Introduction of Light Absorbing Particles in ORCHIDEE snow model

By

**Sujith Krishnakumar, Samuel Albani, Martin Ménégoz,
Catherine Ottlé, Anne Cozic, & Yves Balkanski**

UNIVERSITA' DEGLI STUDI DI MILANO BICOCCA

IGE

LSCE
LABORATOIRE DES SCIENCES DU CLIMAT
& DE L'ENVIRONNEMENT

Light Absorbing Aerosols (LAP) in Snow

1. Major LAP presents in snow are Dust, Black Carbon (BC)/soot and Organic Carbon (OC)
2. LAP influx to snow: Gravitational settling, Dry and Wet deposition, Scavenging due to convective activity.
3. Positive feedbacks with incorporation of LAP:

- Warmer snow increases snow grain size, which darkens snow (Flanner & Zender, 2006, JGR)
- Spring and summer melting increases concentration hydrophobic LAP at snow surface (Clarke and Noone, 1985, JGR)

Flow Chat of LAP mass tracer incorporation in snow

Deposition of LAPs in snow

Discretisation of LAPs in nsnow layers
w.r.t
Discretisation of Snow Depth

Flushing of LAPs through Snow Layers by melt water Infiltration
and
Removal at the bottom layer

Removal of LAPs due to Rainfall

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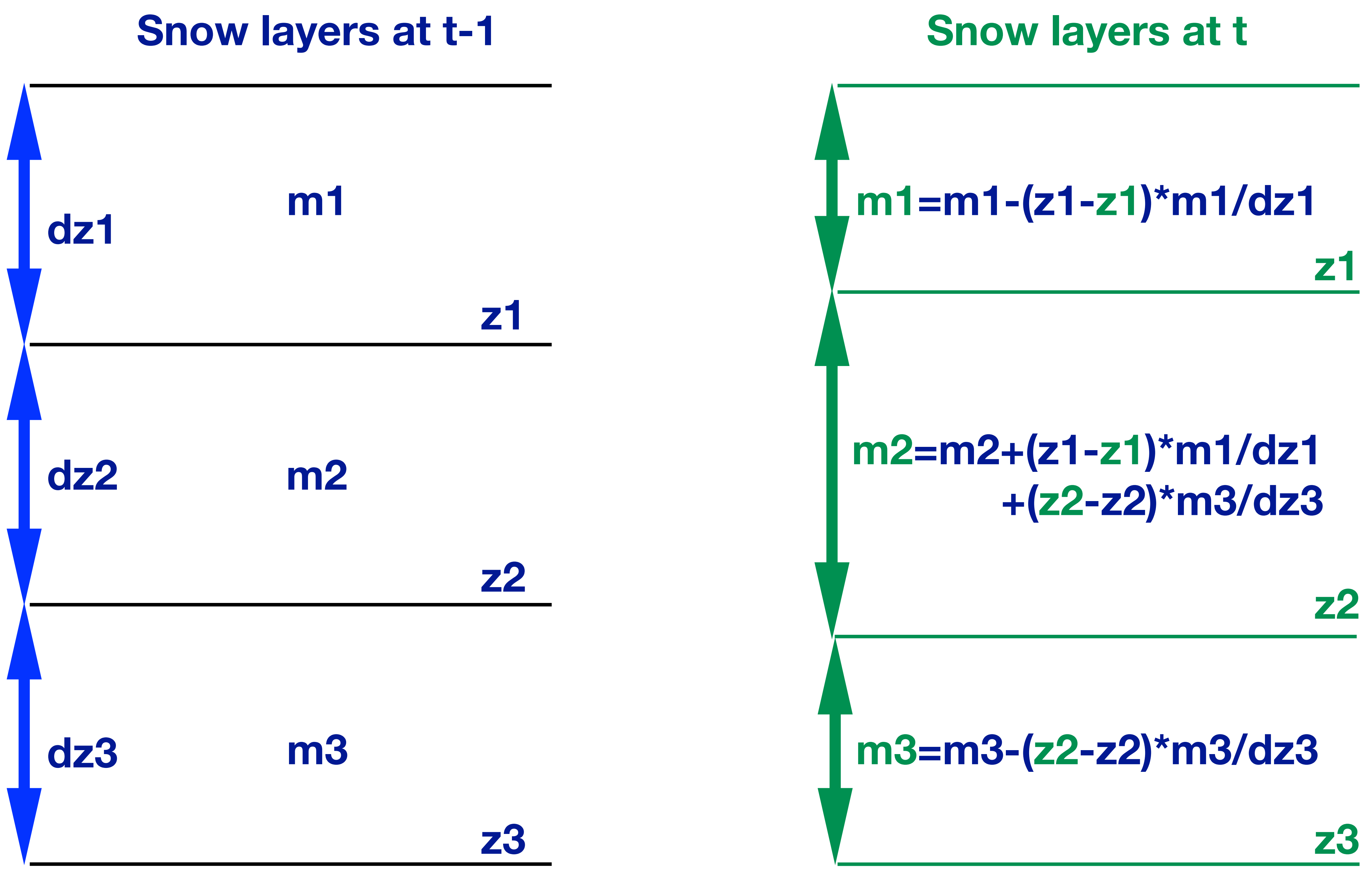


