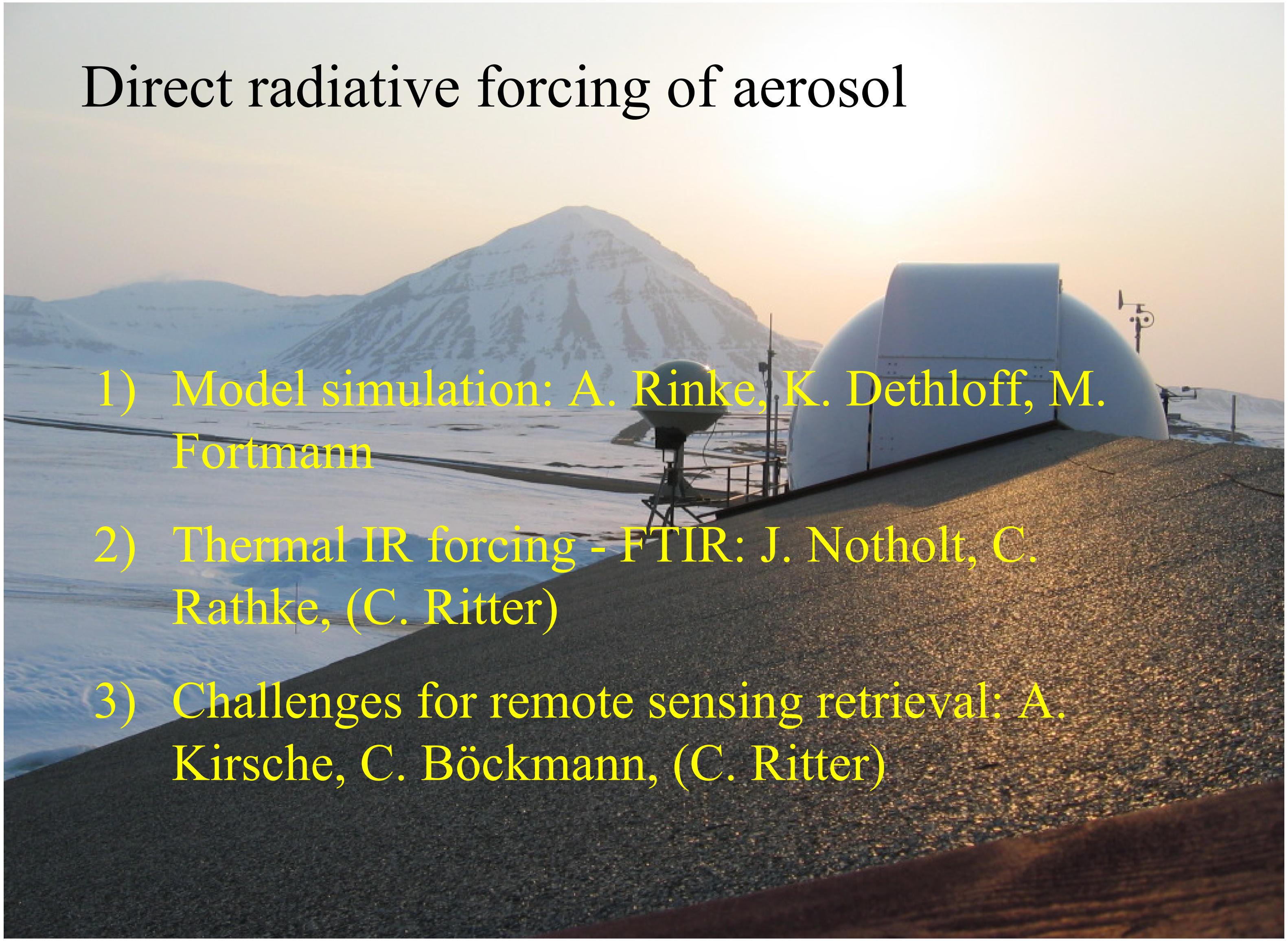
Direct radiative forcing of aerosol



1) Model simulation: A. Rinke, K. Dethloff, M. Fortmann

2) Thermal IR forcing - FTIR: J. Notholt, C. Rathke, (C. Ritter)

3) Challenges for remote sensing retrieval: A. Kirsche, C. Böckmann, (C. Ritter)

A modeling study with the regional climate model HIRHAM

1) Specification of aerosol from Global Aerosol Data Set (GADS)

2) Input from GADS into climate model:
   - for each grid point in each vertical level: aerosol mass mixing ratio (0.5 °, 19 vertical)
   - optical aerosol properties for short- and longwave spectral intervals f(RH)

