



# Ultrafine particles and rainfall modification: experimental evidence from airborne studies?



Wolfgang Junkermann<sup>1,2</sup> and Jorg Hacker<sup>2</sup>

<sup>1</sup>Karlsruhe Institute of Technology, IMK-IFU, Garmisch-Partenkirchen Germany, <sup>2</sup> Flinders University,  
School of the Environment, Adelaide Australia

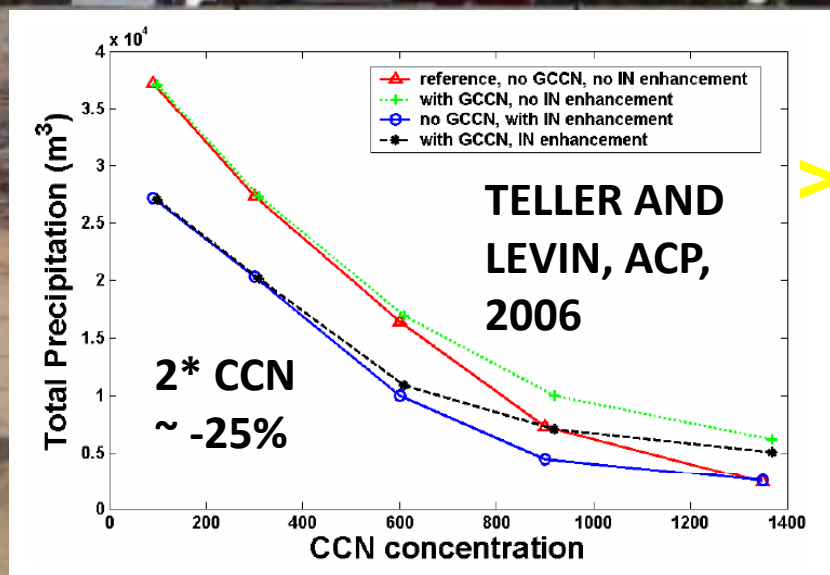




# What to expect?



## from addition of UFP



> regional to continental scale



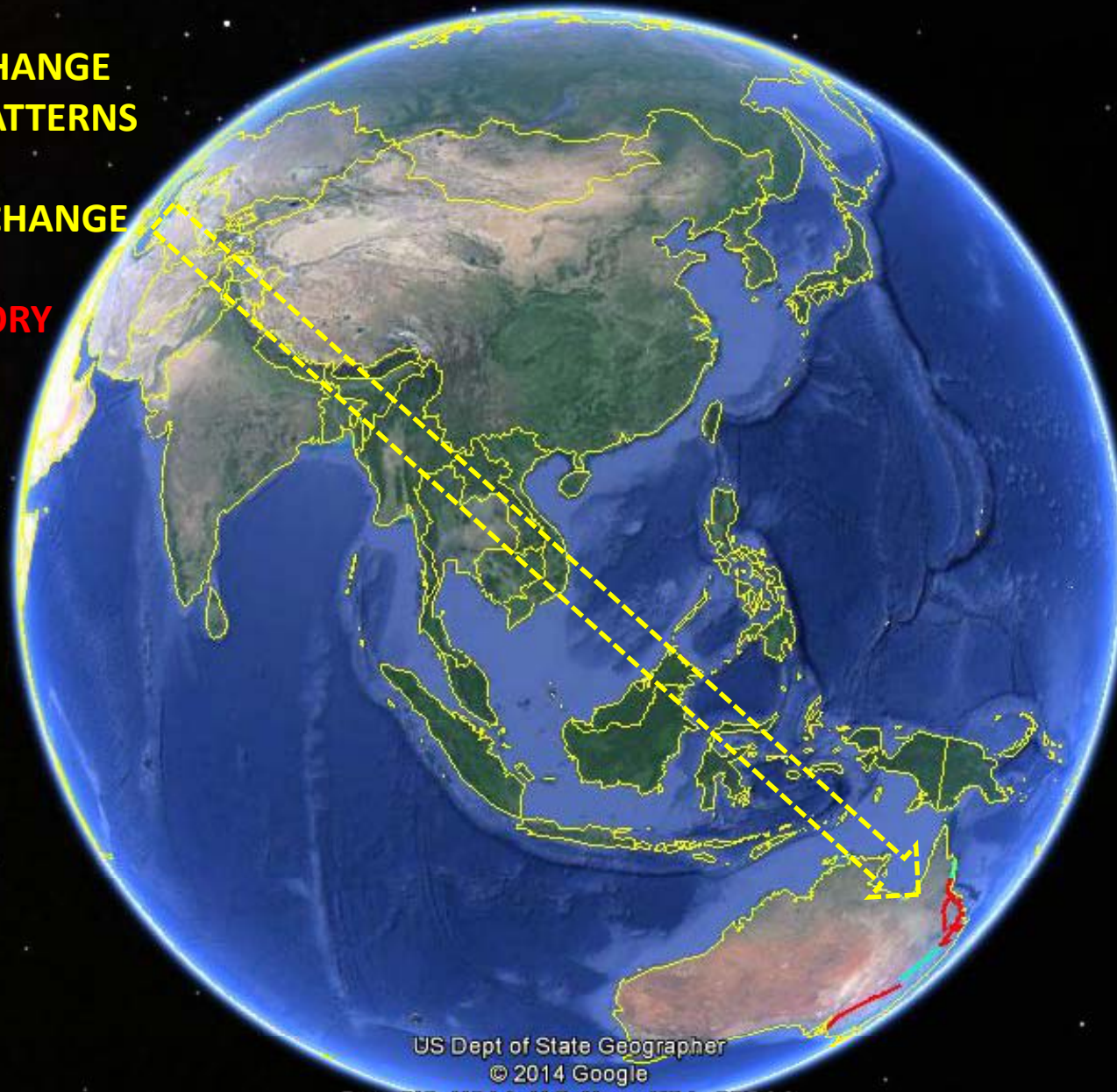


**FINDING A SUITABLE AREA:**

**SIGNIFICANT CHANGE  
OF RAINFALL PATTERNS**

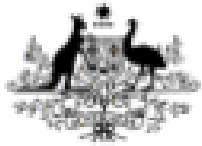
**NO LAND USE CHANGE**

**AEROSOL HISTORY**



US Dept of State Geographer  
© 2014 Google  
Data SIO, NOAA, U.S. Navy, NGA, GEBCO  
© 2009 GeoBasis-DE/BKG

