

Air Pollution Knows No Boundaries

Defining Air Catchment Areas & Making Sense of Physical and Political Boundaries in Air Quality Management

Greg Scott¹, Harold Annegarn² and Melanie Kneen²



¹ CSIR Environmentek, Durban

² Dept Geography, Environmental Management and Energy Studies

University of Johannesburg

han@rau.ac.za

IQPC Conference on Implementing the Air Quality Act
The Castle, Kyalami, 24 and 25 October 2005

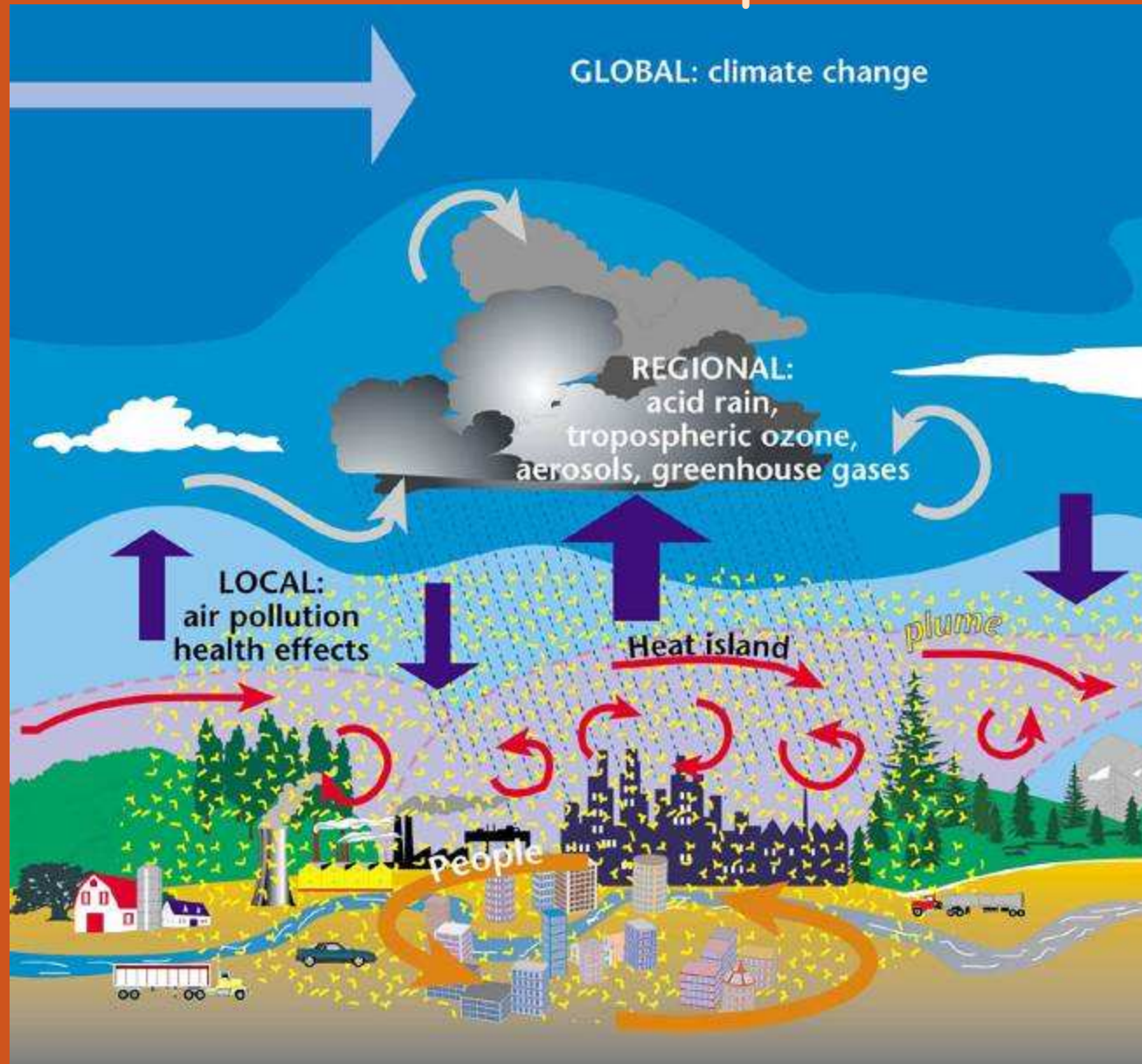
A paradox
and the task of this presentation:

How to impose boundaries on
air pollution which recognises
no boundaries?

Topics for discussion

1. Scales of transport and turbulence in the atmosphere
2. Examples of global, regional and local scale transports - concepts of an "air catchment"
3. Defining air quality management zones - international practice
4. Defining air quality management zones - local constitutional and legal constraints
5. Practical issues - defining AQ management districts in South Africa - three case studies

Scales of transport and turbulence in the atmosphere



Smoke transport

Coast of Mozambique
- Zambezi River delta,
Smoke from veldt
fires blowing in on-
shore winds.

Handheld photograph taken
from an early Space Shuttle



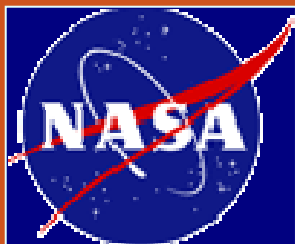
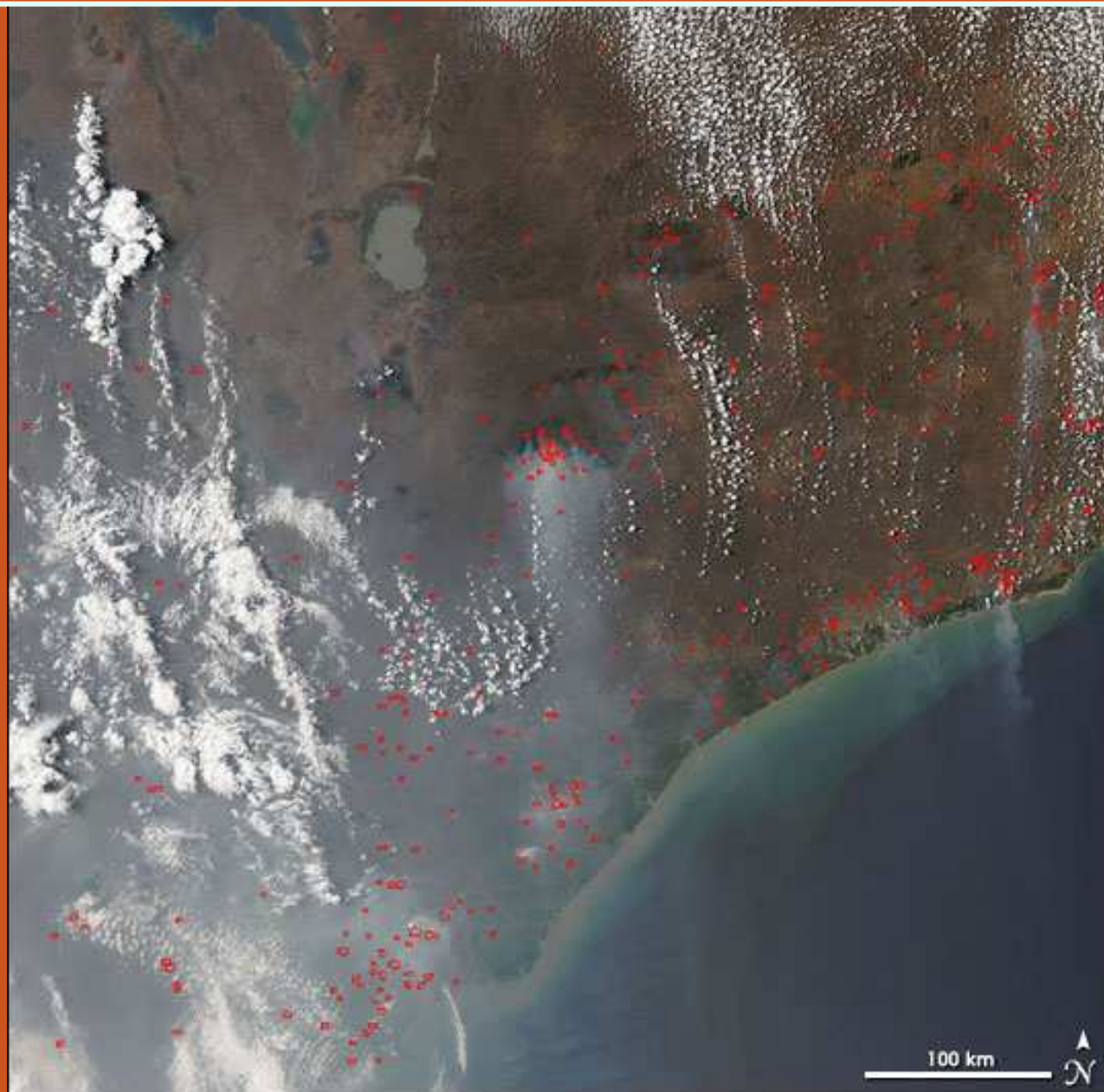
2005 11 25

Scott, Annegarn and Kneen

Fires and smoke over central Mozambique

28 Sep 2005

Courtesy NASA, MODIS

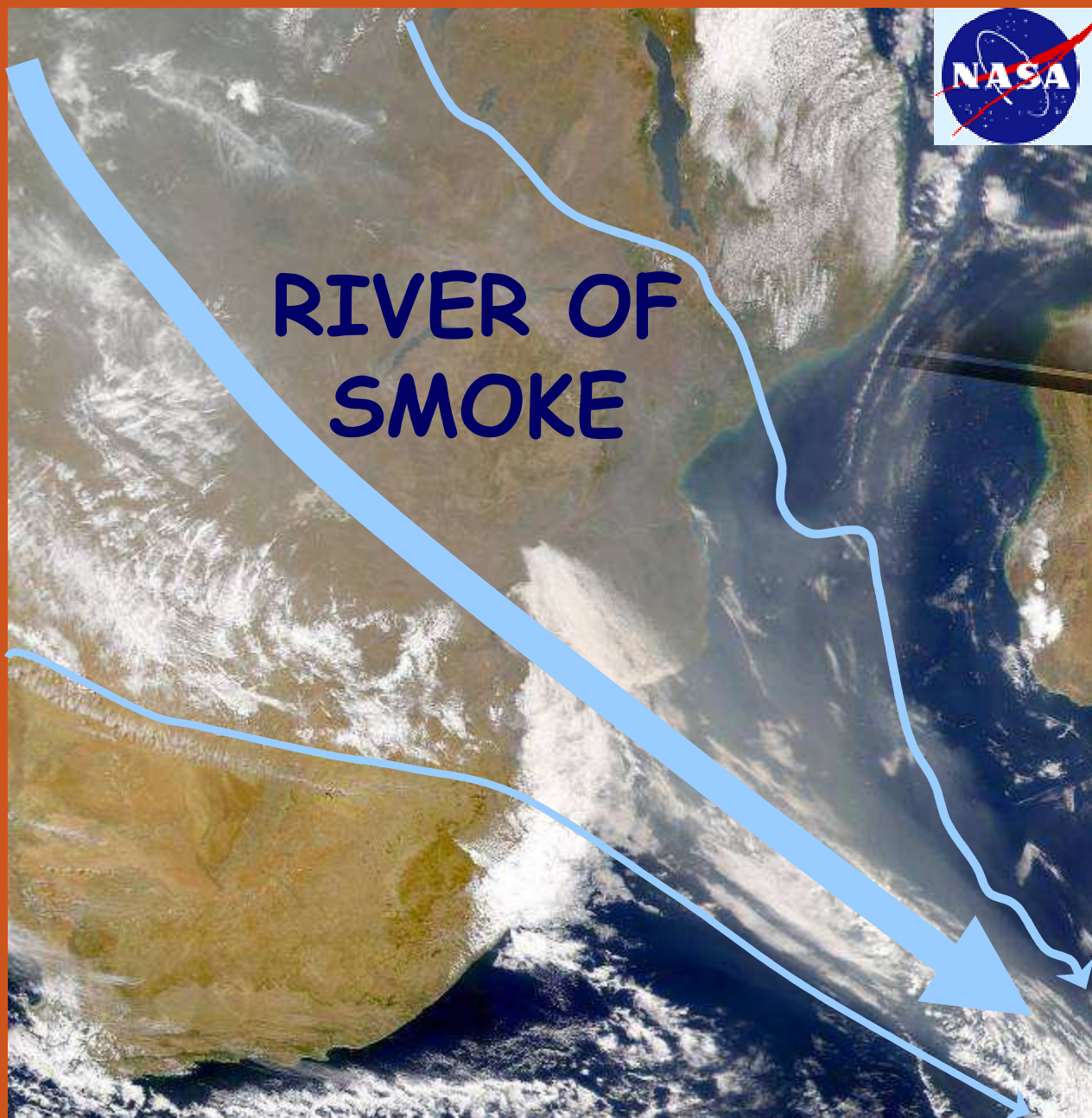


2005 11 25

Effects of regional veld fires (tropical regions of Zambia and Angola) on air quality over South Africa.

