



(Southern) Asian Pollution Outflow: A Historical Perspective

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ACAM Training School
Bangkok, 11 June 2015

Mission

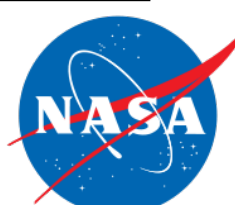


Coordinating and fostering atmospheric chemistry research toward a sustainable world.

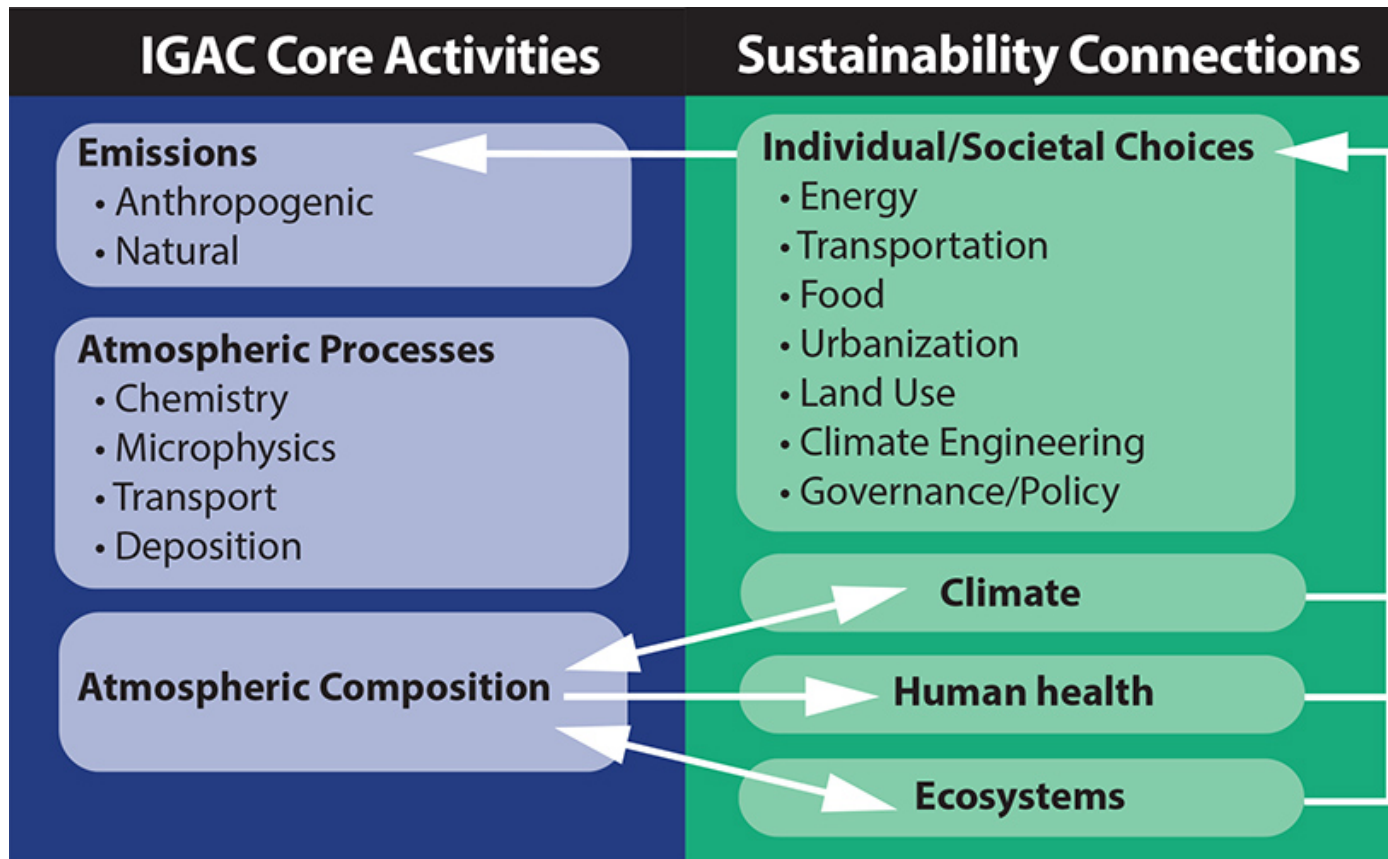
GLOBAL
IGBP
CHANGE



Thanks for Funding
(for Project Office etc.) from:

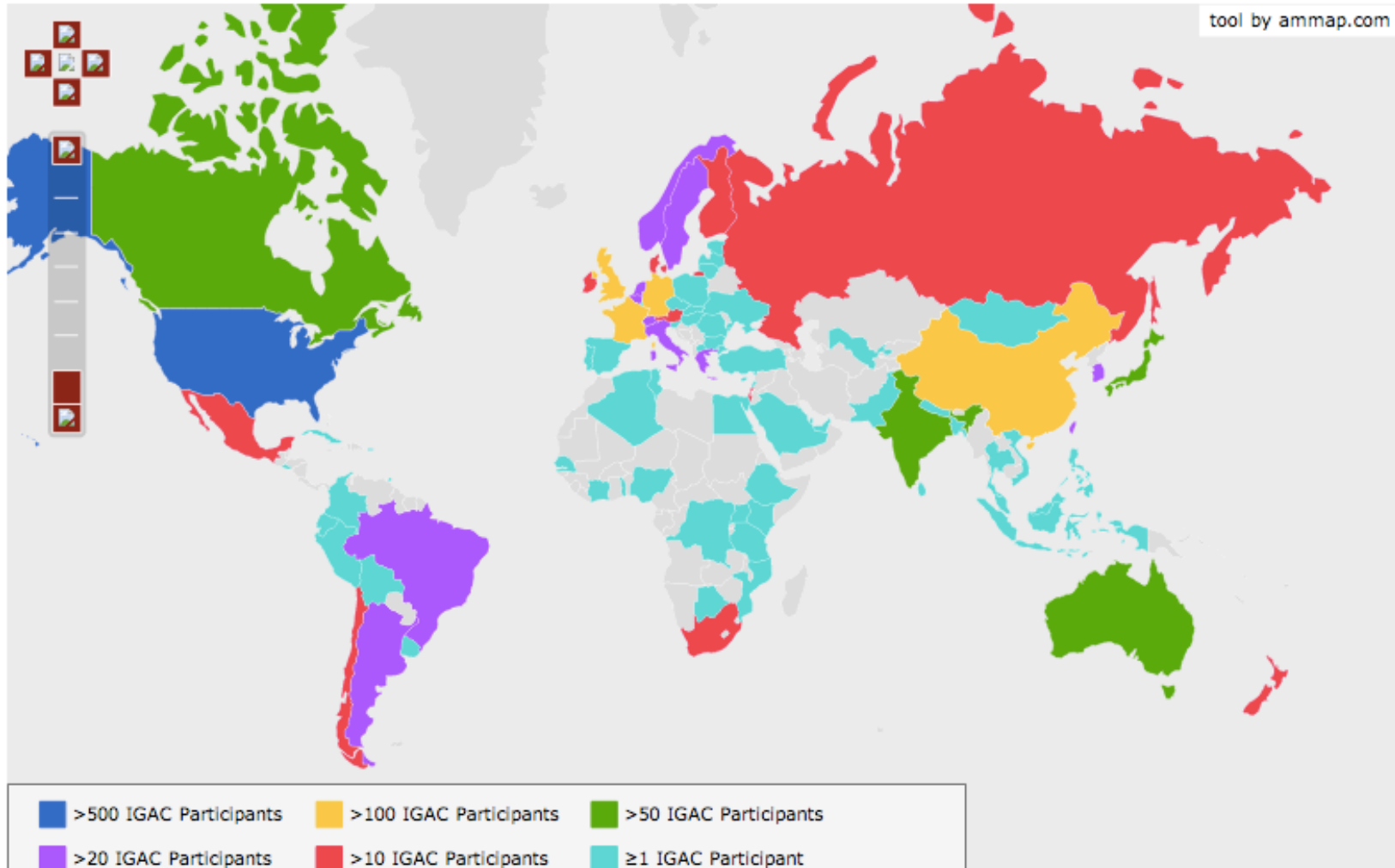


Vision



COMMUNITY

(out of ~3000 mailing list subscriptions as of 2012)



An International Scientific Steering Committee oversees all IGAC Activities:

- 18-19 members
- Currently 6 from Asia and Oceania
- Several here this week (incl. Nguyen Thi Kim Oanh, Hiroshi Tanimoto, Candice Lung, Mary Barth, Jim Crawford, and me)
- Executive Officer: *Megan Melamed*
- Liaisons from IGBP, iCACGP, WMO, SPARC, SOLAS and ILEAPS

IGAC Activities



Capacity Building



IGAC Science Conferences



**8th International
Global Atmospheric
Chemistry Conference**

4 – 9 September 2004
Christchurch, New Zealand

- 2002 Crete, Greece (joint with iCACGP)
- 1999 Bologna, Italy
- 1998 Seattle, WA USA (joint with iCACGP)
- 1997 Melbourne, Australia (joint with iCACGP, IAPSO)
- 1995 Beijing, China
- 1994, Fuji-Yoshida, Japan (Joint with iCACGP)
- 1993 Eilat, Israel

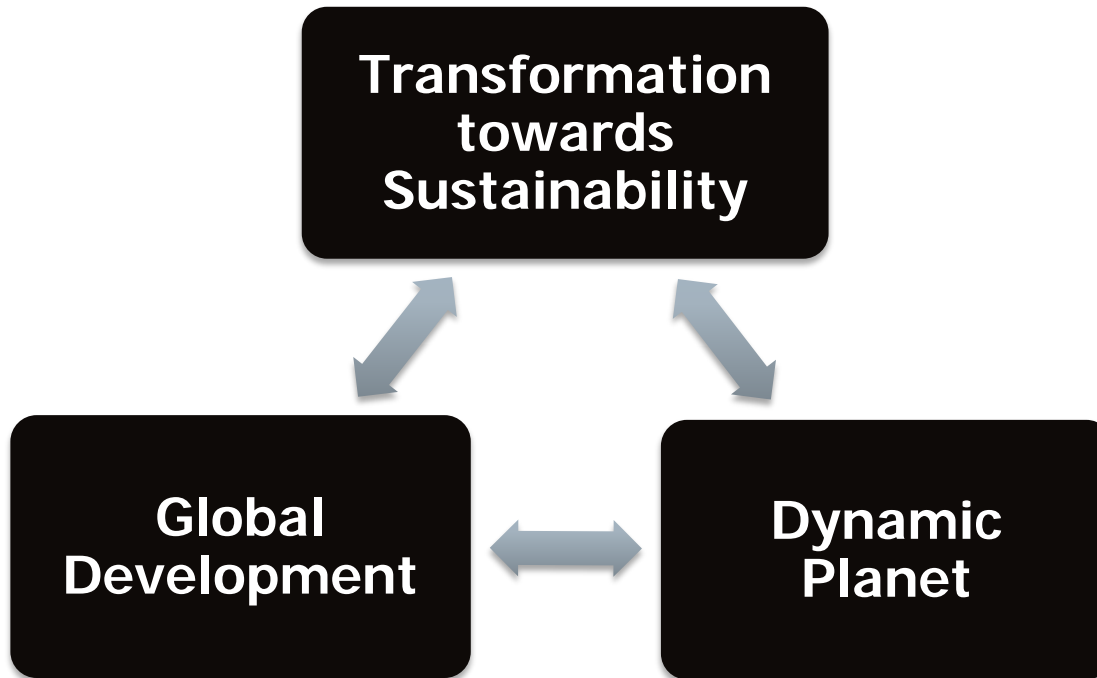
National/Regional Working Groups



**Japan
National
Committee**



***Monsoon Asia and Oceania
Networking Group
(MANGO)***



Combining:

- IGBP
- IHDP
- Diversitas
- (WCRP – “observer”)

Co-funded by a global alliance of partners

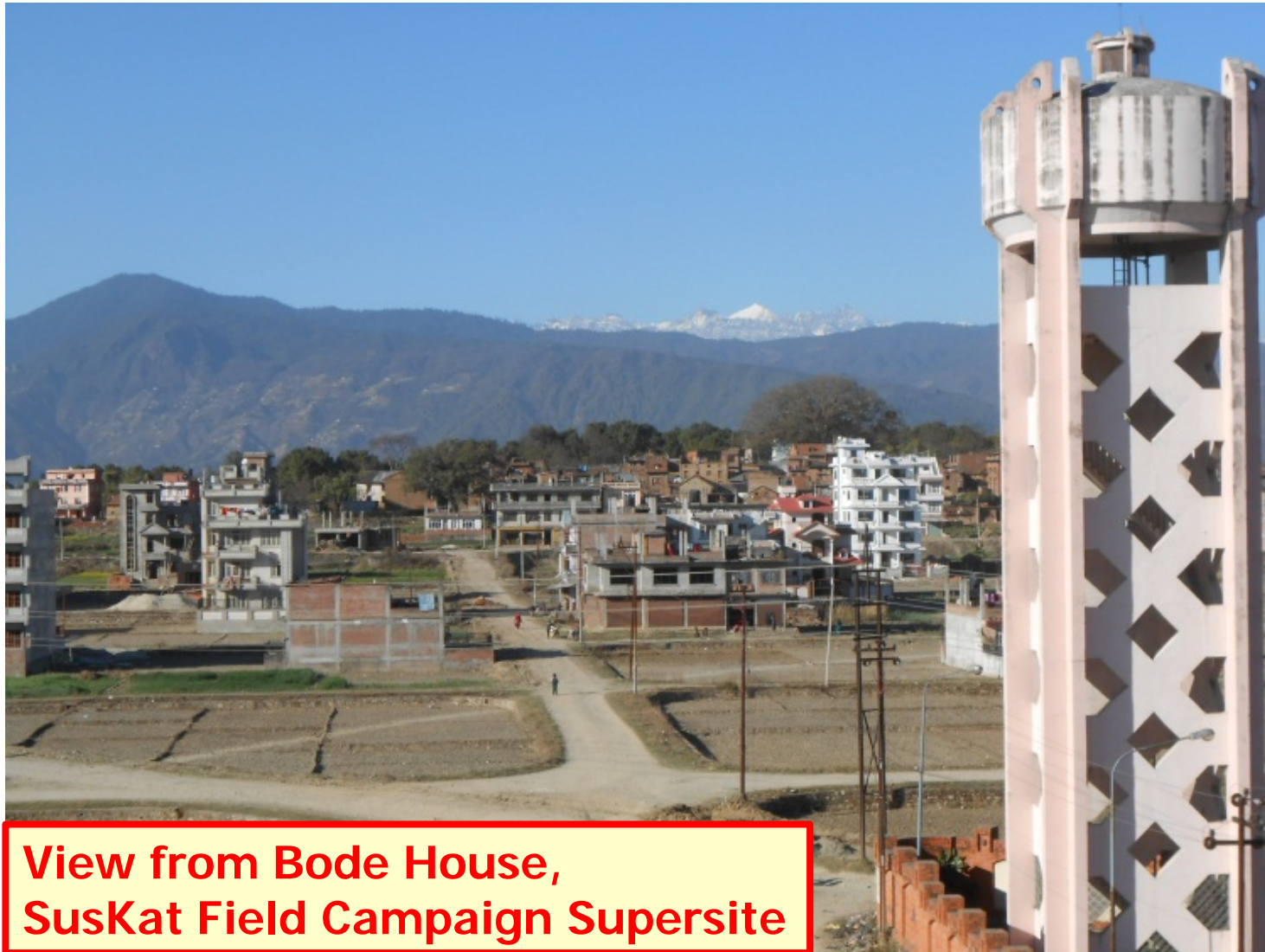
- UNEP
- UNESCO
- ICSU
- Belmont Forum
- Etc.

14th Biennial IGAC Science Conference
26-30 September 2016



igac2016.org

Air Pollution?

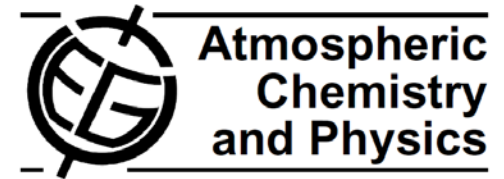


**View from Bode House,
SusKat Field Campaign Supersite**

Air Pollution!



Atmos. Chem. Phys., 10, 11017–11096, 2010
www.atmos-chem-phys.net/10/11017/2010/
doi:10.5194/acp-10-11017-2010
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Atmospheric pollutant outflow from southern Asia: a review

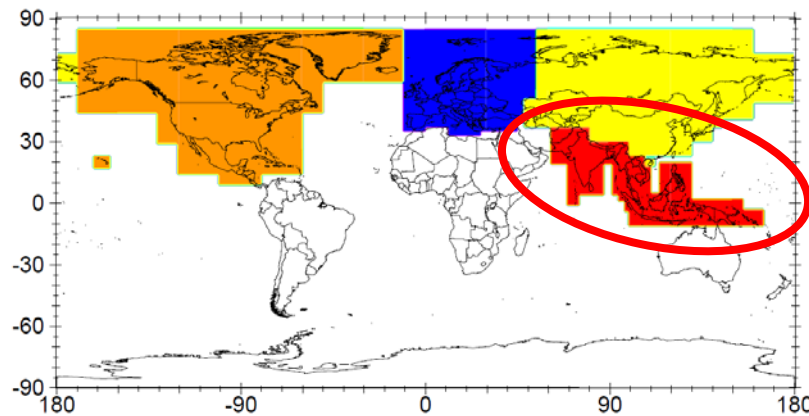
M. G. Lawrence^{1,2} and J. Lelieveld^{1,3}

¹Max Planck Institut for Chemistry, Atmospheric Chemistry Department, Mainz, Germany

²University of Mainz, Institute for Physics of the Atmosphere, Mainz, Germany

³Cyprus Institute, Nicosia, Cyprus

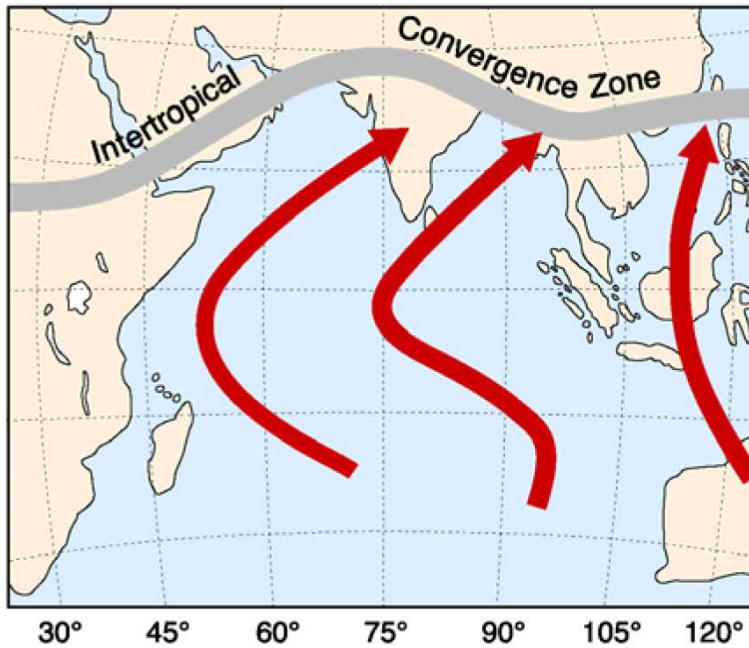
What is feeding the outflow? → Emissions!



