



# THE SOUTH AFRICAN EXPERIENCE IN RAINFALL ENHANCEMENT IN A GLOBAL CONTEXT

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# OUTLINE

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- Water Resources
  - Conflict or cooperation?
- Rainfall formation
  - Inefficiencies, convective storms
  - Continental versus maritime clouds
- Hygroscopic Flare Technology
  - The Hygroscopic flare
  - Physical studies
  - Modeling studies
  - Statistical studies
  - Logistical studies
  - Sustainability
- Conclusions



## WATER RESOURCES CONFLICT OR COOPERATION?

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“When increasing numbers of people must share freshwater, there is a heightened risk of conflict between individuals, interest groups and even countries”

“The total number of water-related events between nations, are weighted towards cooperation: 507 conflict-related events, versus 1,228 cooperative ones, implying that violence over water is not strategically rational, effective or economically viable”

UNESCO, 2005

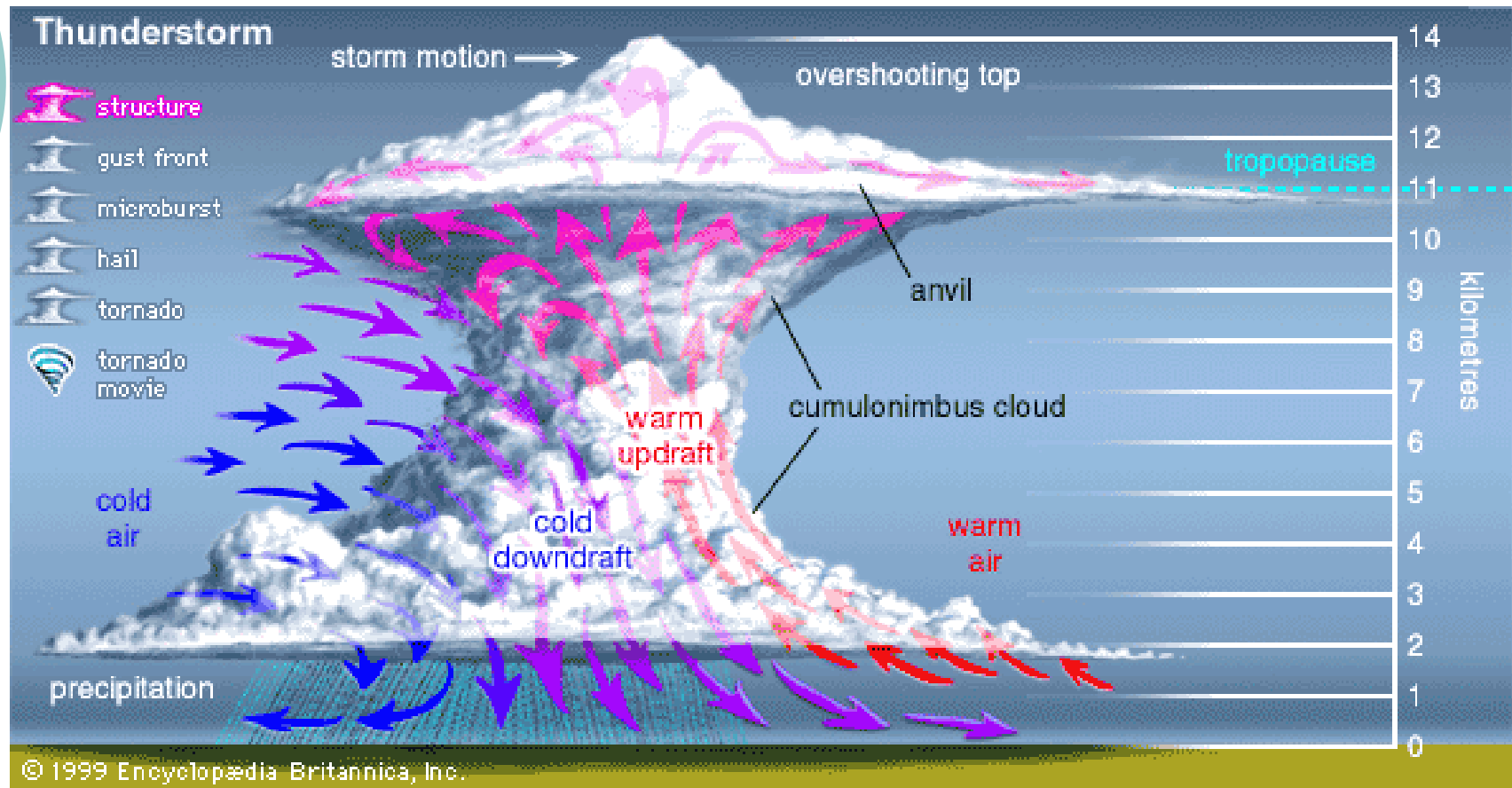


## RAINFALL FORMATION INEFFICIENCIES

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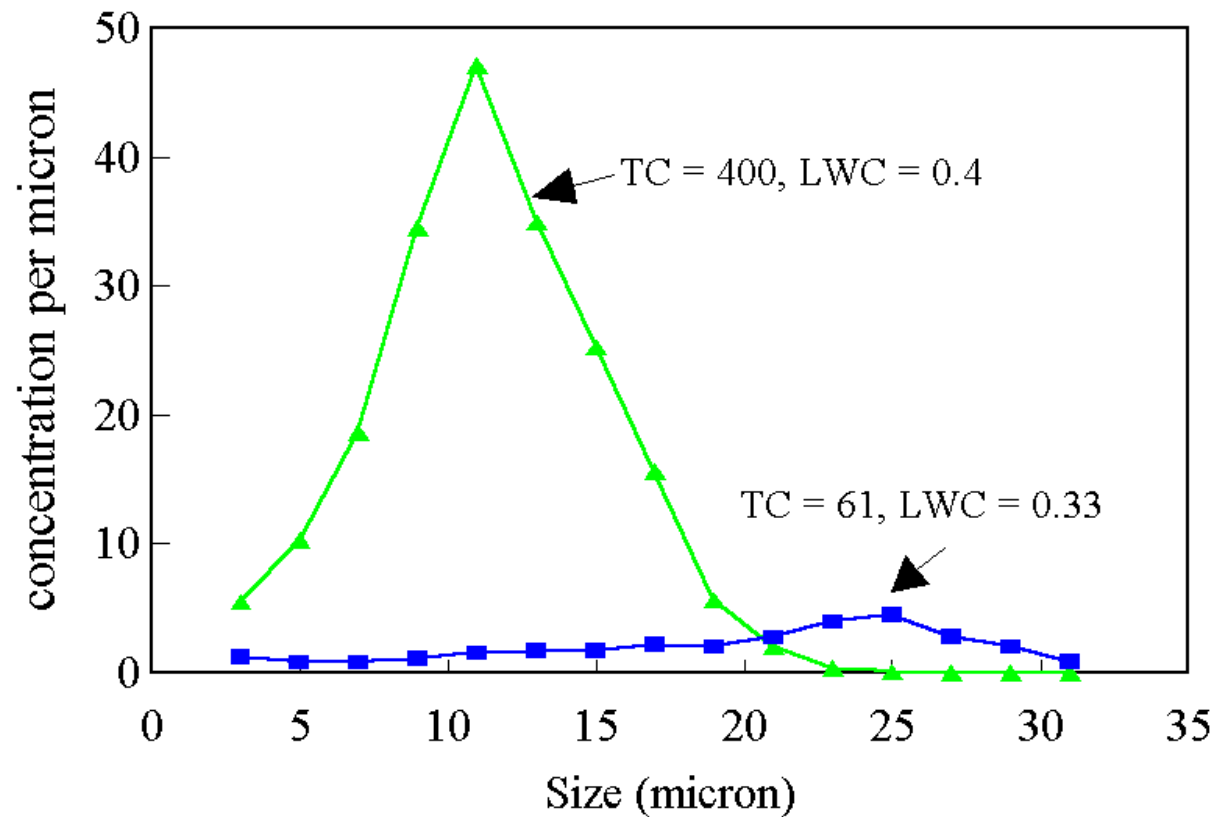
- o Only 10% of moisture transported across South Africa falls out as rain
- o A large percentage of the annual rainfall is produced by convective storms
- o A convective storm converts only ~30% of the moisture ingested into rainfall
- o In the updrafts of moist air at the bases of these storms each drop condenses on a aerosol particle known as a Cloud Condensation Nucleus (CCN).

