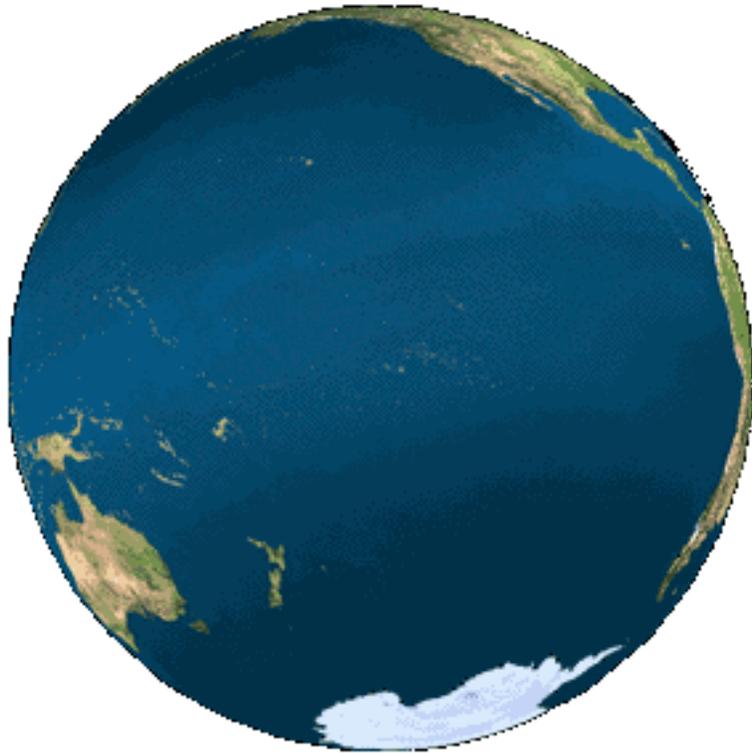


AEROSOLS DOWN UNDER

A YANK LOOKS AT THE CLEANHOUSE



Stephen E. Schwartz

BROOKHAVEN
NATIONAL LABORATORY

Upton, New York, USA

Australian Aerosol Workshop

University of New South Wales
Sydney, Australia

March 30 – April 1, 2005

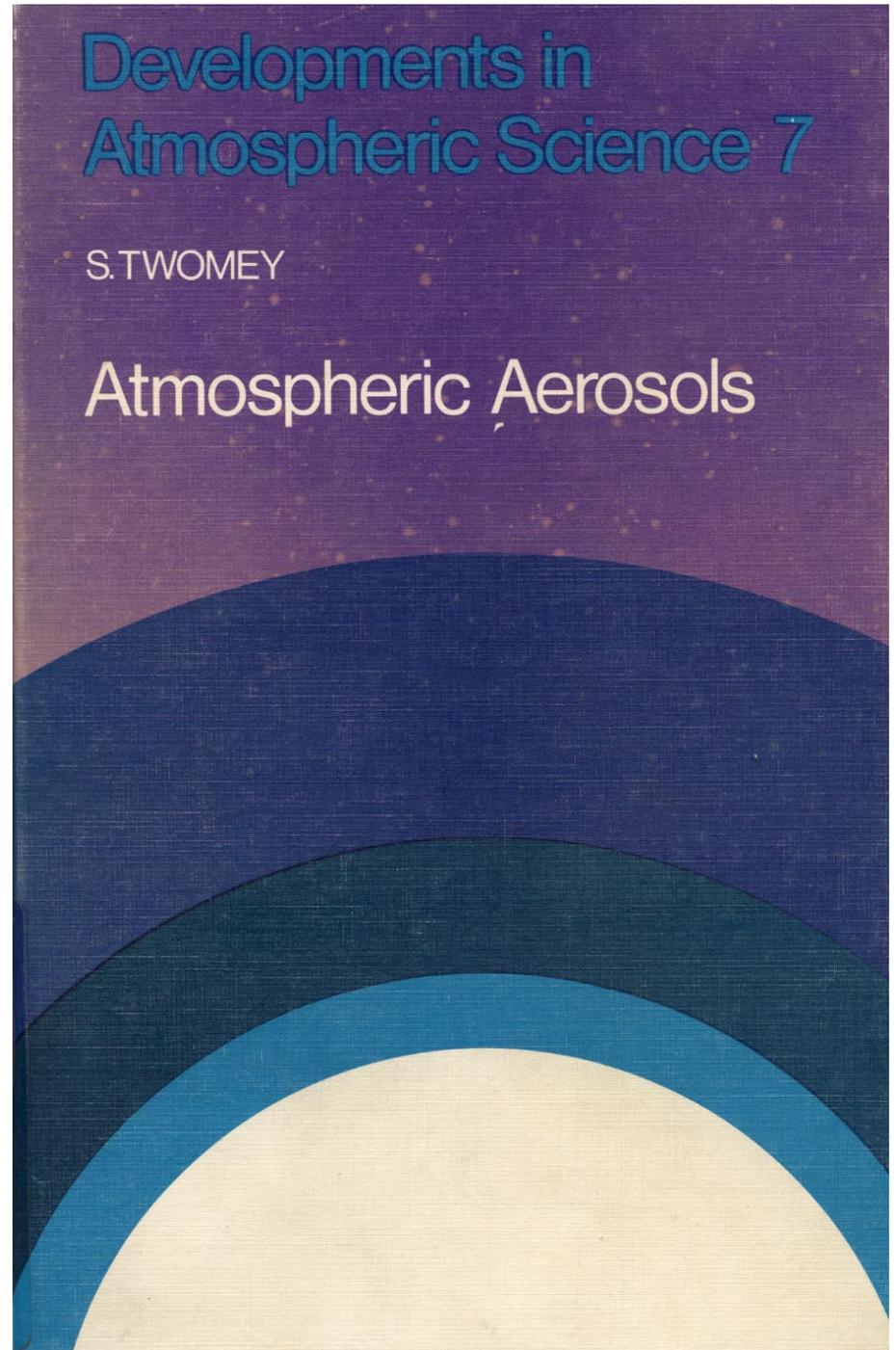
<http://www.ecd.bnl.gov/steve/schwartz.html>

SYDNEY, MARCH 28, 2005



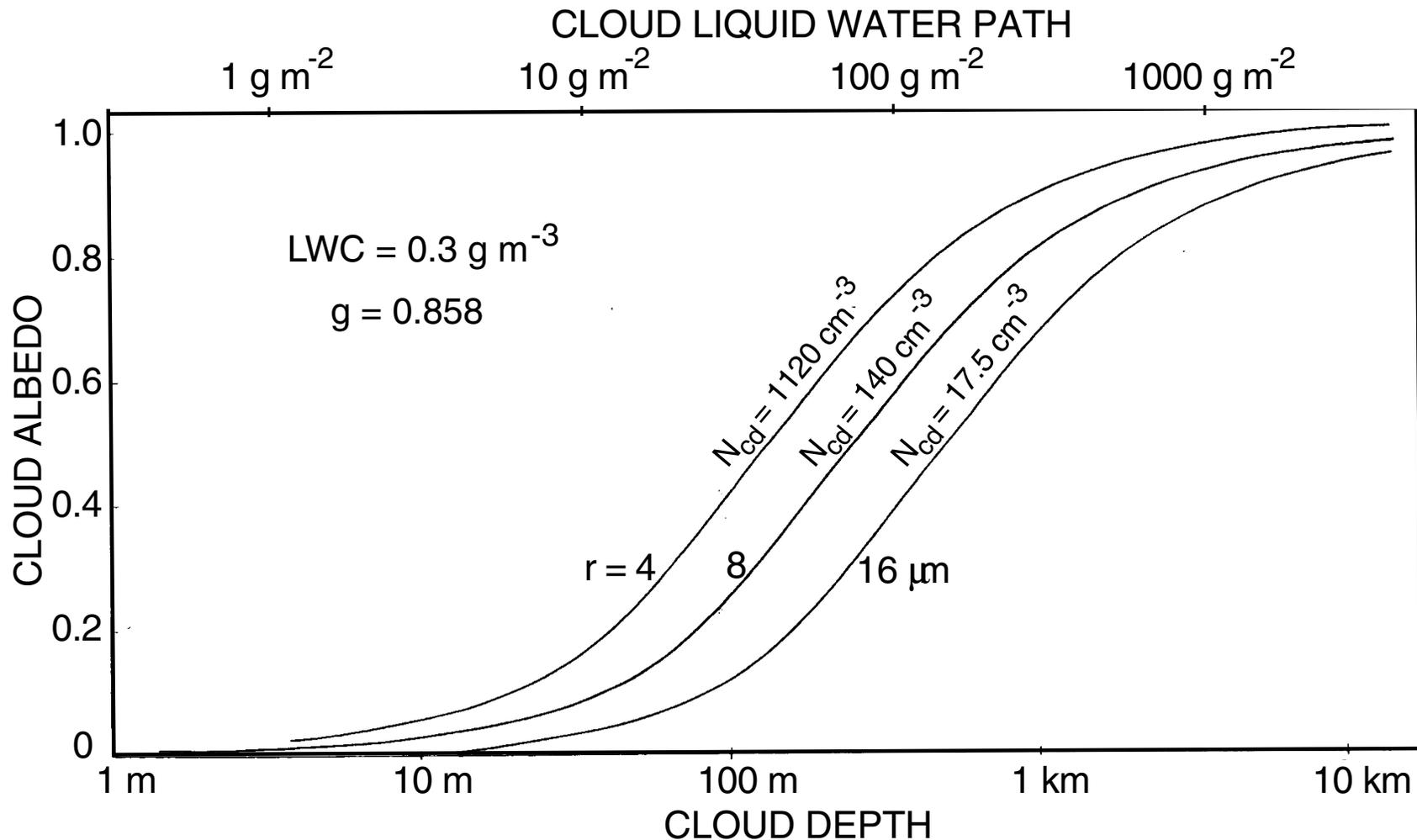
*The one book to buy
if you're buying
only one (1977)*

Sadly, out of print



DEPENDENCE OF CLOUD ALBEDO ON CLOUD DEPTH

Influence of Cloud Drop Radius and Concentration



Twomey, *Atmospheric Aerosols*, 1977

For a given liquid water path, cloud albedo is highly sensitive to cloud drop number concentration or radius.