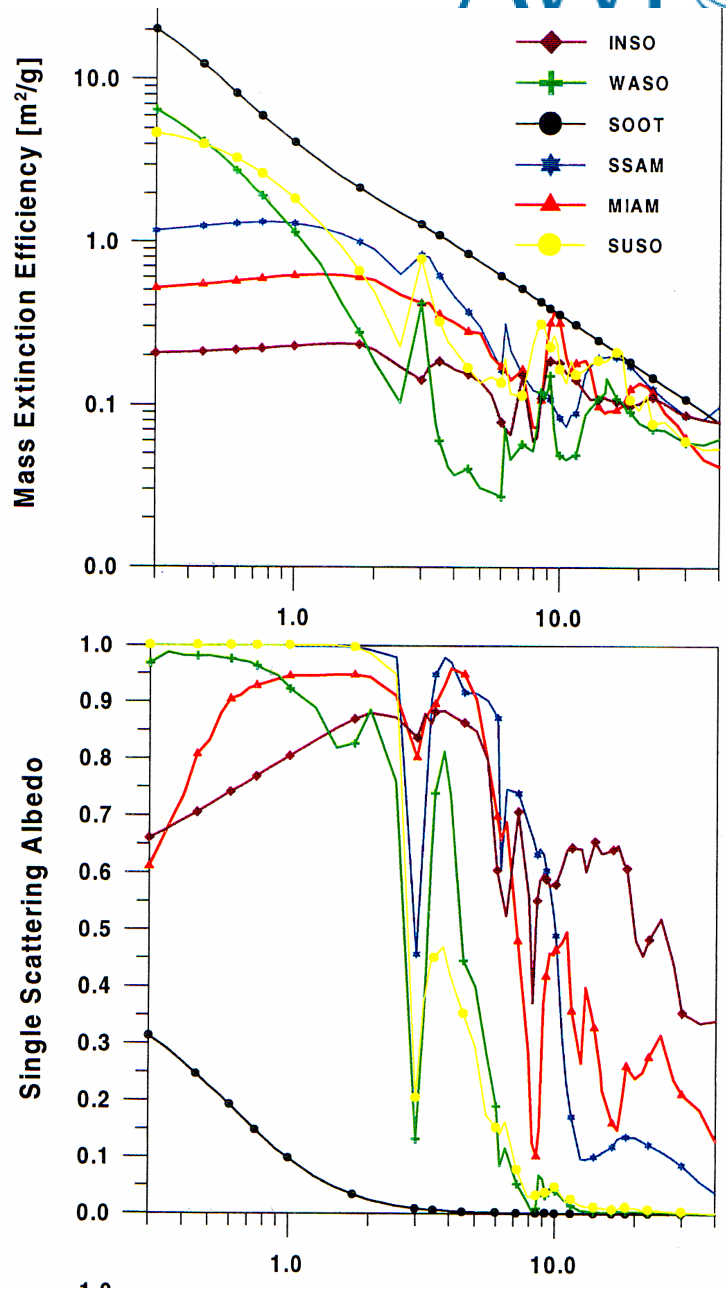
   aerosol was distributed homogeneously between 300 – 2700m altitude, no transport

3) Climate model run with and without aerosol → aerosol radiative forcing months March (1989 – 1995)

Global Aerosol Data Set (GADS); Koepke et al., 1997

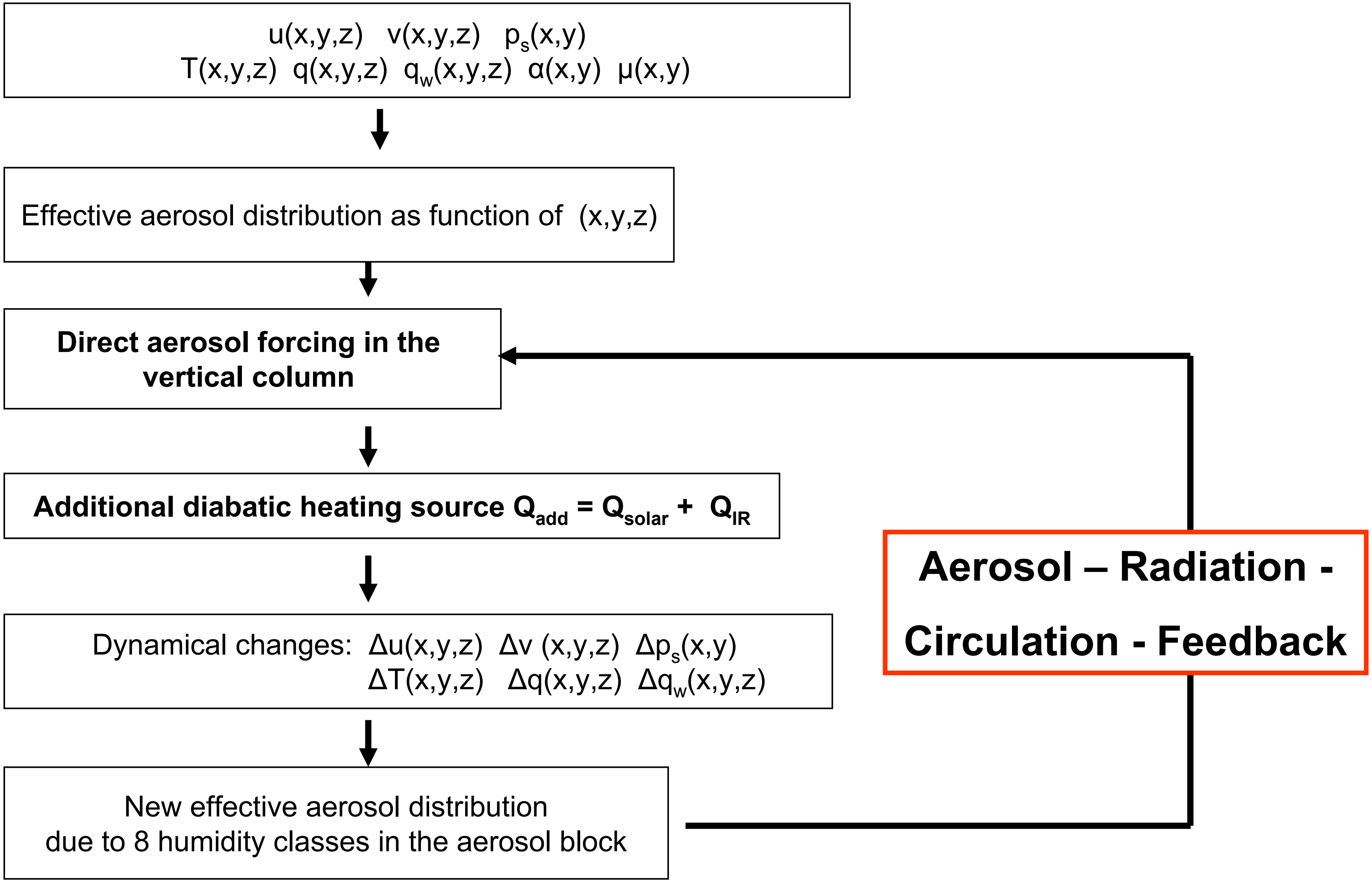
Components of the Global Aerosol Data Set					
No.	Aerosol Component	Name	r_m [µm]	σ	ρ [g/cm^3]
1	Water-insoluble	**INSO**	4.71E-1	2.51	2.0
2	Water-soluble	**WASO**	2.12E-2	2.24	1.8
3	Soot	**SOOT**	1.18E-2	2.00	1.0
4	Sea-salt (accumulation mode)	**SSAM**	2.09E-1	2.03	2.2
5	Sea-salt (coarse mode)	**SSCM**	1.75E+0	2.03	2.2
6	Mineral (nucleus mode)	**MINM**	7.00E-2	1.95	2.6
7	Mineral (accumulation mode)	**MIAM**	3.90E-1	2.00	2.6
8	Mineral (coarse mode)	**MICM**	1.90E+0	2.15	2.6
9	Mineral-transported	**MITR**	5.00E-1	2.20	2.6
10	H_2SO_4-Droplets	**SUSO**	6.95E-2	2.03	1.7