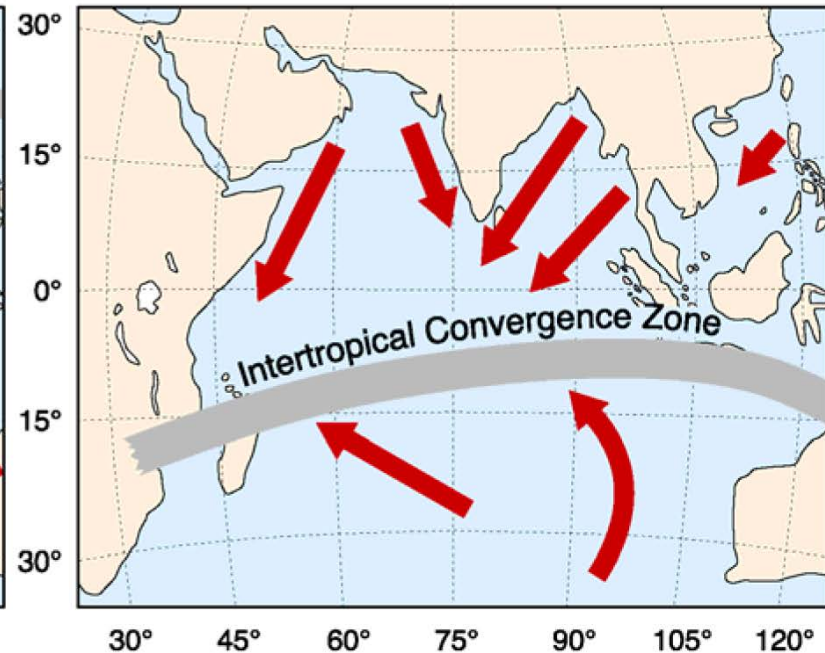
- Southern Asia:
 - inefficient burning and poor filtering, e.g., biofuels, cookstoves, ...
 - → relatively enriched in CO, NMVOCs and BC
 - BC sources: ~60% biofuel+biomass, ~40% fossil fuel (Gustafsson et al., 2009)
- Northern Asia:
 - Moderately efficient burning and filtering, many coal-fired power plants
 - → relatively enriched in SO₂, also somewhat in CO, NMVOCs and BC compared to Europe and North America
- CO/CO₂ ratio (year 2000, EDGAR data):
 - Southern Asia: 5.3%
 - Northern Asia: 1.8%
 - North America: 1.6%
 - Europe: 1.1%
- Changing rapidly! (mostly increasing, though some components in some regions decreasing)



a) **June - September**

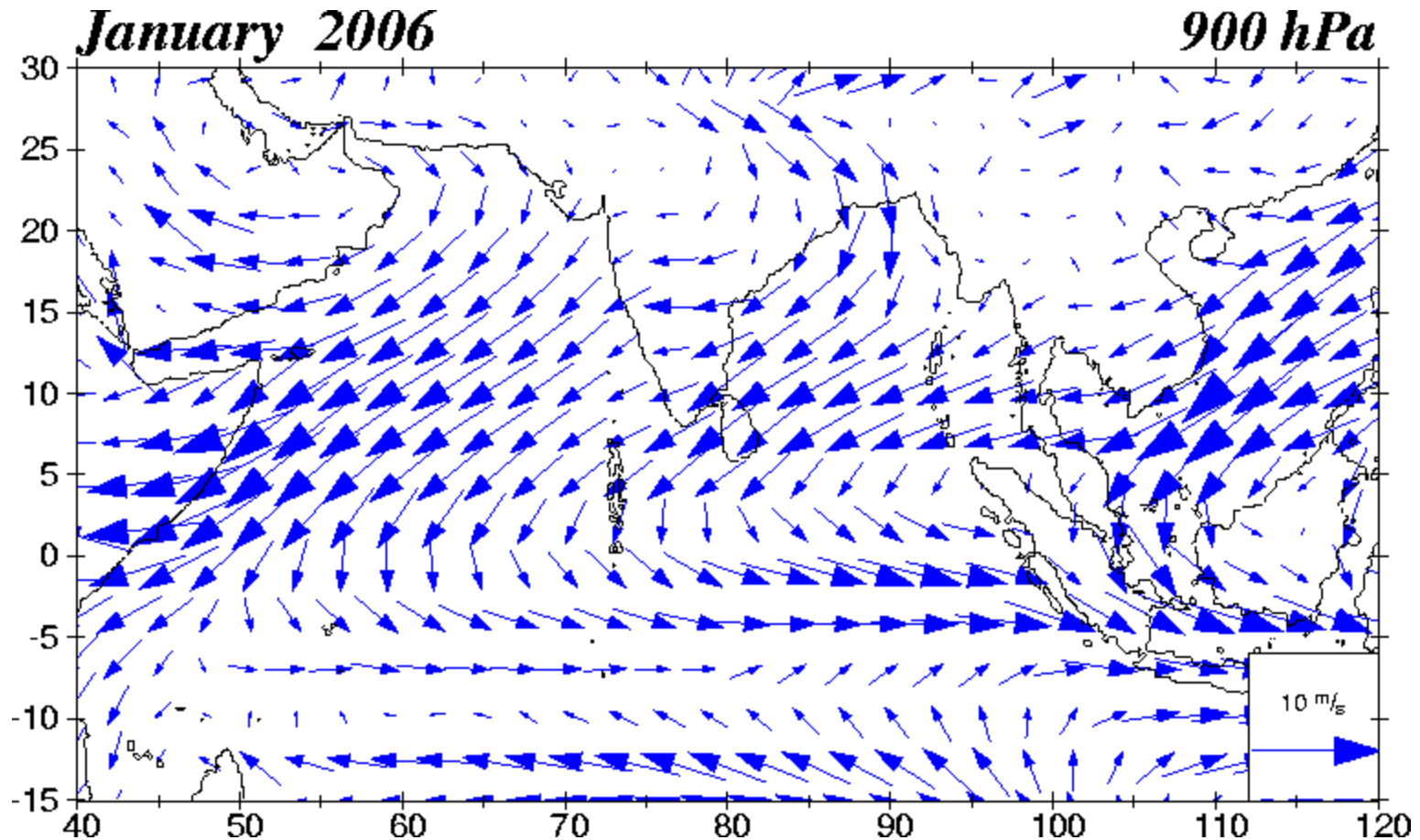


b) **November - March**

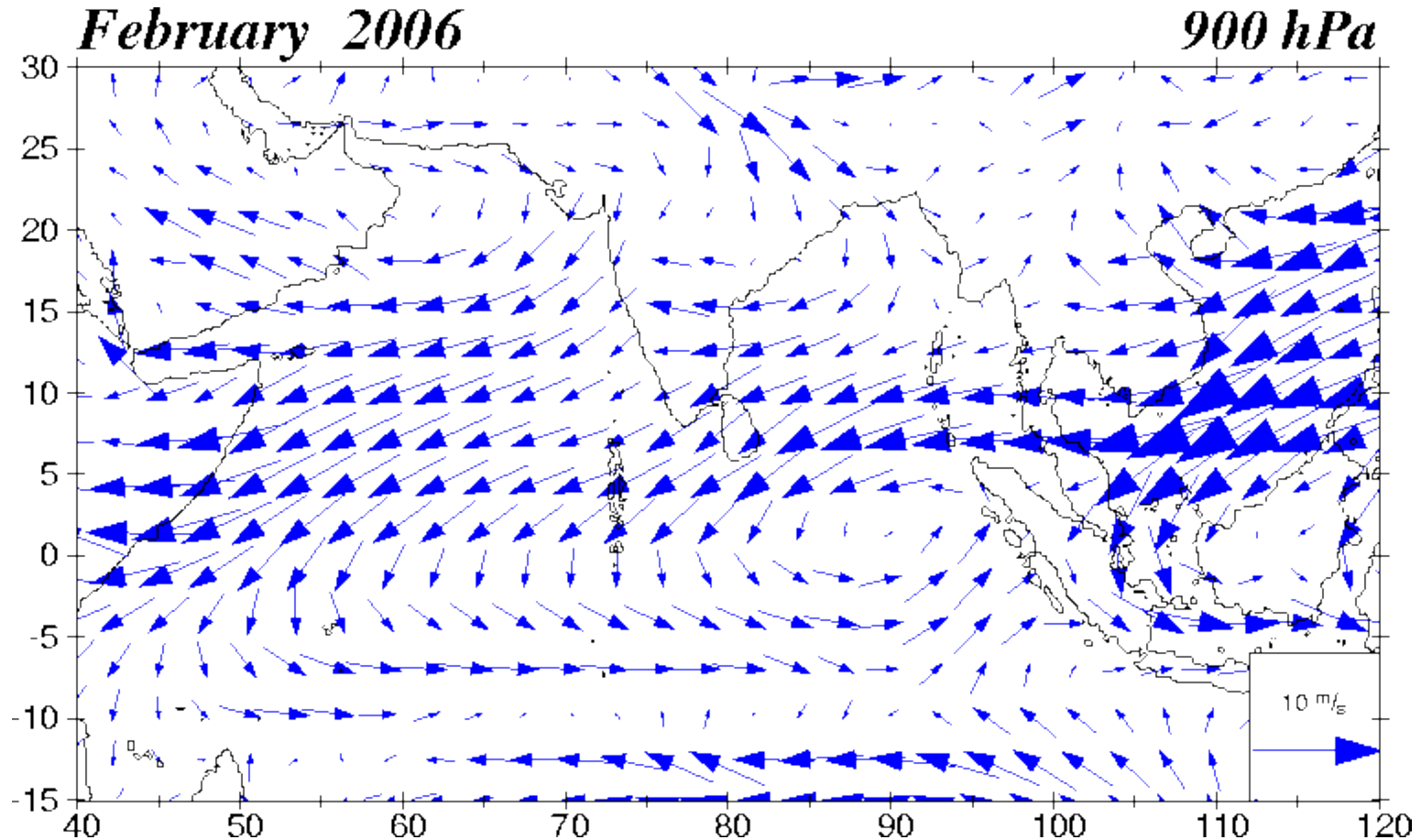


1. **Southern Asian Wintertime Atmospheric Brown Cloud ("SAW-ABC")**
2. **Summer Monsoon Convective Outflow**
3. **Monsoon Transition Periods**

