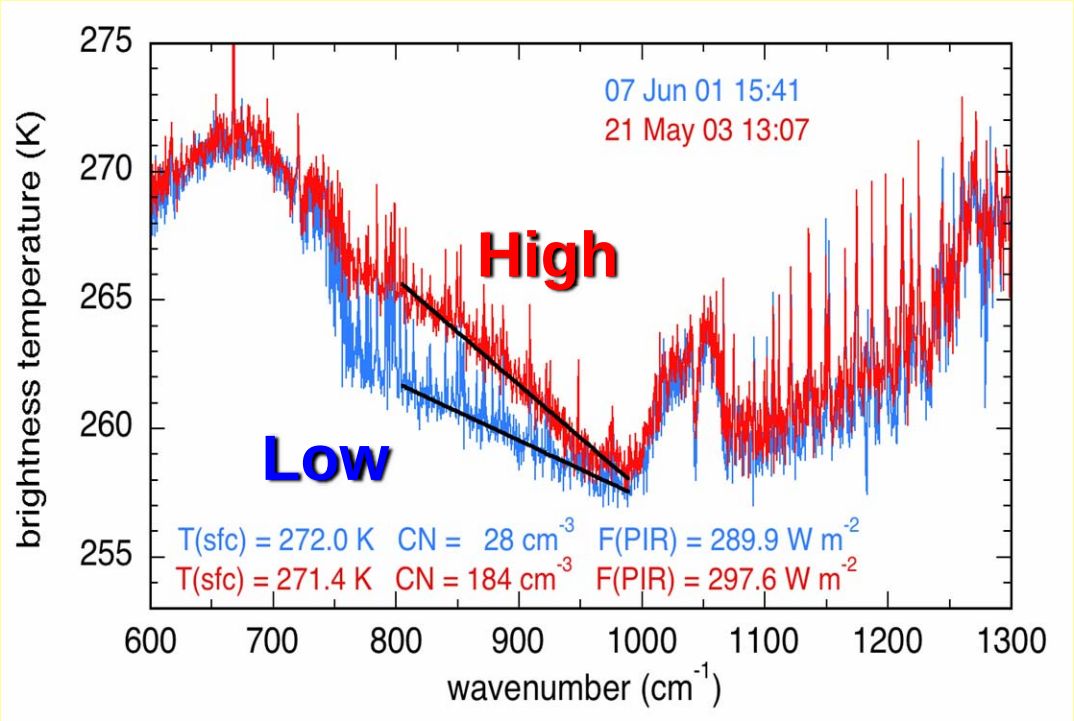
Aerosol Indirect Effects in Springtime Arctic Liquid-Water Clouds

Dan Lubin
Scripps Institution of Oceanography
Andrew Vogelmann
Brookhaven National Laboratory

19 September 2007
Joint RPWG/AWG WG Meeting
Madison, WI

Interpretation of NSA Longwave Surface Observations
Demonstration of the 1st LW Aerosol Indirect Effect



