Assessing the ‘Full Spectral’ ***Potential*** Radiative Impact of Arctic Aerosols: Dust, Smoke, Haze and ***Volcanic***

“A PERTURBATION STUDY!”

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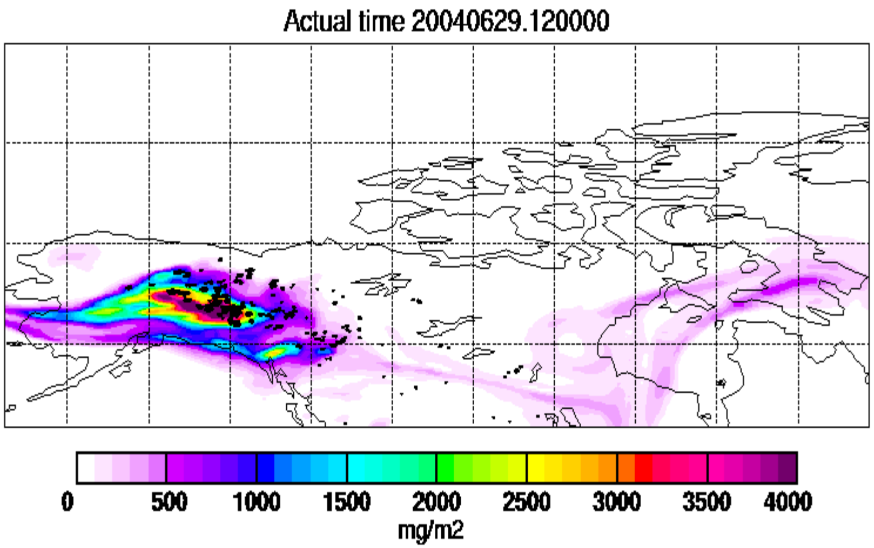
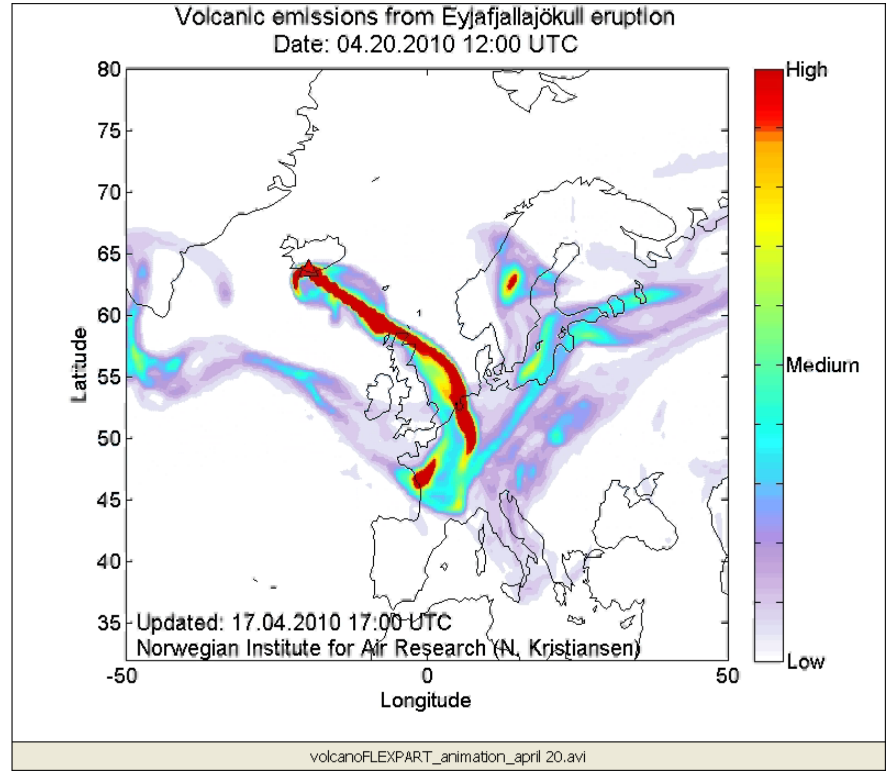
Tracing Aerosol Sources: Smoke & Volcanic

Origins





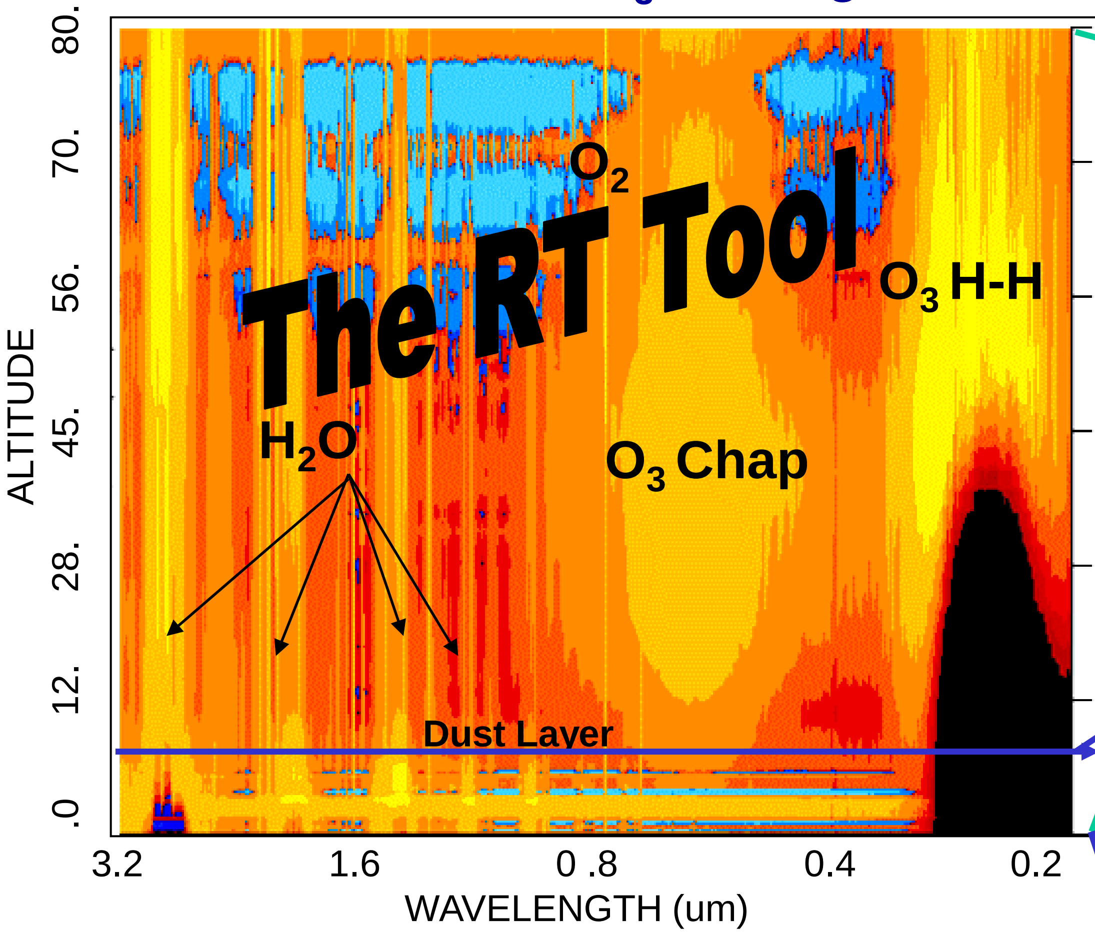
FLEXPART CO Tracer Simulation

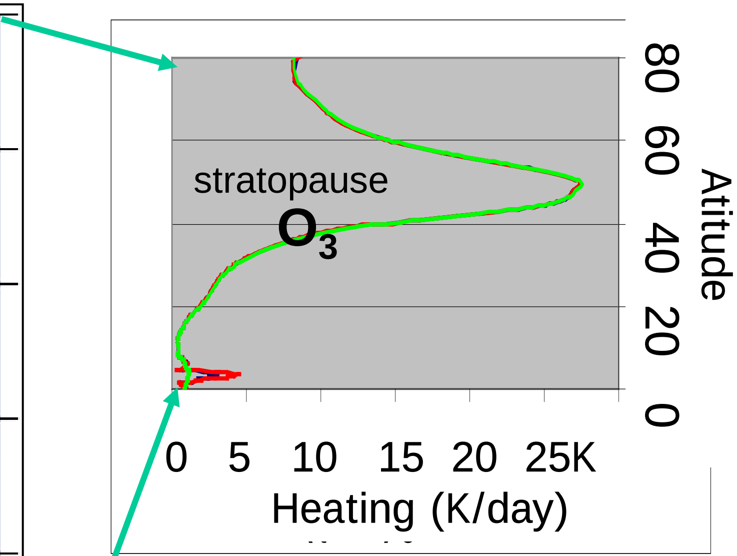
(A. Stohl 2006, Norwegian Institute for Air Research)