Smoke and haze exiting off east coast September 4 2000

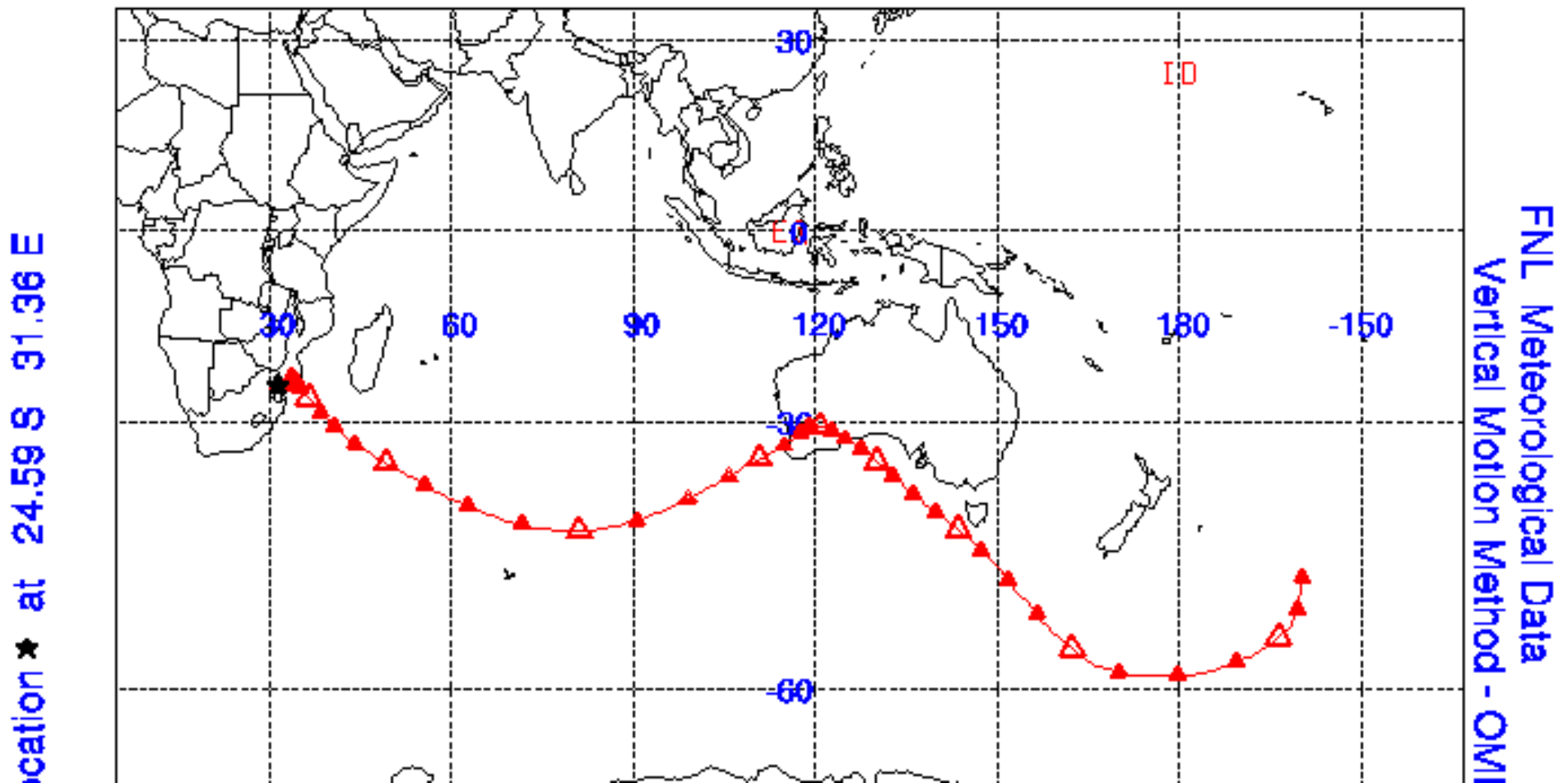
Provided by the SeaWiFS Project, NASA/Goddard Space Flight Center, and ORBIMAGE
Satellite: OrbView-2 Sensor: SeaWiFS
Image Date: 09-04-2000
Image captured by CSIR Satellite Application Centre



Inter-continental pollution transport routes

8-day transport originating in Kruger National Park, 8 Sep 2000

Forward Trajectory Starting- 12 UTC 08 SEP 00

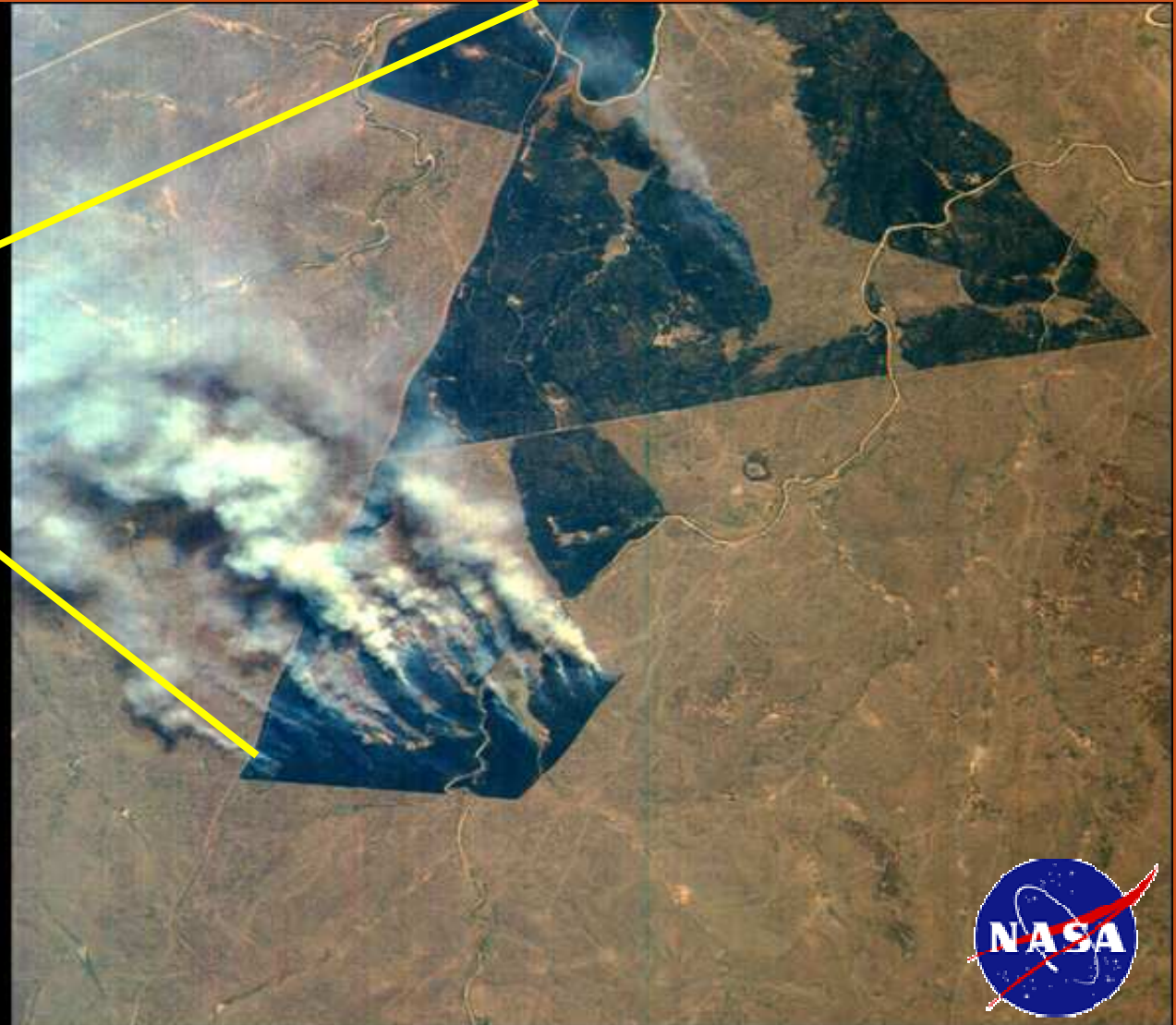


ACTIVE FIRES AND FIRE SCAR DETECTION

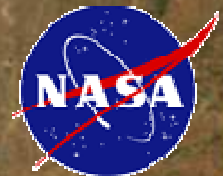
Comparison of MISR (700 km) & Air MISR (20 km altitude)
Timbavati Prescribed Fire, 20 Sep 2000



MISR



AirMISR



Coal burning for cooking and warming

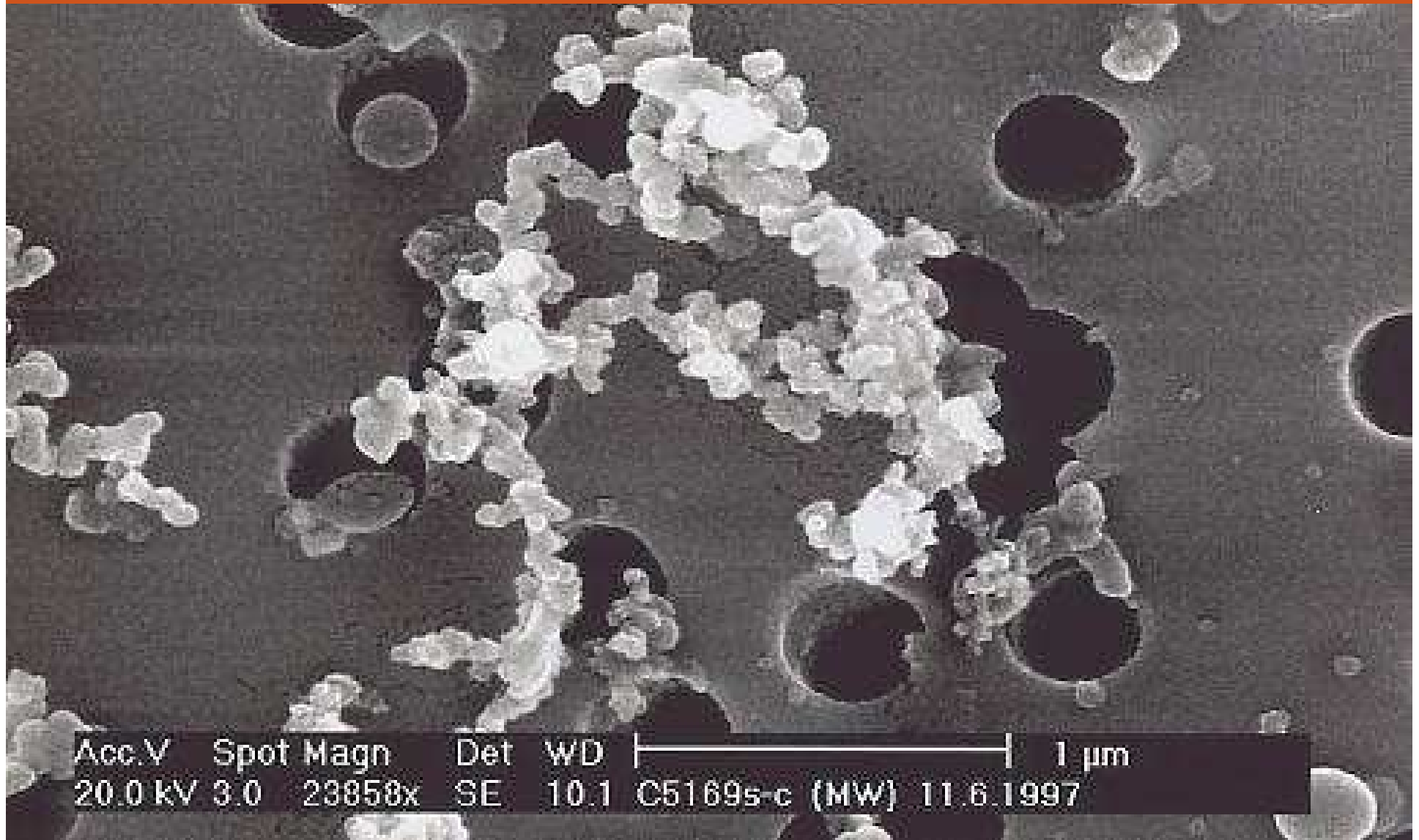


What is the nature of the white smoke?

2005 11 25

Scott, Annegarn and Kneen

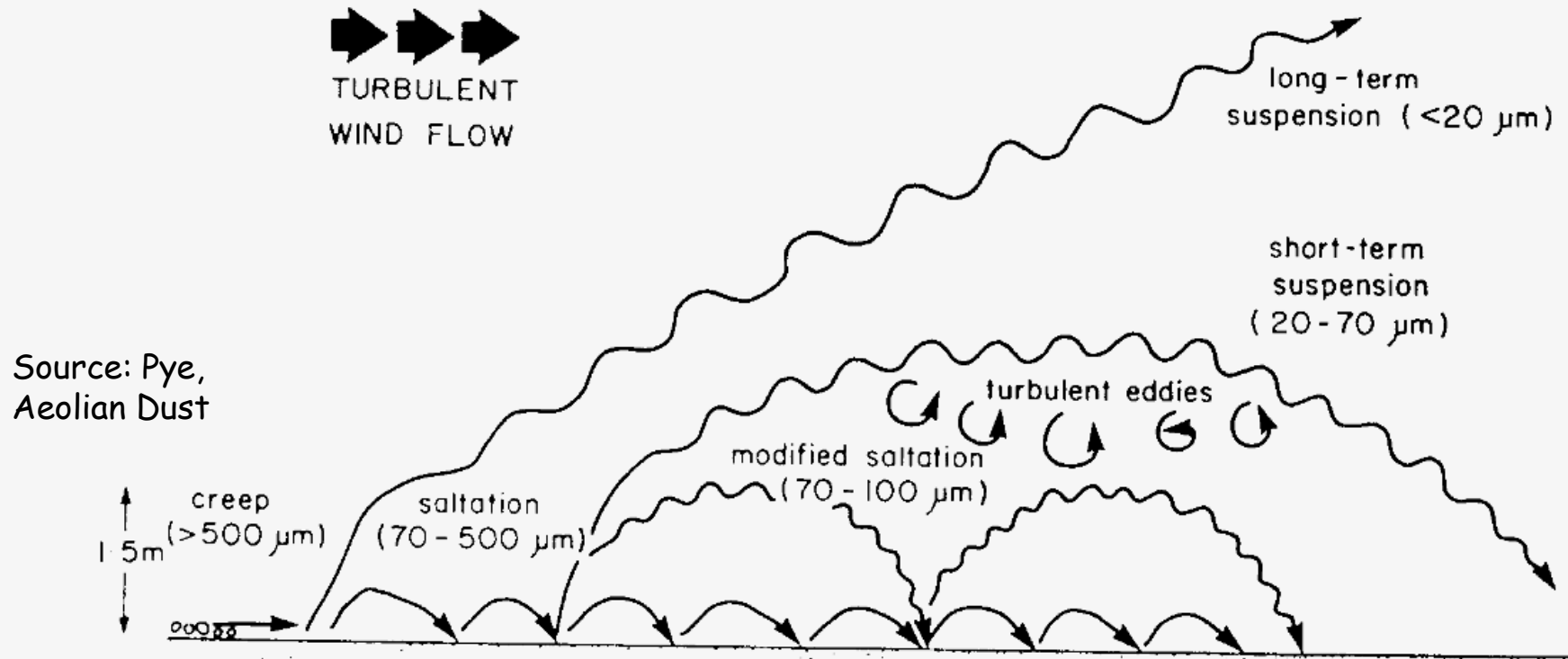
Typical combustion aerosol from low temperature coal burning - condensed VOCs



