Autonomous Unmanned Aerial Vehicles as a Tool for Measuring Aerosol-Radiation-Cloud-Chemistry

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Scripps Institution of Oceanography

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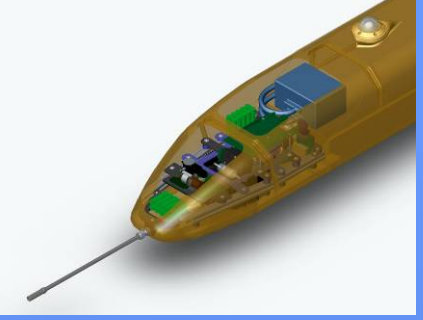
Advantages of Using Lightweight AUAVs

- Complement manned aircraft missions
- Inexpensive, routine operation
- Fly coordinated missions with multiple aircraft
- Can fly in risky environments
- Can operate from remote locations (ships, islands, etc.)

Nature cover article
(August 2, 2007)

ACR Manta

Weight - 23 kg (takeoff)
Wingspan - 2.7 meters
Cruise velocity - 35 m/s
Payload - 5 kg
Flight duration - 5+ hours
Manual or Catapult Launch
Autonomous GPS flight
Satellite communication link



Scripps Payload Design & Integration

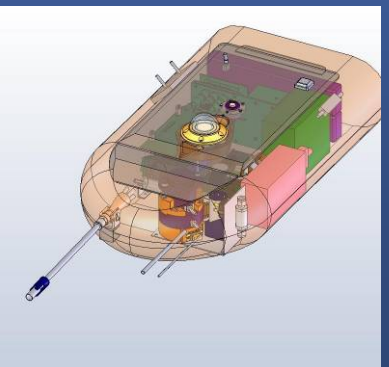
2003 – 2004

Initial development *Jan. – May '03*	Seattle, WA *Sept. '03*	El Mirage, CA *Dec. '03*	Seattle, WA *July '04*	El Mirage, CA *Sept. '04*	MALDIVES *Oct. '04*

2005 – 2006

Tucson, AZ *May '05*	Tucson, AZ *July '05*	Yuma, AZ *Aug. '05*	El Centro, CA *Nov. '05*	MALDIVES *Mar. '06*

Thanks Mari

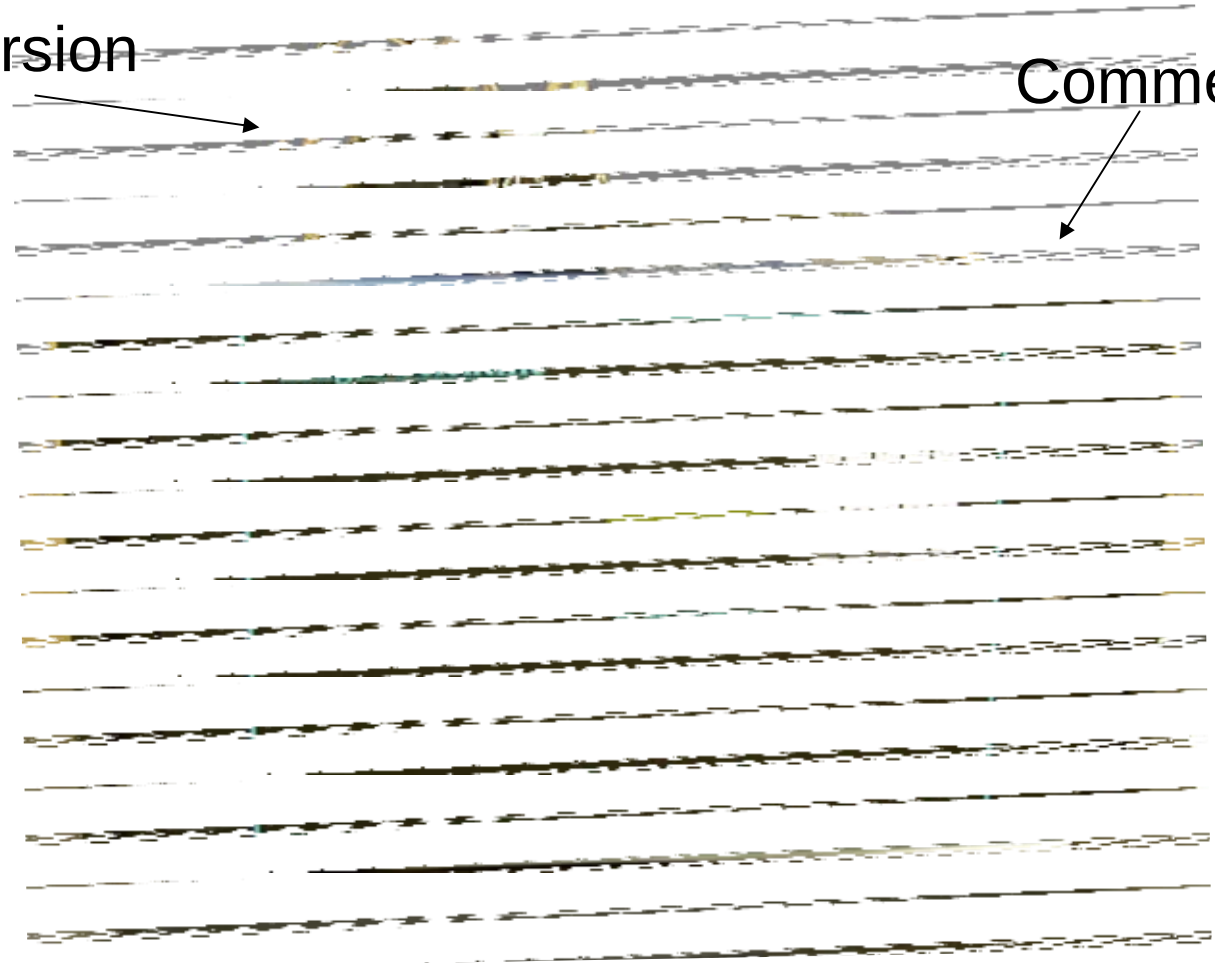


Test Flights

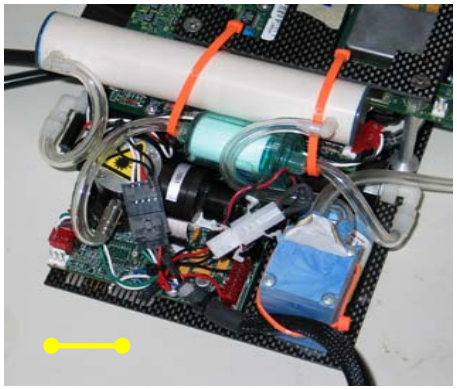
Instrumented Flights

Experiments

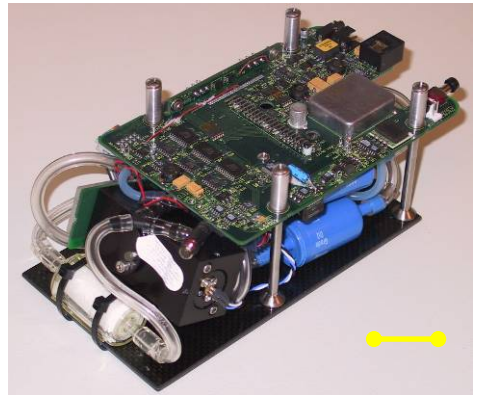
Necessary to Shrink Instruments



Miniaturized Instruments for UAV



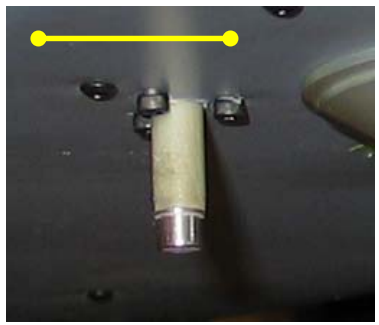
Optical Particle Counter (580 g)
→ N_{OPC}; $0.3 < D_p < 3$ µm