Oceanic phytoplankton, atmospheric sulphur, cloud albedo and climate

Robert J. Charlson , James E. Lovelock , Meinrat O. Andreae & Stephen G. Warren

* Department of Atmospheric Sciences AK-40, University of Washington, Seattle, Washington 98195, USA

† Coombe Mill Experimental Station, Launceston, Cornwall PL15 9RY, UK

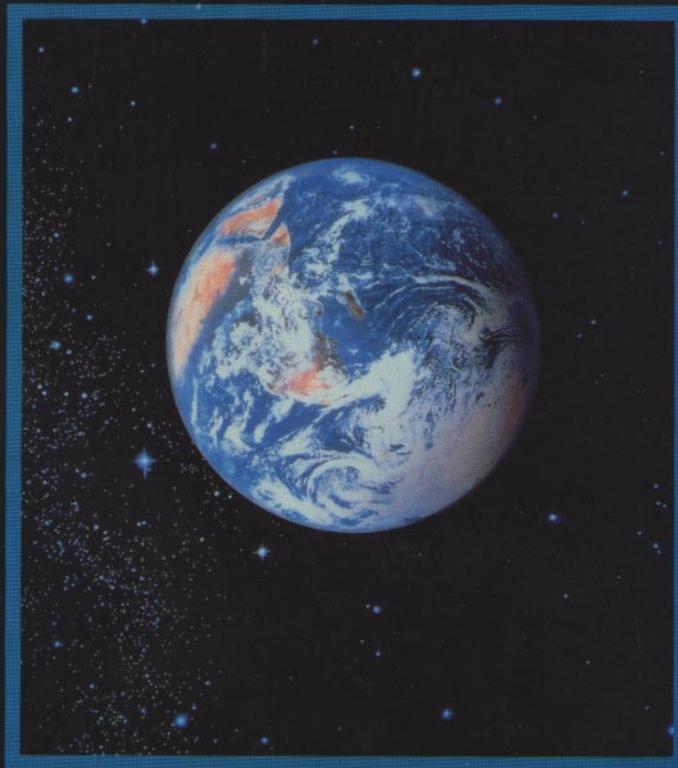
‡ Department of Oceanography, Florida State University, Tallahassee, Florida 32306, USA

The major source of cloud-condensation nuclei (CCN) over the oceans appears to be dimethylsulphide, which is produced by planktonic algae in sea water and oxidizes in the atmosphere to form a sulphate aerosol. Because the reflectance (albedo) of clouds (and thus the Earth's radiation budget) is sensitive to CCN density, biological regulation of the climate is possible through the effects of temperature and sunlight on phytoplankton population and dimethylsulphide production. To counteract the warming due to doubling of atmospheric CO₂, an approximate doubling of CCN would be needed.



GAIIA

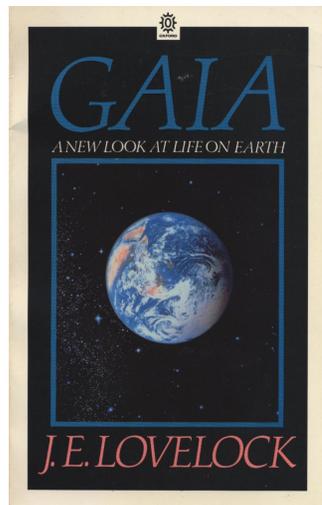
A NEW LOOK AT LIFE ON EARTH



J. E. LOVELOCK

INTERHEMISPHERIC CONTRASTS

- “ An interesting and unexpected feature of the troposphere . . . is a division into two parts, with the *line of separation near the equator*.
- “ Air from the north and south does not freely mix, as any observer traveling on a ship through tropical regions will readily perceive from the *difference in clarity of the skies between the clean southern and the relatively dirty northern hemispheres*.



- James Lovelock, *Gaia*, 1979

COMPARISON OF AEROSOL SULFATE CONCENTRATIONS IN NH AND SH

Table 2 Measured concentration of sulphate (or sulphur) aerosol at remote locations in the Northern and Southern Hemisphere

Location	Sulphate concentration* (ng S m ⁻³)	Comments
<u>Northern Hemisphere</u>		
<i><u>High-latitude sites</u></i>		
Alert, Mould Bay, Igloodik; Canadian Arctic (66–83° N)	(200–1,000) (20–70)	NSS SO ₄ ²⁻ ; 1-week samples; 3- to 4-year data record Winter–Spring Summer
Faeroe Islands (62° N)	1,100 (700–1,400) 140 (30–230)	NSS SO ₄ ²⁻ British trajectory (~1,000 km); 4 1-day samples Atlantic trajectory; 4 1-day samples
Velen, Sweden (58° N)	960 [1.4] 60 [2.2]	Sub-μm S; 1-day samples British trajectory (~1,000 km); 12 samples North Sea trajectory (Northwest air); 14 samples
<i><u>Atlantic and Caribbean</u></i>		
Western North Atlantic (33–38° N, 65–70° W)	800 ± 500	Sub-μm S; 26 8- to 68-hour samples
Bermuda (32° N)	530 [3.0]	Sub-μm S; 10 2- to 4-day samples
Bermuda	1,300 630 390 330 650 ± 230	Sub-2.5-μm NSS SO ₄ ²⁻ ; 39 1-day samples Northeast US trajectory (~1,200 km) Southeast US trajectory (~1,100–1,500 km) Caribbean trajectory Southeast trajectory All
Barbados (13° N, 60° W)	300 ± 190 120 ± 65 250 ± 180	NSS SO ₄ ²⁻ ; 1-day samples 'High dust'—Europe or Africa trajectory 'Low dust' All

cont'd

COMPARISON OF AEROSOL SULFATE CONCENTRATIONS IN NH AND SH (cont'd)

Pacific

Eastern Pacific Ocean off
Washington State (47-48° N)

Midway Island (28° N)

Oahu (21° N)

Guam (17° N)

Belau (7° N)

Fanning Island (4° N)

140 ± 60

80 ± 30

260 ± 90

100 ± 30

190 ± 260

160 ± 130

90 ± 80

120 ± 110

150 ± 240

210 ± 190

210 ± 50

Aircraft sampling, boundary layer; 3 flights; Pacific trajectories; May

Total NSS SO_4^{2-}

Sub-1.5- μm NSS SO_4^{2-}

NSS SO_4^{2-} ; 1-week samples; onshore flow only

'Dusty'; 29 samples

'Clean'; 27 samples

All; 56 samples

NSS SO_4^{2-} ; 1-week samples; onshore flow only

'Dusty'; 24 samples

'Clean'; 32 samples

All; 56 samples

NSS SO_4^{2-} ; 1-week samples; onshore flow only; 49 samples

NSS SO_4^{2-} ; 1-week samples; onshore flow only; 40 samples

NSS SO_4^{2-} ; 1-week samples; onshore flow only; 48 samples

Southern Hemisphere

Samoa (14° S)

Samoa

New Caledonia (22° S)

Norfolk Island (29° S)

Cape Grim, Tasmania (41° S)

Tasmania, off West Coast

Punta Arenas, Chile (54° S)

South Pole

60 [2.4]

130 ± 50

170 ± 130

110 ± 50

90 ± 20

(22-70)

52 [0.3]

83

11

76 ± 24

29 ± 10

Sub- μm S; 17 3- to 5-day samples

NSS SO_4^{2-} ; 42 1-week samples

NSS SO_4^{2-} ; 46 1-week samples

NSS SO_4^{2-} ; 41 1-week samples

NSS SO_4^{2-} ; multi-year data record under 'baseline' conditions

NSS SO_4^{2-} ; aircraft sampling, boundary layer; 8 flights; ocean trajectories; Austral summer

Austral summer; sub- μm S; 9 3- to 5-day samples

Austral summer; NSS S; 140 4-hour samples

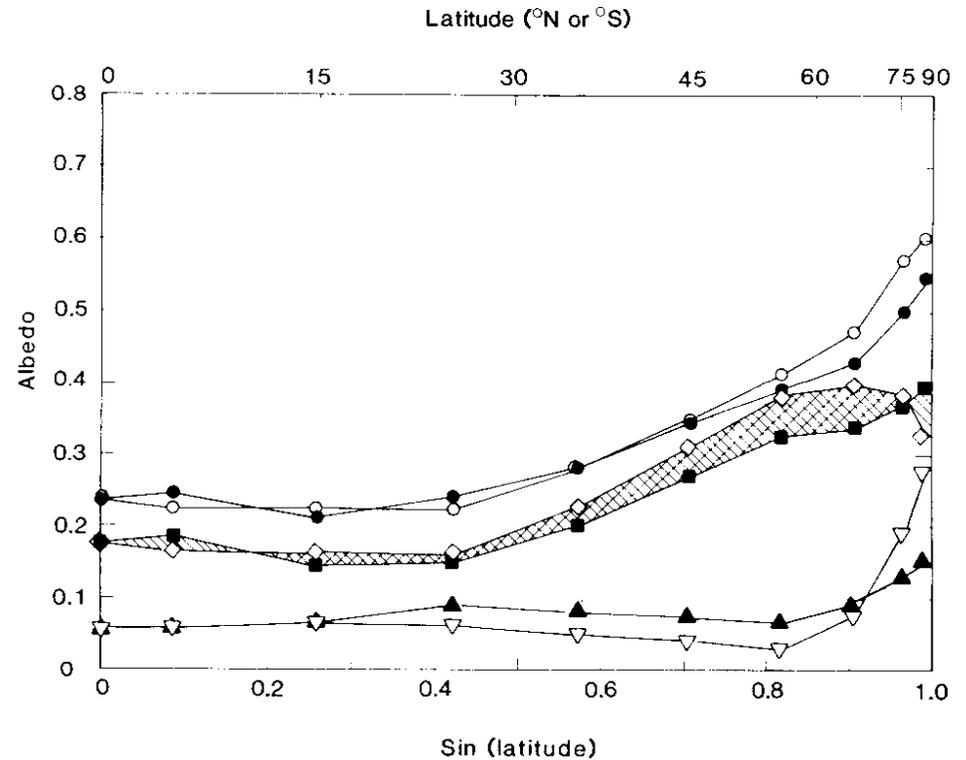
Austral winter; sub- μm S; 1 5-day sample

Austral summer; total S; sea salt small; 40 several-day samples

Austral winter; total S; sea salt 4-10%; 49 several-day samples

NO SIGNIFICANT INTERHEMISPHERIC DIFFERENCE IN CLOUD ALBEDO

Fig. 1 Average annual zonal mean over 10° latitude bands for Northern and Southern Hemispheres of total planetary albedo α_T and of cloud and clear-sky components, $F_C\alpha_C$ and $(1-F_C)\alpha_S$, respectively. The key is as follows: ●, total albedo (NH); ○, total albedo (SH); ■, Cloud component (NH); ◇, cloud component (SH); ▲, clear-sky component (NH); ▽, clear-sky component (SH). Single-hatching indicates that the NH cloud component exceeds the SH component; cross-hatching indicates the reverse. Equal distances on the lower abscissa correspond to equal areas on the Earth's surface.