# RAINFALL FORMATION CONVECTIVE STORMS



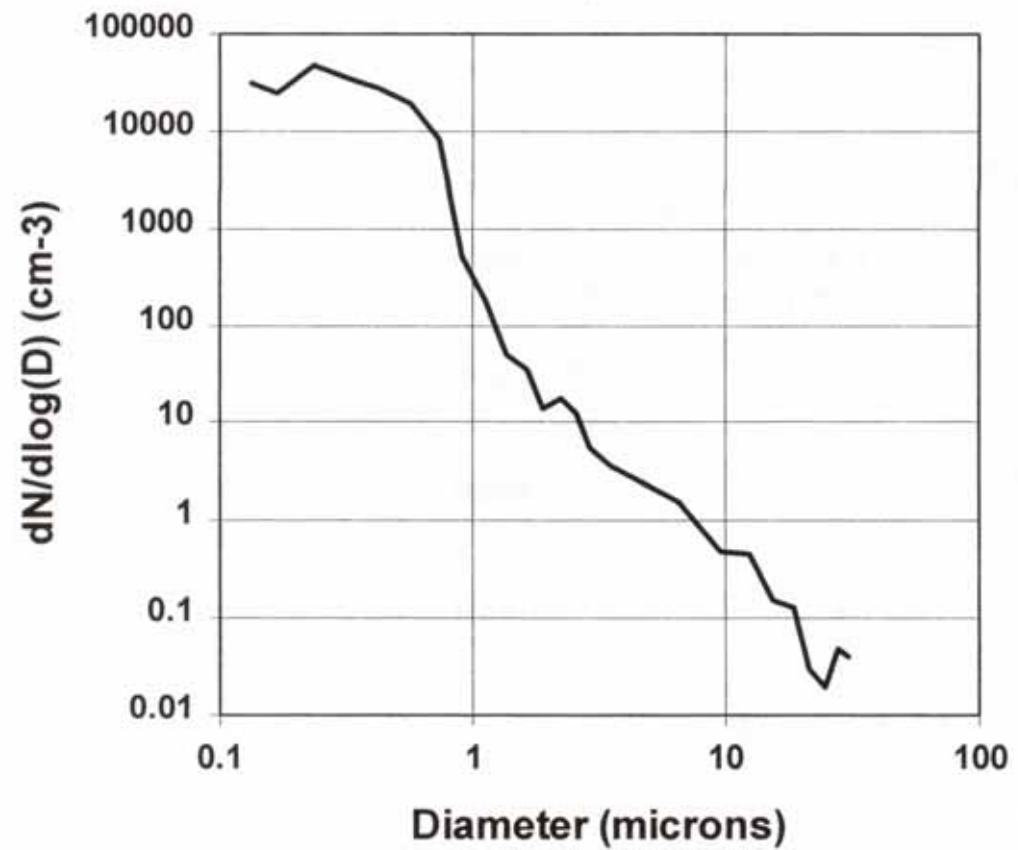
# RAINFALL FORMATION CONTINENTAL VERSUS MARITIME CLOUDS

## Cloud Droplet Spectra



—▲— continental —■— marine

# THE HYGROSCOPIC FLARE



## THE HYGROSCOPIC FLARE

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100 $\mu$ m