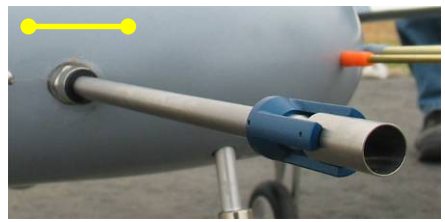
Condensation Particle Counter (870 g) → N_{CN}; $D_p > 10$ nm

[=] 1 inch

Aethalometer (820 g)
→ absorbing aerosol

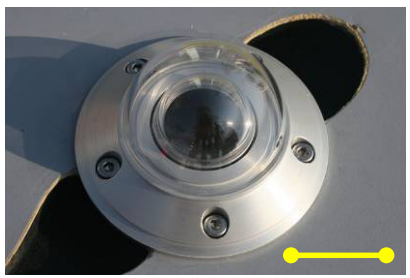


T/RH probe (50 g)
→ Temperature & RH

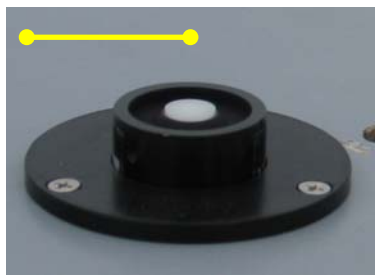


Aerosol inlet & splitter (150 g)
→ unbiased aerosol sampling

Cloud Droplet Spectrometer (1.4 kg) → distr. $1 < D < 50$ µm

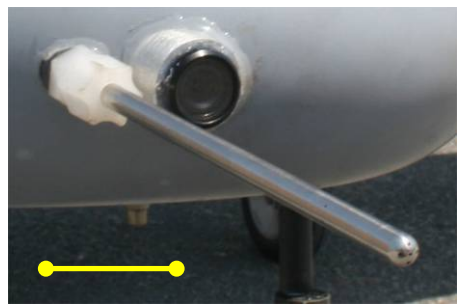


Pyranometer (190 g)
→ irradiance 0.3 – 2.8 µm



PAR radiometer (45 g)
→ irradiance 400 – 700 nm

LWC probe (450 g)
→ Cloud water (g m^{-3})

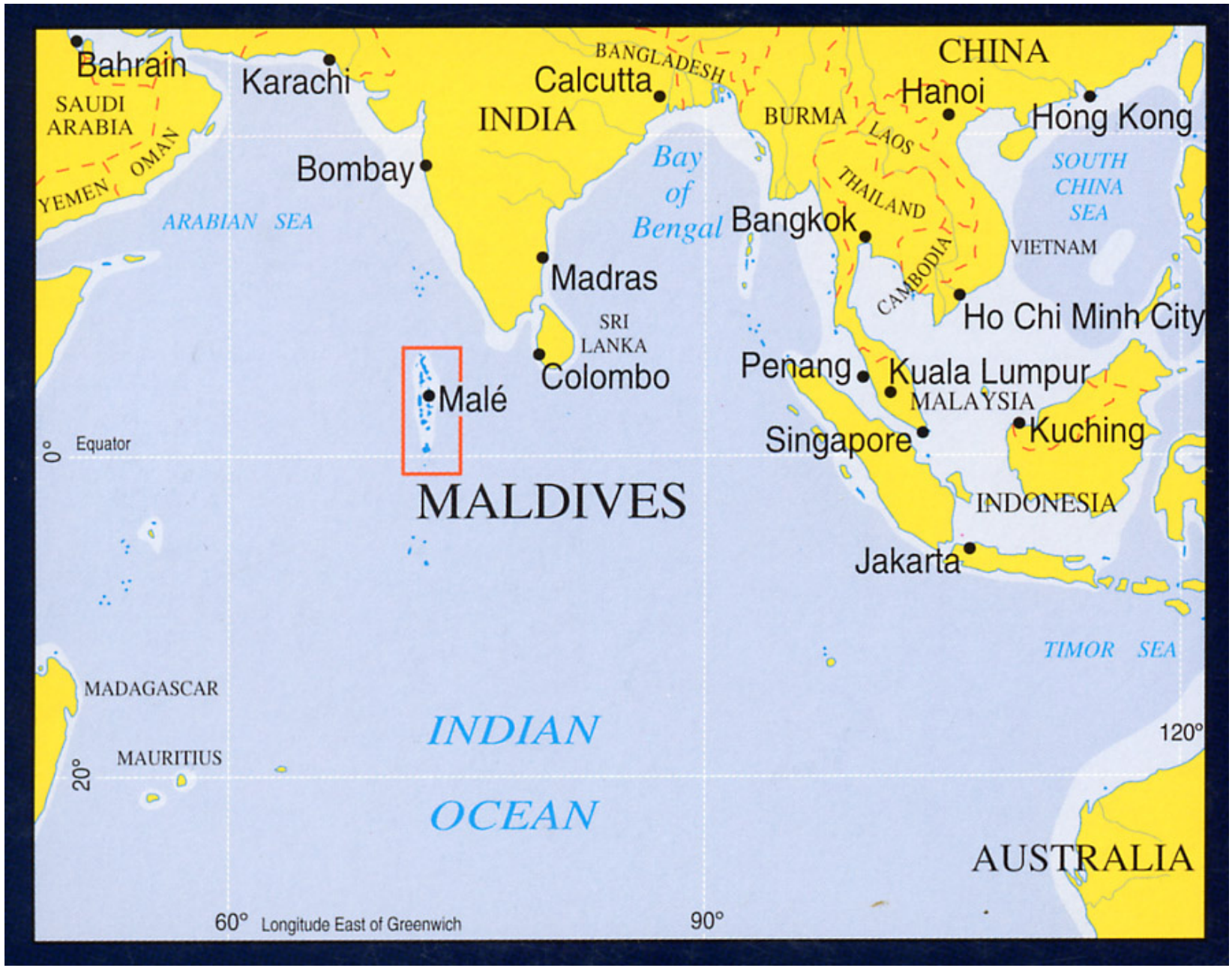


Video camera (280 g)
→ cloud targeting

The Maldives Autonomous Unmanned Aerial Vehicle Campaign (MAC)

06 March - 01 April, 2006

(NSF and NOAA)


Bahrain
Karachi
SAUDI ARABIA
OMAN
YEMEN
Bombay
ARABIAN SEA
BANGLADESH
Calcutta
INDIA
Bay of Bengal
BURMA
CHINA
Hanoi
Hong Kong
LAOS
THAILAND
SOUTH CHINA SEA
Bangkok
VIETNAM
CAMBODIA
Madras
Ho Chi Minh City
SRI LANKA
Colombo
Penang
Kuala Lumpur
MALAYSIA
Malé
Kuching
Singapore
0° Equator
MALDIVES
INDONESIA
Jakarta
TIMOR SEA
MADAGASCAR
INDIAN
120°
MAURITIUS
20°
OCEAN
AUSTRALIA
60° Longitude East of Greenwich
90°

Hanimaadhoo Island

Maldives Climate Observatory - Hanimaadhoo (MCOH)

