

Aerosol-Radiation-Cloud-Gas Measurement using UAS

Scripps Institution of Oceanography

Lead PI – V Ramanathan

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ARM AVP Workshop

October 17, 2008

Univ. of Illinois – Champaign/Urbana

UAVs have arrived as
a tool for studying the
atmosphere.

*Ramanathan
et al, Nature 2007*



MAC Stacked UAV Flight Configuration



3 km asl



In cloud



100 m below cloud



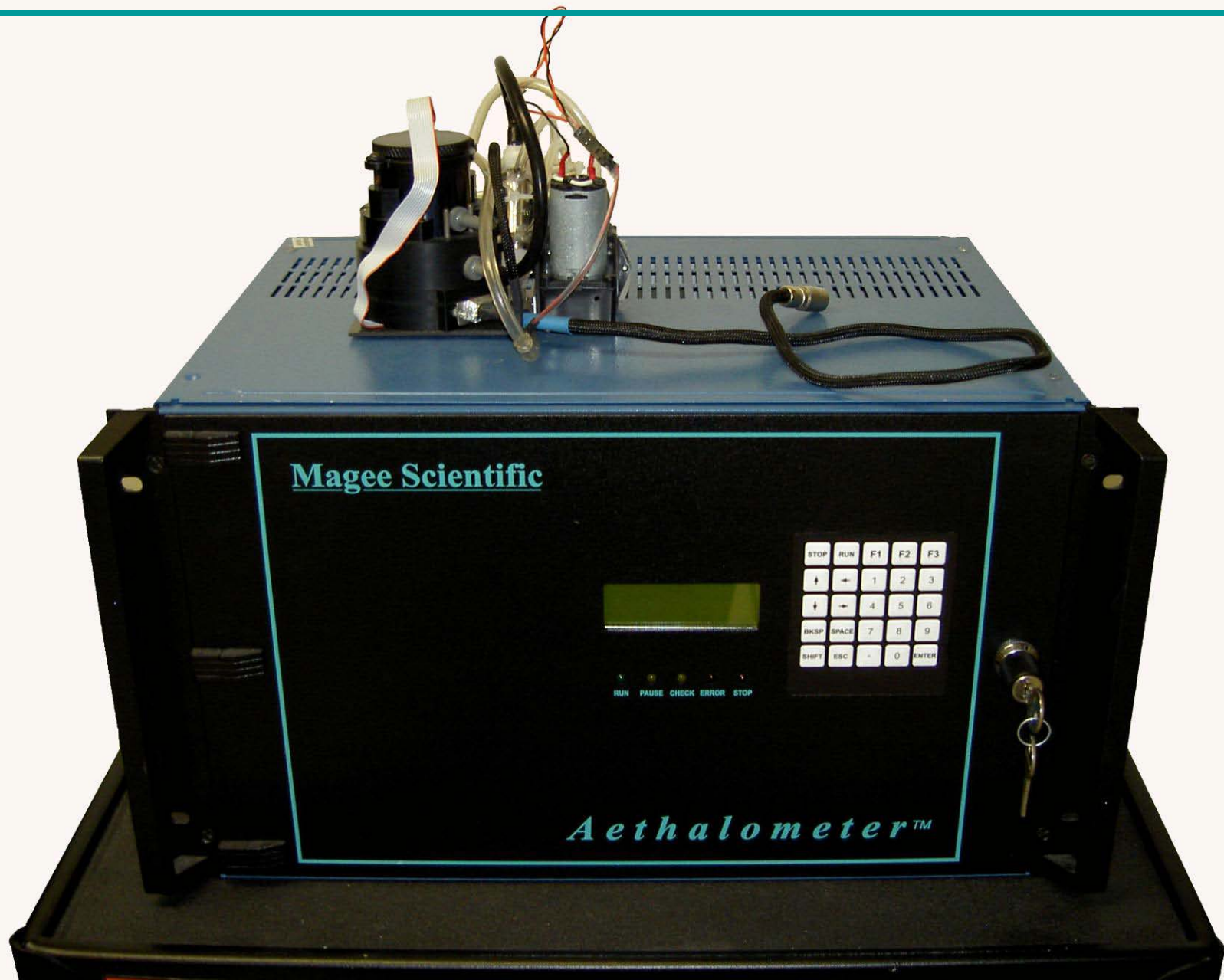
Surface observations

ACR Manta

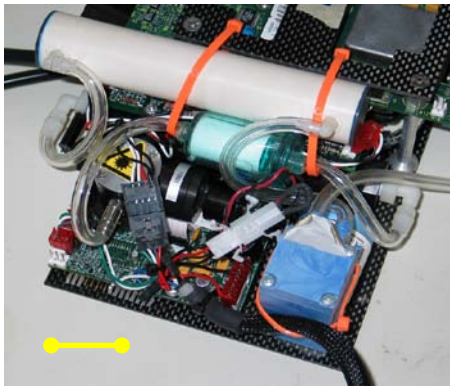
Weight - 23 kg (takeoff)
Wingspan - 2.7 meters
Cruise velocity - 35 m/s
Payload - 5 kg
Flight duration - 5+ hours
Autonomous GPS flight
Satellite communication link
Auto Take-off and Landing



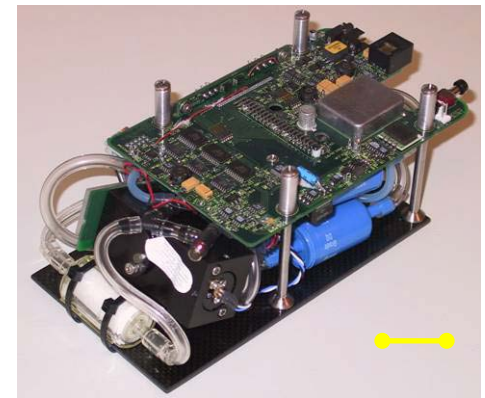
Miniaturization of Instruments



UAS instruments



Optical Particle Counter (580 g)
 → N_{OPC} ; $0.3 < D_p < 3 \mu\text{m}$

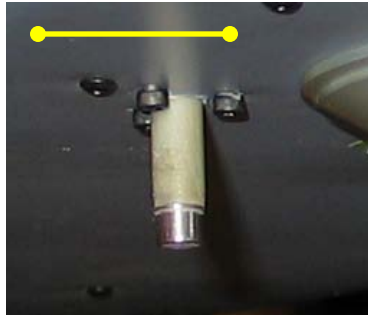


Condensation Particle Counter (870 g) → N_{CN} ; $D_p > 10 \text{ nm}$

— [=] 1 inch



Aethalometer (820 g)
 → absorbing aerosol



T/RH probe (50 g)
 → Temperature & RH



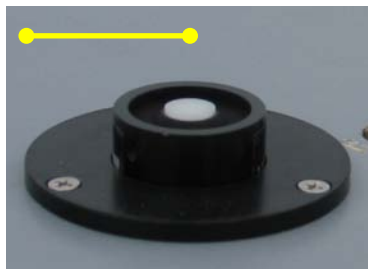
Aerosol inlet & splitter (150 g)
 → unbiased aerosol sampling



Cloud Droplet Spectrometer (1.4 kg) → distr. $1 < D < 50 \mu\text{m}$



Pyranometer (190 g)
 → irradiance $0.3 - 2.8 \mu\text{m}$



PAR radiometer (45 g)
 → irradiance $400 - 700 \text{ nm}$

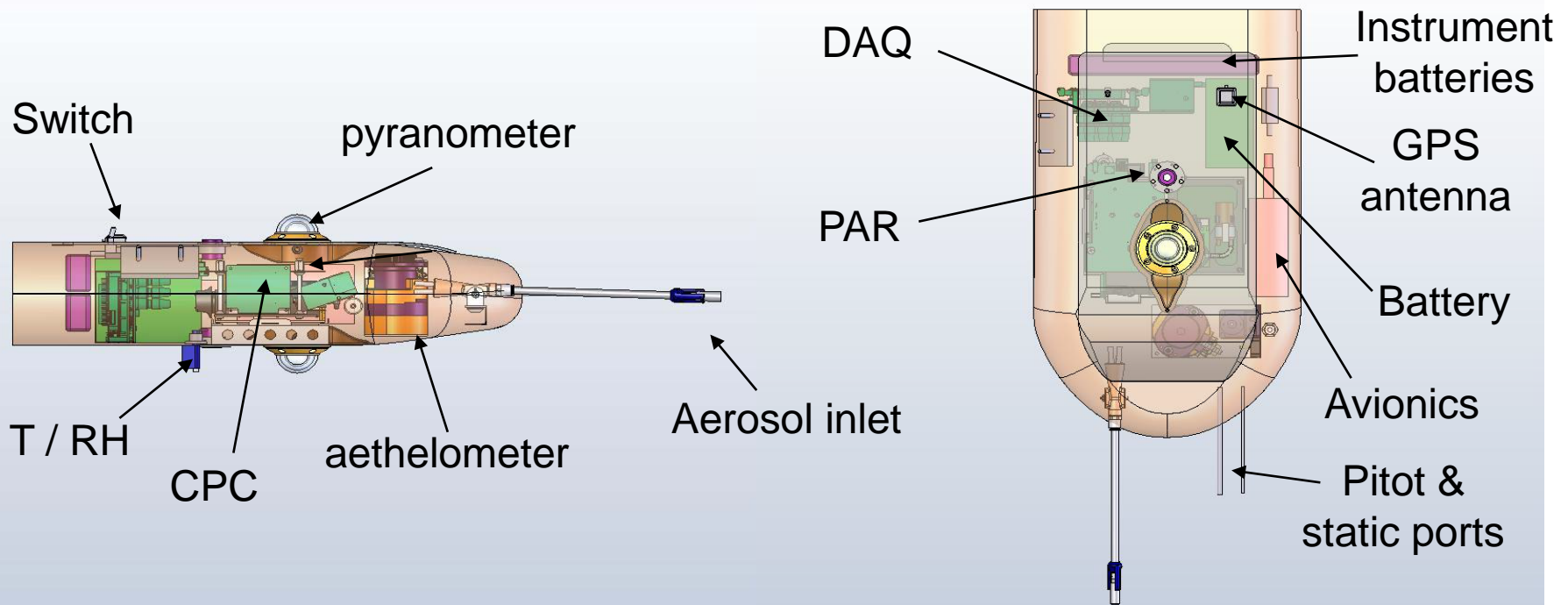


LWC probe (450 g)
 → Cloud water (g m^{-3})



Gust probe (400 g) & video camera (280 g)
 → turbulence & cloud targeting

CAD Modeling of Payload



Cheju ABC Plume-Asian Monsoon Experiment (CAPMEX)