# INFRASTRUCTURE RESEARCH / SEEDING AIRCRAFT

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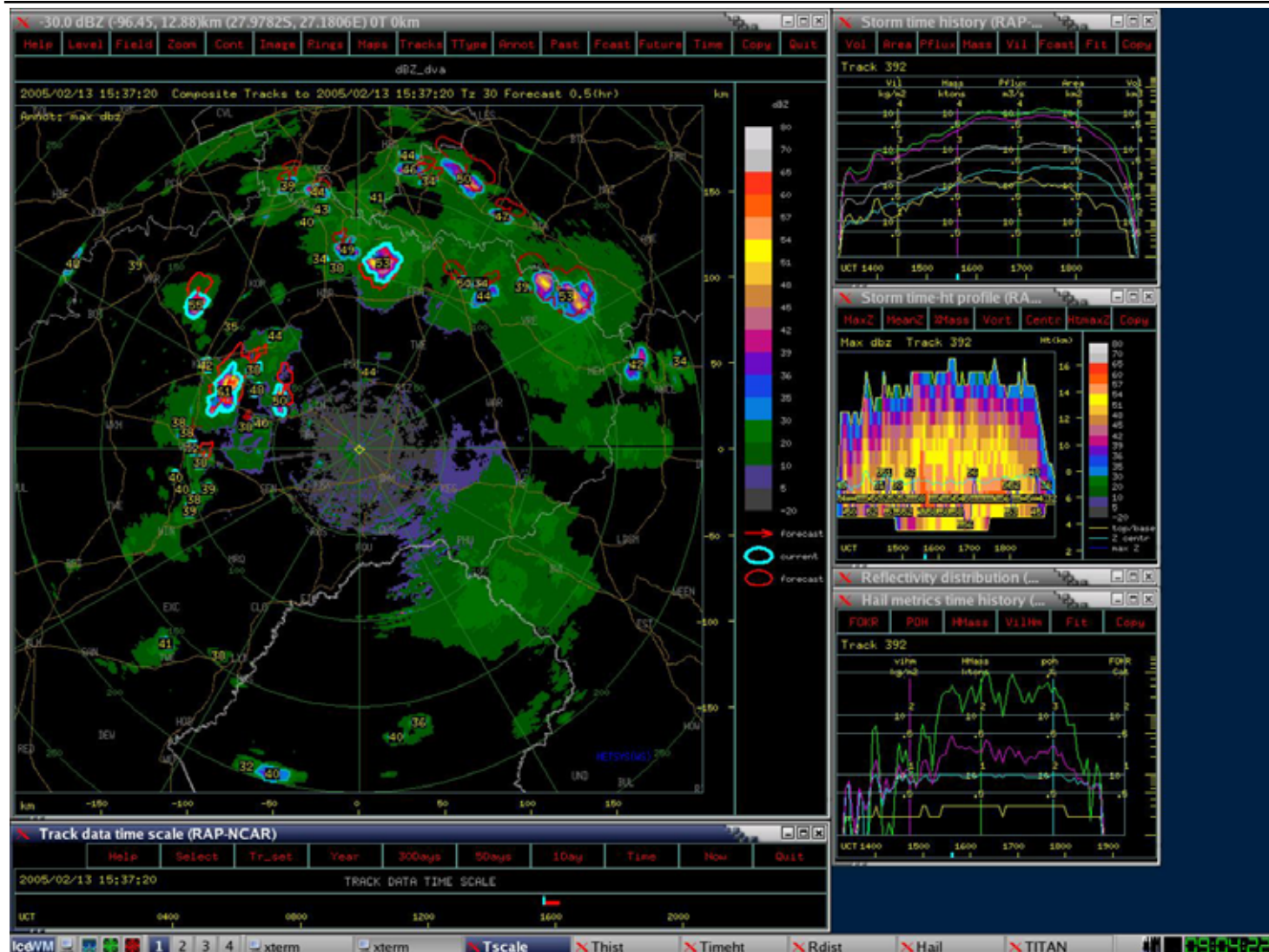


# INFRASTRUCTURE WEATHER RADAR

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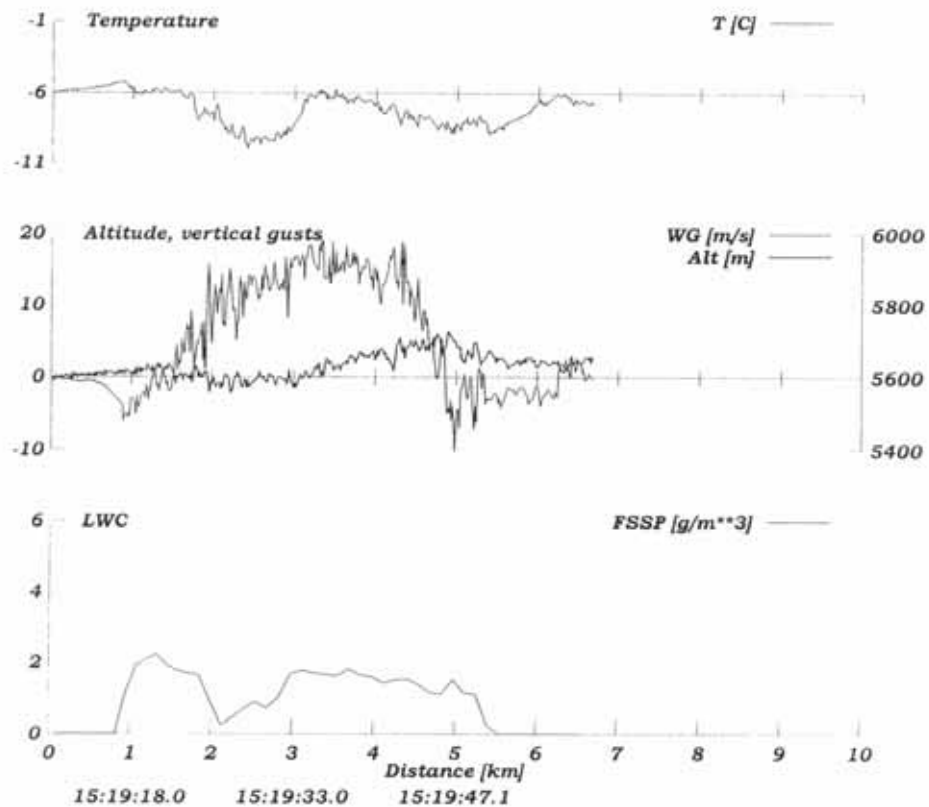
# INFRASTRUCTURE WEATHER RADAR DATA PROCESSING