Schwartz, *Nature*, 1988

Are global cloud albedo and climate controlled by marine phytoplankton?

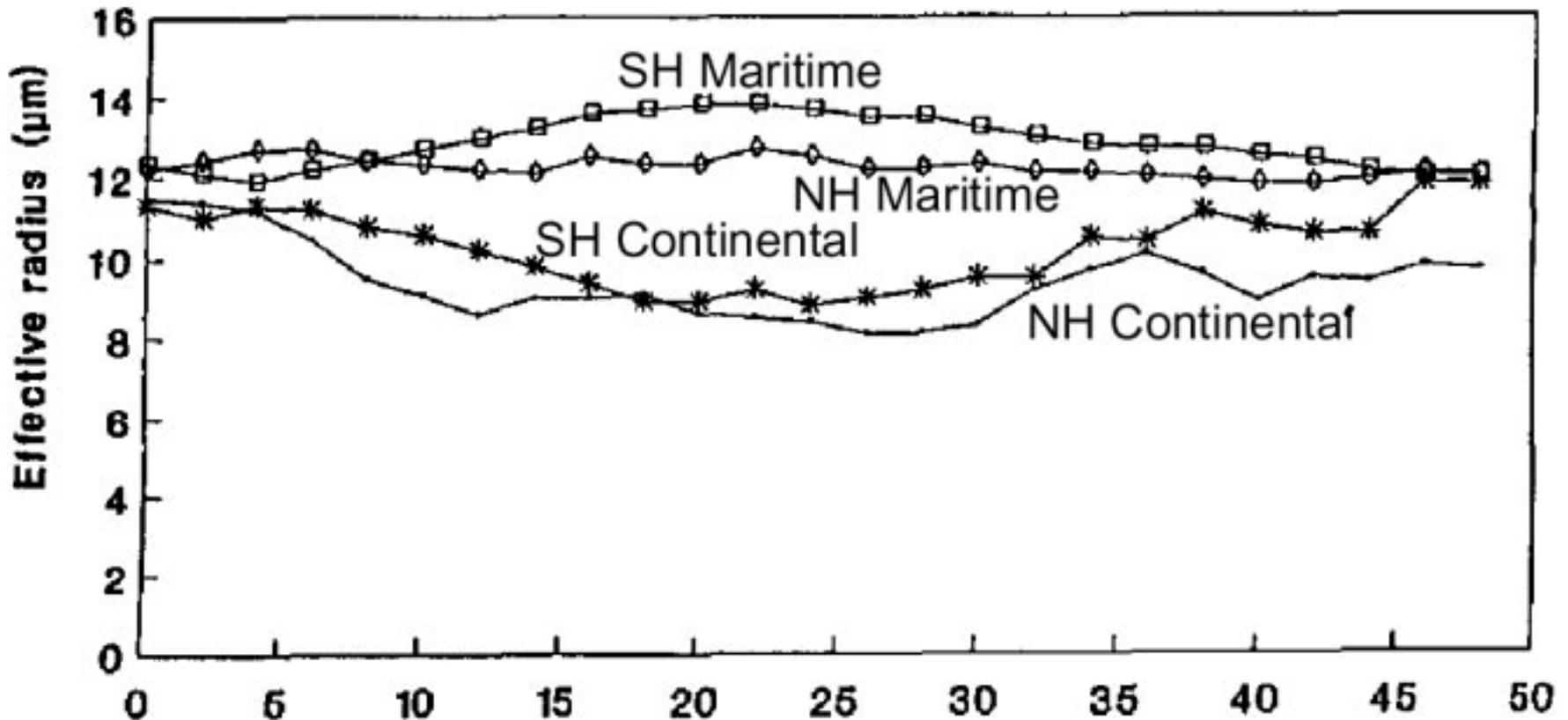
Stephen E. Schwartz

Environmental Chemistry Division, Brookhaven National Laboratory, Upton, New York 11973, USA

The recent suggestion that dimethylsulphide emissions by marine phytoplankton control global albedo and mean temperature would also imply a strong climatic influence of man-made SO₂. Anthropogenic SO₂ emissions exceed marine emissions of dimethylsulphide globally and are confined largely to the Northern Hemisphere. But no such influence of SO₂ emissions is found either in the present cloud component of planetary albedo or in 100-year temperature records.

EXAMINATION FOR INDIRECT EFFECT IN INTERHEMISPHERIC COMPARISONS

Zonal-mean cloud drop effective radius



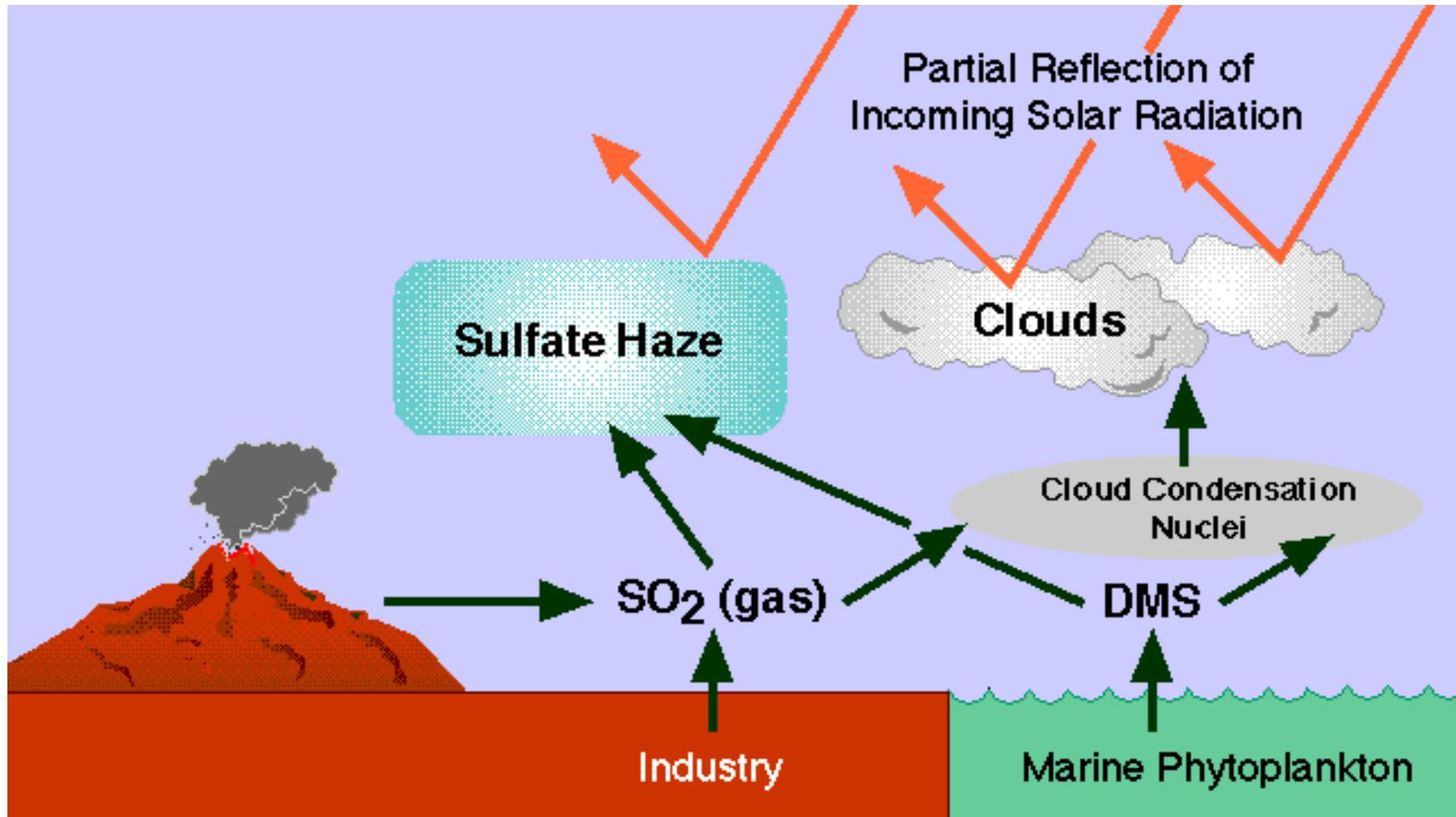
Han, Rossow, and Lacis, 1994

Smaller effective radius in NH would be indicative of greater cloud drop concentration due to industrial aerosol.

But there is no such indication in comparisons of cloud albedo.