V. Ramanathan (PI) and S-C. Yoon (Co-PI)

Mission Director : H. V. Nguyen

Mission Scientists : M. V. Ramana, K. Lehmann, C. Corrigan, S-W. Kim



CAPMEX Collaborators

LEAD INSTITUTIONS

Scripps Institution of Oceanography, US
Seoul National University, Korea

COLLABORATING INSTITUTIONS

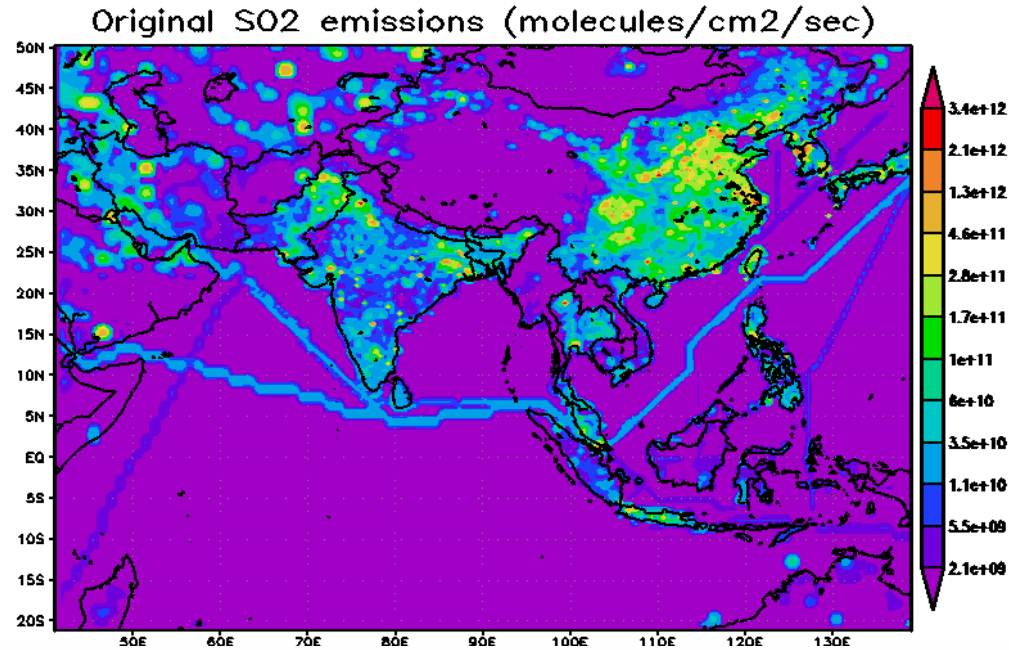
University of Iowa, US
Cheju National University, Korea
Korean Aerospace University, Korea
Korean Airlines, Korea
Institute of Atmospheric Physics, China
Peking University, China
Lanzhou University, China

CAPMEX Objectives :

- Observe modulation of ABCs by the East Asian Monsoonal flow.
- ABCs-direct radiative forcing and interaction with clouds.
- Opportunity to capture emission reduction by sources near Beijing during the recent Summer Olympics.
- August-September, 2008 involved UAV operations along with continuing surface measurements at ABC affiliated sites in East Asia.
- Concurrent flight also performed over California, at NASA Dryden facility, as part of CAPPS project.

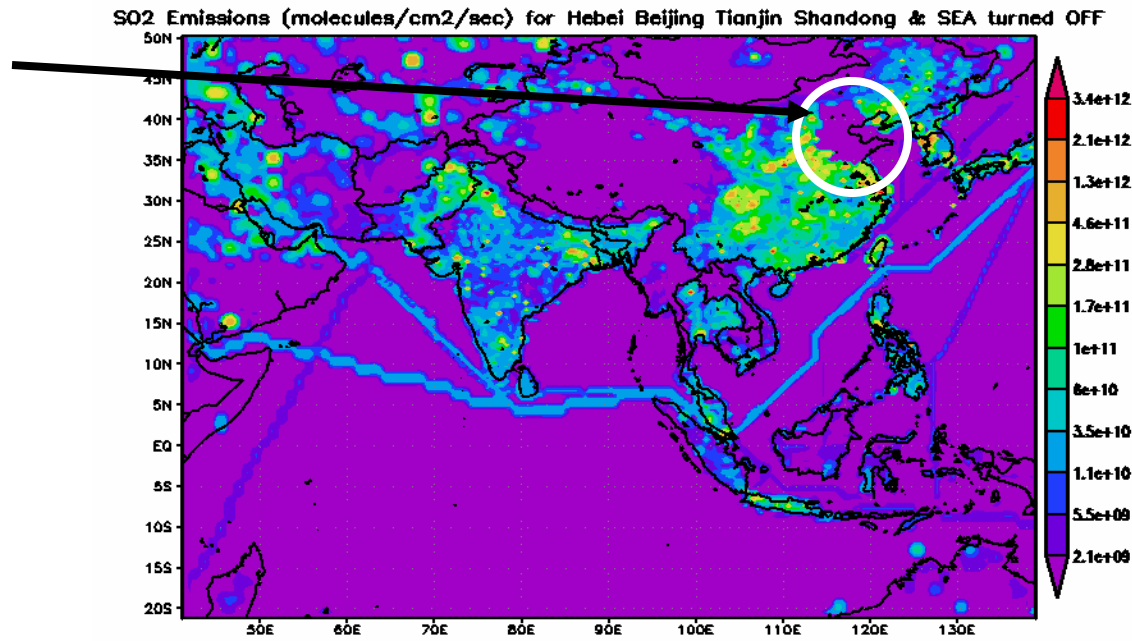
STEM model simulations (Source: G. Carmichael)

Pre Emission
Reductions

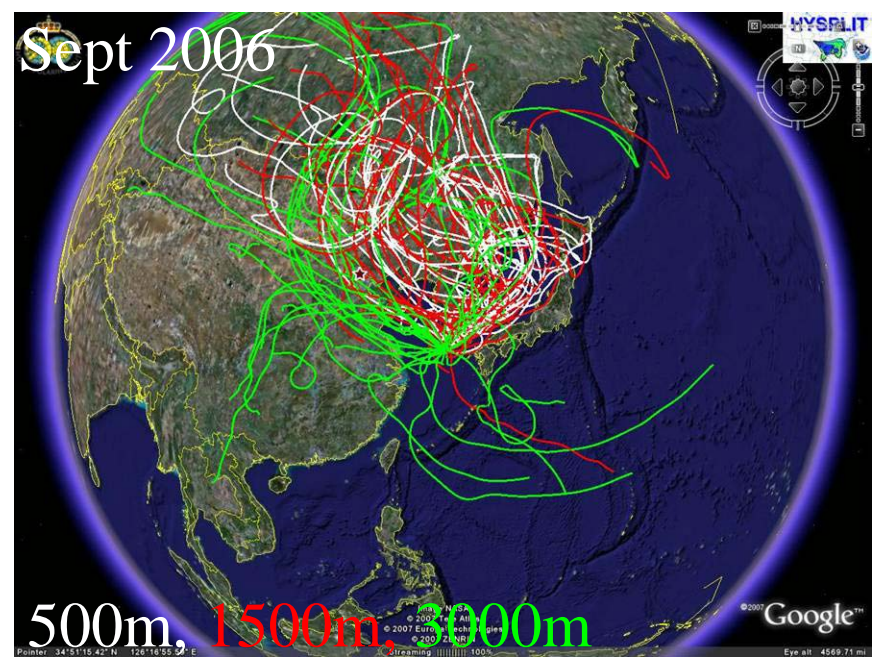
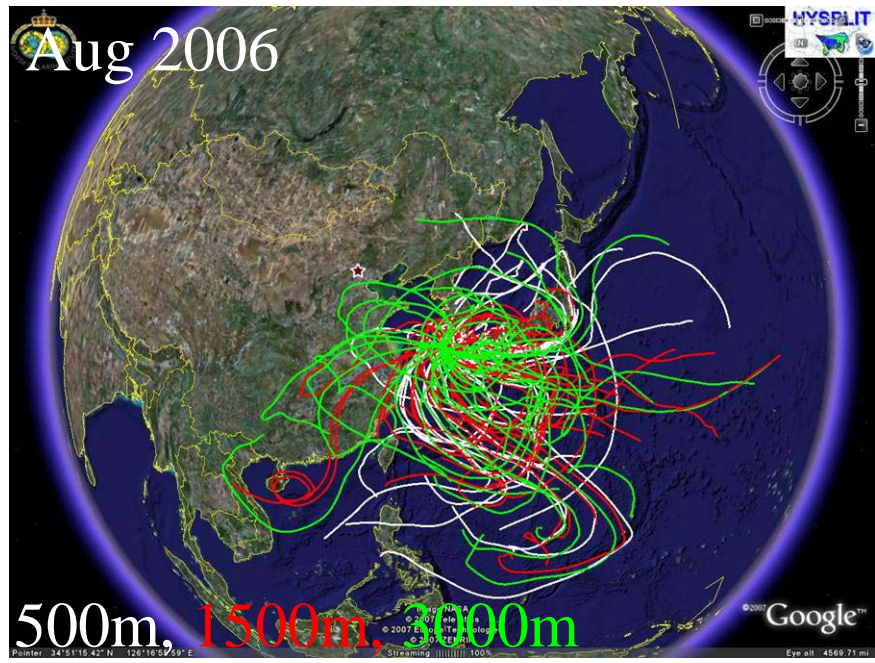
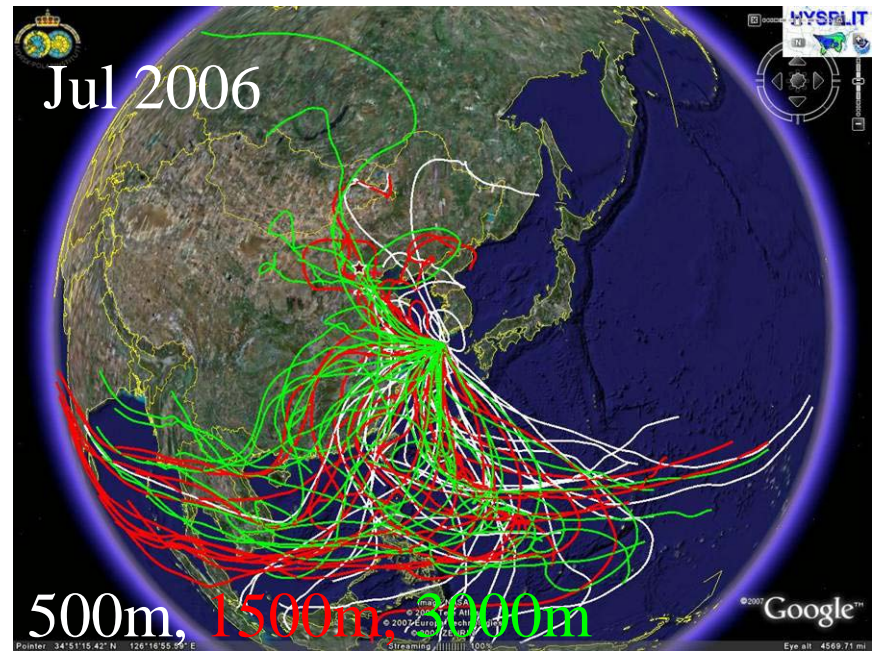
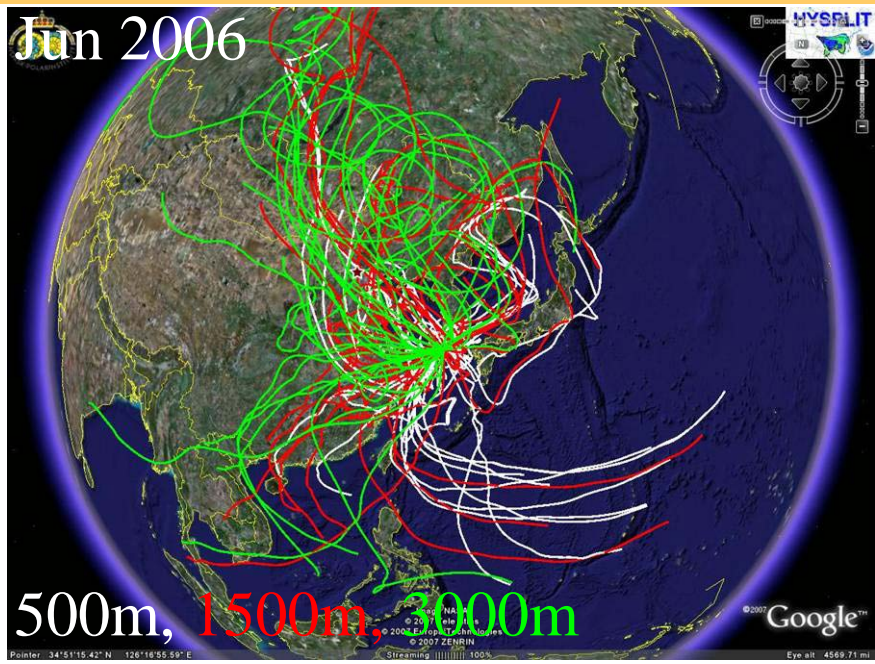