# PHYSICAL STUDIES

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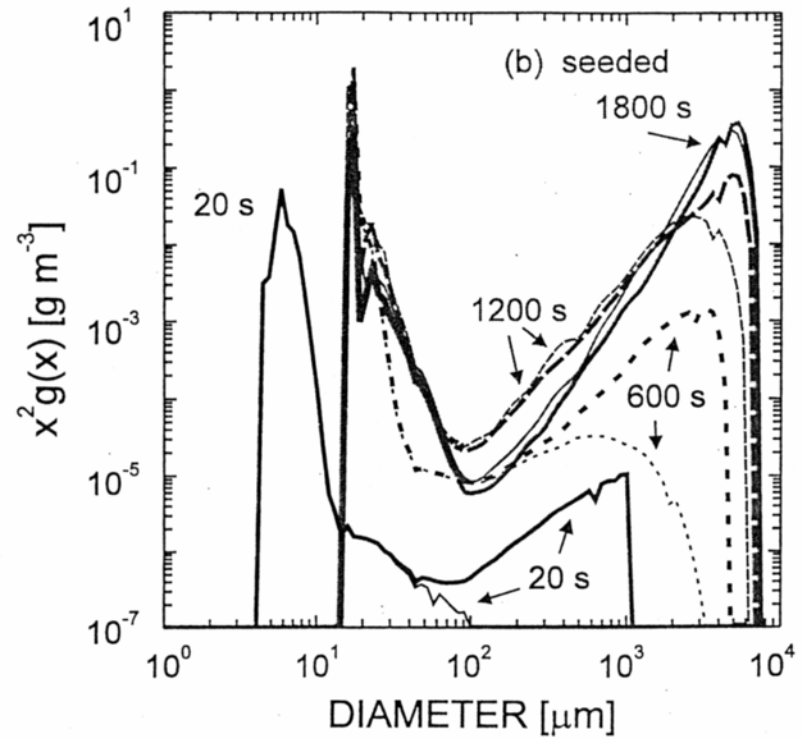
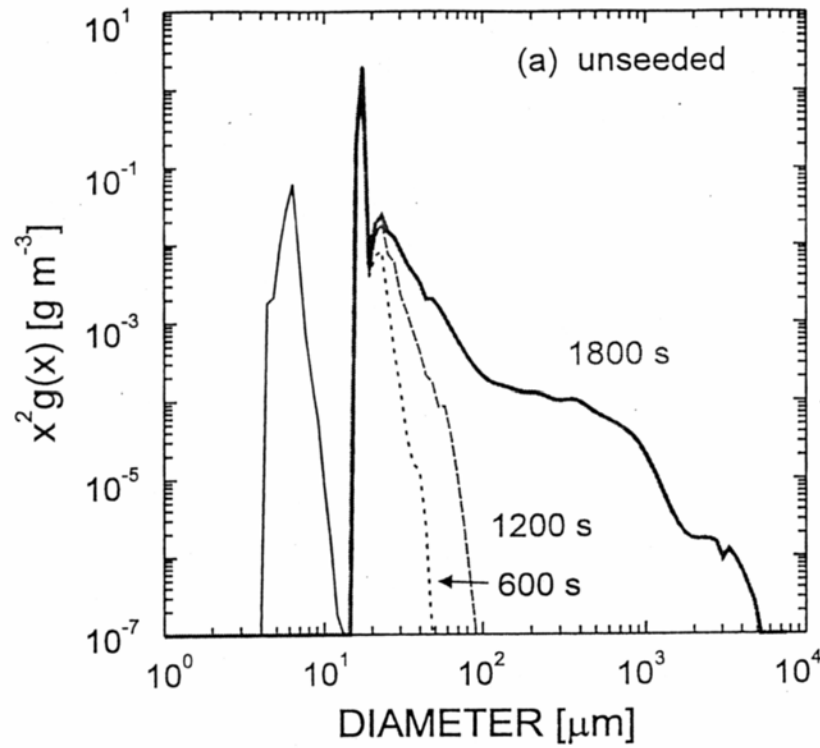




CloudQuest ODAS Images  
 Date : 29/Mar/94 Tape nr : 1 2D Type :2D-P Flightnum : Runtime : 30/11/96 11:06:30  
 Aircraft :LTE Version :2.20 2D rec : 010 File : 15:19:10

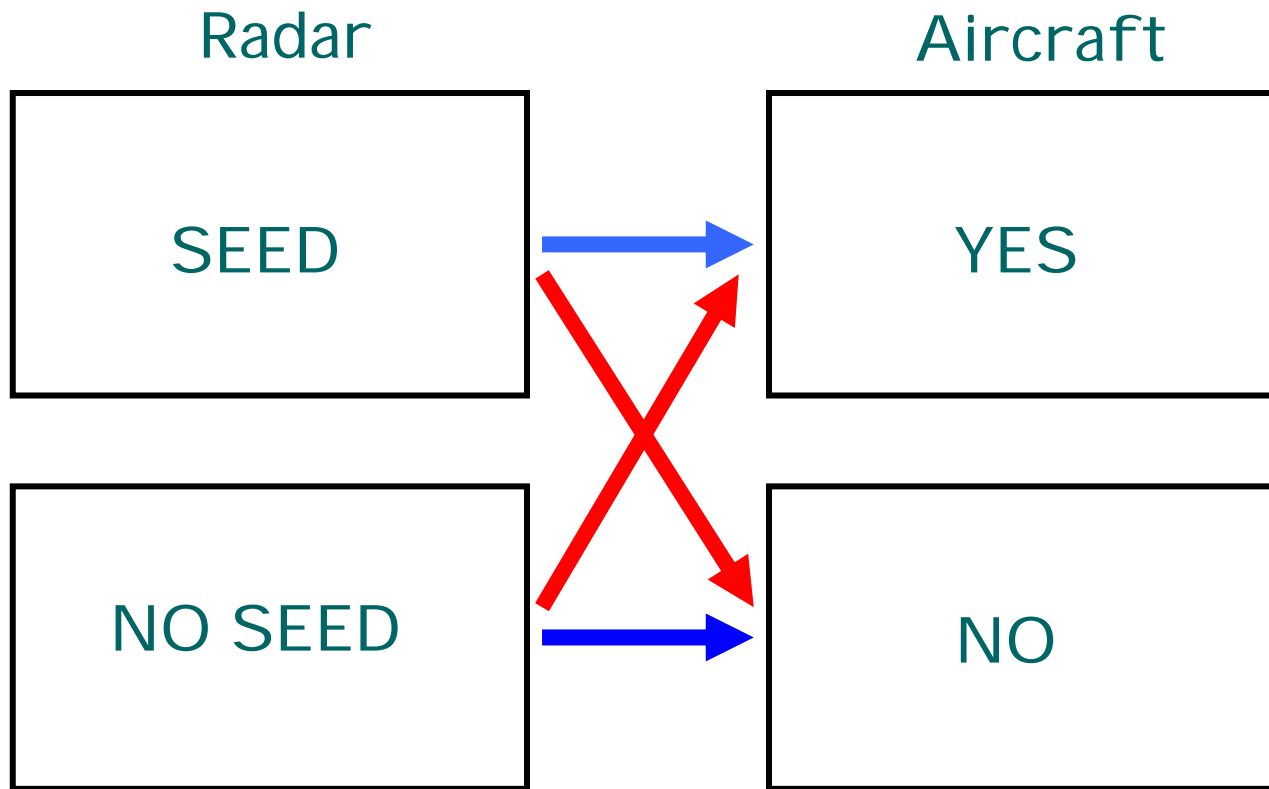
Stop Time	Elapsed Time (ms)	Sample Vol (lit)	Overload	Streaker	Zero	Valid	Gap	Truncated
15:19:37.00	1620	388.2	0	3	20	50	4	0
15:19:38.00	774	176.4	0	2	31	26	6	0
15:19:39.00	695	150.7	0	6	22	37	4	0
15:19:39.00	406	89.6	0	7	45	23	13	0
15:19:41.00	1274	272.5	0	6	24	45	6	0
15:19:43.00	2522	540.1	0	5	26	44	7	0