THE “WHITEHOUSE EFFECT”

RADIATIVE FORCING OF CLIMATE CHANGE BY AEROSOLS



AEROSOL INFLUENCES ON RADIATION BUDGET AND CLIMATE

Direct Effect (Cloud-free sky)

Light scattering -- Cooling influence

Light absorption -- Warming influence, depending on surface

Indirect Effects (Aerosols influence cloud properties)

More droplets -- Brighter clouds (Twomey)

More droplets -- Enhanced cloud lifetime (Albrecht)

Semi-Direct Effect

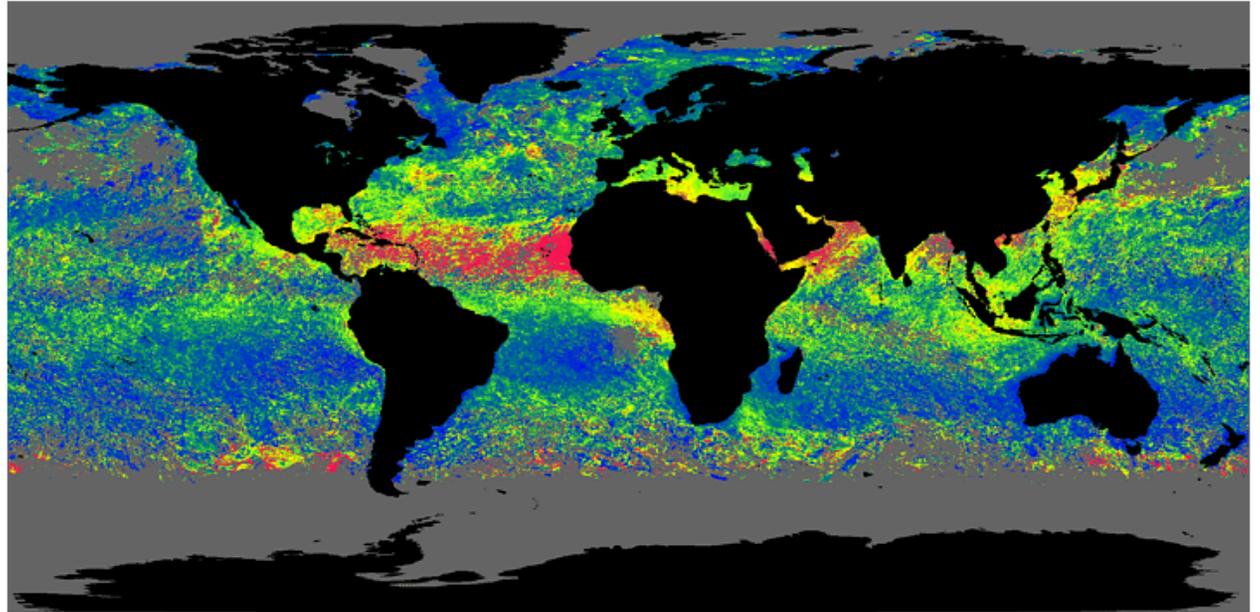
Absorbing aerosol heats air and evaporates clouds