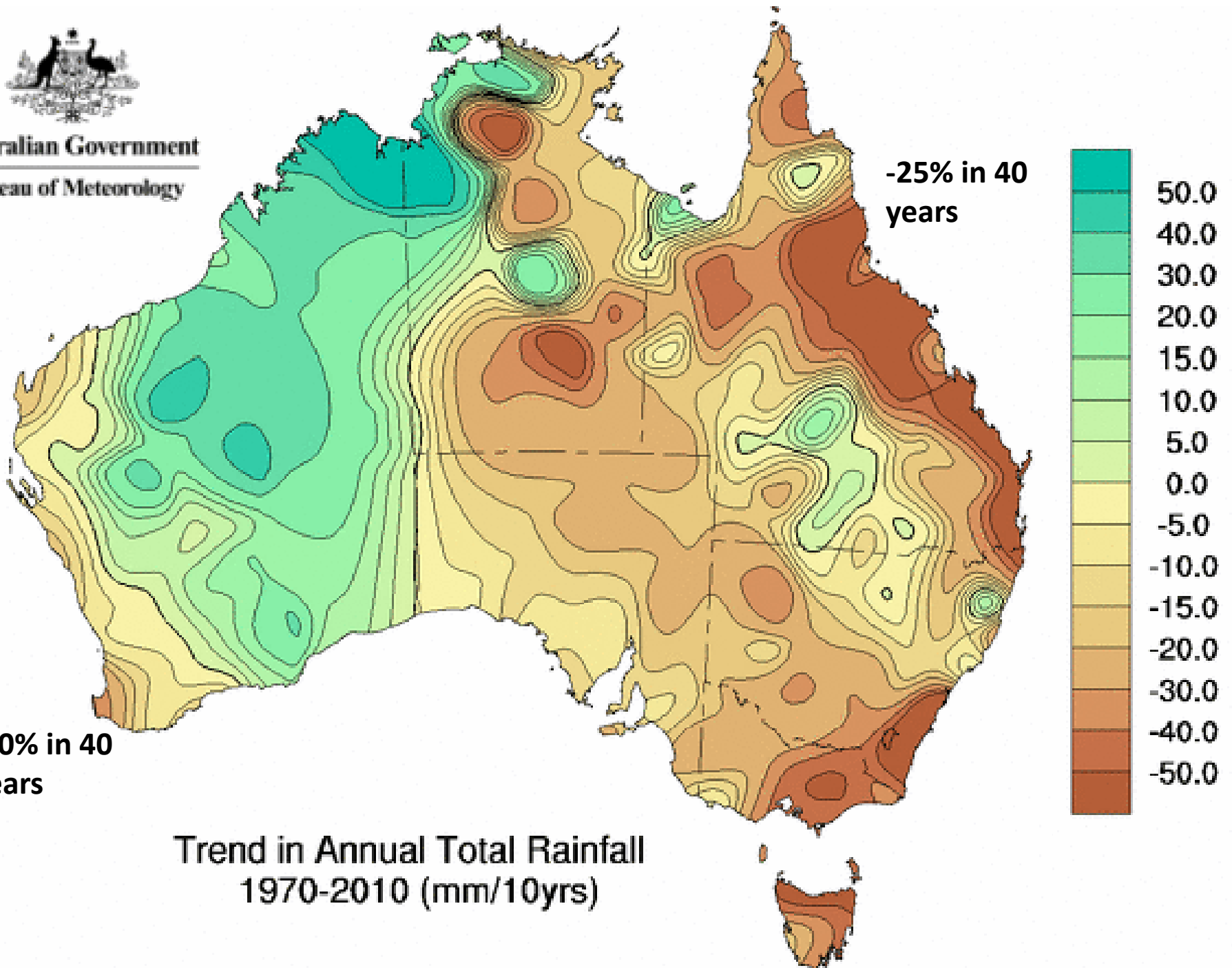
Google earth



Australian Government  
Bureau of Meteorology

-30% in 40  
years

-25% in 40  
years

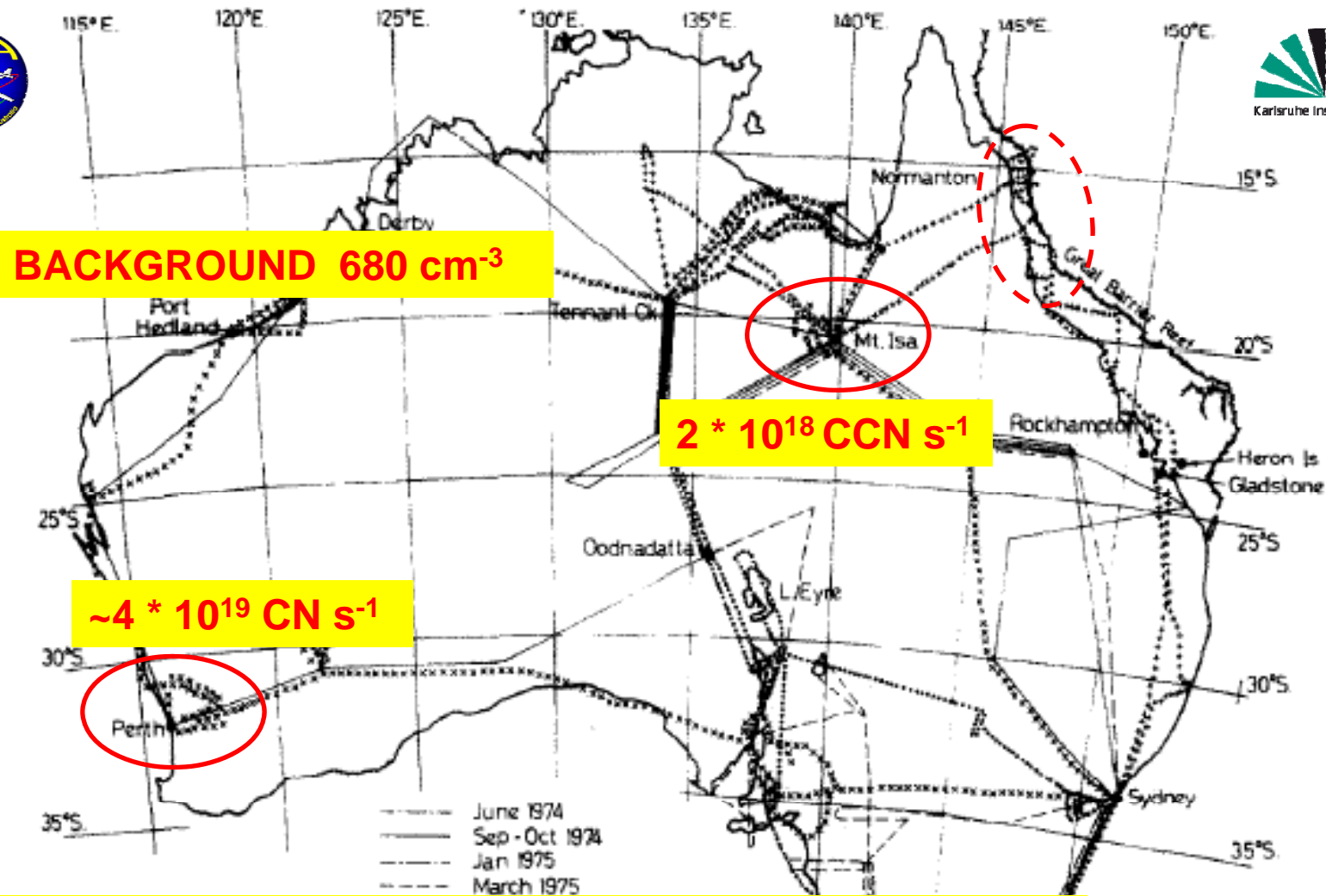


Trend in Annual Total Rainfall  
1970-2010 (mm/10yrs)

# SOURCES OF ATMOSPHERIC PARTICLES OVER AUSTRALIA

E. K. BIGG and D. E. TURVEY

Atmos. Environment, 1978



**MAJOR SOURCES: ANTHROPOGENIC EMISSIONS**  
~ 10% of CN -> CCN ? (30% Andreae, 2009)  
~ 20% Li et al, 2011)  
**TOTAL NATURAL CN - PRODUCTION AUS ~1 \* 10¹⁹ s⁻¹**