Dust generation and transport

DUST ENTRAINMENT, TRANSPORT AND DEPOSITION

49



Modes of transport by wind
- moderate windstorm

turbulence factor $\varepsilon = 10^4 \rightarrow 10^5 \text{ cm}^2 \cdot \text{s}^{-1}$

SALTATION

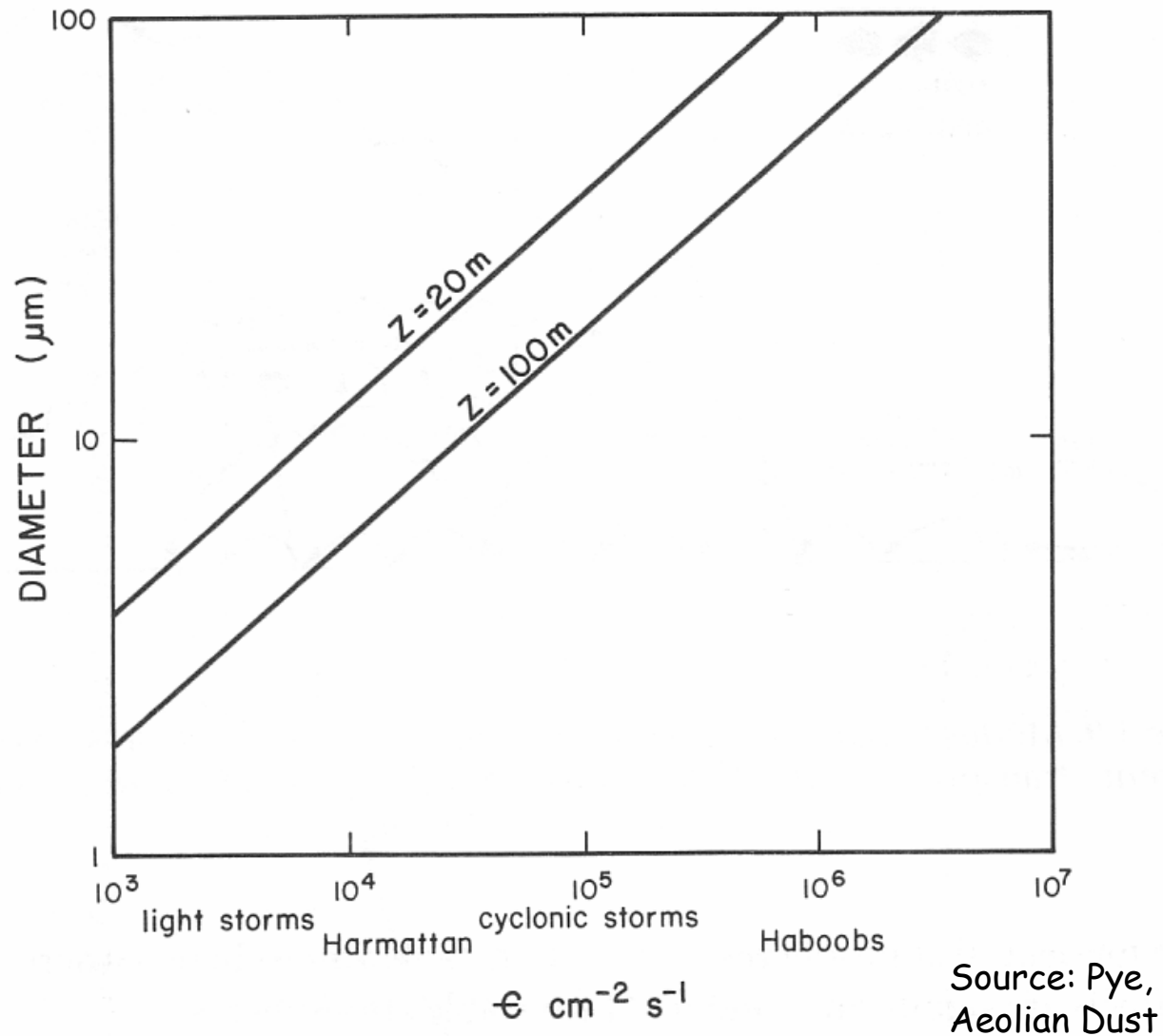


Figure 3.10. The approximate coefficient of turbulent exchange (ϵ) needed to carry a quartz sphere to heights of 20 and 100 m under neutral atmosphere conditions. (After Tsoar and Pye (1987), *Sedimentology* 34, Fig. 2; © International Association of Sedimentologists.)

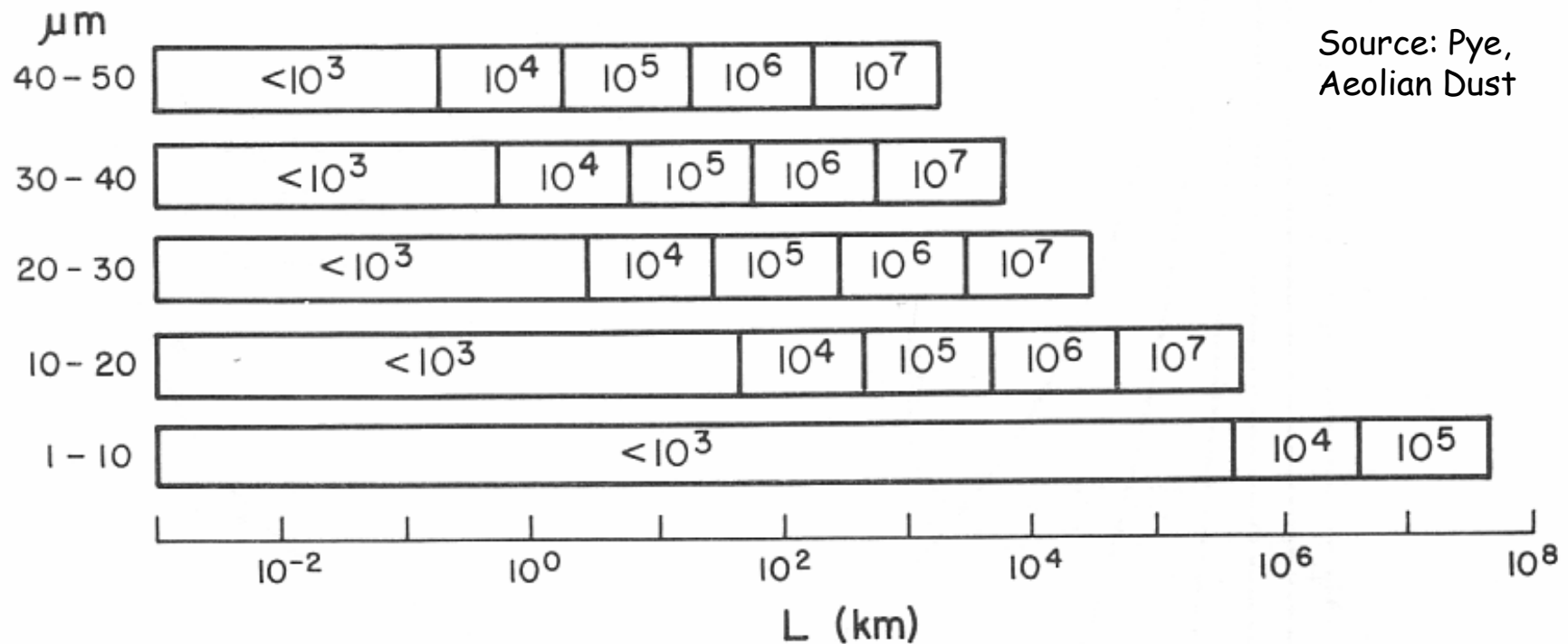
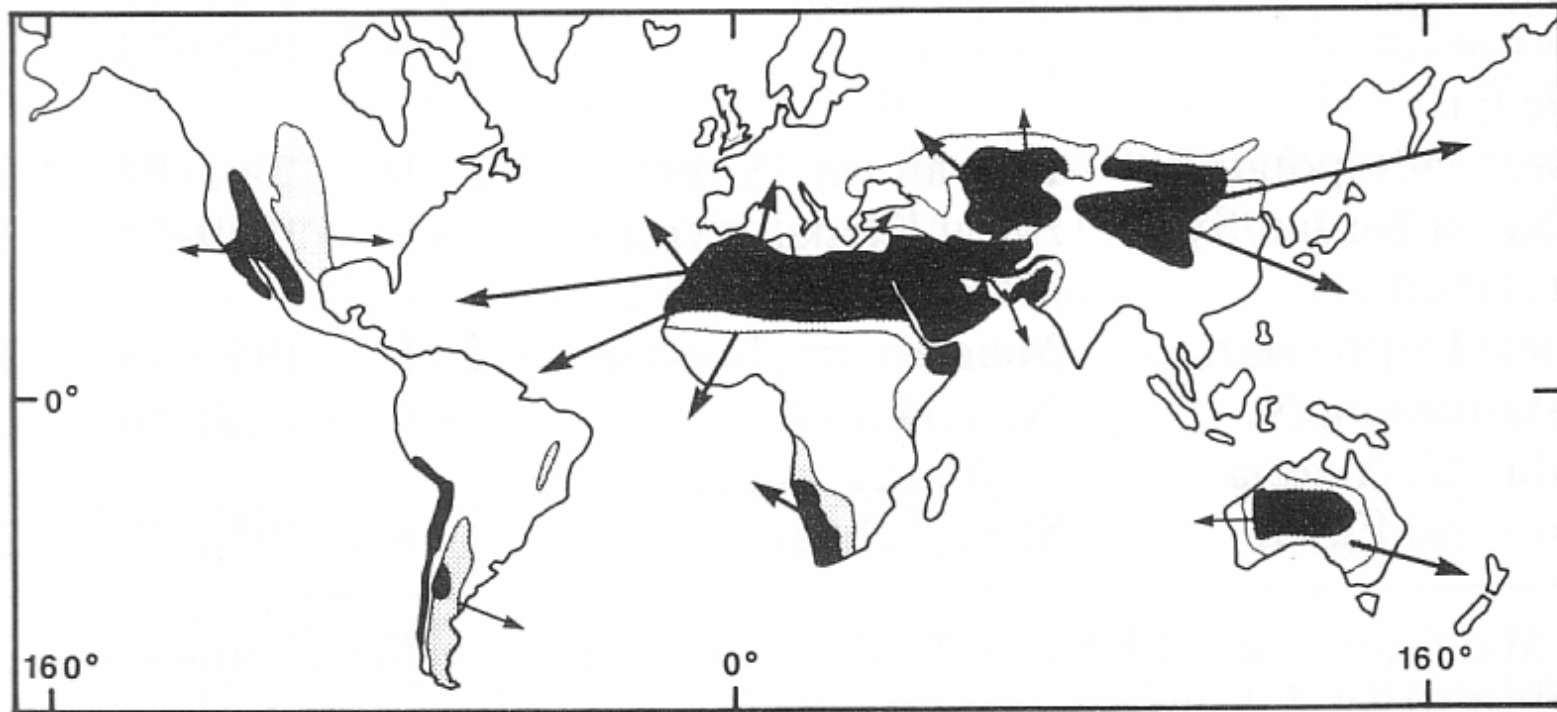


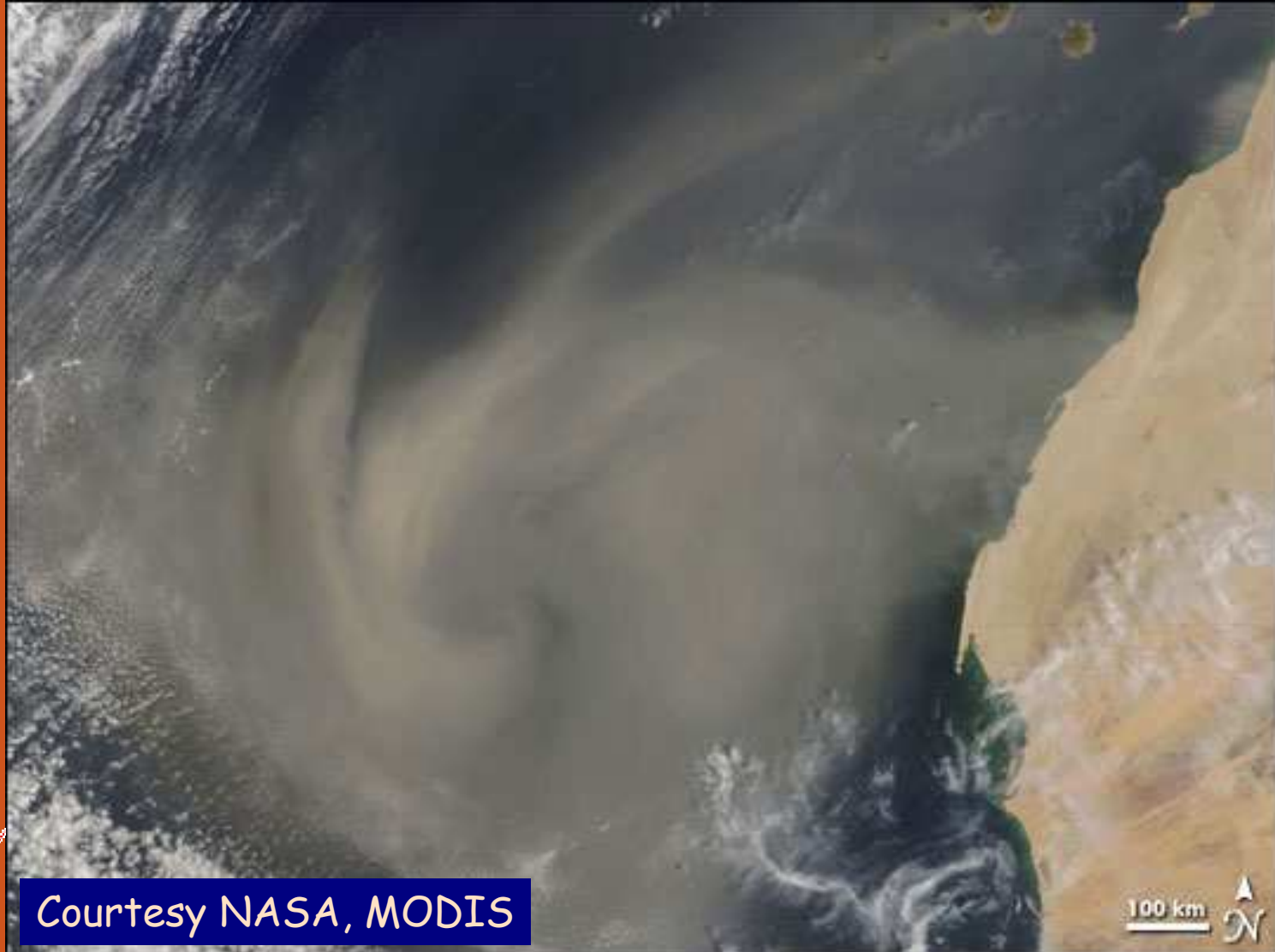
Figure 3.11. The maximum distances likely to be travelled by different-size classes of quartz spheres when $\bar{U} = 15 \text{ m s}^{-1}$ and ϵ varies from 10^3 to $10^7 \text{ cm}^2 \text{ s}^{-1}$. (After Tsoar and Pye (1987), *Sedimentology* 34, Fig. 3; © International Association of Sedimentologists.)



