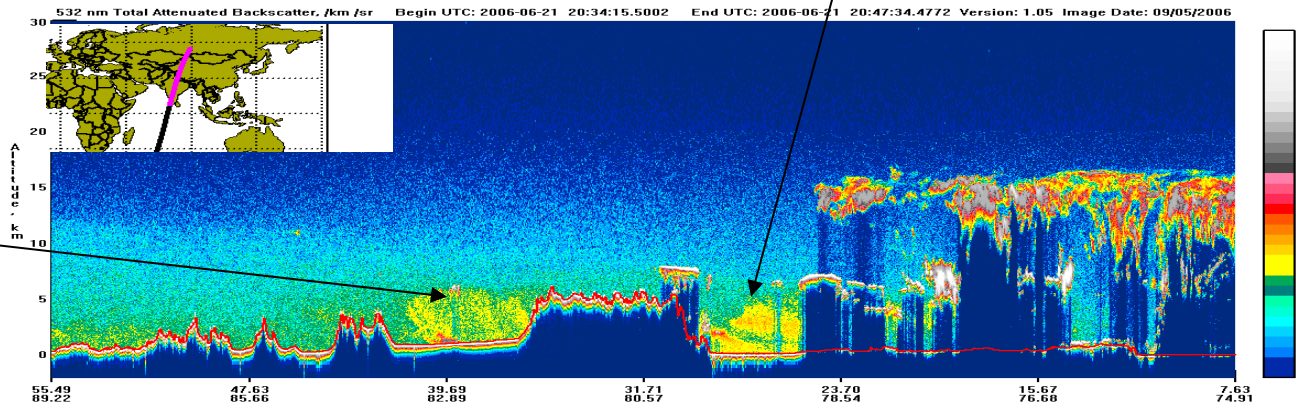


Merdional cross-section of aerosol concentration from Calipso

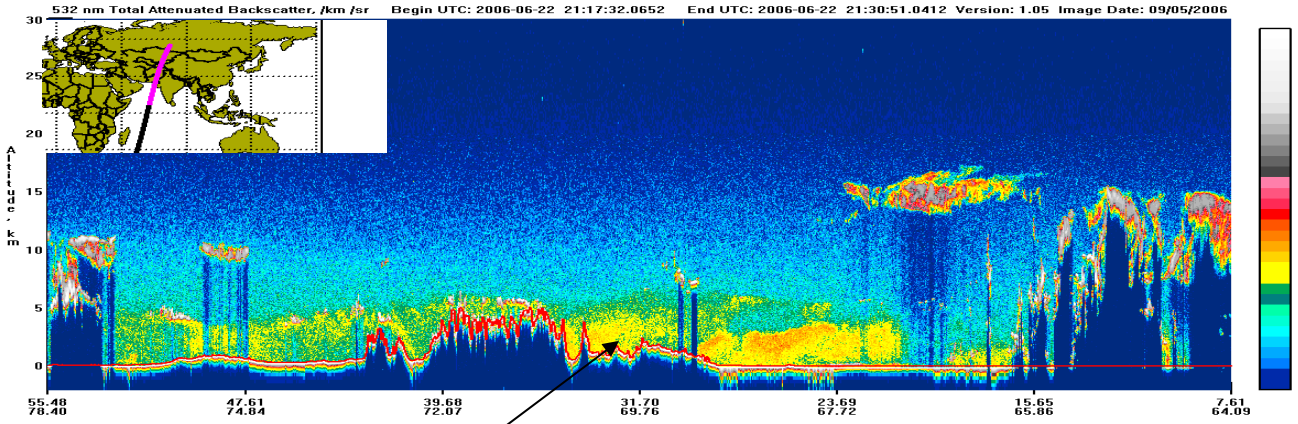
June 21,2006

Indo-Gangetic Basin

Taklamakan Desert



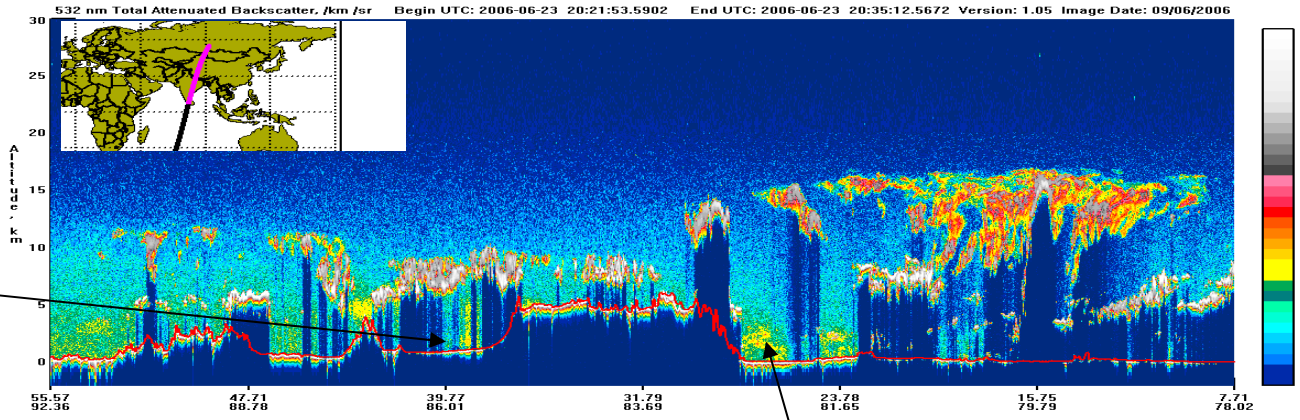
June 22, 2006



northeastern IGB

Merdional cross-section of aerosol concentration from Calipso

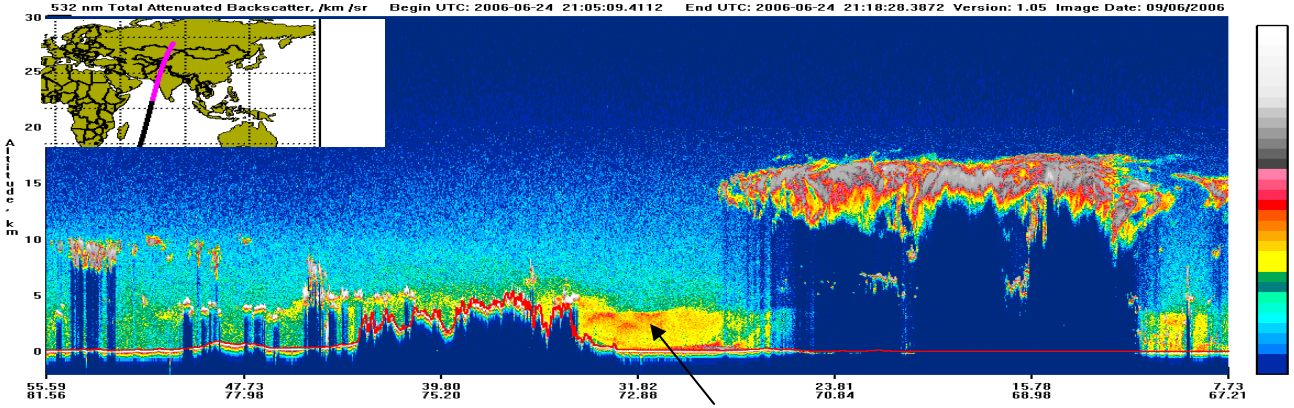
