Radiative Flux Changes by Aerosols from North America, Europe, and Africa over the Atlantic Ocean: Measurements and Calculations from TARFOX and ACE-2

P. B. Russell[1], P. Hignett[2], J. M. Livingston[3], B. Schmid[4], A. Chien[5], R. Bergstrom[4], P. A. Durkee[6], P. V. Hobbs[7], T. S. Bates[8], and P. K. Quinn[8]

[1]NASA Ames Research Center, Moffett Field, CA 94035-1000 USA
[2]United Kingdom Meteorological Office, Meteorological Research Flight, DRA Farnborough, Hampshire, GU146TD, UK
[3]SRI International, Menlo Park, CA 94025 USA
[4]Bay Area Environmental Research Institute, San Francisco, CA 94122 USA
[5]Symtech Corporation, Moffett Field, CA 94035-1000 USA
[6]Naval Postgraduate School, Monterey, CA 93943-5114 USA
[7]University of Washington, Seattle, WA 98195 USA
[8]NOAA-Pacific Marine Environmental Laboratory, Seattle, WA 98115 USA

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5IAC Edinburgh DF Poster
Layout of panels (pages)

Banner (panel #1); 6"

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Abstract. Aerosol effects on atmospheric radiative fluxes provide a forcing function that is a major source of uncertainty in understanding the past climate and predicting climate change. To help reduce this uncertainty, the 1996 Tropospheric Aerosol Radiative Forcing Observational Experiment (TARFOX) and the 1997 second Aerosol Characterization Experiment (ACE-2) measured the properties and radiative effects of American, European, and African aerosols over the Atlantic.

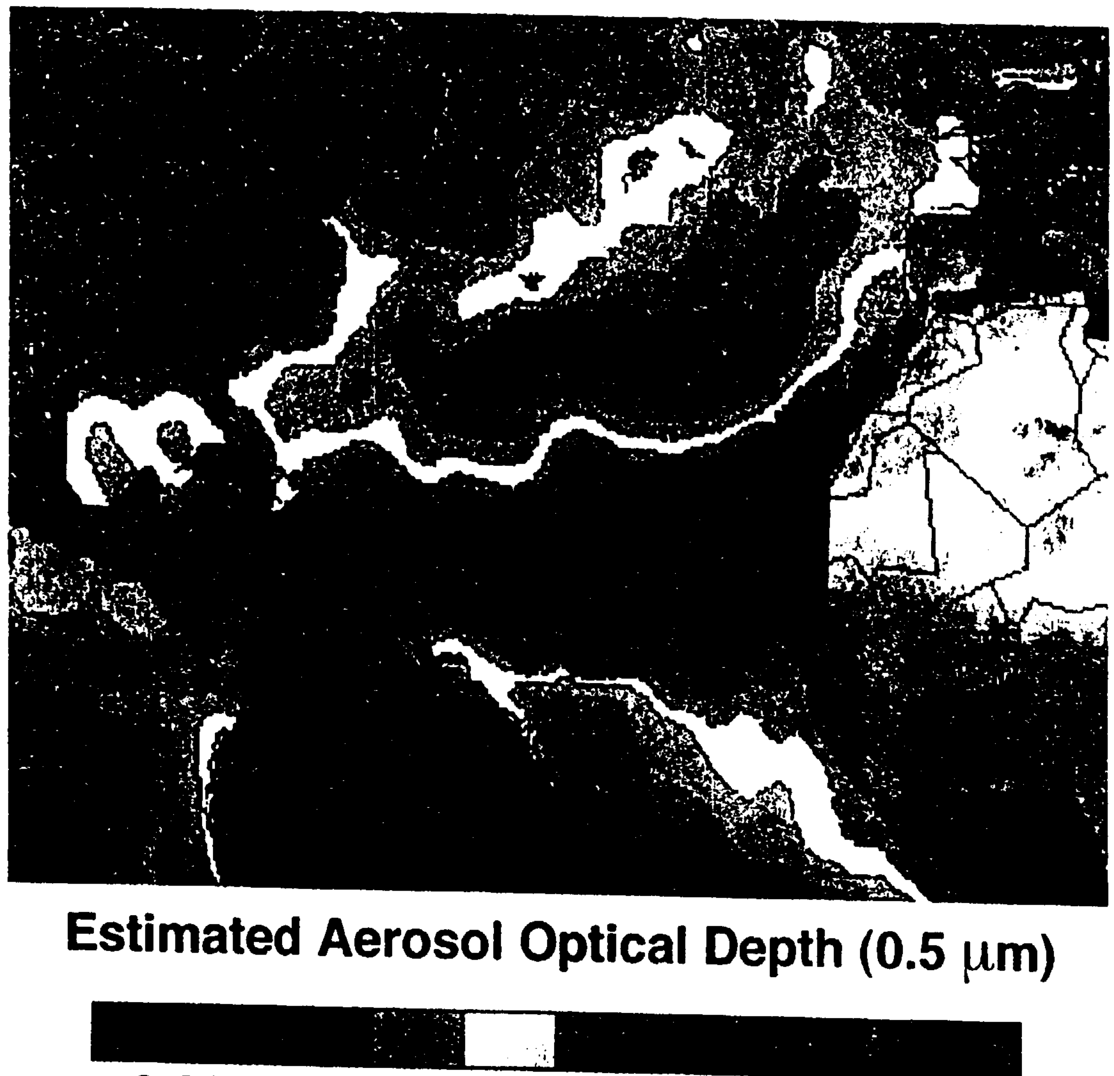
In TARFOX, radiative fluxes and microphysics of the American aerosol were measured from the UK C-130 while optical depth spectra, aerosol composition, and other properties were measured by the University of Washington C-131A and the CIRPAS Pelican. Closure studies show that the measured flux changes agree with those derived from the aerosol measurements using several modeling approaches. The best-fit midvisible single-scatter albedos (~0.89 to 0.93) obtained from the TARFOX flux comparisons are in accord with values derived by independent techniques.

In ACE-2 we measured optical depth and extinction spectra for both European urban-marine aerosols and free-tropospheric African dust aerosols, using sunphotometers on the R/V Vodyanitskiy and the Pelican. Preliminary values for the radiative flux sensitivities (ΔFlux ÷ ΔOptical depth) computed for ACE-2 aerosols (boundary layer and African dust) over ocean are similar to those found in TARFOX. Combining a satellite-derived optical depth climatology with the aerosol optical model validated for flux sensitivities in TARFOX provides first-cut estimates of aerosol-induced flux changes over the Atlantic Ocean.

Aerosol Optical Depth Derived from Upward Scattered Solar Radiance

AVHRR/NOAA 11

Jun, Jul, Aug



Husar et al., *J. Geophys. Res.*, *102*, 16,889, 1997.

Focus of this Poster:

Radiative flux sensitivity
$\equiv \Delta\text{Flux} \div \Delta\text{Optical depth}$

- Needed to determine aerosol radiative forcing of climate

- Can depend strongly on
  - Aerosol composition and size
    (single-scattering albedo and scattering asymmetry)
  - Surface albedo
  - Sun angle

  (Can even change sign, from cooling to heating)