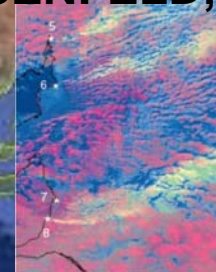




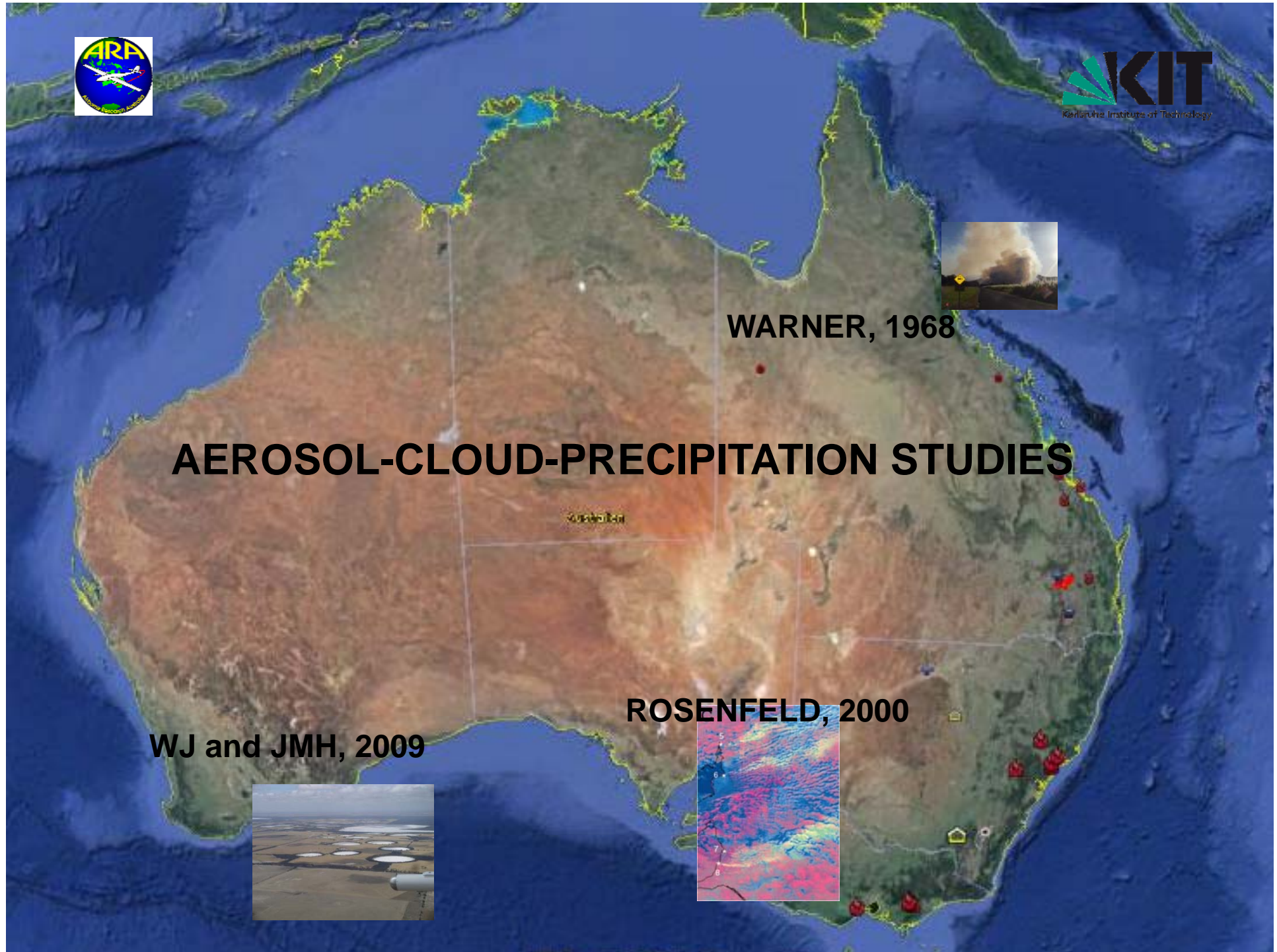
**WARNER, 1968**

# **AEROSOL-CLOUD-PRECIPIATION STUDIES**

**ROSENFELD, 2000**



**WJ and JMH, 2009**







**GRIMM SMPS**

**5-350 nm**

**2 min**

**TSI 3010**

**> 10 nm**

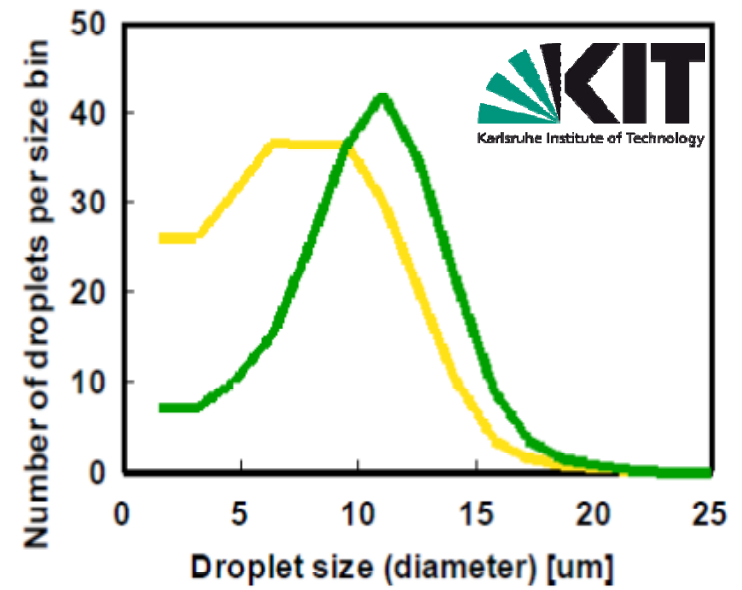
**1 sec**

**GRIMM 1.108 OPC**

**300 nm – 20 um**

**6 sec**

**PLUS FSSP 100**

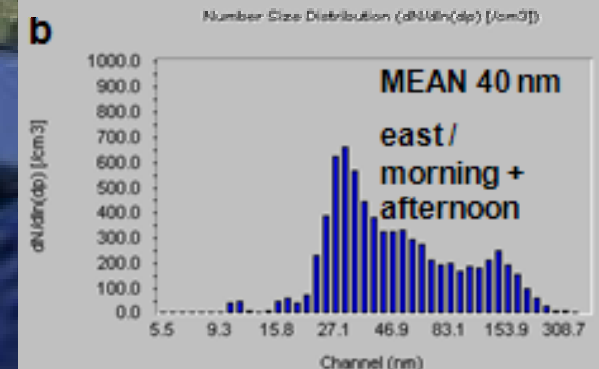
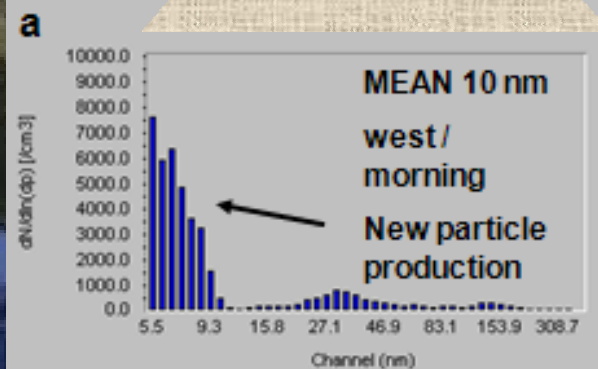


Perth WA, Australien

400 km

1000

UFP SOURCES





Bigg, E.K. Trends in rainfall associated with sources of air pollution, *Environ. Chem.* 2008, 5, 184–193. 1970–2004

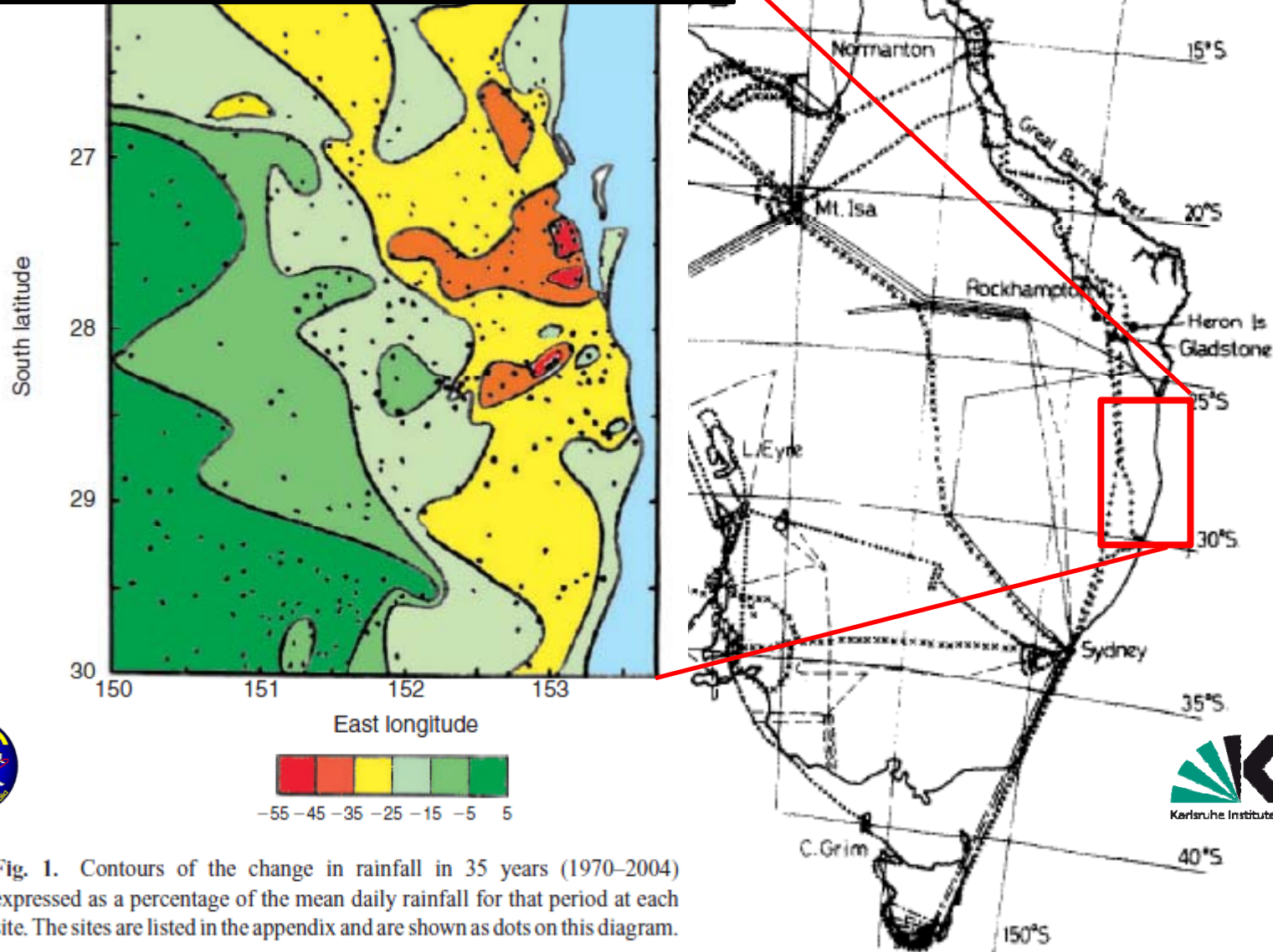
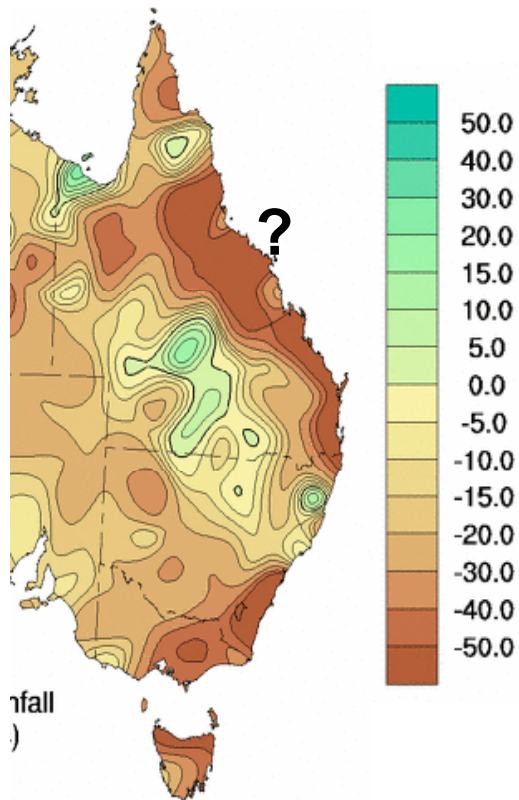


Fig. 1. Contours of the change in rainfall in 35 years (1970–2004) expressed as a percentage of the mean daily rainfall for that period at each site. The sites are listed in the appendix and are shown as dots on this diagram.