Project Atmospheric Brown Cloud

MAC Stacked UAV Flight Configuration

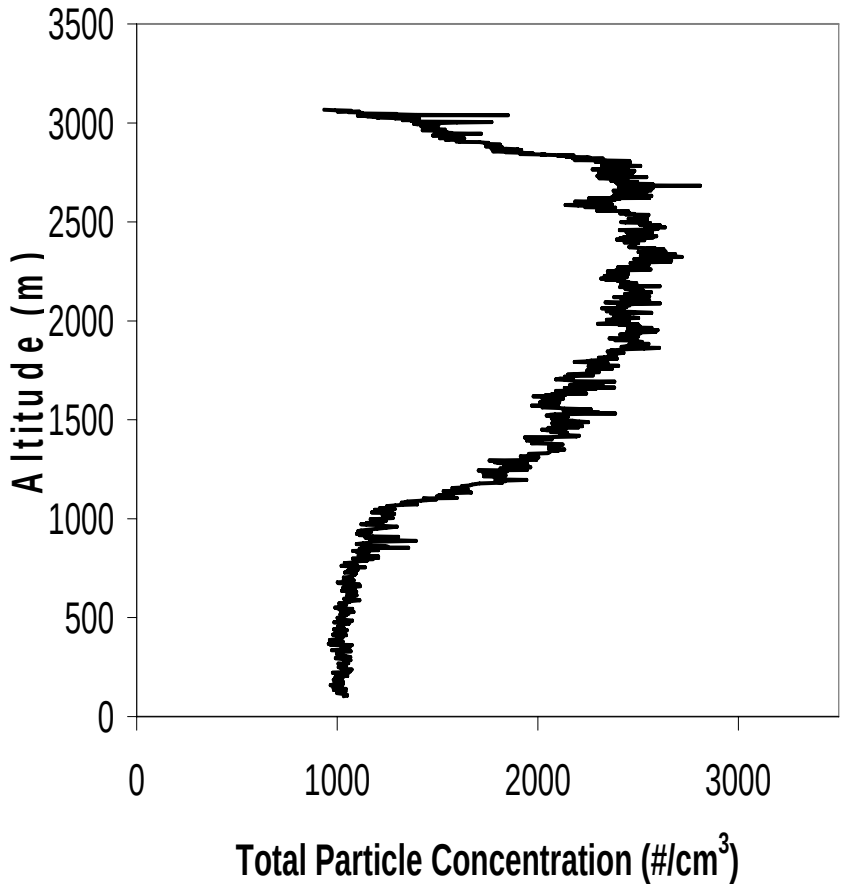
3 km asl

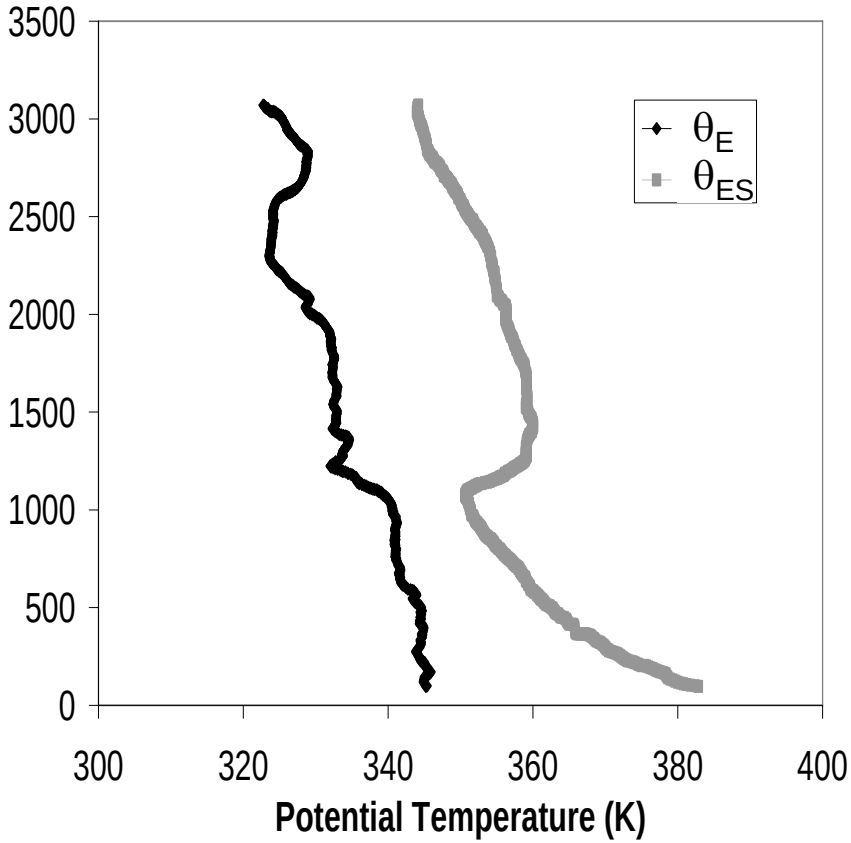
In cloud

100 m below cloud

Surface observations