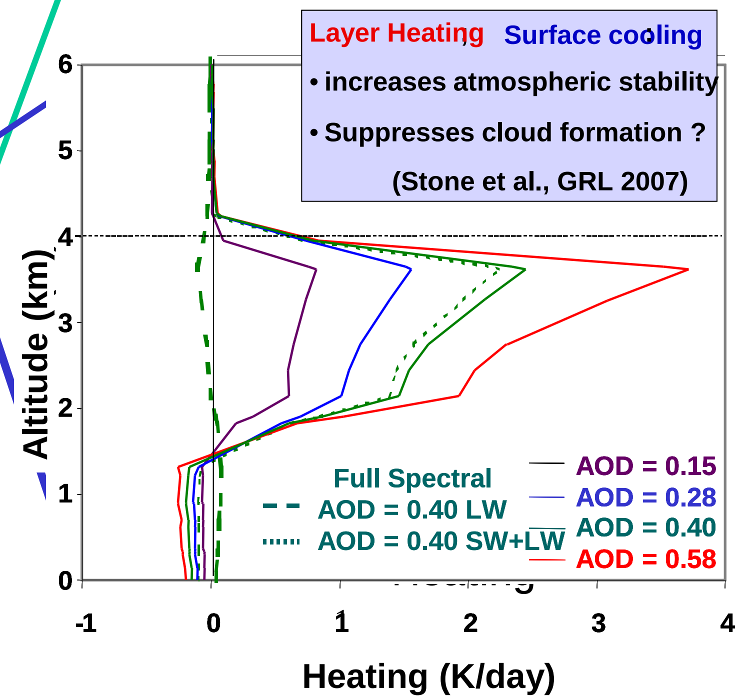
Transport-only, based on mean winds from European Centre for Medium-Range Forecasts, (1x1º resolution, 60 layers, 30 million tracer particles, 30 days)

MODTRAN®5 Spectroscopic Properties:

Asian Dust O_3 Heating & Aerosol Forcing over Barrow







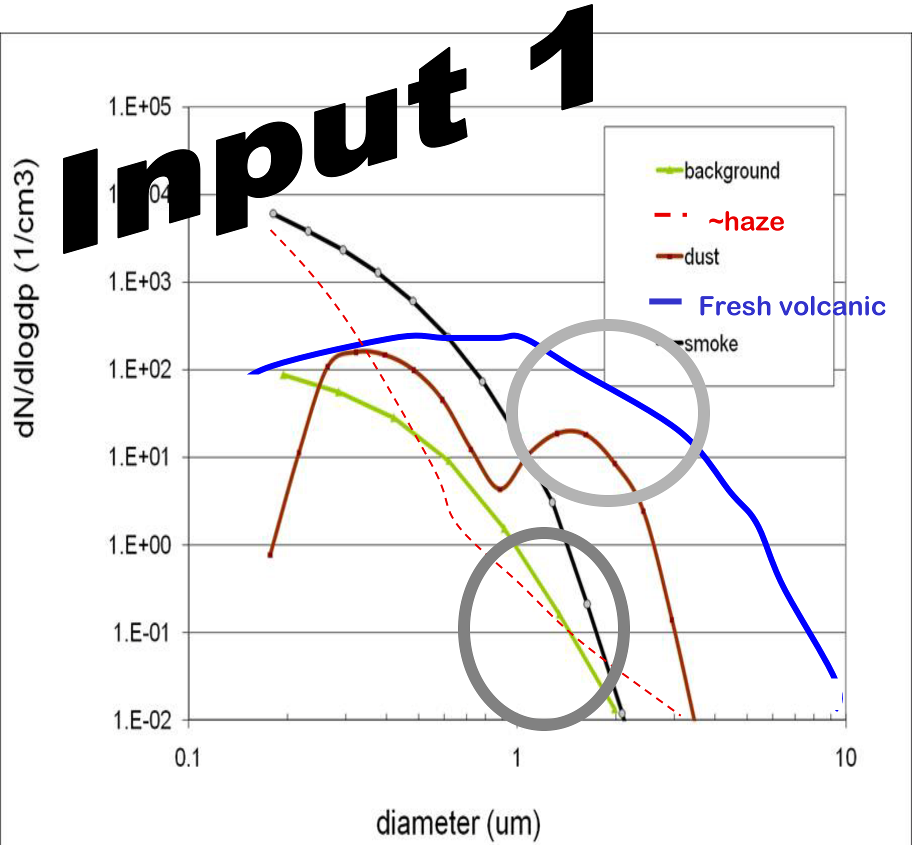
Contour units: (K/day)/cm^{-1}

R. Stone[a,b], B. Andrews[a,b], J. Harris[a], E. Dutton[a], E. Shettle[c]

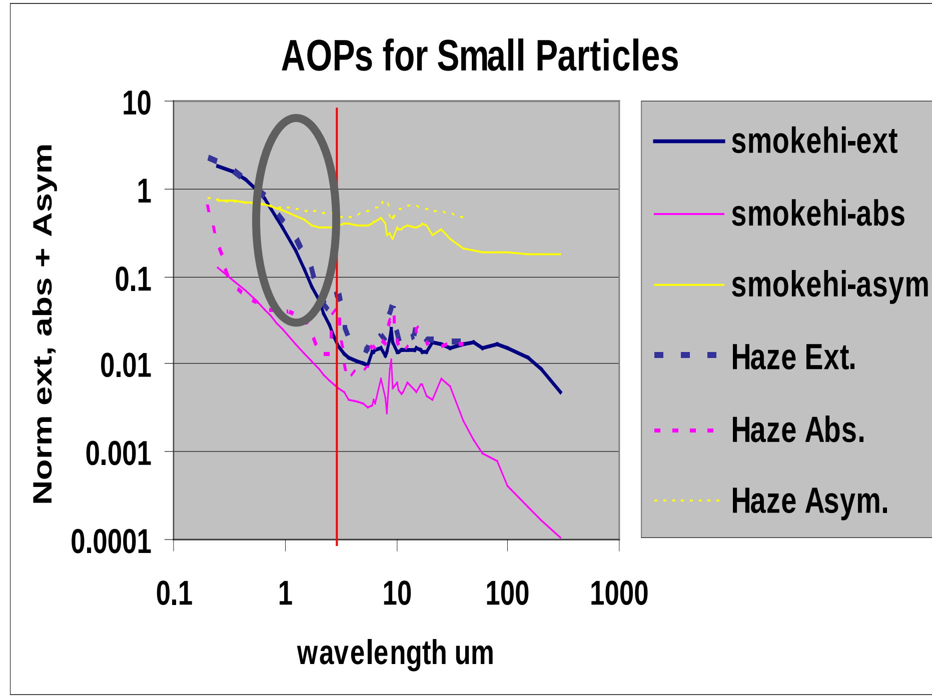
a = NOAA/GMD, b = CIRES, c = NRL, plus Anderson / Berk