## RAINFALL CHANGE, EASTERN AUSTRALIA, 1970-2010

**RAINFALL**  
- 40 mm / dec



**# OF WET DAYS**  
- 6-8 d / dec



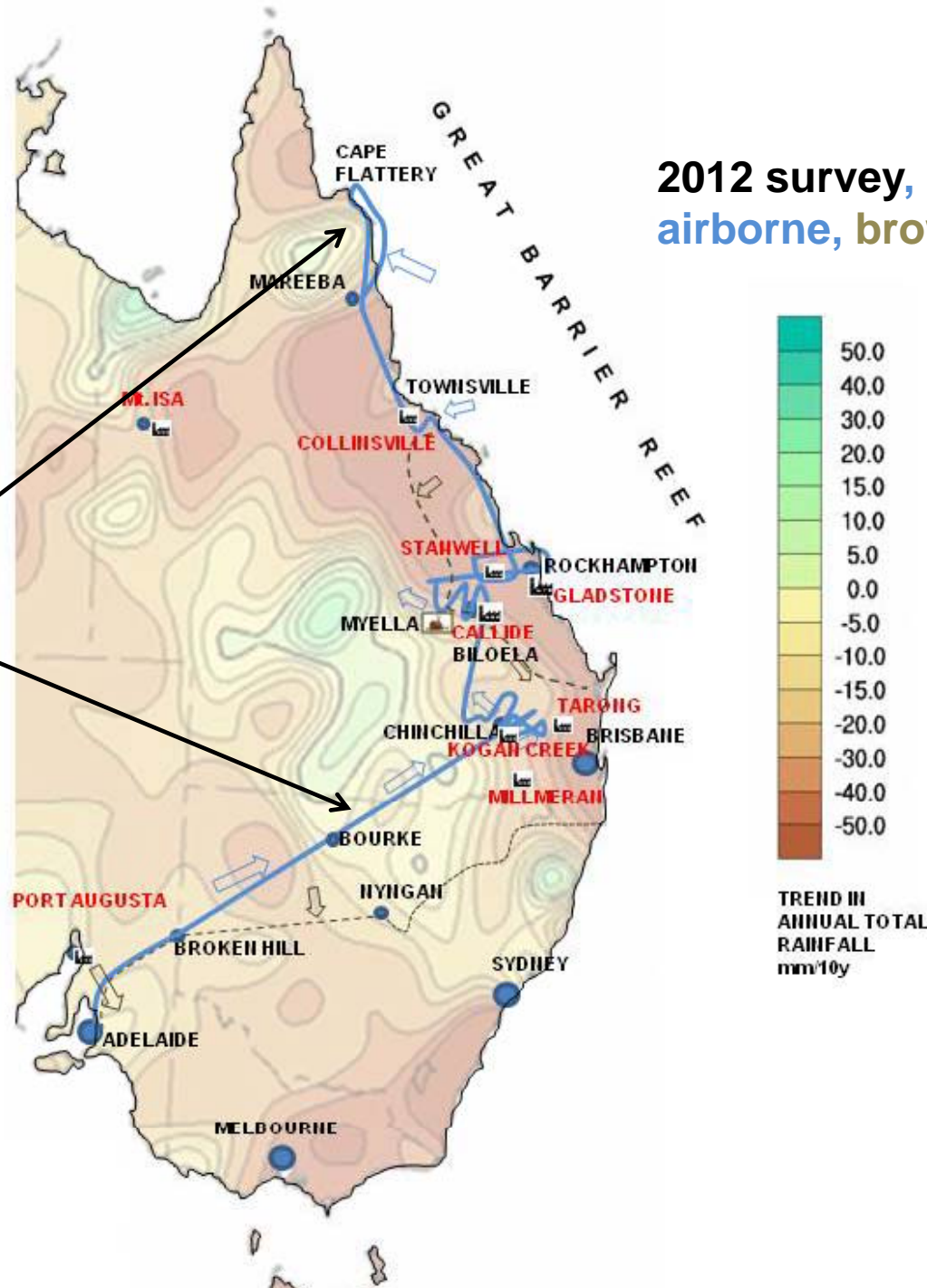




2012 survey, **blue**  
airborne, **brown** vehicle

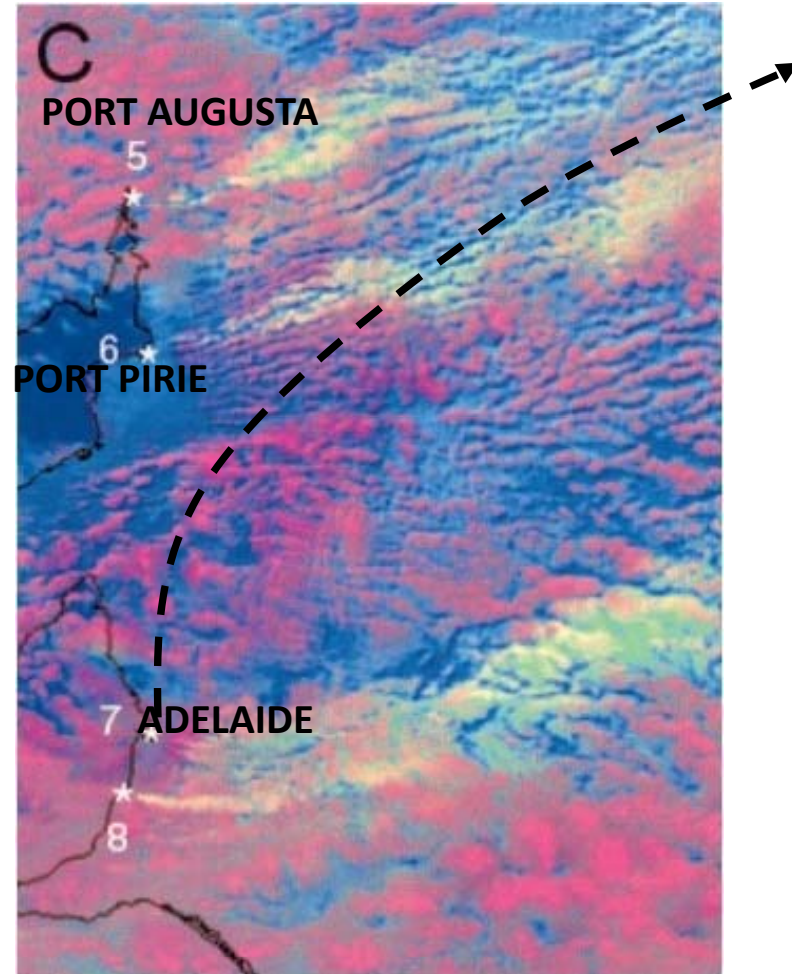
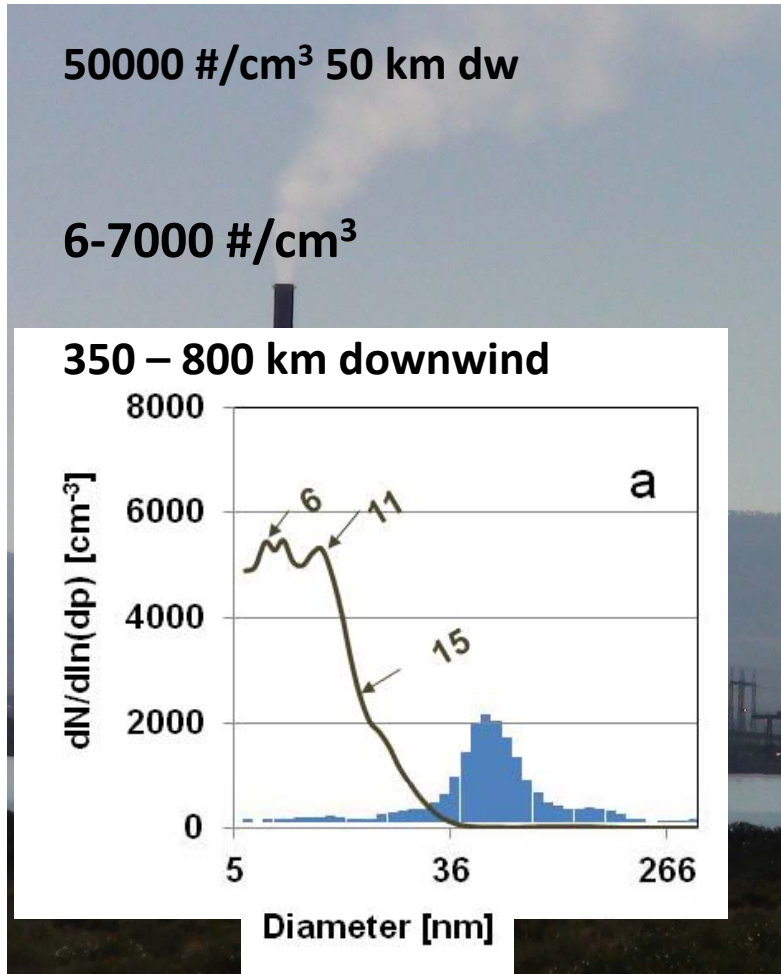
BACKGROUND ?

POWER STATIONS?



PORT AUGUSTA , SA, April  
2011 / Sept. 2012

Daniel Rosenfeld  
*Science* **287**, 1793 (2000):



Visible cloud effects ~ 50 km (2 h) (HYSPLIT)