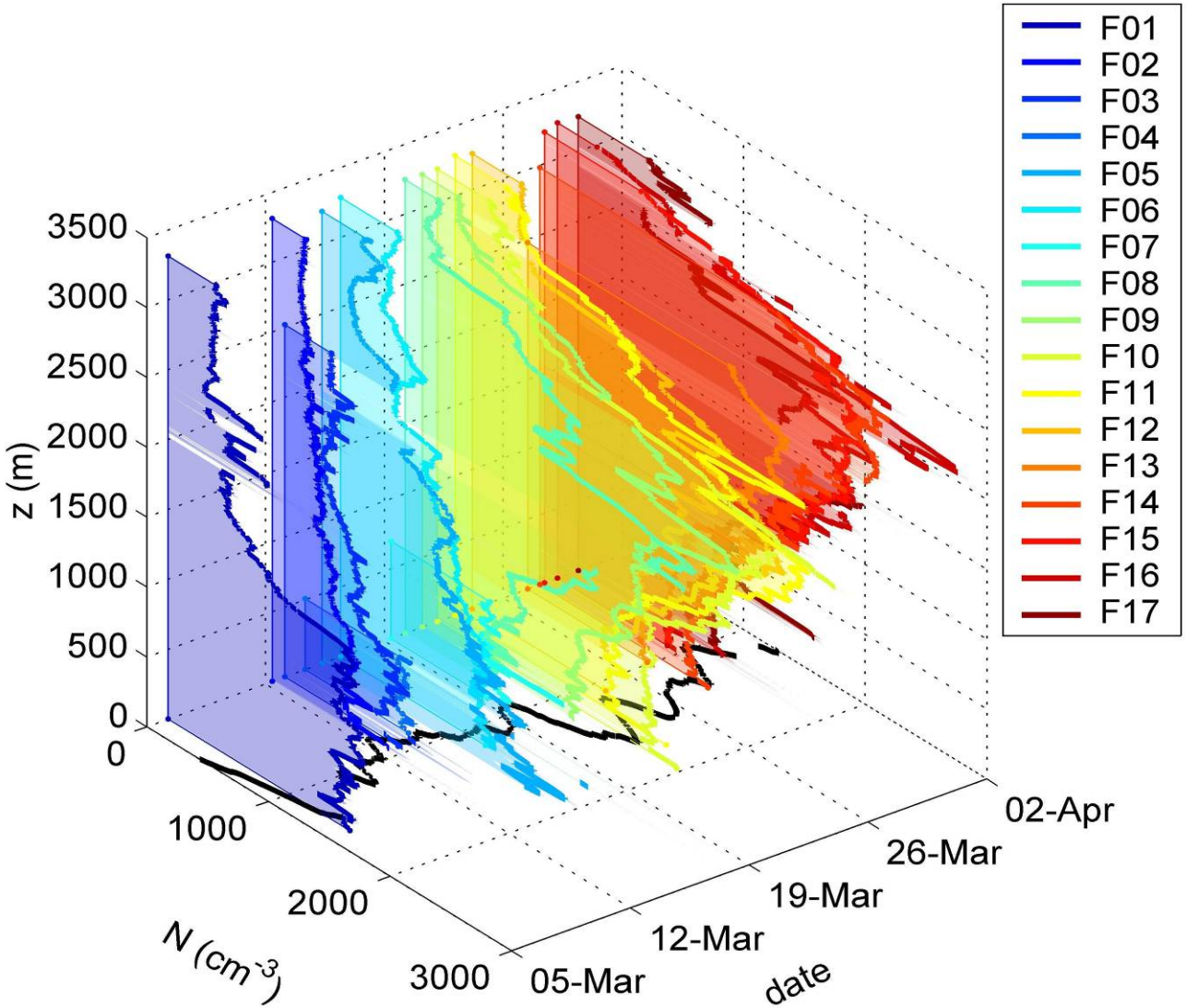
Atmospheric Layers





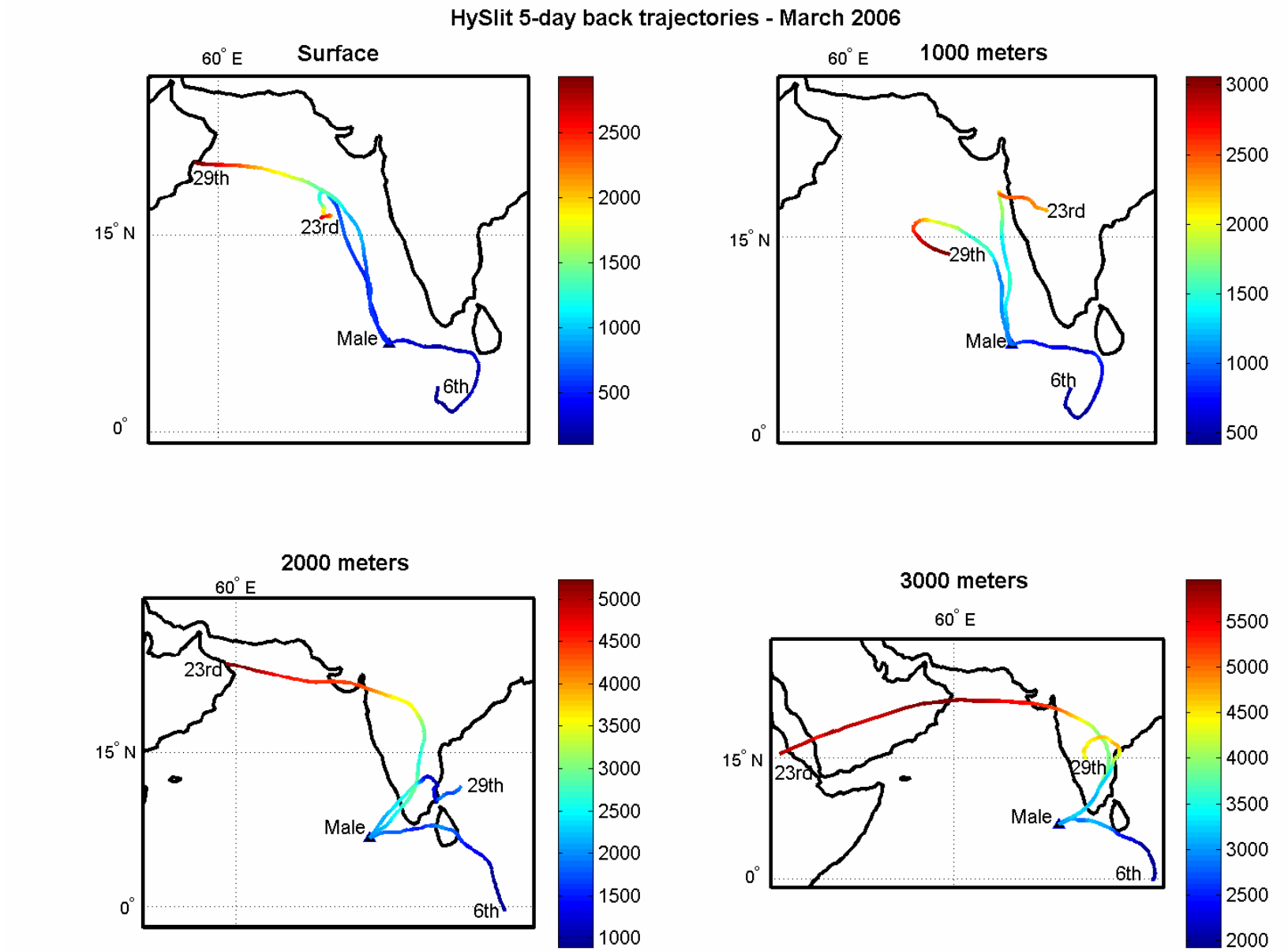
Corrigan et al., 2007

Total Particle Concentration during MAC



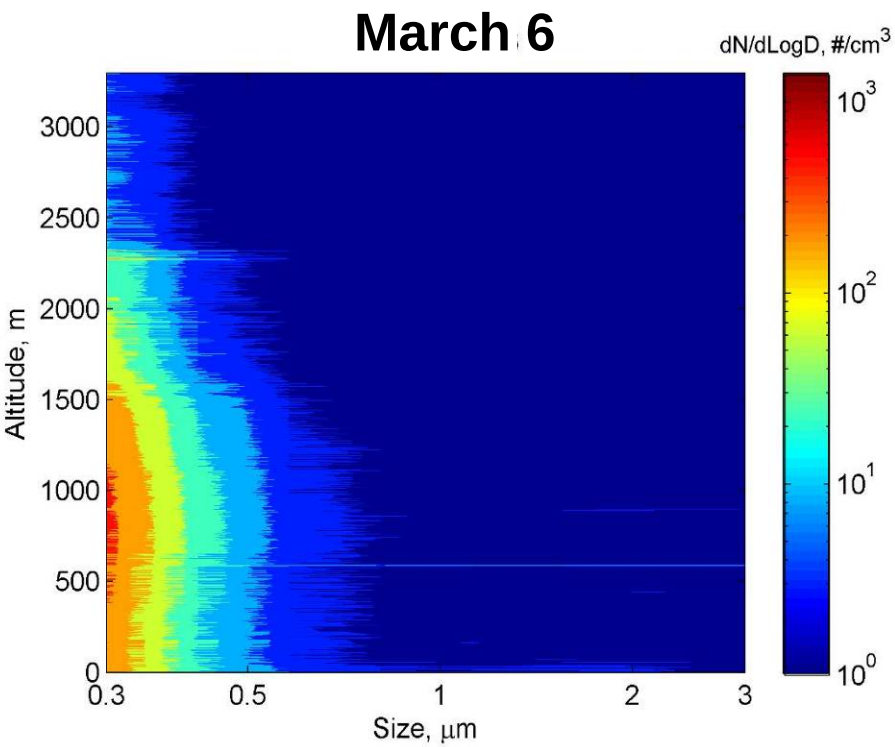
Corrigan et al., 2007