→ Arctic Haze: WASO, SOOT, SSAM



Properties taken from ASTAR 2000 case (local), so overestimation of aerosol effect

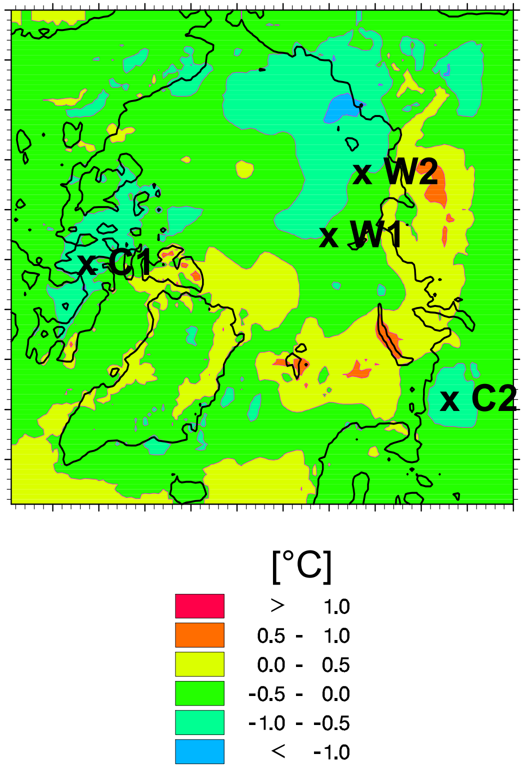
Direct climatic effect of Arctic aerosols in climate model HIRHAM via specified aerosol from GADS



