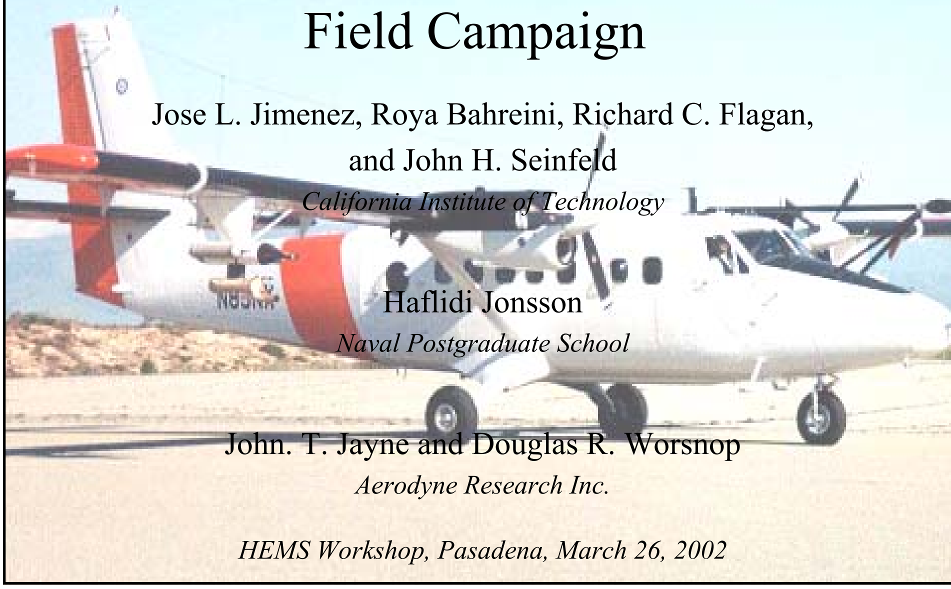
Airborne Deployment of the Aerosol Mass Spectrometer in the ACE-Asia Field Campaign



Jose L. Jimenez, Roya Bahreini, Richard C. Flagan, and John H. Seinfeld

California Institute of Technology

Haflidi Jonsson

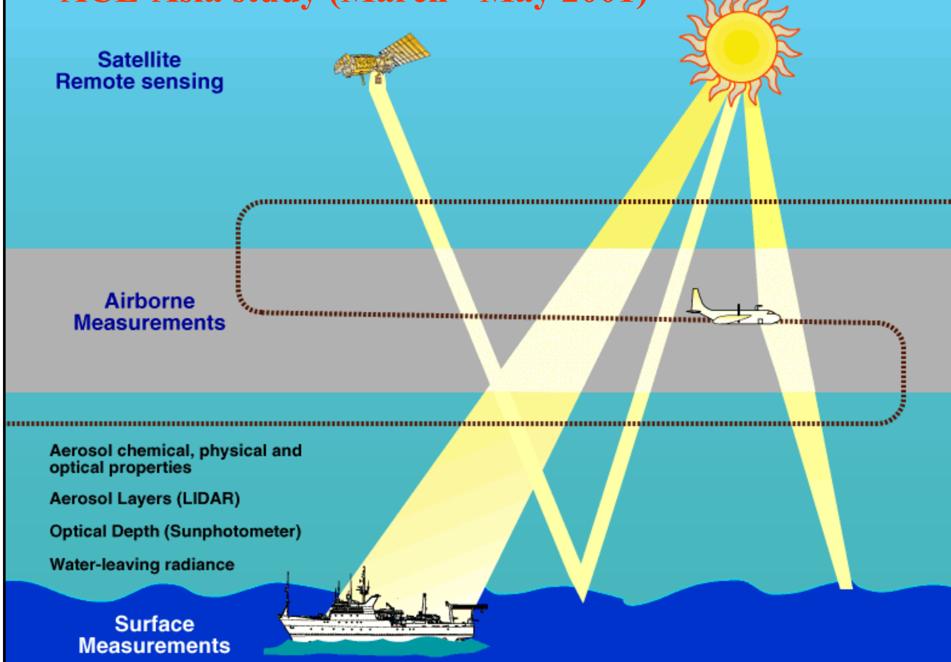
Naval Postgraduate School

John. T. Jayne and Douglas R. Worsnop

Aerodyne Research Inc.