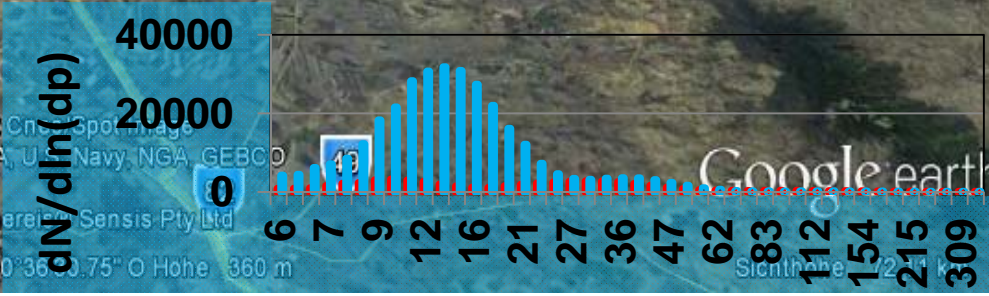






# KOGAN-CREEK, SUNSET

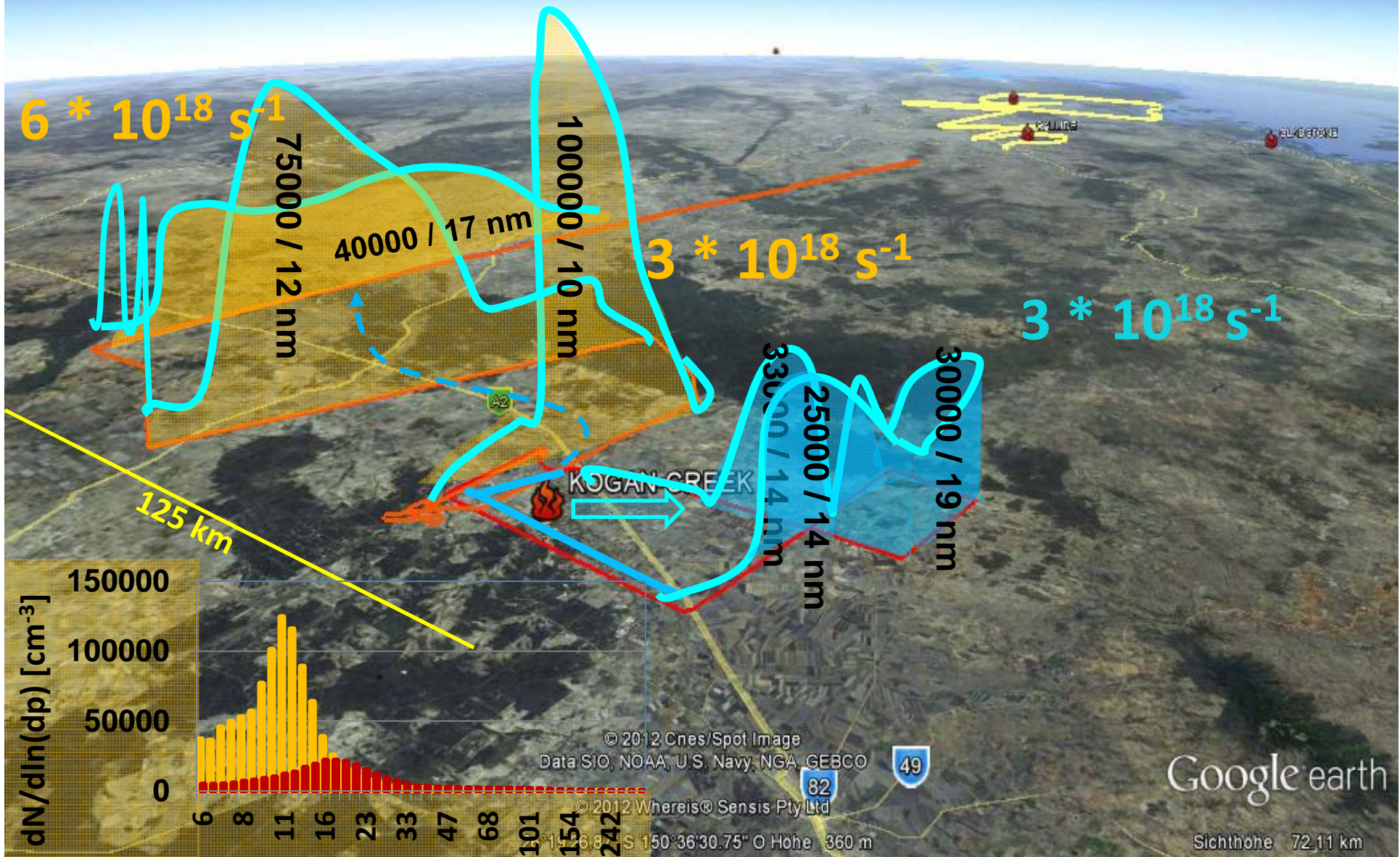
$3 * 10^{18}/\text{sec}$



© 2012 China Spot Image  
 Data SIO, NOAA, U.S. Navy, NGA, GEBCO  
 © 2012 Whereby Sensis Pty Ltd  
 26°19'26.87" S 150°35'0.75" O Hohe 360 m



# KOGAN-CREEK, DAY





$6 * 10^{18}/\text{sec}$

75 nm  
12 nm

HIGH NUMBER OF  
nm PARTICLES AT SUNSET  
> PRIMARY EMISSION

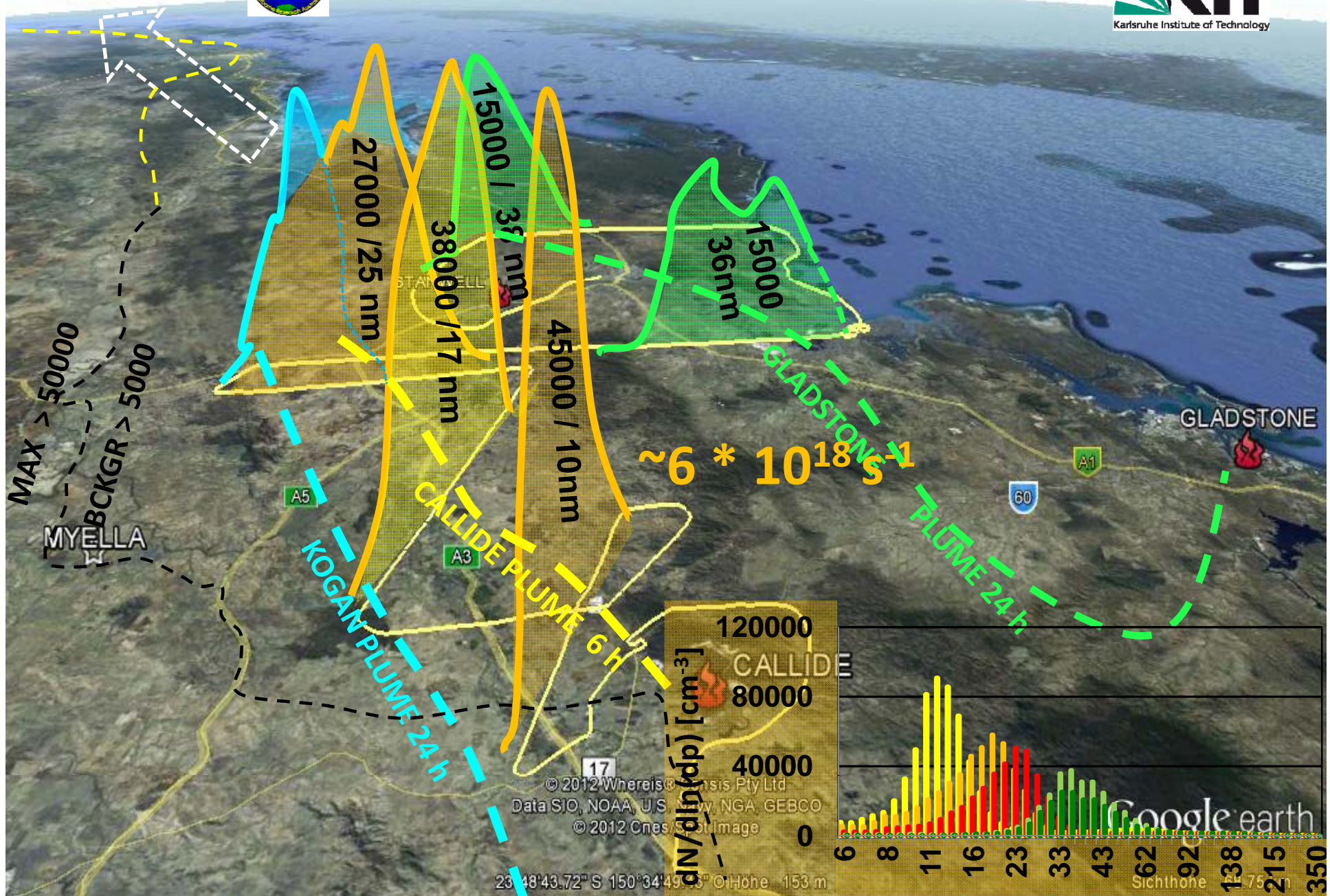
DAYTIME DOWNWIND  
SO<sub>2</sub> OXIDATION AND NPF

$* 10^{18}/\text{sec}$

125 km

4 nm  
nm







**PRIMARY EMISSION  
~ PROPORTIONAL TO  
ENERGY PRODUCTION  
CCN SIZES AFTER ~ 6-10h**

MYELLA

$> 5000 \text{ cm}^{-3}$

6 h  
PLUME 24 h

CALLIDE

GLADSTONE

© 2012 Whereis® Sensis Pty Ltd  
Data SIO, NOAA, U.S. Navy, NGA, GEBCO  
© 2012 Cnes/Spot Image