Snow layers at t-1

dz1 m1 z1

dz2 m2 z2

dz3 m3 z3

Snow layers at t

$m1=m1-(z1-z1)*m1/dz1$ z1

$m2=m2+(z1-z1)*m1/dz1+(z2-z2)*m3/dz3$ z2

$m3=m3-(z2-z2)*m3/dz3$ z3

dz-> thickness; z-> total depth; m-> mass of LAPs in kg/m2

Flow Chat of LAP tracer incorporation in snow

Deposition of LAPs in snow

↓

Discretisation of LAPs in nsnow layers w.r.t Discretisation of Snow Depth

↓

Flushing of LAPs through Snow Layers by melt water Infiltration and Removal at the bottom layer

↓

Removal of LAPs due to Rainfall

- **Flushing of LAPs through the layers**

m(i,j)=m(i,j)+ef(i)*snowmelt(j-1)*mr(i,j-1)
-ef(i)*snowmelt(j)*mr(i,j)
i-> LAP species; j-> snow layer;
ef-> flushing efficiency;
mr-> mixing ratio of LAP
= m/(snowdz*snowrho)

- **Removal of LAPs at the bottom**

Removal(i)=ef(i)*snowmelt(nsnow)*mr(i,nsnow)

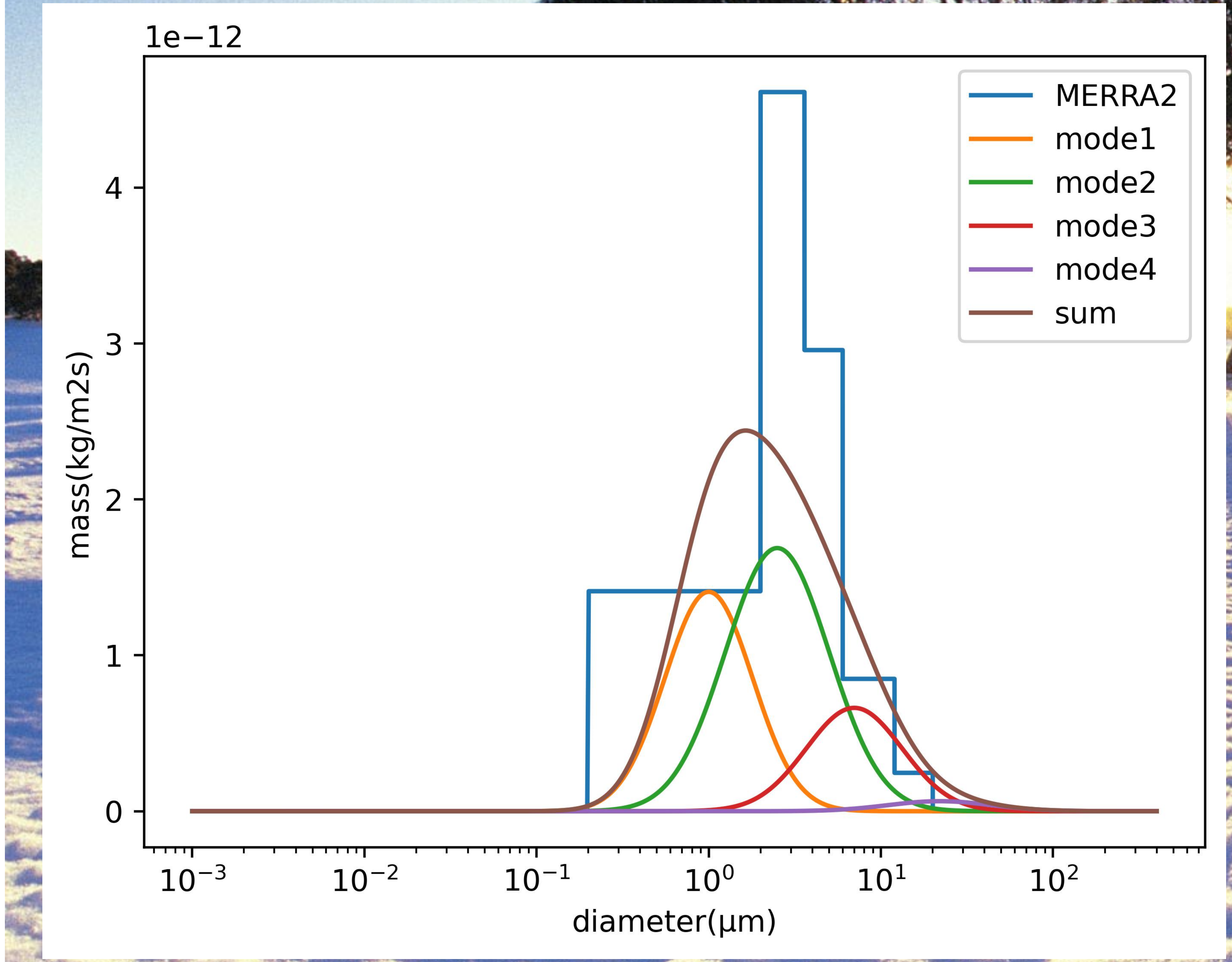
- **Removal of LAPs due to Rainfall**

Removal(i)=$\Sigma_{j=1,nsnow}$ef(i)*rainfall*mr(i,j)