HEMS Workshop, Pasadena, March 26, 2002

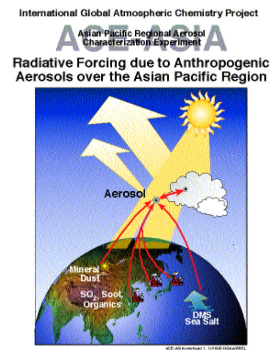
ACE-Asia study (March - May 2001)



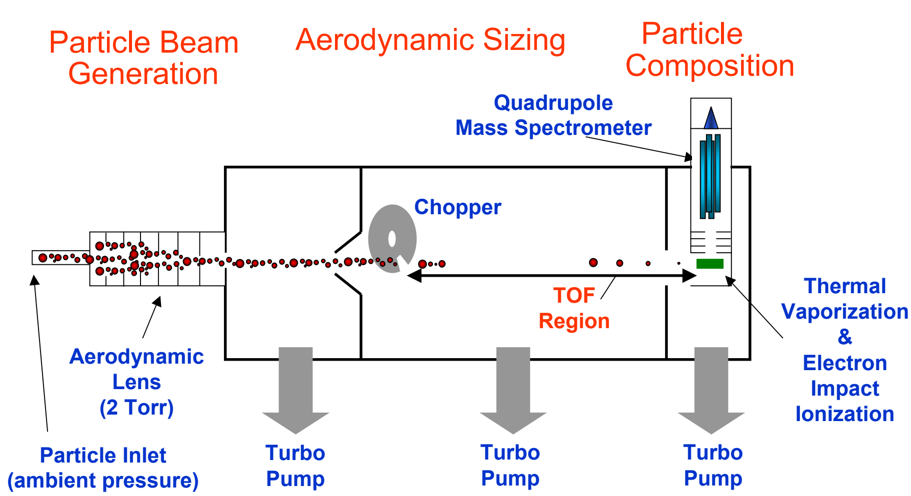
ACE-Asia Twin Otter Science Plan

Focus of this poster

- Characterization of the Asian Aerosol
  - Size distribution data from DMAs, CAPS, FSSP, APS, and AMS
  - Inorganic and organic aerosol composition data from filter samples, AMS, and MOUDI
  - Hygroscopicity from dry/ambient DMAs and TDMA
- Radiative closure
  - Aerosol optical depth (AOD) closure by comparing sunphotometer AATS-14 data and measurements
  - Predict local AOD based on aerosol size and composition measurements and compare with nephelometer data
  - Predict radiative fluxes based on aerosol and gas phase properties and compare with radiometer data
  - Satellite intercomparison with Twin Otter data
- Modeling
  - Evaluate performance of New Regional-Scale Model by comparing model predictions with measurements
  - Evaluate carbonaceous aerosol predictions

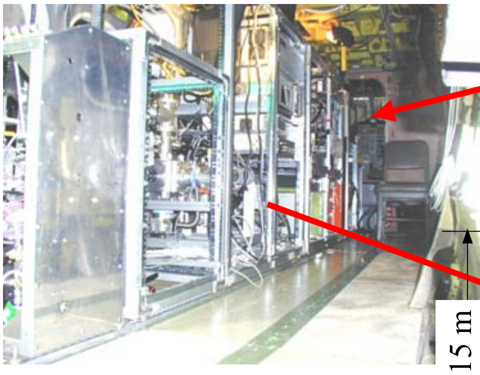


Aerosol Mass Spectrometer (AMS)



100% transmission (60-600 nm), aerodynamic sizing, linear mass signal.
Jayne et al., Aerosol Science and Technology 33:1-2(49-70), 2000.
Jimenez et al., Journal of Geophysical Research, submitted.