Source: Pye,
Aeolian Dust

Figure 4.1. Distribution of areas with high dust-storm activity and major dust trajectories. (Modified after Coudé-Gausson (1984).)

RS image of Saharan dust storm off north west Africa, September 2005



2005 11 25

Courtesy NASA, MODIS

Scott, Annegarn and Kneen

“Desert Storm”
(African version)
Wind-blown dust as a
large scale aerosol
source in
southern Africa.
Namibia,
June 6, 2000

SeaWiFS, NASA Goddard Space Flight
Center, and ORBIMAGE.
The Sea-viewing Wide field-of-view
Sensor (SeaWiFS)



3. Defining air quality management zones - international practice

Criteria for Airshed / Zone Identification

- Population density
 - Population Exposure & Human Health Risk
- Source location and intensity
- Topography
- Synoptic climatology

International Practice: European Community

- EC Framework Directive 96/62/EC
- Guidelines for the definition of air quality management zones across Europe
- Combination of criteria
 - Areas experiencing exceedences of ambient standards
 - Source types and locations
 - Population density
 - **Agglomerations** = population > 250 000
 - **Conglomerations** = population > 1 000 000

International Practice: European Community

- EC documents give guidance on number of monitoring stations required for each pollutant per 250,000 inhabitants
- Minimum monitoring activities are required in agglomerates and conglomerates irrespective of AQ status with respect to sources or standards
- Additional monitoring for high intensity source regions or areas in exceedance of standards

International Practice

- Netherlands
 - Country divided into three regions (North, Middle, South)
 - Location of agglomerations and population density were factors considered when determining air quality management zones
- United Kingdom
 - Zones determined based on jurisdictional boundaries and population density

International Practice: United States

- Air Quality Management Regions (AQMR)
 - Large areas based on topographical and jurisdictional boundaries
- State Implementation Plans with different jurisdictional boundaries created to deal with individual pollutants
 - Los Angeles South Coast Air Quality District encompasses several counties and independent local authorities.
- AQMRs can cross international borders
 - Georgia Basin / Puget Sound Airshed includes US and Canadian territory (Vancouver, Seattle)

International Practice Australia

- Air Quality Management Areas defined based on population distribution and density
- Threshold population size of 25 000 vs 250 000 for Europe

4. Defining air quality management zones

= AIR CATCHMENTS =

The South African scene

- Constitutional and legal framework
- Proposed criteria for South Africa

Key principles outlined by NEMA and IPWM

- integrated planning and environmental management
- equity
- subsidiarity
- precautionary principle
- freedom of information
- public participation

AQ management functions of regional and metropolitan authorities

- Drafting of an Air Quality Management Plan for the region/city
- Establishment and management of air quality monitoring networks;
- Compilation and maintenance of emission inventories;
- Maintenance and management of air quality and emissions inventory data bases;

What are the "Air Catchments" to which these provisions apply?

Empowering provisions of the AQ Act

- Local / Municipal (Section 18)
 - Local / Municipal Priority Area
- Sub-Regional (Section 18)
 - National Priority Area
- Air quality management plans (Section 19)
 - Establishment and implementation of AQ management plans
- Regional (Section 50)
 - International Air Quality Management

AQ Act CHAPTER 4

AIR QUALITY MANAGEMENT MEASURES

Part 1: Priority areas Declaration of priority areas

Part 1: Priority areas

Declaration of priority areas

- 18. (1) The Minister or MEC may, by notice in the *Gazette*, declare an area as a priority area if the Minister or MEC reasonably believes that—
 - (a) ambient air quality standards are being, or may be, exceeded in the area, or any other situation exists which is causing, or may cause, a significant negative impact on air quality in the area; and
 - (b) the area requires specific air quality management action to rectify the situation.
- (2) The Minister may act under subsection (1), if—
 - (a) the negative impact on air quality in the area—
 - (i) affects the national interest; or
 - (ii) is contributing, or is likely to contribute, to air pollution in another country;
 - (b) the area extends beyond provincial boundaries; or
 - (c) the area falls within a province and the province requests the Minister to declare the area as a priority area.
- (3) The MECs of two or more adjoining provinces may by joint action in terms of subsection (1) declare an area falling within those provinces as a priority area.

Management of priority areas

Clause 19

(6) A priority area air quality management plan must—

- (a) be aimed at coordinating air quality management in the area;
- (b) address issues related to air quality in the area; and
- (c) provide for the implementation of the plan by a committee representing relevant role-players.

CHAPTER 6: INTERNATIONAL AIR QUALITY MANAGEMENT

- **Transboundary air pollution**
- 50. (1) The Minister may investigate any situation which creates, or may reasonably be anticipated to contribute to—
 - (a) air pollution across the Republic's boundaries; or
 - (b) air pollution that violates, or is likely to violate, an international agreement binding on the Republic in relation to the prevention, control or correction of pollution.
- (2) If the investigation contemplated in subsection reveals that the release of a substance into the air from a source in the Republic may have a significant detrimental impact on air quality, the environment or health in a country other than the Republic, the Minister may prescribe measures to prevent, control or correct the releases within the Republic.

Proposed criteria for definition of air catchments for AQ "priority area" management in South Africa

CRITICAL POLLUTANTS & ZONES OF IMPACT:

1. Based on specific pollutants or groups of pollutants with similar atmospheric dispersion characteristics and similar zones of impact that are in exceedance, or likely to affect the health of populations or the environment

ADMINISTRATIVE PRACTICALITY:

2. Within the principles of subsidiarity, can be managed at the lowest appropriate administrative level
3. Involve the minimum necessary number of separate jurisdictions
4. Legal catchment boundaries should coincide with or be wholly embedded in the existing boundaries of participating metro and district jurisdictions

CONVERGENCE OF MITIGATION STRATEGIES:

5. Likely mitigating strategies are common to address issues related to the identified pollutants within the identified **PHYSICAL** air catchment

DIVERGENT AIR CATCHMENTS:

6. Recognise that different pollutants may require different and possibly spatially overlapping air catchments in terms of the above criteria

5. Practical issues - defining AQ management districts in South Africa - three case studies

Vaal Triangle

Crossing municipal and provincial boundaries

A rebuttal of the DEATs initial proposal for the Vaal Triangle priority area.

Case study: Vaal Triangle "Priority Area"

Criteria 1: Critical pollutants

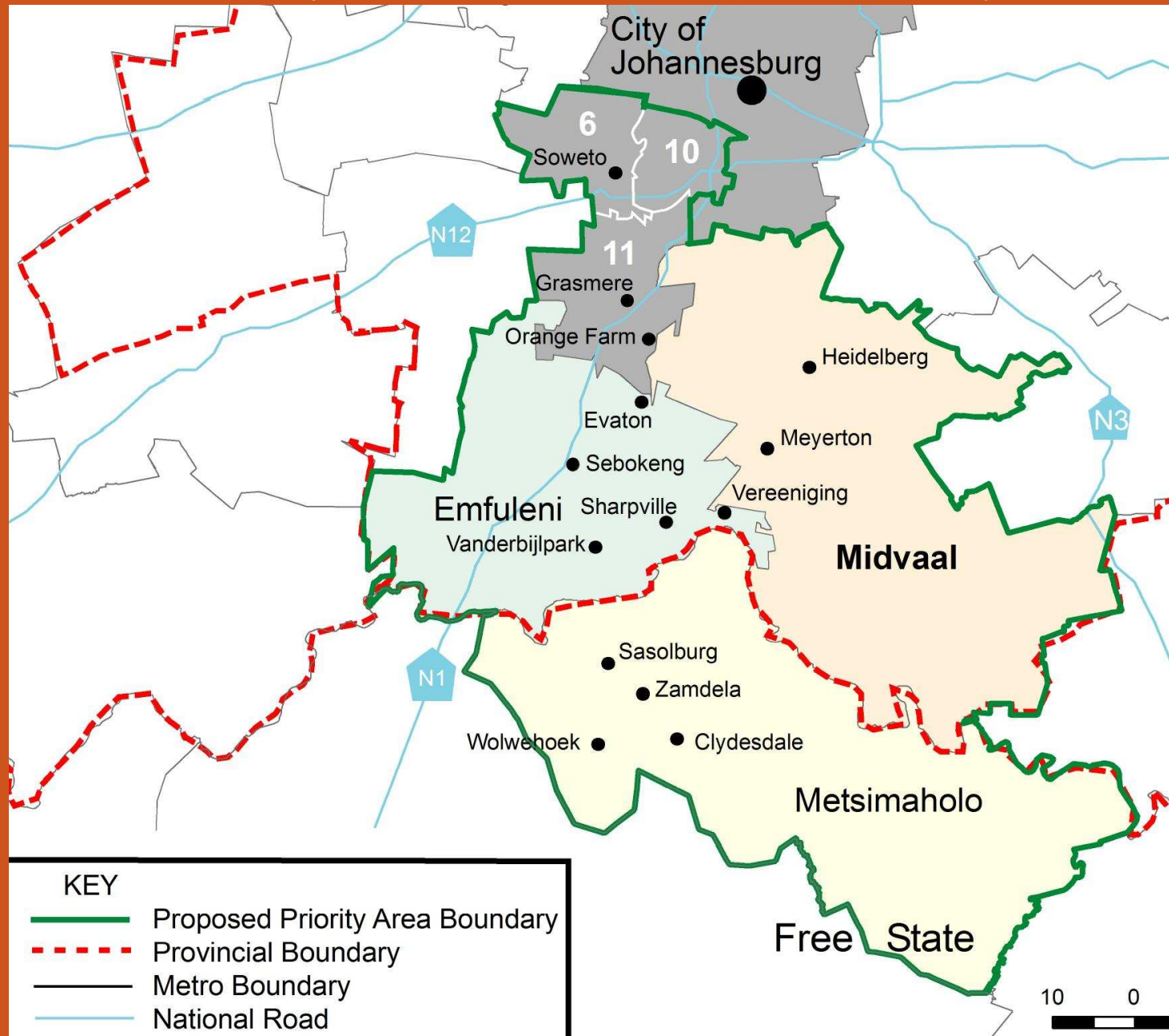
- Particulate matter (PM10, PM2.5)
 - **Domestic coal burning**
 - Surface mining and slag heaps
 - Industry
- Sulphur dioxide
 - **Power plants - electricity and steam**
 - Refineries
 - Domestic coal burning
- Volatile organics & odours
 - **Refineries**
 - Industry

Case study: Vaal Triangle "Priority Area"

Criteria 2: Administrative practicality

- DEAT's proposed Vaal Priority Area includes three entire district councils
 - Emfuleni (Vanderbijlpark and Vereeniging)
 - Midvaal (Meyerton)
 - Metsimaholo (Sasolburg)
- And part of a fourth
 - Johannesburg, regions 6 (Soweto); 9 (Natalspruit, Ennerdale); and 11 (Orange Farm)

DEAT's Proposed Vaal Triangle Priority Area



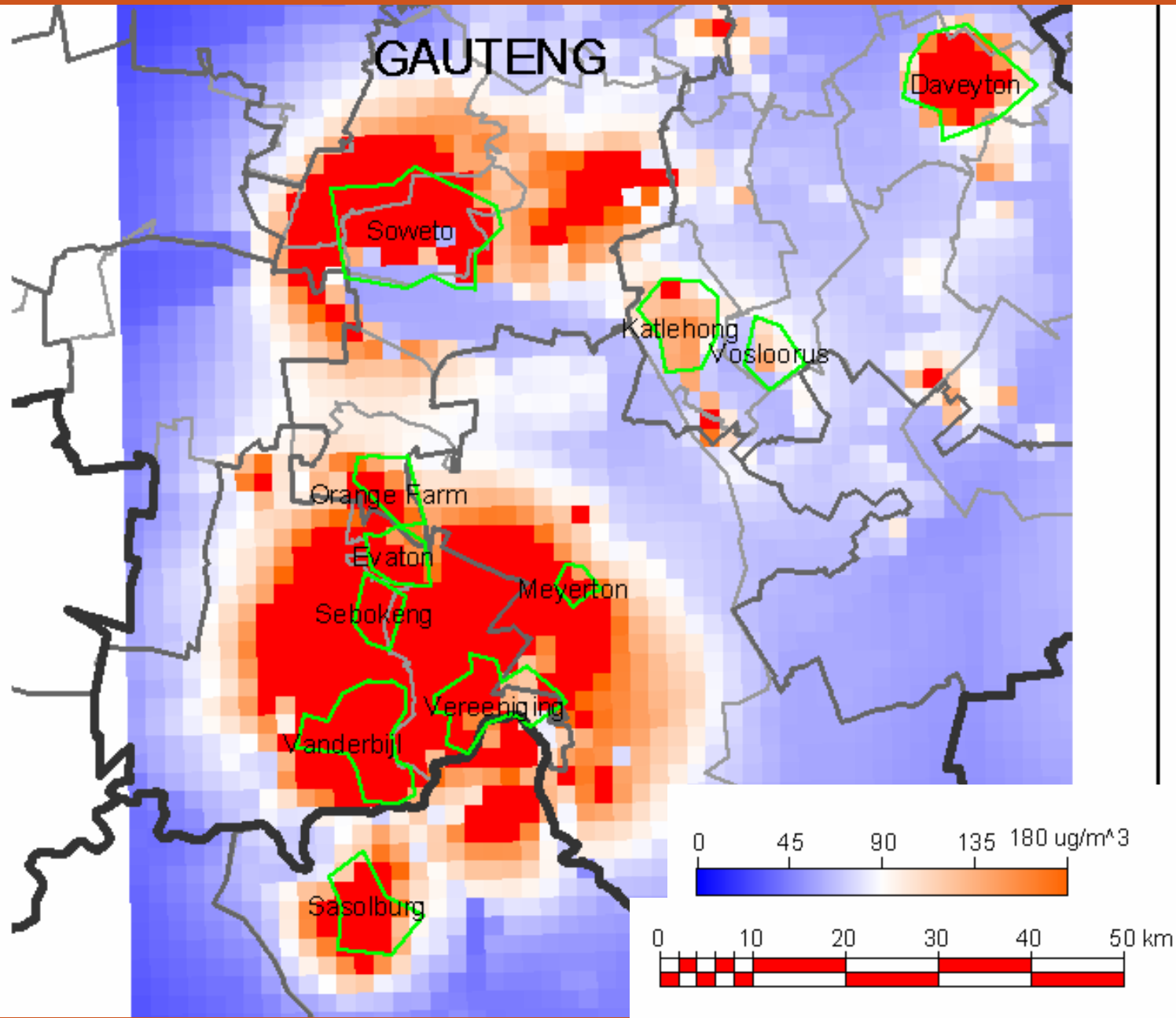
DEAT's proposal for Vaal Triangle AQ Priority Area (October 2005)