Direct effect of Arctic Haze

"Aerosol run minus Control run", March ensemble

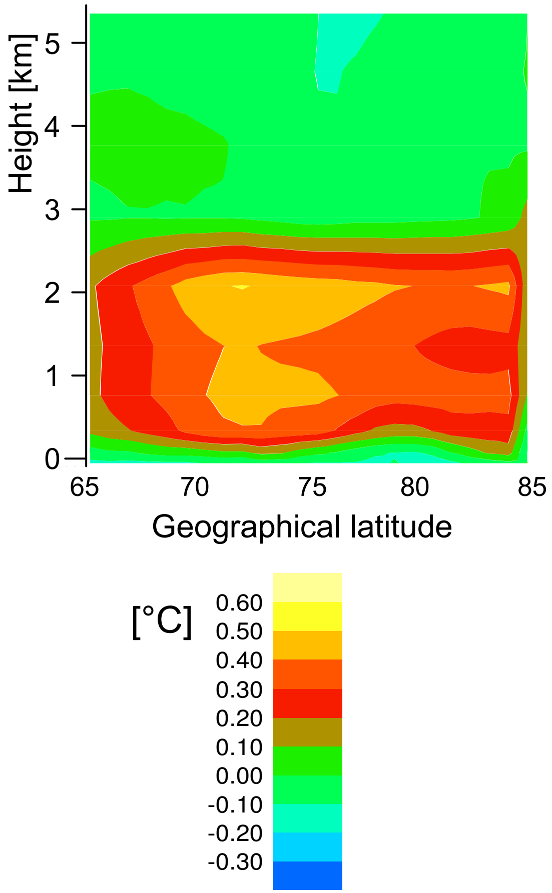
2m temperature change



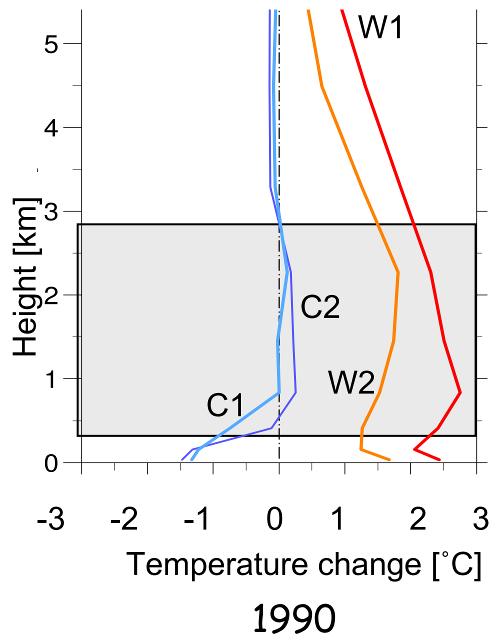
ΔF_{srfc}= 5 to −3 W/m²

1d radiative model studies:
ΔF_{srfc}=-0.2 to -6 W/m²

Height-latitude temperature change



Temperature profiles at selected points



Fortmann, 2004

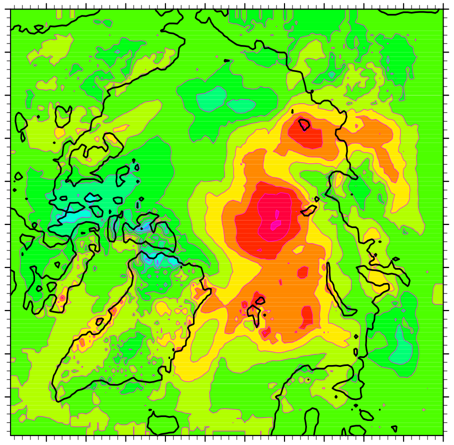
Direct+indirect effect of Arctic Haze

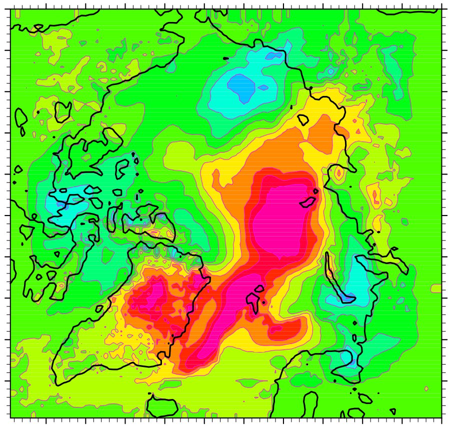
("Aerosol run minus Control run")
direct

March 1990

("Aerosol run minus Control run")
direct+indirect

2m temperature change

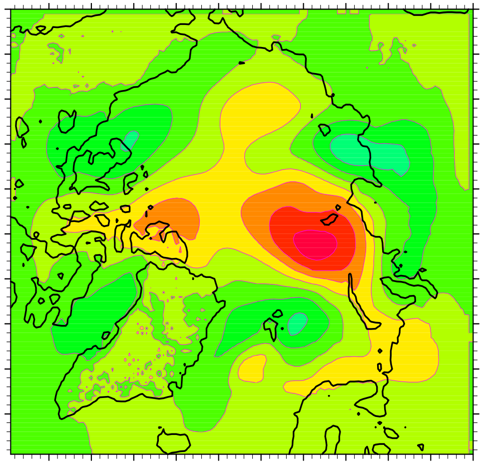


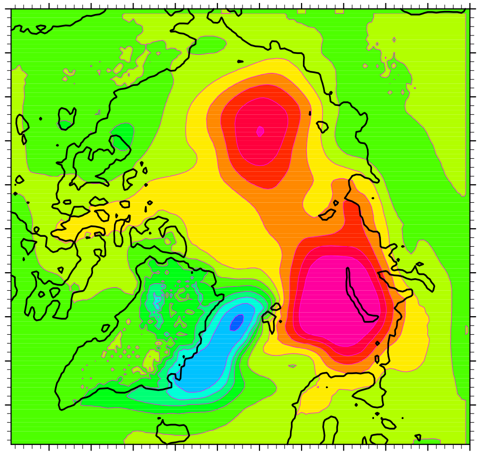


[K]

>	2.5
2.0 -	2.5
1.5 -	2.0
1.0 -	1.5
0.5 -	1.0
0.0 -	0.5
-0.5 -	0.0
-1.0 -	-0.5
-1.5 -	-1.0
-2.0 -	-1.5
-2.5 -	-2.0
<	-2.5

Sea level pressure change





[hPa]

>	2.5
2.0 -	2.5
1.5 -	2.0
1.0 -	1.5
0.5 -	1.0
0.0 -	0.5
-0.5 -	0.0
-1.0 -	-0.5
-1.5 -	-1.0
-2.0 -	-1.5
-2.5 -	-2.0
<	-2.5