Lubin and Vogelmann, Nature, 2006

Similar clouds

Low versus high aerosol
Consistent with theory

Detection Method

Slope of Mid-IR Window

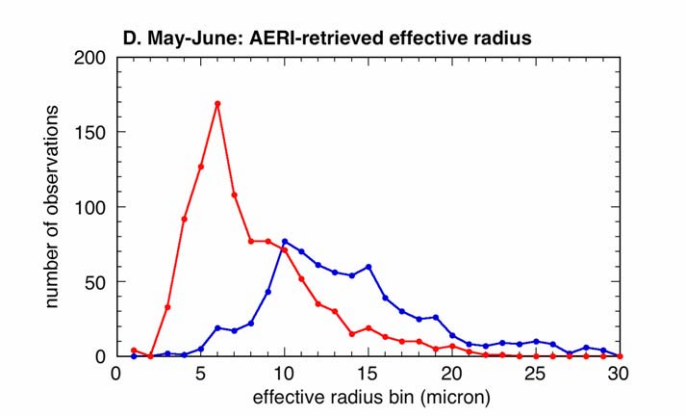
$dT_b/d\nu$

Reff

High 7 μm
Low 11 μm

Culled 6-years of ARM NSA data & CMDL aerosol data

Attribution of First Indirect Effect

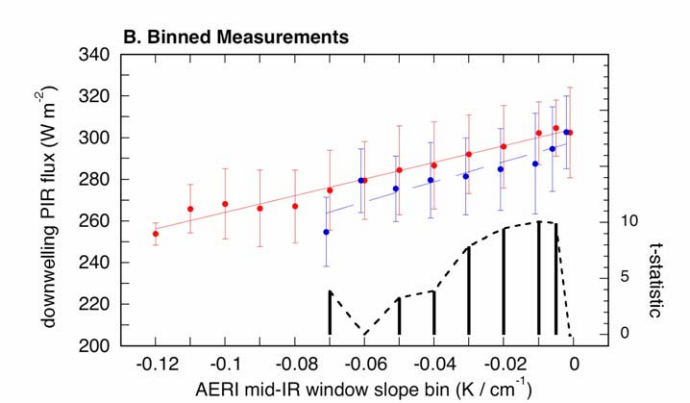


Reff modes

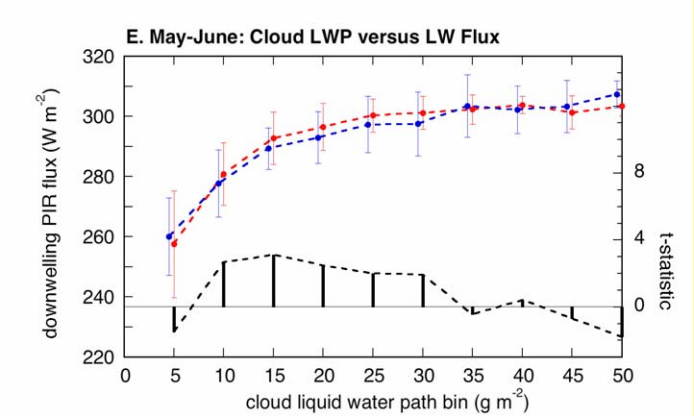
7 μm

10 μm

T_{scf}=267-274 K



Δ = 8.2 Wm^{-2}



LW 1st AIE
Δ = 3.4 Wm^{-2}

Lubin and Vogelmann (2006)

How Does this Longwave 1st Indirect Effect Compare with the Shortwave 1st Indirect Effect ?

Lubin, D., and A. M. Vogelmann, 2007: Expected magnitude of the aerosol shortwave indirect effect in springtime Arctic liquid water clouds, *Geophys. Res. Lett.*, 34, L11801, doi:10.1029/2006GL028750.

Shortwave Indirect Effect Simulation

Approach

- Estimate using diurnally averaged calcs for Surface and TOA
- "Low" and "high" aerosol effects/amounts
- Difference yields an estimate of the shortwave indirect effect

Simulations

Radiative Transfer Model

179-band Discrete-Ordinates (Stamnes et al., 1988; Lubin et al., 2006)

Surface Albedo from SHEBA (Perovich et al., 2000)

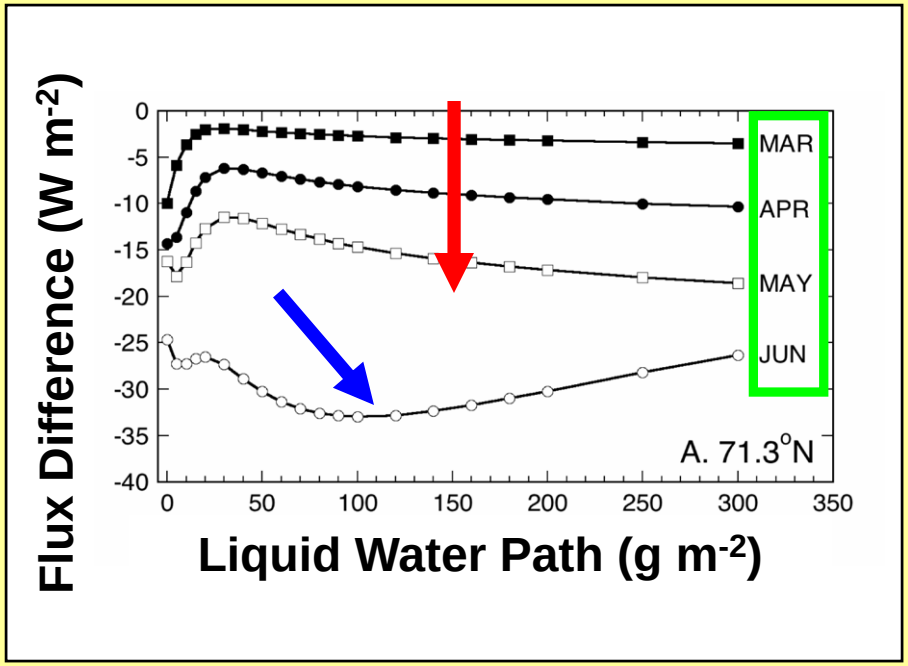
- Snow covered ice March-May
- Bare sea ice June (onset of melt season)