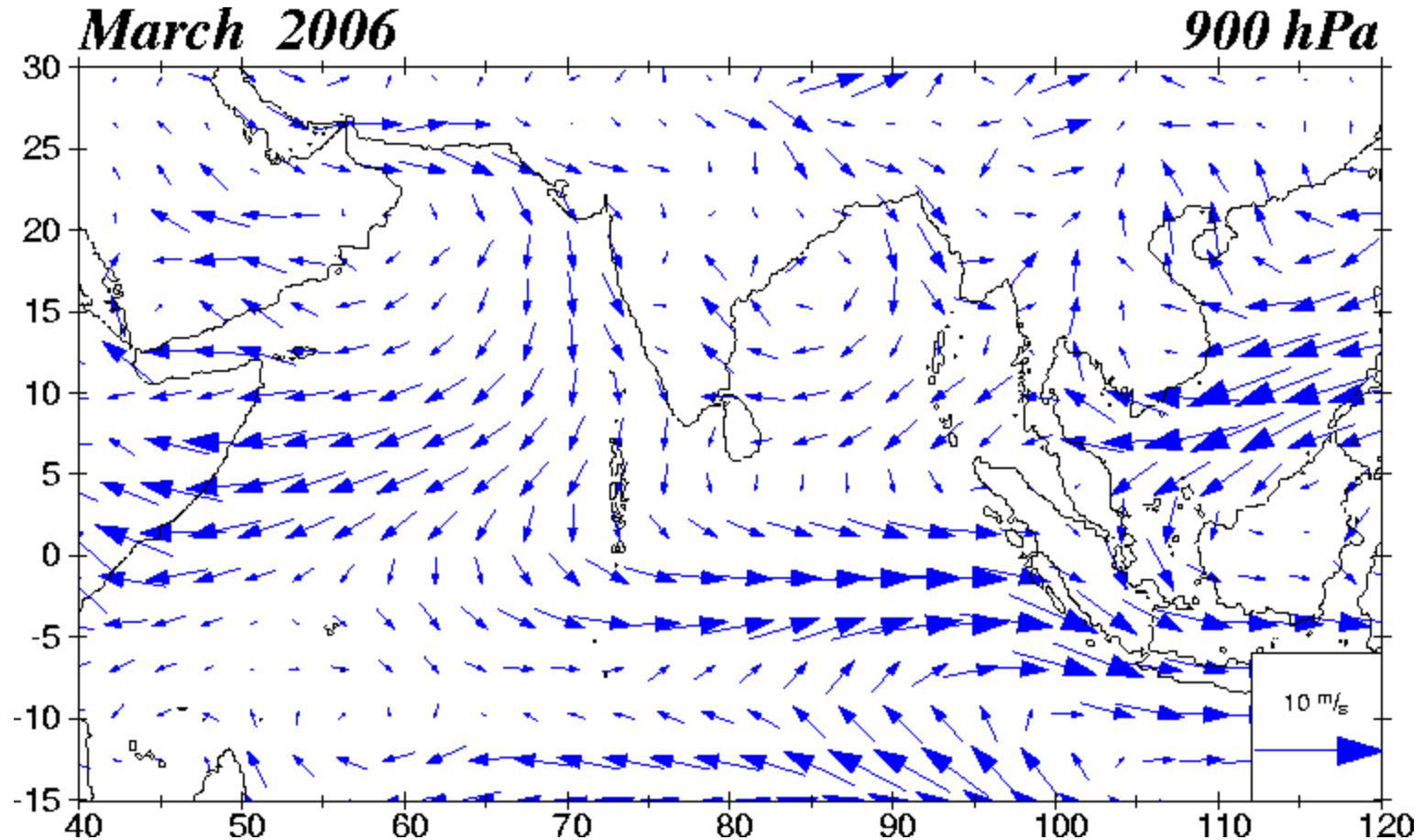
Southern Asian Monsoon Winds



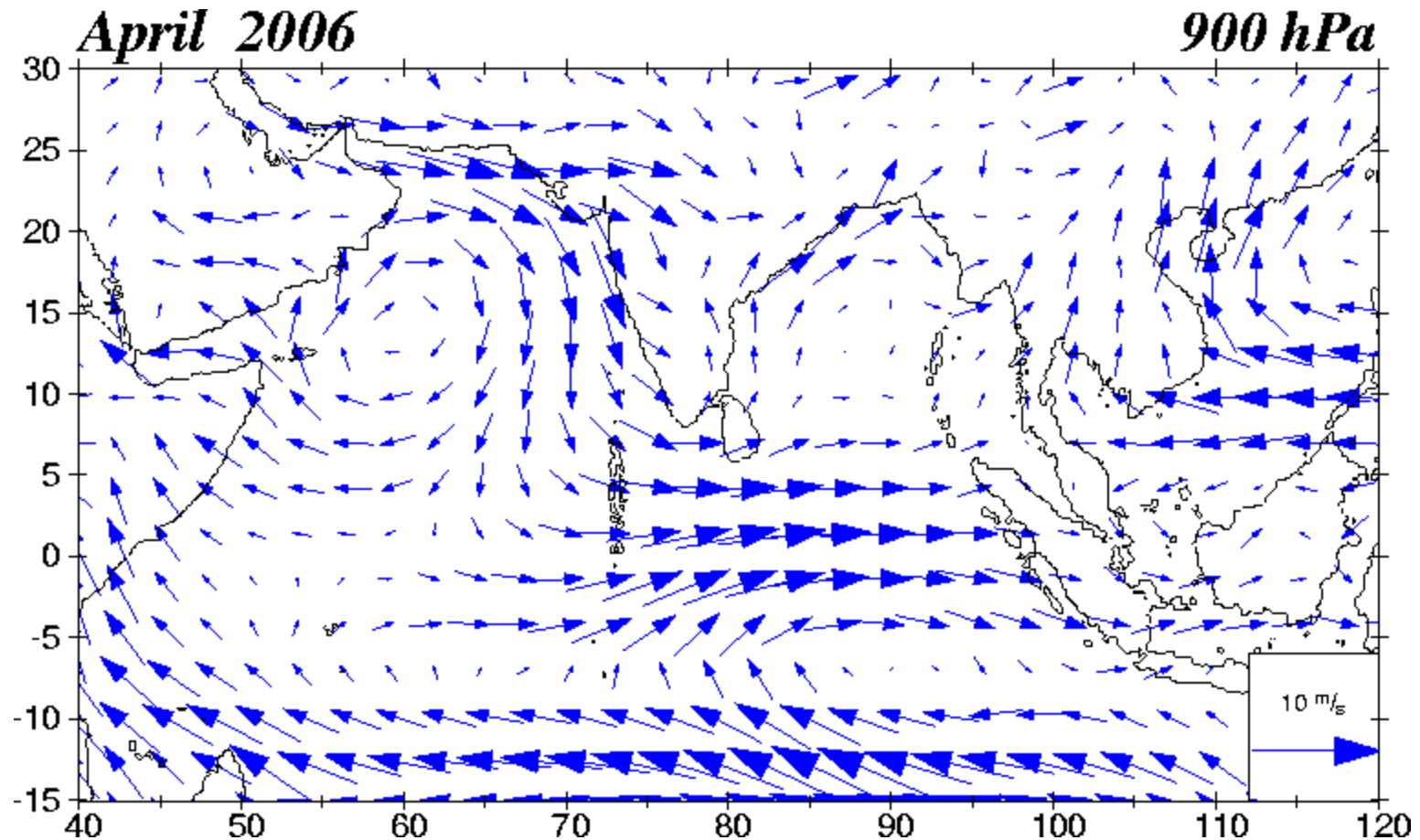
Southern Asian Monsoon Winds



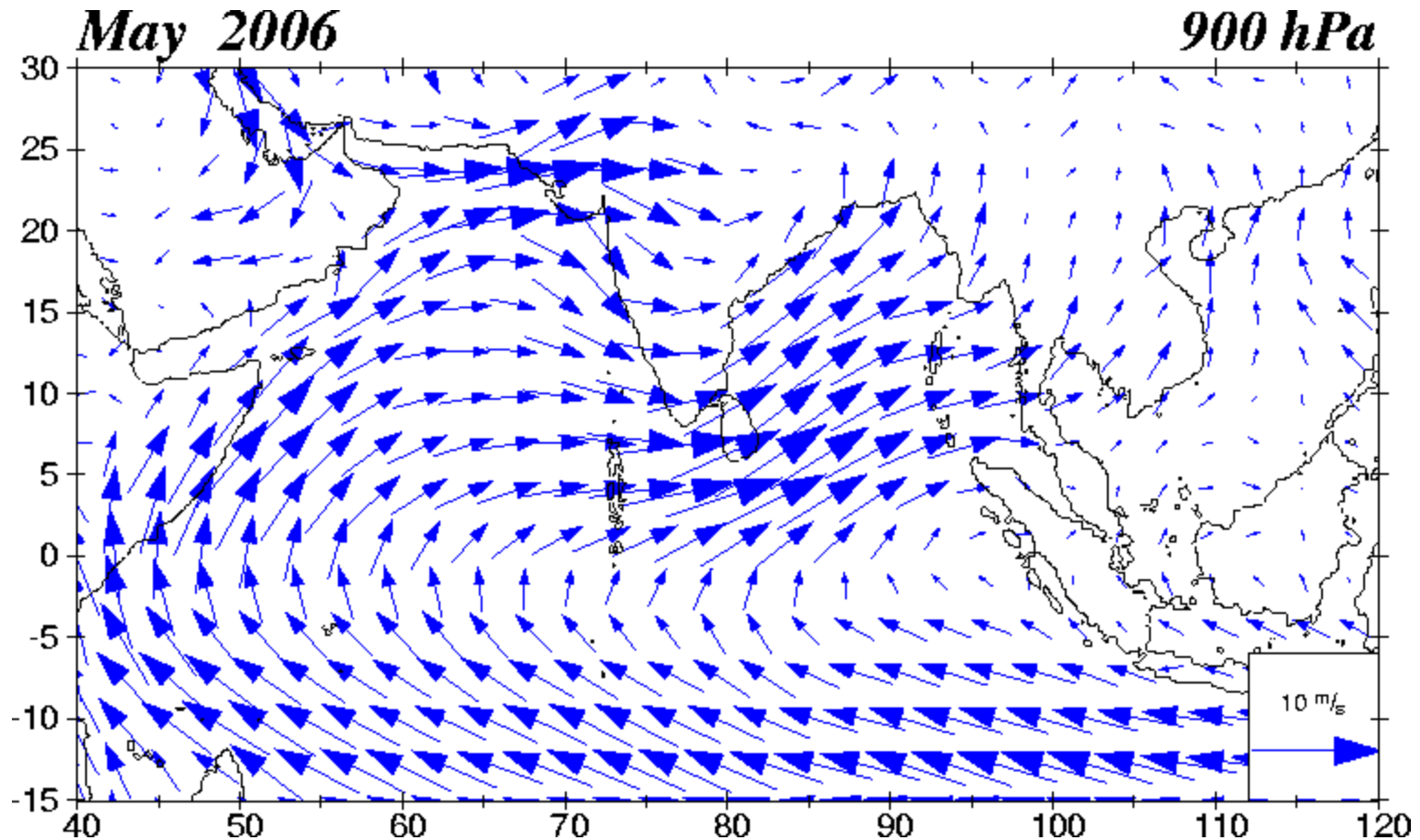
Southern Asian Monsoon Winds



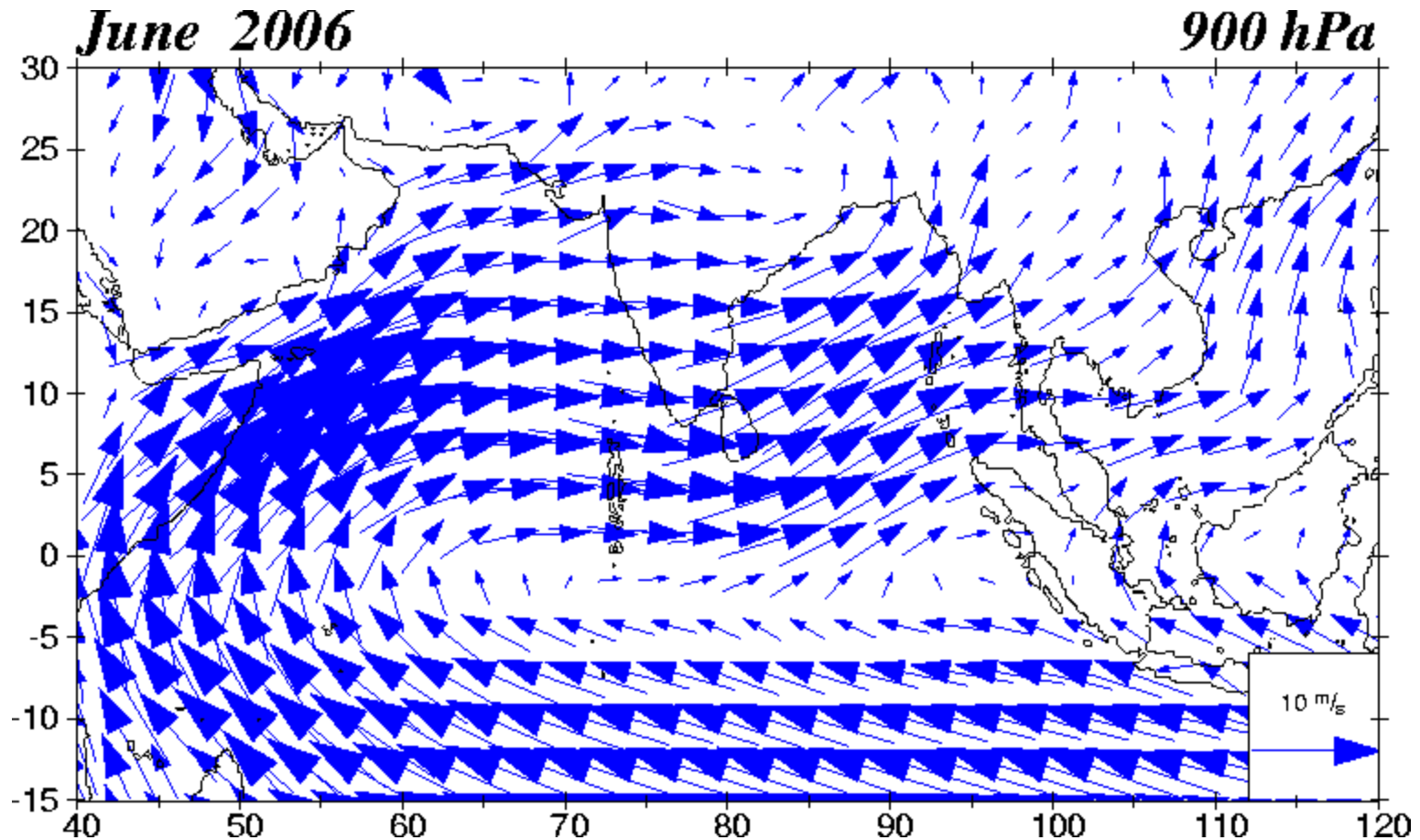
Southern Asian Monsoon Winds



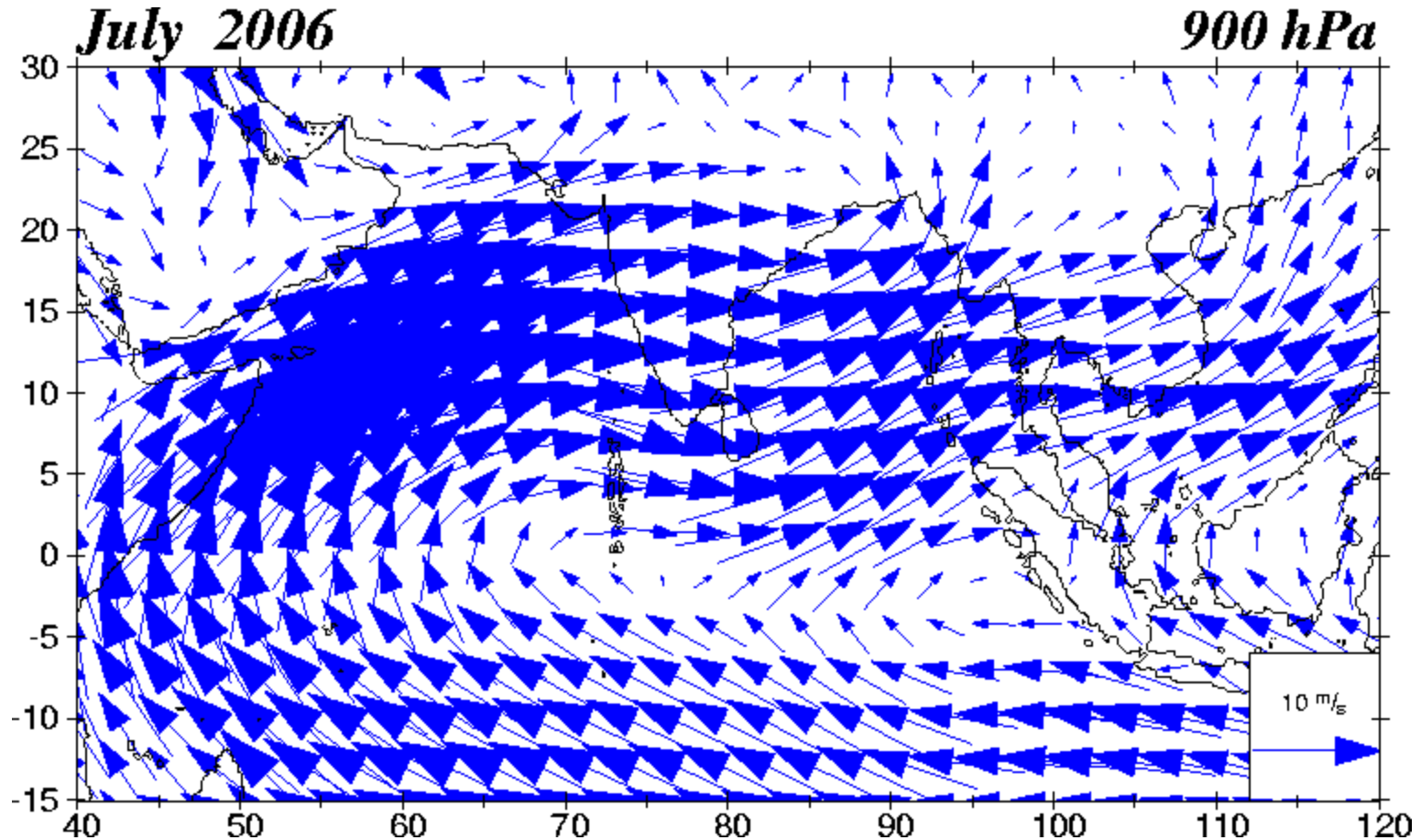
Southern Asian Monsoon Winds



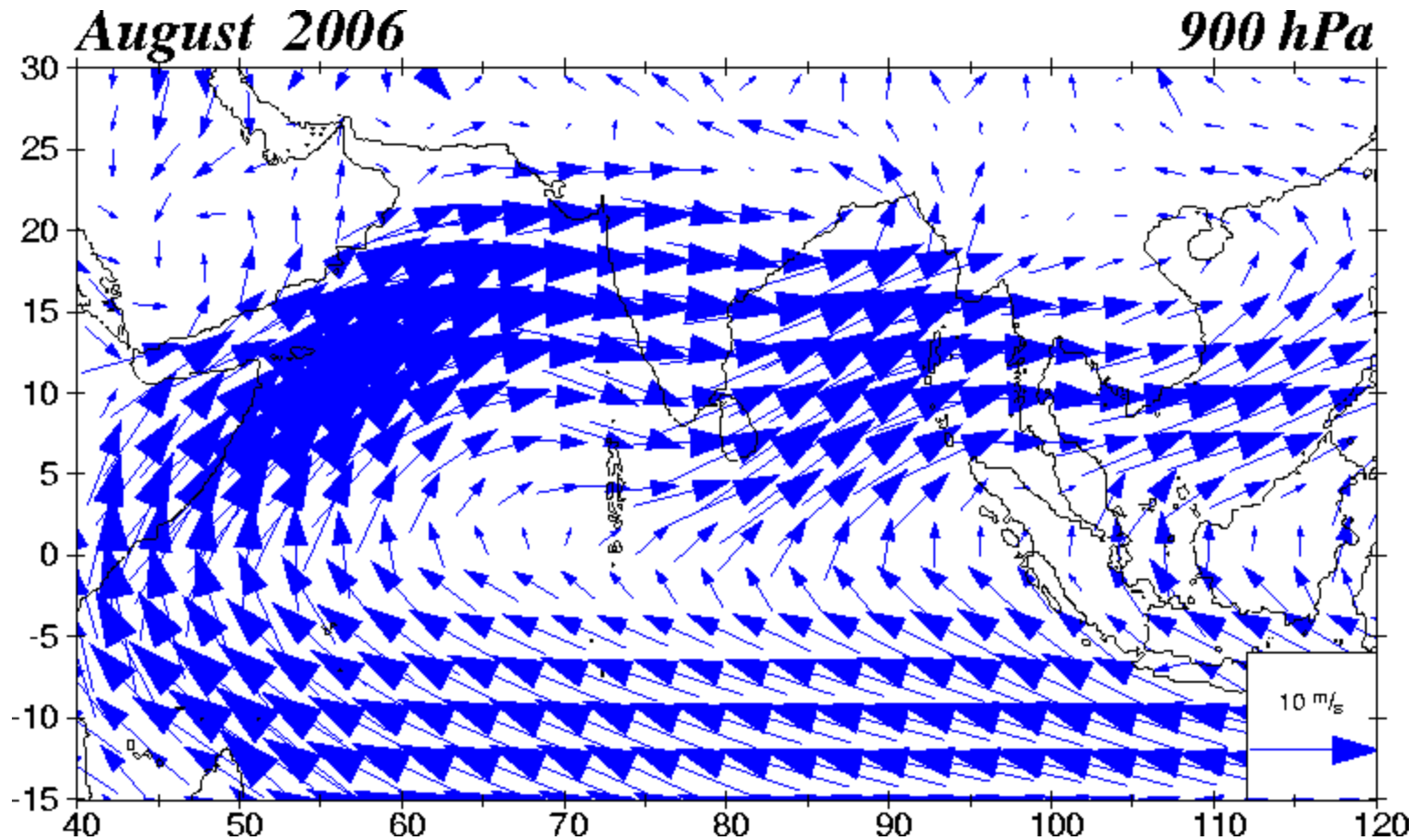
Southern Asian Monsoon Winds



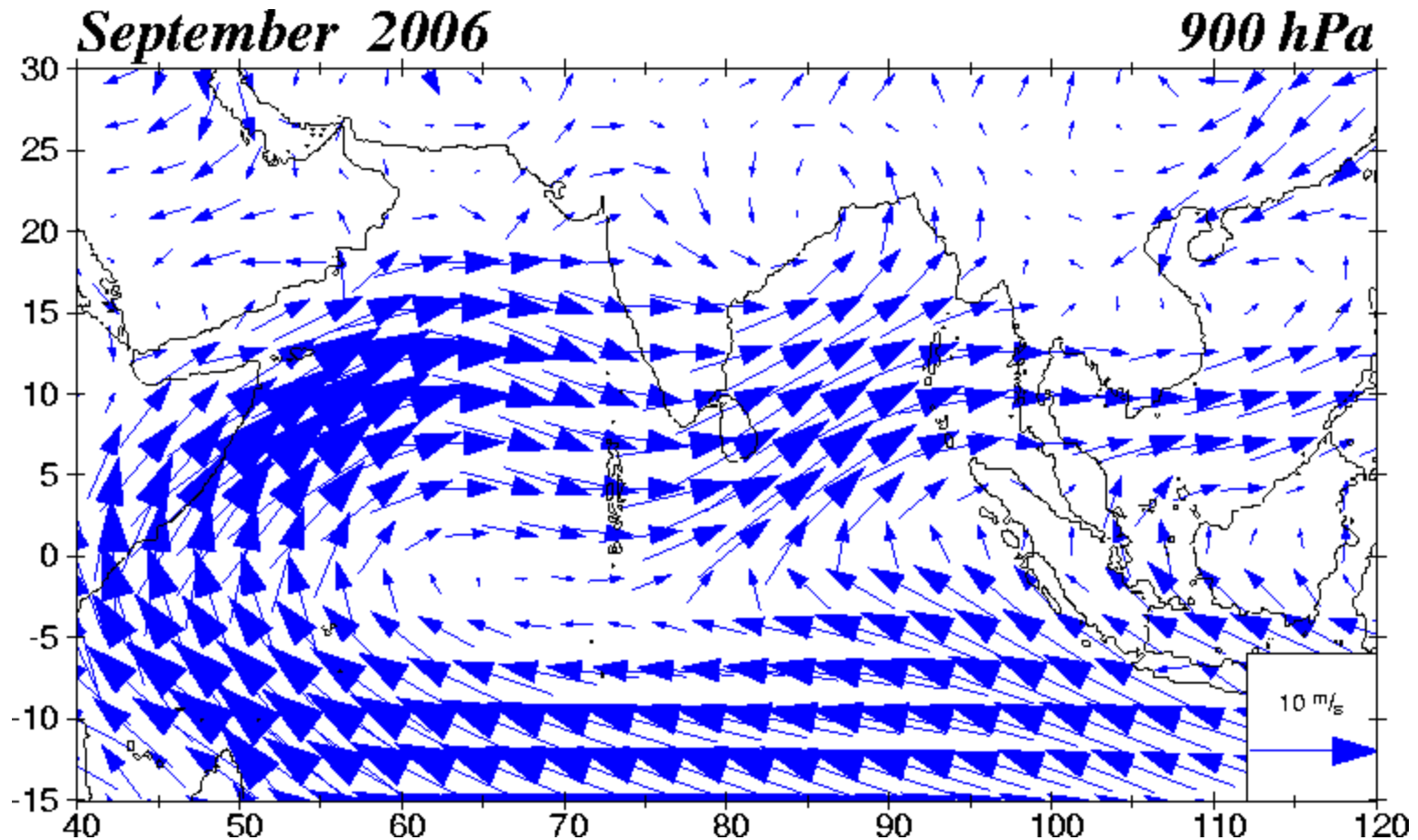
Southern Asian Monsoon Winds