- Assumed reasons for inclusion of southern Joburg Metro area:
 - that coal burning suburbs of Soweto will be included - prevalent NW winds blow Soweto smoke over Vaal Triangle?
- Not specified for which pollutants the priority area is declared - "Everything has to be managed"

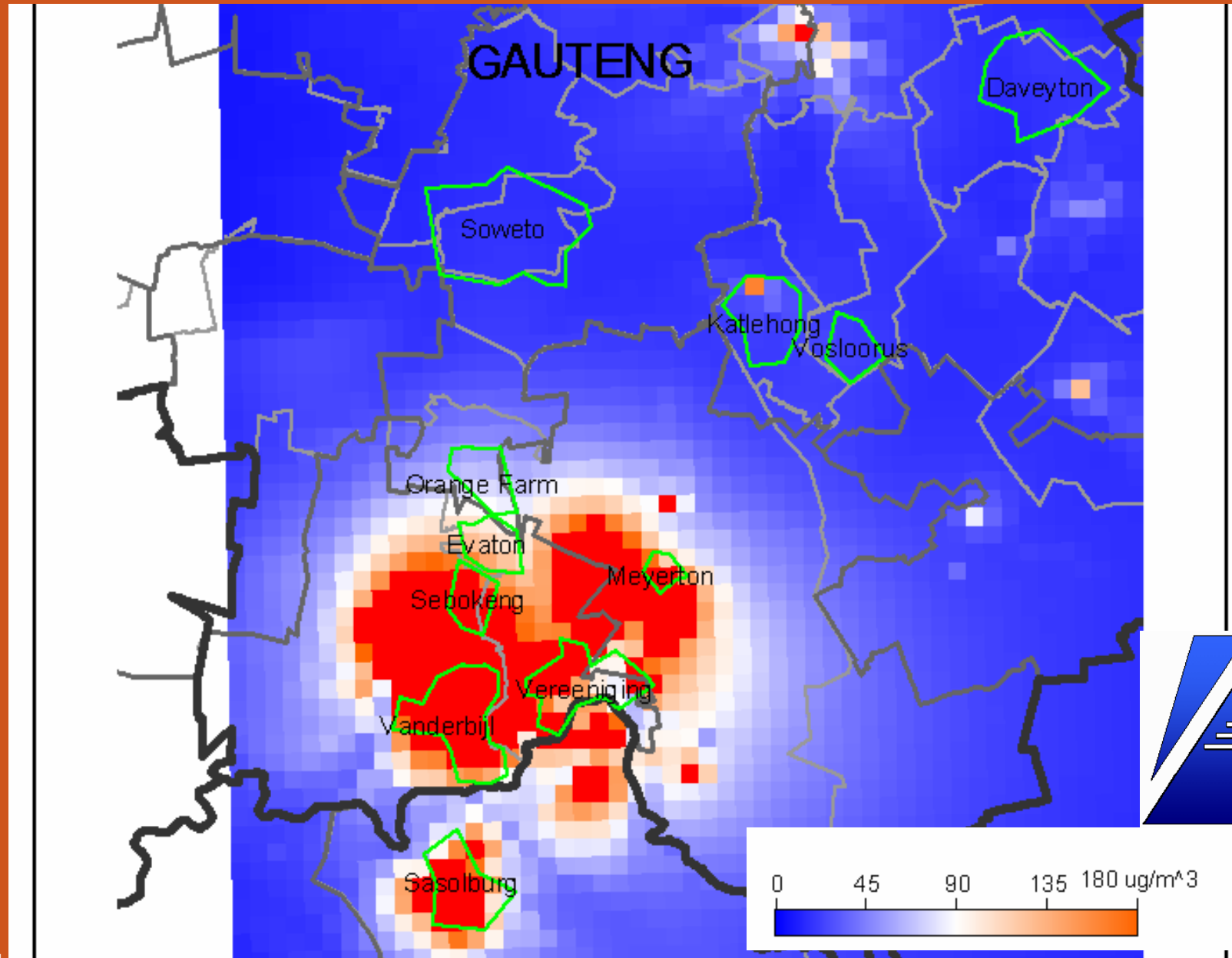
Examine existing studies for guidance:

- NEDLAC "FRIDGE" Combustion Fuels Study
- Soweto Air Monitoring - Project SAM

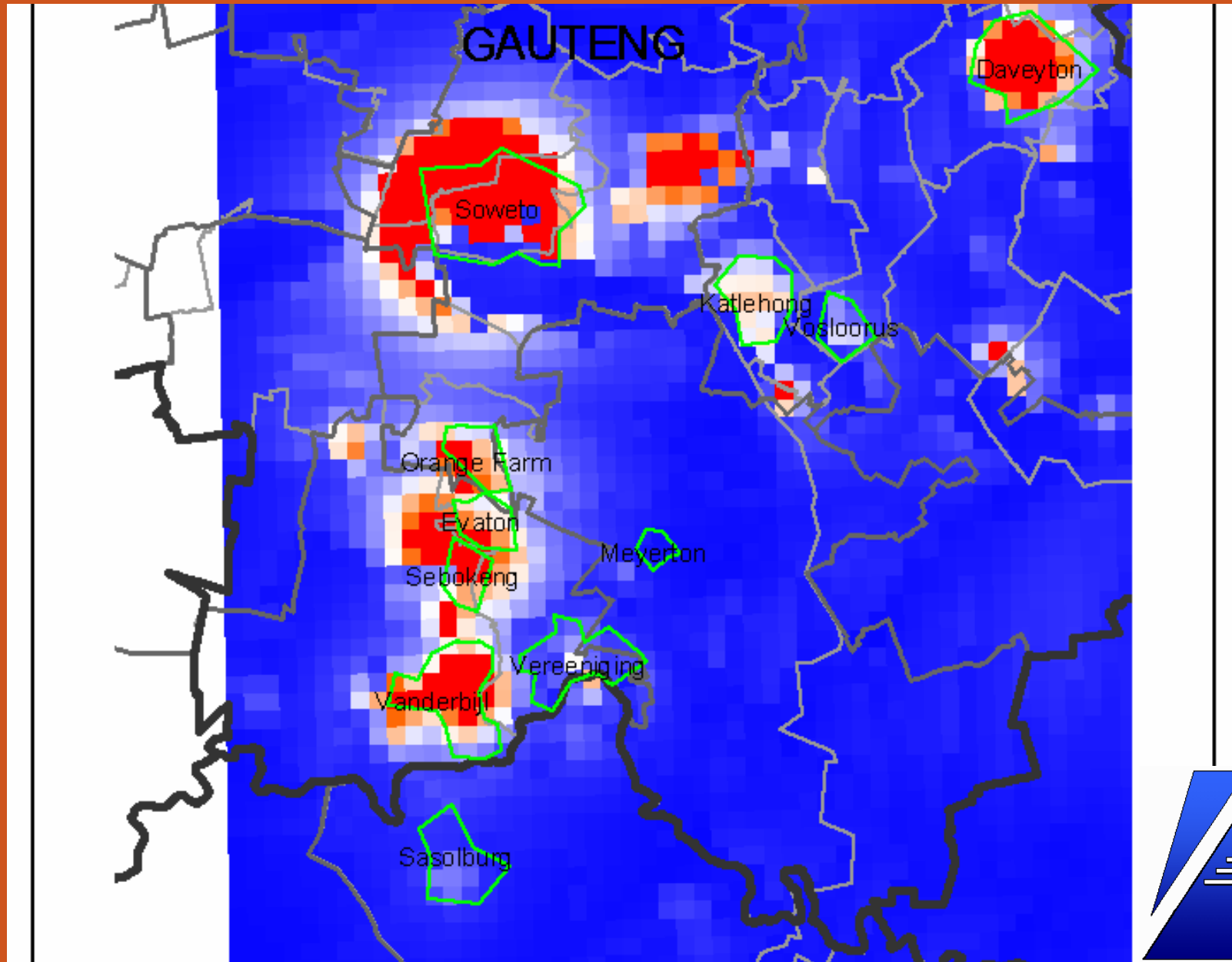
PM10 All sources, worst day



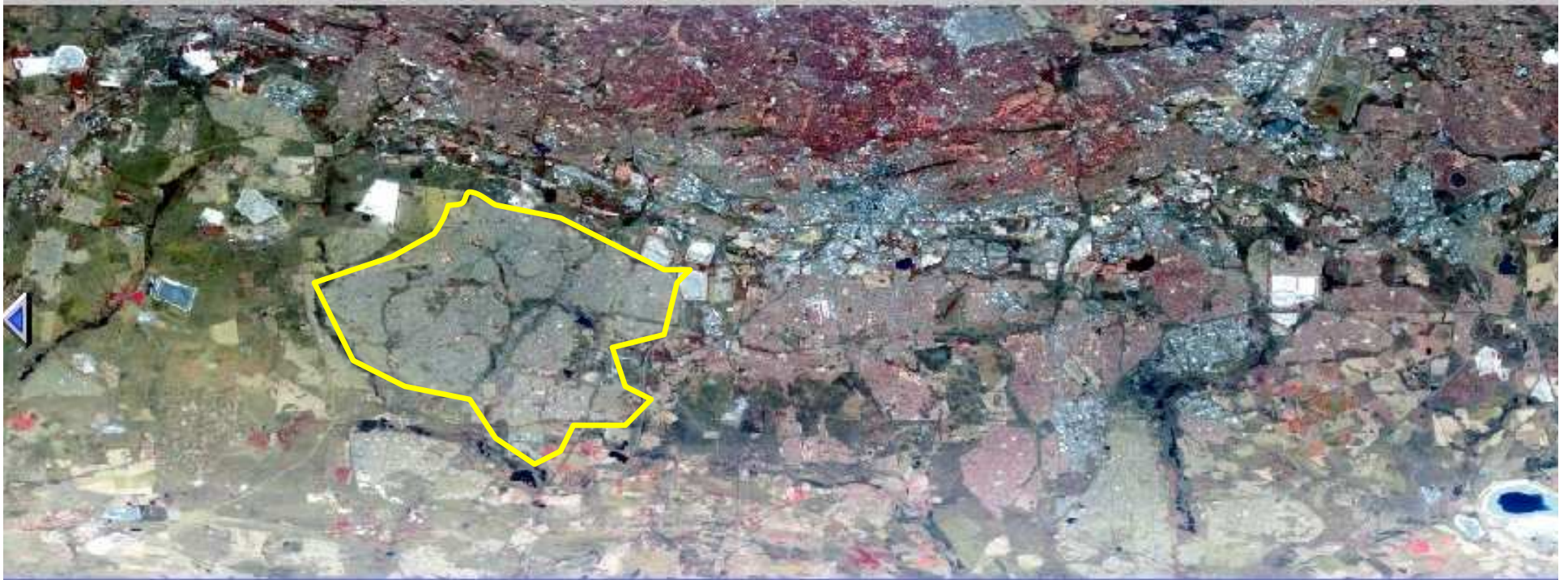
PM Industrial sources, worst day



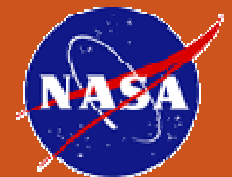
PM10 domestic fuel sources: worst day



MODIS Airborne Simulator: ER2 Flight 22 August 2000
Central Witwatersrand
from 20 km altitude



Soweto
~ 12 km



Case study: Vaal Triangle "Priority Area"