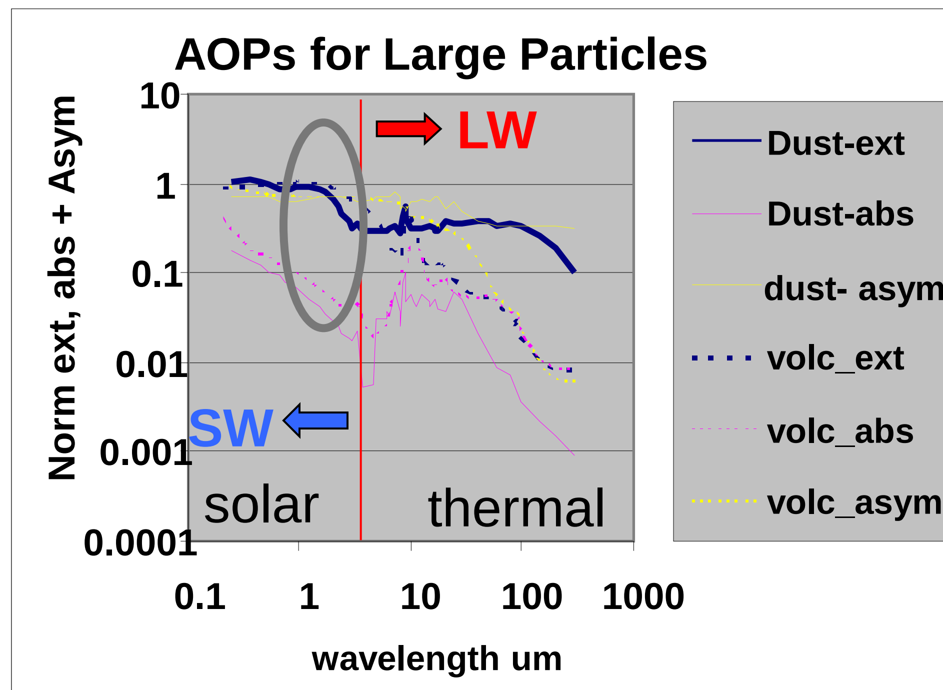
MODTRAN®5 Input Requirements for Aerosol Studies:

- **Aerosol Optical Properties,**
- **Derived from size distribution, extended to LW**



King et al. inversion (1978),
AFRL Handbook (1986)

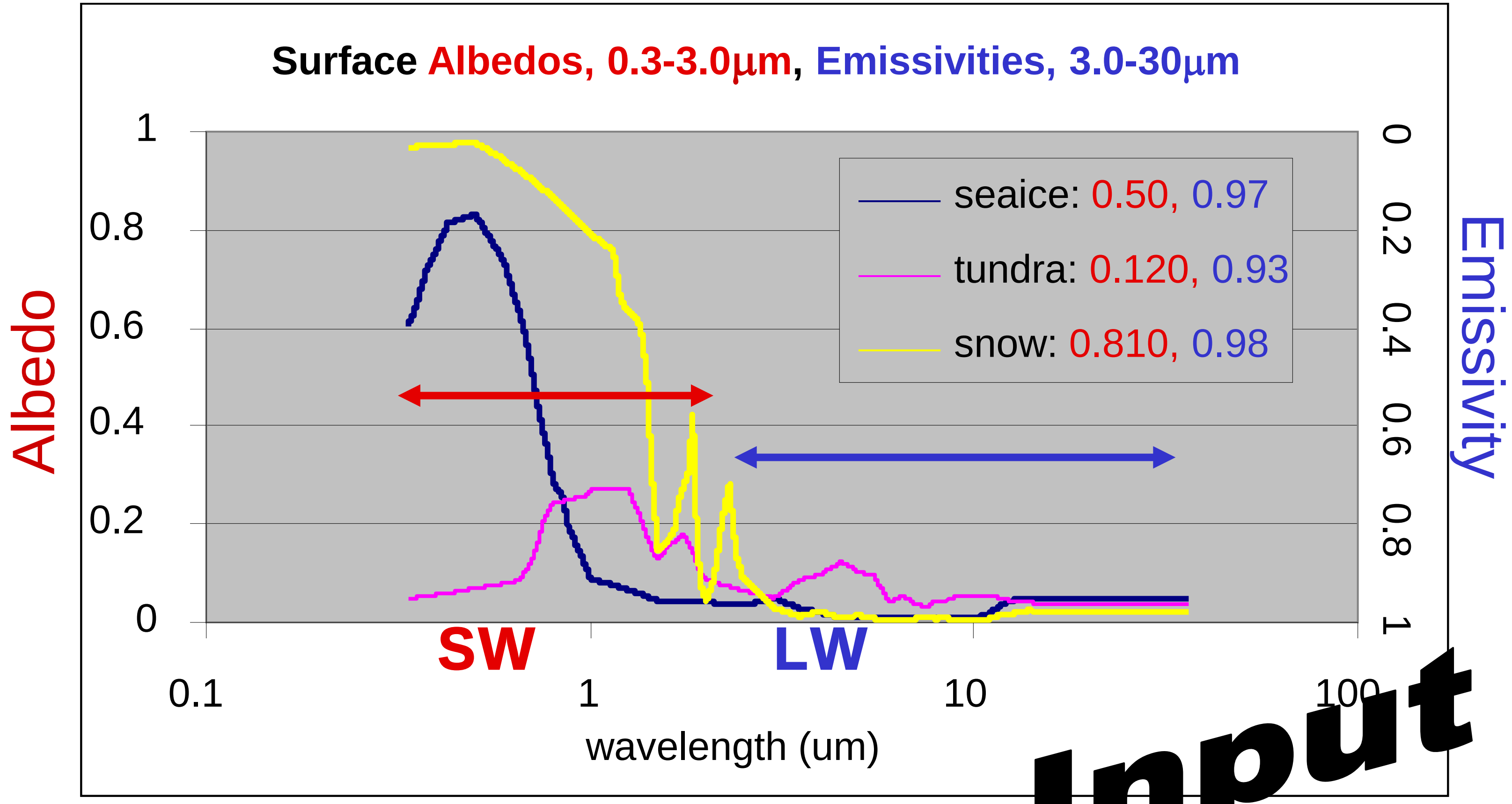




MODTRAN®5 Input Requirements for Aerosol Studies:

Sensitivity Study INPUT :

Barrow albedos: tundra, sea ice, snow (ref: MODTRAN)