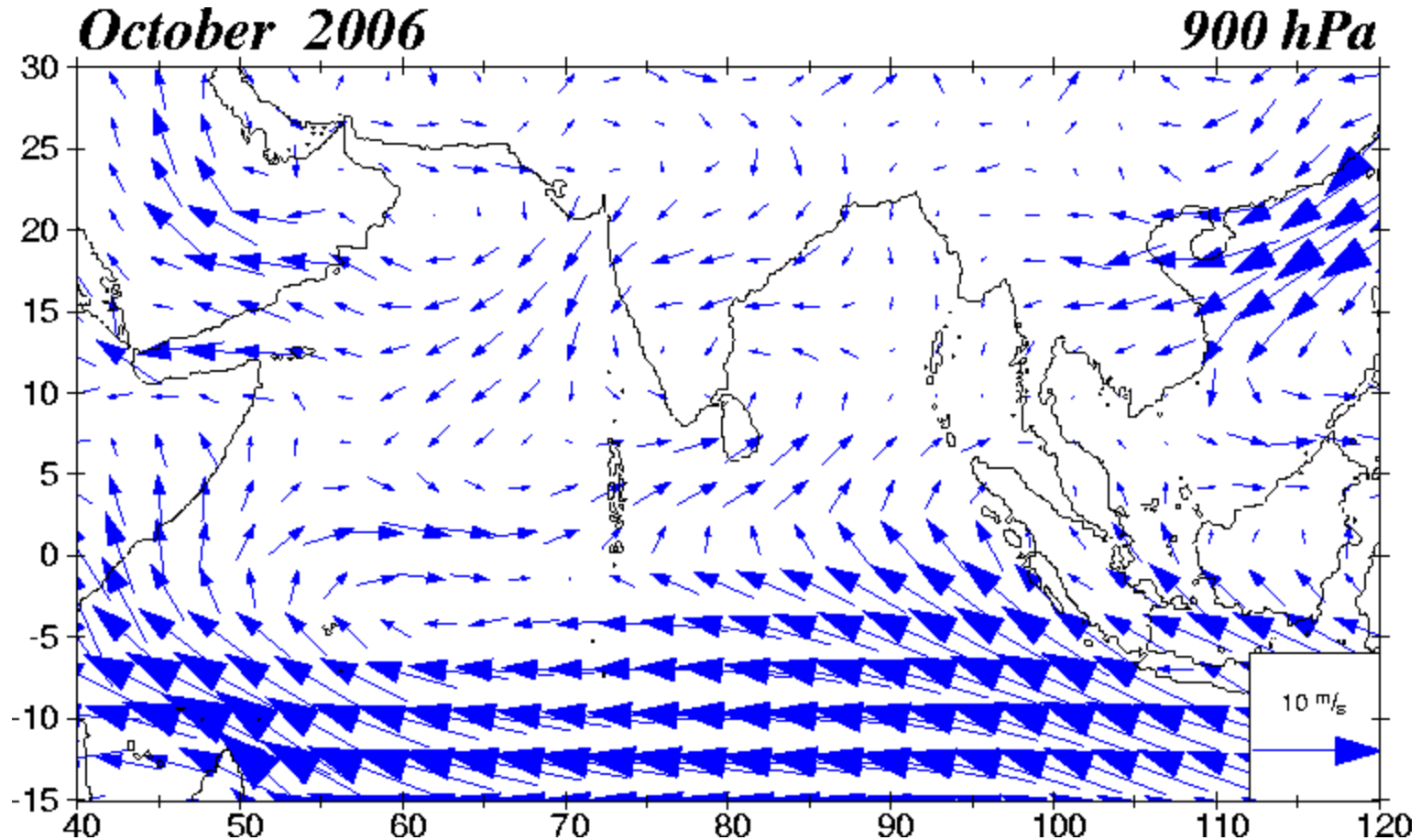
Southern Asian Monsoon Winds



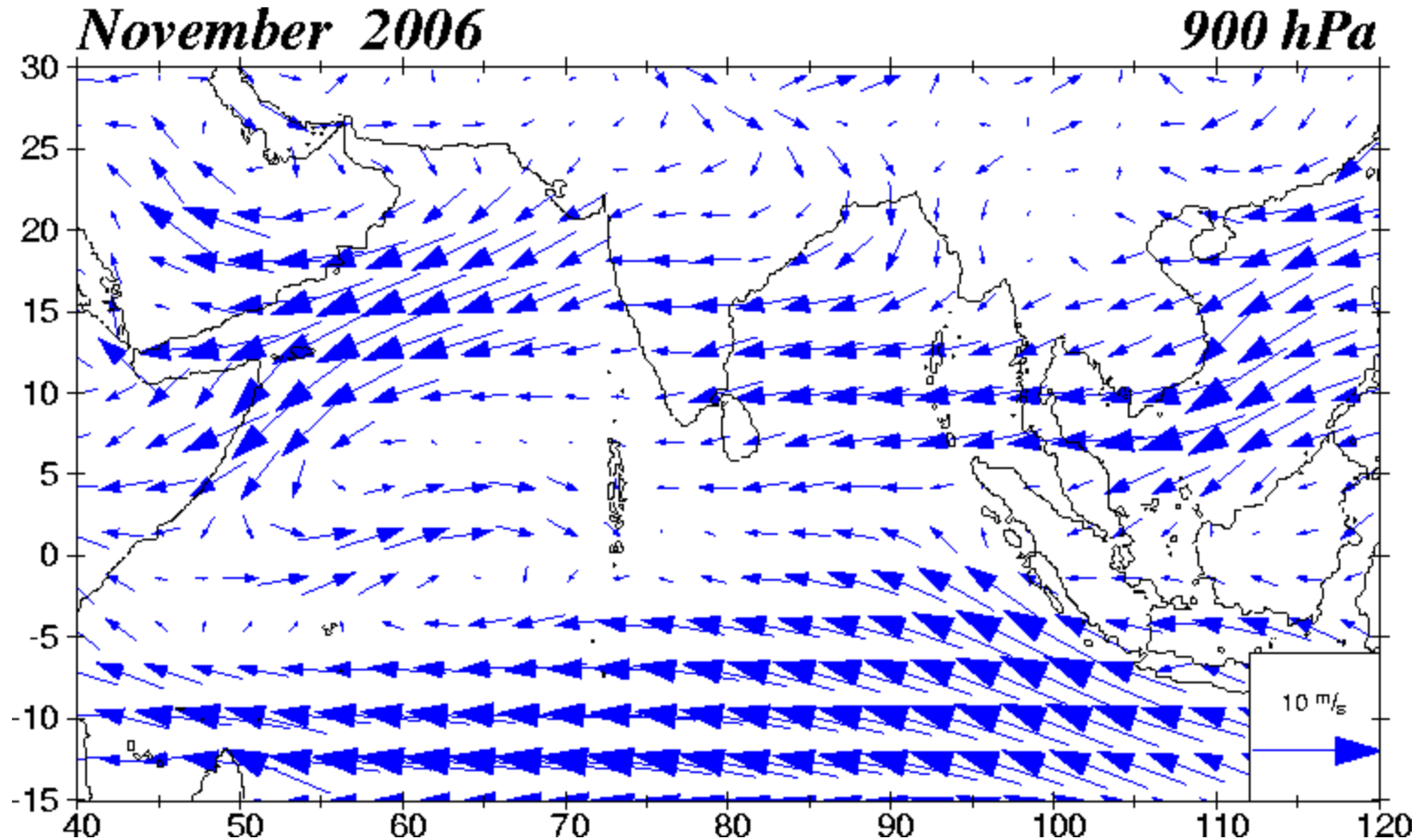
Southern Asian Monsoon Winds



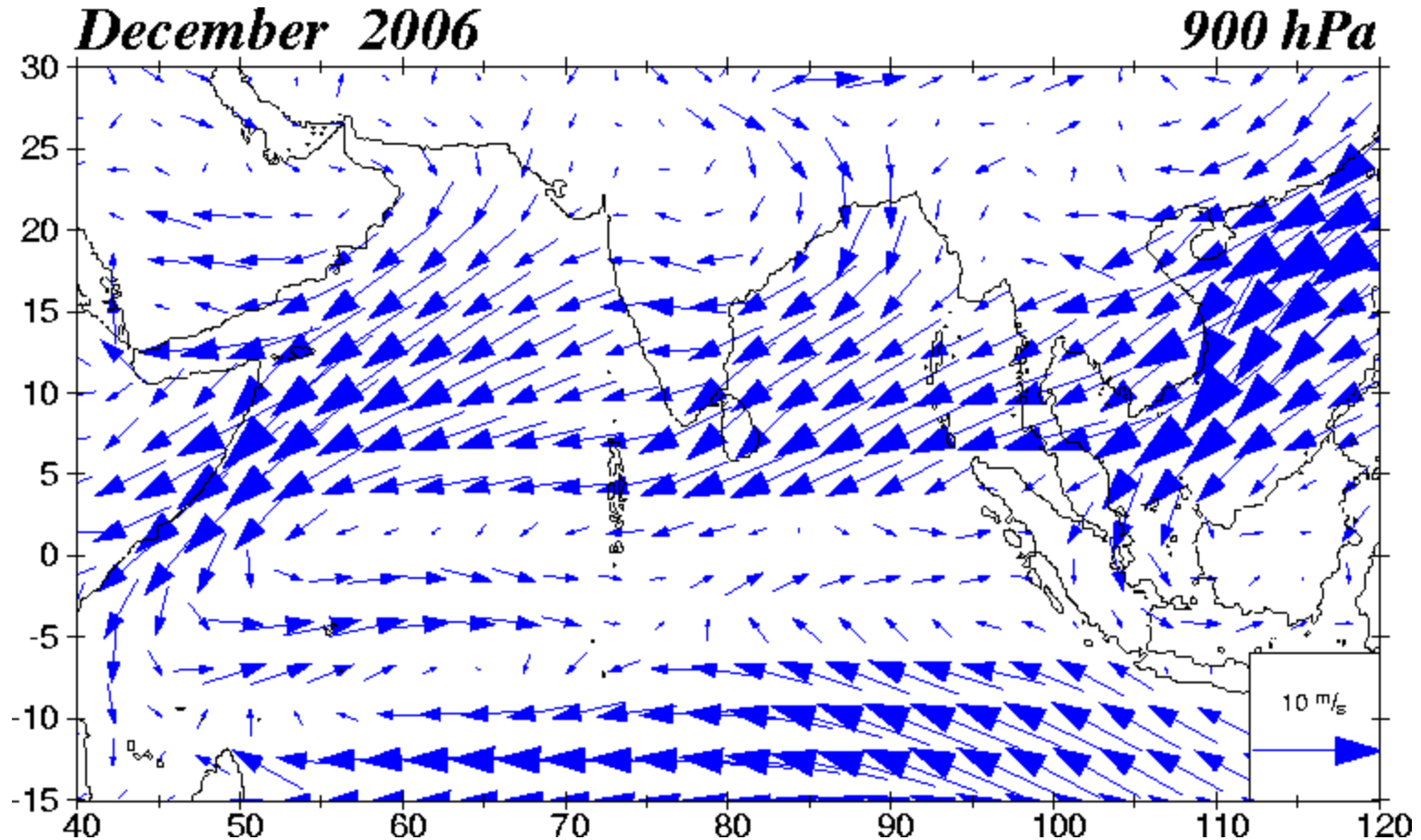
Southern Asian Monsoon Winds



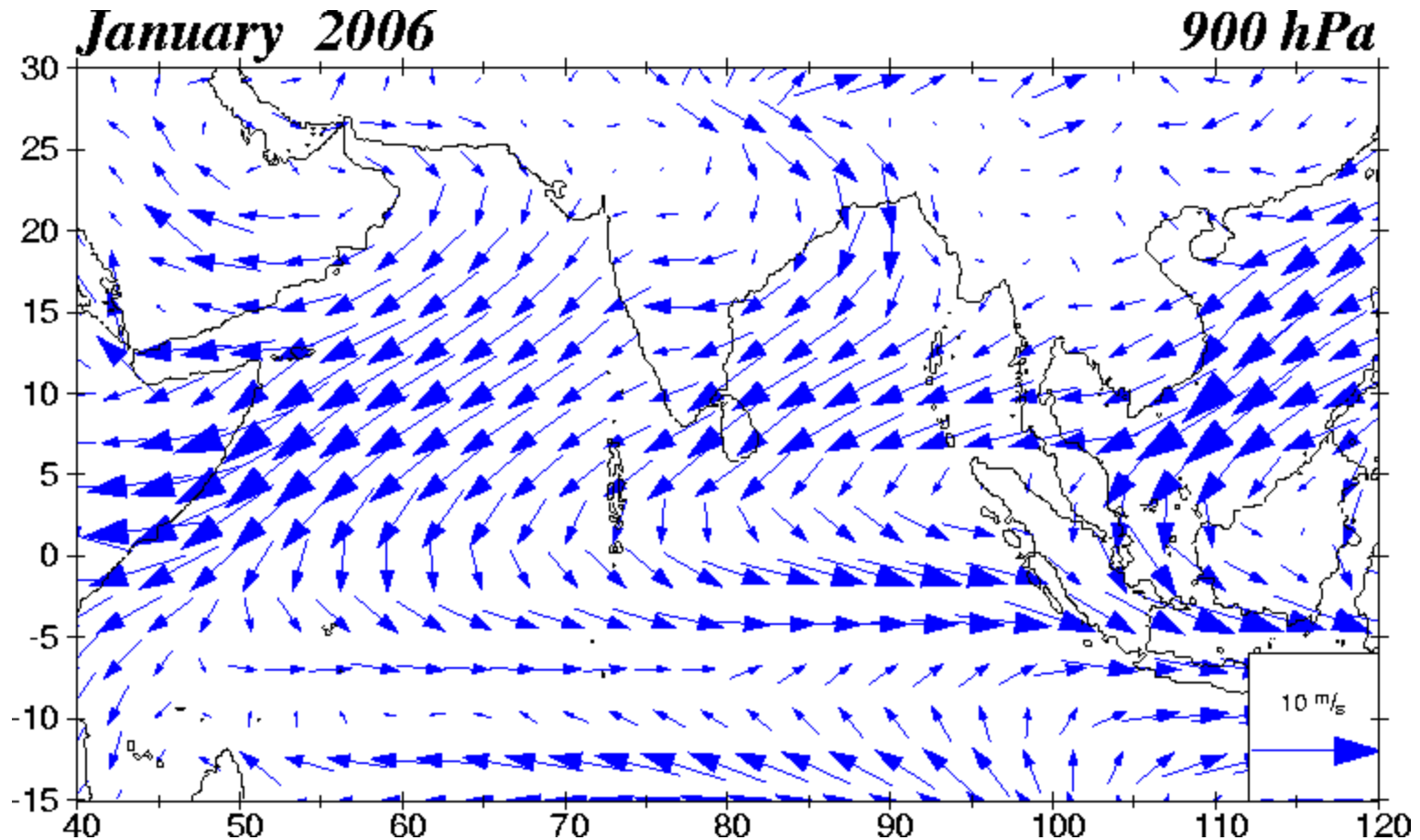
Southern Asian Monsoon Winds



Southern Asian Monsoon Winds

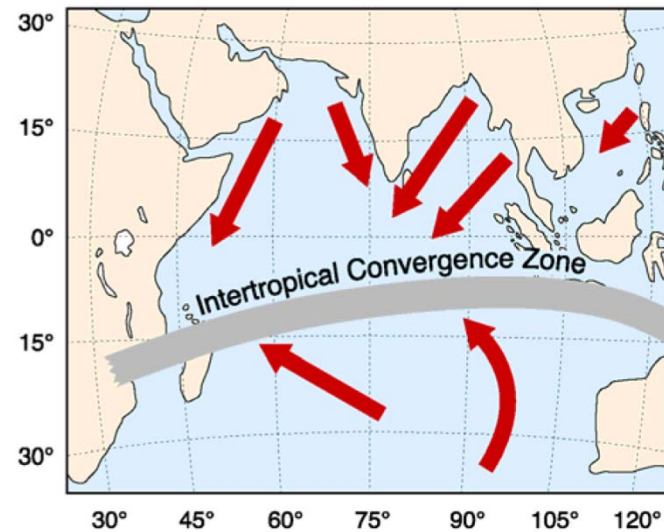


Southern Asian Monsoon Winds

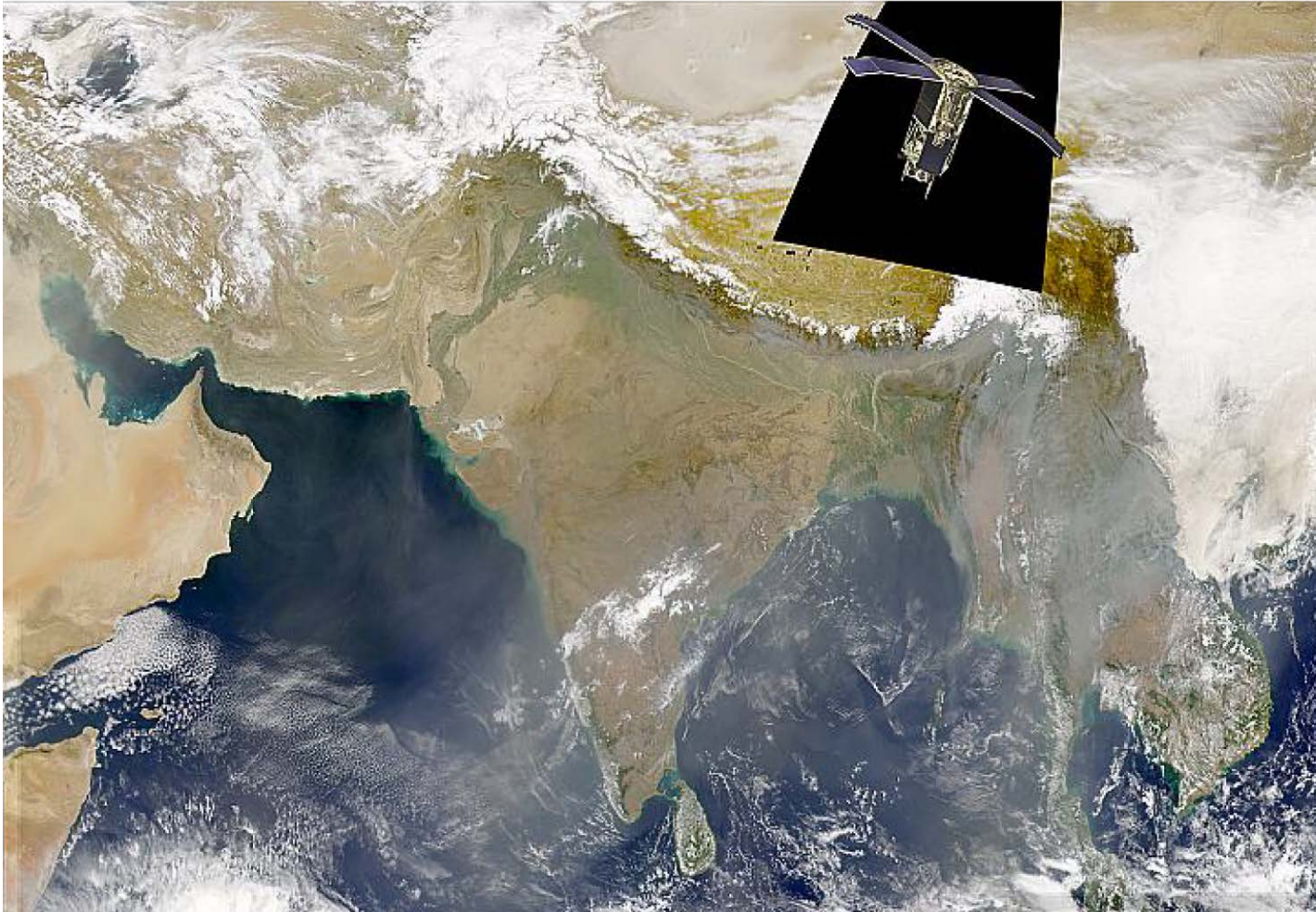


Southern Asian Wintertime Atmospheric Brown Cloud ("SAW-ABC")