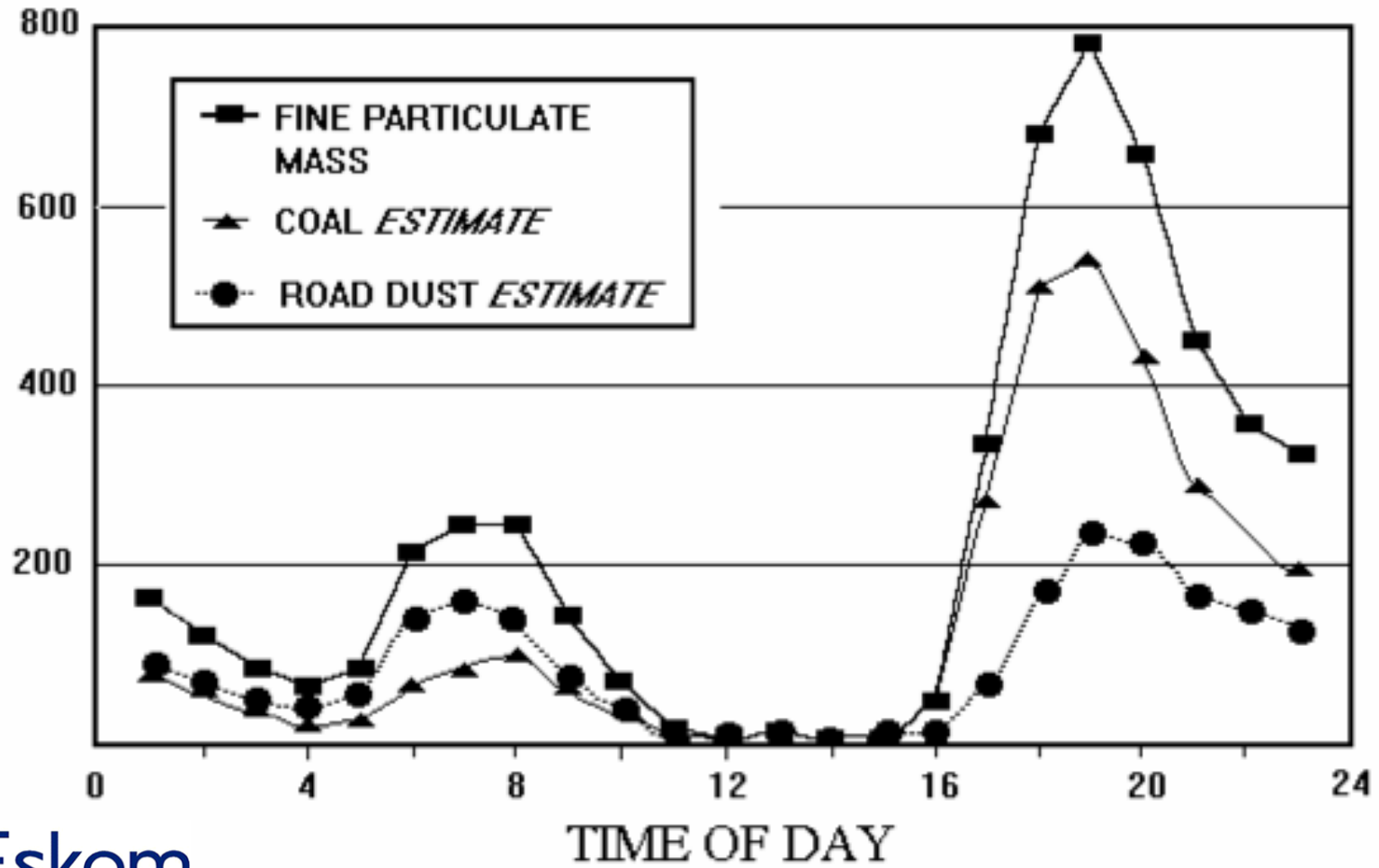
Criteria 1: Zones of impact (of exceedances)

- Diurnal graphs of both particles and SO_2 in Soweto show that even in winter, ventilation and dilution result in these pollutants dropping to background levels during daylight hours
- Supports contention that transported pollution from Soweto is likely to be minor contribution to Vaal Triangle particulate or SO_2 exceedances
- Hence pollution transport from Soweto is **NOT** a valid reason for including districts 6 and 9 in the Vaal Priority Area.

SMOKE CONCENTRATION IN SOWETO (JUNE 1991)

CONCENTRATION
 $\mu\text{g}/\text{m}^3$

[Diurnal Variation]



Diurnal SO_2 concentrations in Soweto

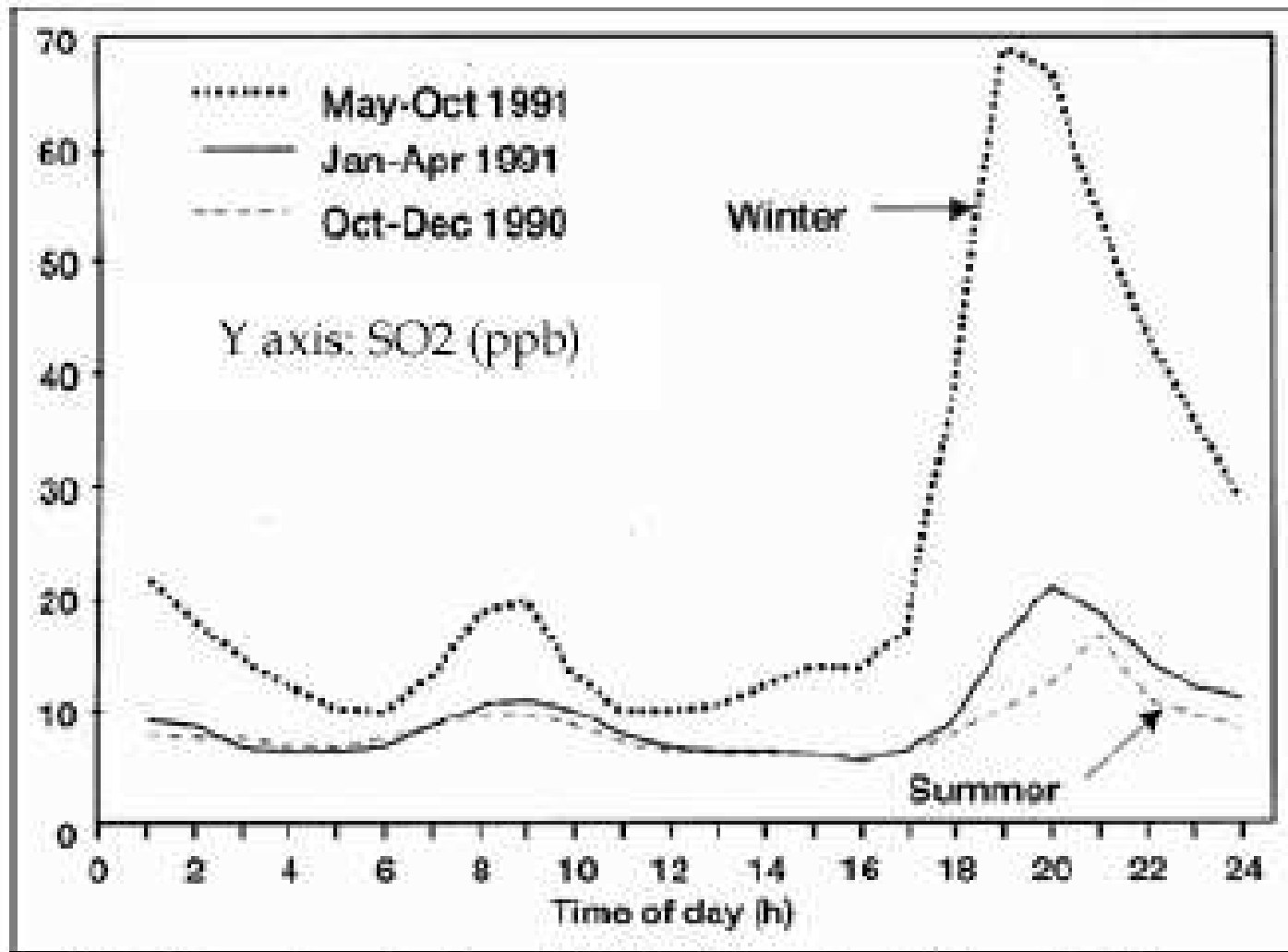
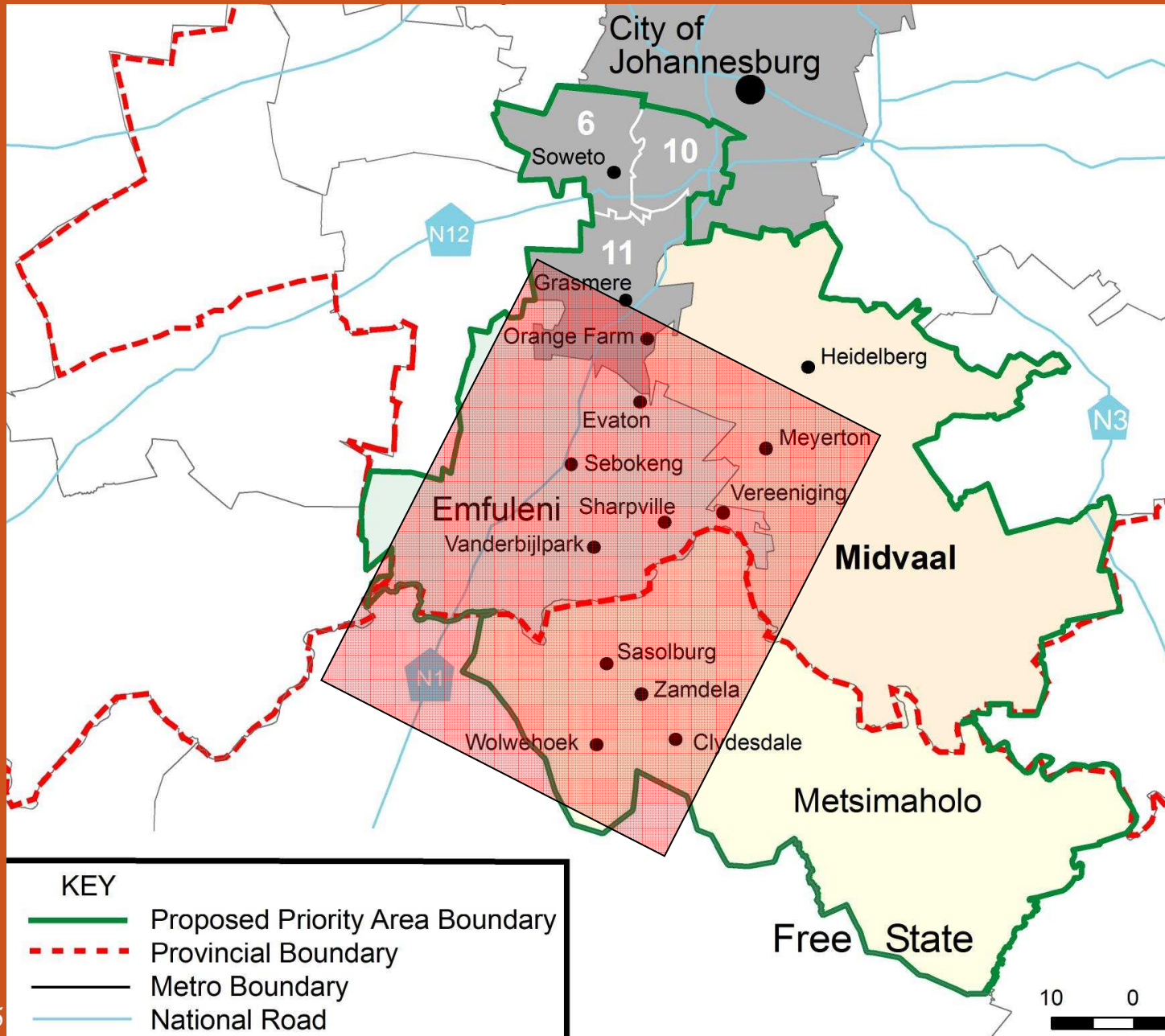


Figure 2.6: Diurnal variation of SO_2 at Soweto Dhlamini. [Annegarn *et al.*, 1996]

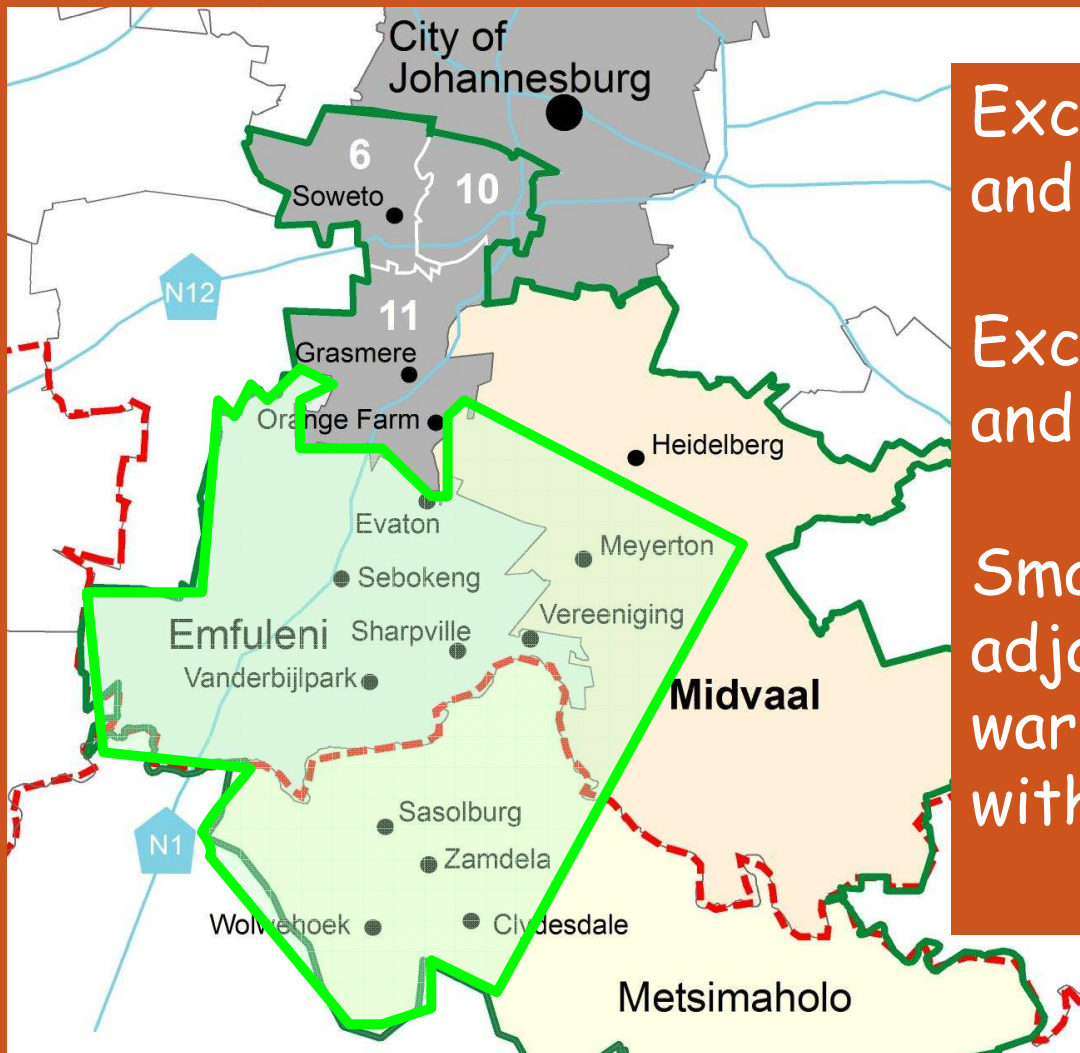
Evaluation of Vaal air catchment: PM10

- The issue in Vaal Triangle is industrial - with lesser component of domestic fuel
- The issue in Johannesburg is domestic fuel emissions - almost no industrial PM10.
- The exceedance values in Joburg (Soweto) and Vaal Triangle are not continuous or contiguous - wide space of "cleaner" air.
- Extensive areas of Midvaal and Metsimaholo are rural and are not in exceedance
- Hence:
 - Mitigation strategies will have different foci
 - **No justification of administrative complexity of including parts of Joburg metro into the combined Vaal Triangle Priority consortium**
 - Re-examine proposed outline of Vaal priority area to redefine a logical air catchment management area.