First Airborne Deployment of an Aerodyne AMS



- Power Consumption: 650 W
- Weight: 220 lb = 98 kg
- Depth: 24"=0.60 m

AMS Power and Weight Specifications (20.5" Short Chamber)

System	Amps	Volts[1]	Watts	Weight (pounds)	Mass (kilos)
Vacuum Chamber[2]				89	40.5
5-Turbo Pumps Under Load	7.2	24	172.8		
5-Cooling Fans	0.625	24	15		
DC Backing Pump[3]	2	24	48	*18*	*8.2*
Detection					
Balzers Quad				28	12.7
Balzers Ionizer Controller	0.9	115	103.5	26	11.8
RF Box				11.5	5.2
Rack Mount Boxes (w/cables)					
Turbo Pump Control Box				11.5	5.2
Chopper/Heater/Mult. Supply	2	24	48	7.5	3.4
AC/DC 24 V supply				9.5	4.3
SenTorr P. Gauge Controller	0.1	115	11.5	6	2.7
Data Acquisition					
Rack Mount Computer	0.6	115	69	29	13.2
		Total	**467.8**	**236**	**107.3**
	Design Goals		**<1000**	**<330**	**<150**

Instrument occupies a volume of approximately 3' x 2' x 2'   Electronics fit into a half rack

1) All DC powered components can operate with a maximum input voltage of 32 VDC

2) Weight of vacuum chamber includes fiberglass frame (~12 lbs), cooling fans, pressure gauges and 5 turbo pumps

3) AC powered diaphragm backing pump (MD60) uses 2.5 amps at 115VAC, weight is 37 lbs.

Mass Calibration

- Ionization efficiency (*IE*) is defined as the ratio of total number of ions per particle by number of molecules per particle. *IE* of nitrate is determined during calibration. *IE* of other species can be estimated from IE_{NO3} by the ratio of the respective molecular weights:

$$\frac{n_s^{e^-}}{IE_s} = \frac{n_{NO_3}^{e^-}}{IE_{NO_3}} \Rightarrow \frac{MW_s}{IE_s} = \frac{MW_{NO_3}}{IE_{NO_3}}$$

- Calibration factor (*CF*) of nitrate is defined as unity. CF_s of other species is determined by comparing the mass response of the instrument with a known concentration of the species introduced into the instrument during calibration

Quantifying TOF Signal

- TOF MODE
  - By using time-step per average signal point and the single ion's signal, one can convert the raw signal to ions/TOF (I_{sf}^{TOF} for each fragment or I_s^{TOF} for sum of the fragments)
  - Mass concentration (C_s, μg/m^3) is obtained by incorporating in the ionization efficiency (IE_s), calibration factor (CF_s), sample flow rate (Q), chopper frequency (f) and chopper duty cycle (D_c): (N_A is Avogadro's number)

$$C_s = \frac{I_s^{TOF} \cdot CF_s}{IE_s} \cdot \frac{MW_s}{N_A} \cdot \frac{f}{D_c \cdot Q} = \frac{I_s^{TOF} \cdot CF_s}{IE_{NO_3}} \cdot \frac{MW_{NO_3}}{N_A} \cdot \frac{f}{D_c \cdot Q}$$