Rinke et al., 2004

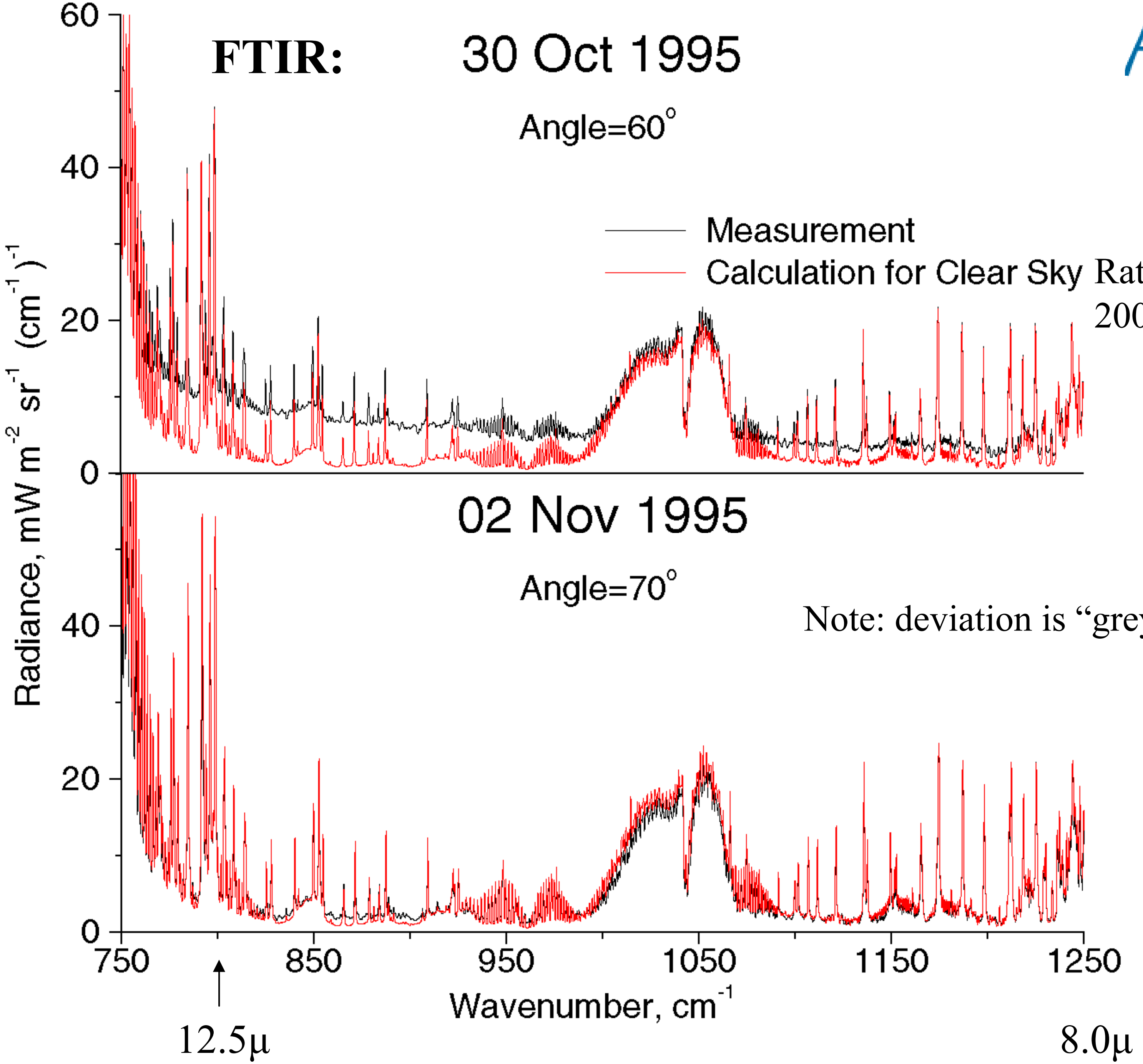
Conclusion modeling:

- Critical parameters are:

  Surface albedo, rel. humidity, aerosol height (especially in comparison to clouds) (indirect: liquid water)

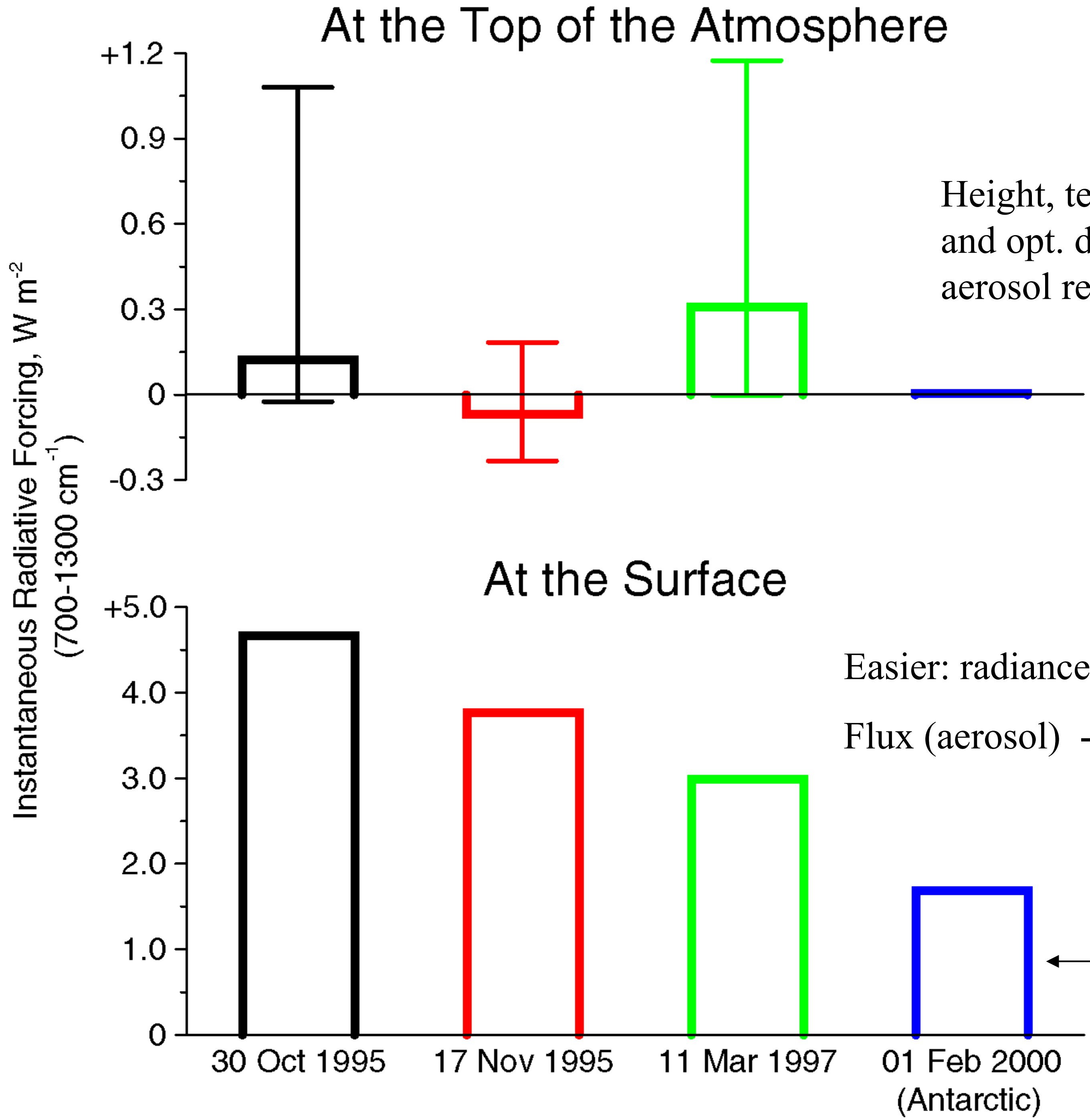
  But aerosol properties were prescribed here – so no direct statement on sensitivity of aerosol properties (single scat. albedo…) according to GADS,

  however: chemical composition, concentration and size distribution of aerosol did show strong influence on results (surface temperature)
- aerosol has the potential to modify global-scale circulation via affected teleconnection patterns