Ideal Vaal Triangle Priority Area



Case study: Vaal Triangle "Priority Area"
Criteria 2,3 & 4: Administrative practicality
A revised proposal for Vaal Triangle AQ Priority Area



Exclude Joburg regions 6, 10 and 11.

Exclude rural areas of Midvaal and Metsimaholo

Small area of Orange Farm adjacent to Evaton does not warrant including Joburg area with Vaal Triangle.

Case study 2:
Need for a Provincial Priority Zone
Witwatersrand - Mine Tailings Dust

Criteria 1a: Critical pollutants

- Particulate matter (Fall out dust & PM10)
 - Wind blown dust from reclaimed mine dumps and active slimes dams
 - Wind blown dust from abandoned mine dumps

Dust from mine dumps in early 60's (and up to the present)



2005 11 25

Scott, Annegarn and Kneen

Mineral particle

5 μm

Acc.V Spot Magn Det WD: |-----| 2.0m
15.0 kV 4.0 15000x SE 10.3 DIP5340s 14.12.97 DYS

Case study 2: Need for a Provincial Priority Zone Witwatersrand - Mine Tailings Dust

Criteria 1a: Critical pollutants

- Particulate matter (Fall out dust & PM10)
 - Wind blown dust from reclaimed mine dumps and active slimes dams
 - Wind blown dust from abandoned mine dumps

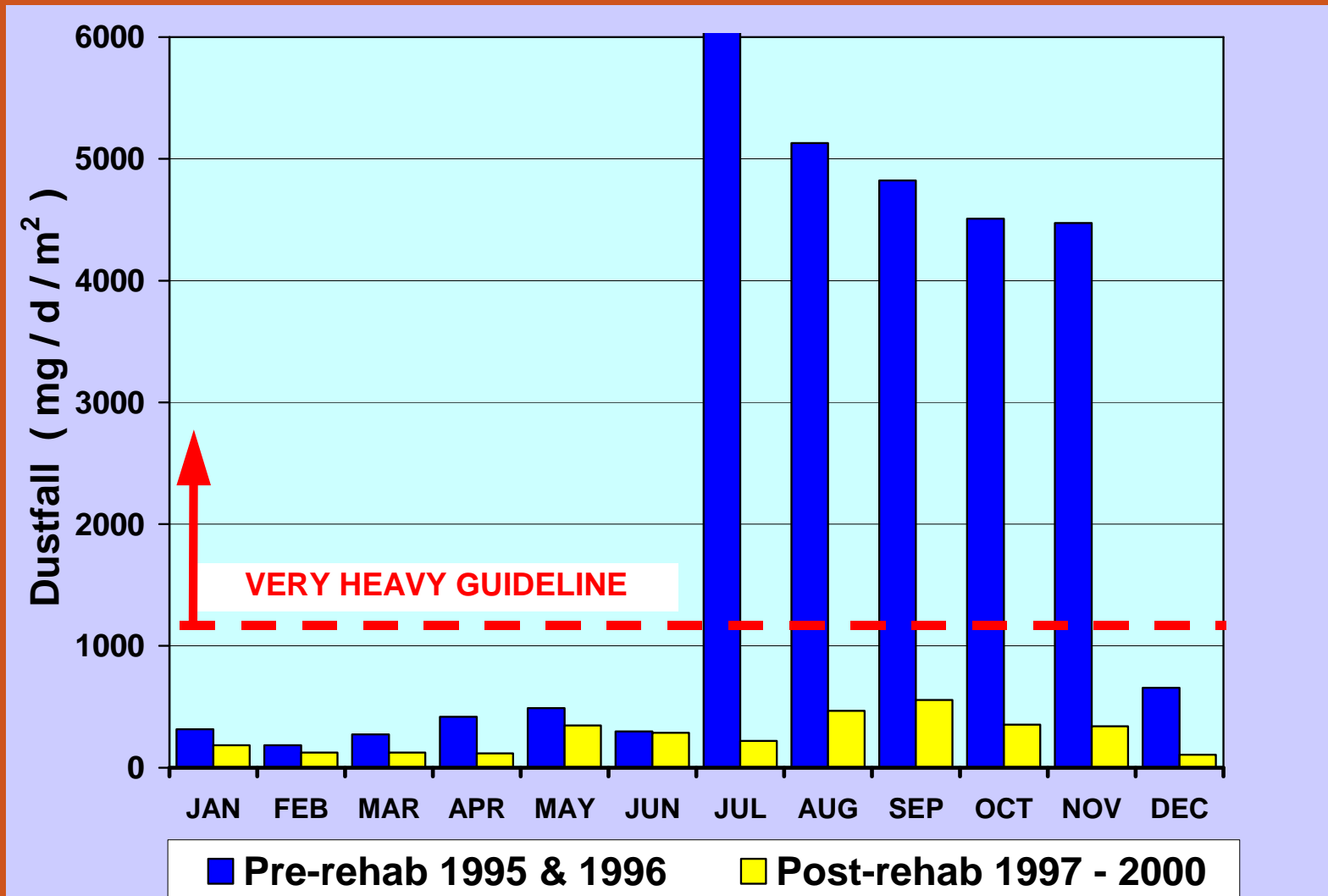
Criteria 1b: Zone of impact

- 1 to 2 km down wind from source
- Witwatersrand from Nigel to Carltonville

Rand Leases dump close to Meadowlands

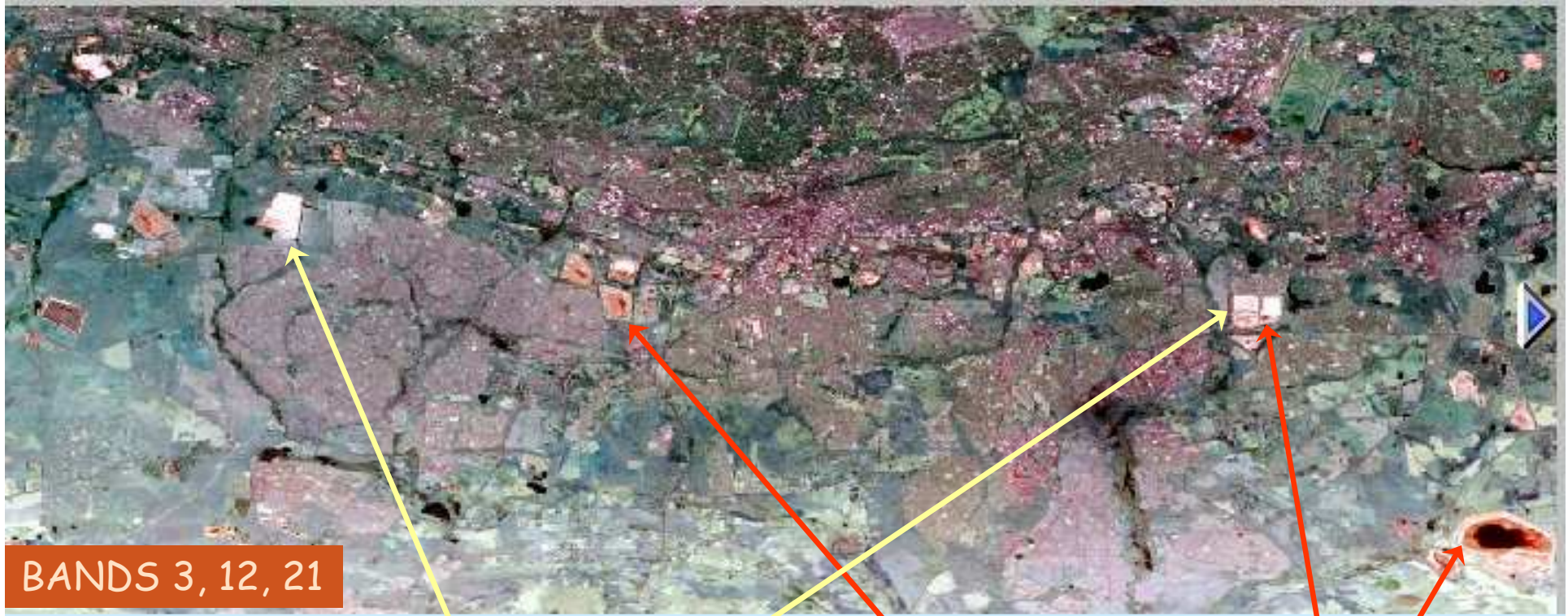


Mean monthly dustfalls at Moroeroe Primary School, before re-vegetation (1995-1996) and after re-vegetation (1998-2000) of nearby tailings dam.



Witwatersrand: Gold Mine Tailings

MODIS Airborne Simulator (MAS) 22 August 2000



BANDS 3, 12, 21

Unrehabilitated -dry
surface tailings

Active tailings - Fe-
contaminated water

2005 11 25

Scott, Annegarn and Kneen












Case study 2: Witwatersrand Goldfields Mine Tailings Dust

Criteria 2: Administrative practicality

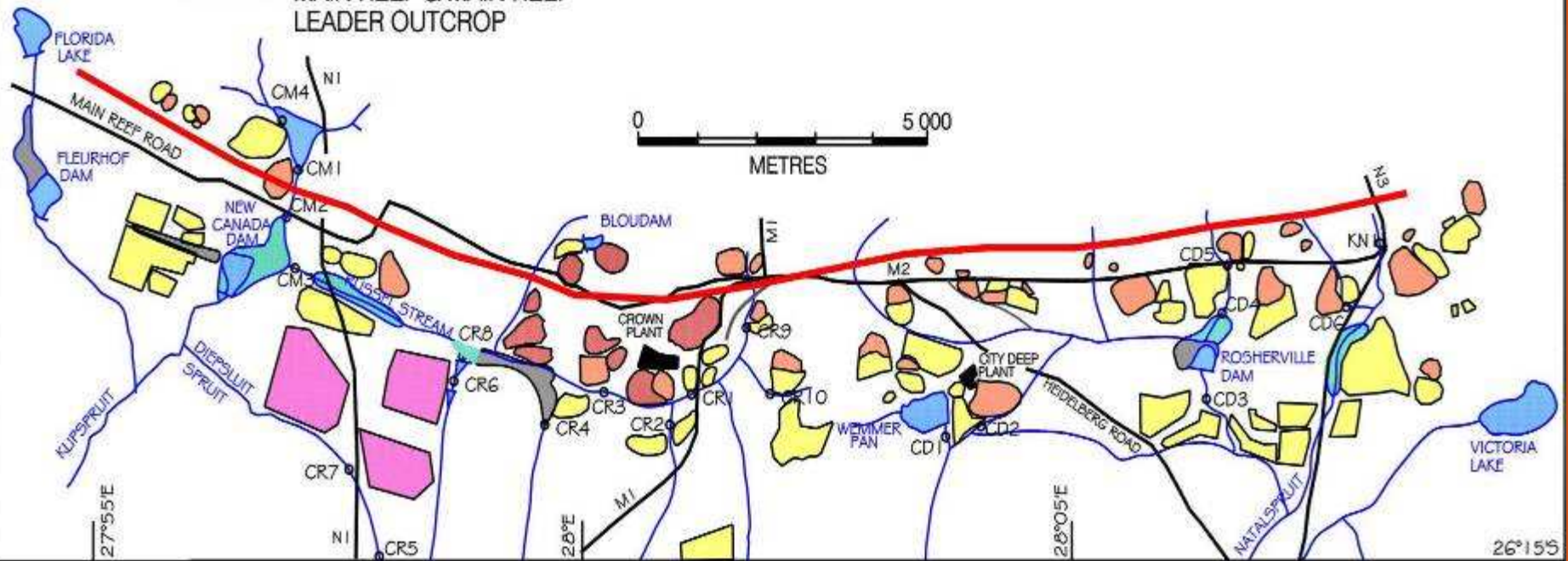
- Impact zone crosses several local authorities in relatively narrow strip
- Major source activities controlled by relative few mining companies
- Cross cutting reporting to National Department of Minerals and Energy (EMP Reports)

Tailings dams on the Central Rand

TAILINGS DAMS OF THE CENTRAL RAND IN RELATION TO DRAINAGE

-  RIVER / DAM
-  VLEI / REED AREA
-  ROADS
-  SAND DUMP
-  SLIMES DAM
-  MAIN REEF & MAIN REEF LEADER OUTCROP
-  TAILINGS FOOTPRINT
-  ACTIVE SLIMES DAM
-  TREATMENT PLANT
-  SILT ACCUMULATION IN STREAMS AND DAMS
-  CROWN GOLD RECOVERY WATER SAMPLING POINTS