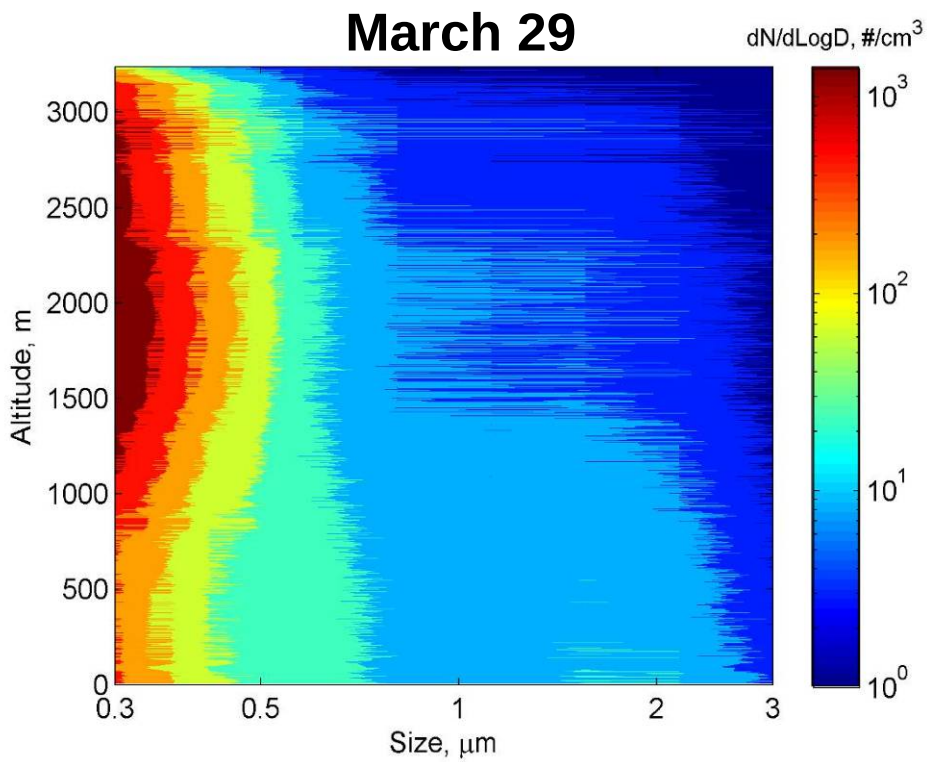
Five day back trajectories during MAC



Corrigan et al., 2007

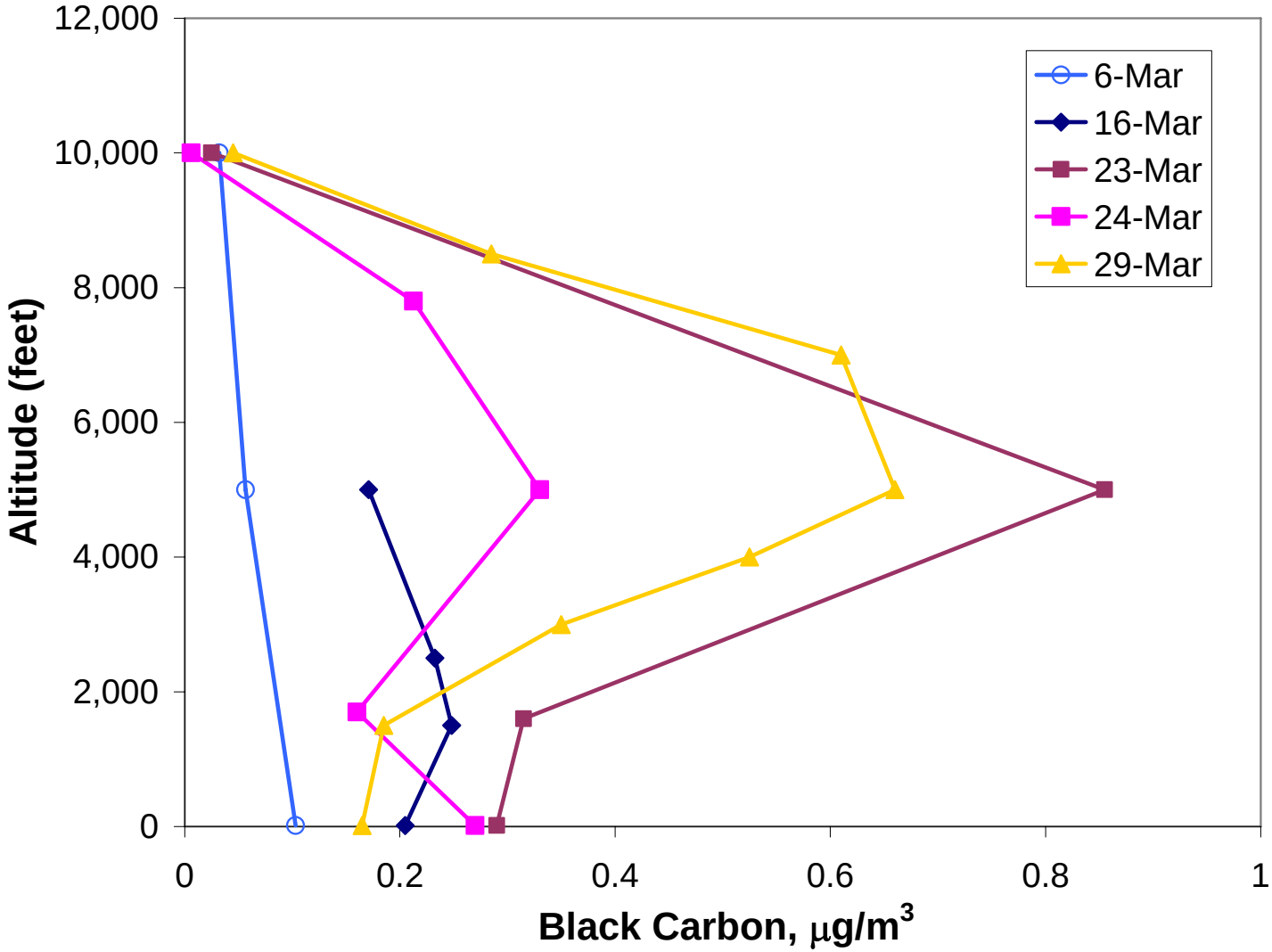
Aerosol Size Distribution from Clean and Polluted Periods