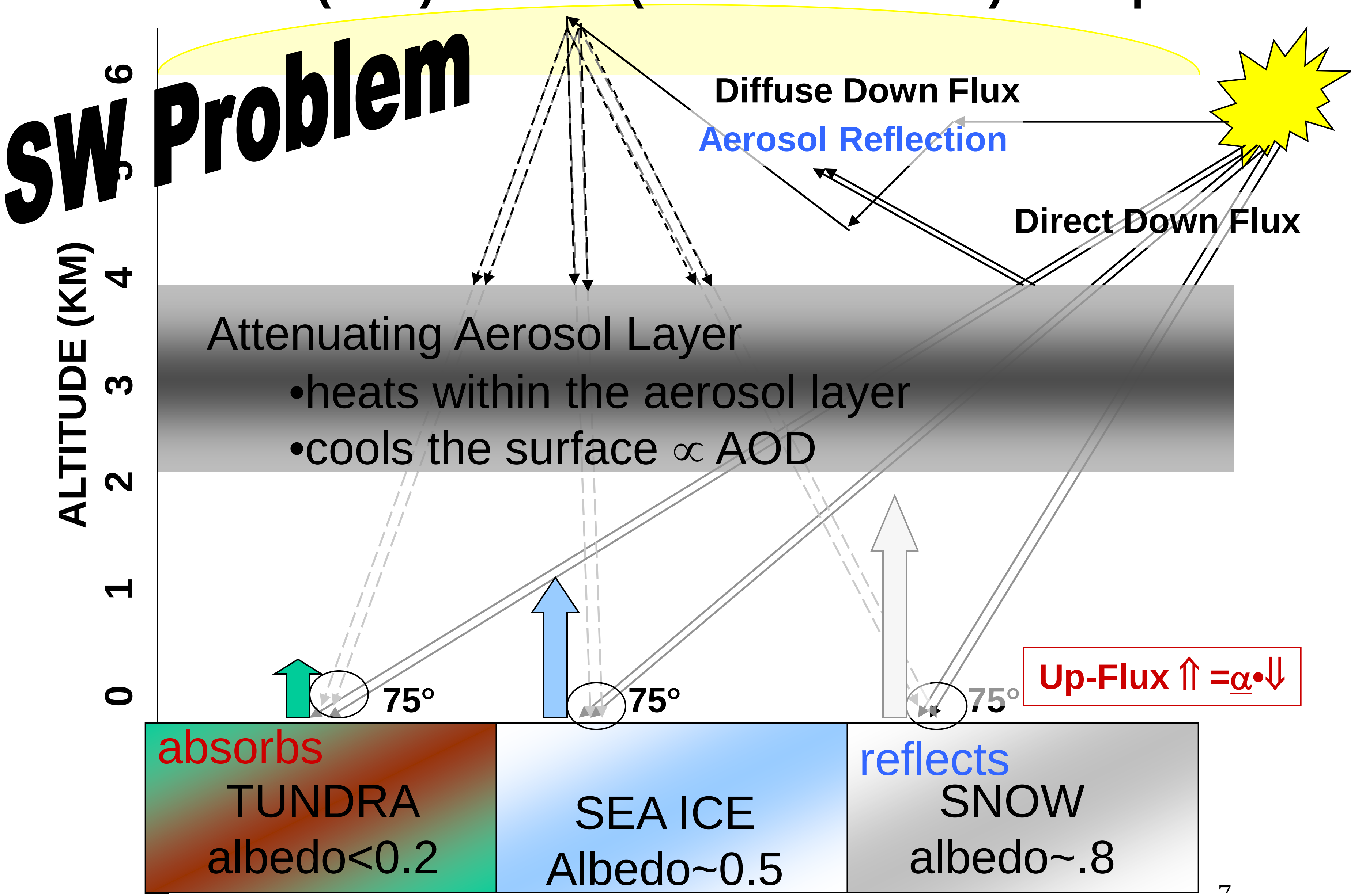


Input 2

Outline

- Re-establish Short Wave Aerosol Impact
  - Heating within Aerosol Layer (2-4km)
  - Cooling at Surface
  - Evaluate the Direct Aerosol Radiative Forcing ‘At the Surface’ $\Rightarrow$ DARF
- Project same Aerosols into the LW
  - Establish Simple Sensitivity Study
    - No Feedbacks, No Chemistry, No Deposition. No Dynamics
    - 4 Aerosol types, 3 Arctic Surfaces, 1 solar angle (75°)
  - Provide Aerosol Optical Properties
- Assess Mitigation in the thermal (LW) by Aerosols
  - Small Δ thermal effect within layer (cooling)
  - Small ΔHeating at Surface

SW Net Flux(surf) = Down (Diffuse + Direct) ⇓ – Upflux⇑



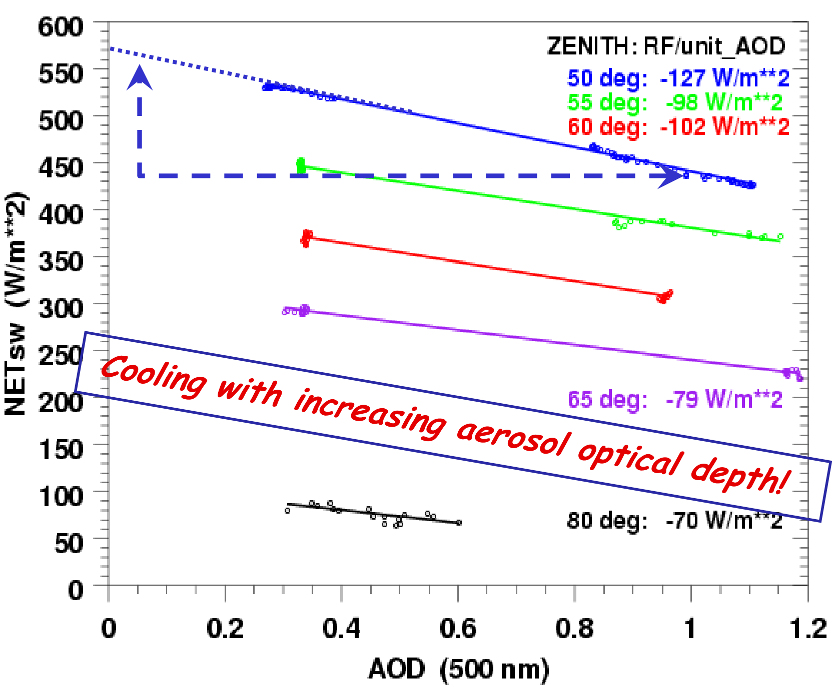
Solar heating more effective over darker surfaces!

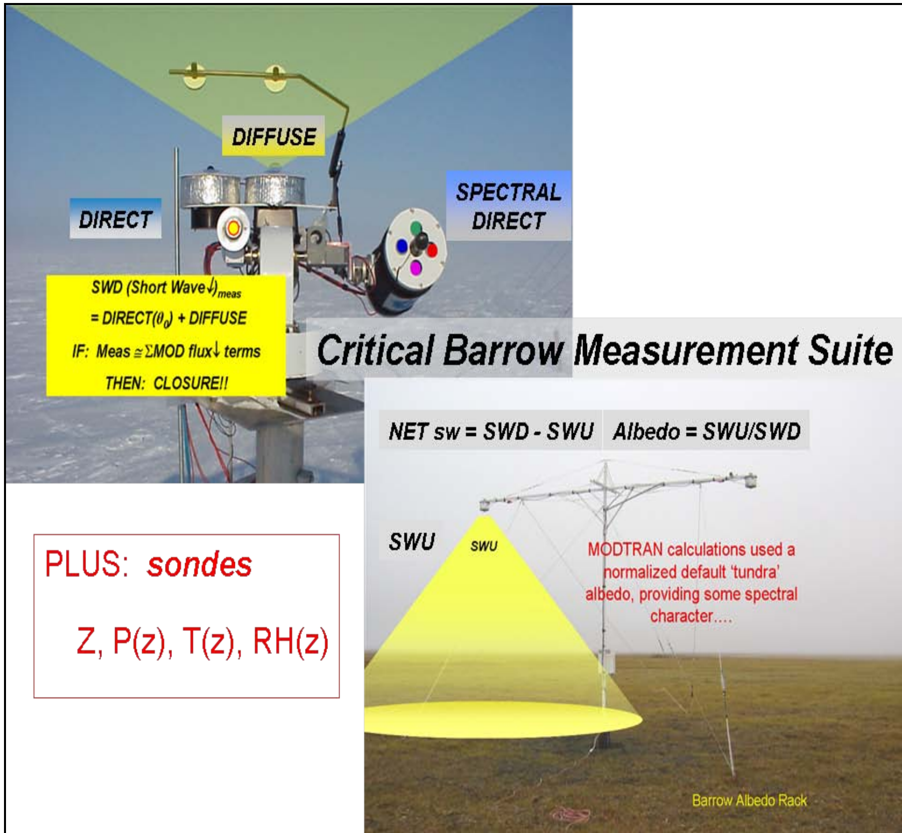
Model Simulations vs. Observations

Measurements

1. Measure ***NETsw*** **radiation and** ***AOD***
2. **Infer size distribution from** ***AOD(λ),*** **via King Inversion**
3. **Derive optical properties (AOP) using Mie Theory**
4. **Determine *Direct Aerosol Radiative Forcing* *(DARF) from Measurements***