Post Emission
Reductions

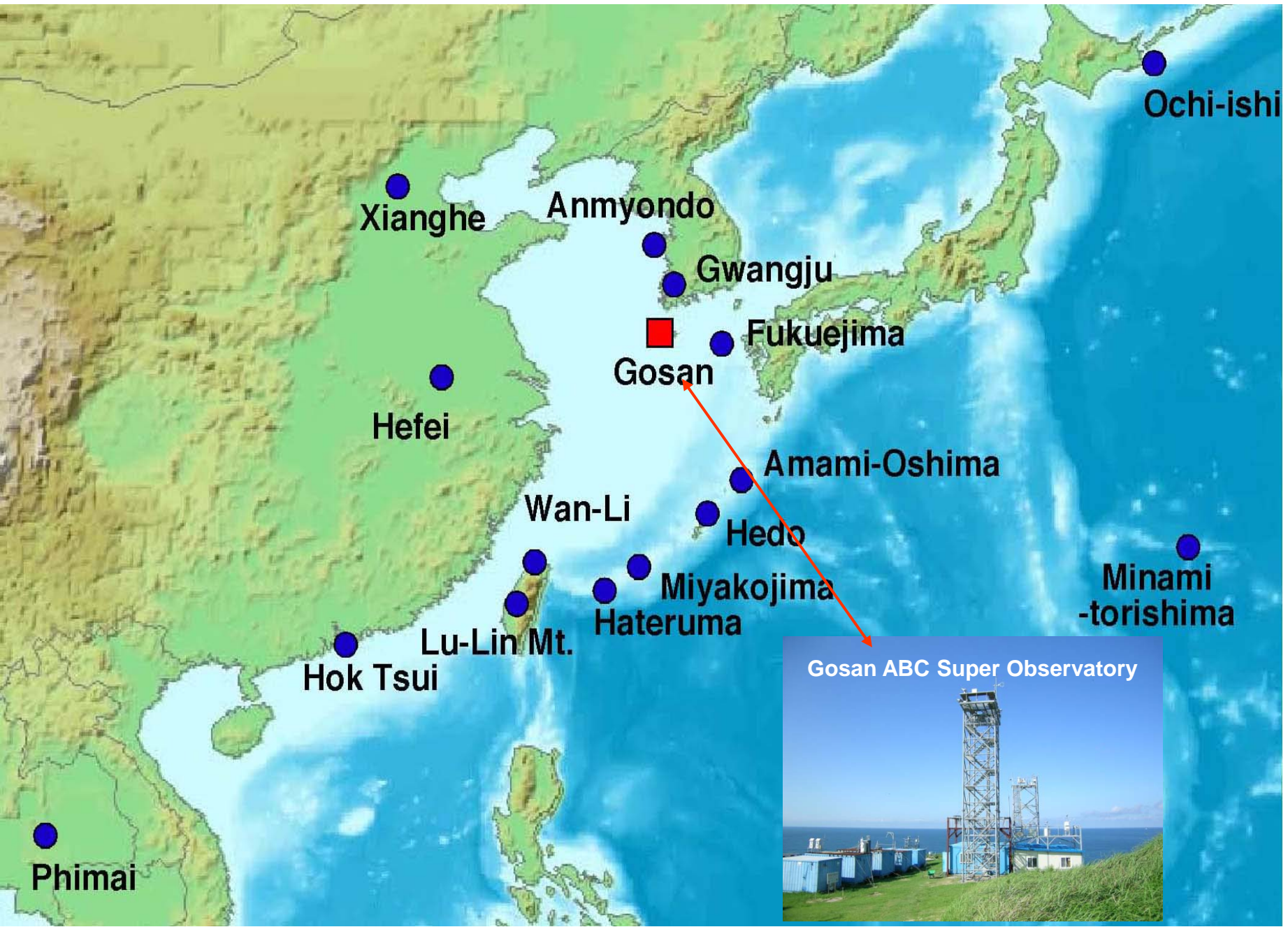
~20% reduction
in anthropogenic
emissions from
China!



7-day Back Trajectory Cheju Island, Korea (2006)



CAPMEX UAV operations: Jeju Island, Korea



CAPMEX Observation System: Gosan Site and UAV Sites



CAPMEX: New Instruments

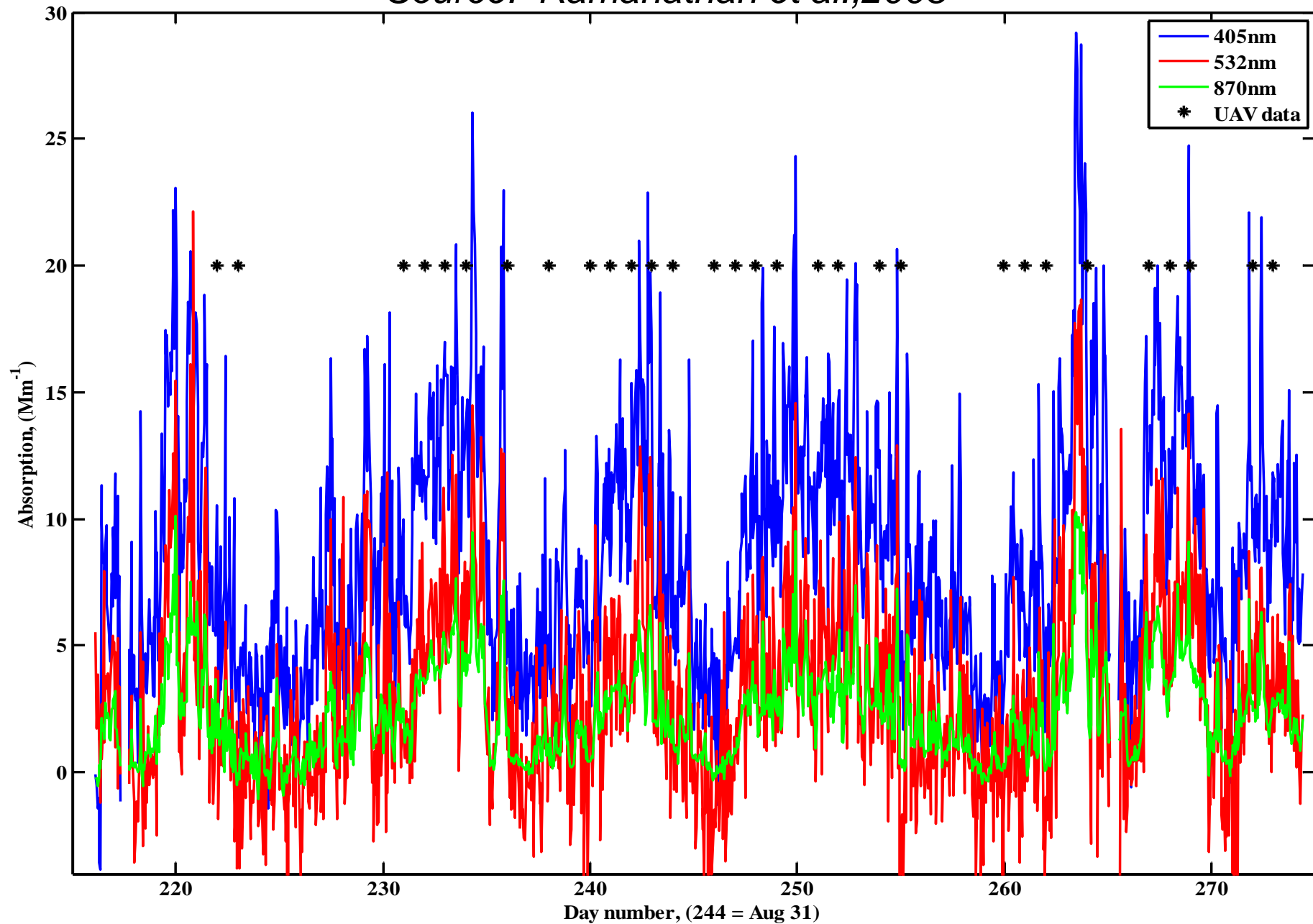
- Spectroradiometer (200-1100nm) for spectral radiation measurements
- Nanocrystal VOC sensor
- Water vapor fluxes (IR absorption)
- Gust probe with Inertial Navigation system
- Laser Altimeter

CAPMEX: Flight Summary

Total number of flight days	= 32
Total number of flights	= 75
Flights at Jeongseok airfield	= 18
Flights at Sangmo-ri airfield	= 57
Total flight hours	= 130 hrs
Aerosol-radiation platforms missions	= 53
Cloud physics missions	= 9
Spectroradiometer	= 9
Flux measurement missions	= 2
VOC measurement missions	= 2