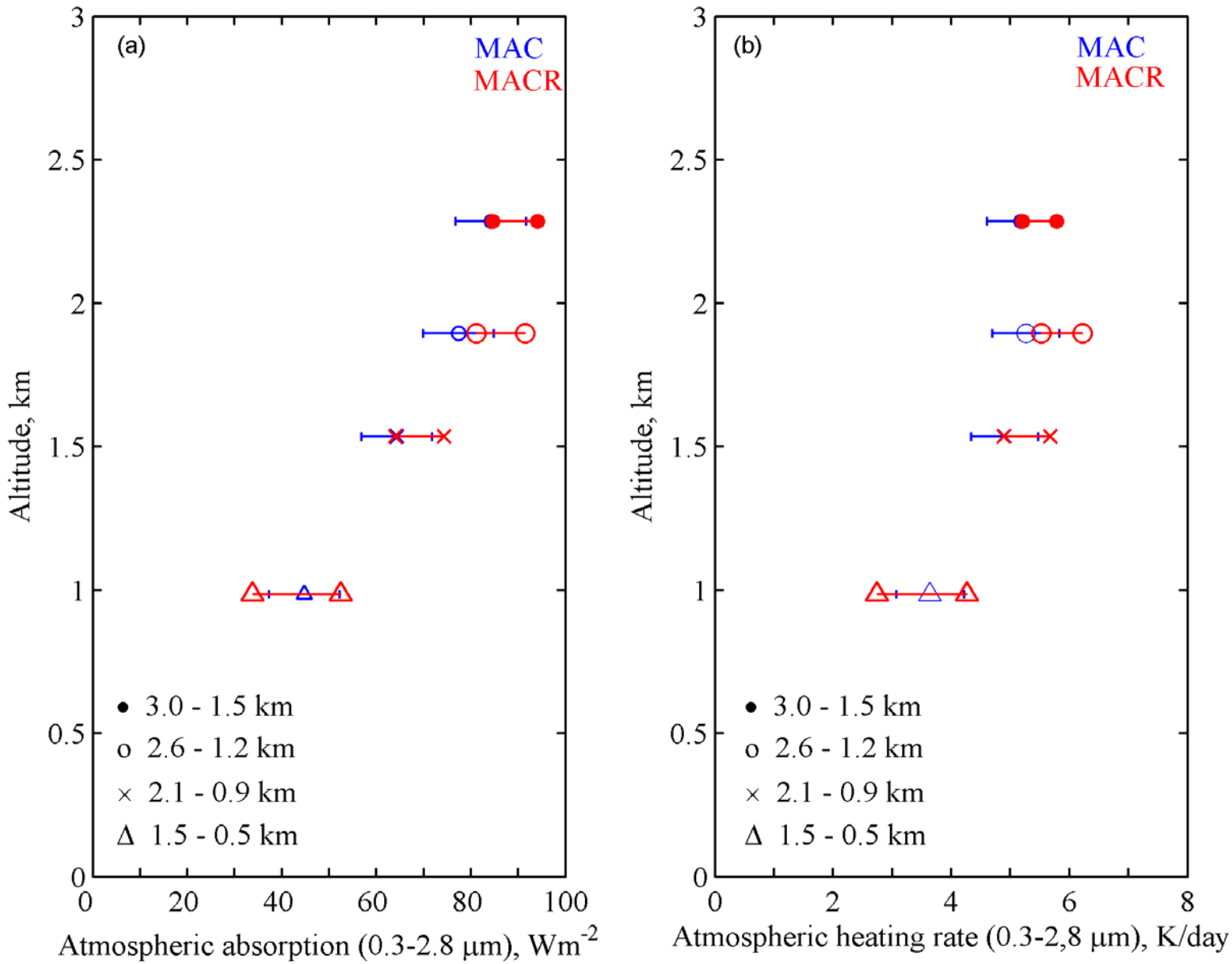
Corrigan et al., 2007

Black Carbon Vertical Profiles during MAC



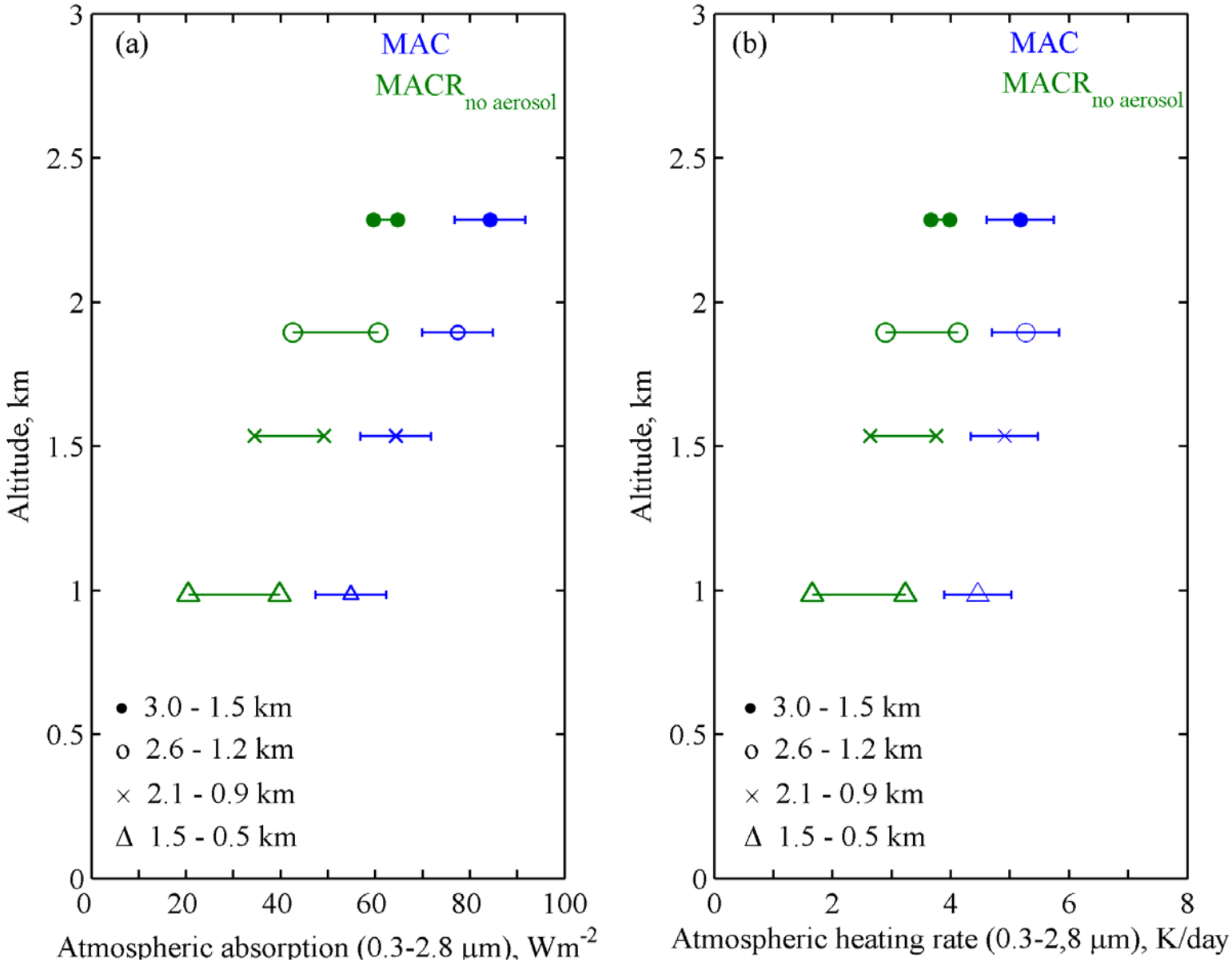
Corrigan et al., 2007

Atmospheric Absorption and Heating rate : Aerosols



Ramana et al., 2007

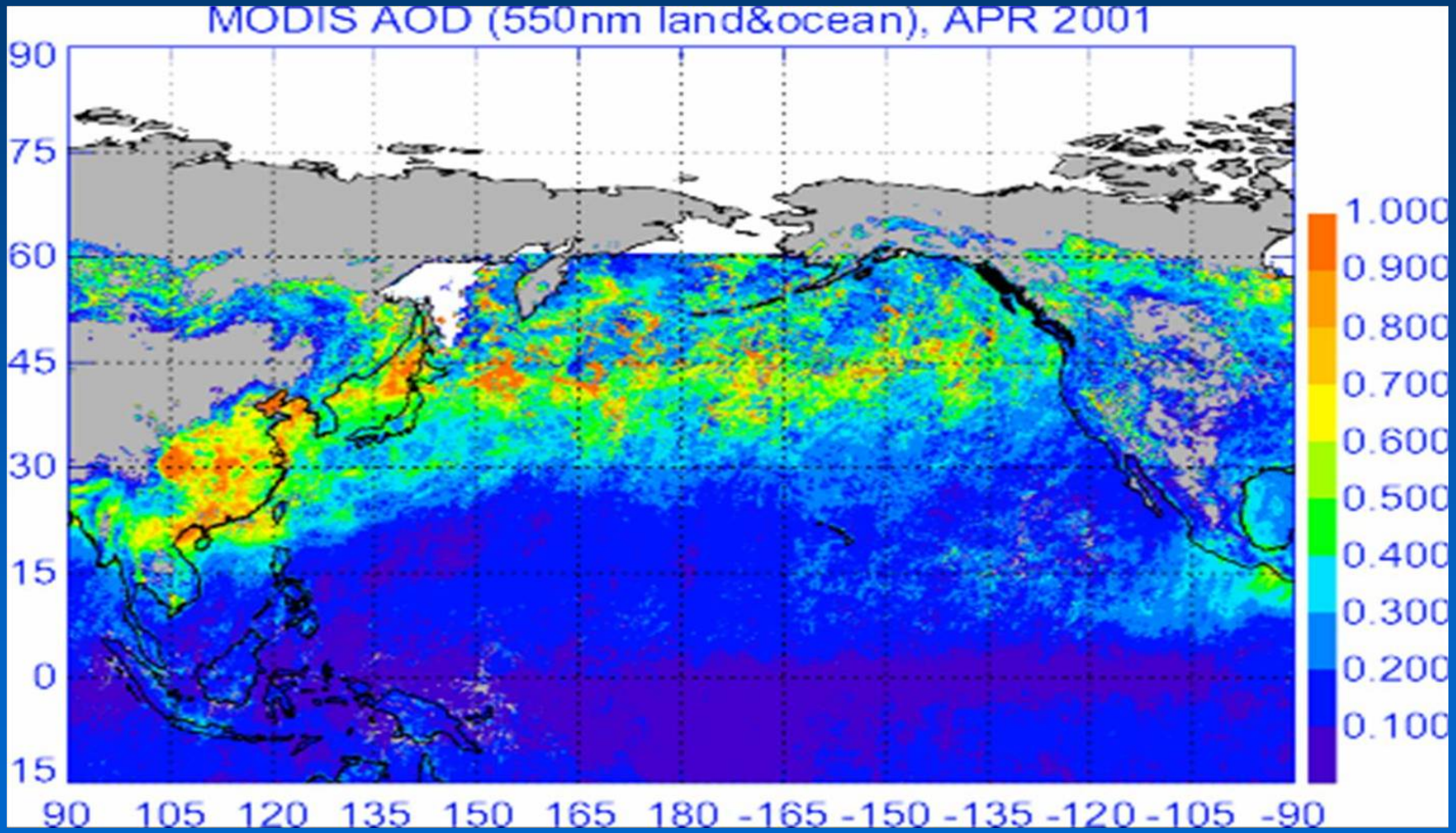
Atmospheric Absorption and Heating rate : No Aerosols