b) November - March



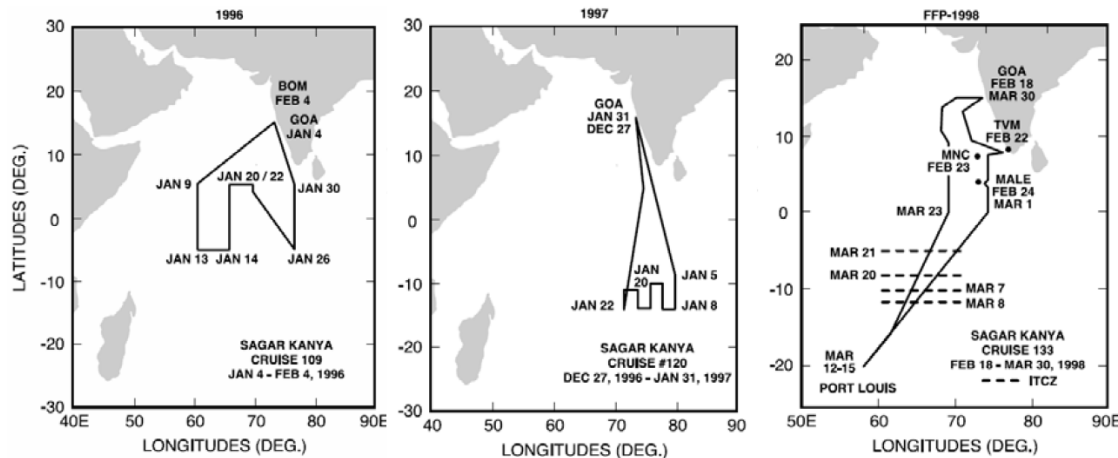
The SAW-ABC



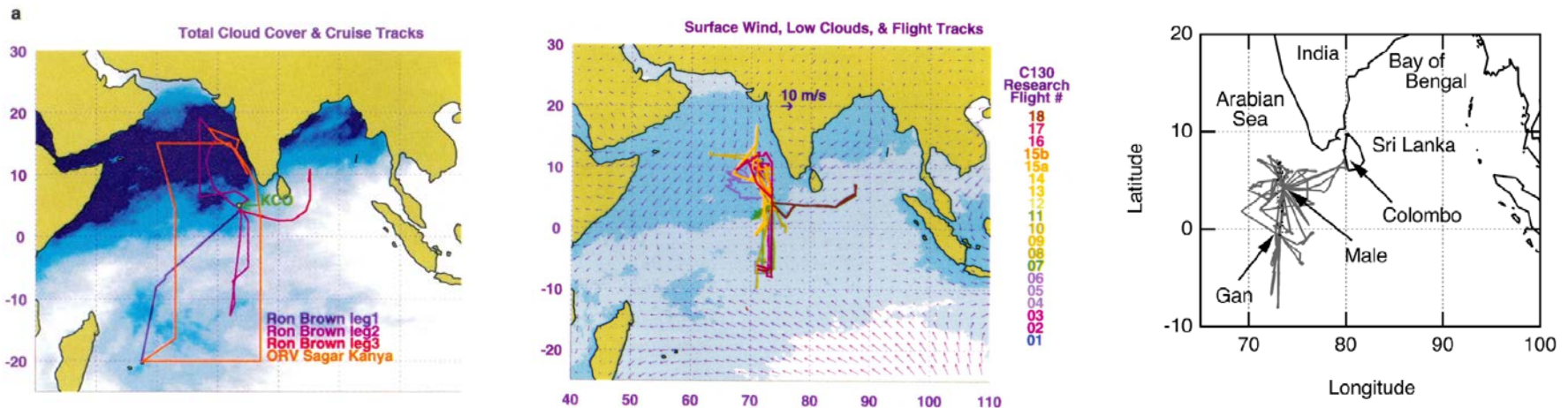
courtesy of the SeaWiFS Project, the NASA/Goddard Space Flight Center and ORBIMAGE

INDOEX – The Indian Ocean Experiment

→ pre-INDOEX cruises: Sagar Kanya 1996-8 (+ Malcolm Baldrige 1995)

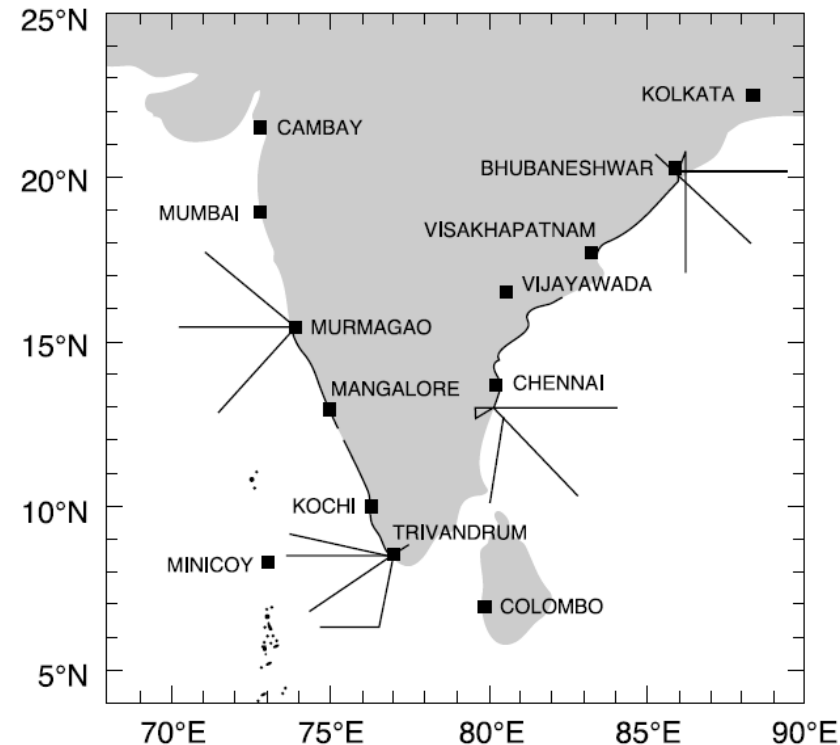
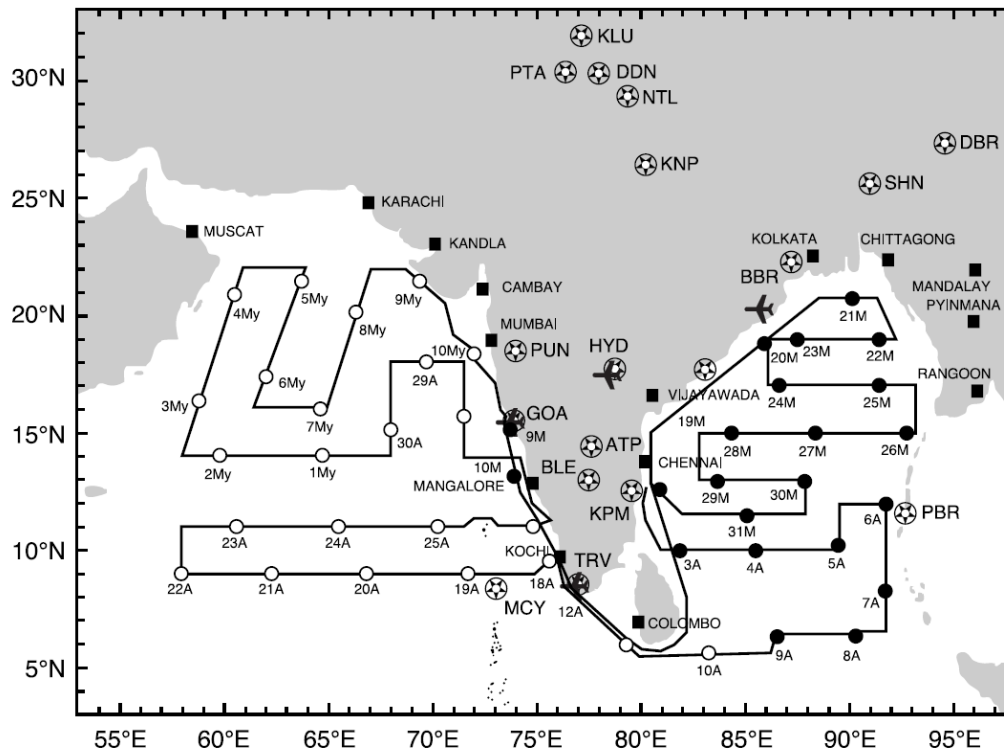


→ intensive phase cruises and flights: Jan-Apr 1999



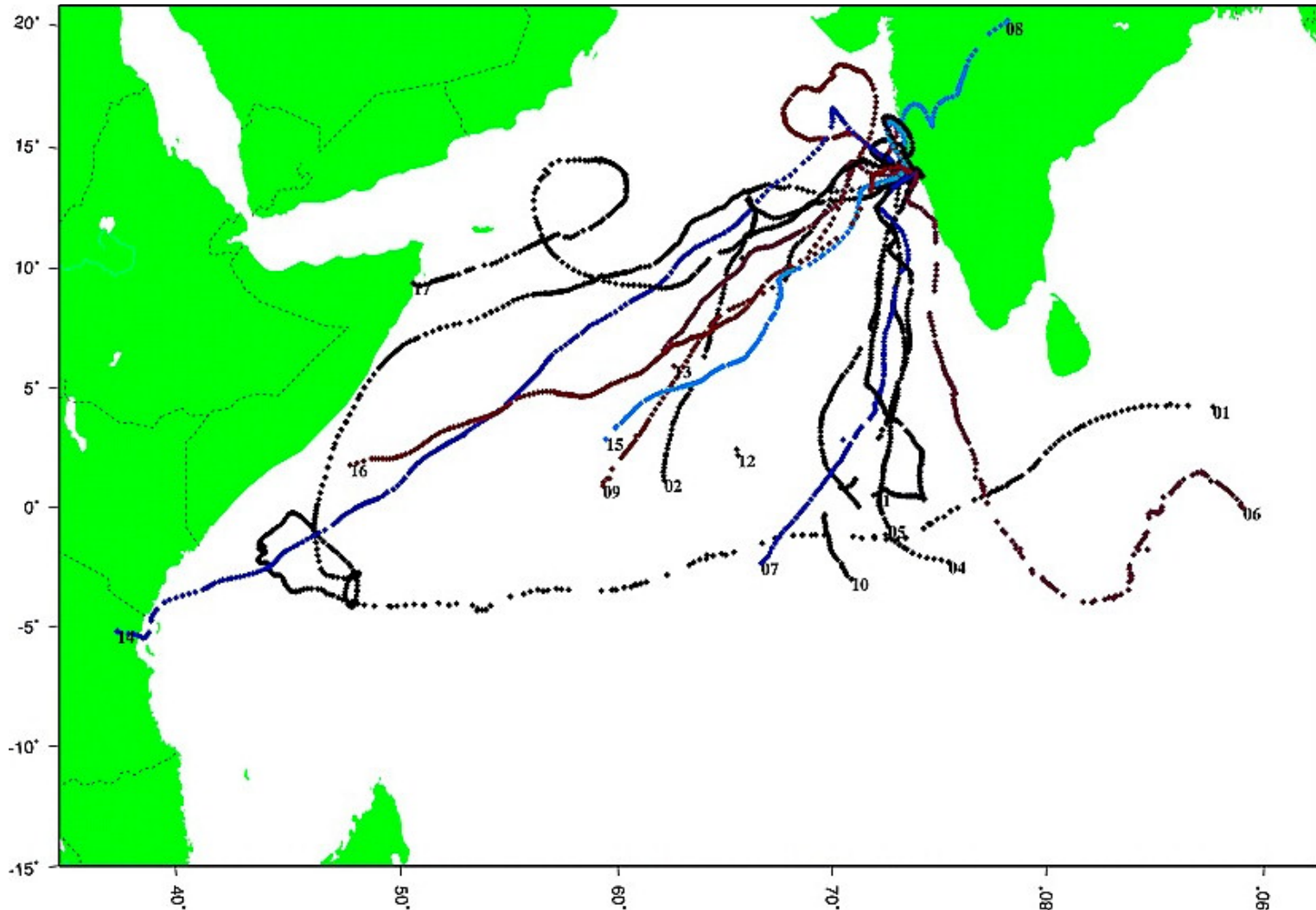
Post-INDOEX campaigns

- Several other campaigns followed INDOEX
- Largest so far: ICARB (Integrated Campaign for Aerosol, gases, and Radiation Budget), March-May 2006



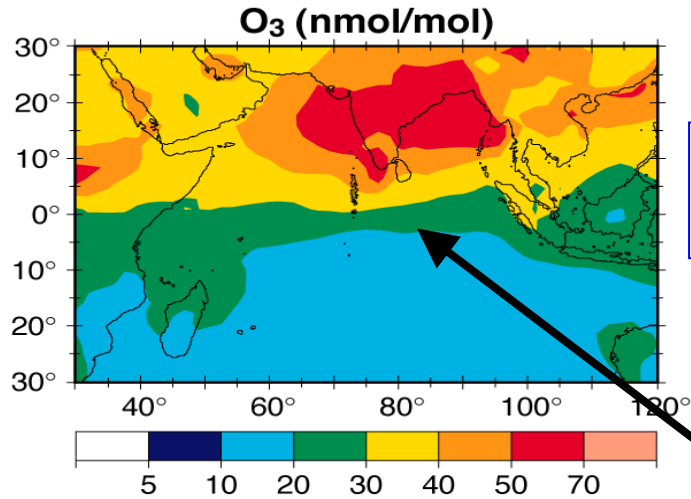
INDOEX Constant-Level Balloons:

→ SAW-ABC Character and Variability



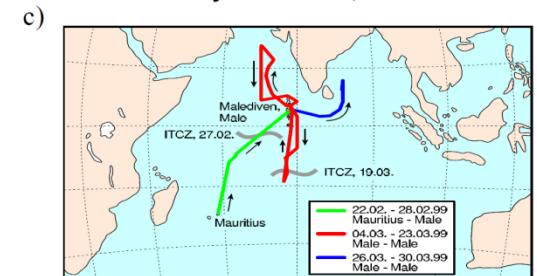
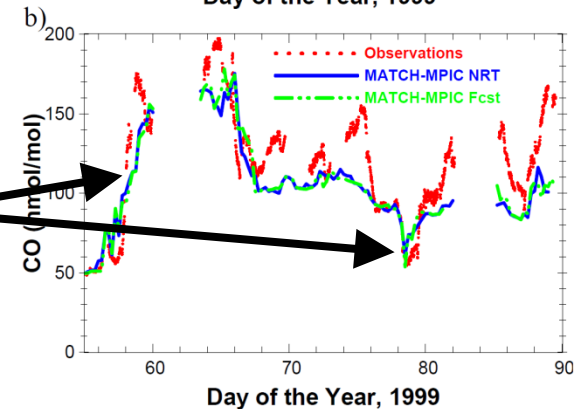
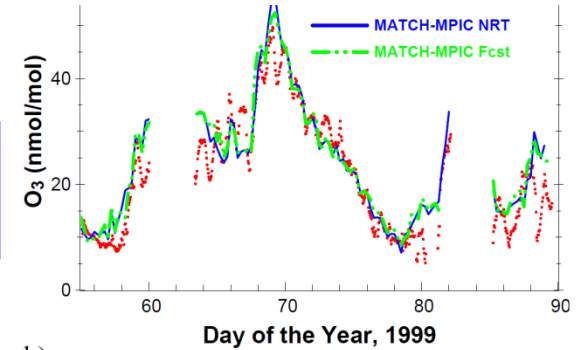
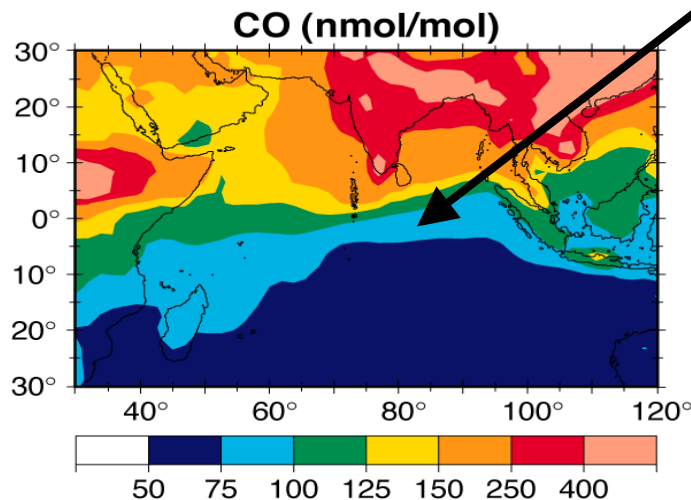
Strong gradients down to the ITCZ

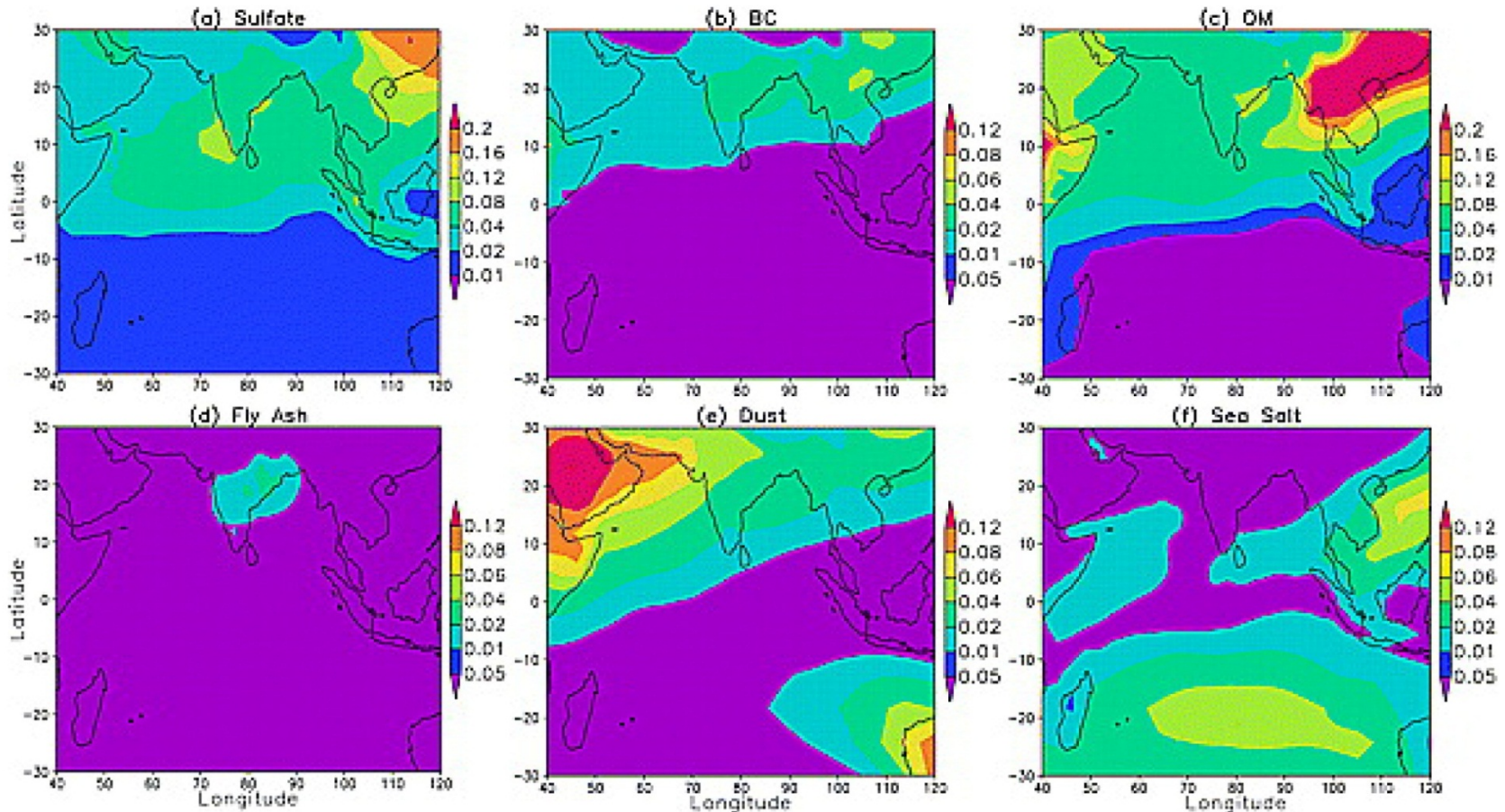
February Surface-Layer Means (MATCH-MPIC)