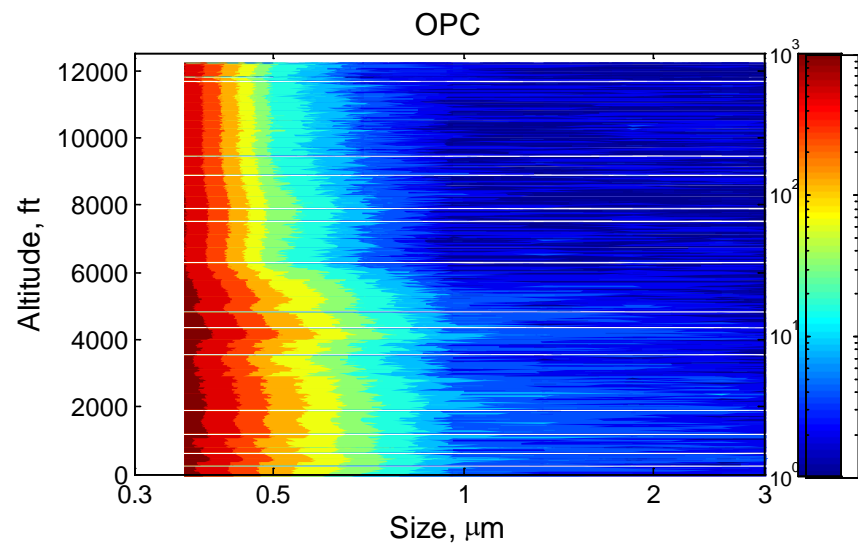
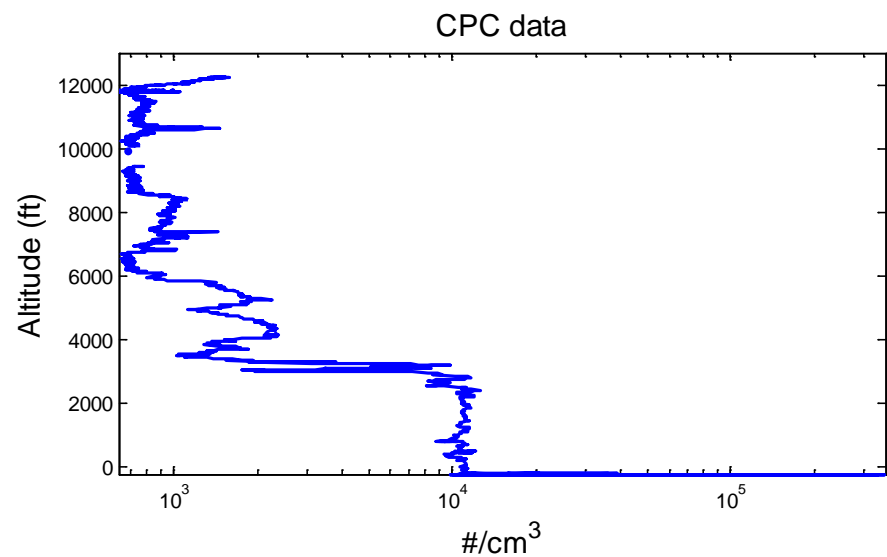
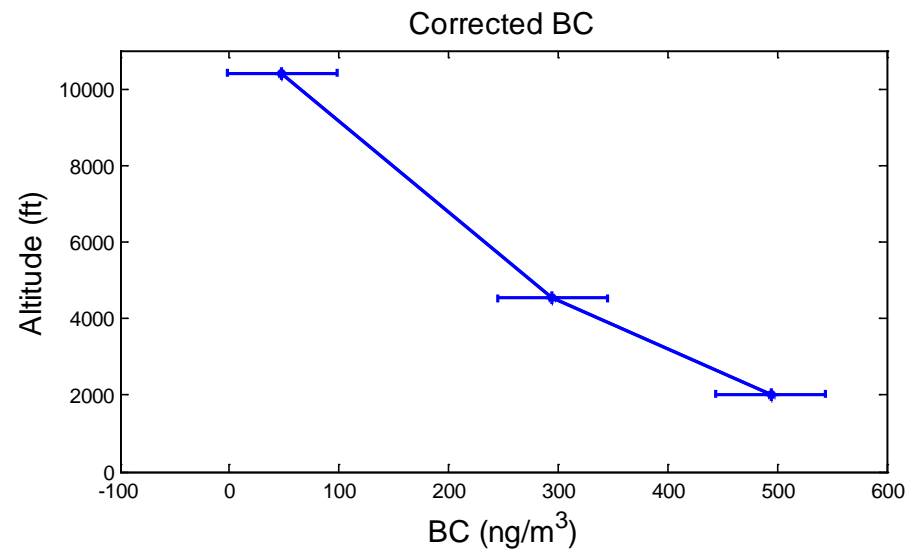
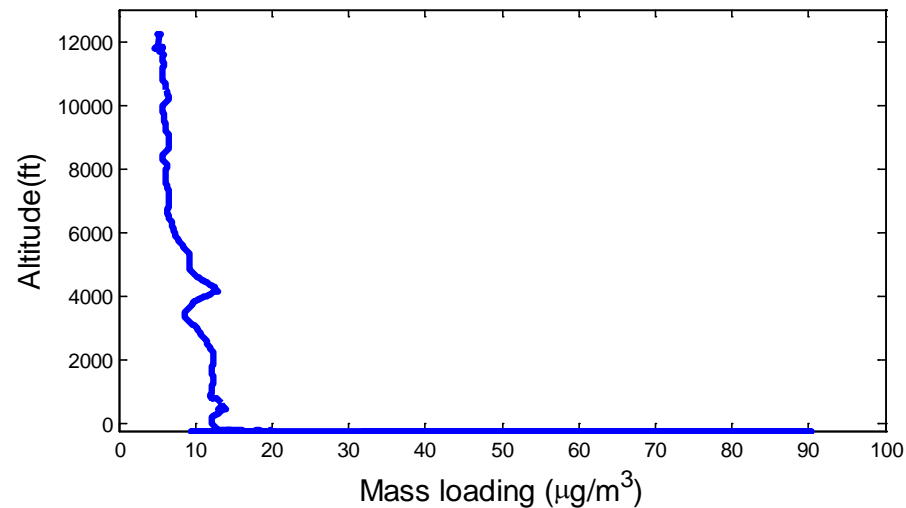
Absorption Coefficient: Surface data

Source: *Ramanathan et al., 2008*



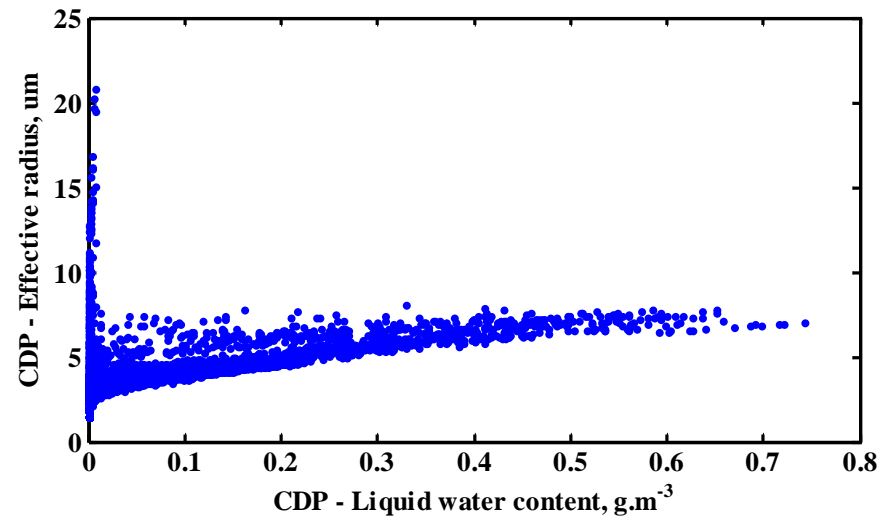
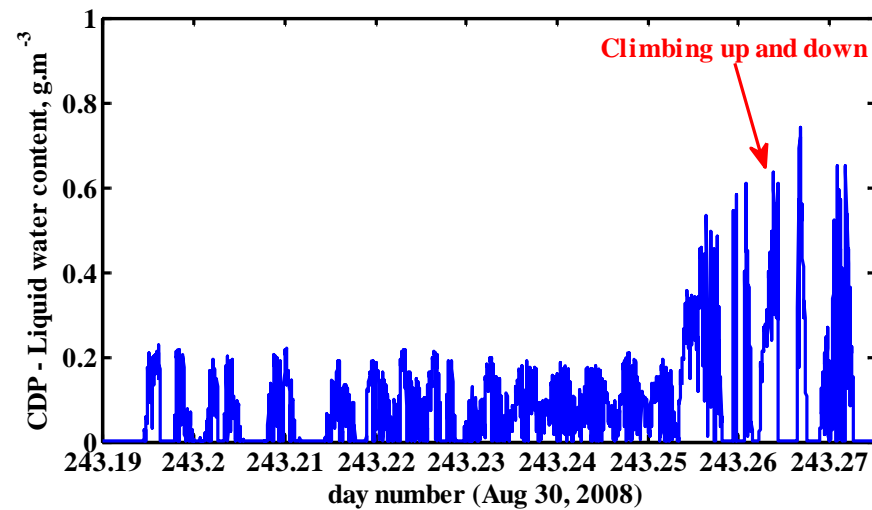
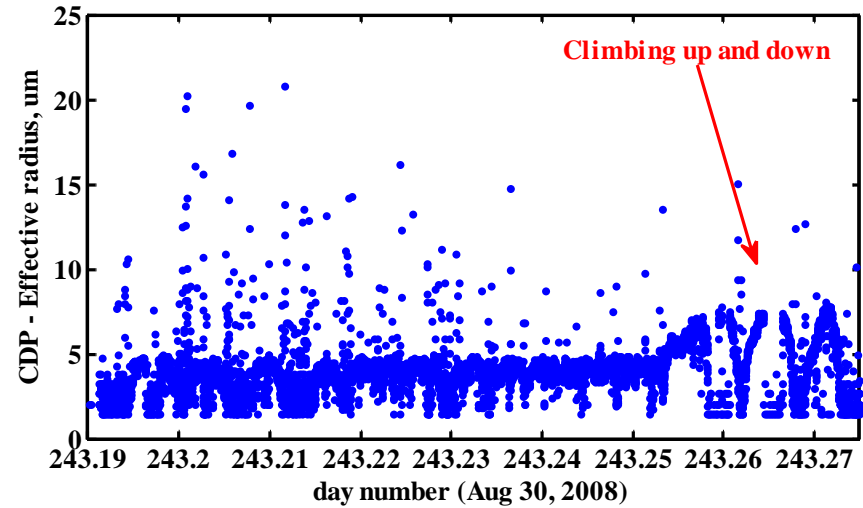
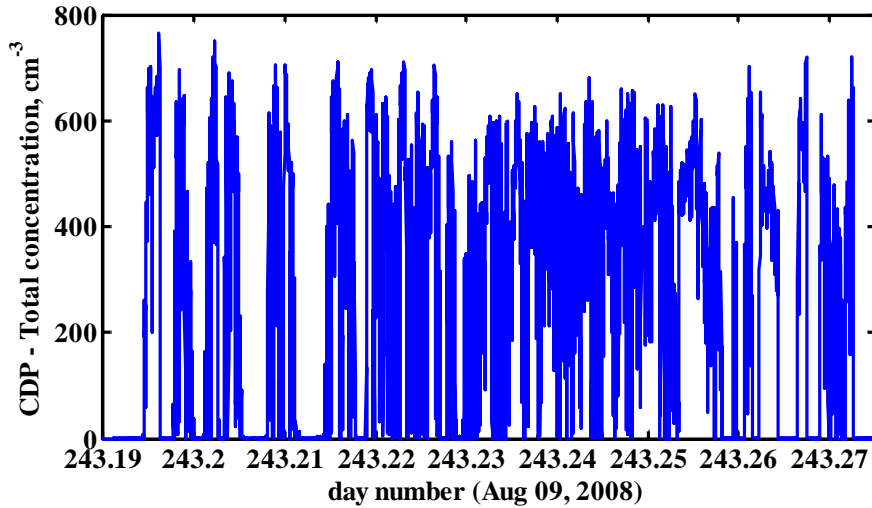
Aerosol-Radiation platform: 27-08-2008