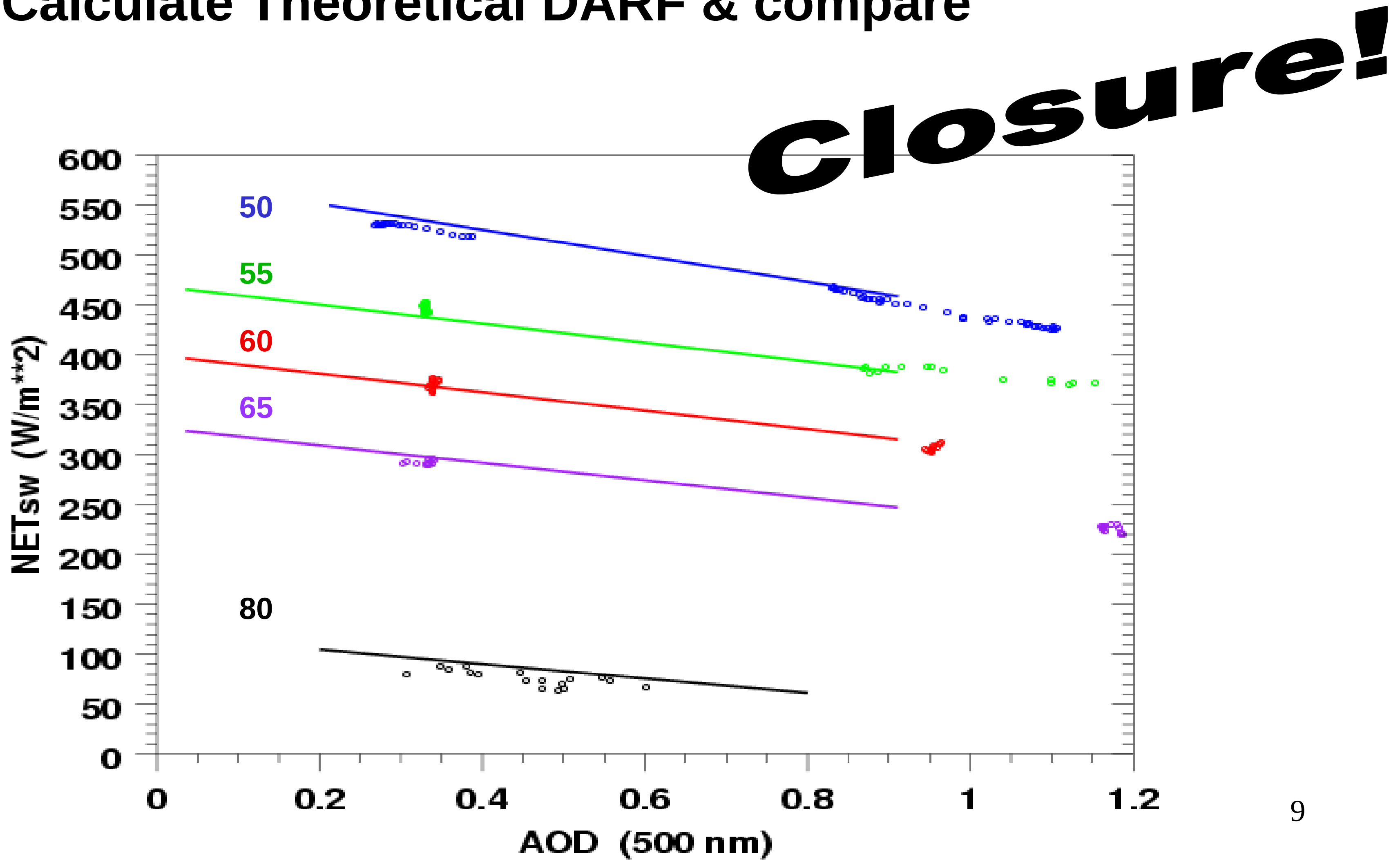
Direct Aerosol Radiative Forcing = ΔNETsw AOD^{-1}





Broadband Measurement vs. MODTRAN® Model Calculations

1. **Initialize MODTRAN®; compute *NET_SW FLX(AOD)***
2. **Calculate Theoretical DARF & compare**



Radiative Transfer Sensitivity Study

Given <u>CLOSURE</u> - Design SENSITIVITY TEST

Using MODTRAN®5, 'soda straw' RT code

- ***<u>NO chemistry,</u>***
- ***<u>NO deposition.</u>***
- ***<u>NO feedbacks.</u>***

Reprise !

Extend to Long-Wave (LW); magnitude of mitigation?

Extend to other Aerosols:

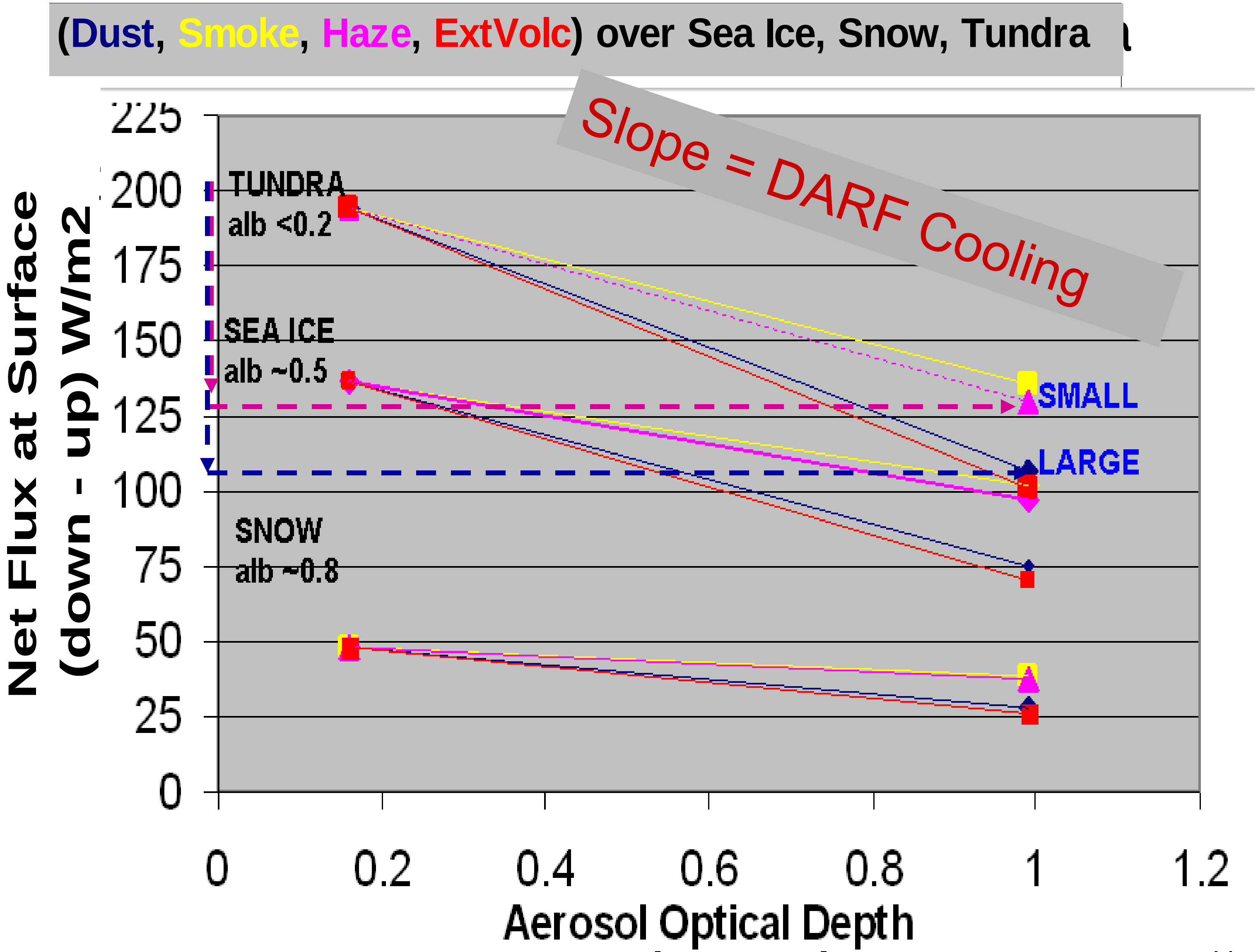
Dust, Smoke, Haze, Fresh Volcanic

CONTROLS

- ***Maximum AOD = ~1.0***
- ***Layer confined to 2-4km (relatively insensitive)***
- ***All other parameters the same:***

sonde, surface T, Io, 75° solar zenith

75° Model Simulations: SW + LW



SENSITIVITY TEST RESULTS: 75°, 3 surfaces, 4 aerosols

DARF *

Aerosol Forcing (Dust, Smoke, Haze, ExtVolc) over Sea Ice, Snow, Tundra

Full Spectral: SW+LW

	SMALL		LARGE	
	Smoke	Haze	Dust	Volcanic
		~2W/m2	>10 W	
Tundra	-70.0	-75.0	-94.0	-96.0
			~10 W	
Sea Ice	-40.0	-46.0	-63.0	-64.0
			~10 W	
snow	-10.0	-11.0	-11.0	-13.0