# MODELLING STUDIES

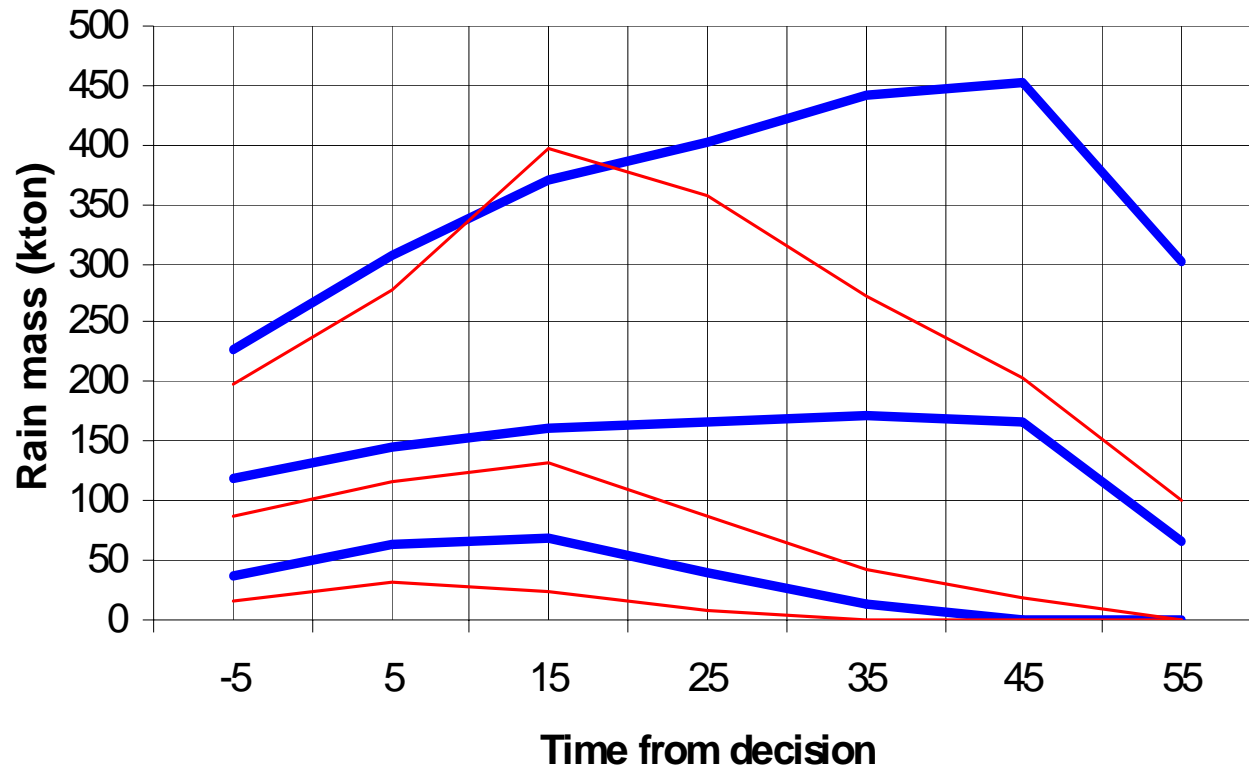


# STATISTICAL STUDIES

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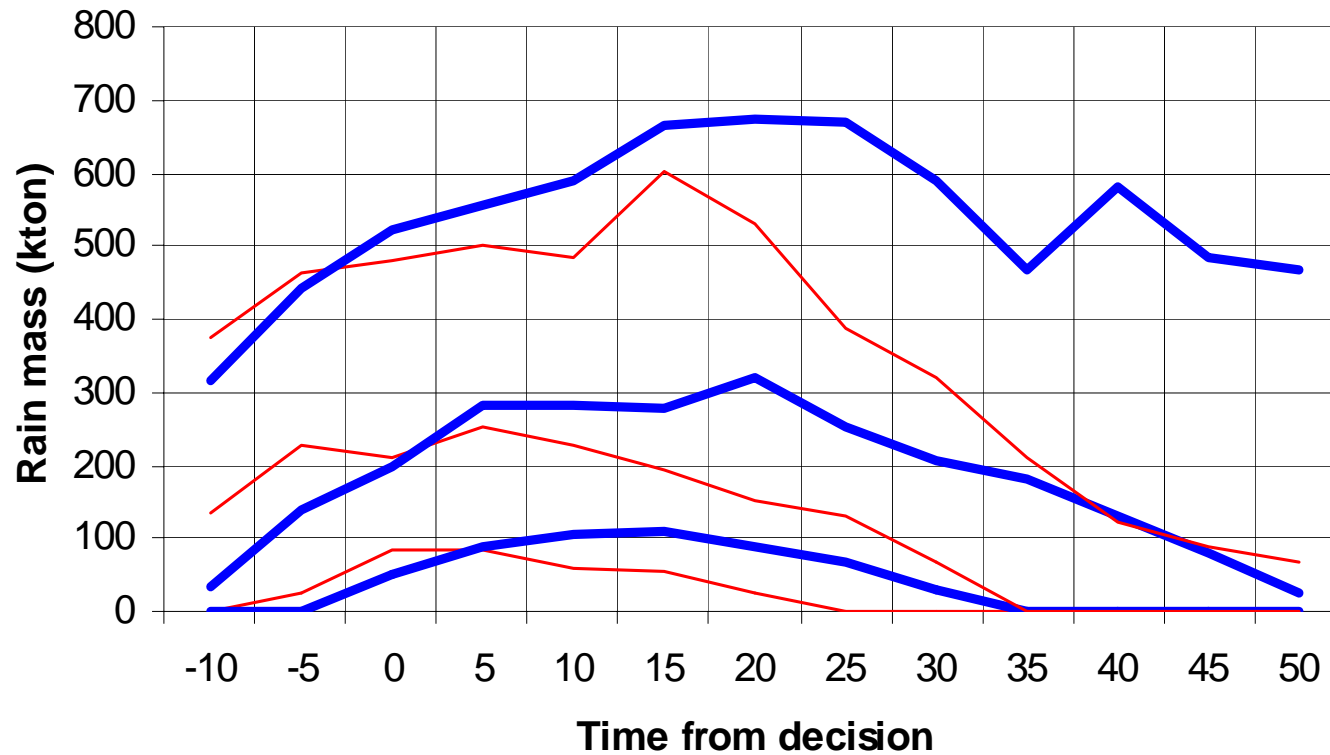