28°48'43.72" S 150°34'49.46" O Höhe 153 m

Google earth

Sichthöhe 68.75 km

27000 / 2

15000 / 3

38

60

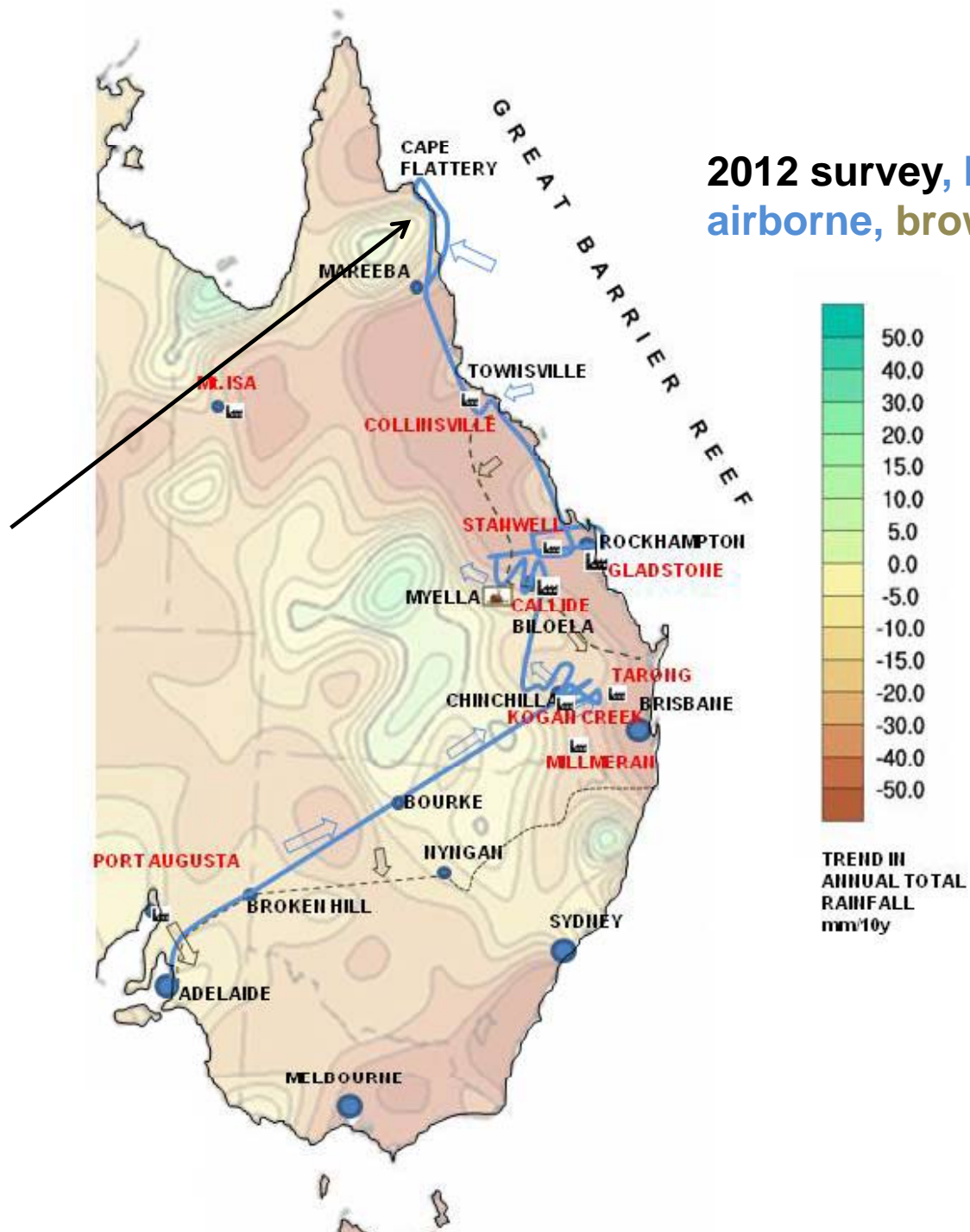
A1

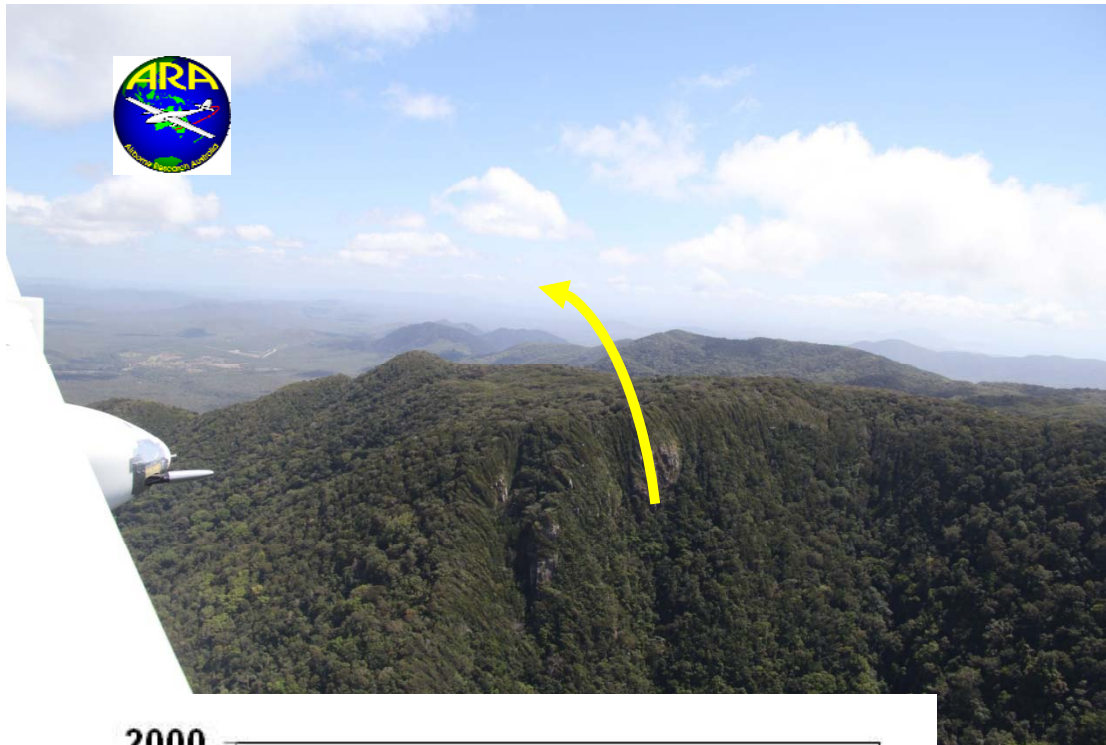
17





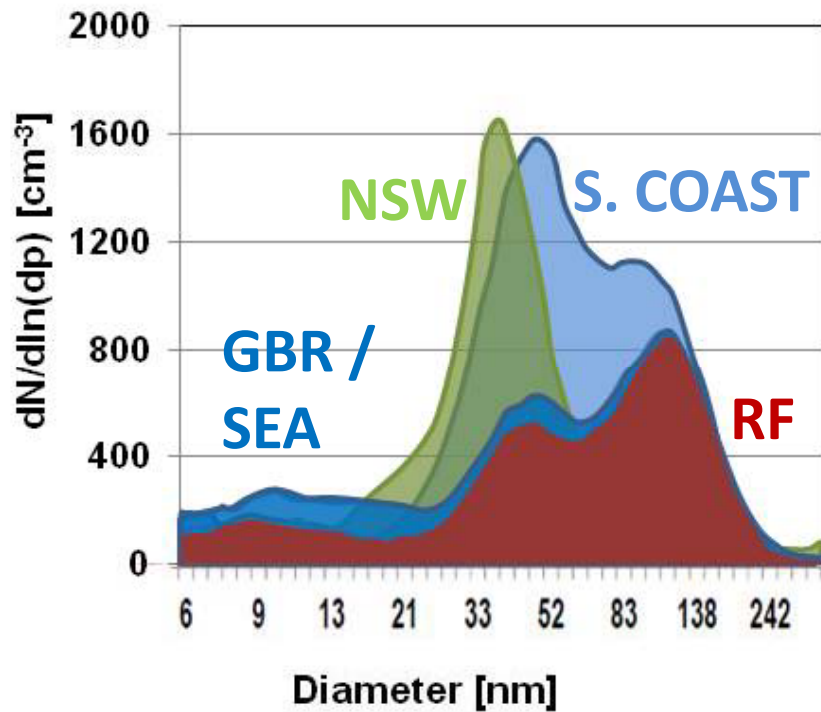
# BACKGROUND





**RAINFOREST 1000 - 1500**  
**GBR / SEA 1300 - 2000**  
**CAPE FLATTERY < 1000**

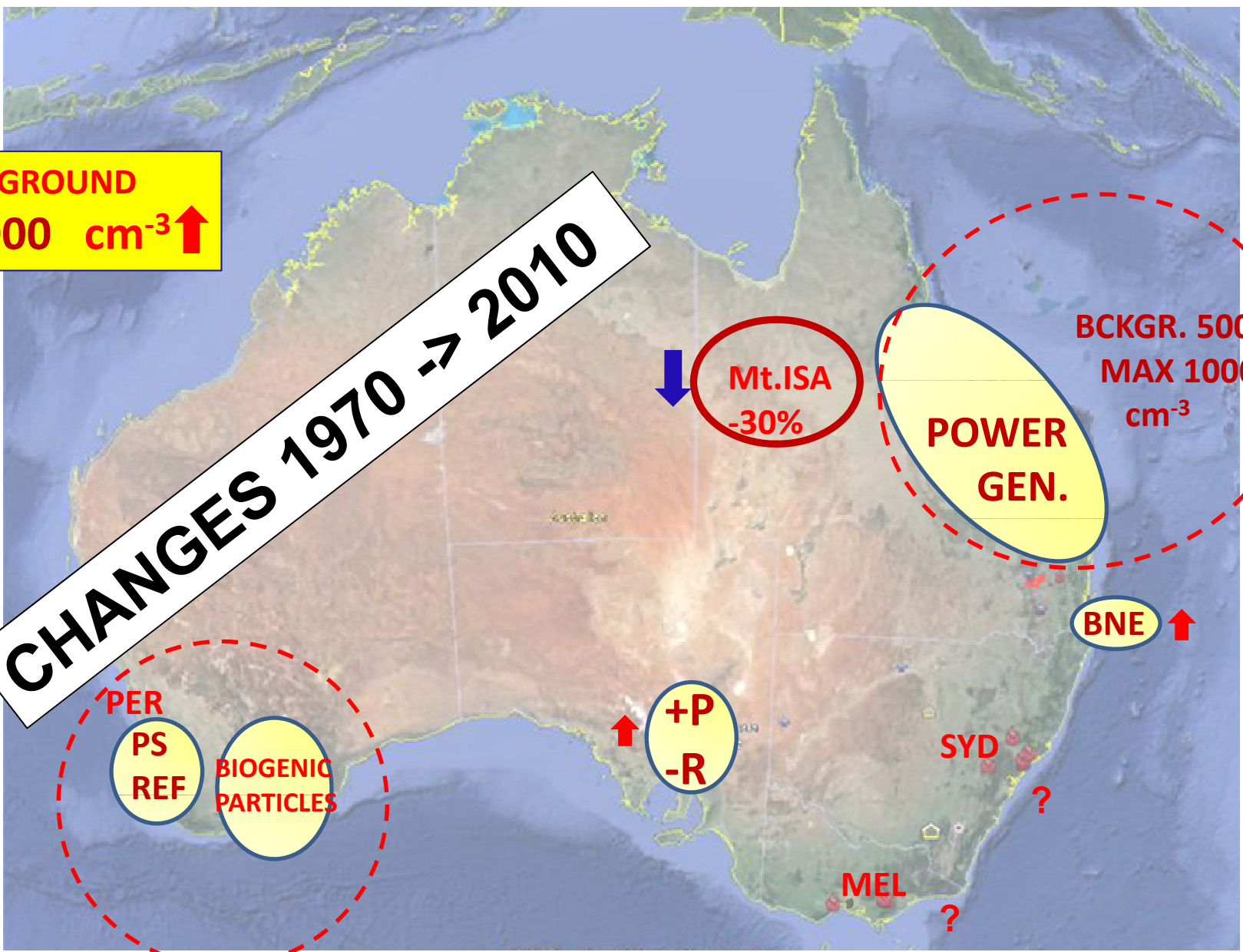
**B&T background 680**





**BACKGROUND**  
~ 1000 cm<sup>-3</sup> ↑

**CHANGES 1970 → 2010**



**Mt. ISA**  
-30%

**POWER GEN.**

**BCKGR. 5000**  
**MAX 100000**  
cm<sup>-3</sup>

**BNE** ↑

**+P**  
**-R** ↑

**PER**  
**PS**  
**REF**

**BIOGENIC**  
**PARTICLES**

**SYD**

**MEL**

?

