Observations of Aerosol Effects on the Microphysics and Radiative Properties of Arctic Liquid-Phase Clouds

Environment Canada Environnement Canada

Michael E. Earle[1], Peter S.K. Liu[1], J. Walter Strapp[1], Alla Zelenyuk[2], Dan Imre[3], Greg M. McFarquhar[4], Nicole C. Shantz[1], W. Richard Leaitch[1], Mikhail Ovchinnikov[2], and Steven J. Ghan[2]

[1] Environment Canada, [2] Pacific Northwest National Laboratory, [3] Imre Consulting, [4] University of Illinois

ASR Atmospheric System Research

Overview

- Aerosol indirect effects
  - Key climate system process; uncertainty
  - Requirement for studies in Arctic
- Indirect and Semi-Direct Aerosol Campaign (ISDAC)
  - Barrow, Alaska – April 2008

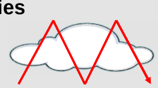
Project aircraft: National Research Council of Canada (NRC) Convair-580

Approach

- Focus on liquid-phase stratocumulus
- April 8, 26, 27: clean aerosol conditions
- April 19, 20: biomass burning (BB)
- In-situ observations
  - In-cloud: droplet concentration, size (CDP, FSSP-100); liquid water (King probe)
  - Below-cloud: aerosol particle concentration, size (PCASP, FSSP-300), single particle composition (SPLAT II)

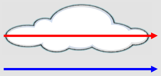
Part 1: cloud microphysical and radiative properties

- Vertical profiles; porpoising legs



Part 2: cloud droplet activation

- Horizontal legs in- and below-cloud
- Droplet closure analysis



Part 1: Average Cloud Properties

- Two distinct aerosol-cloud regimes
- Higher *Re*, *LWP*, albedo for clouds in more polluted conditions

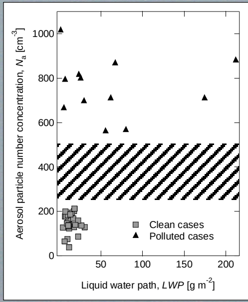


Figure 1: Aerosol concentration vs. liquid water path for all profiles.

Parameter	Clean	Polluted
Aerosol concentration, N_a [cm^{-3}]	147 ± 41	756 ± 132
Droplet concentration, N_d [cm^{-3}]	136 ± 31	304 ± 81
Activated fraction	0.96	0.41
Temperature, *T* [°C]	-12.9 ± 1.1	-7.5 ± 1.1
Liquid water content, *LWC* [g m^{-3}]	0.07 ± 0.02	0.16 ± 0.11
Cloud thickness, H_c [m]	180 ± 43	296 ± 64
Liquid water path, *LWP* [g m^{-2}]	13.4 ± 6.1	61.9 ± 66.8
Droplet effective radius, *Re* [μm]	5.4 ± 0.7	5.7 ± 1.2
Cloud optical thickness, τ	3.60 ± 0.30	14.13 ± 13.64
Cloud albedo, *A*	0.34 ± 0.08	0.55 ± 0.25

Table 1: Average cloud and aerosol parameters and standard deviations for all profiles under clean and polluted aerosol conditions.

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Part 1: Insight into Indirect Effects

- For comparable *LWP*: larger optical depth τ, smaller *Re* for polluted cases
  - Consistent with 1st indirect effect
- Precipitation inhibition: *Re* below ~ 10 μm (drizzle threshold) for all profiles
  - 2nd indirect effect
  - Clean cases: low *LWC* limits droplet growth
  - Polluted cases: high N_d limits droplet growth

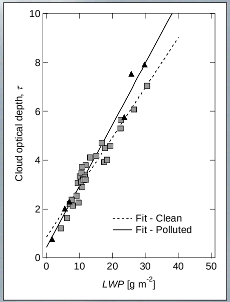


Figure 2: Optical depth as a function of *LWP* for clean and polluted cases with *LWP* < 50 g m^{-2}.

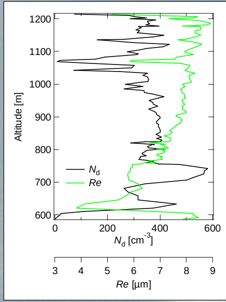
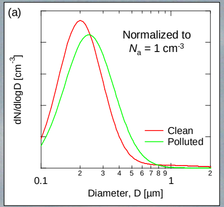


Figure 3: Vertical profiles of N_d and *Re* in-cloud for a representative polluted case on April 20.

Part 2: Aerosol Properties and Droplet Closure



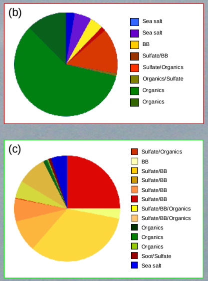


Figure 4: (a) Size distributions and chemical composition of below-cloud aerosol for (b) clean case on April 27 and (c) polluted case on April 20.

Case	Hygroscopicity κ	Updraft velocity cm s^{-1}	% Difference N_d
Clean	0.3	0.6 – 1 σ_ω	8 %
Polluted	0.3	0.5 σ_ω	3 %

Table 2: Parcel model simulation results. All simulations assume an internally-mixed aerosol and condensation coefficient of 1.

- Differences in size, composition of below-cloud aerosol
- Simulate activation in adiabatic parcel model
  - Updraft velocity from standard deviation of vertical velocity measurements in-cloud, σ_ω
  - Minimize difference between measured and simulated N_d
- Polluted case: more sensitive to updraft velocity
  - Lower activated fraction, lower maximum supersaturation
  - Preferential activation of larger or more hygroscopic particles
- Different particle sizes activated in each aerosol-cloud regime
  - Implications for *Re*

Summary and Future Work

- Two distinct aerosol-cloud regimes observed in Arctic springtime clouds (liquid-phase)
- Assessment of indirect effects complicated by variations in *LWP*, droplet activation
- Precipitation suppression (2nd indirect effect) observed in both clean and polluted cases
- **Future Work:** extend analysis to additional cases; incorporate updrafts from LES