First global “Chemical Weather Forecasts”

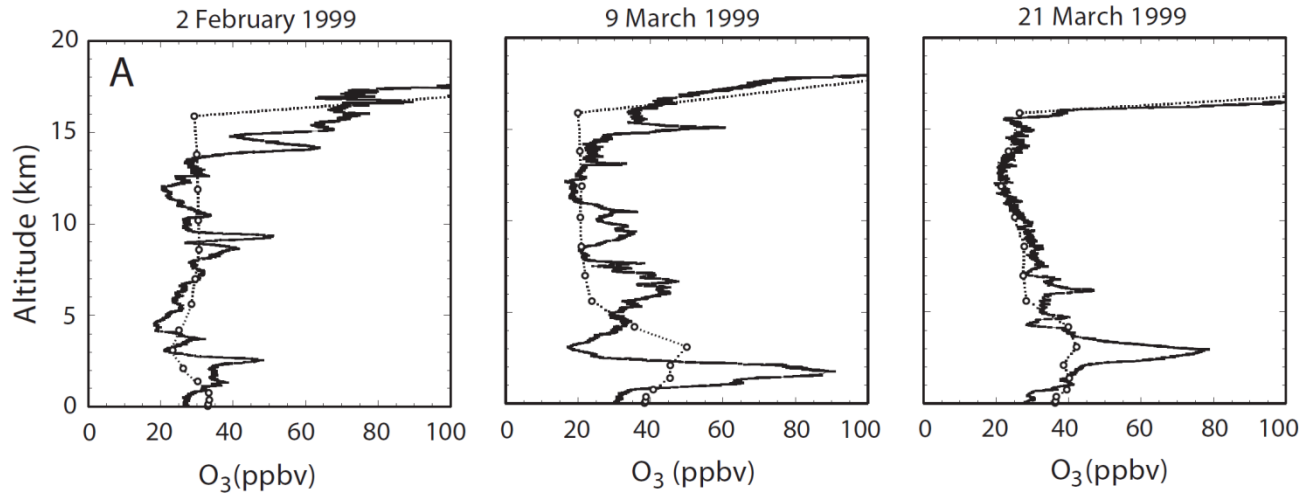
ITCZ – Intertropical Convergence Zone



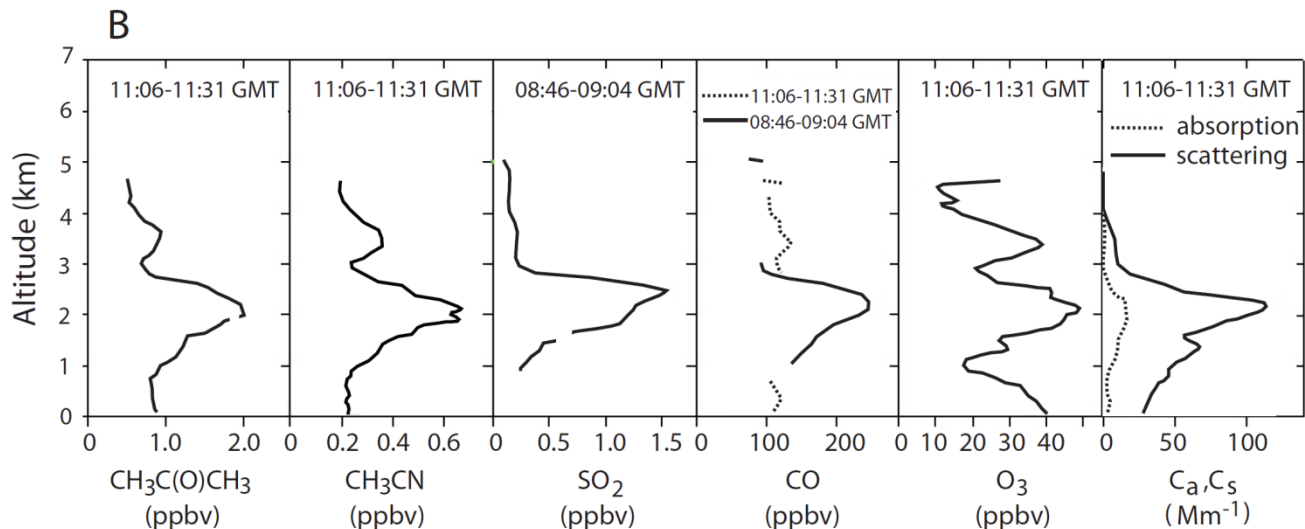


➔ Each aerosol component (except BC and fly ash) dominates somewhere

Frequent elevated pollution layers

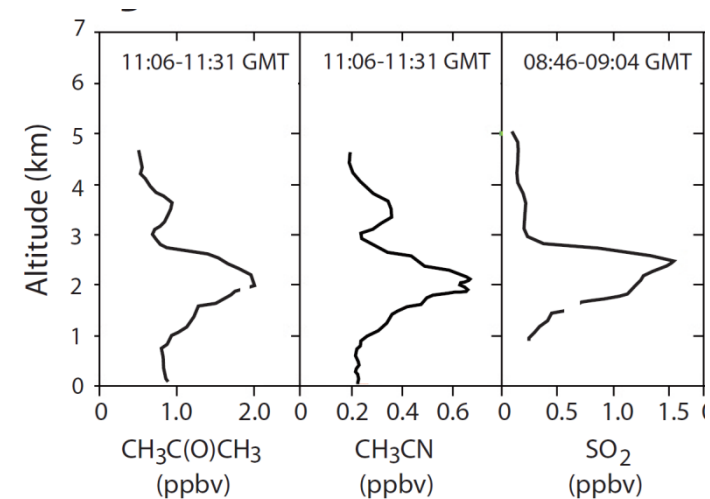
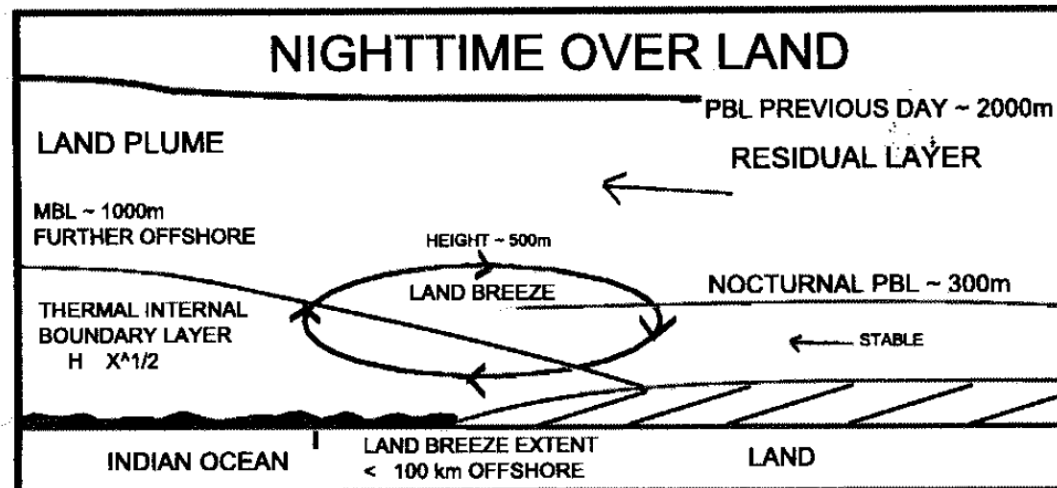
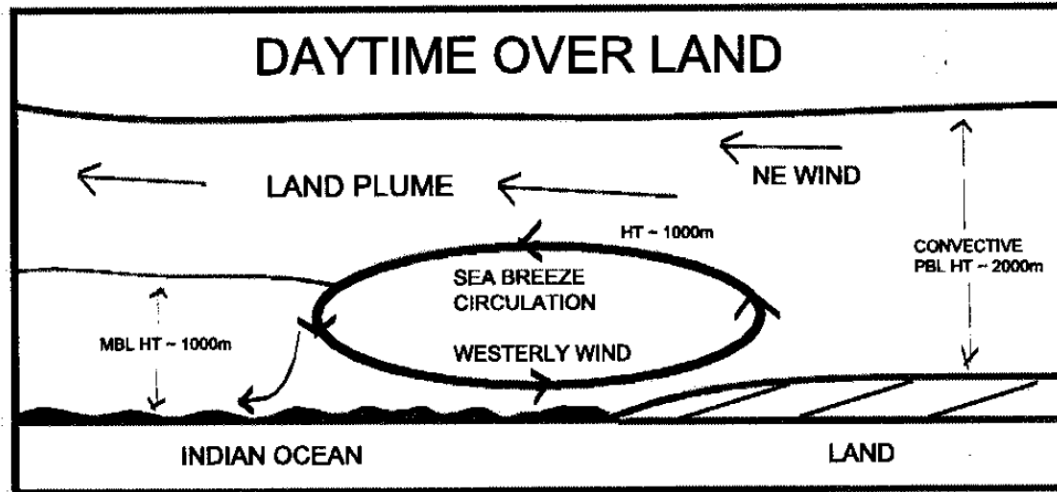


Ozone soundings from the Ron Brown



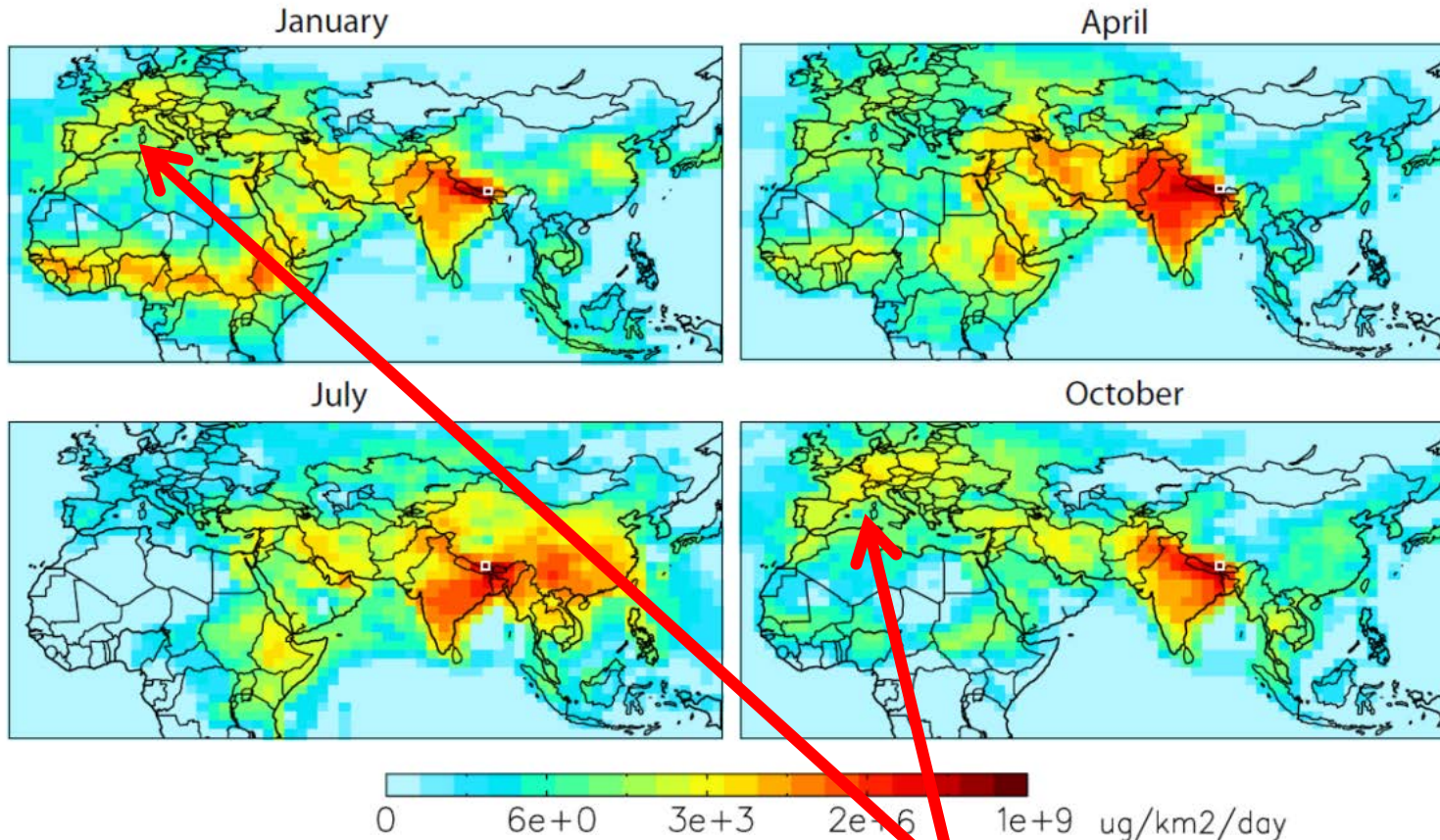
Vertical profiles with the Cessna Citation

Influence of Land/Sea Breeze on Vertical Profiles



...and even higher up: Himalayas

Seasonal origin of Black Carbon at Mt. Everest, GEOS-Chem model simulations:

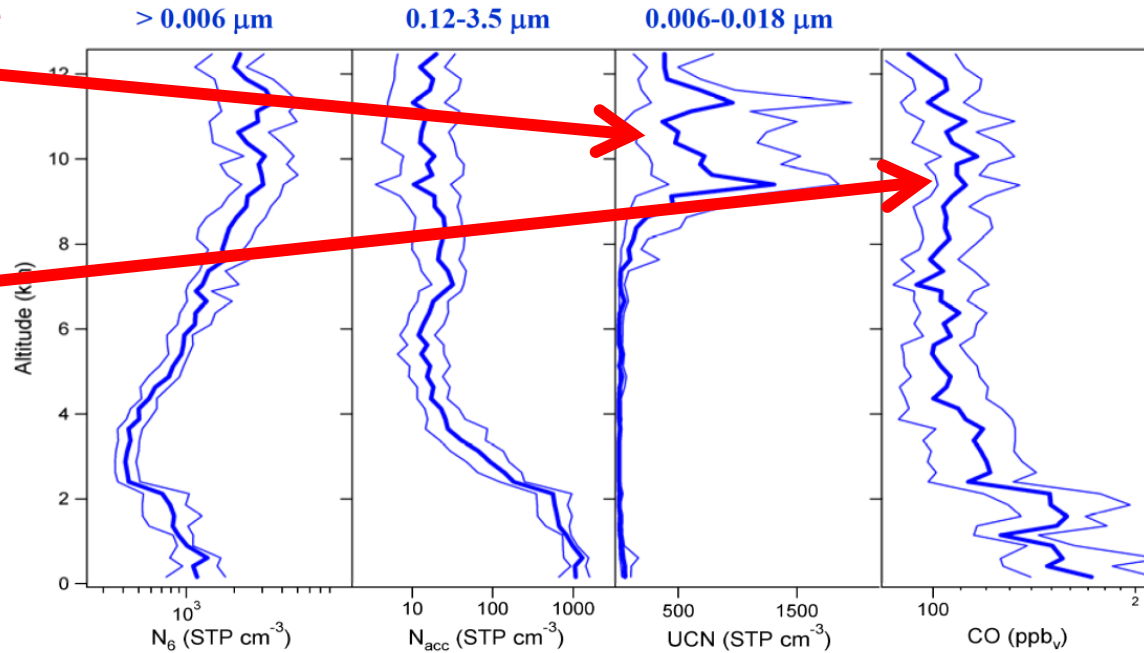


Himalayan ice cores: large BC deposition from Europe in 1950s and 1960s (Xu et al., 2009)

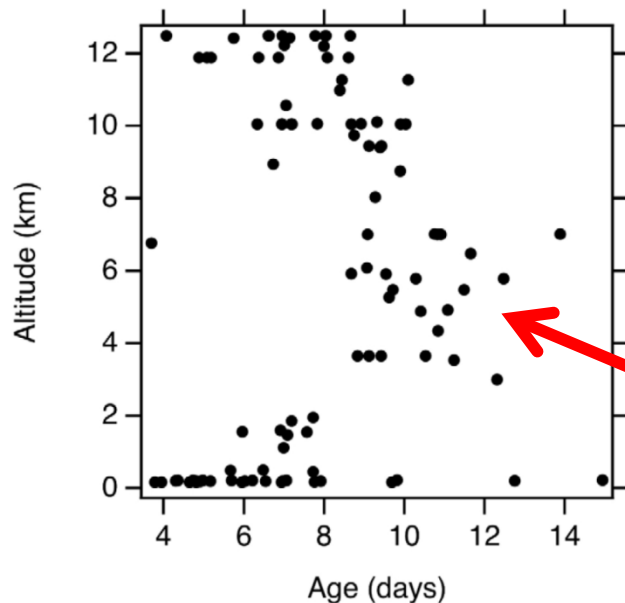
...and still higher up: Convective Outflow

Convective outflow conducive to new particle formation (precip-scavenged air)

...also causes relative enhancement in CO



(de Reus et al., 2001)



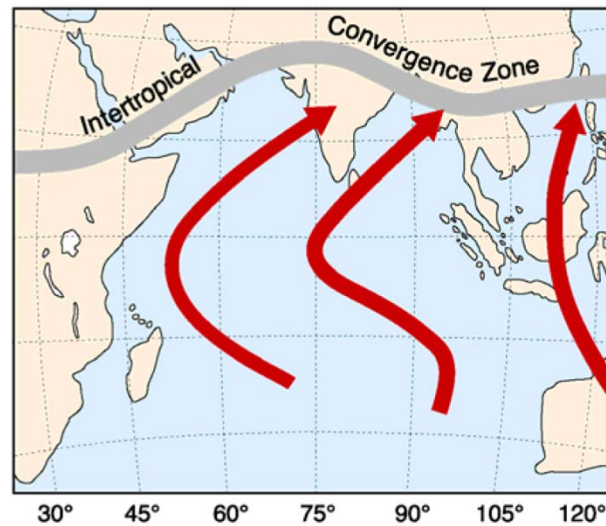
Oldest airmasses in the middle troposphere (subsidence after direct convective transport)

(de Gouw et al., 2001)

- Trends and interannual variability
 - Effects on monsoon circulation and mountain cryospheric reservoirs
- ➔ See Lawrence and Lelieveld (2010) for more info