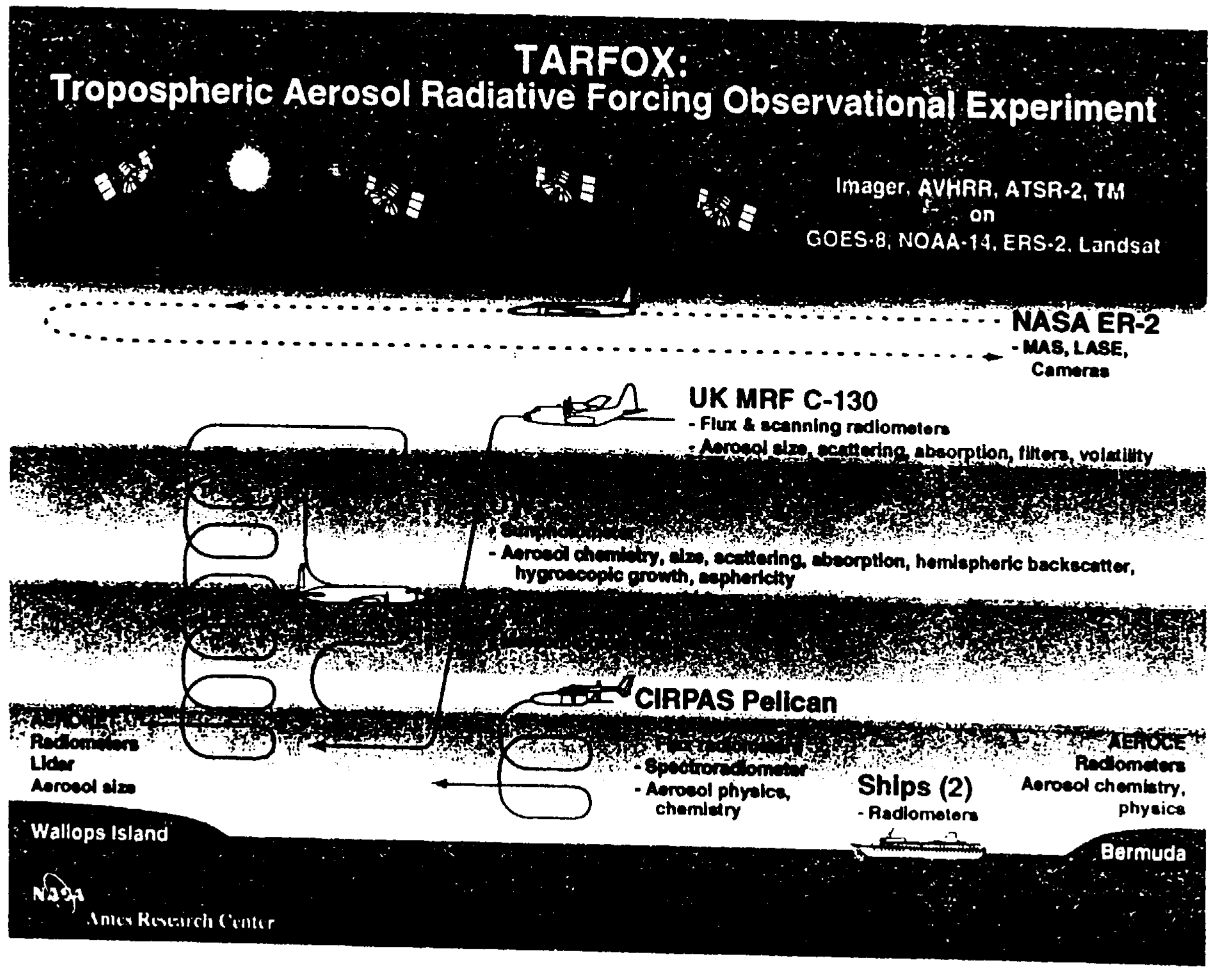


Plate 2. Schematic overview of TARFOX platforms, instruments, and experimental approach.

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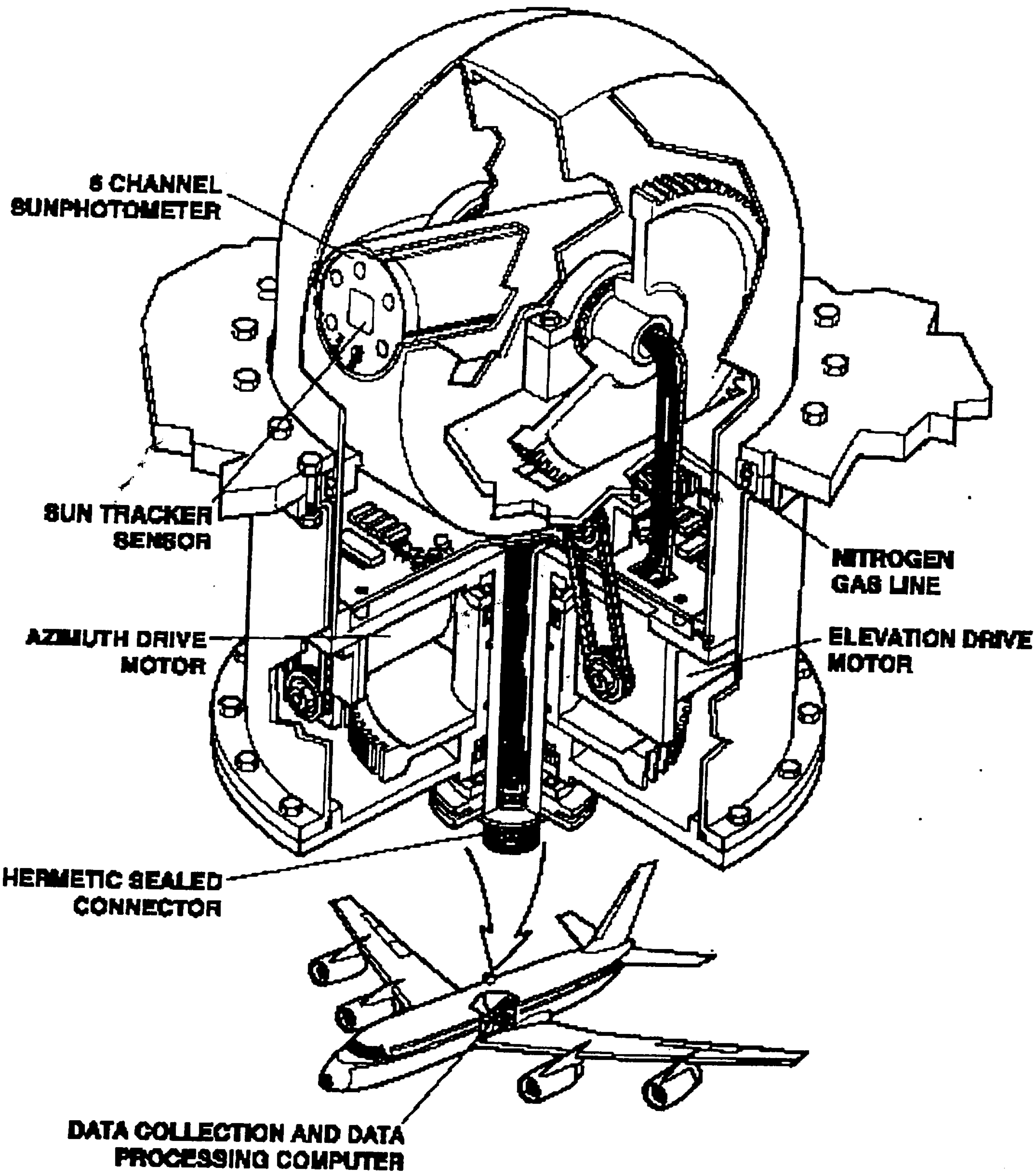
AIRBORNE SUNPHOTOMETER