$(CF_{NO_3} = 1, \text{others determined by calibration})$

AMS Detection Limits in ACE-Asia

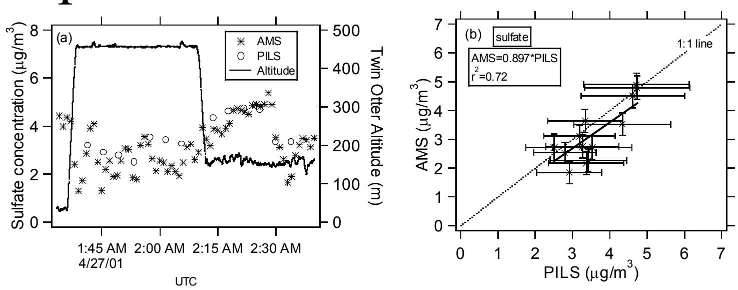
Compound	Estimate Detection limit* ($\mu g/m^3$)
Sulfate	0.53
Nitrate	0.12
Alkane	1.4
Alkanoic acid	0.39
Alkenoic acid	1.8
Alkanol	3.5
Dicarboxylic acid	0.93

*Detection limit defined as 2σ (not final) for 1min averaging time

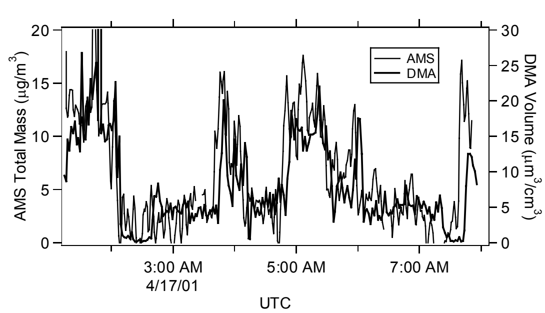
References: 1) Seinfeld, J.H., S.N. Pandis, *Atmospheric chemistry and physics: From air pollution to climate change*, John Wiley & Sons Inc., 1998.
2) NIST Mass spectrum data base

Comparison to Other Instruments

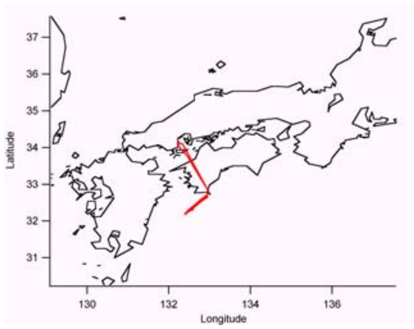
PILS:



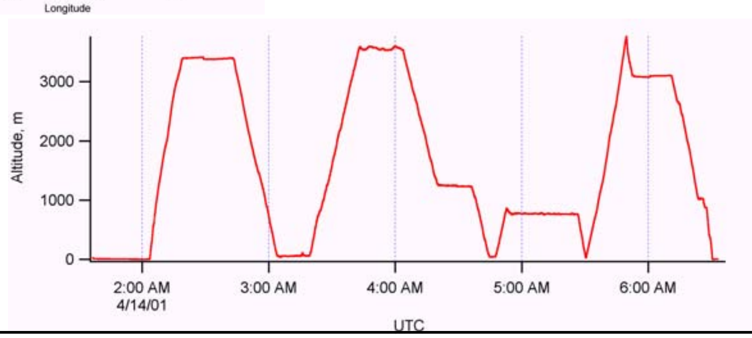
DMA:



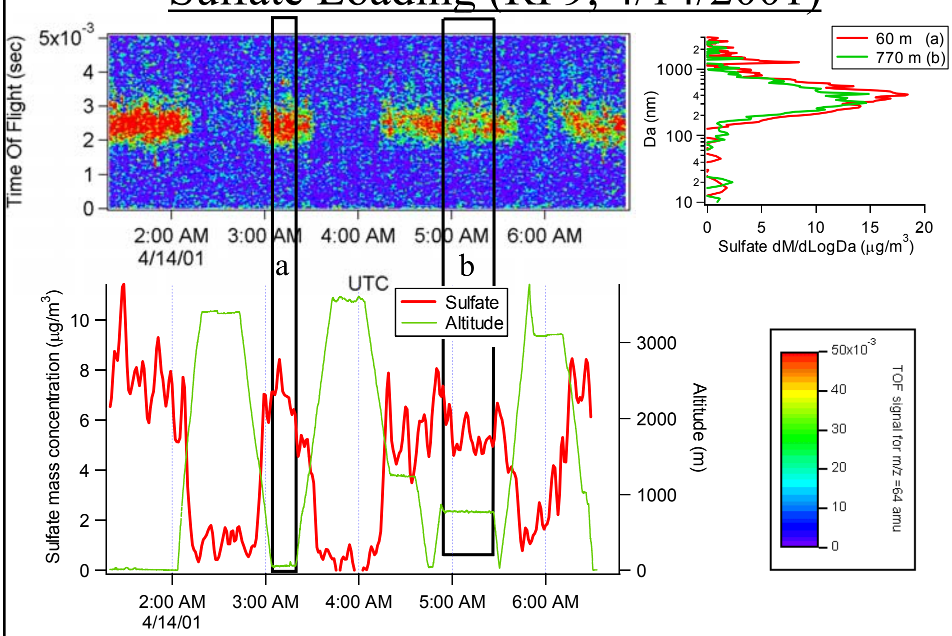
Twin Otter (RF9, 4/14/2001)



Legs East of Miyazaki, Japan



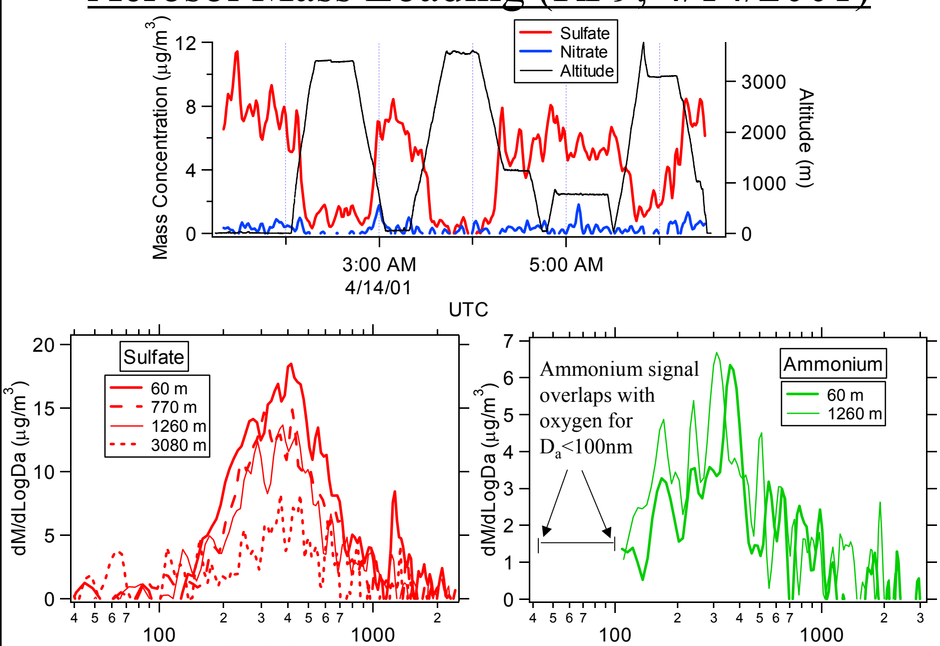
Sulfate Loading (RF9, 4/14/2001)



Sulfate Loading (RF9, 4/14/2001)

- Top Plot:
  - Image plot for the raw signal from AMS in Time OF Flight mode for a fragment of sulfate (*m/z*=64) during the flight
  - The more reddish the color, the more intense the signal
  - It shows that going in/out of the different layers, sulfate concentration increases/decreases
  - Also, size distribution of sulfate seems to be uniform in different layers (time of flight is the measure of size)
- Right side plot:
  - By converting the raw TOF signal vs. time of flight to mass concentration vs. aerodynamic diameter, one can get mass distribution
  - The distributions correspond to averaged TOF signal for the constant altitude legs, indicated as “a” and “b”.
- Bottom plot:
  - By integrating the mass distribution ($dM/dLogD_a$) with respect to $LogD_a$, we can obtain mass concentration. (Independently, one can also convert the raw signal from the Mass Spectrum mode to mass concentration for different species)
  - It shows variation of sulfate concentration with altitude during the flight