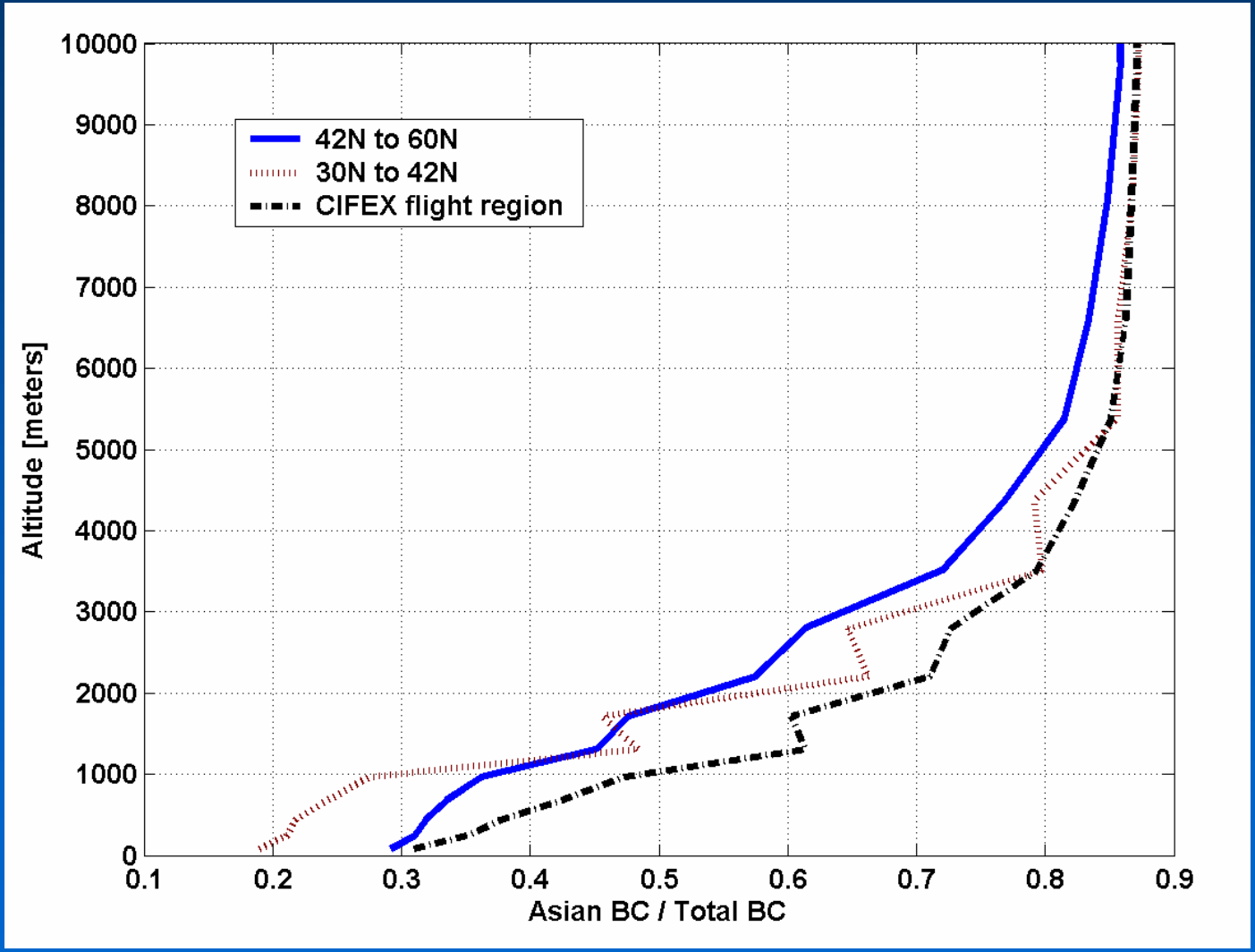
CAPPS
(California AUAV Air Pollution Profiling Study)
Funded by Calif. Energy Commission.

- Collect an annual record of aerosol, black carbon, ozone, NO_x* and CO* pollution concentrations from surface up to 12,000 feet asl.
- California generated pollution vs. long-range pollution from other regions.
- Look at the impact of pollution layers on radiative forcing to quantify the amount of solar dimming and heating rates.

Asian particulate pollution transported to North America

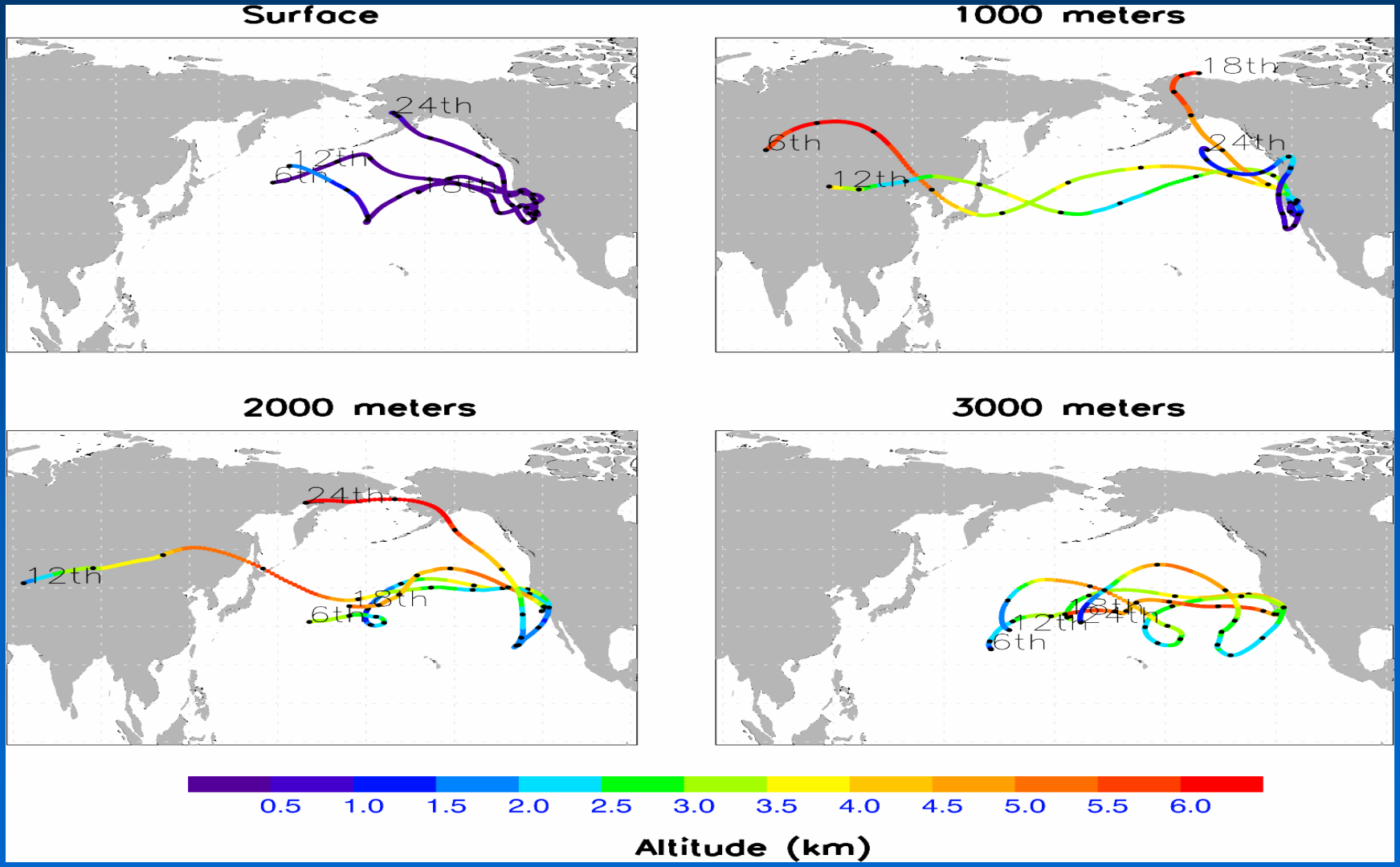


Influence of Asian black carbon increases with altitude.