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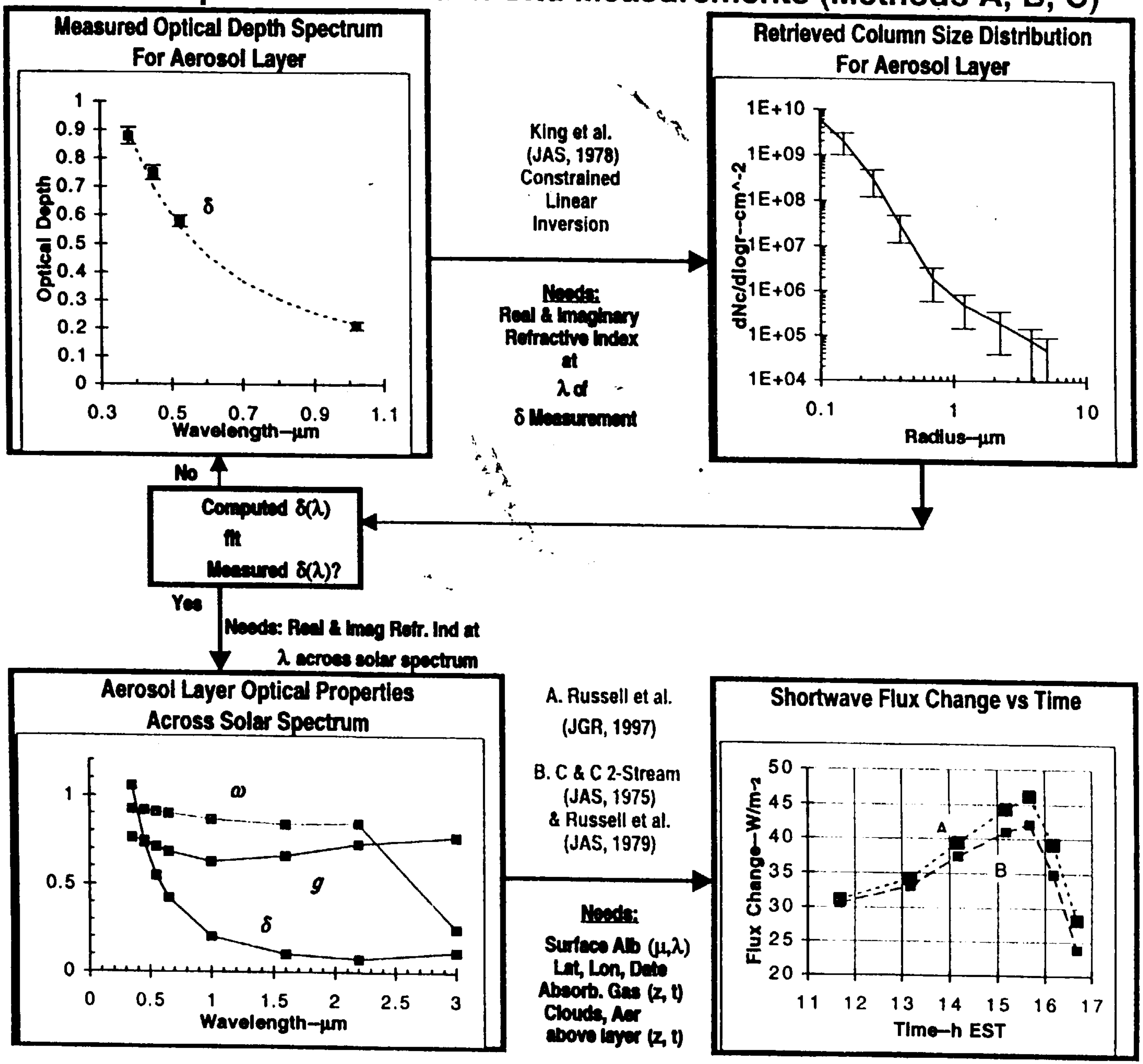
Procedure for Computing Aerosol-induced Flux Changes From Sunphotometer and In Situ Measurements (Methods A, B, C)



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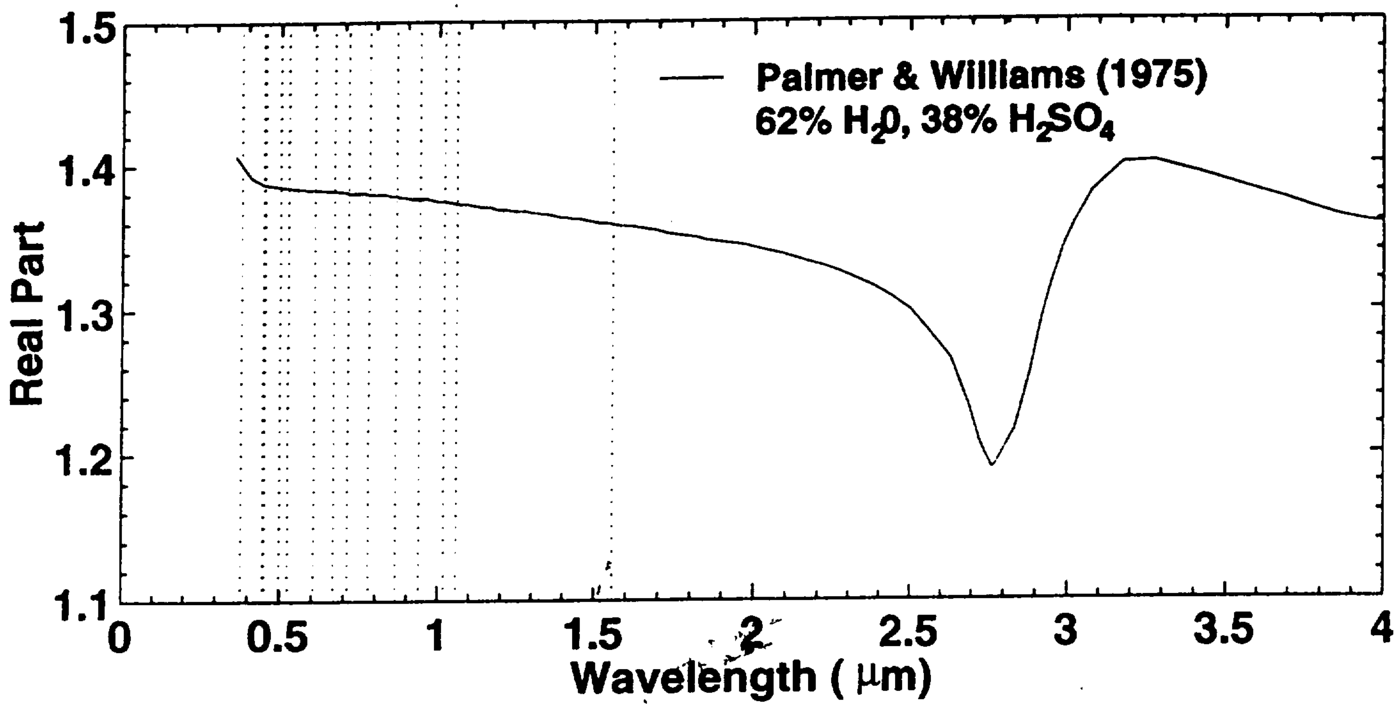
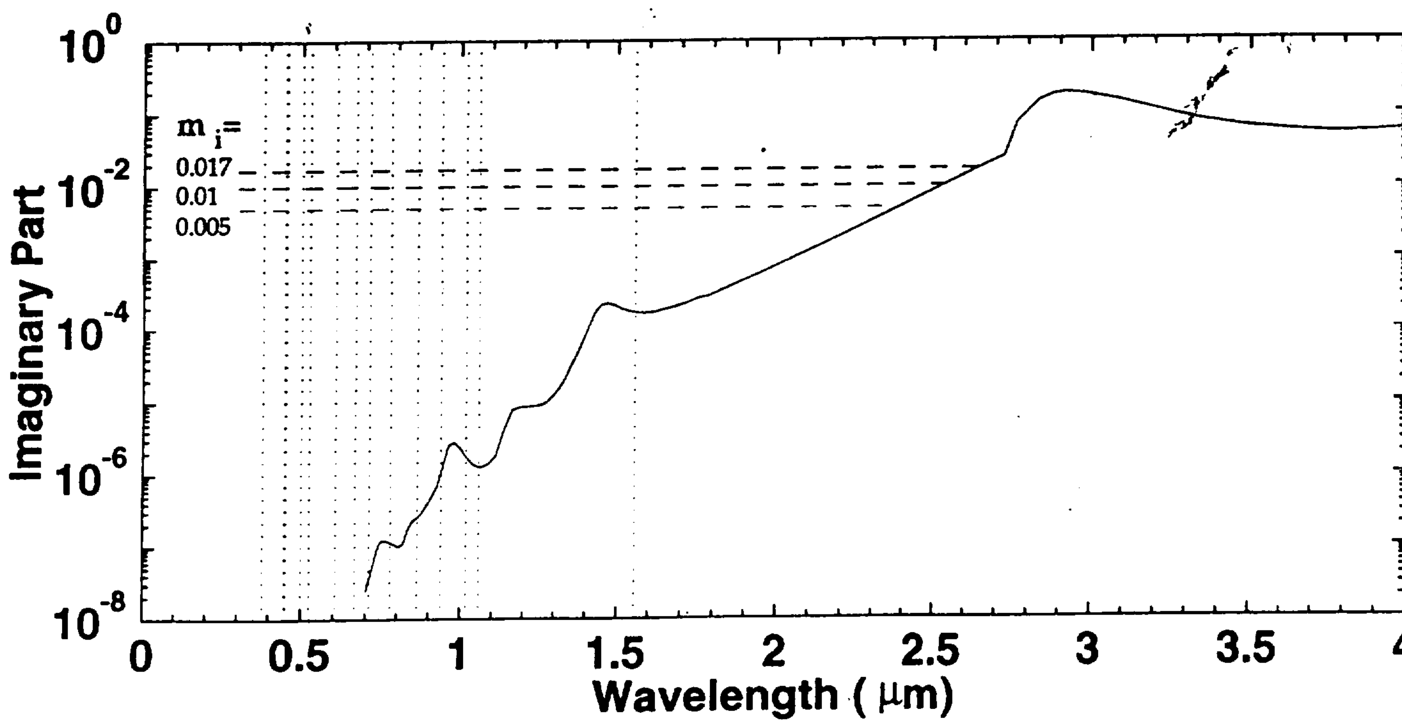
MODEL REFRACTIVE INDEX SPECTRA