Rathke, Fischer 2000

Note: deviation is “grey”

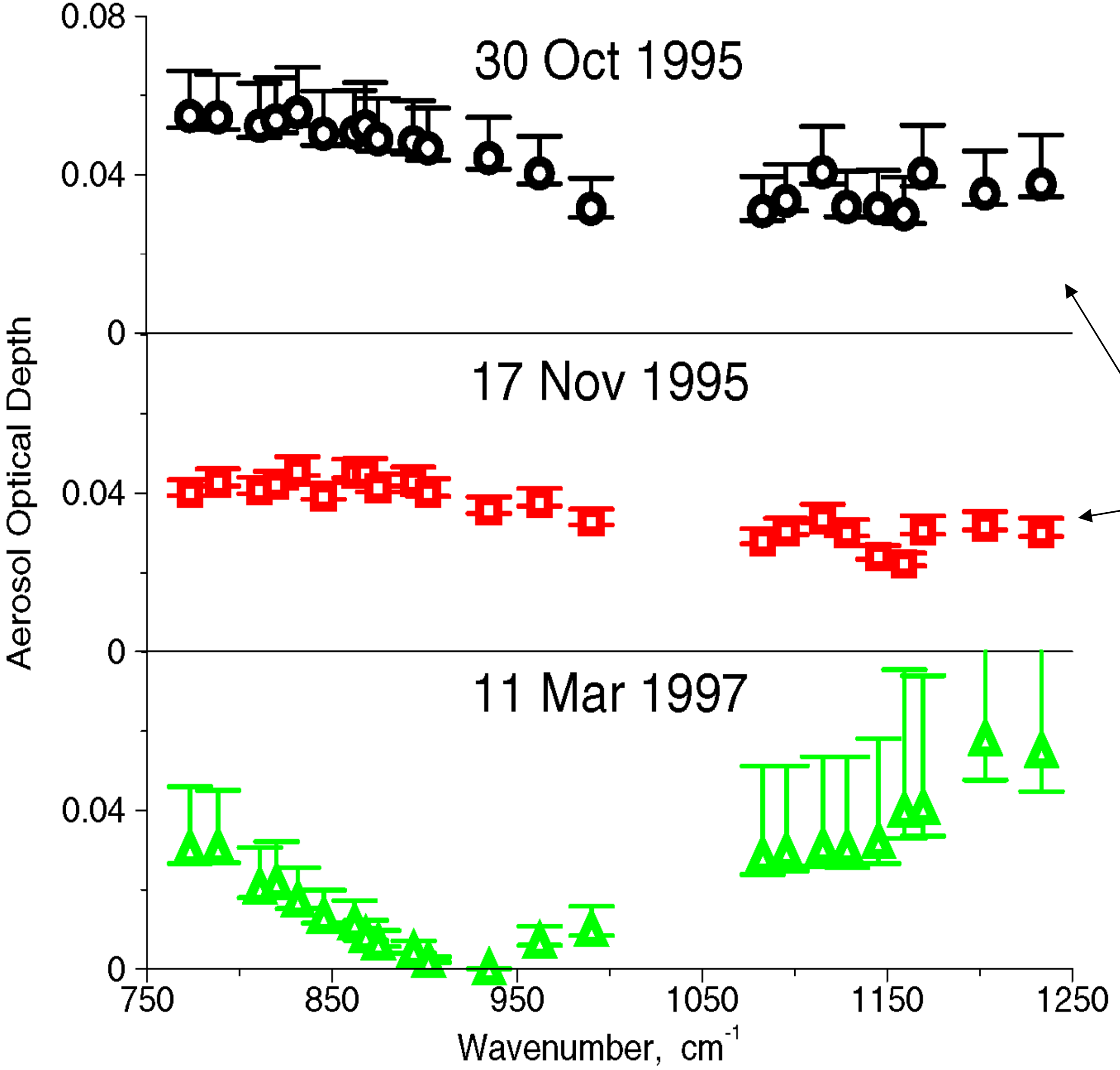


Height, temperature and opt. depth of aerosol required

Easier: radiance → flux

Flux (aerosol) - flux (clear)