Source: Raman than and Ramana, 2008



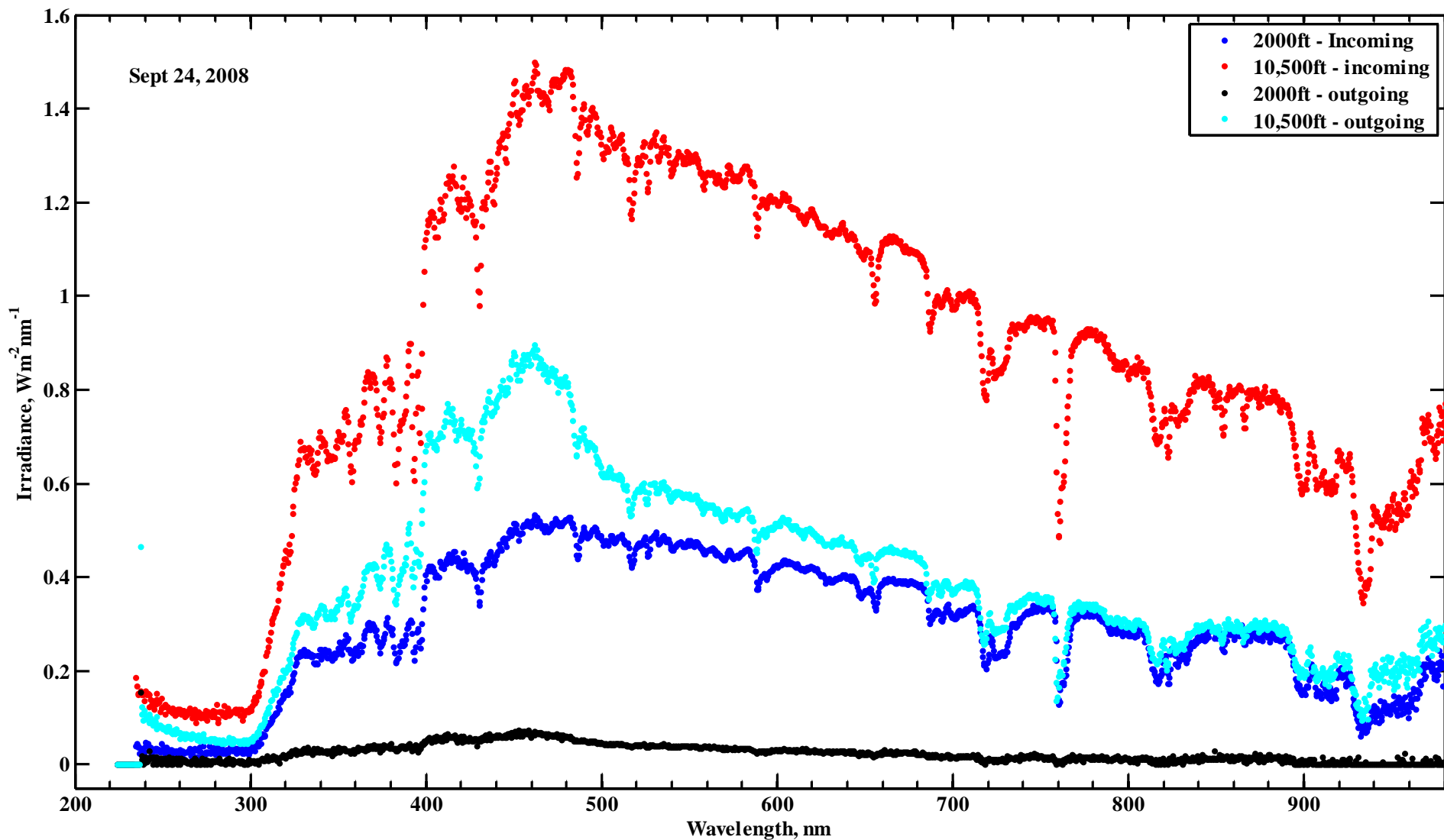
Cloud Physics : 30-08-2008

Source: Ramanathan et al., 2008



Spectroradiometer: Sept 24, 2008 (cloudy day)

Source: Ramanathan et al., 2008



California AUAUV Air Pollution Profiling Study - CAPPS

Craig Corrigan, Co-PI
V. Ramanathan, Co-PI



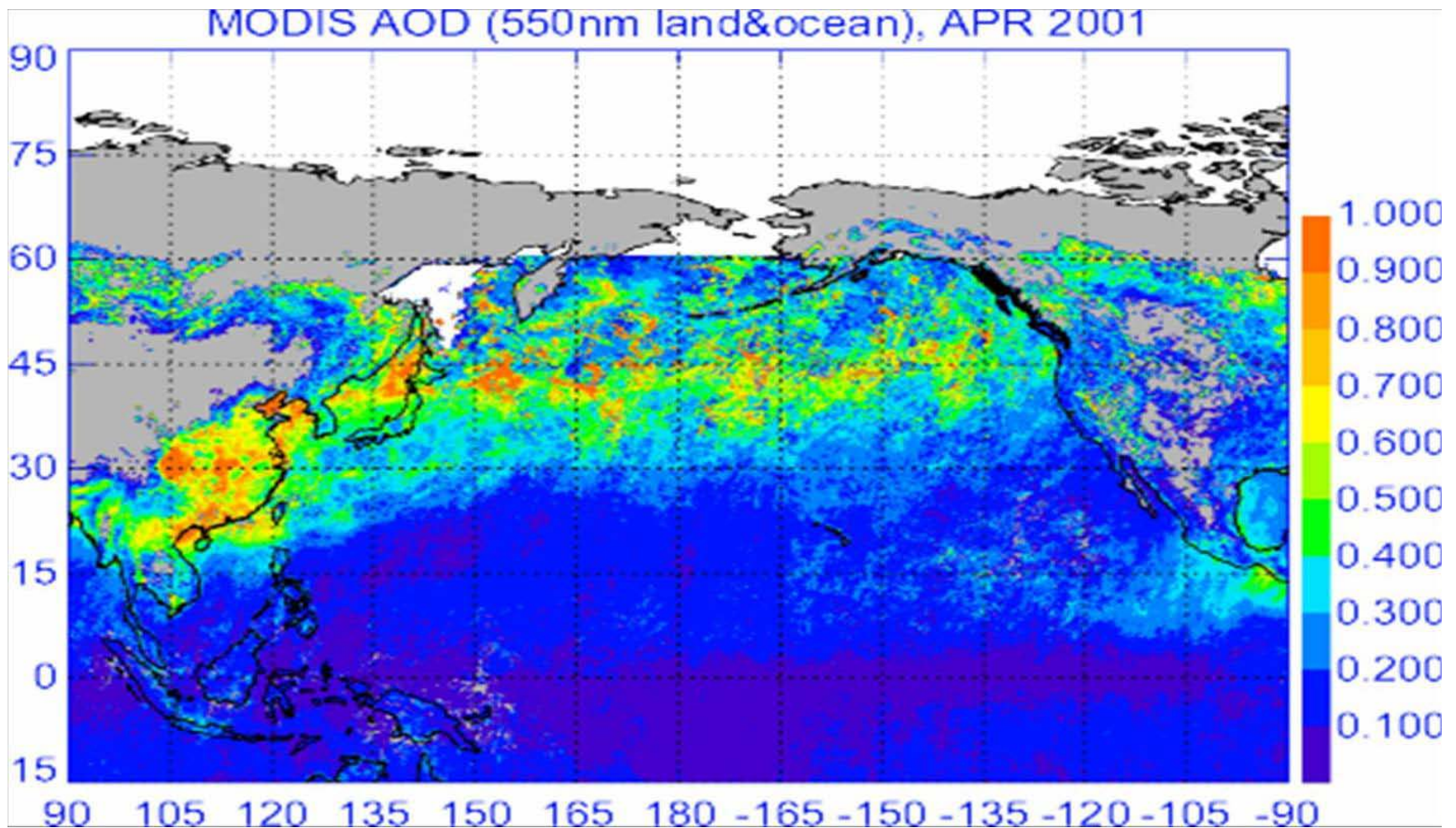
CAPPS

(California AUAUV Air Pollution Profiling Study)

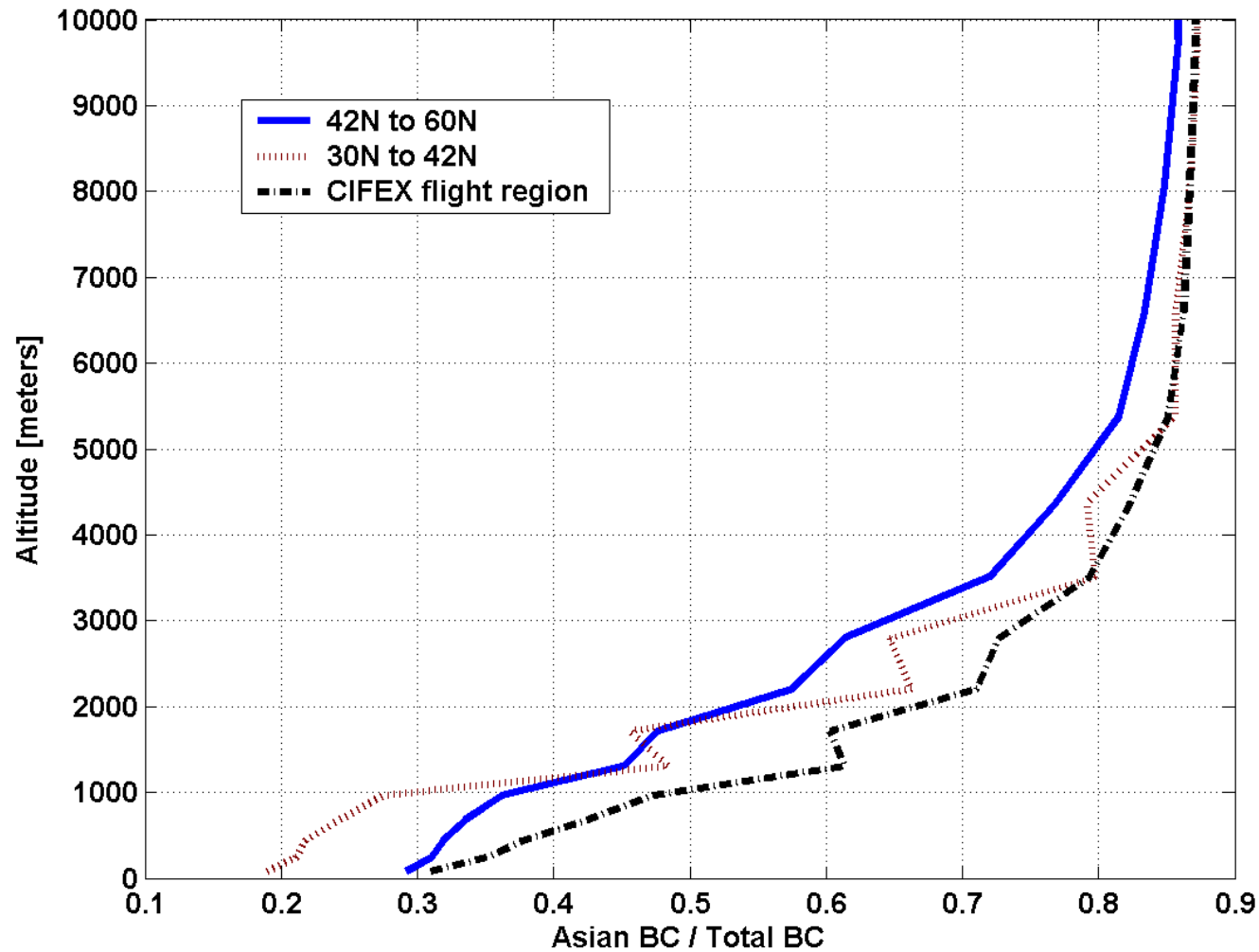
Funded by California Energy Commission.

- Collect a **seasonal record** of aerosol, black carbon and ozone 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.