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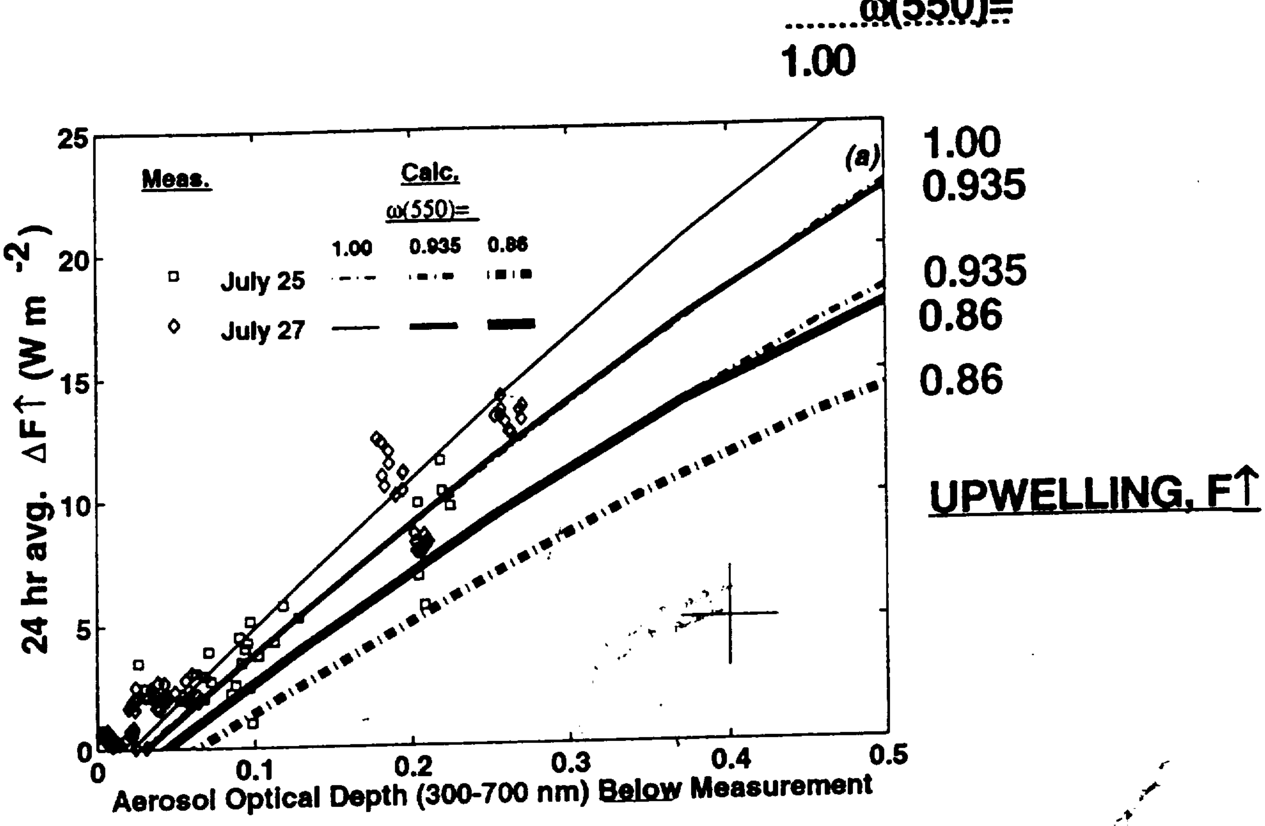
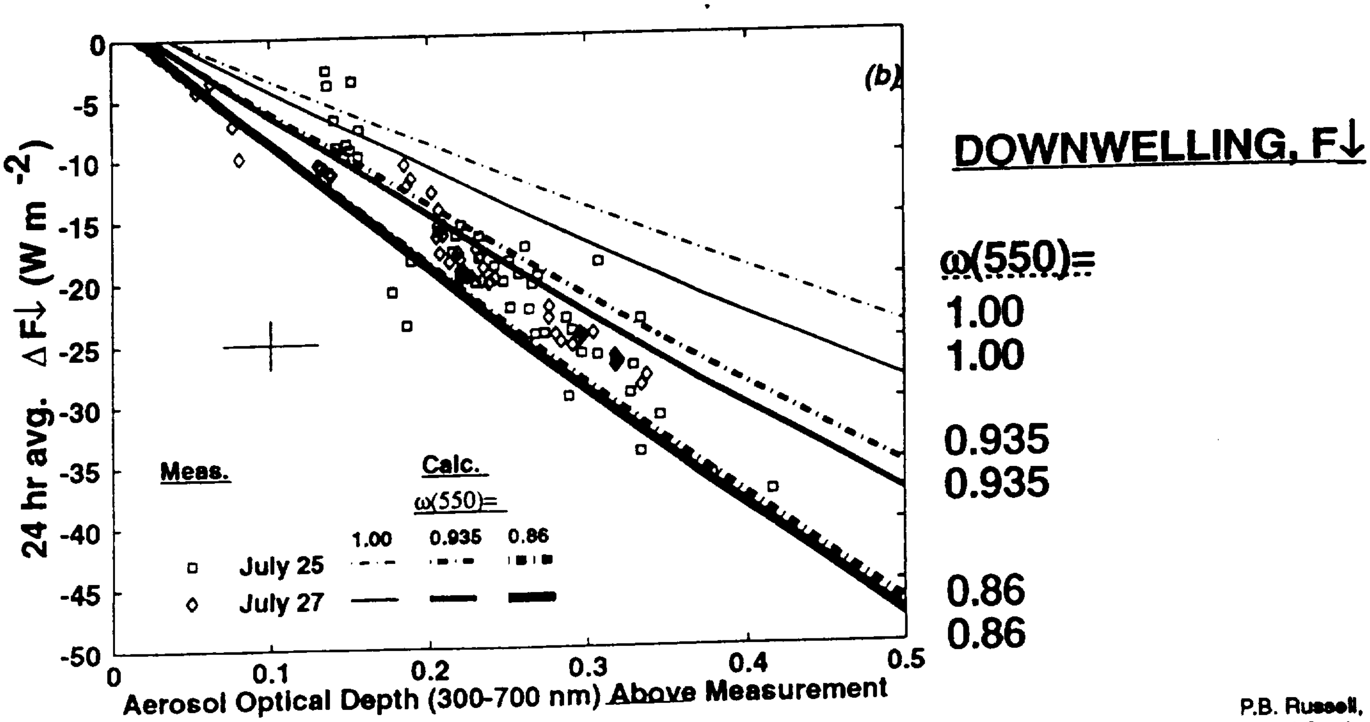
COMPARISON BETWEEN AEROSOL-INDUCED RADIATIVE FLUX CHANGES