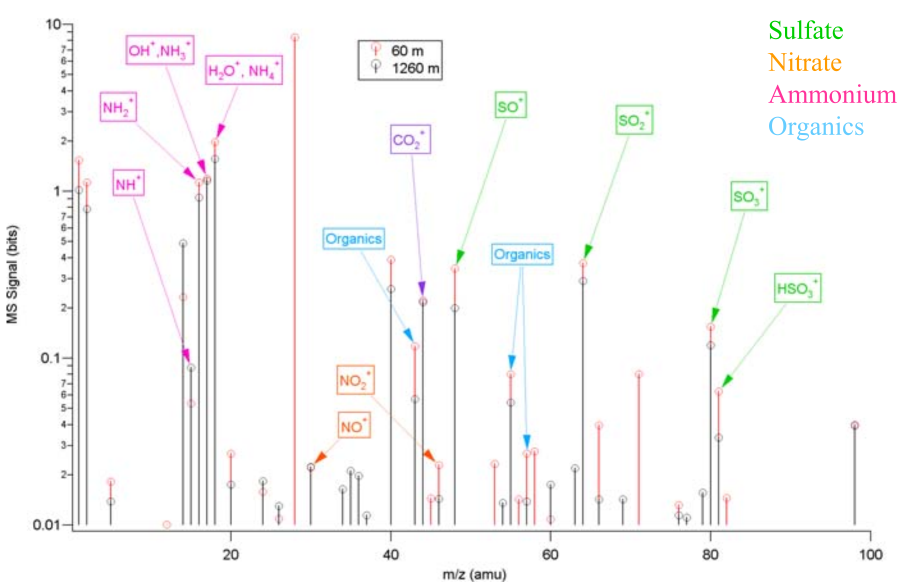
Aerosol Mass Loading (RF9, 4/14/2001)



Aerosol Mass Loading (RF9, 4/14/2001)

- Top plot:
  - Mass concentration profiles of Sulfate and nitrate using MS signal
  - Little nitrate was detected. Organic and ammonium analysis is underway
- Bottom plots:
  - Size distribution of sulfate and ammonium at different altitudes obtained in the TOF mode
  - Ammonium signal overlaps with oxygen signal from the gas-phase for D_a<~100nm; thus it's not shown

Sample Mass Spectrum (RF9, 4/14/2001)



Conclusions

- AMS operated successfully on most Twin Otter flights (15 out of 19)
  - Sensitivity to sulfate ~ 0.53 $\mu g\ m^{-3}$
- Submicron aerosols were present in discrete layers
- SO_4 was a major component of submicron aerosols and was observed in all flights
- SO_4 size distribution was relatively uniform for several flights
- Very good correlation of AMS SO_4 mass and DMA volume
- NO_3, NH_4, and organics were detected in some flights
- Future work:
  - Sensitivity improvement
  - Next deployment: July 2002, Florida, CRYSTAL-FACE Project (NASA)

Acknowledgements

- CIRPAS Team: Bob Bluth, Reg Burch, Denis, Roy Wood, Mike Hobble, Nava Roy, Bob Rogell, Richard, Jackie Rosenkrantz, Mike Duncan, and Sara Moore
- JOSS (especially Brian Jackson)
- Office of Naval Research
- National Science Foundation
- Iwakuni Marine Corps Air Station (especially Jim Roberts, Rose Cole, and Lee Chieffalo)
- Jian Wang at Caltech
- Kari Maxwell, Doug Orsini, and Rodney Weber at GeorgiaTech
- Dean Hegg and Song Gao at University of Washington