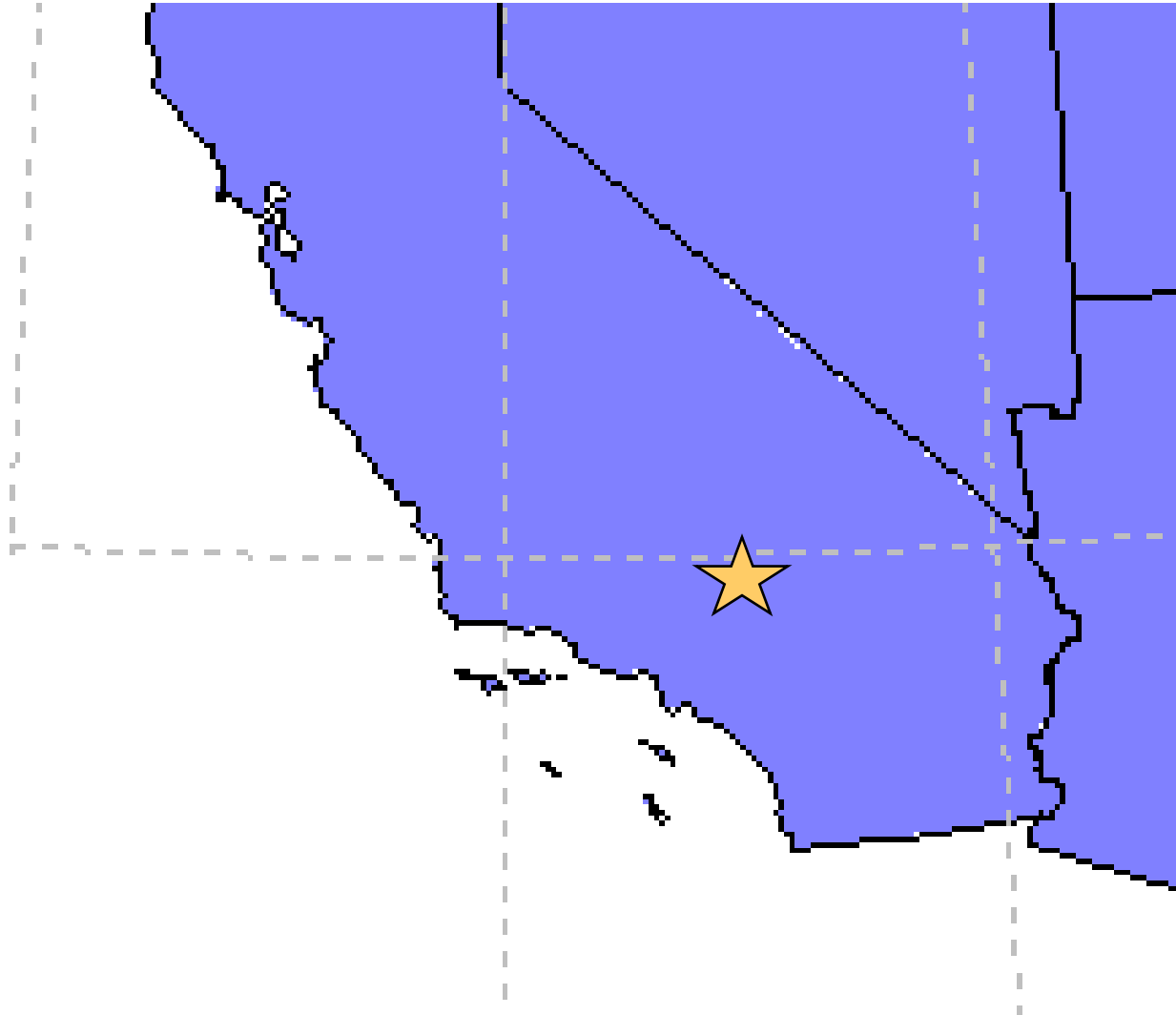


Measurements for CAPPS

- Aerosol Number Concentration
- Aerosol Size Distribution (0.3 – 3 μm)
- Aerosol Absorption/Black Carbon Concentration
- Ozone
- Solar Flux
- Temperature, Pressure, Relative Humidity

Sampling Site – NASA Dryden

Edwards Air Force Base in Mojave Desert

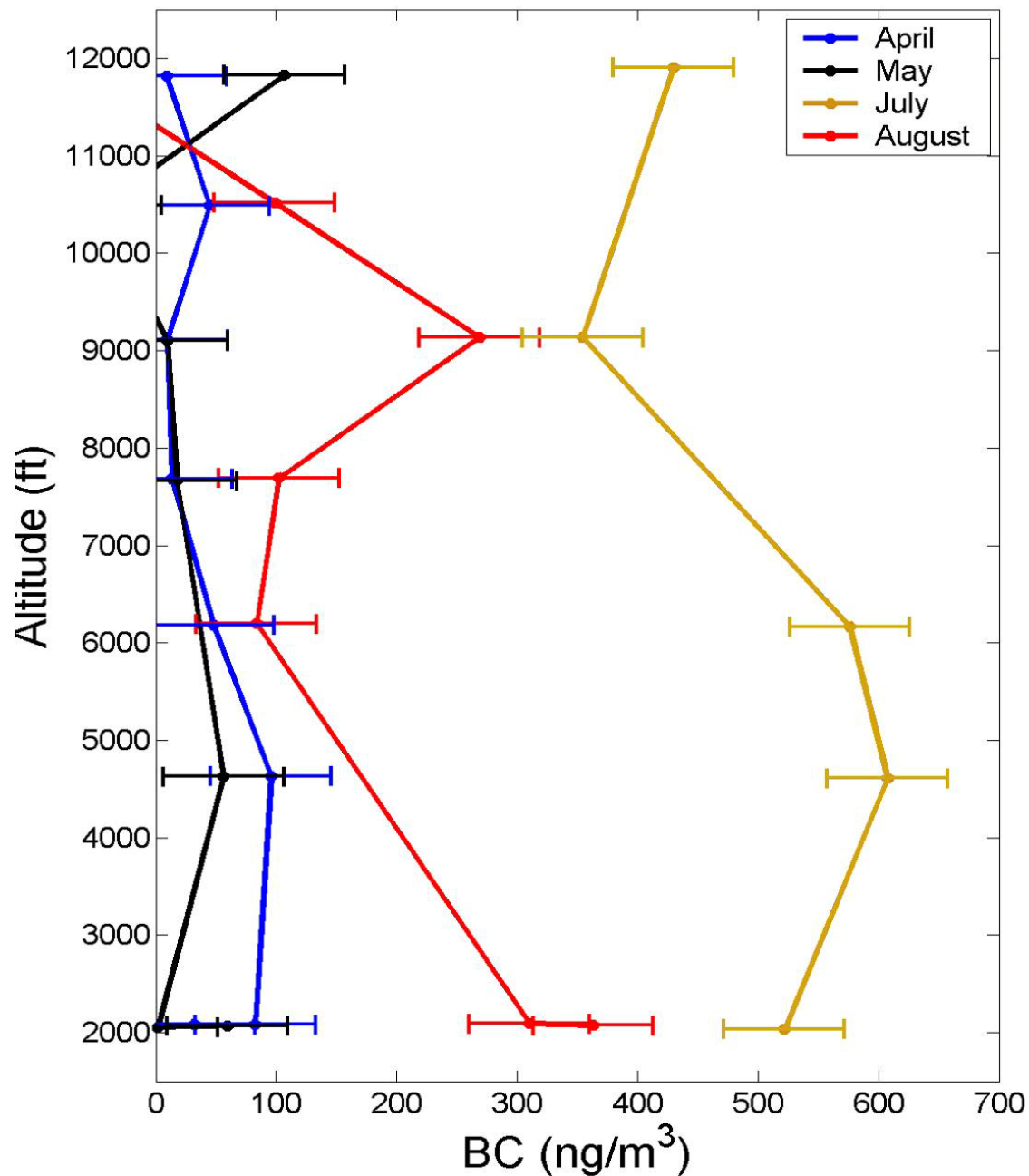




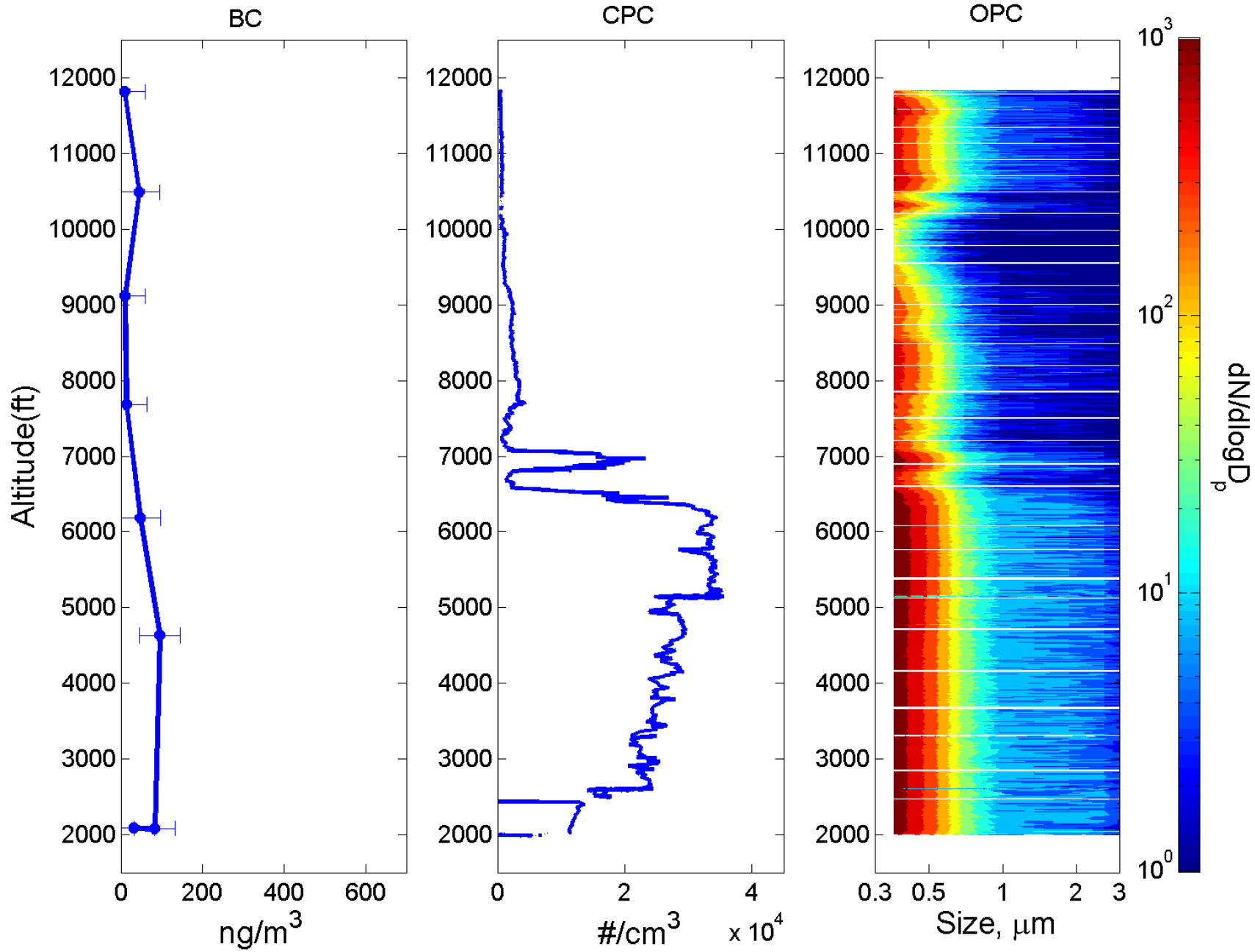
CAPPS Missions

- Flights started in early April
- Attempting 1 to 2 flights per month
- Aerosol Flights to date = 11
- Ozone Flights to date = 4