# STATISTICAL STUDIES



South African randomized experiment, Journal Applied Meteorology 1997

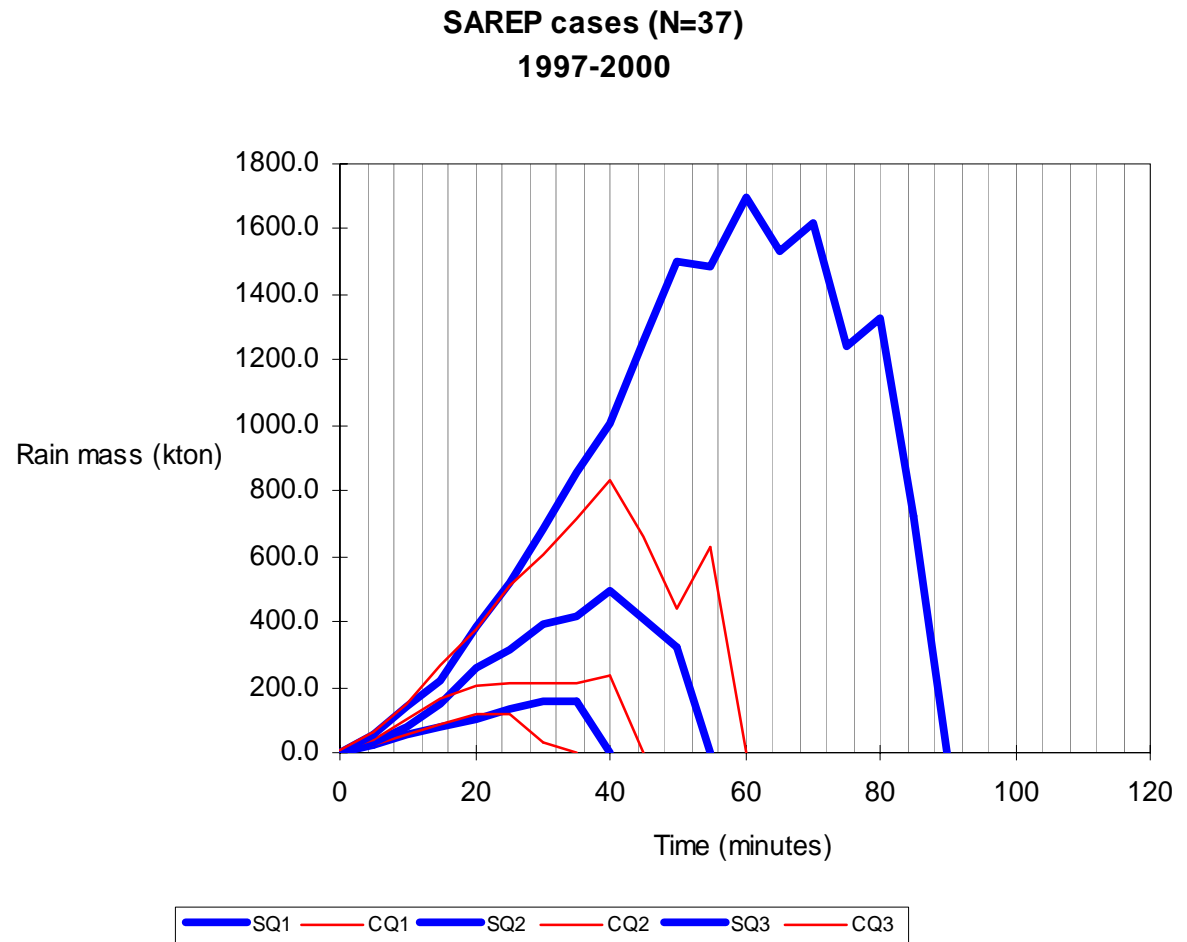
# STATISTICAL STUDIES



Mexican randomized experiment, World Meteorological Organization, 1999

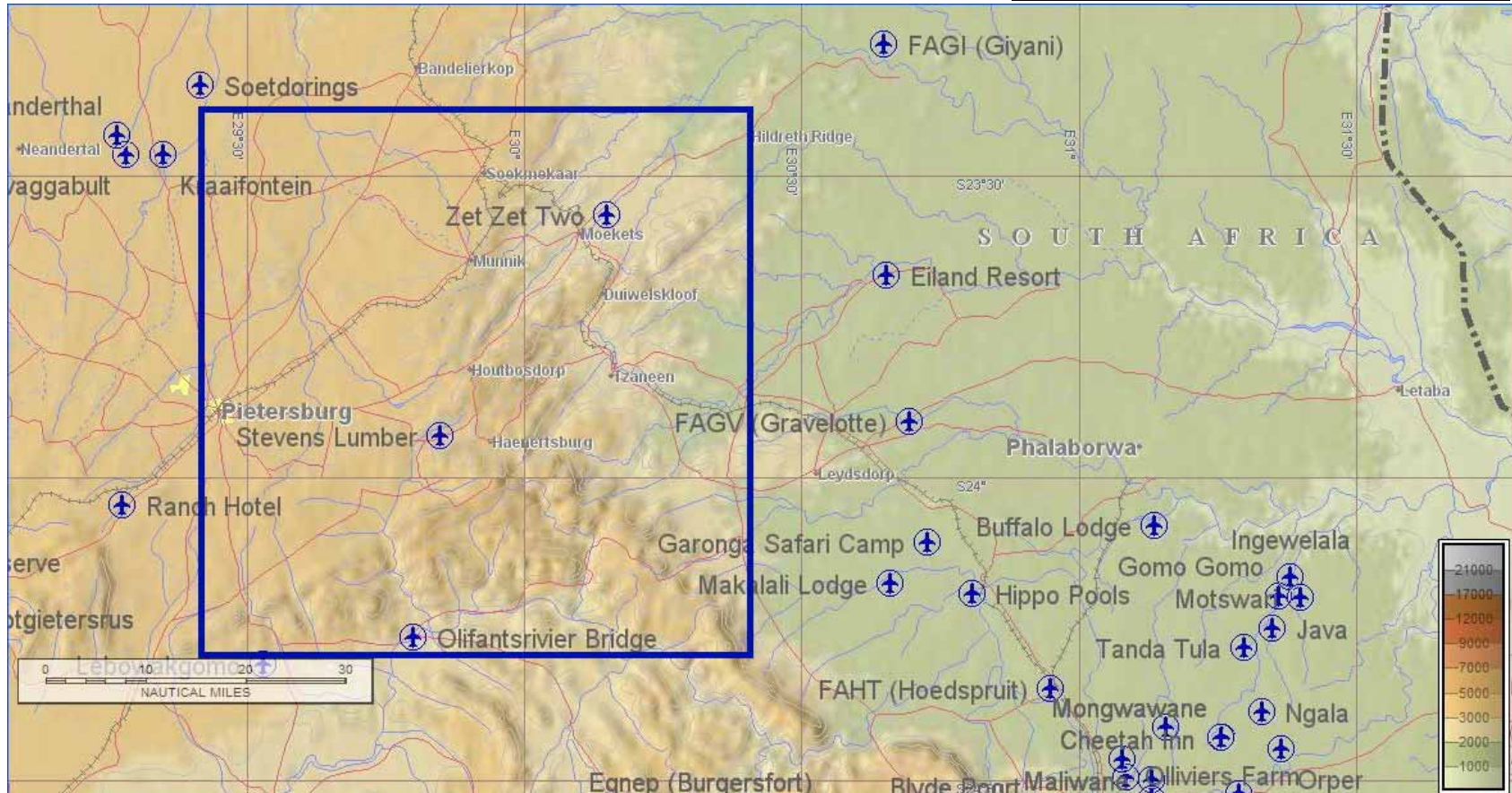
# STATISTICAL STUDIES

- An average doubling in rain mass on storm scale
- For the 37 storms analyzed it amounts to about  $296 \times 10^6 \text{ m}^3$  of additional rainfall
- a cost of R0.04 per  $\text{m}^3$



SAREP, Water SA, 2005