Summer Monsoon Convective Outflow

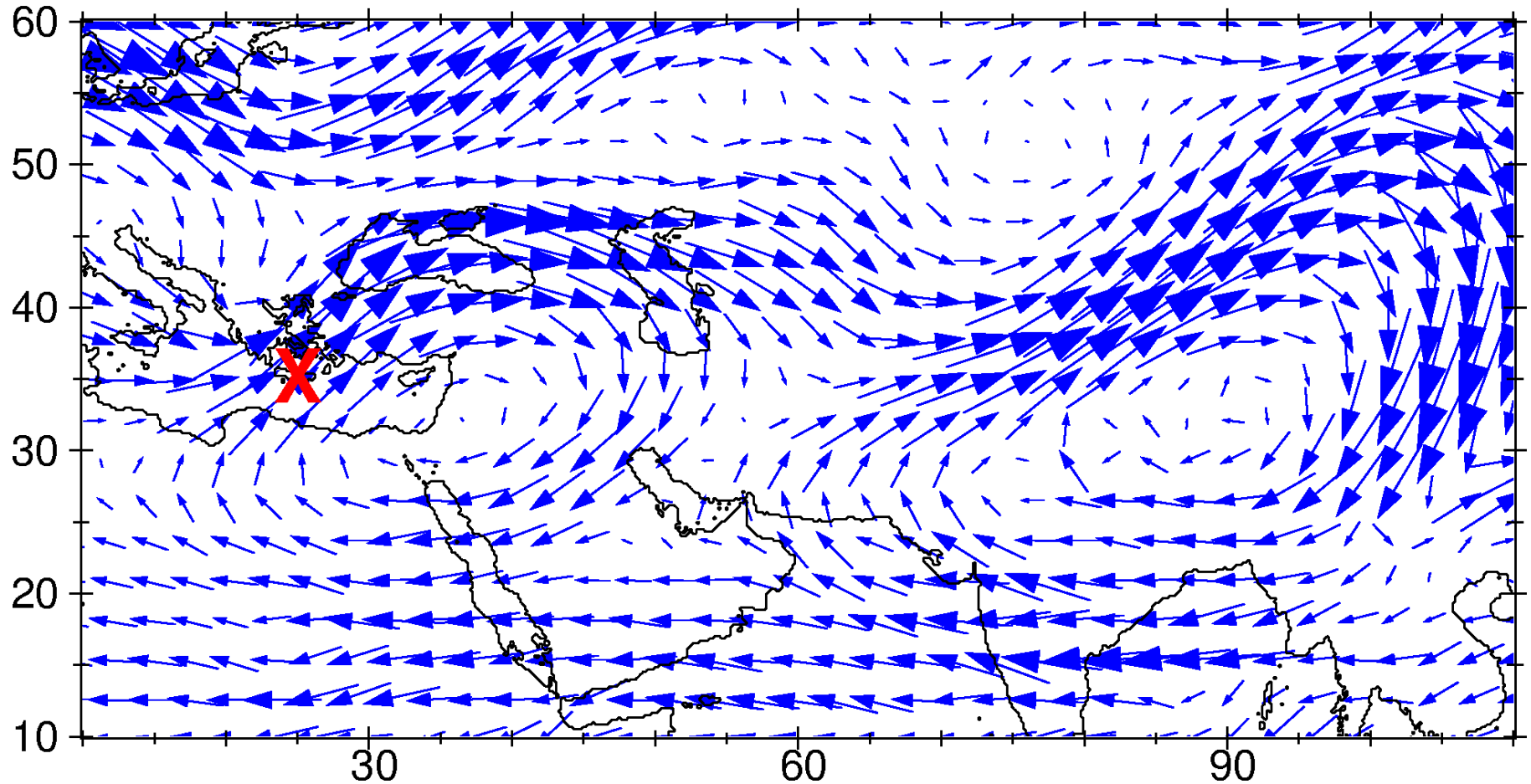
a) June - September



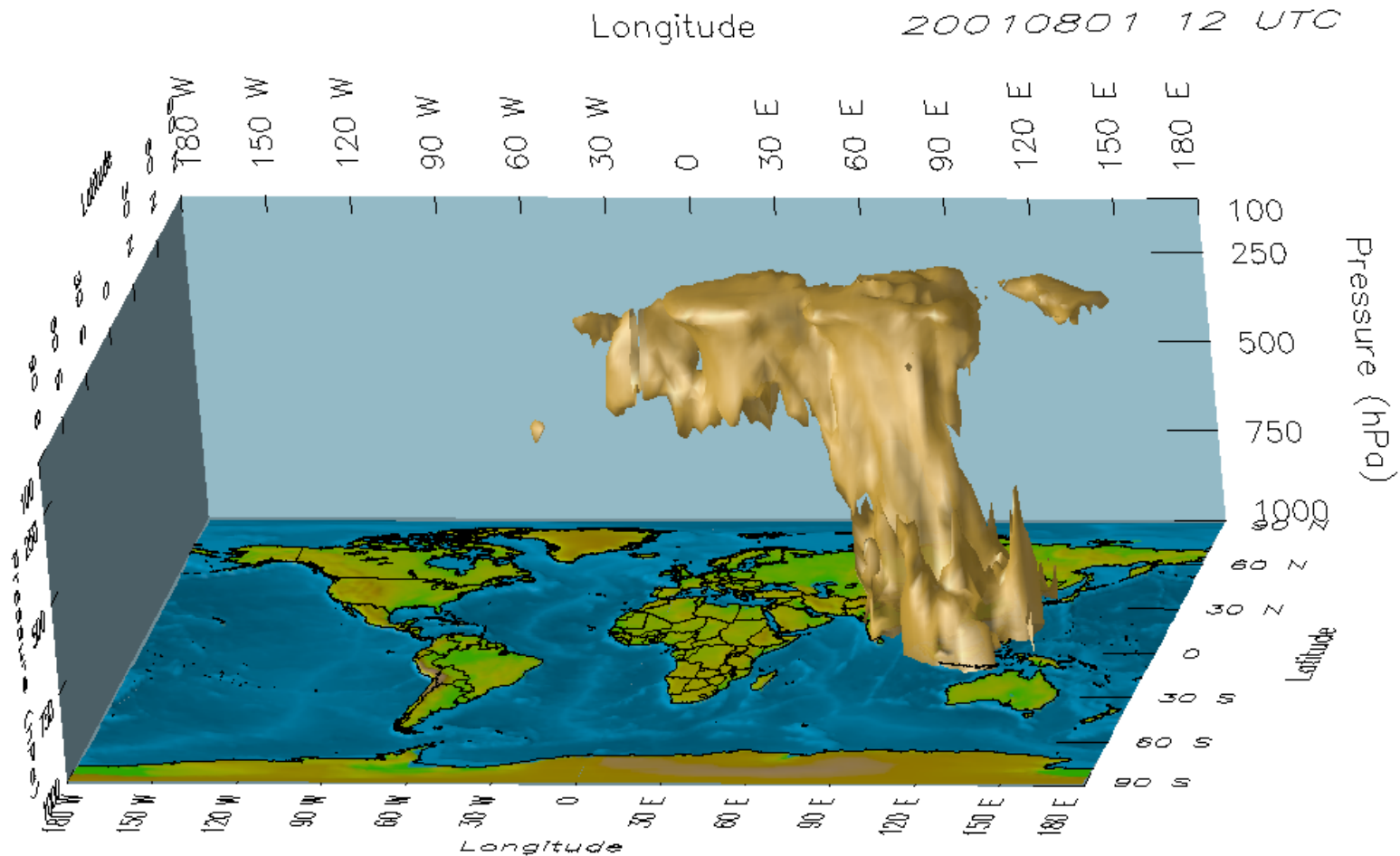
Southern Asian Summer Monsoon Outflow: Upper Tropospheric Winds

20010801 12 UTC

200 hPa



Southern Asian Summer Monsoon Outflow



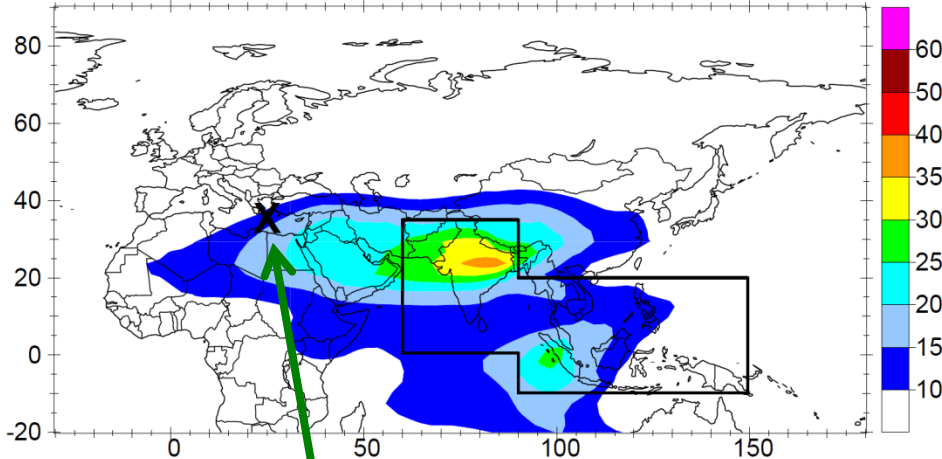
Simulation with the MATCH-MPIC model, CO isosurface at 25 nmol/mol

Northern Asian Summer Monsoon Outflow

Southern Asian CO (nmol/mol)

Monthly Mean: August, 2001

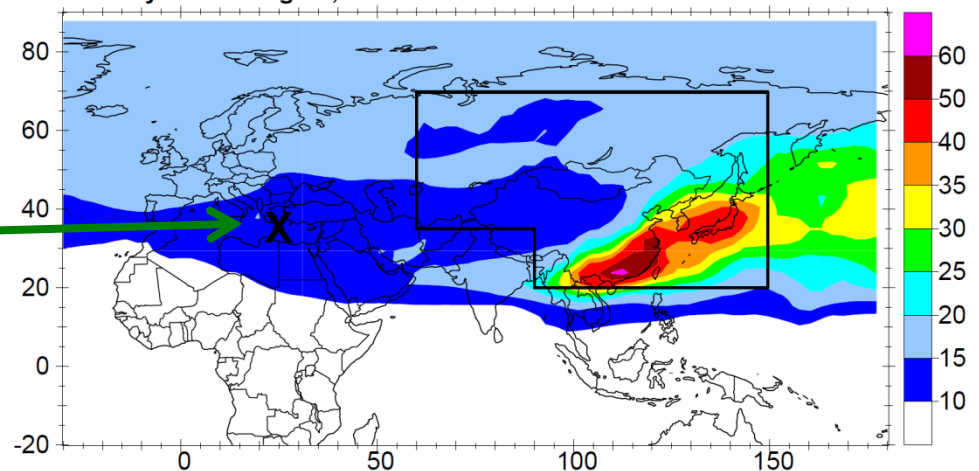
200 hPa



Northern Asian CO (nmol/mol)

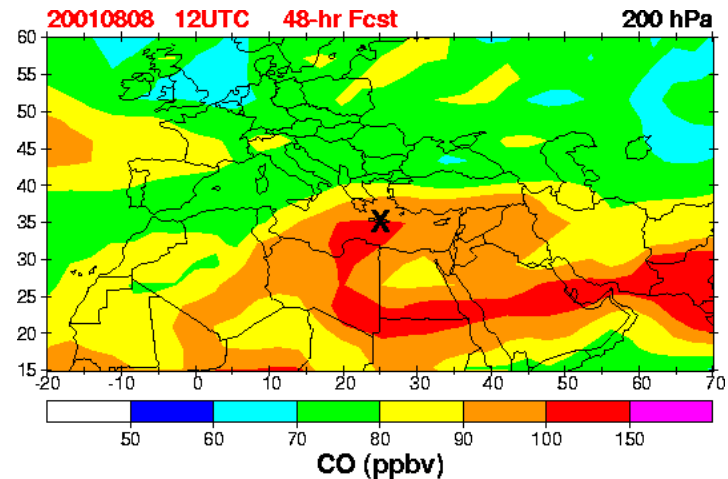
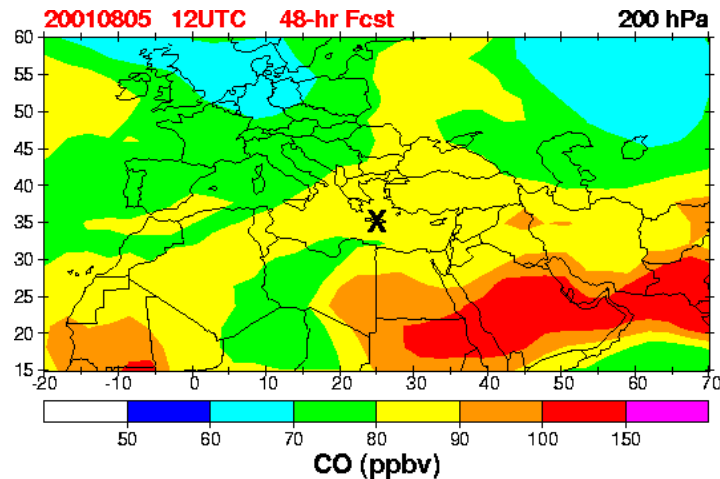
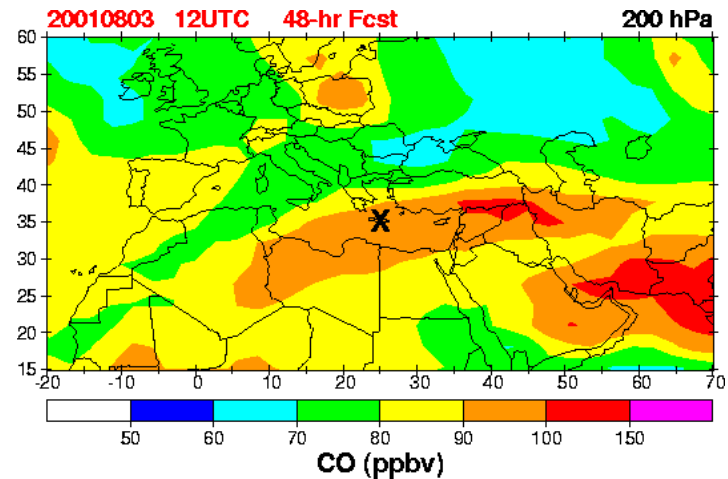
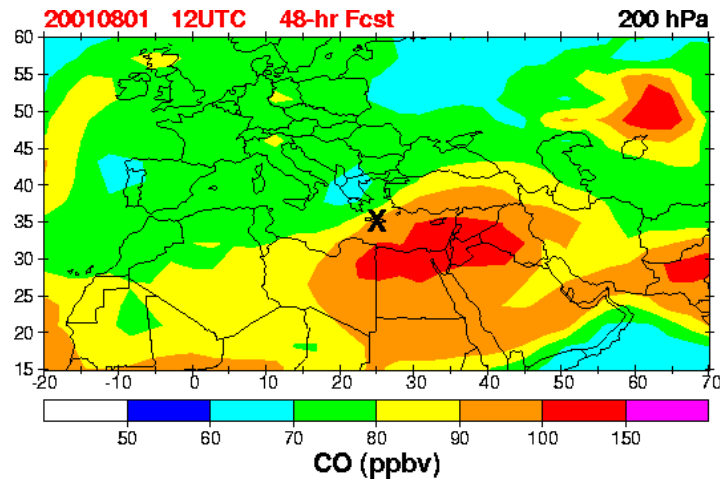
Monthly Mean: August, 2001

200 hPa



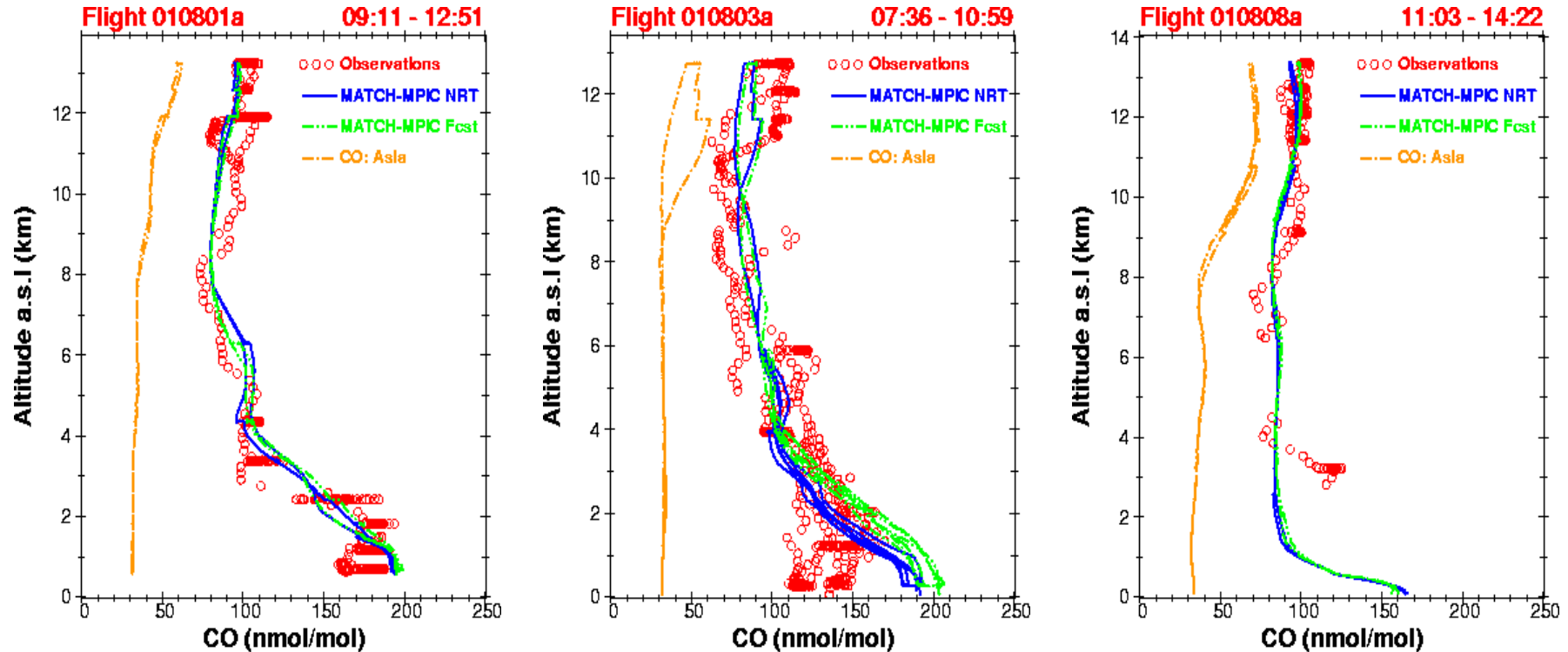
**"X" marks Crete
(Field campaign base for MINOS:
Mediterranean Intensive
Oxidants Study)**