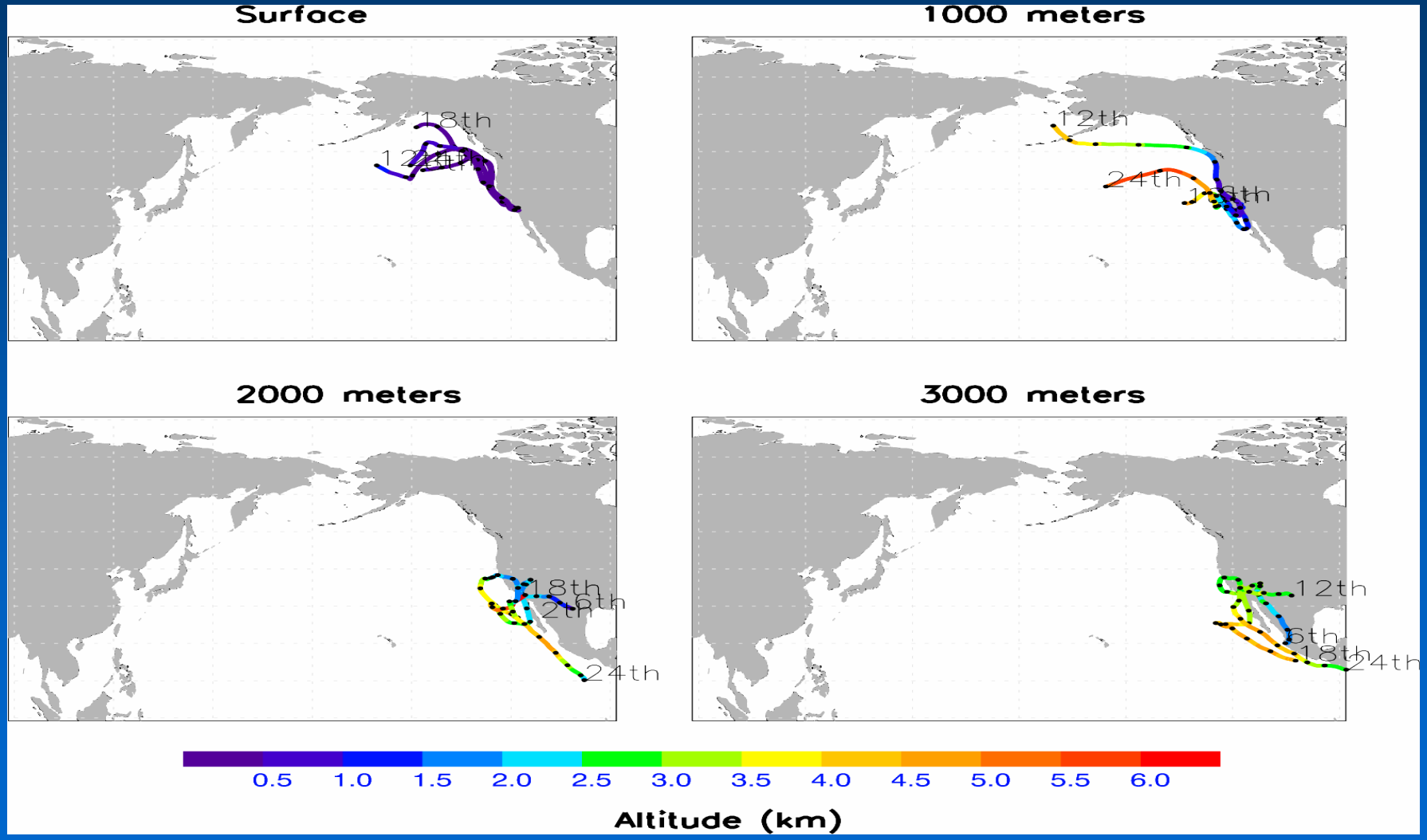


Hadley et al., 2006

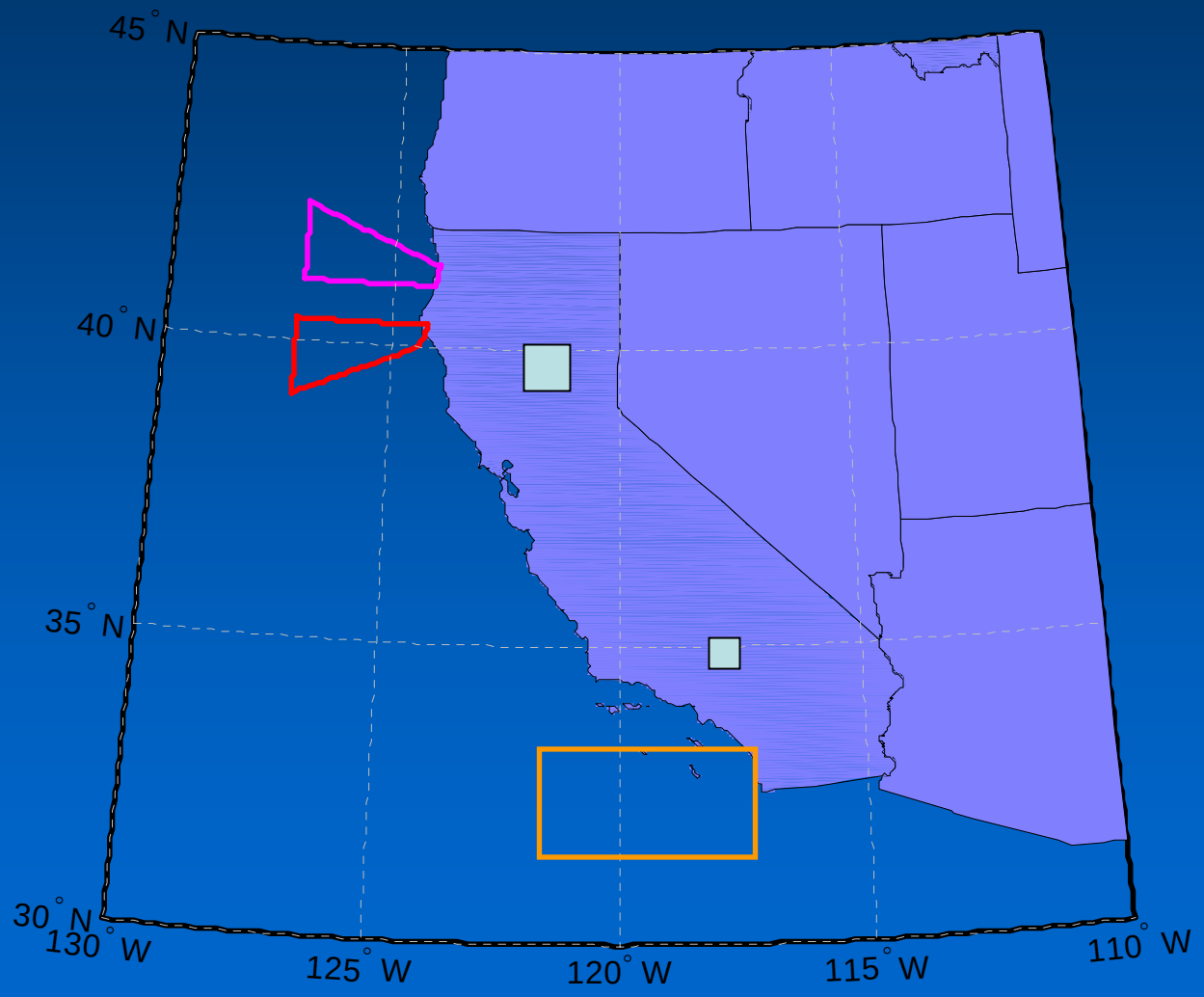
Nine-day back trajectories from Edwards Air Force Base for Spring 2005



Nine-day back trajectories from Edwards Air Force Base for Summer 2005



Flight Locations of Interest



Measurements for CAPPS

- Aerosol Number Concentration
- Aerosol Size Distribution (0.3 – 3 μm)
- Aerosol Absorption/Black Carbon Concentration
- Ozone
- CO*
- NO_x/NO/NO_2*
- Solar Flux
- Temperature, Pressure, Relative Humidity

Project Summary

- Fly one evening and one morning mission twice a month (flexible)
- Missions will climb to 12,000 ft asl.
- Missions will last approx. 4-5 hours.
- Two aircraft will be launched (aerosol and gas measurements)
- Jan – Dec 2008