Clean Air Versus Polluted Air Scenarios

	Aerosol loading (τ_a @ 0.5 μm)	Cloud Reff
Clean – Background	0.1	11 μm
Polluted - Arctic haze	0.5	8 μm

Reffs estimated based on Lubin and Vogelmann (2006), Garrett and Zhao (2006)

Indirect Effect: Surface Forcing



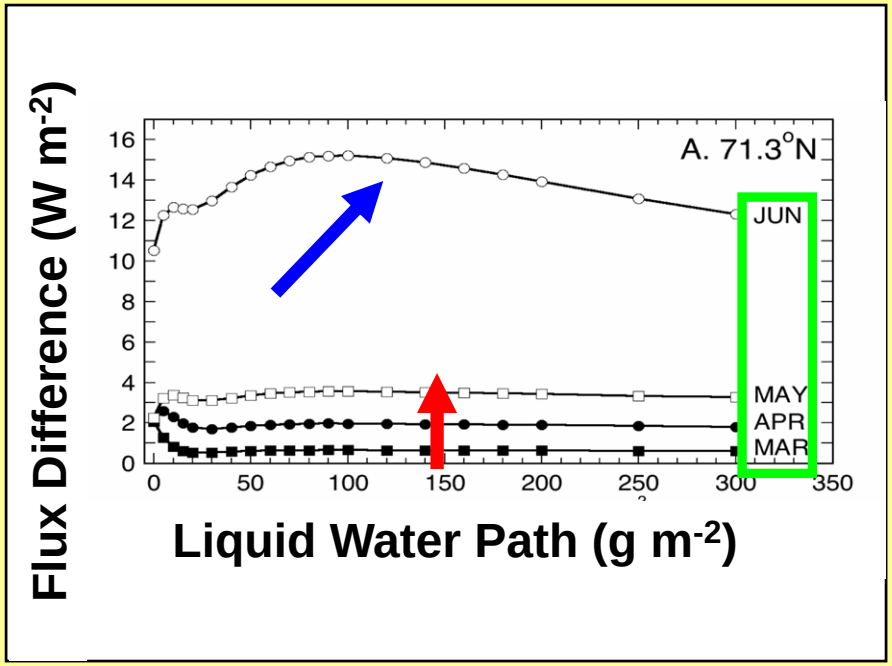
March through May

- Flux difference increases
- Increasing solar elevation and day length

June

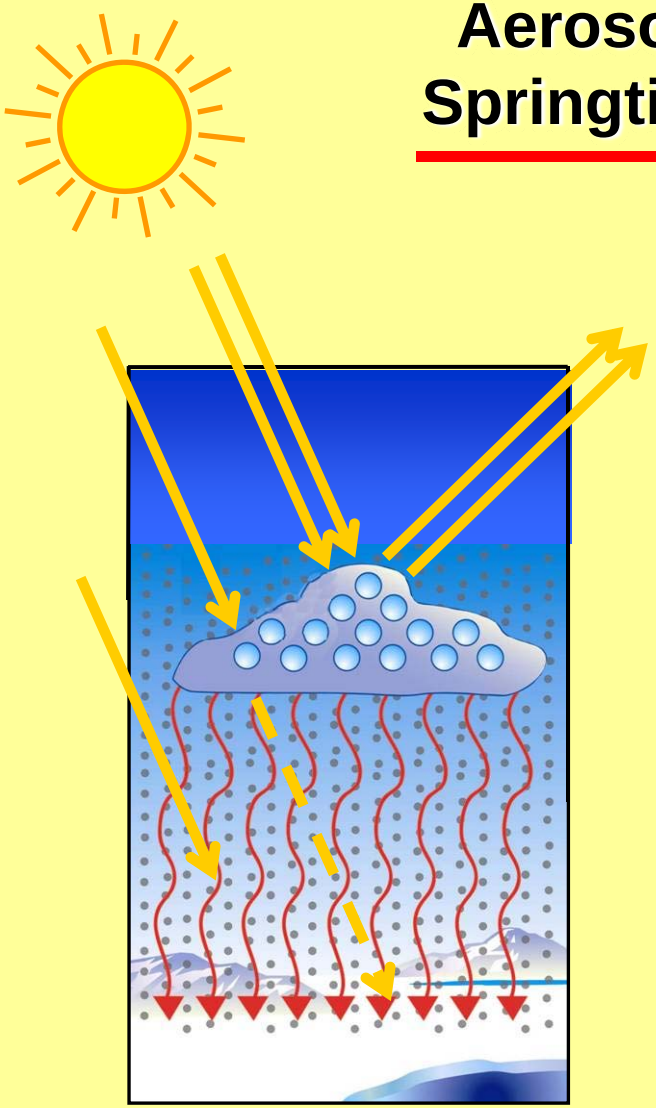
- Differences **<u>enhanced</u>**
- Onset of sea ice melt
  - ➔ Lower surface albedo
  - ➔ Fewer multiple reflections

Indirect Effect: TOA Forcing



- TOA effect is ~1/2 of the Surface (opposite sign)
- Difficult to detect from space during early spring (snow surface)