- Calculated from Sunphotometer Optical Depth Spectra (METHODS B′, C′)
- Derived from C-130 Flux Measurements





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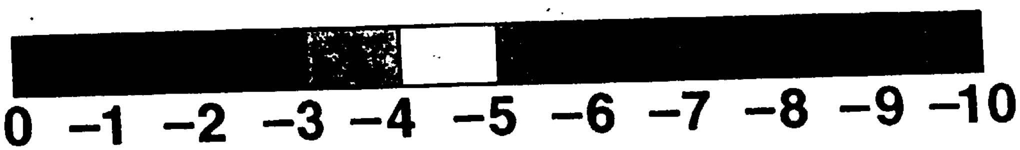
Aerosol-Induced Change in Net Shortwave Flux at Tropopause

($\lambda < 4\ \mu m$, 24-hr Average, No Clouds)

Jun, Jul, Aug

Net Flux Change (W m^{-2})



Based on:

- AVHRR/NOAA Aerosol Optical Depths
  - Husar et al. [*J. Geophys. Res.*, *102*, 16,889, 1997]
  - Data period: July 1989-June 1991
- TARFOX Flux Sensitivities, $\Delta F/\Delta \tau$
  - Calculated for TARFOX model aerosol with $\omega_{500} \approx 0.9$
  - Validated by comparison to C-130 flux measurements

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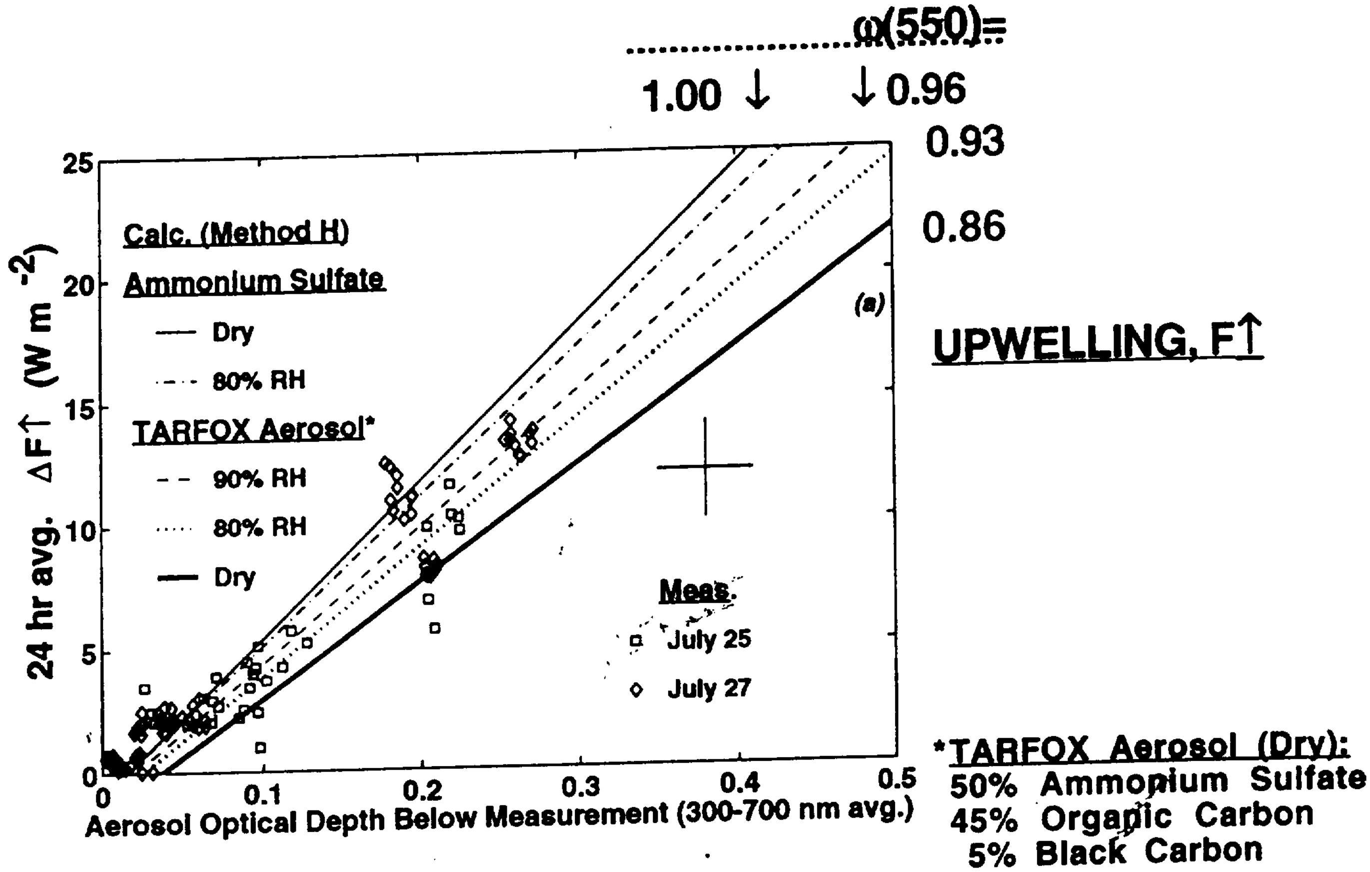
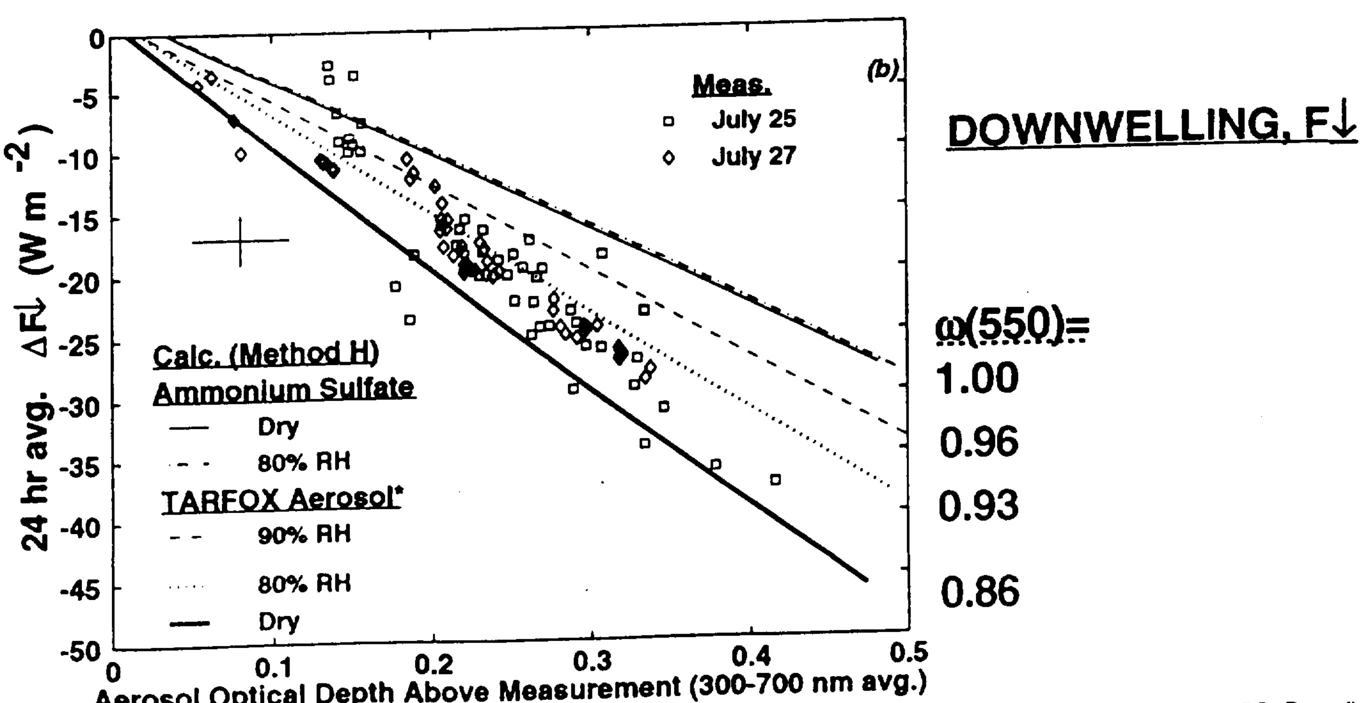
COMPARISON BETWEEN AEROSOL-INDUCED RADIATIVE FLUX CHANGES

