Case study of the 9 April 2009 'brown' cloud: Observations of Unusually High Cloud Droplet Concentrations in Saudi Arabia



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Research Motivation for Weather Modification

- Water Resource Stresses
- Severe Weather Hazards
- Inadvertent Weather Modification
- New Observational, Computational, Statistical Technologies
- Operational Programs with Little Scientific Basis





Scope of Operational Programs

- Operational programs in more than 37 countries worldwide
- At least 69 programs in 11 U.S. states in 2001.



Objective

- Determine if cloud seeding in Saudi Arabia could be beneficial.
- Characterize the aerosol and cloud micro-physics in Saudi Arabia to determine optimal seeding method for enhancing precipitation in the region.





King Air 200 Saudi Arabia Spring 2009









Saudi Arabia Dust



Sun Low in the Sky Riyadh, Saudi Arabia



MODIS Image 11 March 2009

Al Faisaliyah Center

Airborne Data Set

Quality Control - The process of conducting tests to check that measurements are being made correctly and accurately.

Quality Assurance - The process of reviewing a data set to eliminate (replace with missing value codes) measurements that are invalid due to known problems.





<u>Flight</u> Tracks

March 17 March 18 March 19 March 20 March 21 March 23 March 26a March 26b March 28 March 31 **April 2 April 8 April 9** April 12

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Saudi Arabia Spring 2009

Image U.S. Geological Survey Image © 2009 Digital Globe © 2009 Read Dog Consulting © 2009 Ruropa Lechnologies



9 April 2009 Picture 13:32 UTC



9 April 2009 ~13:32 UTC

Brown Ice Layer White Ice Layer Aircraft Wing

9 April 2009 Case Study

Observation: Ice accumulation on the unprotected leading edge of the aircraft's wing show a color change from white to brown.

Objective: Test the hypothesis that the observation of brown ice build up on the aircraft wings were the result of the ingestion of a large concentration of aerosols by the cloud and document the differences in cloud properties between the brown ice cloud and a typical cloud.

9 April 2009 Flight Track

Take Off 12:40 Riyadh Airport

12:58

13:32

26.4 mi

13:19

Image U.S. Geological Survey © 2009 Europa Technologies © 2009 LeadDog Consulting Image © 2009 DigitalGlobe



Al Sharl Roar

9 April 2009 Riyadh Sounding



Riyadh Sounding Comparisons



12Z

TITAN Radar Display

Riyadh Saudi Arabia

9 April 2009 13:19:40

Aircraft' Track





Liquid water content at 1 Hz measured by a DMT Hot Wire Probe on the 9 April 2009 research flight in Saudi Arabia.



Time serial of cloud droplet concentration (1 Hz average) at 18,000 ft measured by an FSSP on the 9 April 2009 Saudi Arabia flight.



Time series of mean droplet diameter (1 Hz data) at 18,000 ft measured by an FSSP on the 9 April 2009 Saudi Arabia flight.

Radar Reflectivity Composite 9 April 2009 13:14:17 13:26:42



Aircraft Track

9 April 2009 13:20 - 13:28



Only 1 Hz measurements with DMT Hot Wire liquid water content above 1.0 g/m^3 are included.

9 April 2009 13:20 - 13:28



Only 1 Hz measurements with DMT Hot Wire liquid water content above 1.0 g/m^3 are included.



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Descent Profile 9 April 2009

Dust (1-3 um) Optical Aerosols (0.1-3 um) Cloud Condensation Nuclei (0.6 %) Condensation Particle



Conclusions

- The 'brown' ice cloud cell had very high droplet concentrations (up to 1200 #/cm³) and reduced average mean droplet diameters compared to a normal cell.
- Cloud base CCN measurements in Saudi Arabia are variable with some very high concentrations.
- The increases in droplet concentration was probably the result of increases in cloud base CCN concentration which may have resulted in the cell's death.

Acknowledgments

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Thanks for Listening

Any Questions



Liquid water content equivalent (1 Hz data) at 18,000 ft measured by 2-DC probe on a research flight in Saudi Arabia.



Images from the 2-DC between 13:00:26.45 and 13:00:28.19 (less than 2 seconds total) which correspond to the maximum liquid water content equivalent (1 Hz data) measured by 2-DC probe between on 9 April 2009 research flight in Saudi Arabia.



Images from the 2-DC between 13:24:52.46 and 13:24.59 (9 seconds total) which correspond to the low liquid water content equivalent (1 Hz data) measured by 2-DC probe on 9 April 2009 research flight in Saudi Arabia.