Expected Magnitude of the Aerosol Shortwave Indirect Effect in Springtime Arctic Liquid Water Clouds



Radiative transfer calculations constrained by ARM NSA data suggest that the shortwave aerosol indirect effect (AIE) will:

- **Increase with solar elevation and day length;**
- **Increase dramatically at the onset of sea ice melt around June.**

Compared to the recently discovered longwave (LW) AIE, the shortwave AIE would be nonexistent during winter months, and be:

- **Comparable to LW AIE in March & April**
- **Larger in May in June**

The shortwave AIE forcing at the top-of-atmosphere (TOA) is half that at the surface so:

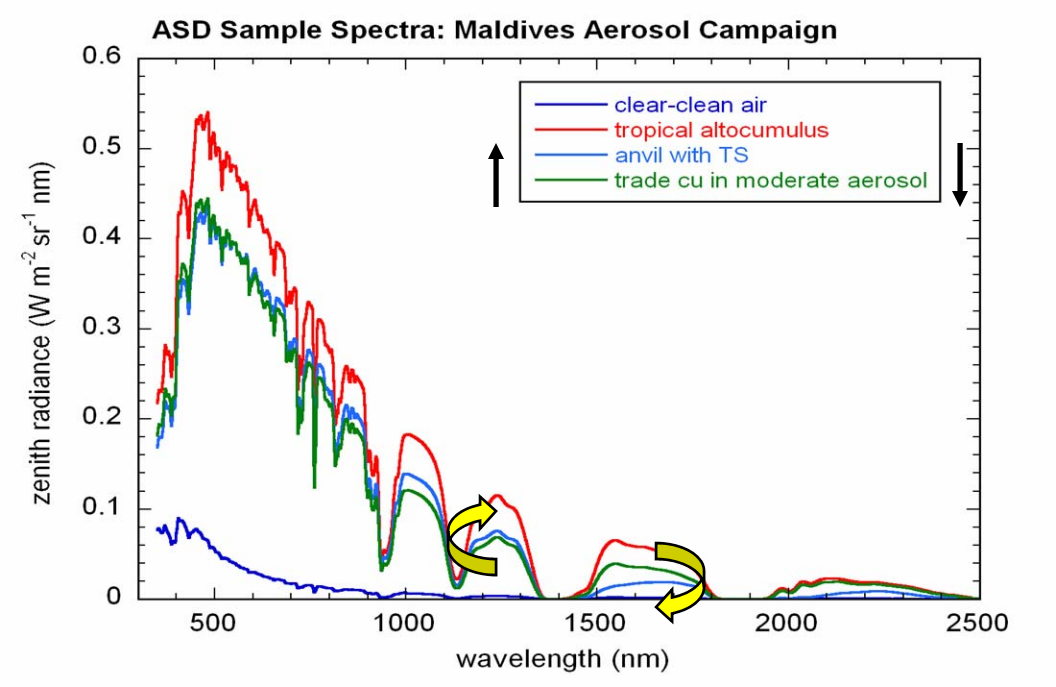
- **Easier to detect in surface observations;**
- **Possibly difficult to detect from space during early spring (snow surface)**