# SAREP TARGET AREA





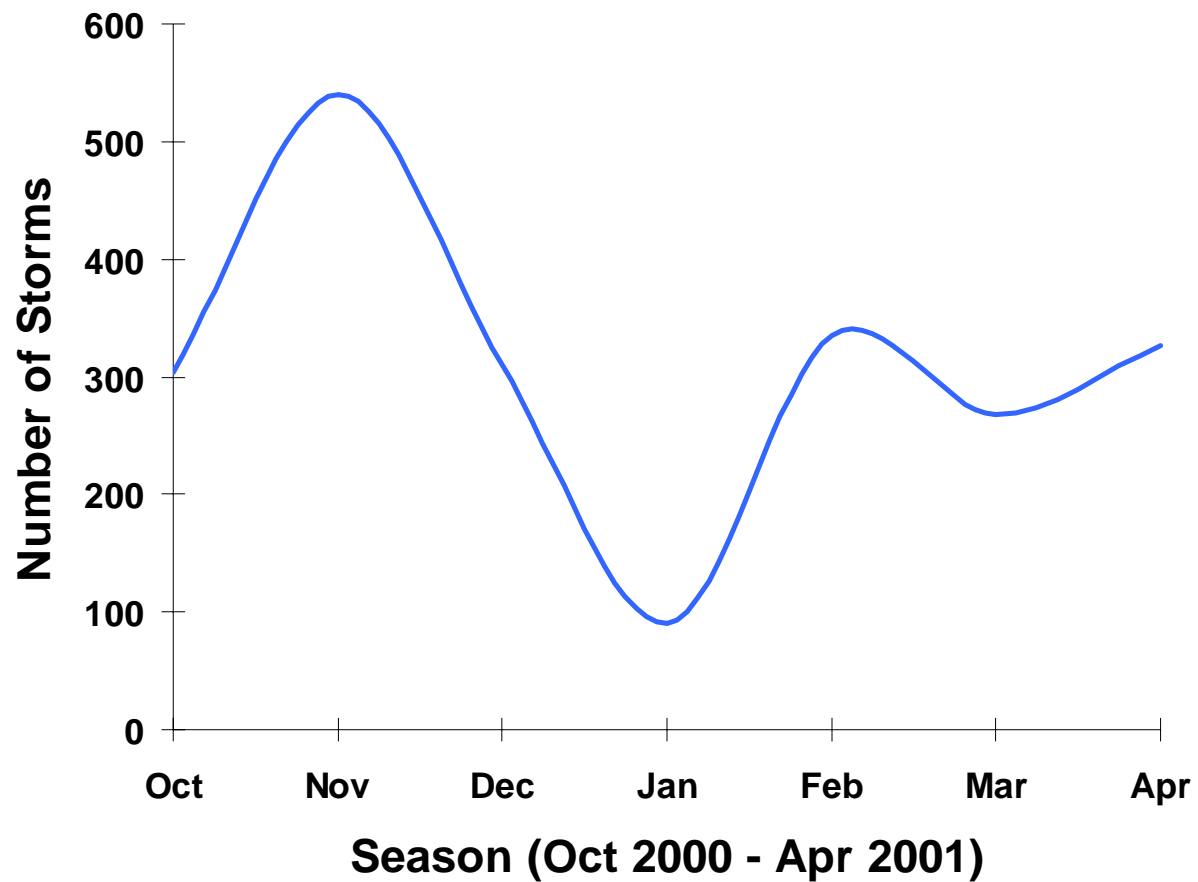
## STORM CLIMATOLOGY

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- The seeded SAREP storm on average produced about  $16 \times 10^6$  ton of rainfall compared to the  $8 \times 10^6$  tons of the controls
- One of the treated storms will be required to produce an additional 0.8 mm on average over the target area
- Therefore if the seasonal rainfall of the target area amounts to 600 mm, 75 seeded storms would produce a 10% increase in area rainfall