- Calculated by METHOD H
- Derived from C-130 Flux Measurements





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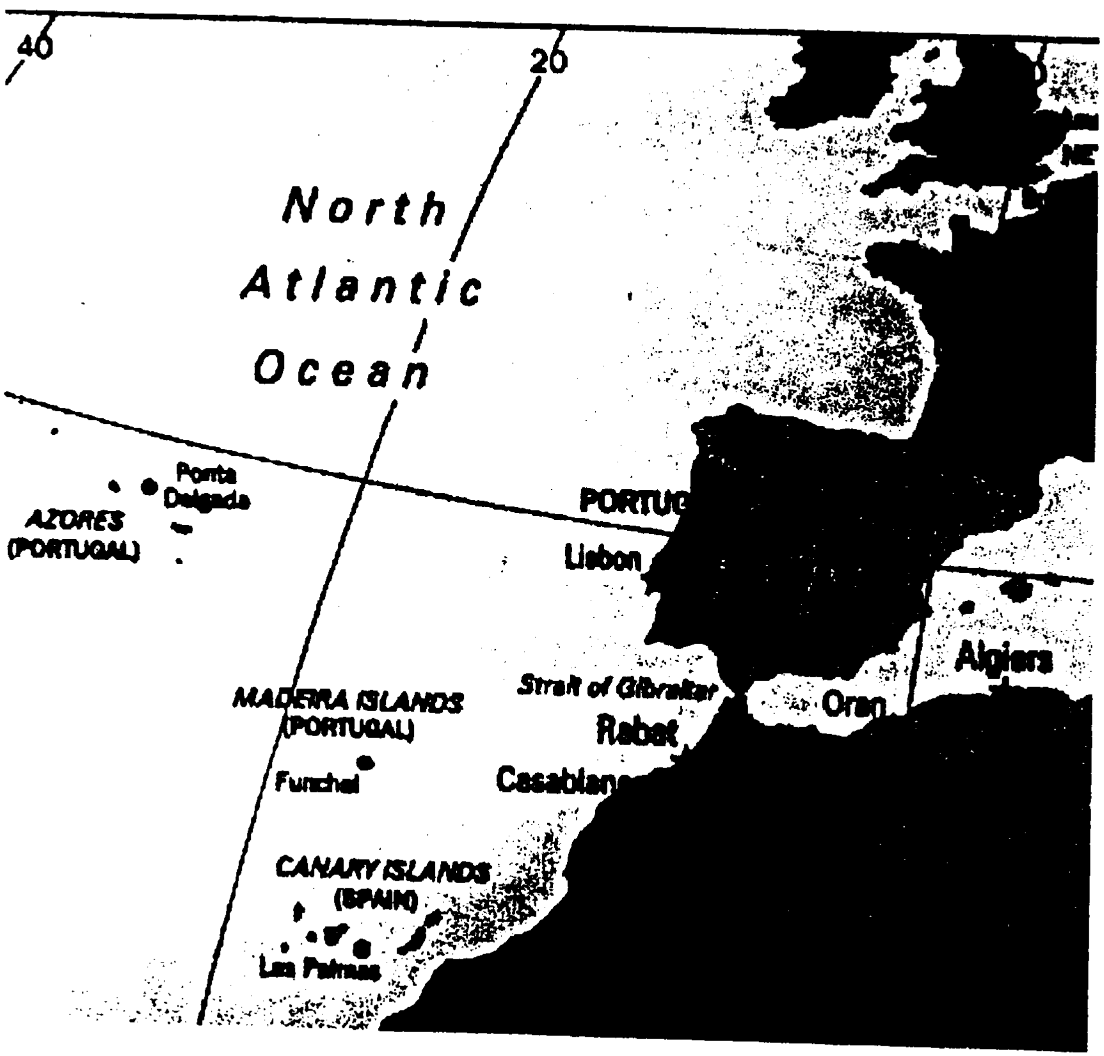
SUMMARY OF OPTICAL/RADIATIVE CALCULATION METHODS

	Methods A, B, C	Method H
Optical Depth	Measured by tracking sunphotometer (380, 453, 525, 1020 nm)	Measured by occulted pyranometer (300-700 nm avg)
Size Distribution	Inverted from optical depth spectrum	Measured by optical particle counter
Real Refractive Index	62% H2O, 38% H2SO4 [Palmer & Williams 1975] based on composition from Novakov et al. [1997], Hegg et al. [1997]	ELSIE [Lowenthal et al., 1995] based on composition from Novakov et al. [1997], Hegg et al. [1997]
Imaginary Refractive Index	As above, but increased to yield ω(500 nm)≈0.86 to 0.96 [Remer et al., 1997; Hegg et al., 1997; Hignett et al., 1998]	As above
Flux Changes	A) Russell et al. [1997] B) Coakley and Chylek [1975], Russell et al. [1979] C) Chylek and Wong [1997], Coakley and Chylek [1975]	Edwards and Slingo [1996]

International Global Atmospheric Chemistry Project (IGAC)
EC/DG XII Environment and Climate Programme, NERC (UK), NSF (USA), NOAA (USA)
Meteo France, UK Meteorological Office, Instituto Nacional de Meteorologia (ES)

ACE-2 North Atlantic Regional Aerosol Characterization Experiment

June 16 - July 25, 1997



- radiative effects and controlling processes of anthropogenic aerosols from Europe and desert dust from the Africa as they are transported over the North Atlantic Ocean
- 250 research scientists
- 60 coordinated aircraft missions with 6 aircraft (for a total of 450 flight hours), one ship, and ground stations on Tenerife, Portugal and Madeira.