← significant

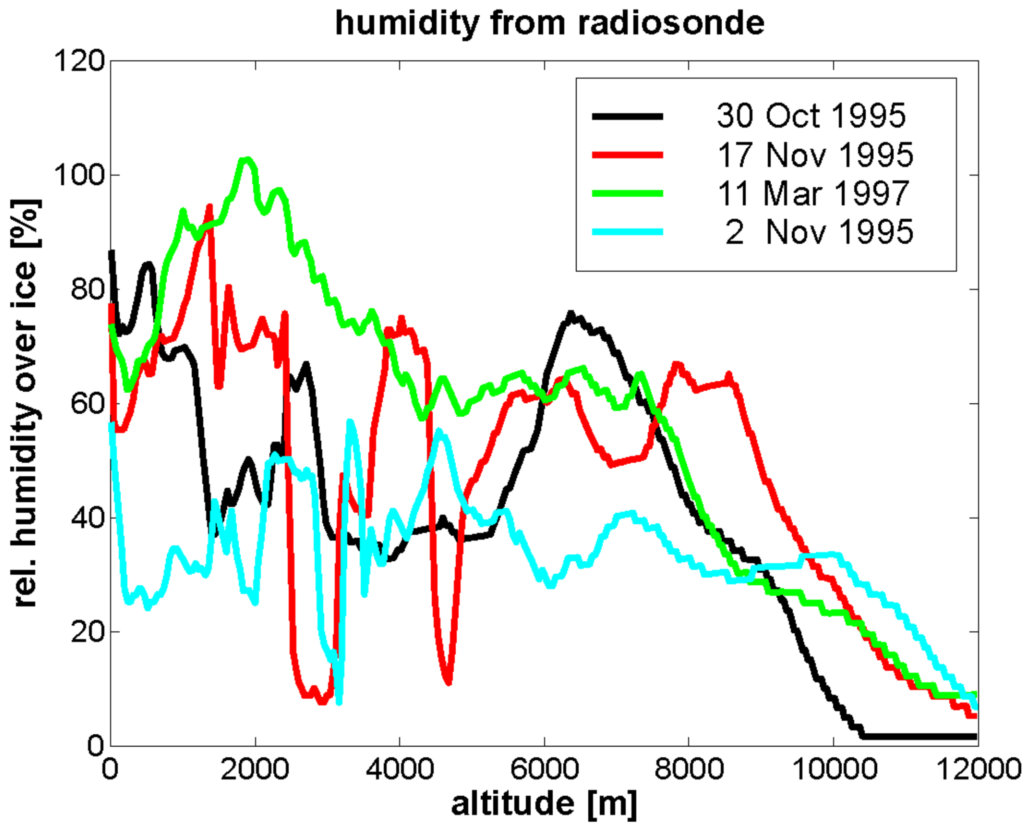


AOD from spectrum of radiance residuals

Note similar spectral shape

For TOA:

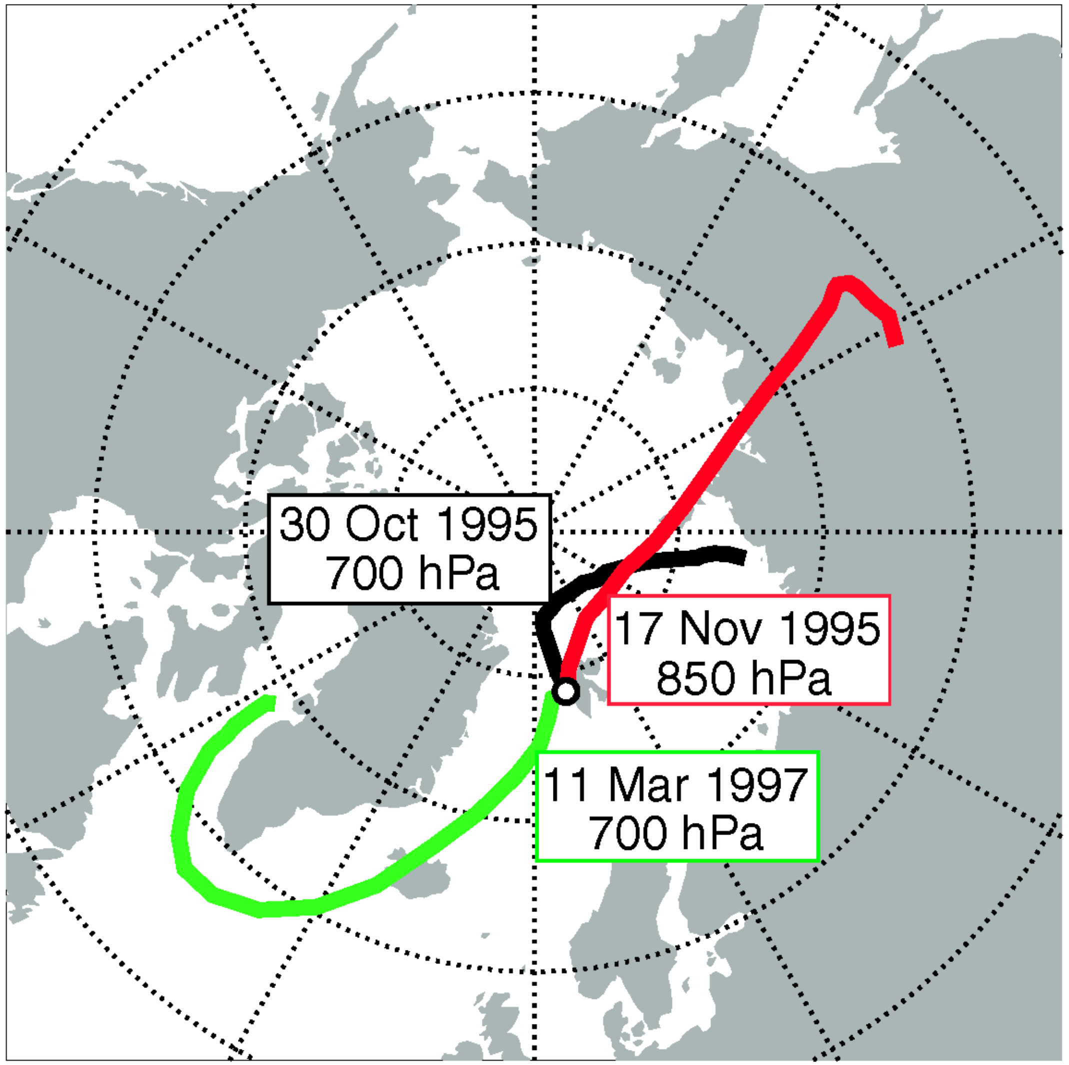
Assumption: purely absorbing (!)