MONTHLY AVERAGE AEROSOL JUNE 1997

Polder radiometer on Adeos satellite

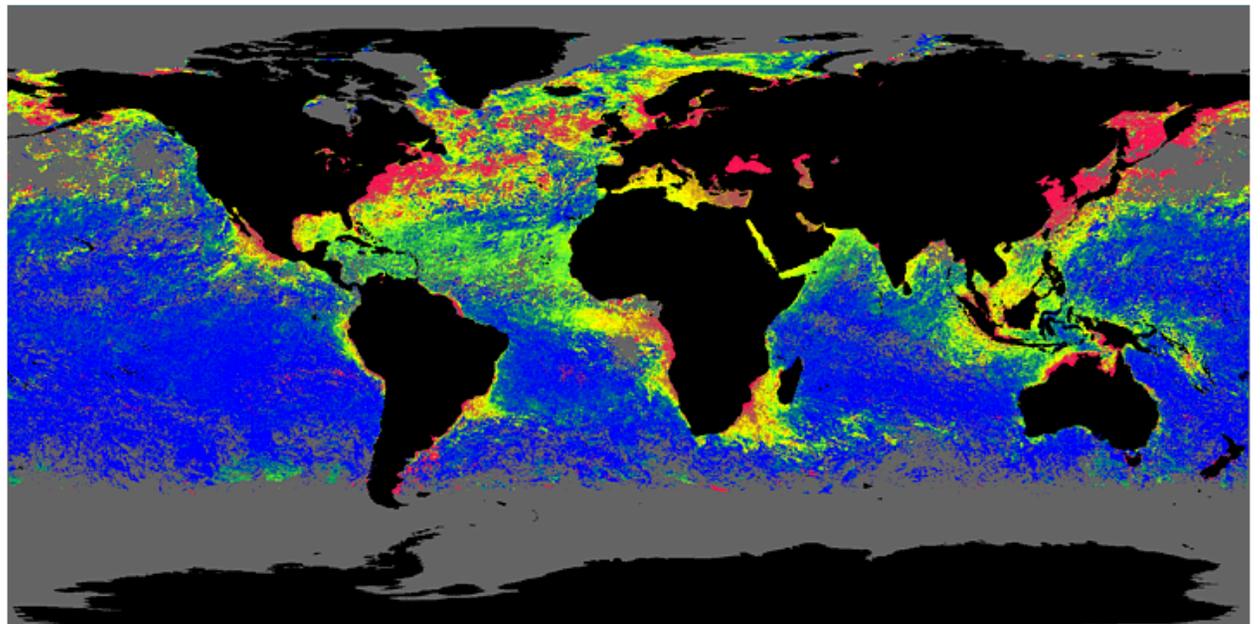
Optical Thickness τ

$\lambda = 865 \text{ nm}$



Ångström Exponent α

$\alpha = -d \ln \tau / d \ln \lambda$



SYDNEY, JULY 15, 2001



BRISBANE, JULY 2, 2001



TOWARD DAINTREE, JULY 5, 2001



TOWARD DAINTREE, JULY 5, 2001



OUT OF CAIRNS, JULY 6, 2001



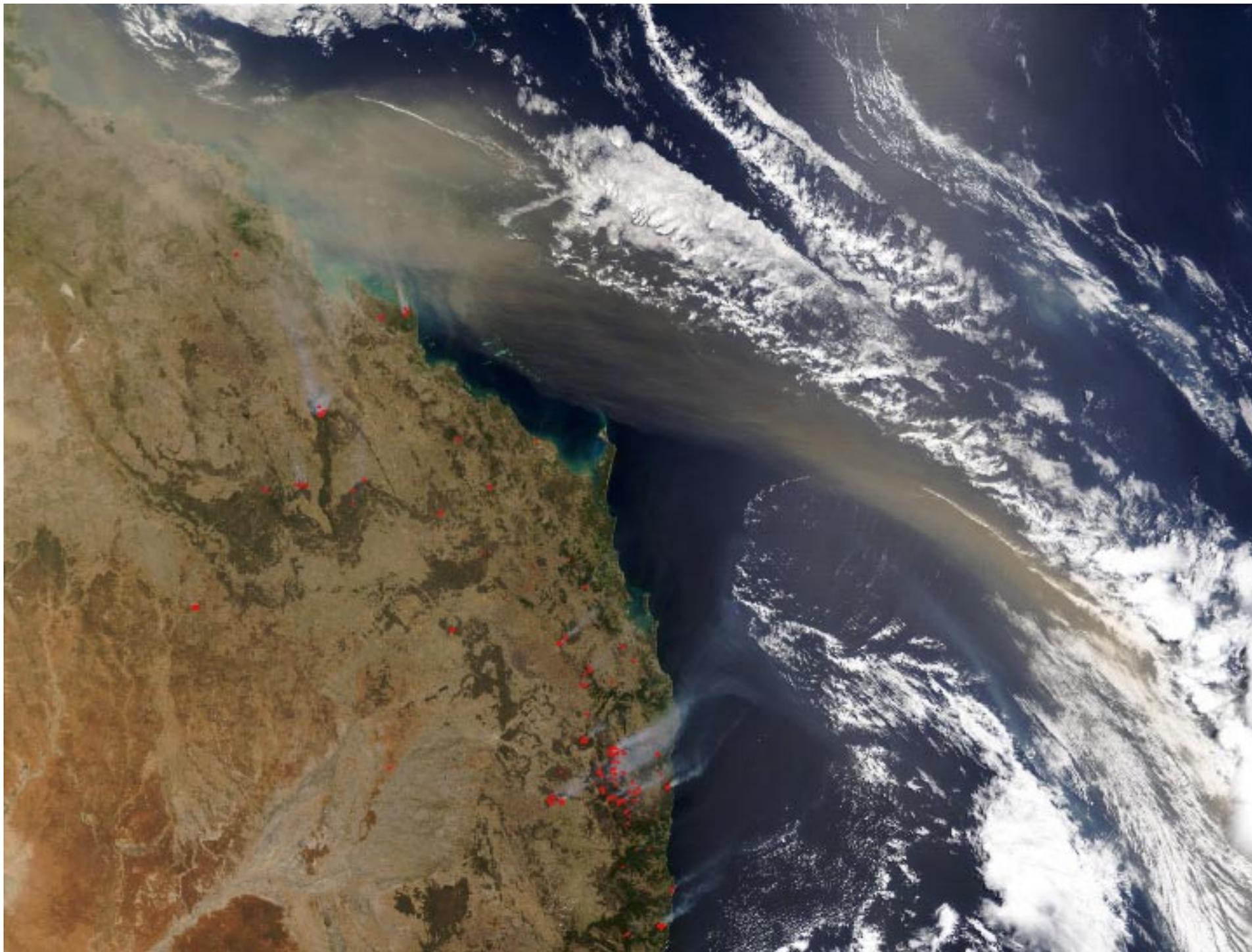
OUT OF SYDNEY, JULY 17, 2001



SOUTH PACIFIC, JULY 18, 2001



DUST AND SMOKE PLUMES OCTOBER 23, 2002



SUGAR CANE FIRE

Between Bundaberg and Bargara, September 25, 2003



John Maddocks

“HABOOB” TYPE DUST STORM, GRIFFITH, NSW



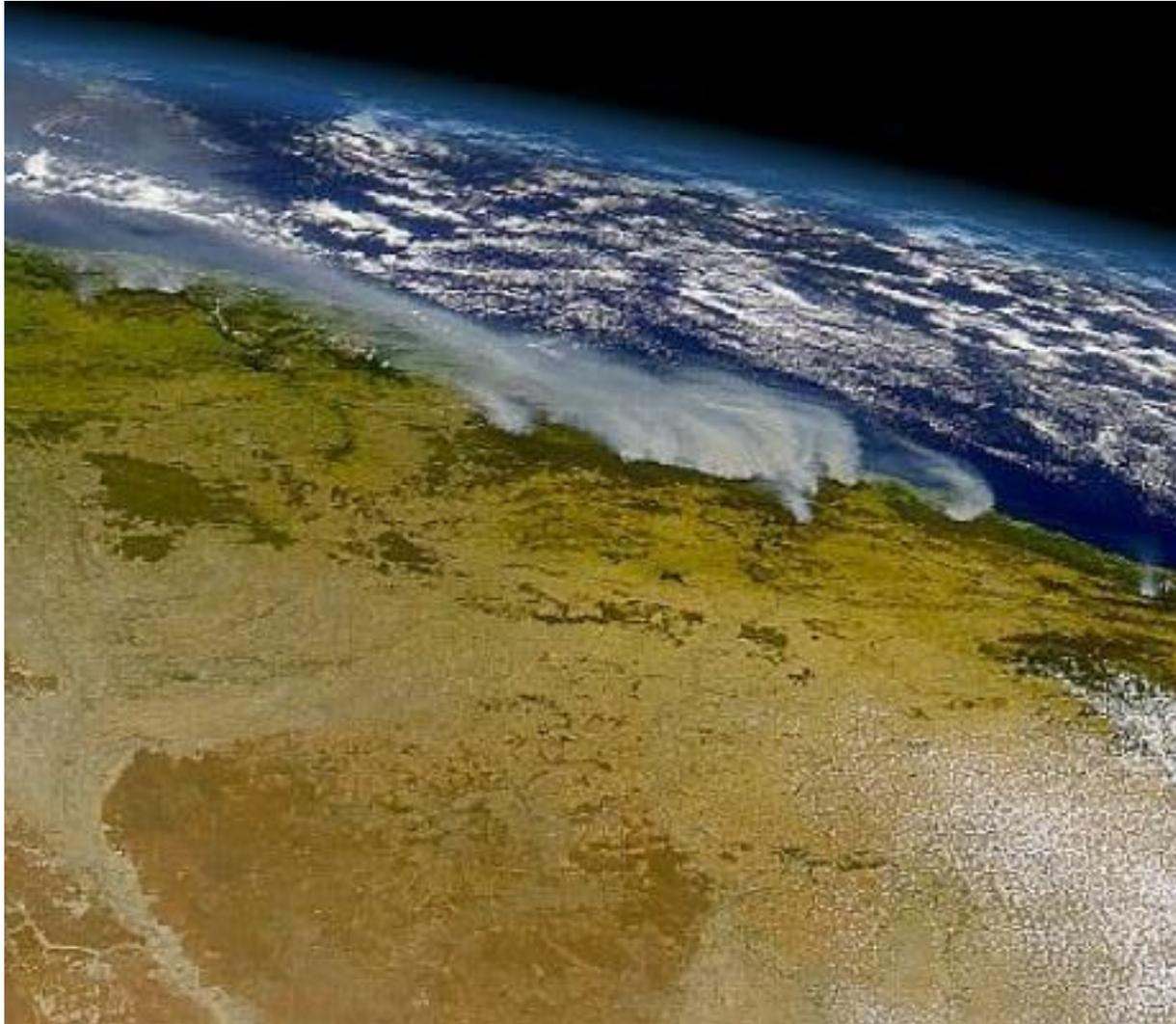
Mark Lewis <mklb@optusnet.com.au>

BUSHFIRE SMOKE PLUMES, JANUARY 16, 2003



NASA, MODIS, http://naturalhazards.nasa.gov/shownh.php3?img_id=5350

OBLIQUE ANGLE VIEW, LOOKING EASTWARD, JANUARY 23, 2003



NASA/GSFC ORBIMAGE SeaWiFS Project
Earth Science Picture of the Day Archive
<http://epod.usra.edu/archive/epodviewer.php3?oid=82016>

BUSHFIRE SMOKE OVER SYDNEY, DECEMBER 30, 2001



26-Degree forward-viewing camera



60-Degree forward-viewing camera

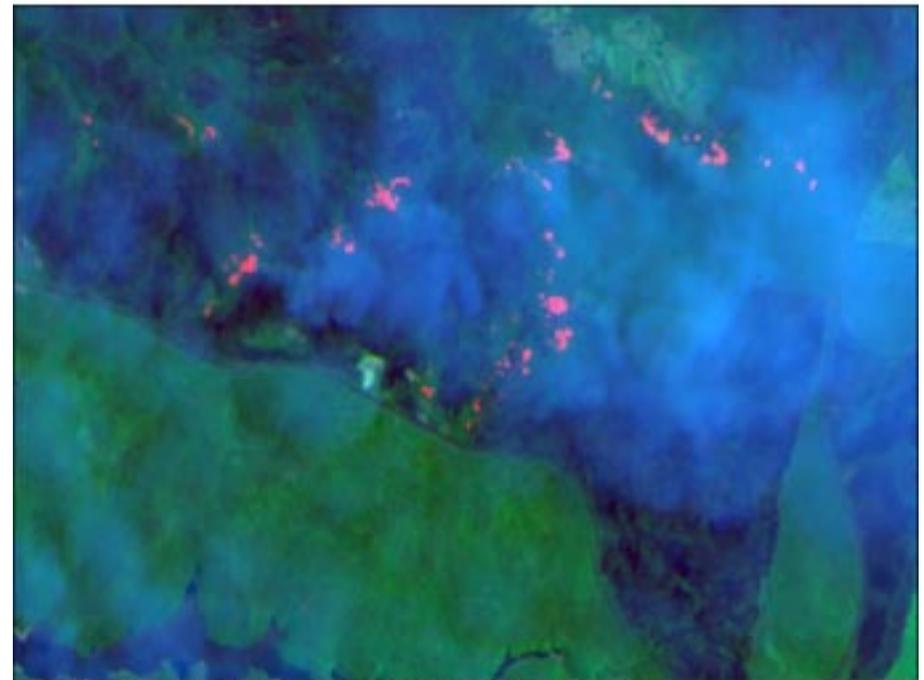
NASA/GSFC/LaRC/JPL, MISR Team

LOOKING THROUGH SMOKE IN THE INFRARED

December 28, 2001



true color (red=red, green=green, blue=blue)



false color (2.2 μm =red, 0.79 μm =green, 0.57 μm (green)=blue)

Advanced Land Imager (ALI), flying aboard
NASA's Earth Observing-1 (EO-1) satellite

[http://earthobservatory.nasa.gov/Newsroom/
NewImages/Images/ali_sydney_comparison.jpg](http://earthobservatory.nasa.gov/Newsroom/NewImages/Images/ali_sydney_comparison.jpg)

PRESCRIBED BURNS

Experimental fire in Australia's eucalypt forest



http://www.fire.uni-freiburg.de/iffn/country/au/au_6.htm

- Unburned forest is “unnatural.”
- Unburned forest, when it burns, burns hotter and smokier.
- Air quality issues: Prescribed burns are “air pollution.”

MIDLAND JUNCTION, WESTERN AUSTRALIA



<http://www.railpage.com.au/modules.php?name=Forums&file=viewtopic&t=11384>

HOW DARK IS BLACK CARBON?



KUWAIT OIL FIRES



http://www.kolchak.org/History/Desert%20Storm/photo_gallery_Gulf_War.htm

KUWAIT OIL FIRE PLUMES



Jay Apt

http://www.orbitexperience.com/Photo_Gallery/Earth_Photos/earth_photos.html

- Absorbing aerosol over bright surface increases solar absorption.

AEROSOL INFLUENCES ON CLOUD DROP SIZE

South Australia

August 12, 1997

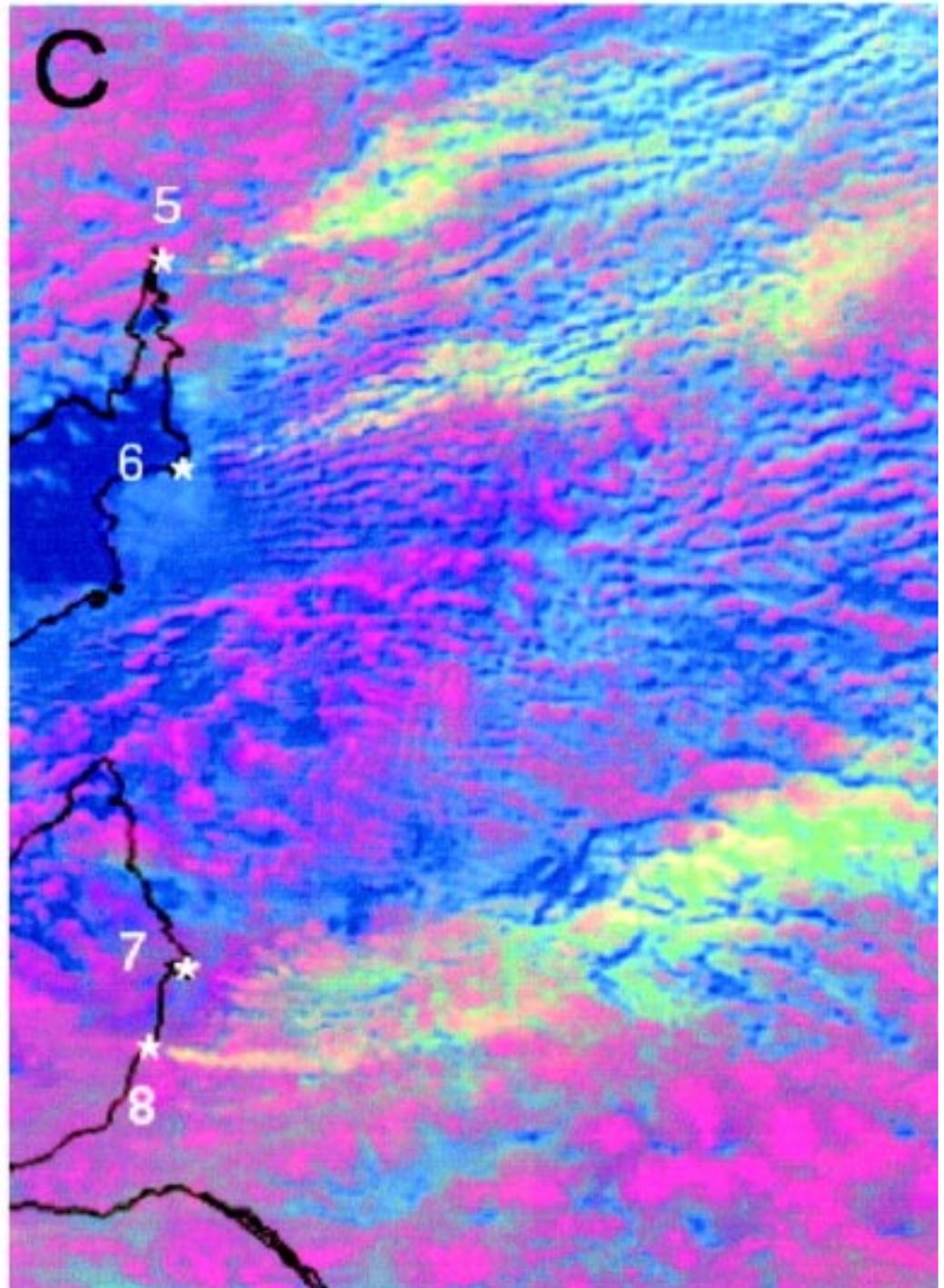
- 5 Port Augusta power plant
- 6 Port Pirie lead smelter
- 7 Adelaide Port
- 8 Oil refineries