?

**BACKGROUND**  
**~ 1000 cm<sup>-3</sup>**

**INCREASED BACKGROUND**  
**MAJOR PARTICLE SOURCES NOW IN THE REMOTE OUTBACK**

**CHANGES**

PER  
PS  
REF  
BIOGENIC  
PARTICLES

**+P**  
**-R**

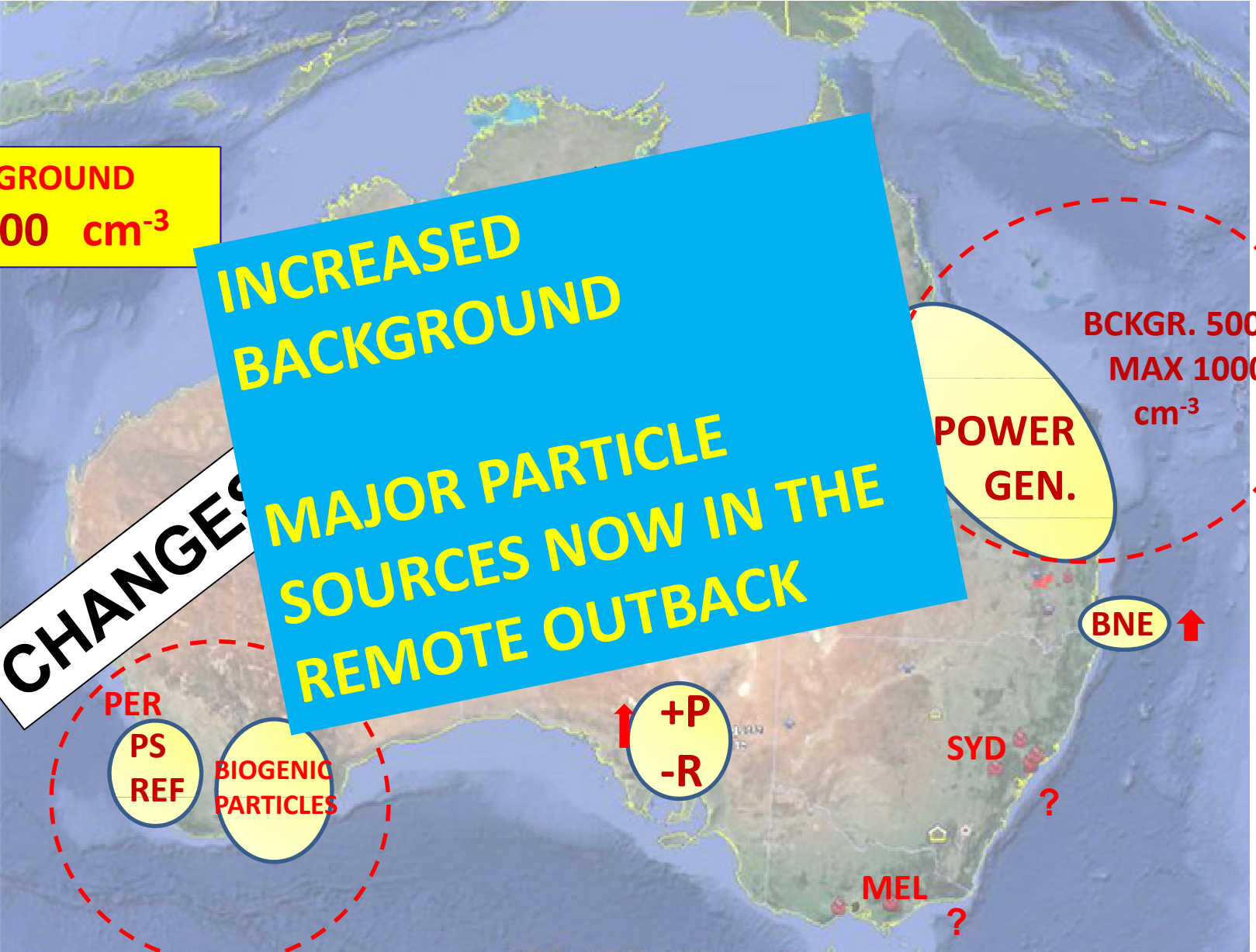
**POWER GEN.**

**BCKGR. 5000**  
**MAX 100000**  
**cm<sup>-3</sup>**

**BNE** ↑

**SYD**

**MEL**







# ***SUMMARY***



## **Major sources**

- anthropogenic**
- in remote areas with negative rainfall trends.**

**CLOUD RELEVANT (D.R.)**

**SUFF. FOR REGIONAL CCN INCREASE**

**TIMING AGREES WITH RAINFALL TRENDS**

**QLD - 'NATURAL SMOG CHAMBER'**

**'LAB NOTEBOOK' CAN BE REWRITTEN**





# ***SUMMARY***



**Major sources similar to B&T, 1978**  
**Significant change 1970 – 2010, 10 new units**

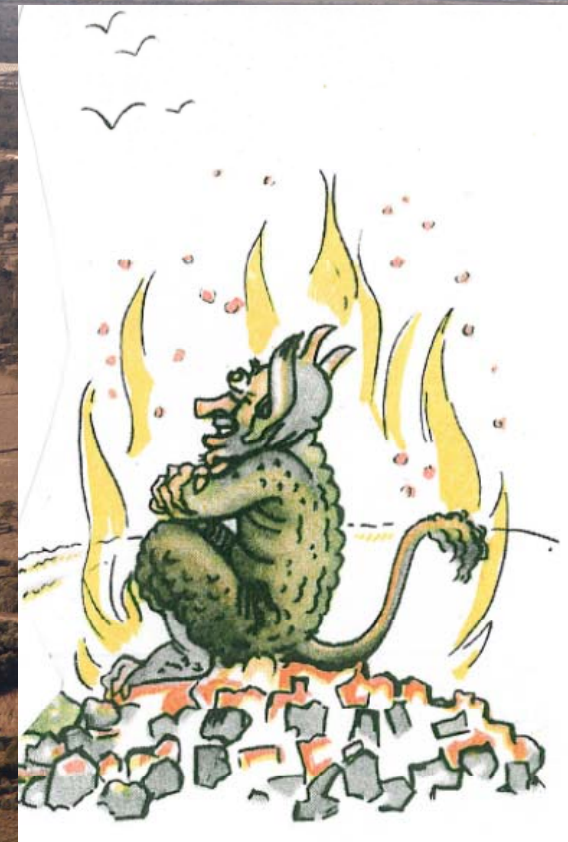
**Experimental evidence?**







***THANK YOU FOR YOUR ATTENTION***

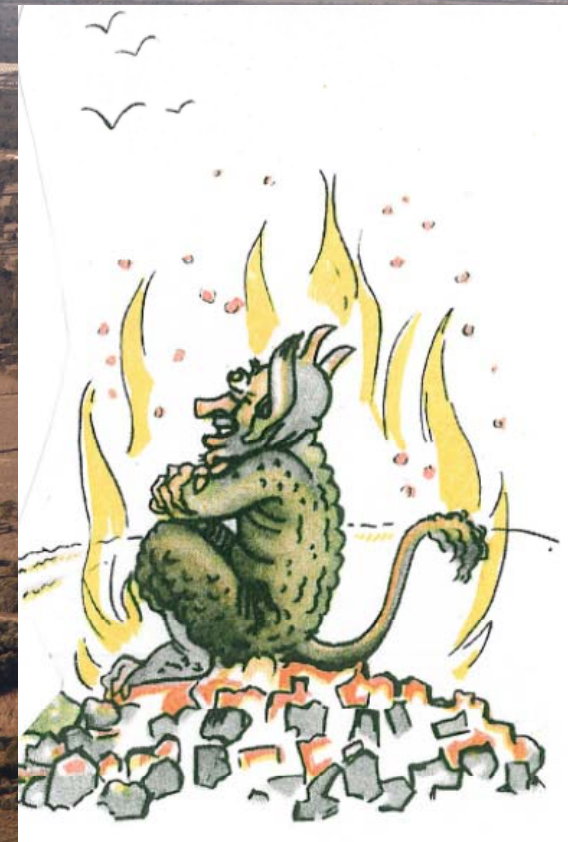






**THANKS TO**  
NRG, Rio Tinto, CS Energy, Stanwell Corporation...  
**FOR PROVIDING THE AEROSOL FOR THE**  
**EXPERIMENT**