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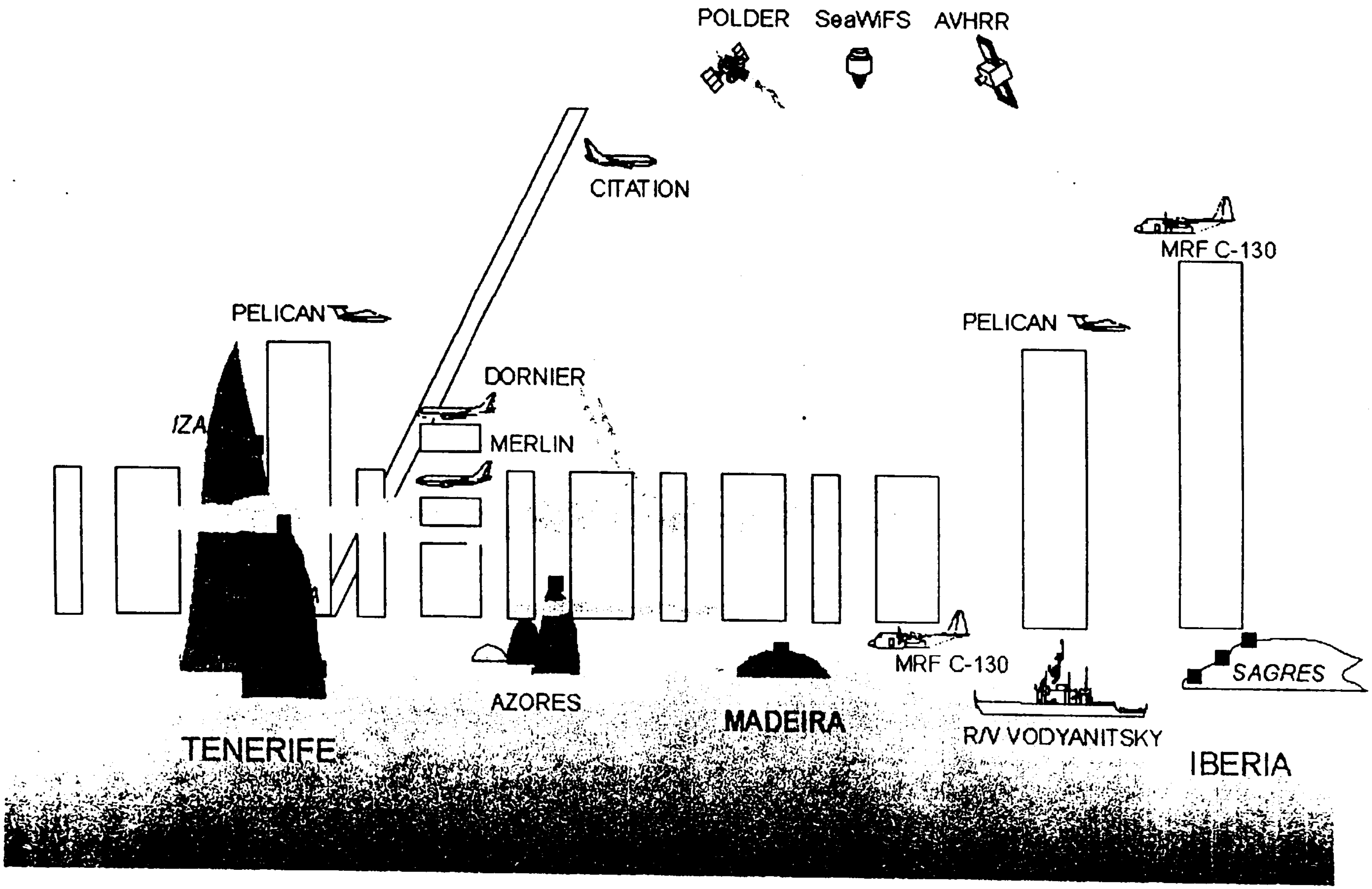

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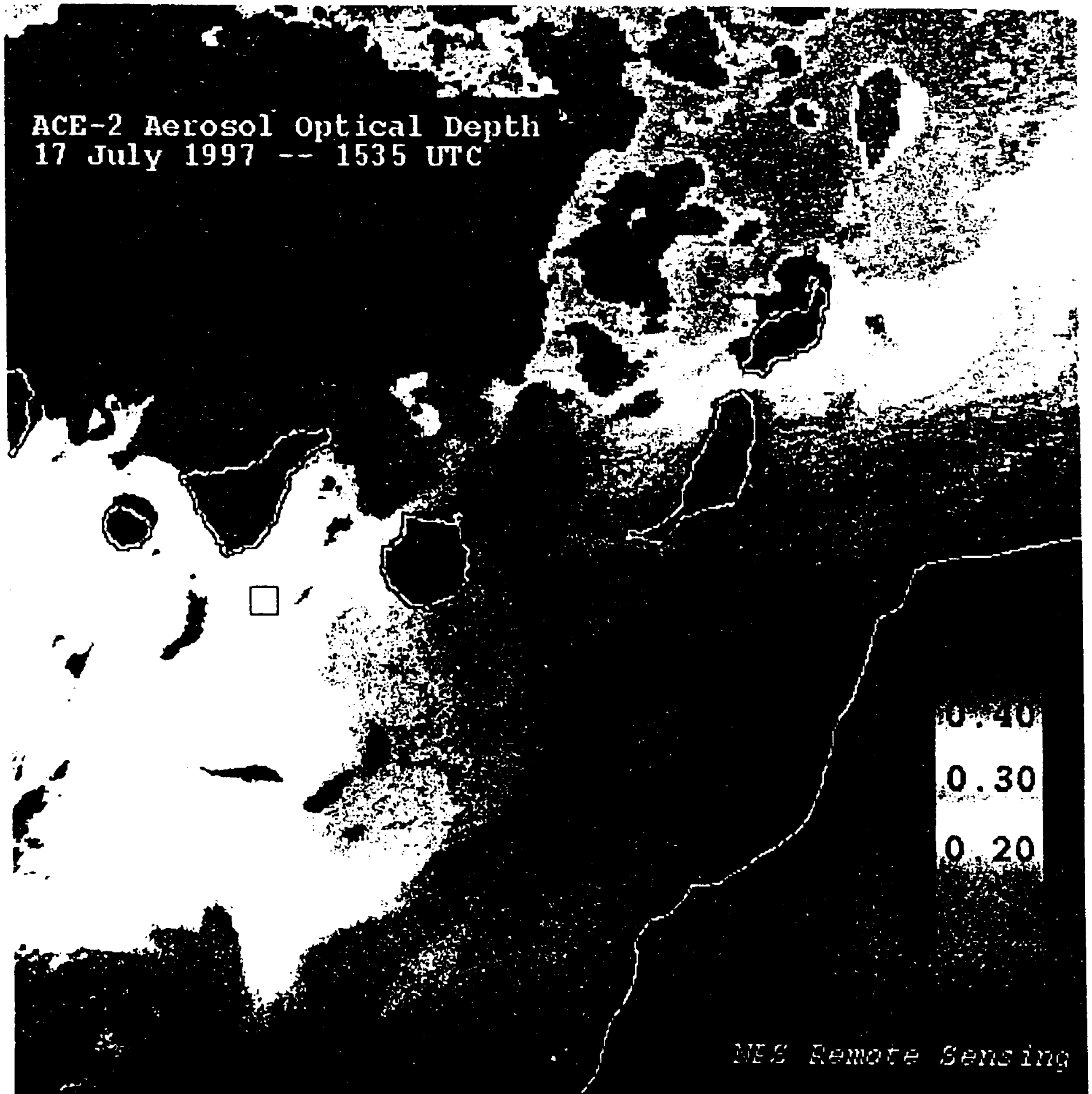
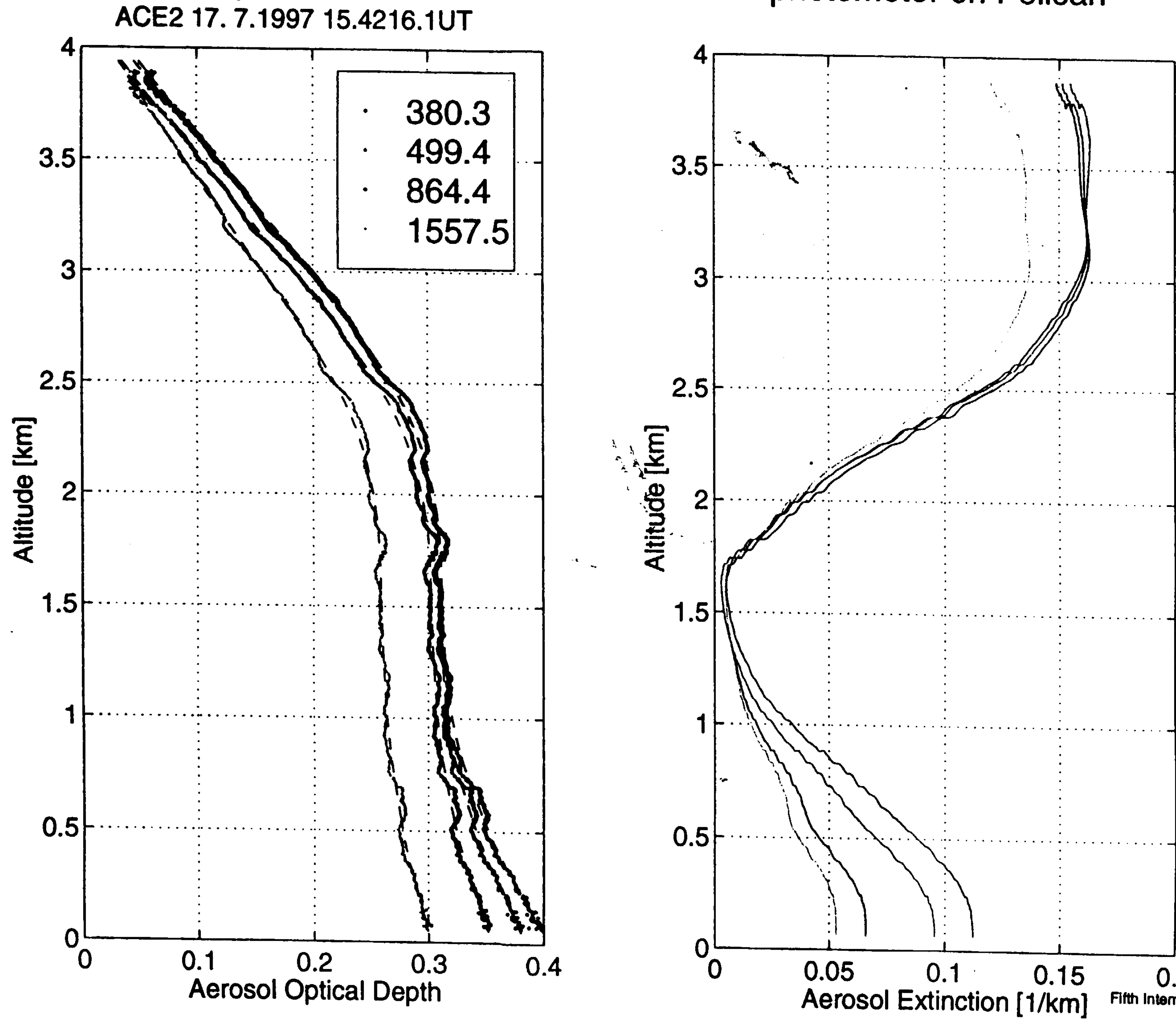