Red	Clouds with large drops
Yellow	Clouds with small drops
Blue	Surface

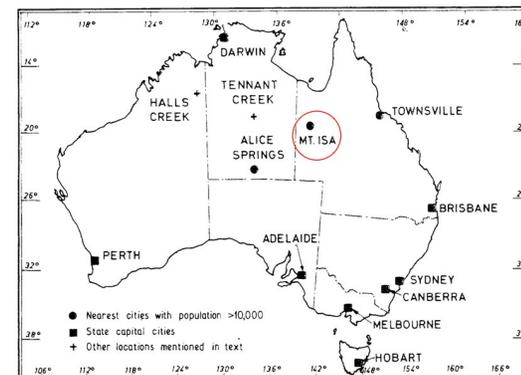
NOAA AVHRR image

(350 km by 450 km).

Rosenfeld, *Science* (2000).



LONG RANGE PLUME AND DEPOSITION STUDIES



Atmospheric Environment Vol. 15, No. 10/11, pp. 2255–2262, 1981
Printed in Great Britain.

0004-6981/81/102255-08 \$02.00/0
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THE OXIDATION AND LONG-RANGE TRANSPORT OF SULPHUR DIOXIDE IN A REMOTE REGION*

D. J. WILLIAMS, J. N. CARRAS, J. W. MILNE

CSIRO Division of Fossil Fuels, North Ryde, NSW, Australia

A. C. HEGGIE

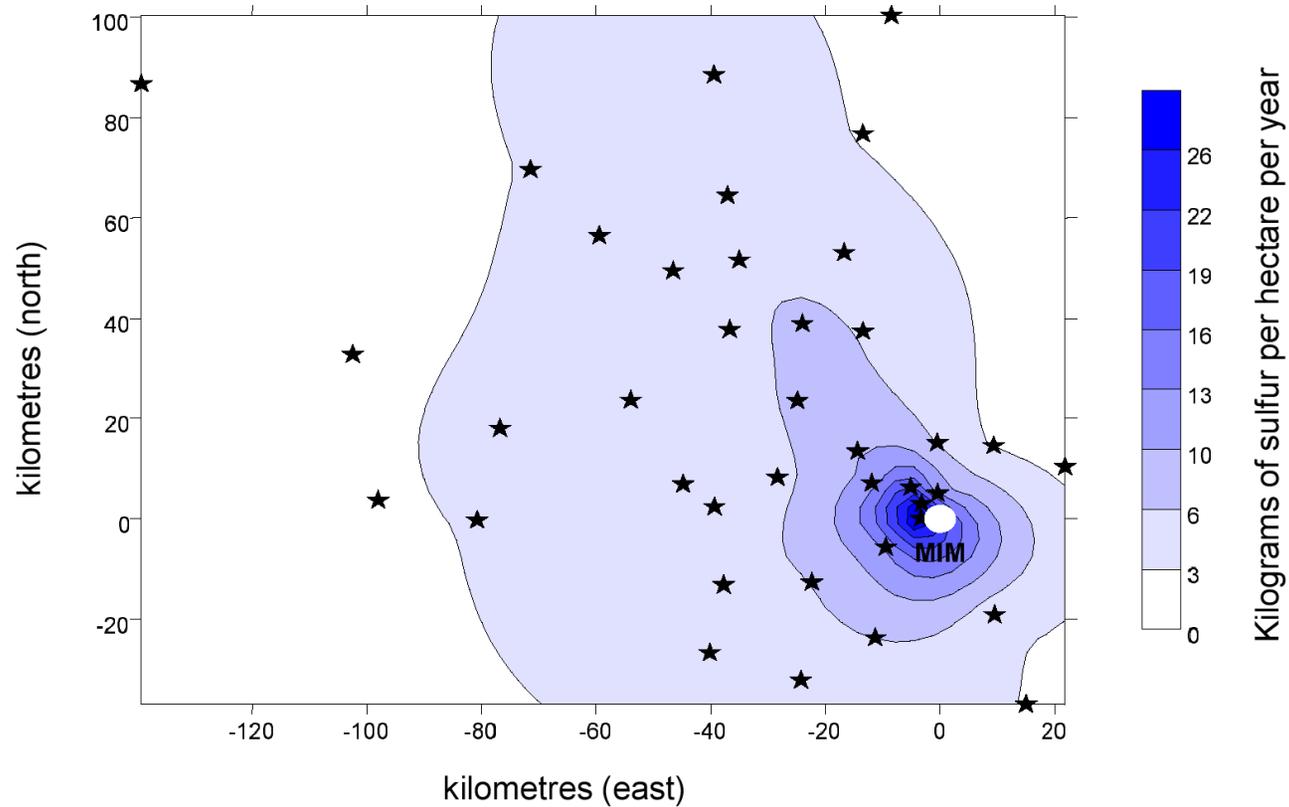
School of Earth Sciences, Macquarie University, North Ryde, NSW, Australia

Abstract—The flux of sulphur dioxide has been measured in the plume of a remotely situated smelter (Mount Isa, Australia) at distances of up to 1000 km from the source. These measurements were made with an airborne correlation spectrometer in plumes ranging in age from 1.0 to 42.5 h, the latter corresponding to a photolytic age of almost two periods of daylight. Ground-based experiments were also performed to determine the rate of dry deposition of sulphur dioxide in the area situated about 500 km from the source.

The implications of an error in the deposition velocities, reported by Milne J. W., Roberts D. B. and Williams D. J. (*Atmos. Envir.* **13**, 373–380, 1979.), are considered. The average velocity for the Mount Isa region is higher than that previously employed by Roberts D. B and Williams D. J. (*Atmos. Envir.* **13**, 1485–1489, 1979). Along with a reassessment of the diurnal model and the average mixing height encountered by Roberts and Williams, this necessitates a reduction in the estimate of the photochemical oxidation rate of sulphur dioxide from 0.25 to 0.15% h⁻¹, when averaged over 24 h.

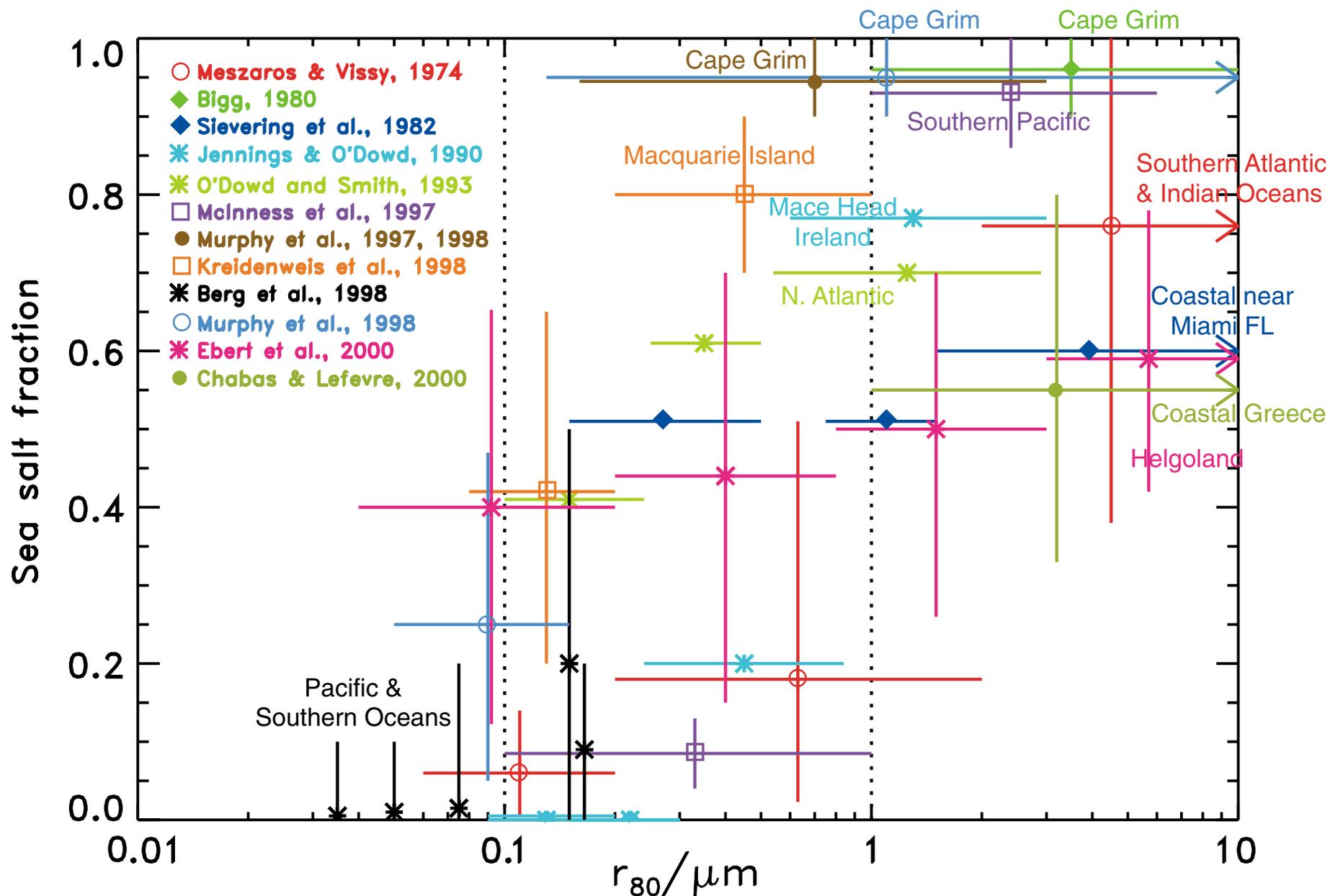
LONG RANGE PLUME AND DEPOSITION STUDIES

Map of estimated total acid deposition around Mount Isa resulting from the emissions from the smelters in 1997 – 98 (in kilograms of sulfur per hectare per year)