Lubin and Vogelmann (*GRL*, 2007)

ASD Spectroradiometer for IPY/ISDAC
(Lubin and Vogelmann)

Instrument Capabilities:

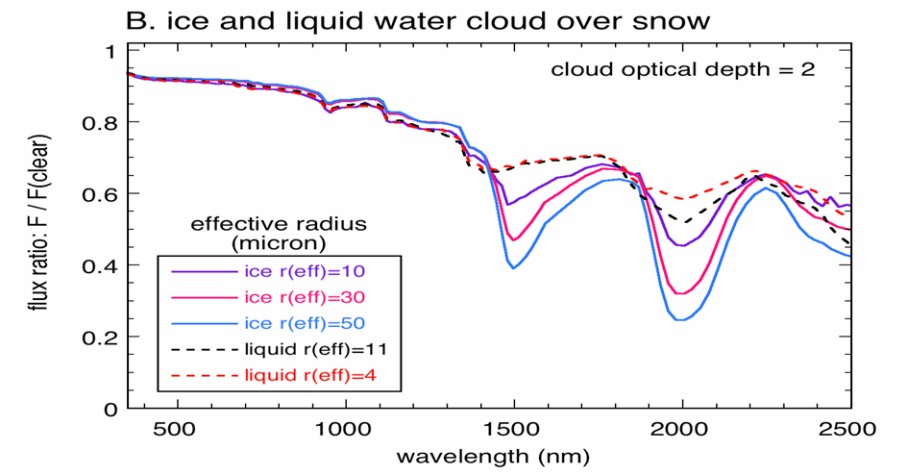
- **Either Irradiance or Radiance (17 mrad FOV)**
- **Wavelength coverage 350-1100 nm at 1 nm res., 1100-2500 nm at 10 nm res.**
- **Rapid sampling (ms) with data averaging/recording every few seconds.**



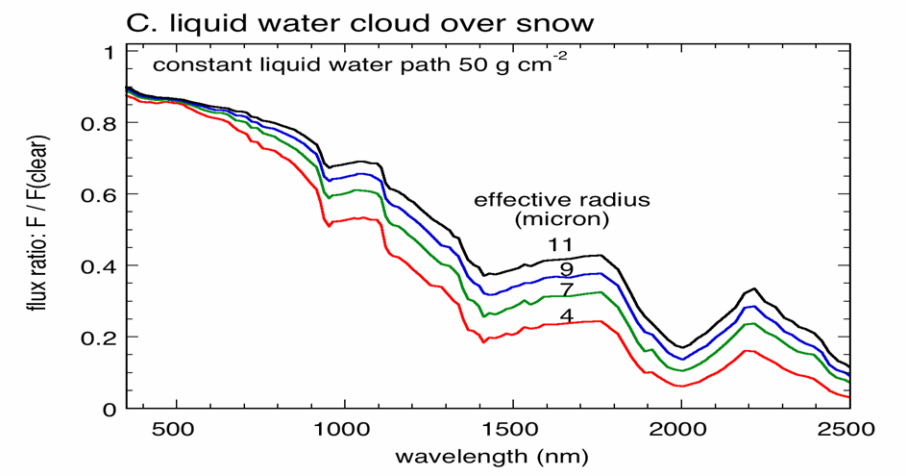
Sample zenith radiance spectra from Hanimaadhoo Island, March 3-8, '06

- **Note the cloudy sky measurements in the 1.6-micron window: the anvil has an opposite slope from the others, indicating primarily an ice cloud.**
- **Radiance: cloud is much brighter than clear sky.**

ASD Potential for Cloud Optical Property Retrieval: RT Simulations of Spectral Cloud Transmission



τ
Phase
Reff
LWP



Stand alone
or
in concert

*** Note: these are <u>transmissivity from hemispheric irradiance</u>, *not* zenith radiance, hence qualitatively different curves from previous example!**

U. S. COAST GUARD
11