June 23 2006



Taklamakan Desert

IGB

June 24, 2006



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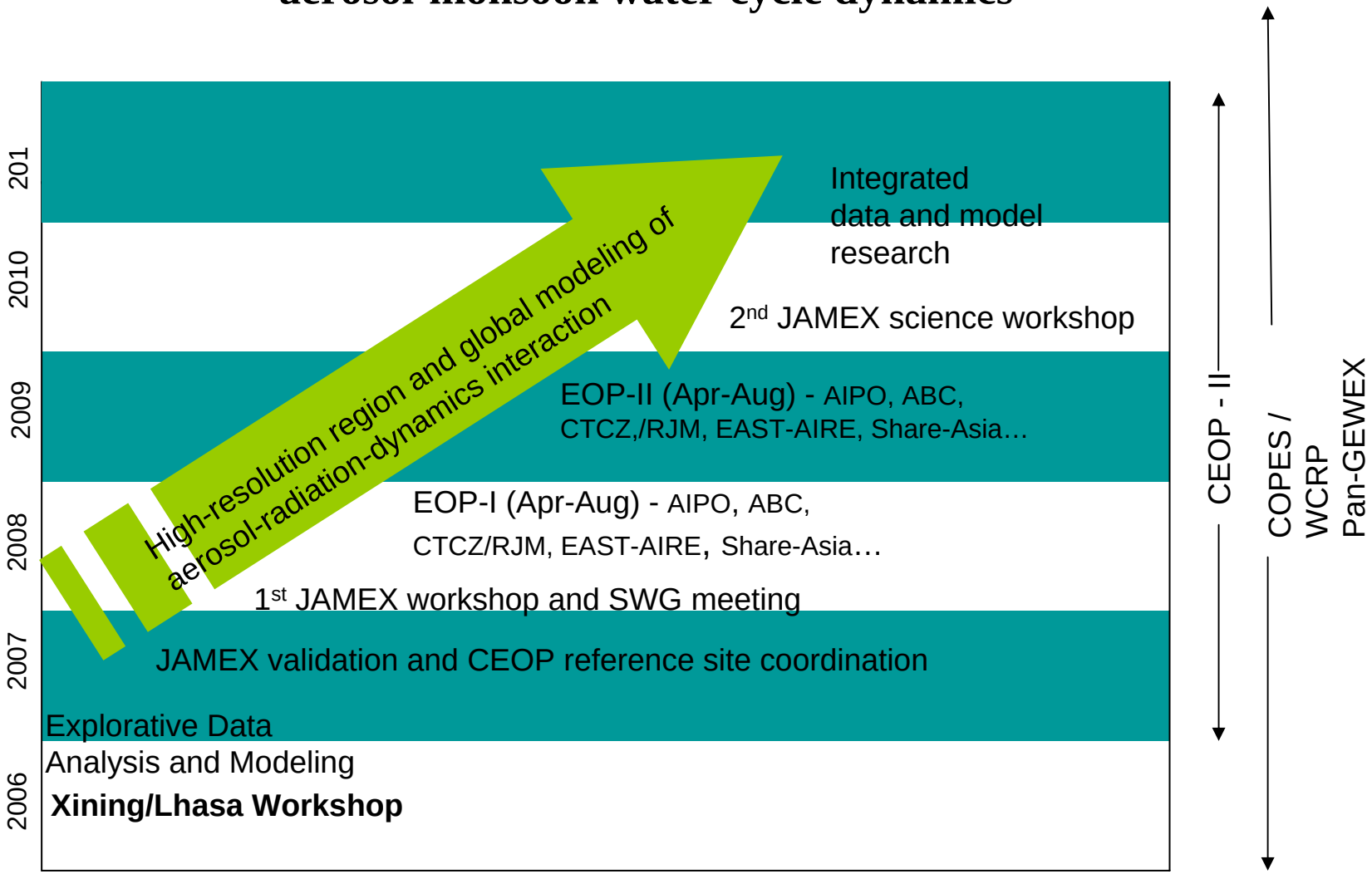
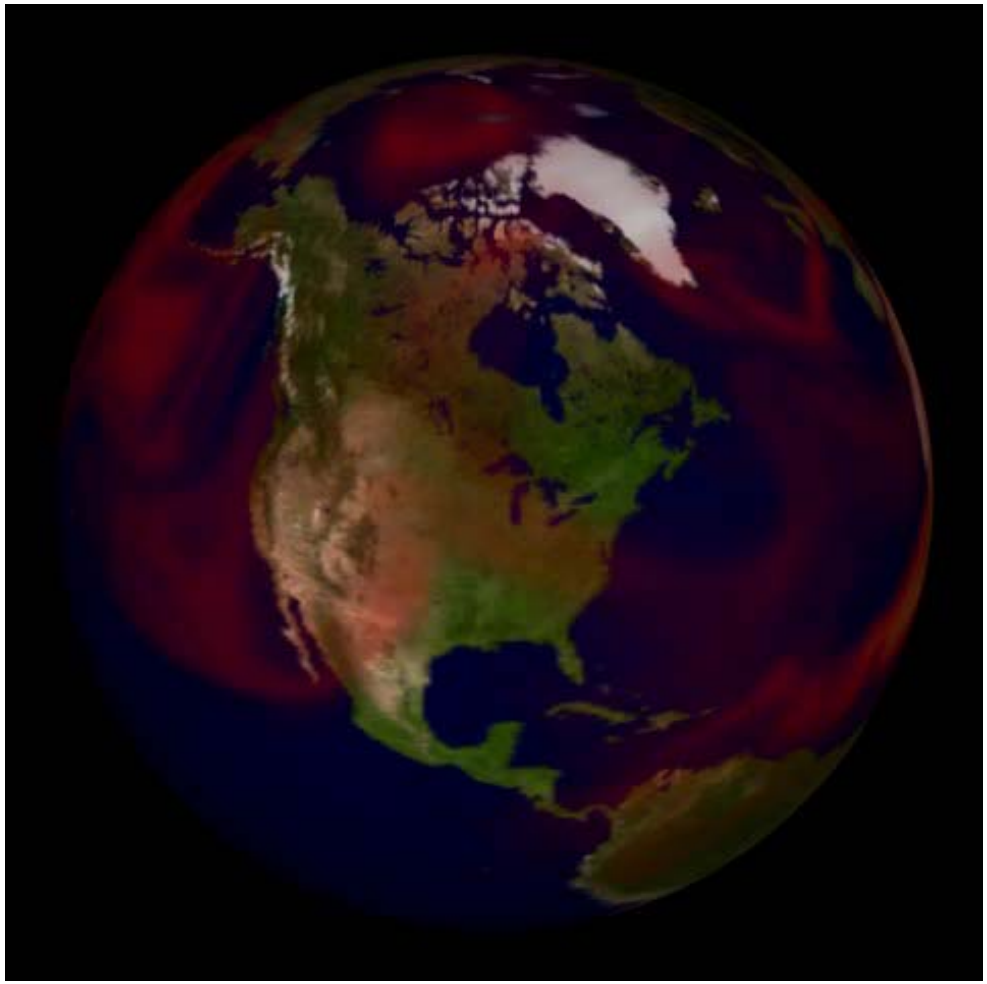
Joint Aerosol-Monsoon Experiment (JAMEX) – a multi-national integrated observation modeling effort to study aerosol-monsoon water cycle dynamics



We need High-Resolution global GCM with Interactive Aerosols with Improved aerosol Microphysics to better understand Aerosol- Monsoon Water Cycle Interactions



NASA GEOS5 model 5-day forecast of dust emission and transport (May 1-5, 2006)

Please submit your paper

Special Session in "Aerosol-Monsoon Interaction" in IUGG/IAMAS, July 6 2-13, Perugia, Italy.

Abstract submission deadline: January 31, 2007

Co-Convener: W. Lau, and V. Ramanathan