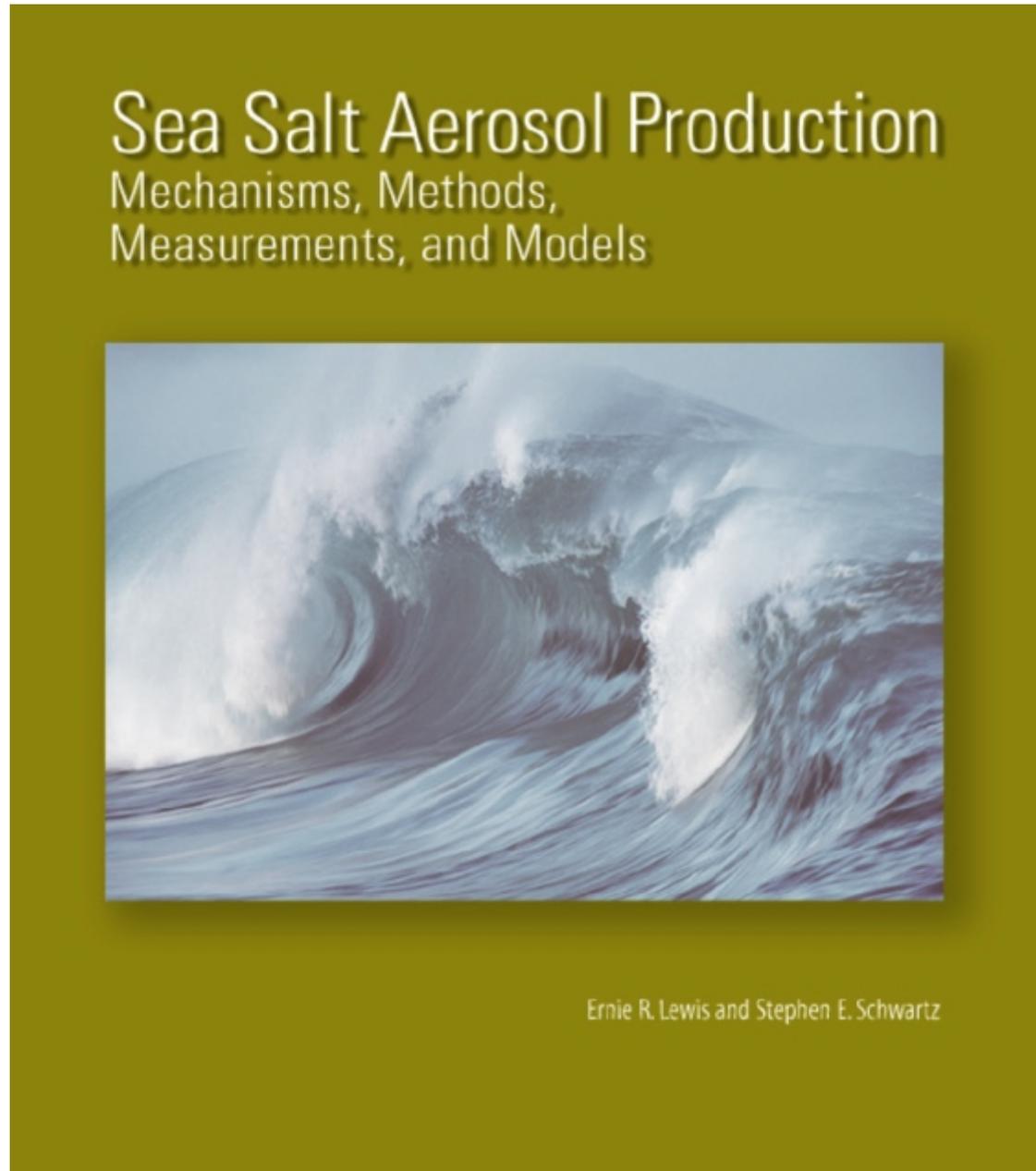


SEA SALT FRACTION OF MARINE AEROSOL, BY NUMBER

Dependence on radius at relative humidity 80%, r_{80}



*The second
book to buy
if you're
buying only
two*



AGU Monograph Series, 2004

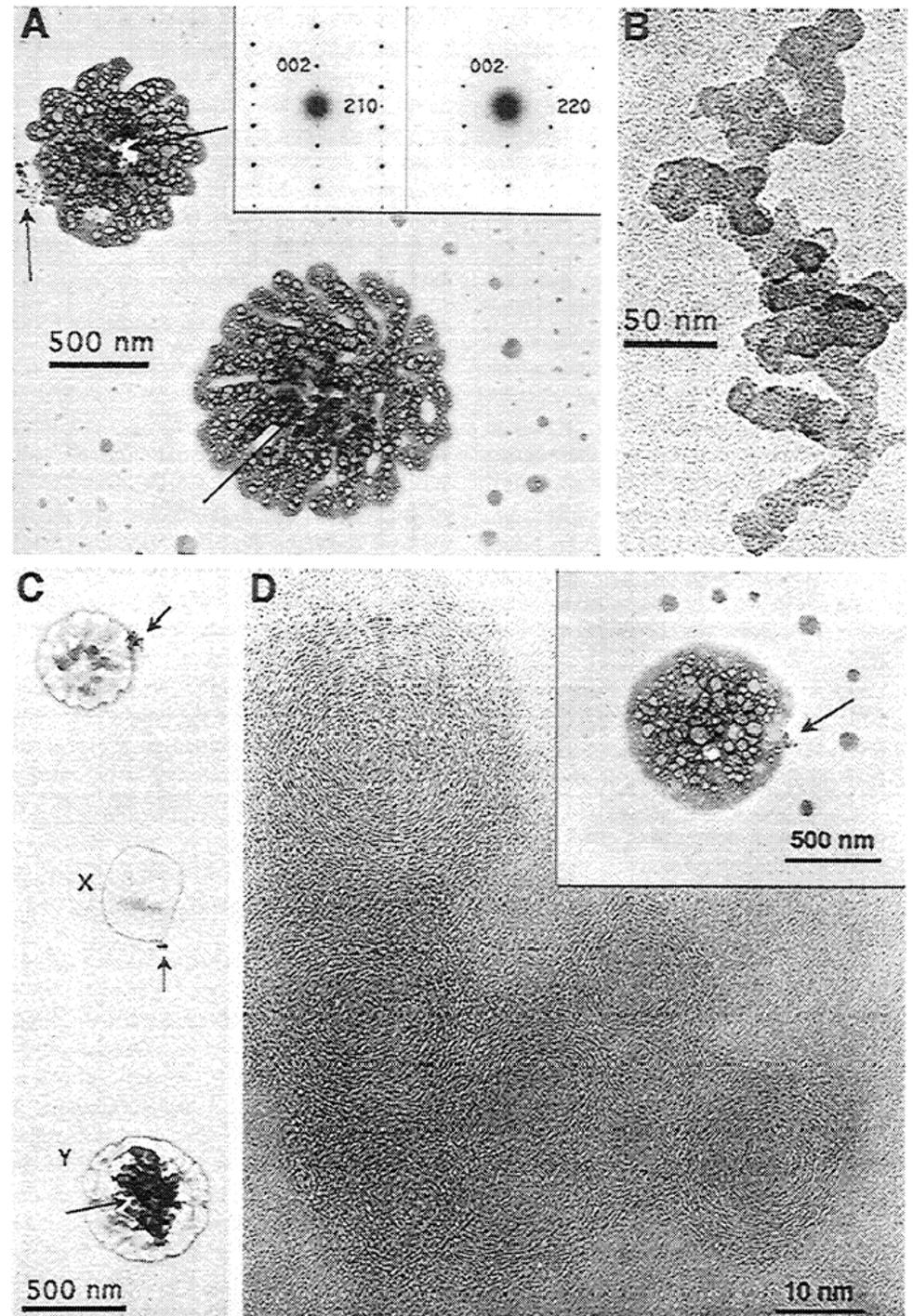
<https://www.agu.org/cgi-bin/agubookstore?book=ASGM1524173>