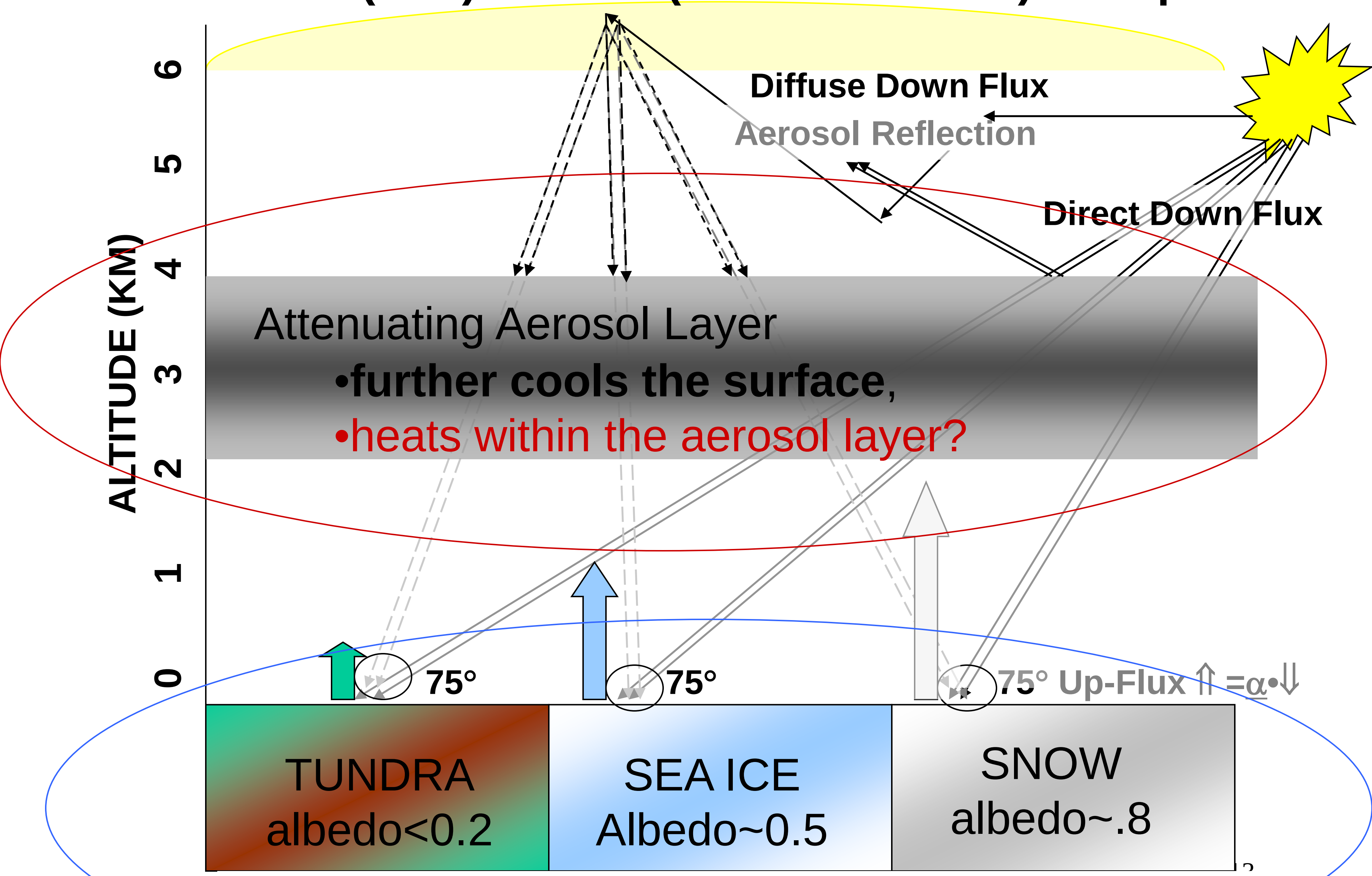
Solar Spectral: SW

	SMALL		LARGE	
	Smoke	Haze	Dust	Volcanic
Tundra	-71	-77	-105	-111
Sea Ice	-42	-48	-74	-79
snow	-11	-13	-24	-26