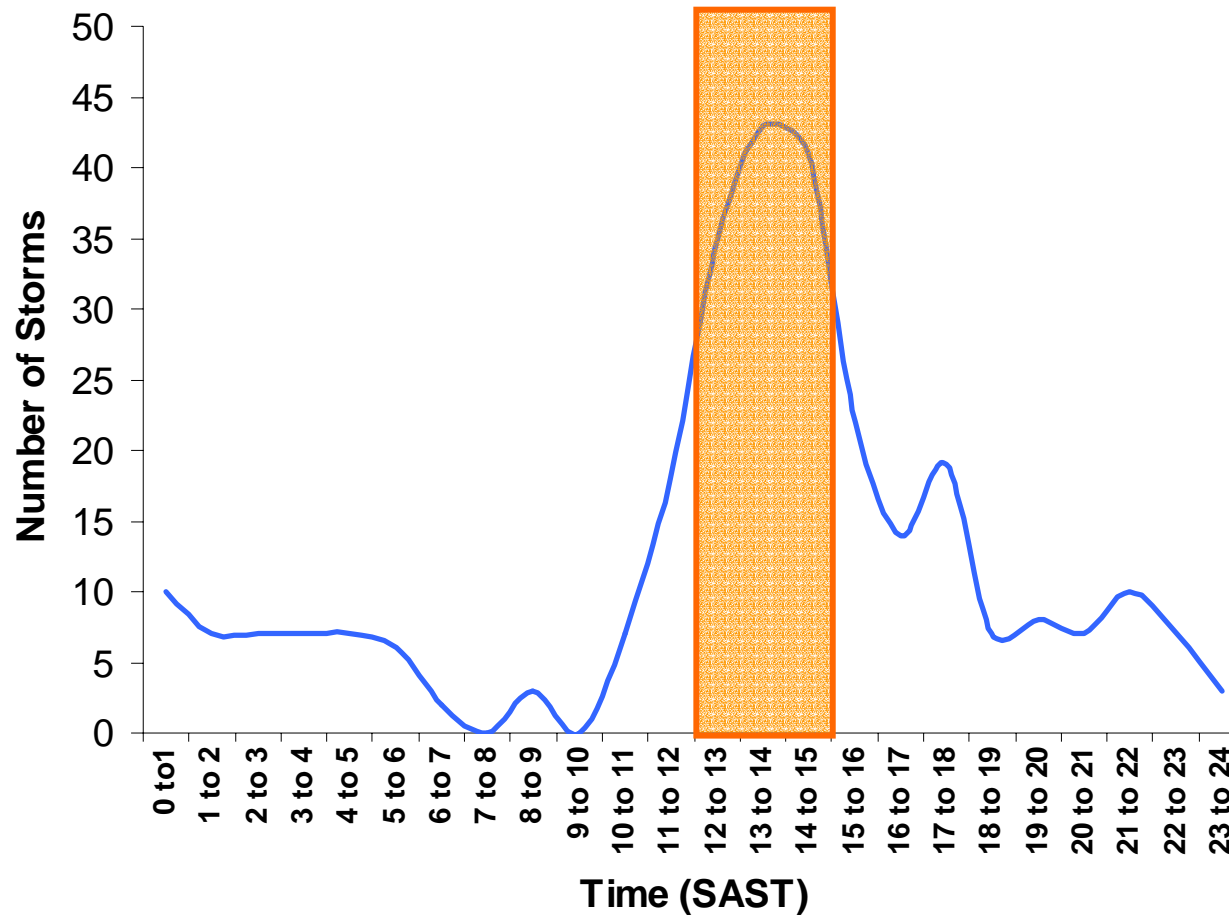
# STORM CLIMATOLOGY

2174 storm tracks



# STORM CLIMATOLOGY

290 "legitimate" seeding candidates



## NEW DELIVERY METHODS





## Three pillars of Sustainable development

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## Economic

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- In the Bethlehem-Nelspruit corridor, the simulated average median increase in mean annual runoff (MAR) due to seeding was 32%, while the equivalent increase in annual water yield for a one-MAR capacity dam was 27%.
- The average median increase in timber yield for the thirteen catchments was modelled to be 22%.

(Howard and Görgens, 1994).



## Social

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- Working within the context of local legislative frameworks and norms
- Involving communities
- Placing people and their needs first
- Communication
- Climate change and people



## Environment

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- Environment impacts
- Listed activity
- Growing concern for the environment
- Possibly an opportunity to “repair” some of the damage already done
- Climate change and the environment



**TABLE 1**  
**Summary of the potential impacts identified**

Impact	Status	Significance	Confidence
<b>Potential physical impacts</b>			
Irrigation	+	High	High
Dam yields	+	High	High
Streamflow ad run-of river yields	+	High	Low
Flooding	-	Medium	Low
Reduction in Fire Risk	-	Low	High
Increased surface runoff	Uncertain	High	High
Soil erosion	Uncertain	Medium	Low
Pollution due to seeding agent	-	Low	High
Soil fertility	-	High	Low
Soil physics	Uncertain	High	Low
Lightning	Uncertain	Low	Low
Hail	Uncertain	High	Low
River morphology	Neutral	High	Low
Climate change	+	Medium	Low
Water cycle	Uncertain	Low	Medium
Groundwater recharge	+	Medium	Low
Water temperature	-	Low	Medium
Water turbidity	-	Low	Medium
<b>Potential biological impacts</b>			
Distribution of vegetation and fauna	Uncertain	High	Low
Biodiversity	Uncertain	High	Low
Timing of biological processes	-	Medium	Low
Faunal behaviour	Uncertain	High	Low
Pests	-	Medium	Medium
Wetlands	Uncertain	High	Low
Biological stress	Uncertain	Medium	Low
Natural pasture and fodder production	+	Medium	High
Dryland crop production	+	High	Medium
Livestock production	+	Medium	Low
<b>Potential social impacts</b>			
Conflict and inequities	Uncertain	Low	High
Legal liability	-	High	High
Dependency on additional rainfall	Uncertain	Low	High
Ethics of enhancing rainfall	-	Low	Medium
Diseases	Uncertain	Medium	Low
Research and technology	-	High	High
Capacity and expertise	Uncertain	High	High
Demographics	Uncertain	Low	Medium
Competition	Uncertain	Low	Medium
Strains on system and infrastructure	-	Low	High
Economics	+	High	High

Shading = impacts considered to be of high significance

Uncertain = impacts could be negative or positive depending on the circumstances and degree of impact.



## CONCLUSIONS

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- 75 seeded storms would produce a 10% increase in area rainfall over the 100 km X 100 km target area
- The radar storm climatology compiled for the period October 2000 to April 2001 showed that 290 legitimate storm tracks, to be considered as seeding candidates, occurred over the target area during the season
- 212 of these storm tracks occurred during day light hours with a peak between 12:00 SAST and 15:00 SAST
- The hygroscopic seeding technology holds much promise as a viable method to augment water resources in South Africa and many other regions of the world
- Sustainability a major consideration



## CONCLUSIONS

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- Water is central to all economic activities – rainfall enhancement can be used to reduce the risk involved in its scarcity. This is especially true for the agricultural sector which uses about 70% of the water in SA
- “As water become more scarce, market solutions are bound to emerge. Water rights are already traded electronically in the U.S. Private utilities and water markets are the next logical step.” Sam Vaknin, 2005
- “According to the World Bank, close to USD 600 billion will be needed by 2010 just to augment existing reserves and to improve water grade levels”



*The High Authority of UAE have approved the final distribution of the UAE Prize for Excellence in Weather Modification, as follows:*

*The South African National Precipitation Research and Rainfall Enhancement Programme (Graeme Mather, Deon Terblanche, Francois Steffens, Lizelle Fletcher and Andre Gorgens), receives the UAE Prize (200,000 US\$) for the design and execution of a successful weather modification experiment involving the revolutionizing concept based on hygroscopic nuclei injection and superb radar tracing software.  
etc.*

<http://www.uaewxmodprize.ae/prizedist.htm>

Thank you

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