Radiosonde launch:
11UT (RS82)

11. Mar: cold and wet: diamond dust possible

For 30. Oct, 17. Nov: ΔT of 1.5 C needed for saturation



Ritter et al., Figure 5

Conclusion FTIR observation:

- Observational facts:
  grey excess radiance was found for some days where back trajectories suggest pollution
  diamond dust unlikely for 30 Oct, 17 Nov.

- So IR forcing by small (0.2µm) Arctic aerosol?
  Consider: complex index of refraction at 10µm for sulfate, water-soluble, sea-salt and soot (much) higher than for visible light! ("Atmospheric Aerosols")
  example

λ \ specimen	sulfate	water-solu.	soot	oceanic
0.5 µ	1.43+1e-8i	1.53+5e-3i	1.75+0.45i	1.382+6.14e-9i
10µ	1.89+4.55e-1i	1.82+9e-2i	2.21+0.72i	1.31+4.06e-2i

Mie calculation (spheres 0.2µm, sulfate): vis: no absorption, ω=1
IR: almost no scat. ω=0

so: ω, n, phase function are all (λ)

Scattering properties by remote sensing?

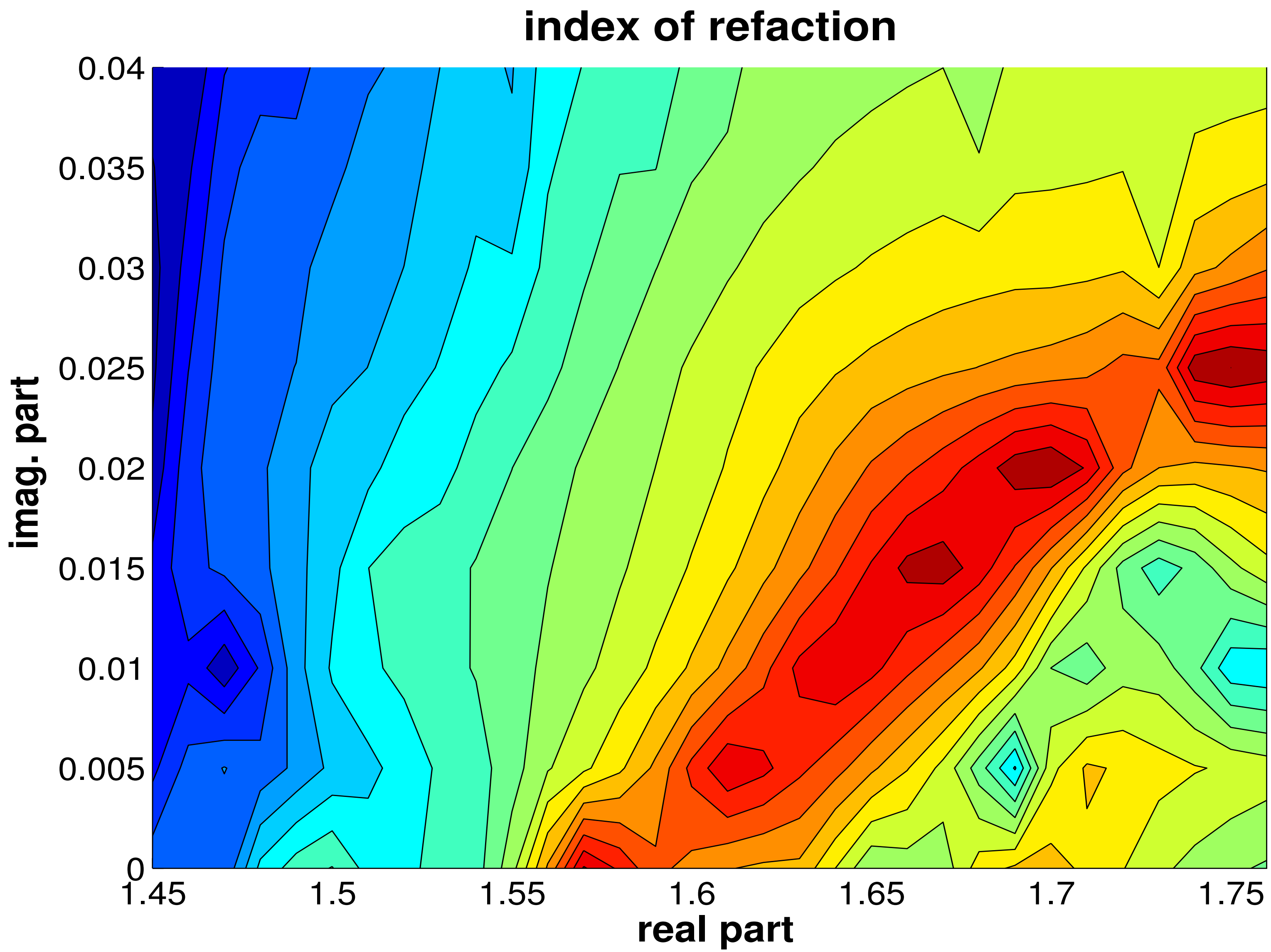
- Have seen: single scattering very important, depend on index of refraction.
- Multi wavelengths Raman lidars can principally calculate / estimate size distribution & refractive index (n) => scattering characteristics.
- One difficulty: estimation of n:

forward problem:

$$\min_{vd \in \Re^k} \left\| M_n \cdot vd - d \right\| > \min_{vd \in \Re^k} \left\| M_{n_{true}} \cdot vd - d \right\|$$

d: data; vd: coefficients of volume distribution function

M: matrix of scattering efficiencies (λ, k), depend on n



index of refaction
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
imag. part
1.45
1.5
1.55
1.6
1.65
1.7
1.75
real part