*W/m2 cooling at surface per **1.0** increment in AOD

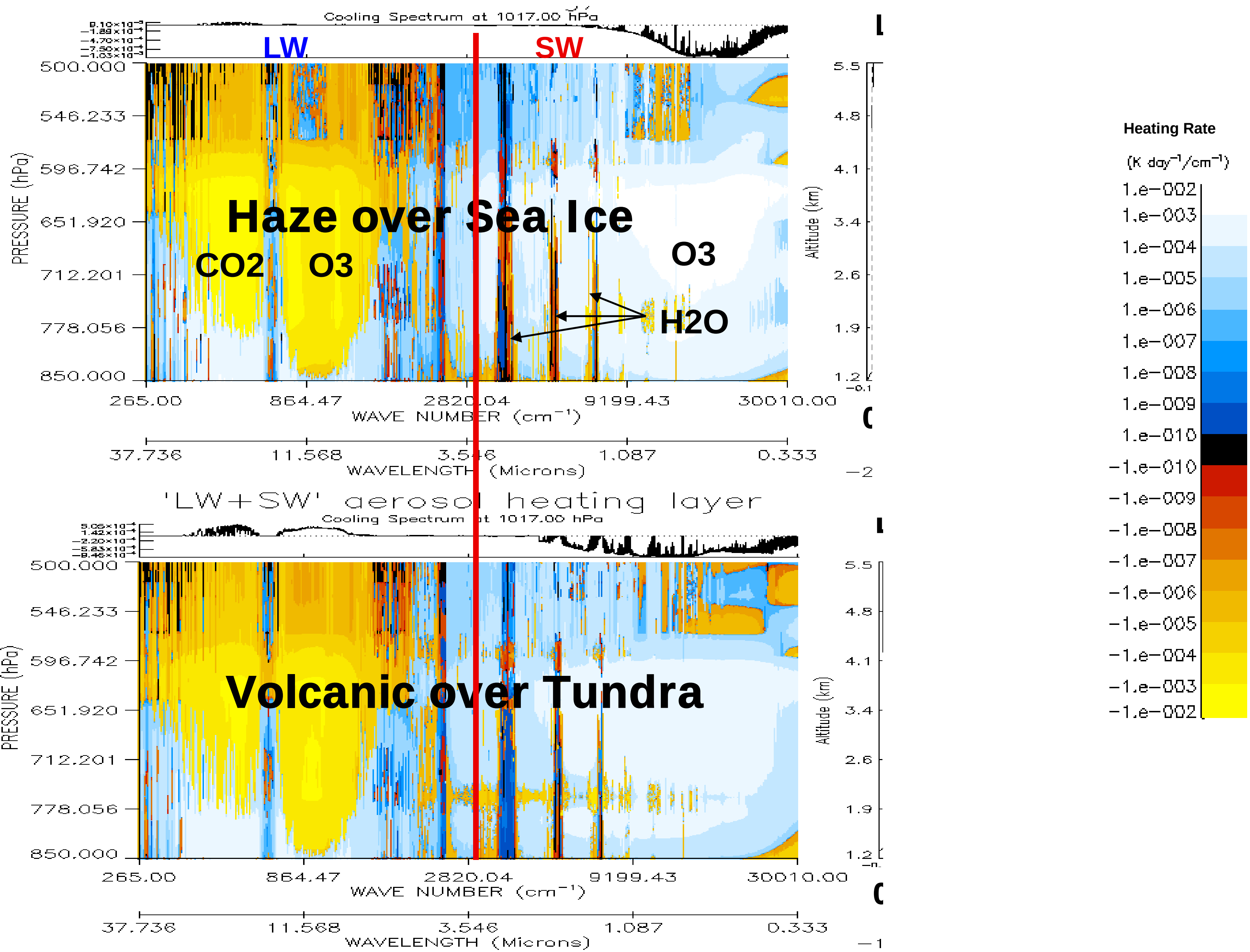
Large Aerosols have LW impact

SW Net Flux(surf) = Down (Diffuse + Direct) ⇓ – Upflux⇑

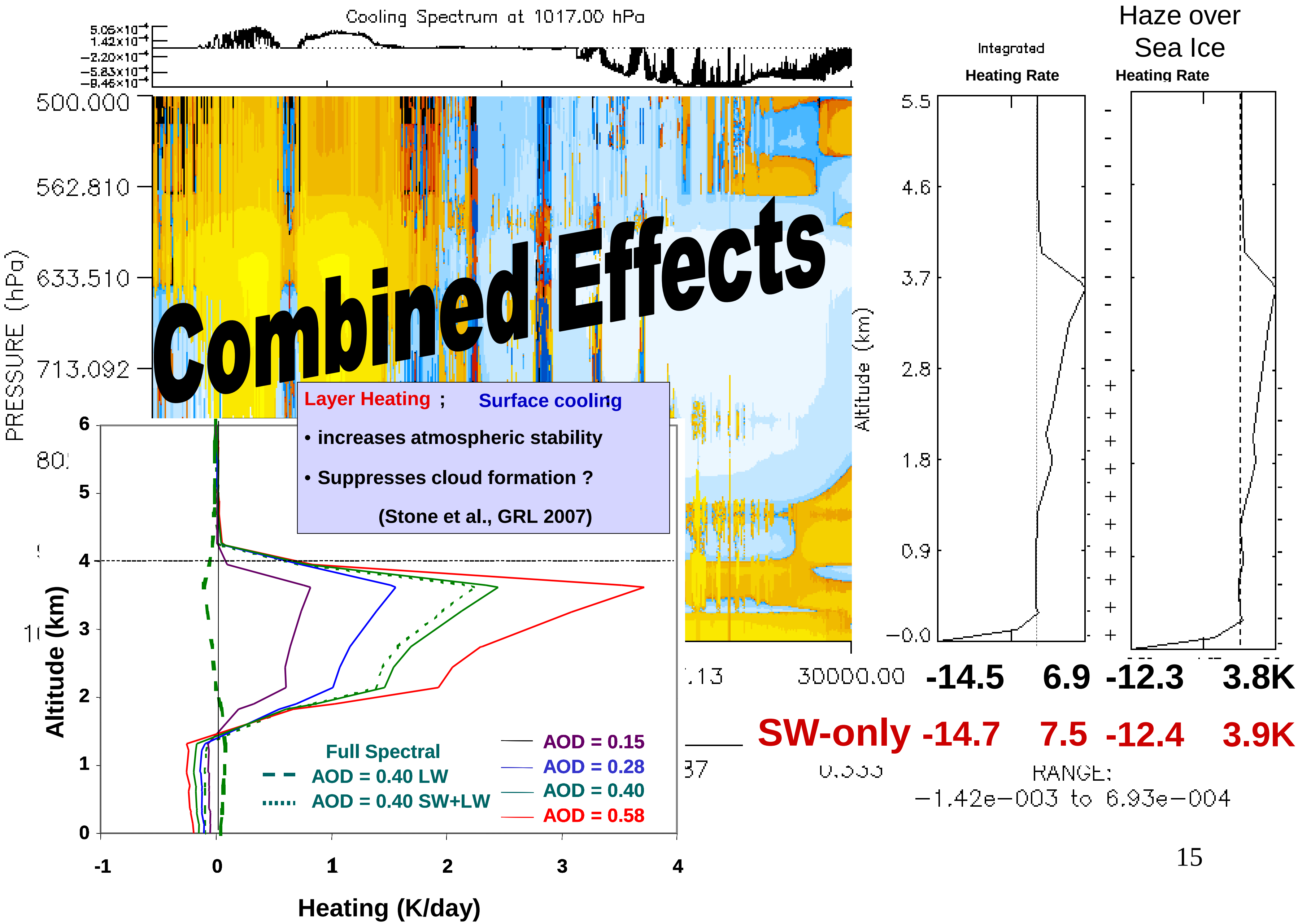


Solar heating more effective over darker surfaces!

Perturbation: bkg – (bkg+haze), over Sea Ice



Maximum Perturbation: bkg – (bkg+volcanic), over Tundra



DISCUSSION

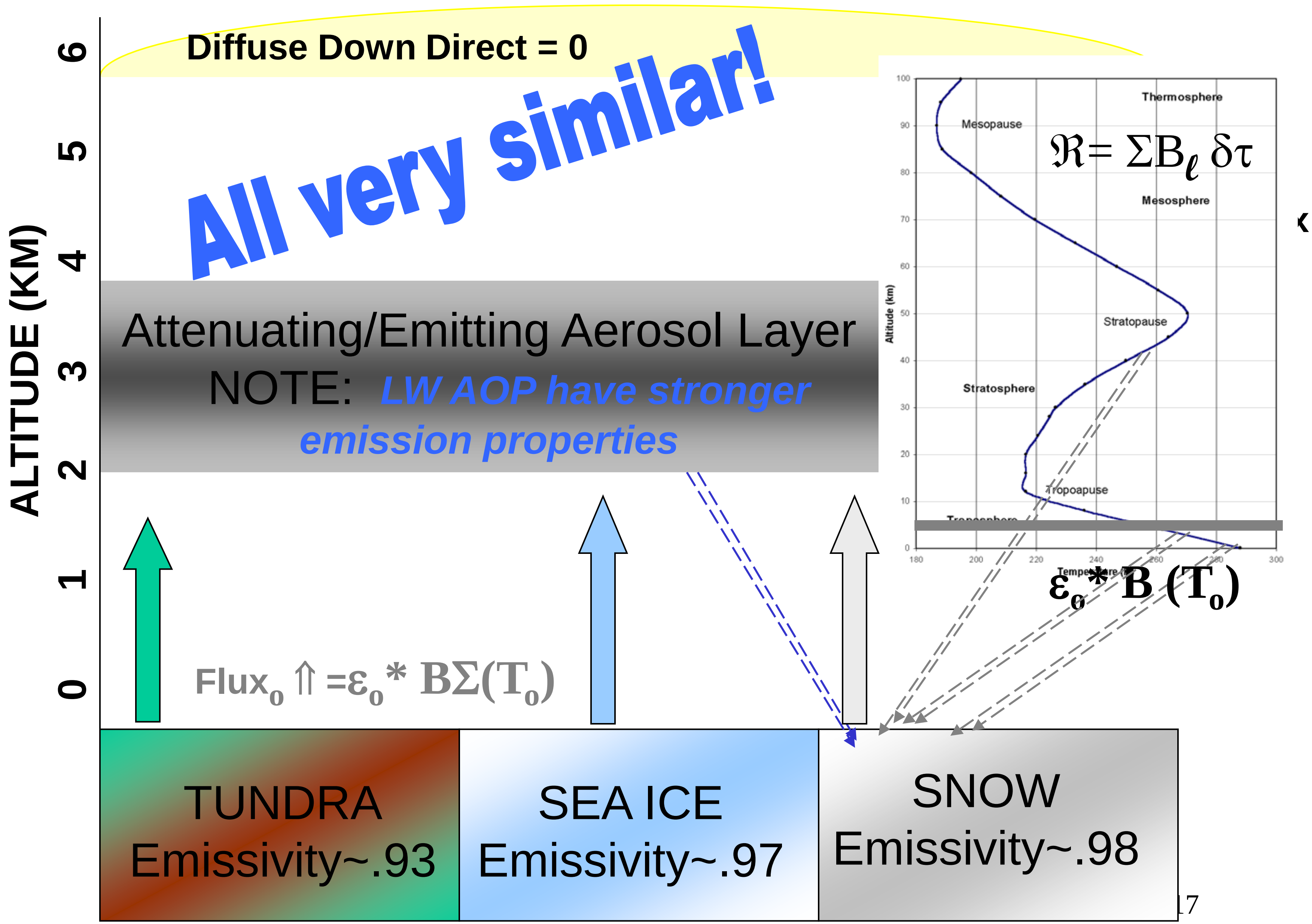
The Magnitude of Aerosol Perturbations depends upon:

1st order: SW Solar 'heating within the aerosol layer' and 'cooling at the surface' are the dominant terms.
2nd order: LW 'Δcooling within the layer' and 'Δheating at the surface' are impacted by the particle size and surface type.