ACE-2 Aerosol Optical Depth
17 July 1997 -- 1535 UTC
0.40
0.30
0.20
Remote Sensing

Optical Depth and Extinction Profiles from Sunphotometer on Pelican



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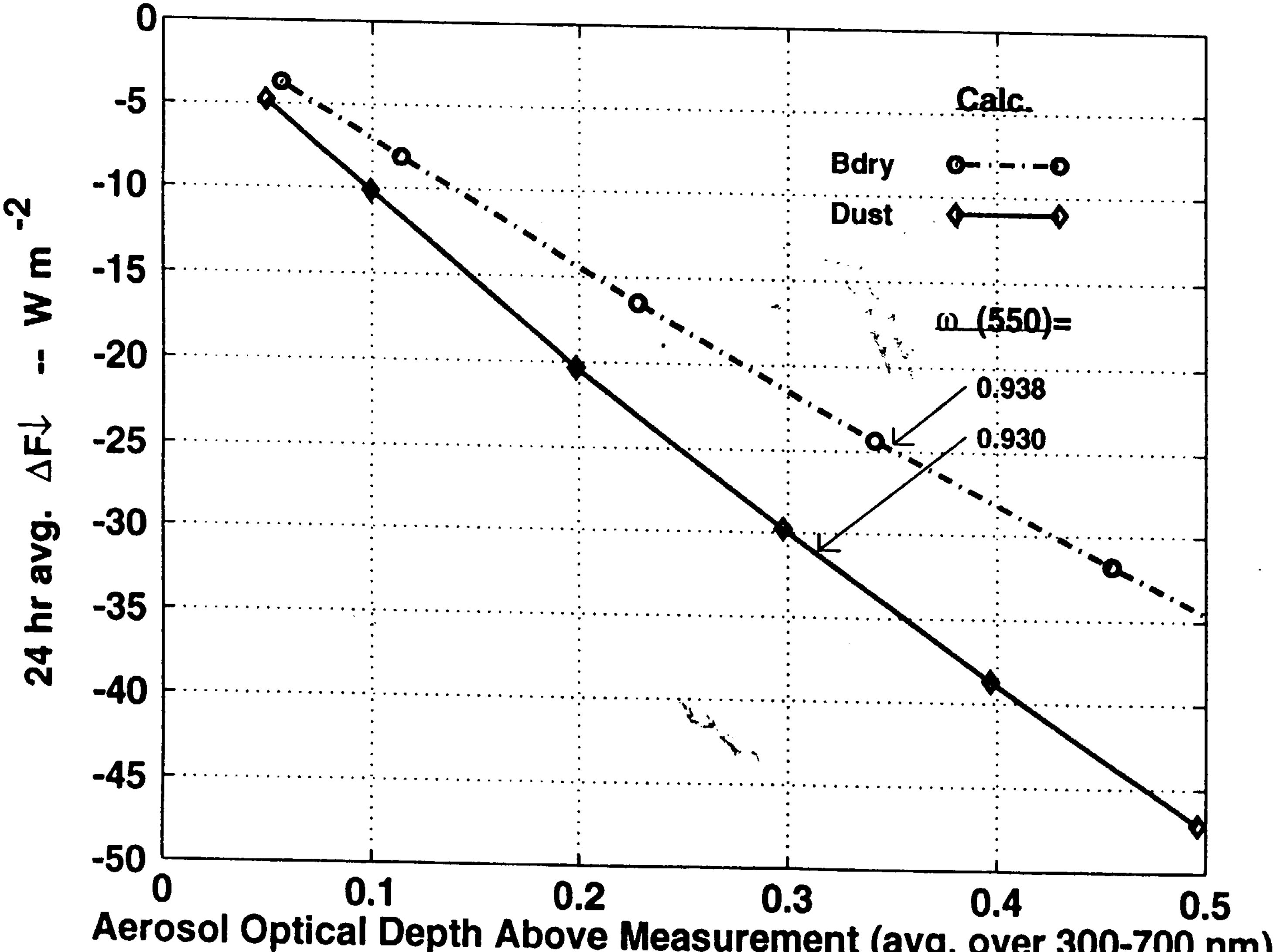
Downward Shortwave Flux Change Below Layer
Computed for
Boundary Layer Aerosol and Elevated Dust Aerosol
Sampled by Pelican
17 July 1997, South of Tenerife (28 N, 16 W)



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CONCLUSIONS

- Closure (i.e., consistency) achieved among
  - TARFOX-derived aerosol properties
  - modeling techniques
  - radiative flux measurements

  provided the aerosols are modeled as moderately absorbing ($0.89 \leq \omega_{midvis} \leq 0.93$).

- These ω_{midvis} values are in accord with independent measurements of the TARFOX aerosol (e.g., Hegg et al., 1997).

- This closure was obtained by two approaches, which differed in methods used to:
  - Measure optical depth
  - Determine aerosol size distribution
  - Model aerosol composition & complex refractive index
  - Compute radiative transfer

CONCLUSIONS
(Cont'd)

- Radiative flux sensitivity (ΔFlux $\div$ ΔOptical depth) computed for ACE-2 aerosols (boundary layer and African dust) over ocean similar to TARFOX.

$$\Delta F\uparrow_{24\text{-hr}}/\delta(550\ \text{nm}) \approx 40\ \text{W m}^{-2}$$
$$\Delta F\downarrow_{24\text{-hr}}/\delta(550\ \text{nm}) \approx -70\ \text{W m}^{-2}$$

- An aerosol model that gives validated ΔF $\div$ ΔO.D. can be used to derive regional ΔF from a climatology of O.D. (e.g., from AVHRR).