0 5 000
METRES



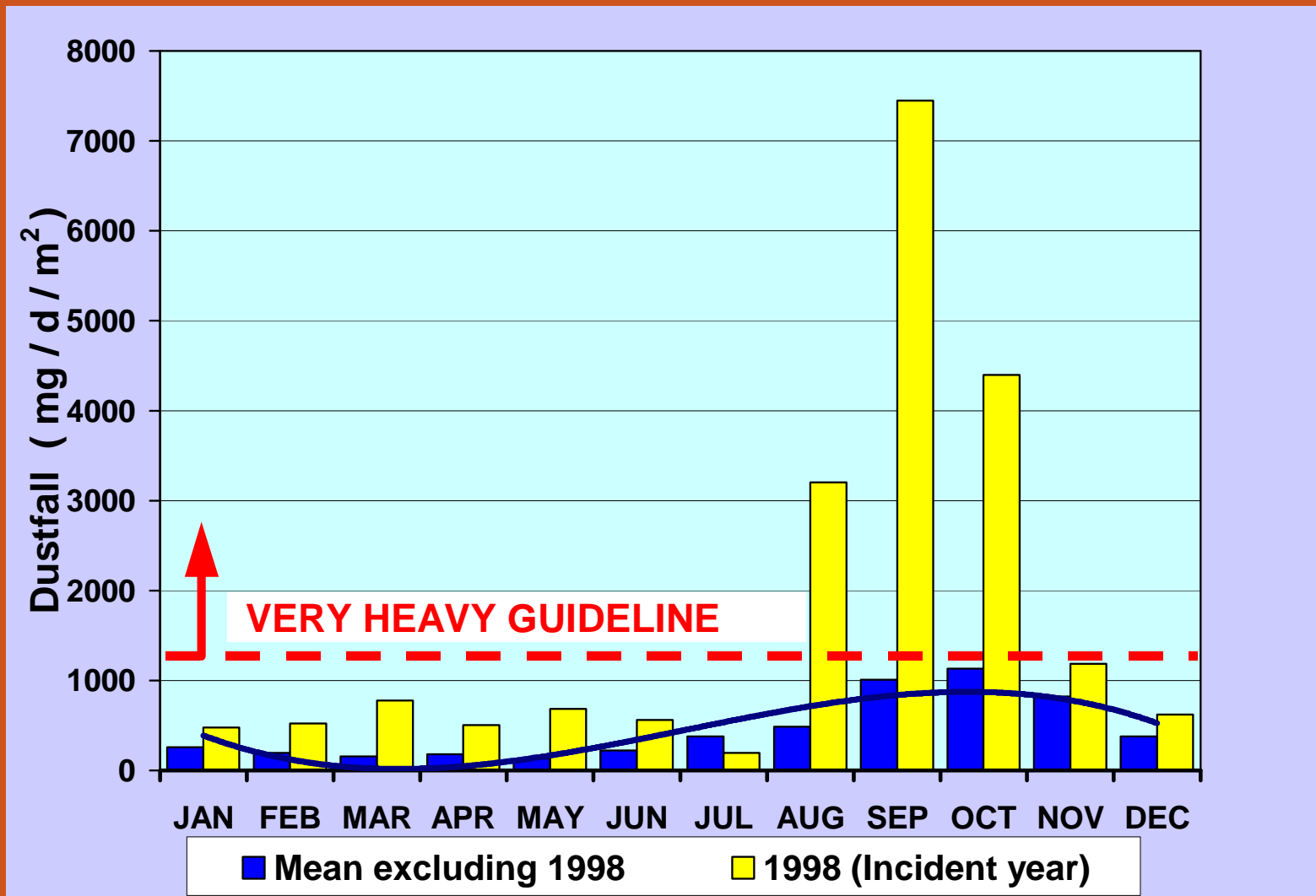
Case study 2: Need for a Provincial Priority Zone Witwatersrand - Mine Tailings Dust

Criteria 5: Convergence of mitigation strategies

- Technology exists for mitigating dust generation from active reclamation, deposition and closed tailings dumps.
- Same agreed control strategies needed across local authorities, and within each operating mine.
- ➔ Sensible to define a "mine tailings dust" management area in terms of Gauteng provincial boundary.

Dustfall before and after mitigation

Site 50 m downwind of active reclamation site.
Mean dustfall 1994 to 2001 excluding 1998.



Witwatersrand - Mine Tailings Dust

Criteria 5: Convergence of mitigation strategies

- Poor town planning aggravating situation by allowing new developments within active mining zones - DME recommendations routinely bypassed
- Uncontrolled informal settlements on declared mining land building in future exposure situations
- National compact needed on agreed mitigation, land use planning and urban development needed to maximize utility of Witwatersrand space

Case study 2:

Concept proposal for a Provincial Priority Zone Witwatersrand - Mine Tailings Dust

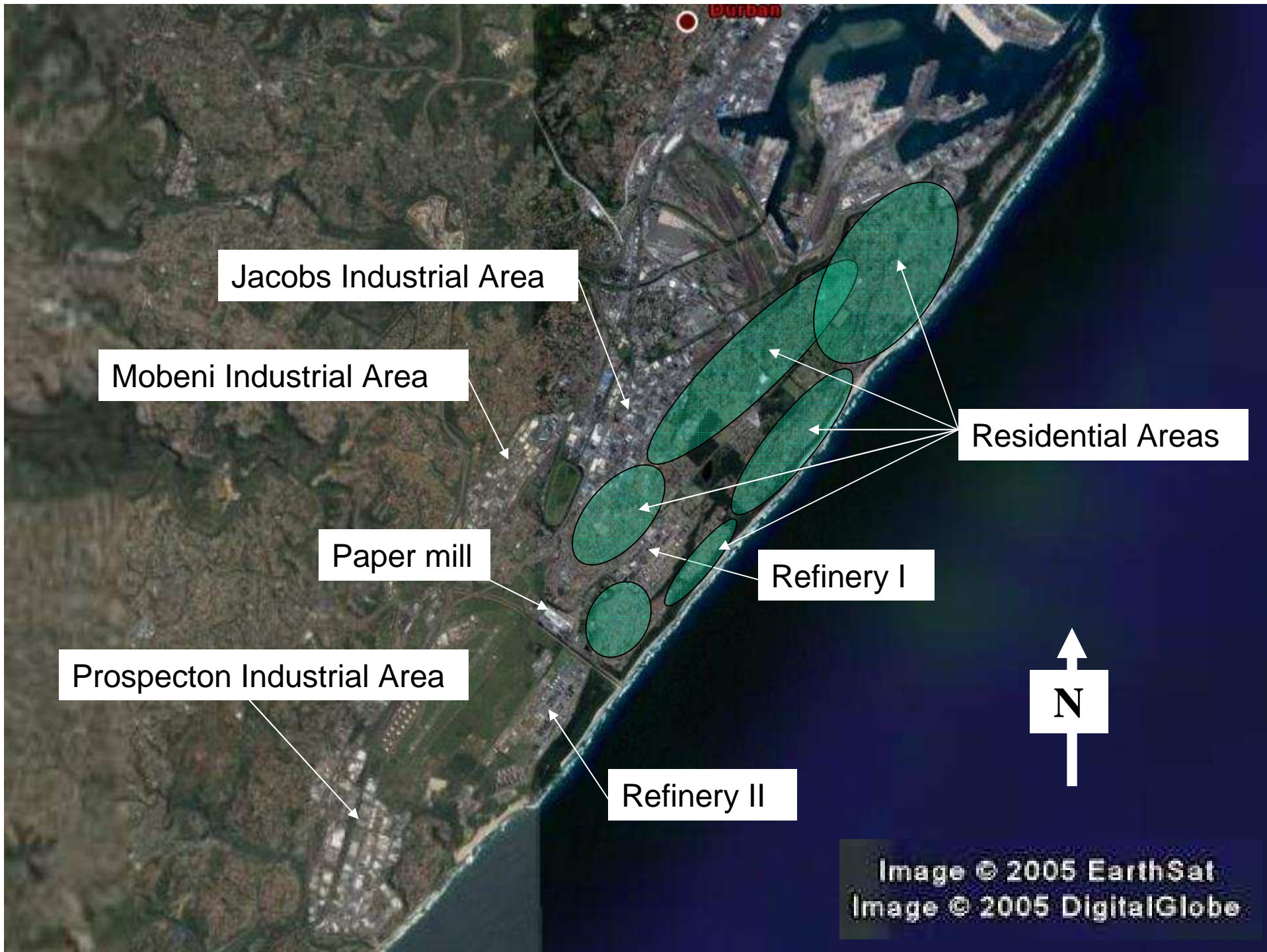


Witwatersrand: Gold Mine Tailings
MODIS Airborne Simulator (MAS) 22 August 2000

Case study 3: "Hotspot" Priority Zone within a municipal jurisdiction South Durban

Criteria 1a: Critical pollutants and zones

- Heavy industrial development surrounded by high density residential areas
- Generally low stack heights - proximity to Durban International Airport
- Low level sources - small boilers and fugitive emissions
- High traffic density - residential and industrial
- Topography - located within a valley
- Synoptic climatology - prevailing winds NE and SW - up and down the valley



Jacobs Industrial Area

Mobeni Industrial Area

Paper mill

Prospecton Industrial Area

Refinery II

Refinery I

Residential Areas



Image © 2005 EarthSat
Image © 2005 DigitalGlobe

South Durban

- **Criteria**
 - **Synoptic climatology** - calm stable conditions during ridging high pressure or prefrontal results in high air pollution potential
 - **Regional contribution** - the regional and sub-regional circulation patterns result in pollution transport into the Greater Durban and South Durban areas (i.e. valley winds)

South Durban

- Pollutants of Concern
 - SO_2
 - Source - industry and other combustion sources
 - PM_{10} and smaller fractions
 - Source - industry, biomass burning and traffic
 - VOCs
 - Source - industry, bulk storage and other related industries
 - NO_x
 - Source - industry, traffic and other combustion sources

South Durban

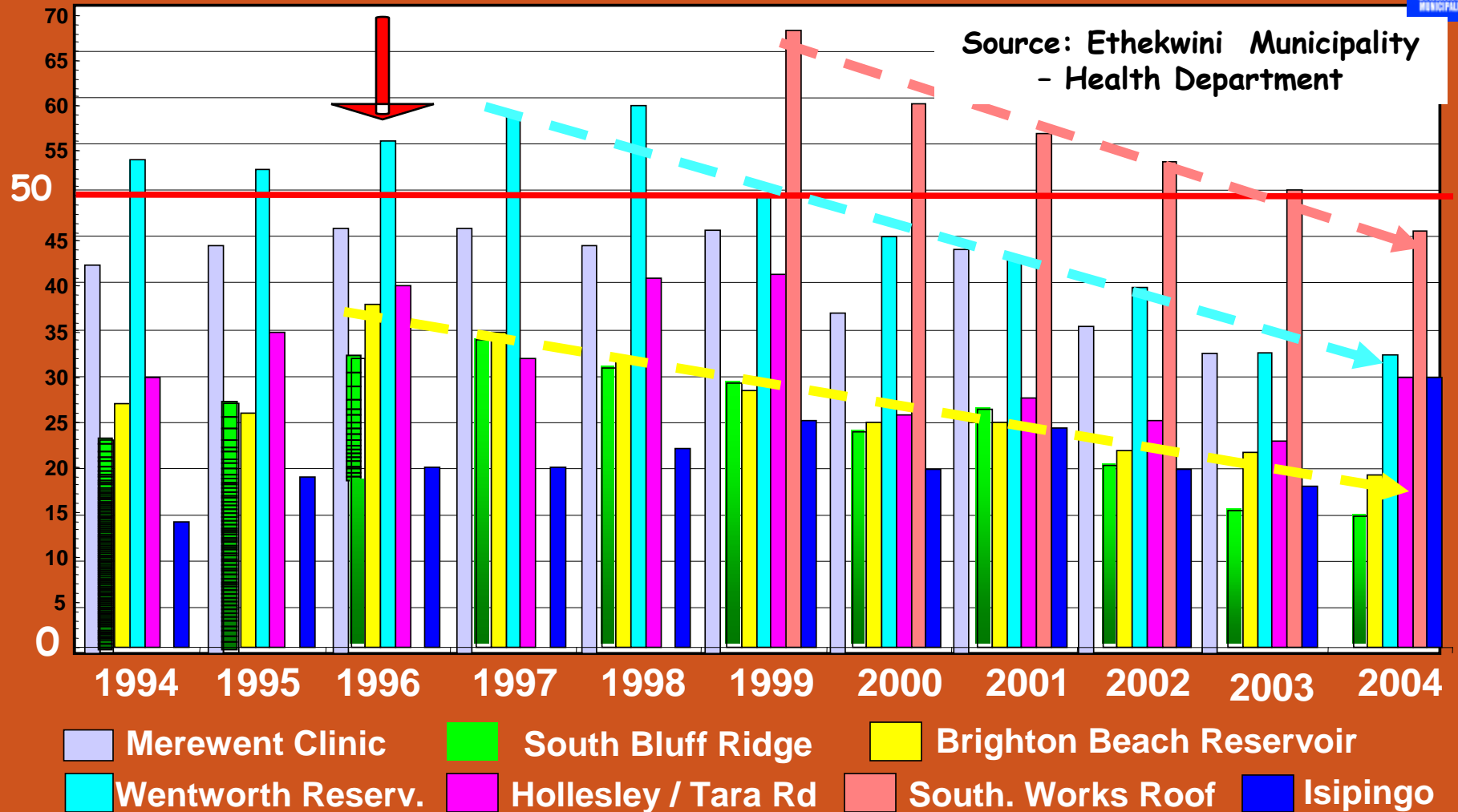
- Interventions - Multi-Point Plan initiated by Minister Vali Moosa
 - Industrial
 - Low hanging fruit - retrofit cleaner technology
 - This has already seen large reductions in SO_2 emissions
 - Phasing out of dirty fuels
 - Financial implications for smaller operators
 - Improved planning - moving new heavy industry to more suitable locations
 - Identification and reducing fugitive emissions from plants and storage facilities

10-year Annual Average SO₂ Trends in South Durban

Ambient SO₂ Concentration (ug/m³ SO₂)



Source: Ethekwini Municipality - Health Department



S.A. Dept of Environmental Affairs & Tourism (& World Health Organization)

Annual Average Guideline Value = 50 µg/m³

South Durban

- **Interventions**
 - **Traffic**
 - Traffic planning - alternative routes for heavy vehicles in residential areas
 - Decongestion - upgrading of main routes within the city - lane widening / intersection upgrading / traffic light synchronization
 - Vehicle testing - national initiative required to set vehicle emission standards

Case study 3: Notional Priority Zone within a municipal jurisdiction South Durban

- Priority pollutants include multiple species
- Some are particular to sources within the Durban South Basin
- Some are shared with other areas of the Ethekewini Municipality
- Although South Durban has historically been a separate “priority zone” embedded within Greater Ethekewini, ADMINISTRATIVE PRACTICALLITY and DISPERSION PATTERNS linked to synoptic meteorology likely to dictate that the jurisdictional air shed should encompass the whole of the Ethekewini Municipal District

CONCLUSION:

Five major air quality issues in South Africa

- Power plant emissions & acid rain
- Mine dust
- Industrial pollution - metallurgical and refineries
- Vehicle pollution and ozone
- Domestic coal smoke

Shown by FRIDGE and other studies that **domestic coal smoke** has been and remains the major air quality issue in South Africa, affecting the health and quality of life of the largest numbers, generally in the poorest communities in direct and serious ways.



Acknowledgements to Crown Gold Recoveries,
New Vaal Colliery, Eskom TSI and Anglo
Technical Services for long-term support for
atmospheric research to Wits University and to
University of Johannesburg