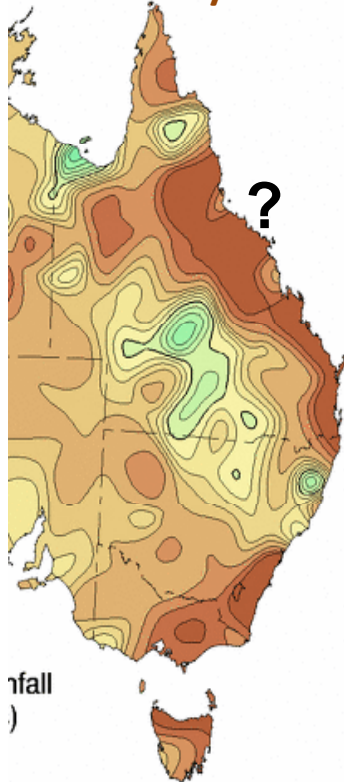
e



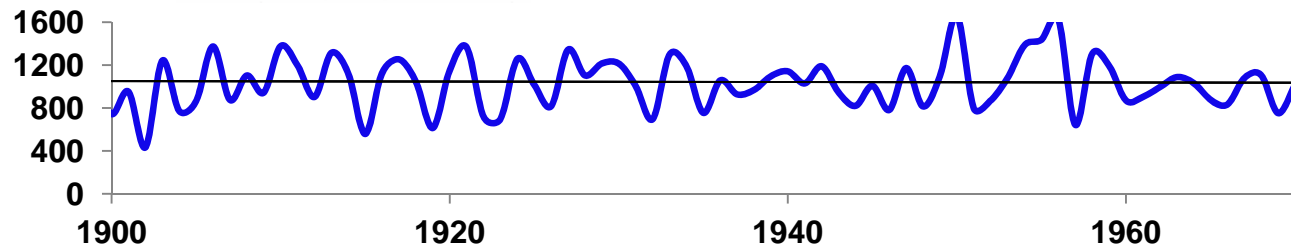
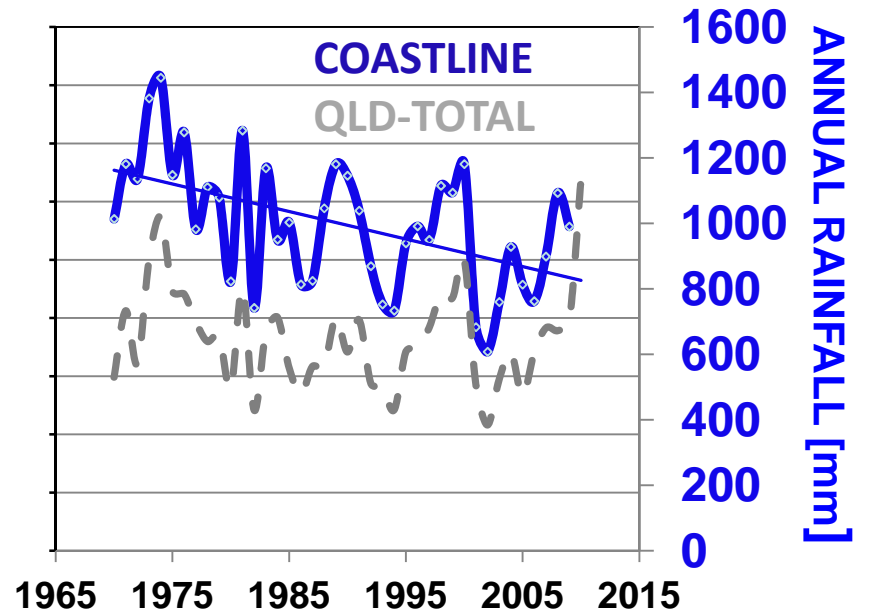
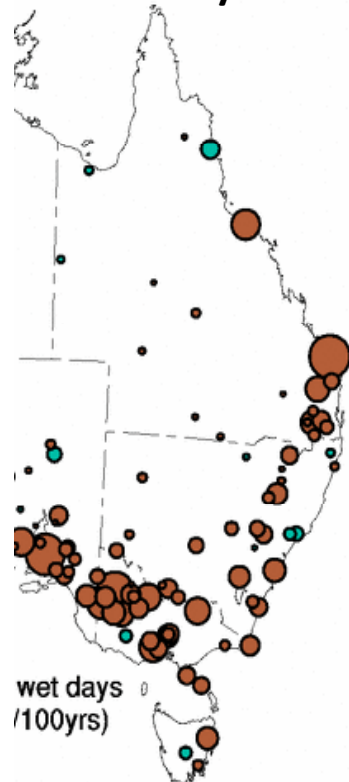


# RAINFALL CHANGE, EASTERN AUSTRALIA, 1970-2010

**RAINFALL**  
- 40 mm / dec



**# OF WET DAYS**  
- 6-8 d / dec



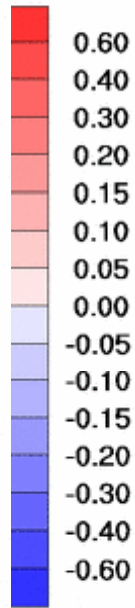
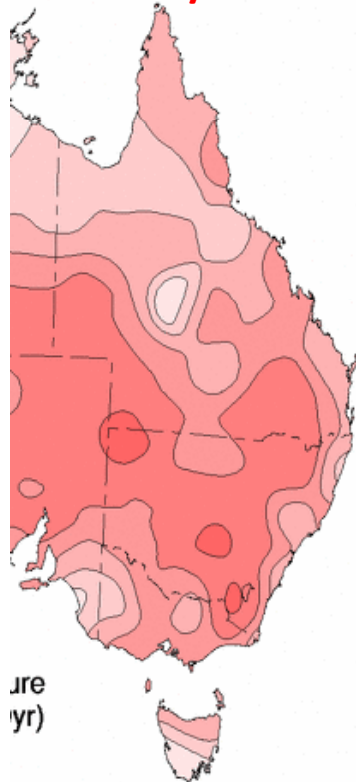




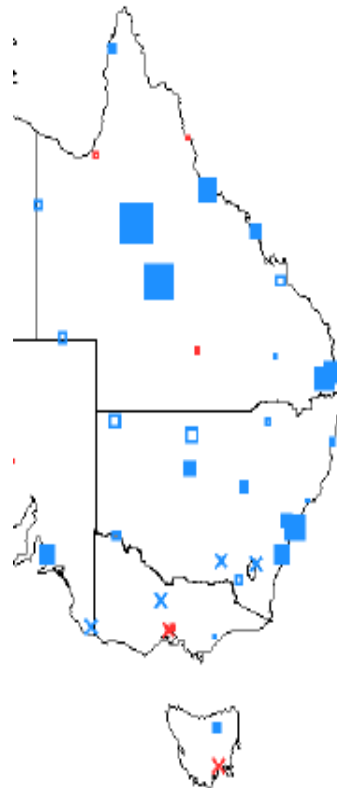


# REGIONAL CLIMATE CHANGE IN AUSTRALIA, 1970-2010

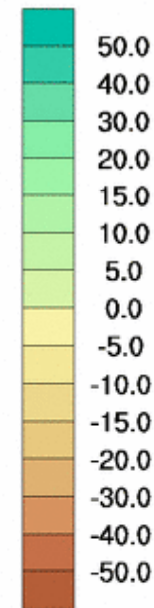
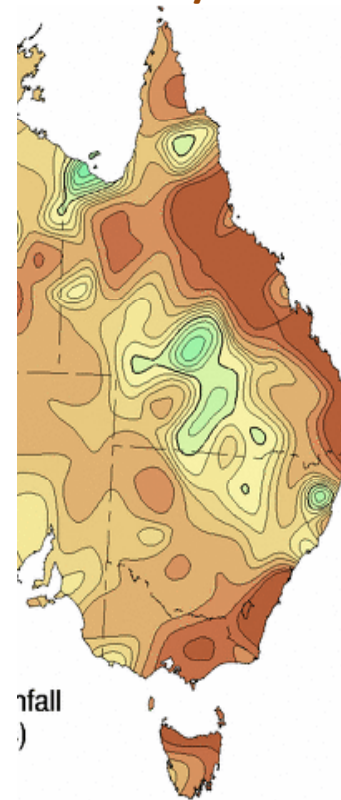
**TEMPERATURE**  
**+ 0.2 ° / dec**



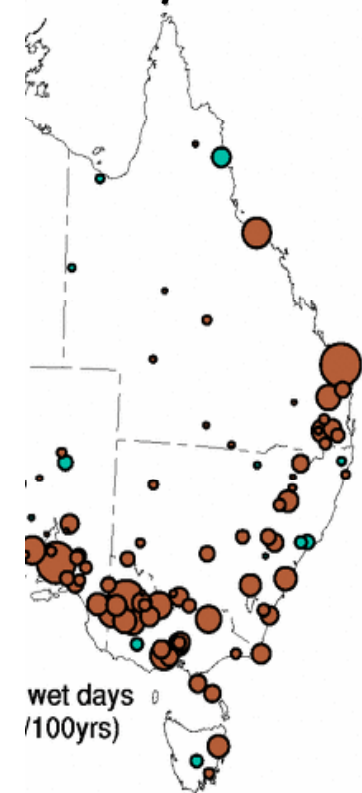
**DEWPOINT**  
**+0.25 ° / dec**



**RAINFALL**  
**- 40 mm / dec**



**# OF WET DAYS**  
**- 6-8 d / dec**



re  
yr)

nfall  
)

wet days  
(100yrs)



# CLOUD DROPLET SIZE DISTRIBUTION

300 ft above cloud base

base  $\leftrightarrow$  top  $\sim$  1200 ft

DEWPOINT BELOW CLOUD 8 °C

AGRICULTURE

DEWPOINT BELOW CLOUD 6 °C

NATIVE VEG.