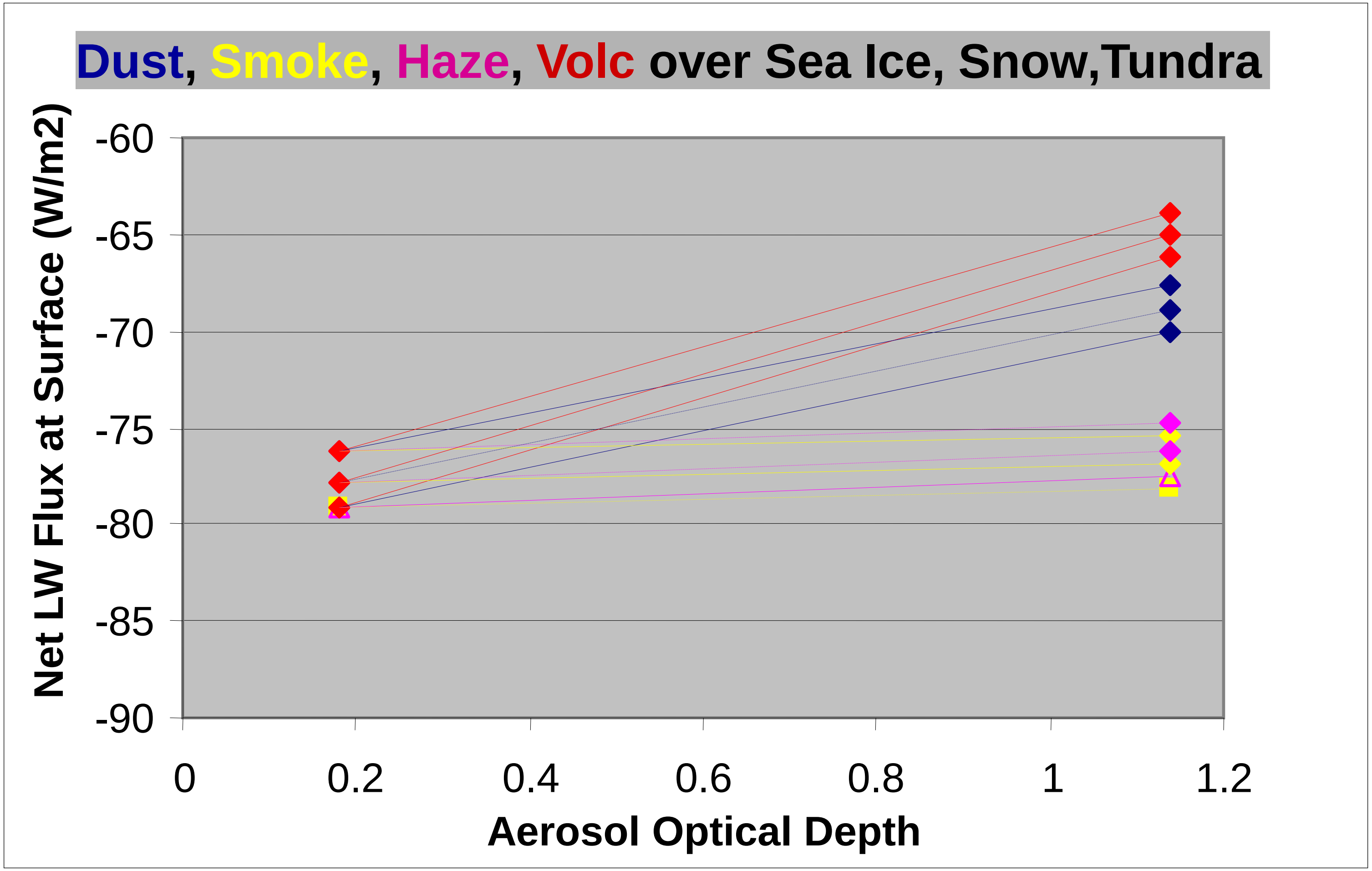
Surface Cooling is typically linear in AOD^{-1}, but the radiative forcing (DARF) depends on the size of the aerosol particulates, especially at and above 1um in diameter.

Aside: In prior studies the altitude of the aerosol layer was not very relevant; however, the emissive (LW) regime would be more sensitive to hot plumes, near originating sources (volcanic or fire).

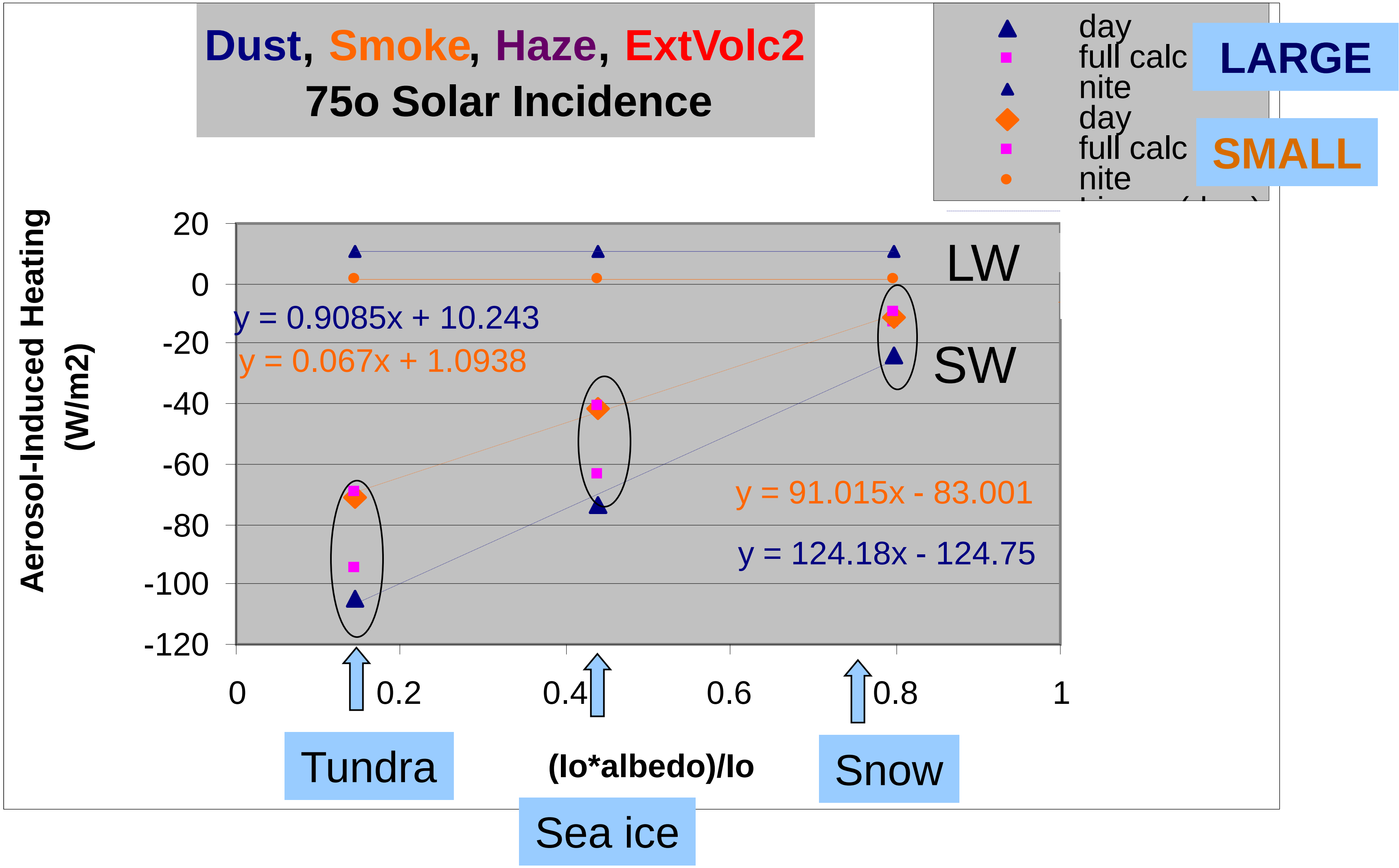
LW Net Flux(surf) = Down (Diffuse + Direct) ⇓ – Upflux⇑



75° Model Simulations: LW



AEROSOL-INDUCED SURFACE COOLING



DARF (Total & SW) ~ -1/albedo

hypothesis: high albedo leads to more multiple reflections between surface & atmosphere, diminishing the surface cooling