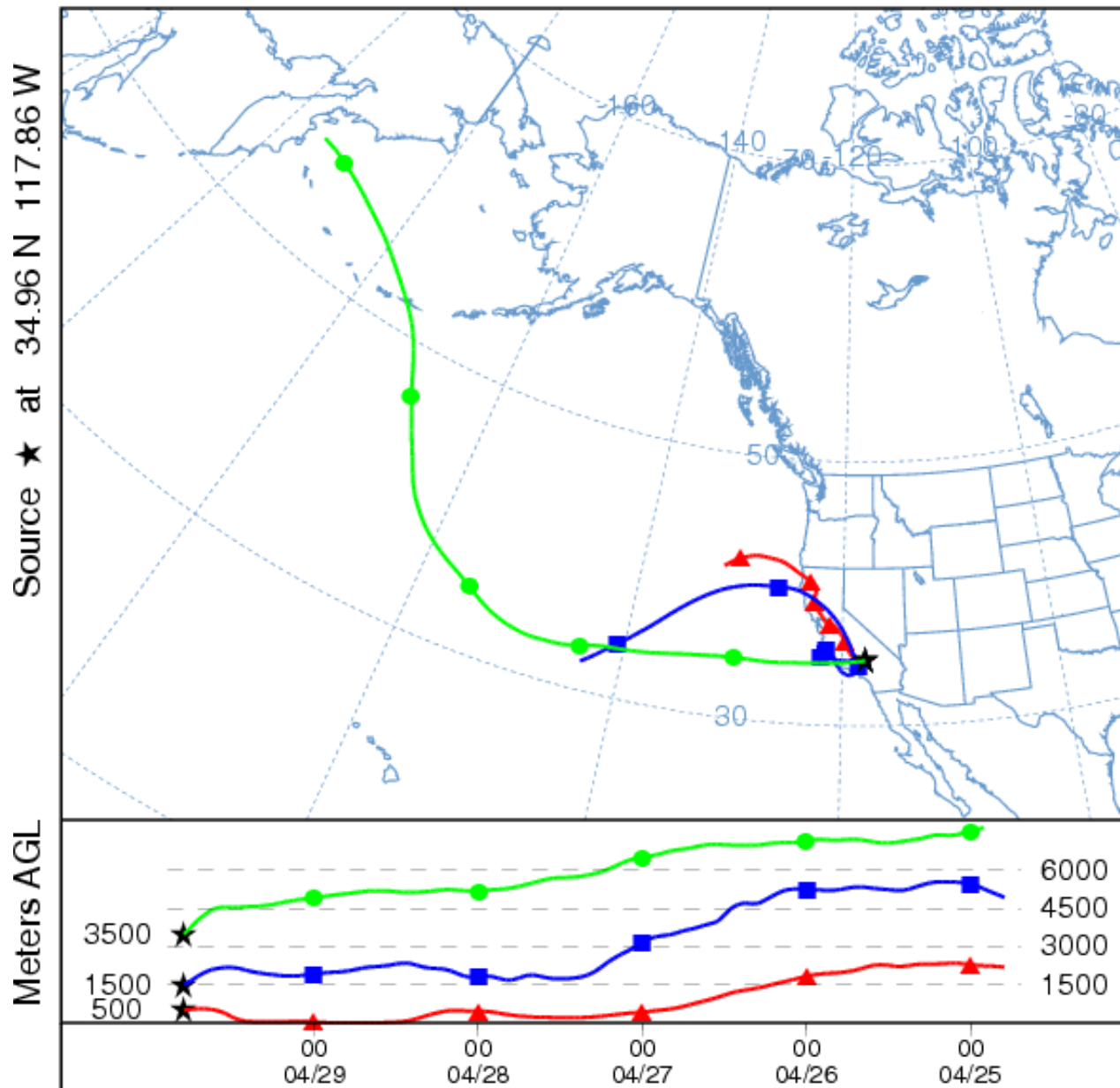
Black Carbon Concentration Vertical Profiles



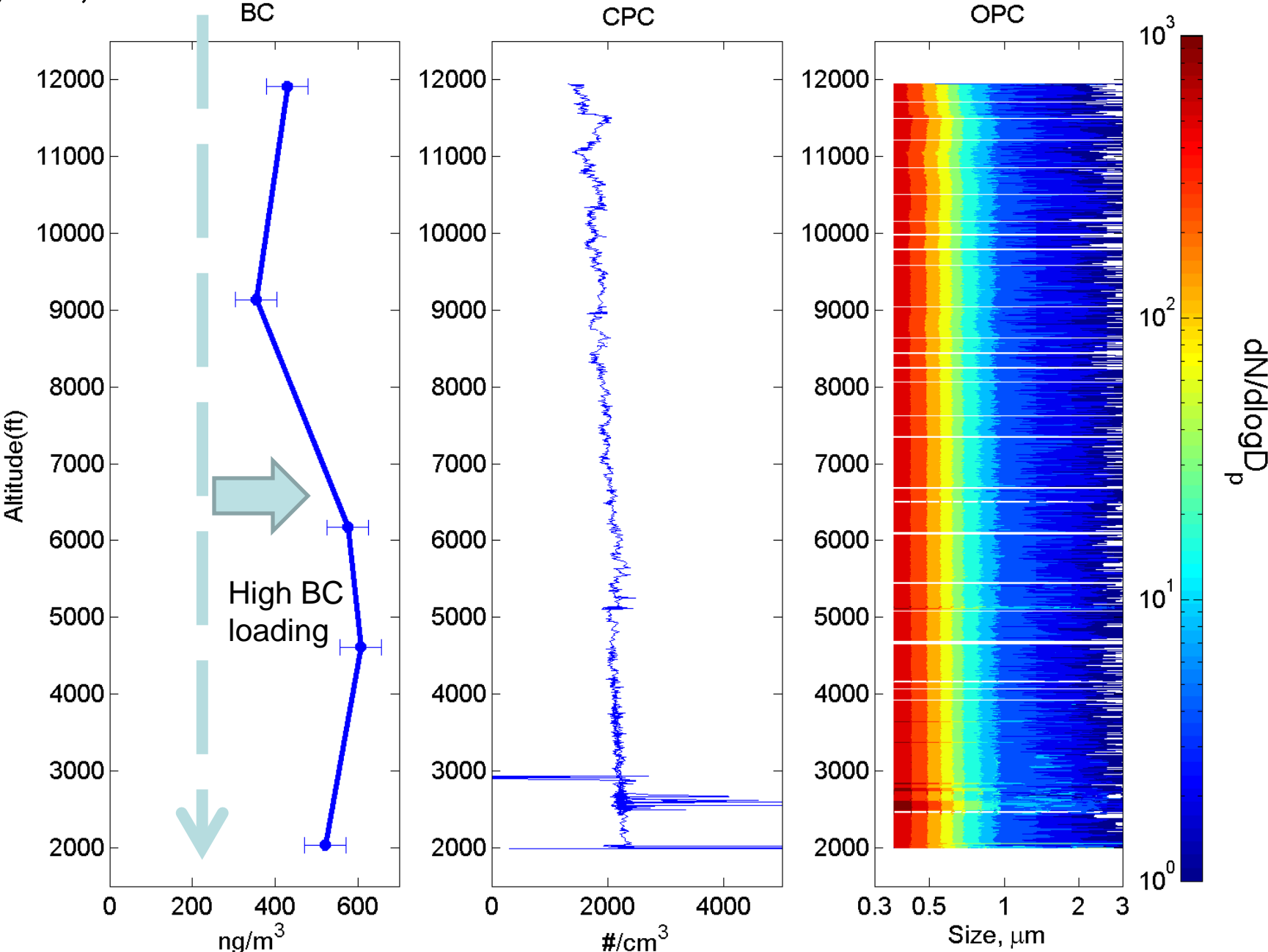
April 29, 2008



NOAA HYSPLIT MODEL
Backward trajectories ending at 19 UTC 29 Apr 08
GDAS Meteorological Data

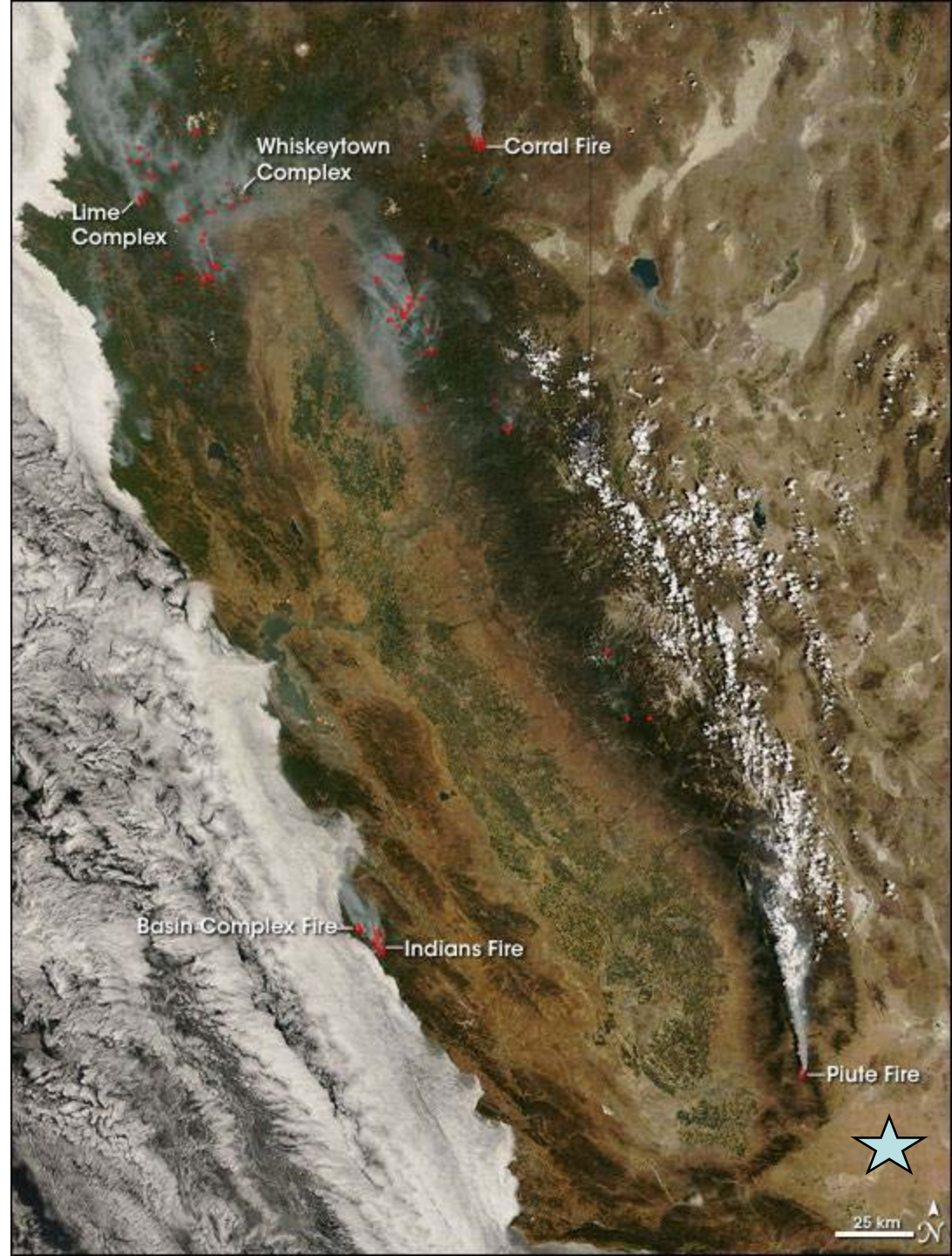


July 10, 2008



Wildfires are a significant local source of black carbon for summer and fall season.