SOOT IN THE CLEANHOUSE

ACE - 1

Southern Ocean
South of Tasmania

Soot inclusions in submicrometer sulfate aerosols



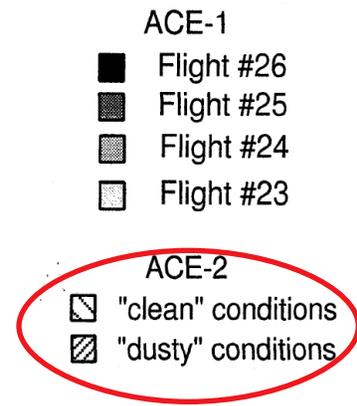
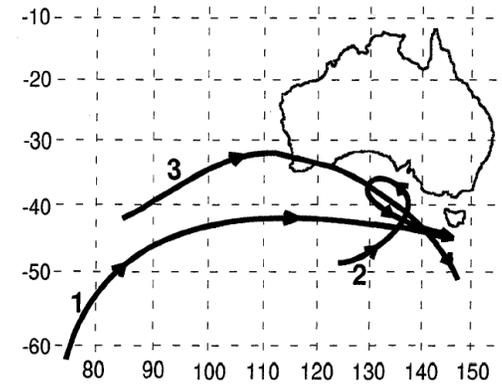
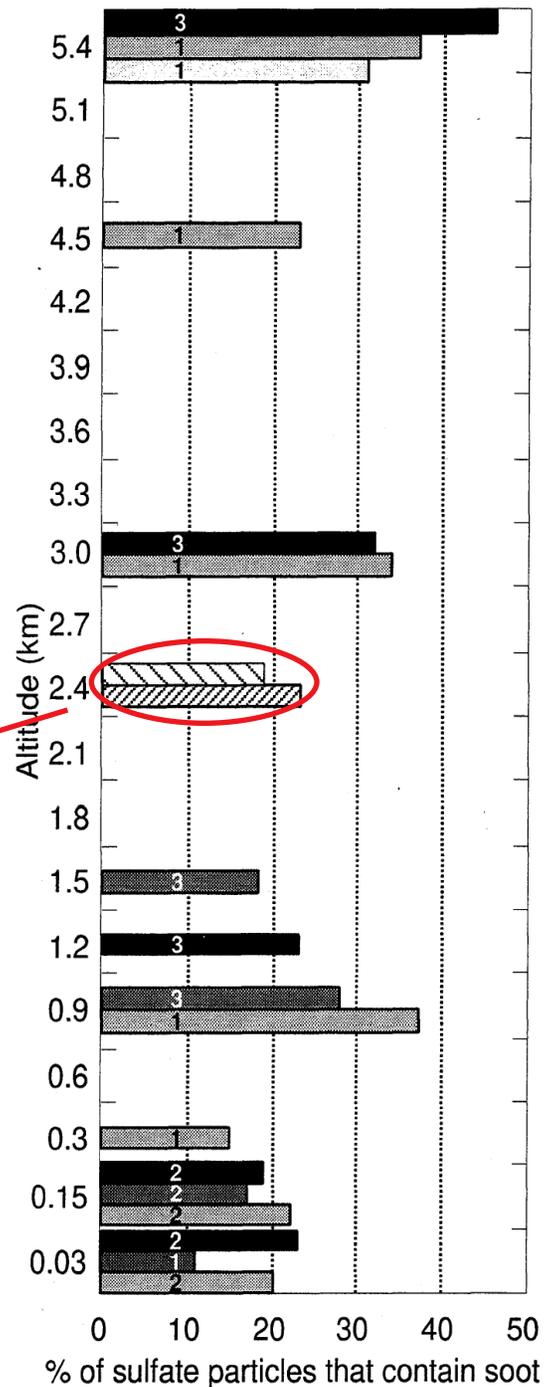
SOOT IN THE CLEANHOUSE

ACE - 1

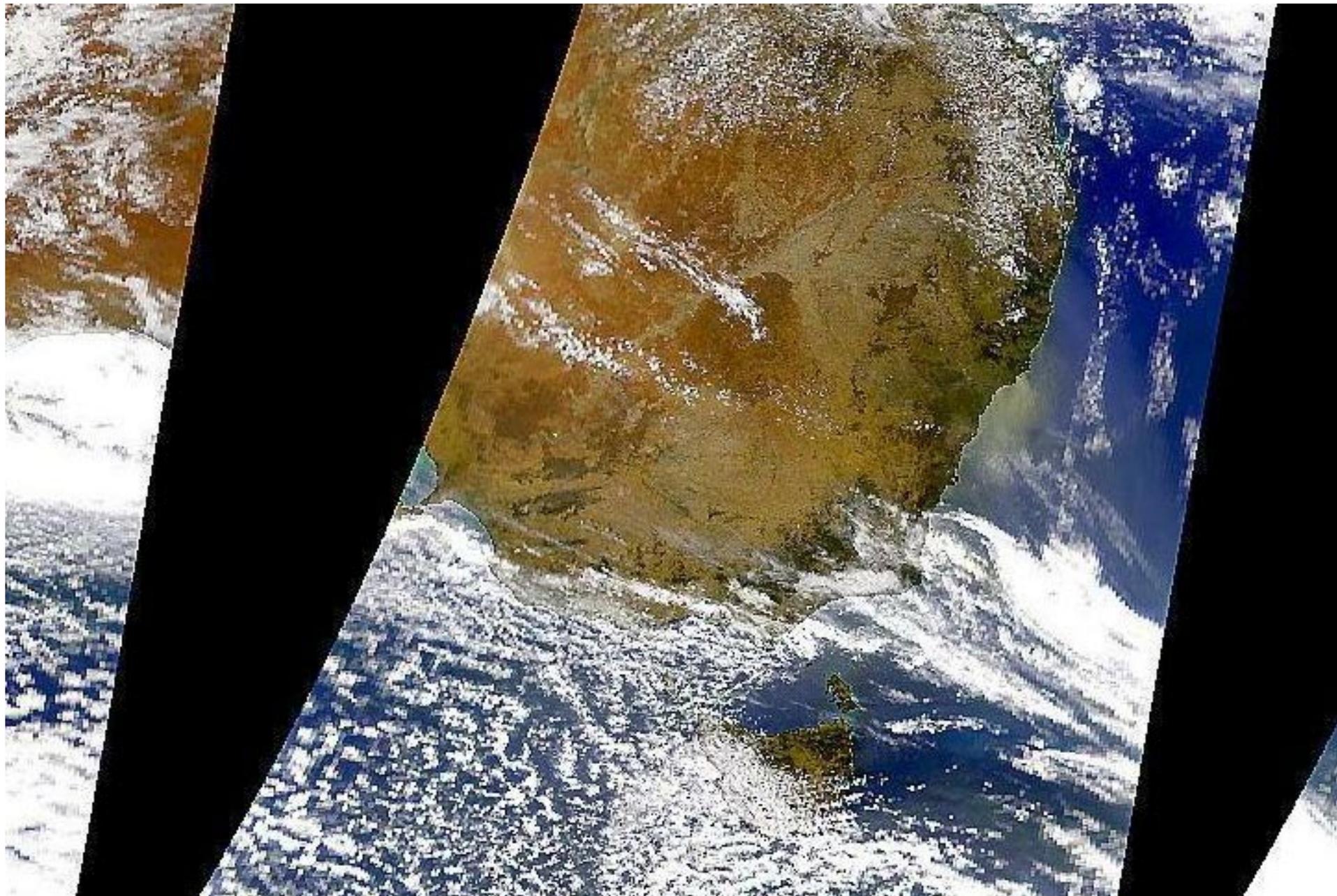
Southern Ocean
South of Tasmania

A substantial fraction of sulfate particles contain soot inclusions.

Comparable to or exceeding North Atlantic.



AUSTRALIAN BROWN CLOUD, DECEMBER 22, 2002

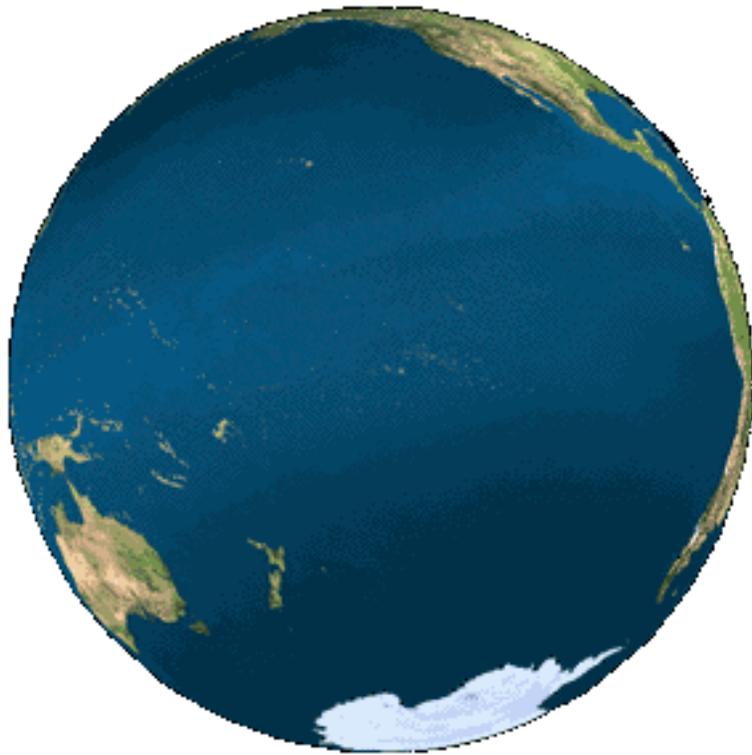


http://www.nrlmry.navy.mil/aerosol/satellite/seawifs/australia/200212/2002122200_australia.jpg

FINAL THOUGHTS ABOUT THE CLEANHOUSE

- Down Under is a wonderful testbed for examining *aerosol chemistry, microphysics, and life cycle*.
- Much better approximation to *anthropogenically unperturbed aerosol* than anywhere in the Northern Hemisphere.
- Relative paucity of anthropogenic sources permits study of *aerosol evolution without confounding influences*.
- Opportunity to *unambiguously attribute* long-range-transported aerosol to source regions.
- Opportunity to study *sea salt* with minimal interference from anthropogenic aerosol.
- *Large contrasts* between anthropogenically influenced vs. uninfluenced situations . . .
- . . . Especially valuable for examining *aerosol influences on cloud microphysical properties, radiative properties, lifetime against drizzle formation*.

AEROSOLS DOWN UNDER A YANK LOOKS AT THE CLEANHOUSE



*Thank
You*

<http://www.ecd.bnl.gov/steve/schwartz.html>