Forecasts used for the MINOS campaign



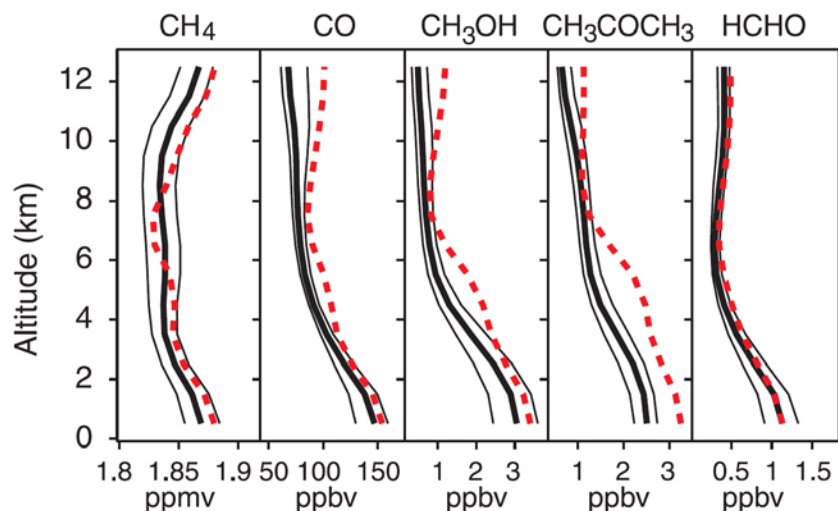
=> Also similar CO tracer forecasts from the ECHAM model

Observations during the MINOS campaign

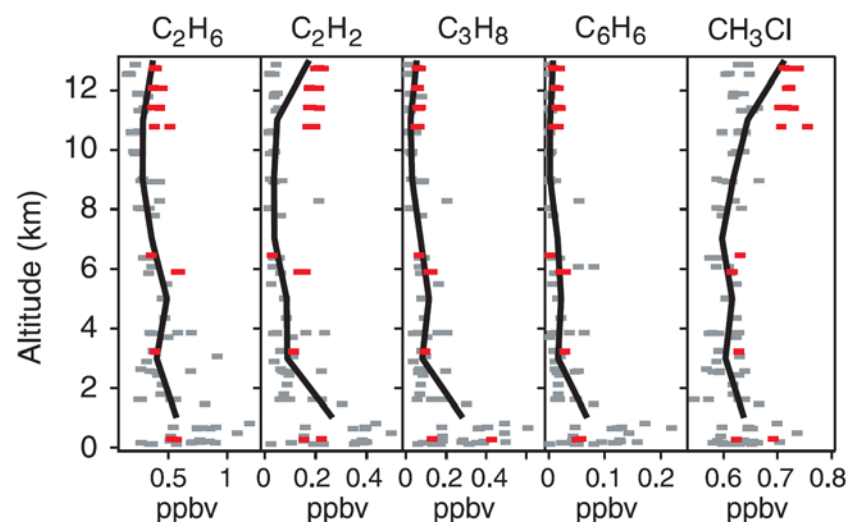
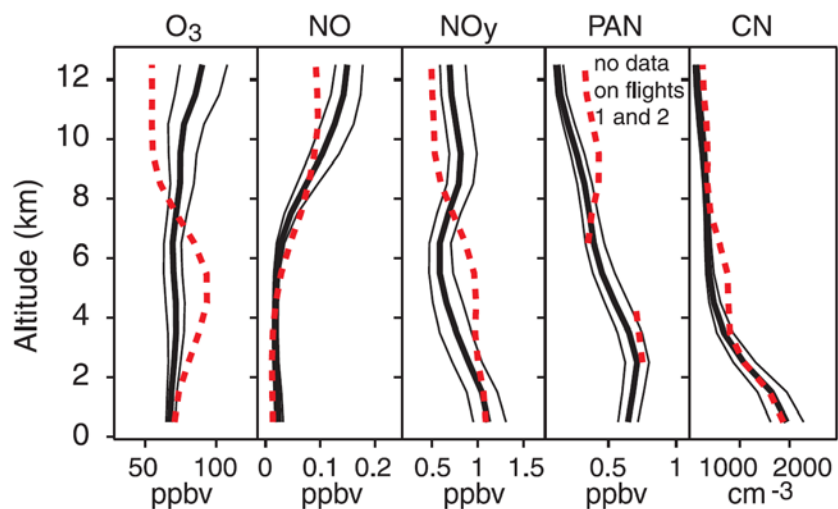


=> Enhancement over campaign average $> 1 \sigma$!

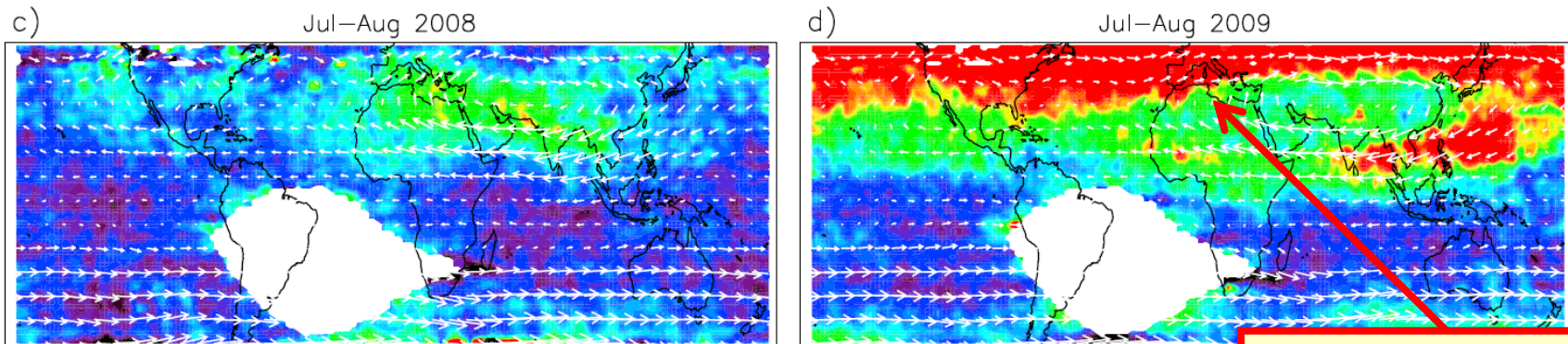
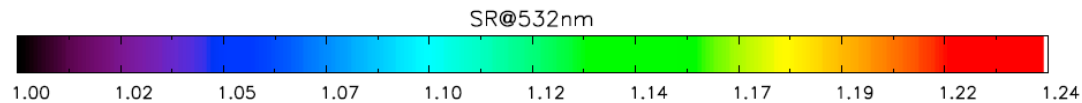
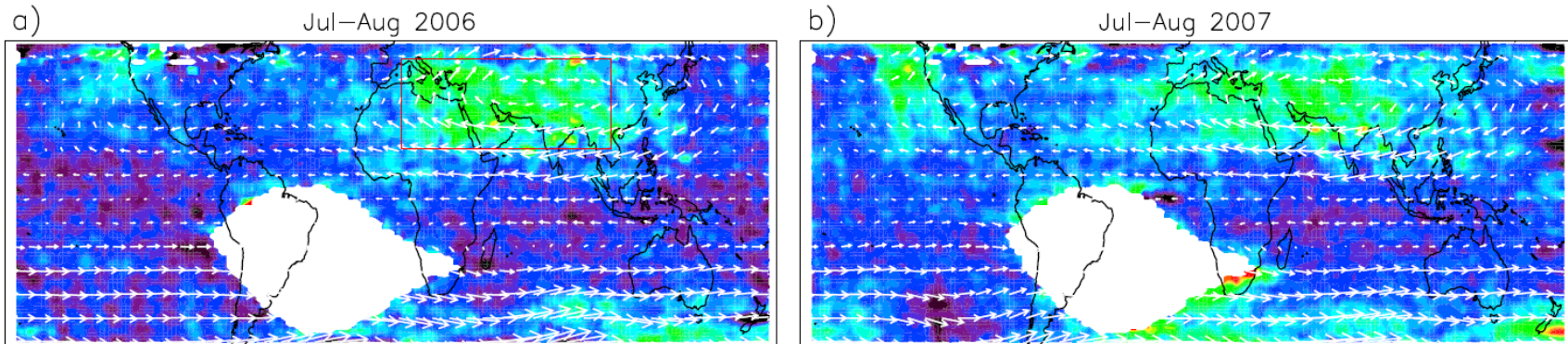
Observations during the MINOS campaign



— Median of all flights
- - - Median of first 3 flights
 (which sampled the Southern Asian plume)



Southern Asian Summer Monsoon Outflow: Also an Enhanced UT Aerosol Layer



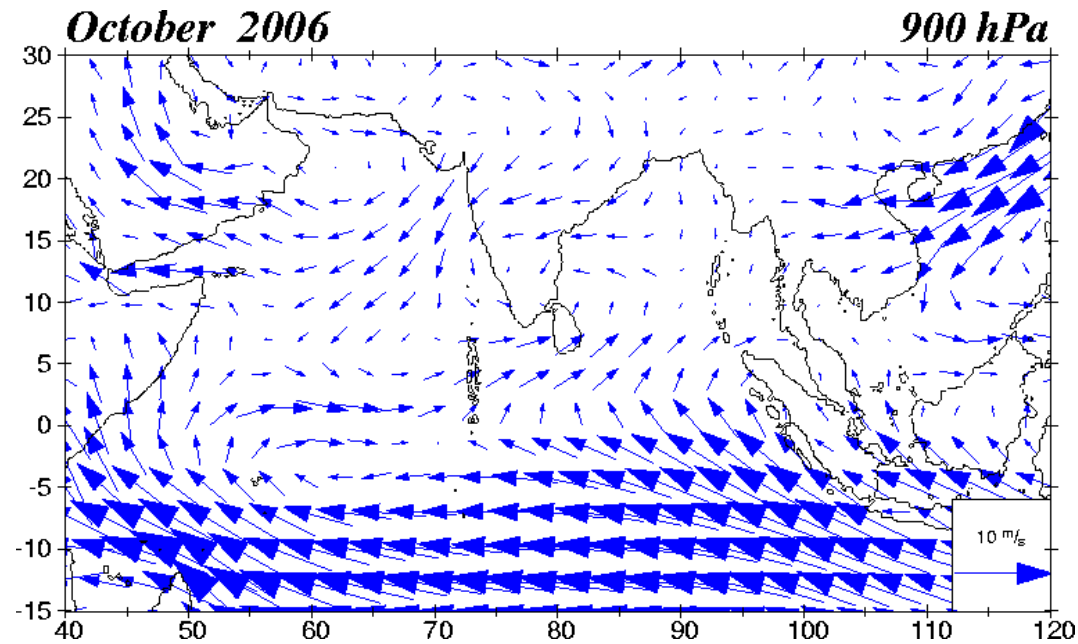
Sarychev Volcano

Southern Asian Summer Monsoon Outflow: Further Effects

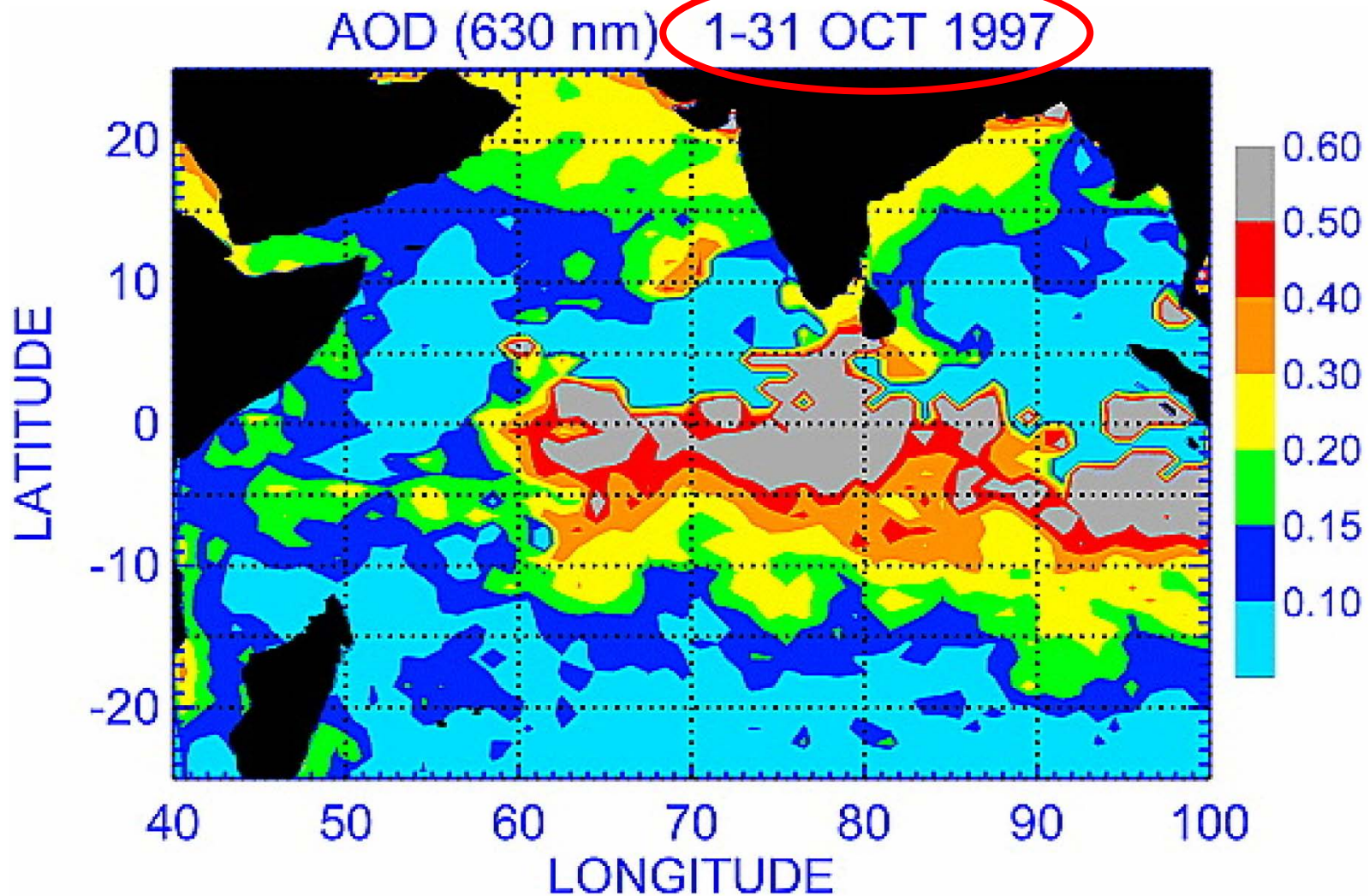


- Influence on regional upper tropospheric cirrus
 - Pathway for transport of pollutants into the stratosphere
- ➔ See Lawrence and Lelieveld (2010) for more info

Monsoon Transition Periods

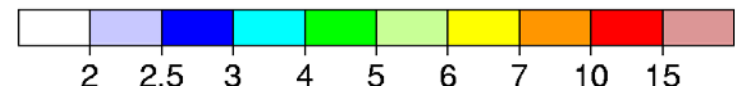
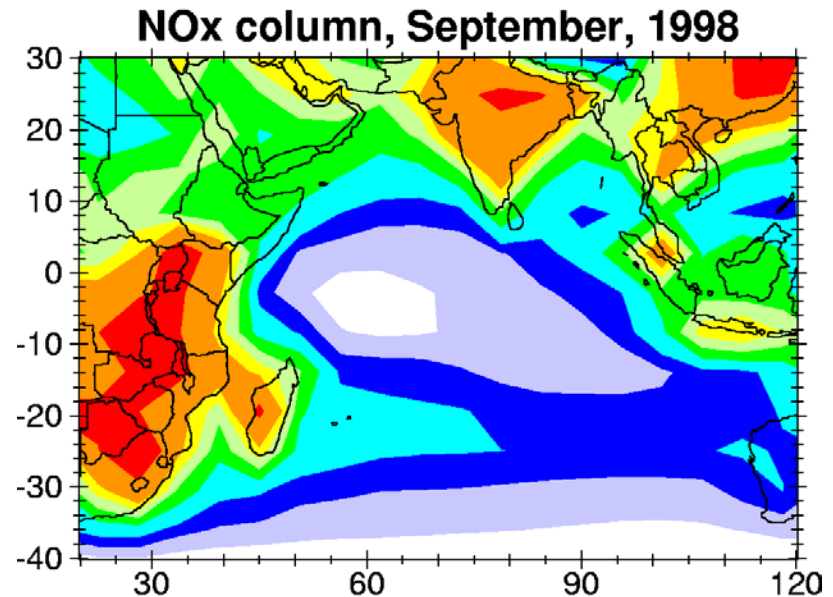
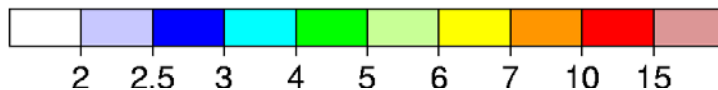
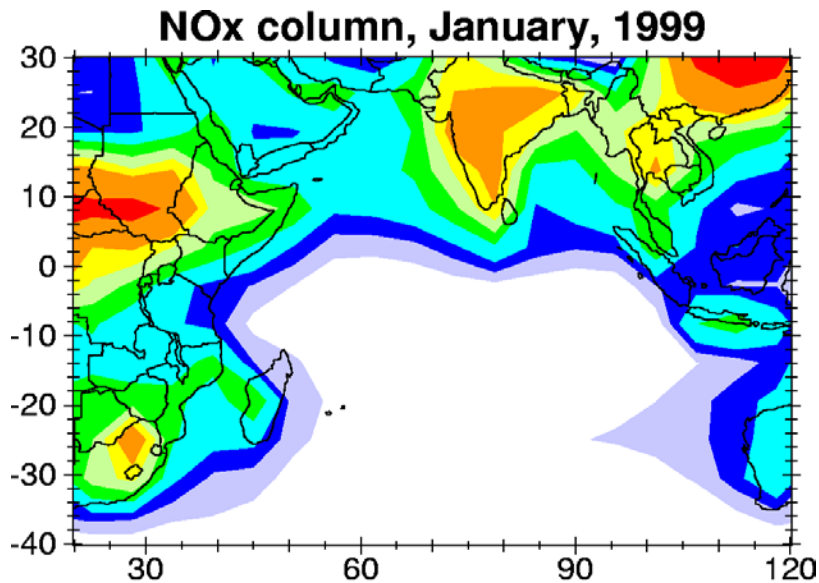


Occasional Very Strong Pollution Plumes from Biomass Burning (esp. during El Nino)



Contrast of Winter Monsoon and the Monsoon Transition Periods

Calculations with the MATCH-MPIC model



- **Recurrent Phenomenon: 2x yearly (monsoon onset and withdrawal)**
- **Varies inter-annually in intensity**
- **Contributions from both SE Asia and Africa**

→ Future research needs – better understanding of:

- Pollutant origins details (surface concentrations and emissions)
- Aerosol aging and chemical reactions in the outflow
- Effects on large-scale monsoon meteorology

Final Note:

Not only is outflow of pollutants from Asia important, but also inflow of pollutants into Asia from other regions can contribute to regional pollutant levels... and of course, the local pollution issues are of greatest concern to those living in Asia!



<http://www.rrcap.unep.org/abc/>