Image from NASA Earth Observatory June 30, 2008

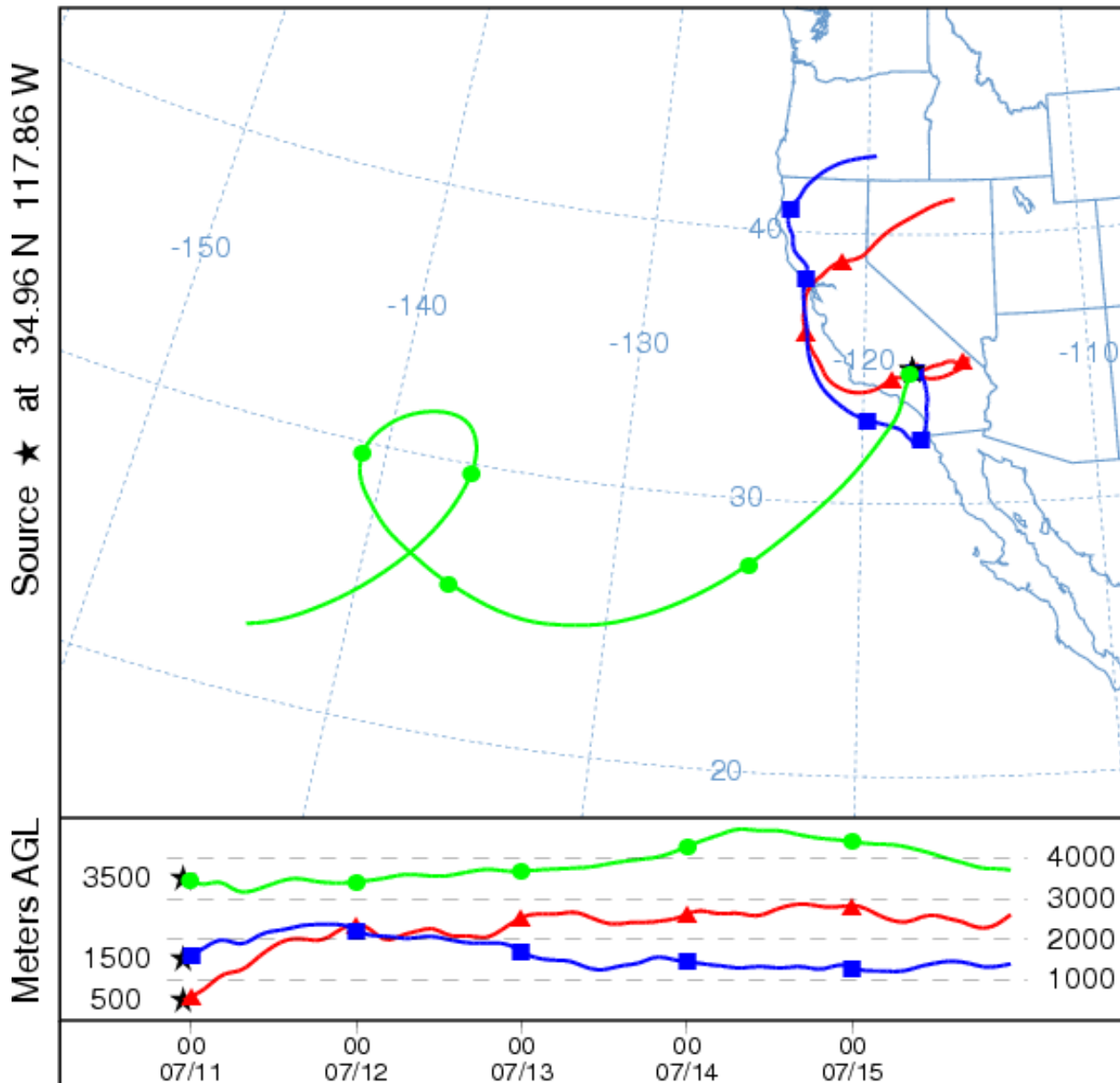


11 days later

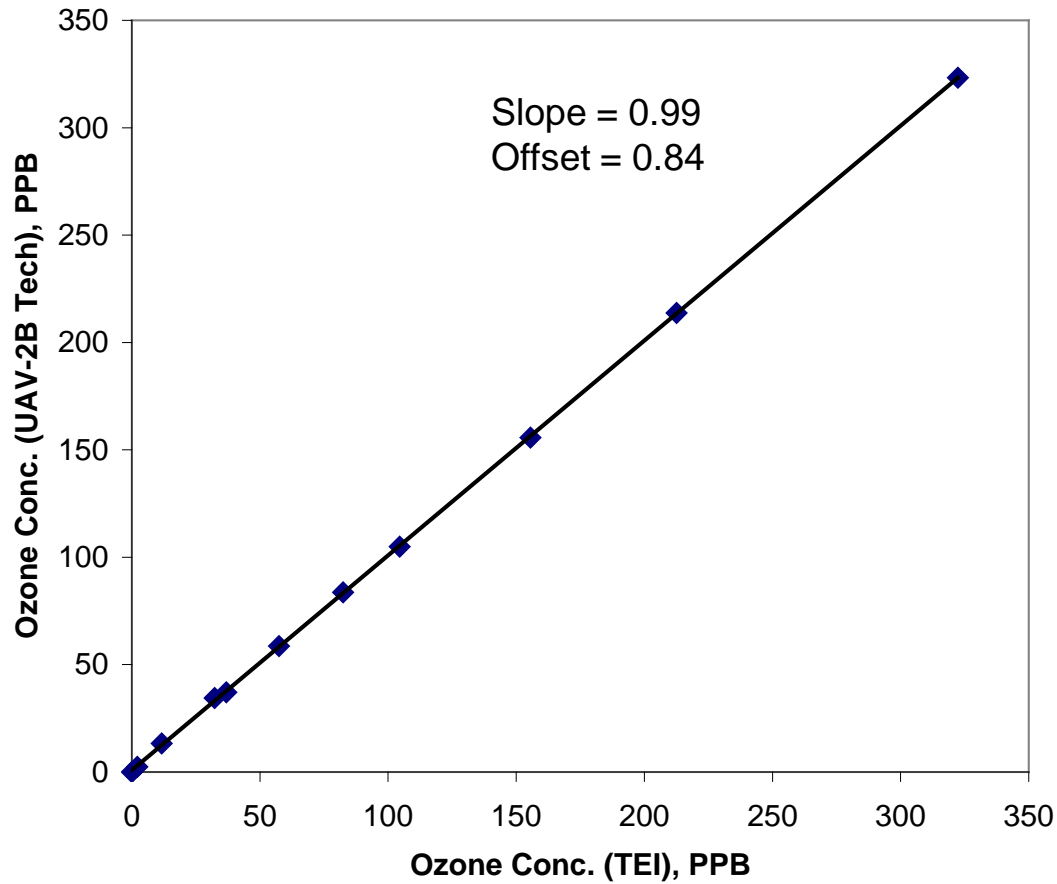


Image from NASA Earth
Observatory July 10, 2008

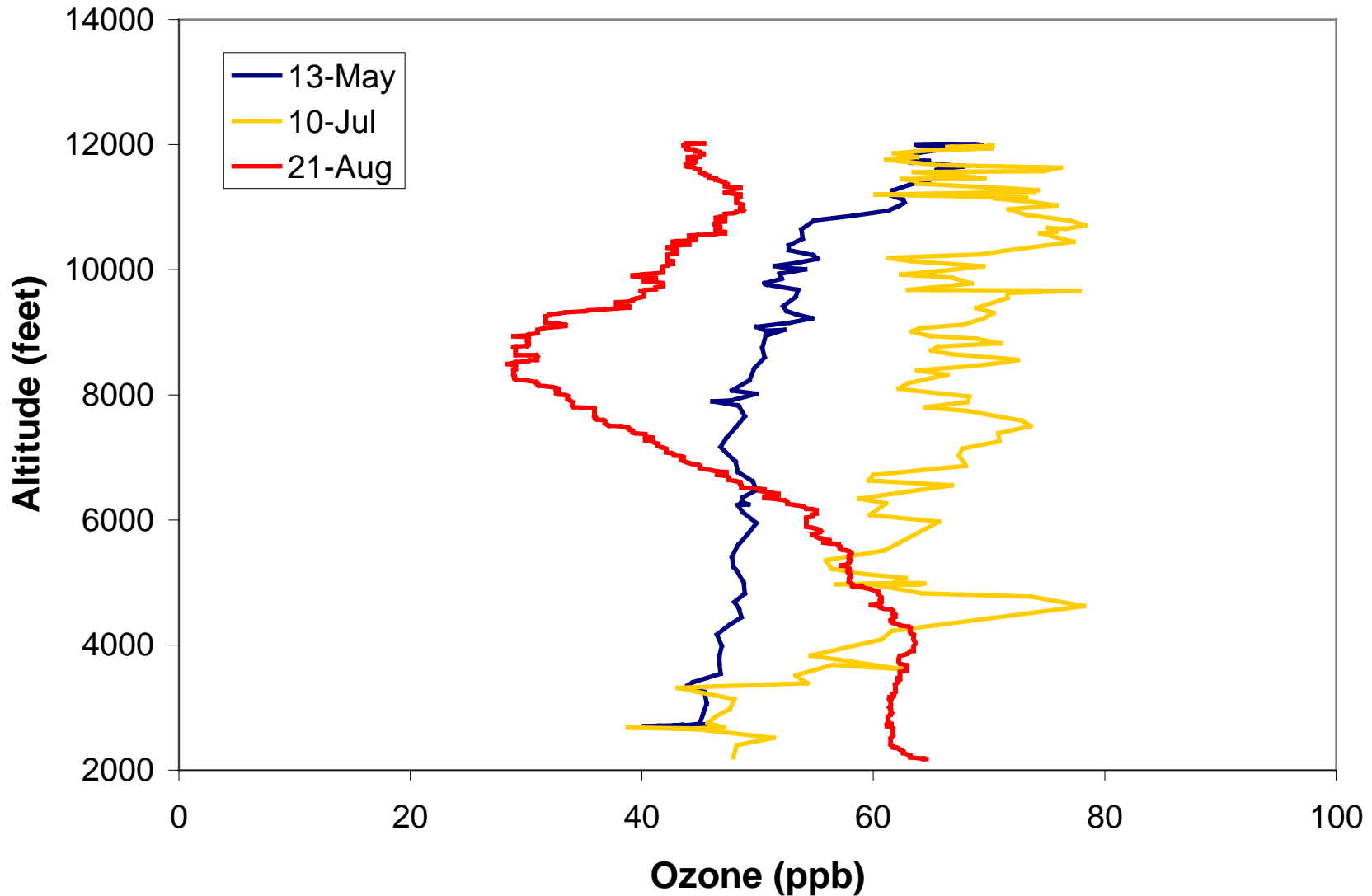
NOAA HYSPLIT MODEL
Forward trajectories starting at 23 UTC 10 Jul 08
GDAS Meteorological Data



UAV Ozone Instrument



Ozone Concentration Vertical Profiles over NASA Dryden



PACTEST

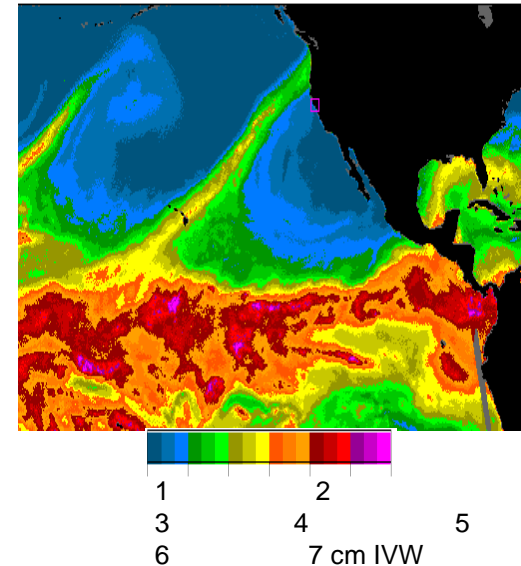
Pacific UAS Test Bed

Pilot project in collaboration with NOAA



PACTEST

- Scripps Mantas one component of NOAA's Pacific UAS test bed
- Study Atmospheric Rivers (ARs), responsible for 90% of meridional water vapor transport
- Improve precipitation and flood forecast for west coast
- Water vapor budget study planned for 2010/2011
- Scripps UAS contribution: measurements of the ARs vertical and horizontal structure and of the surface moisture flux



Water Flux Measurements for PACTEST

- Measure surface moisture flux at an altitude of only 100-300 meters above ocean surface.
- Water vapor: KH20 Krypton hygrometer (Campbell Scientific)
- Sample rate: 100 Hz

- Sept 2008 tested at cloud base (CAPMEX)
- November 2008 at Vandenberg AFB

Summary

- CAPMEX project studied ABCs and water clouds off of Korea in Aug-Sept 2008.
- CAPPs project has collected measurements of aerosol and ozone profiles during the past 6 months.
- PACTEST project will perform water vapor flux measurements in a Nov. 2008 pilot study.