LAP	Flushing efficiency
Dust r=1um	0.02
Dust r=2.5um	0.015
Dust r=7um	0.01
Dust r=22um	0.00
Soot Hydrophobic	0.03
Soot Hydrophylic	0.20
O.Carbon Hydrophobic	0.03
O.Carbon Hydrophylic	0.20

Yasunari et. al, 2014, SOLA

DUST: Merra Bins to INCA Modes



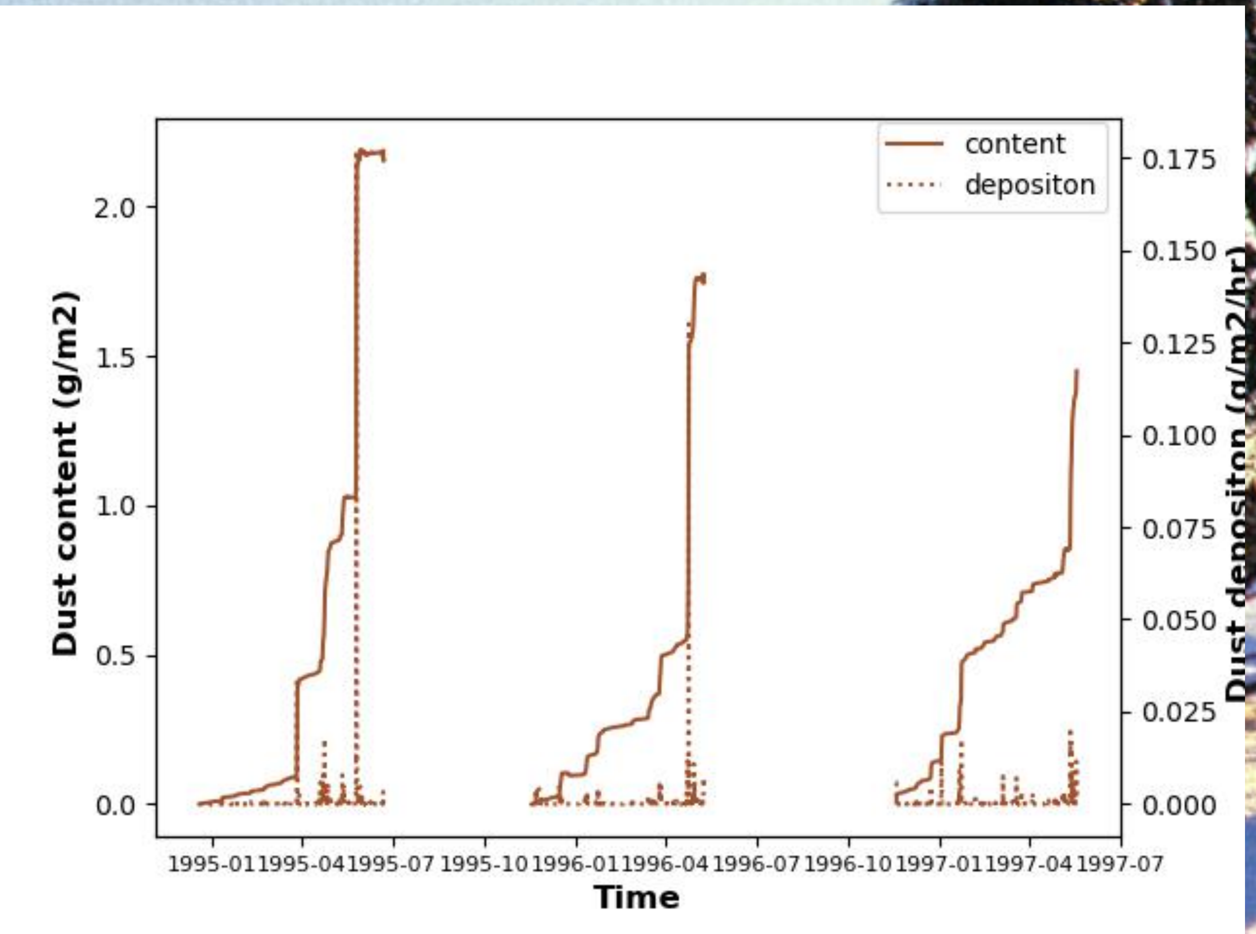
- **MERRA2 have 5 bins with diameter range: 0.2-2, 2-3.6, 3.6-6, 6-12, 12-20*μm***
- **INCA has 4 log-normal modes with mean diameters of 1.0, 2.5, 7.0 ,22.0*μm***

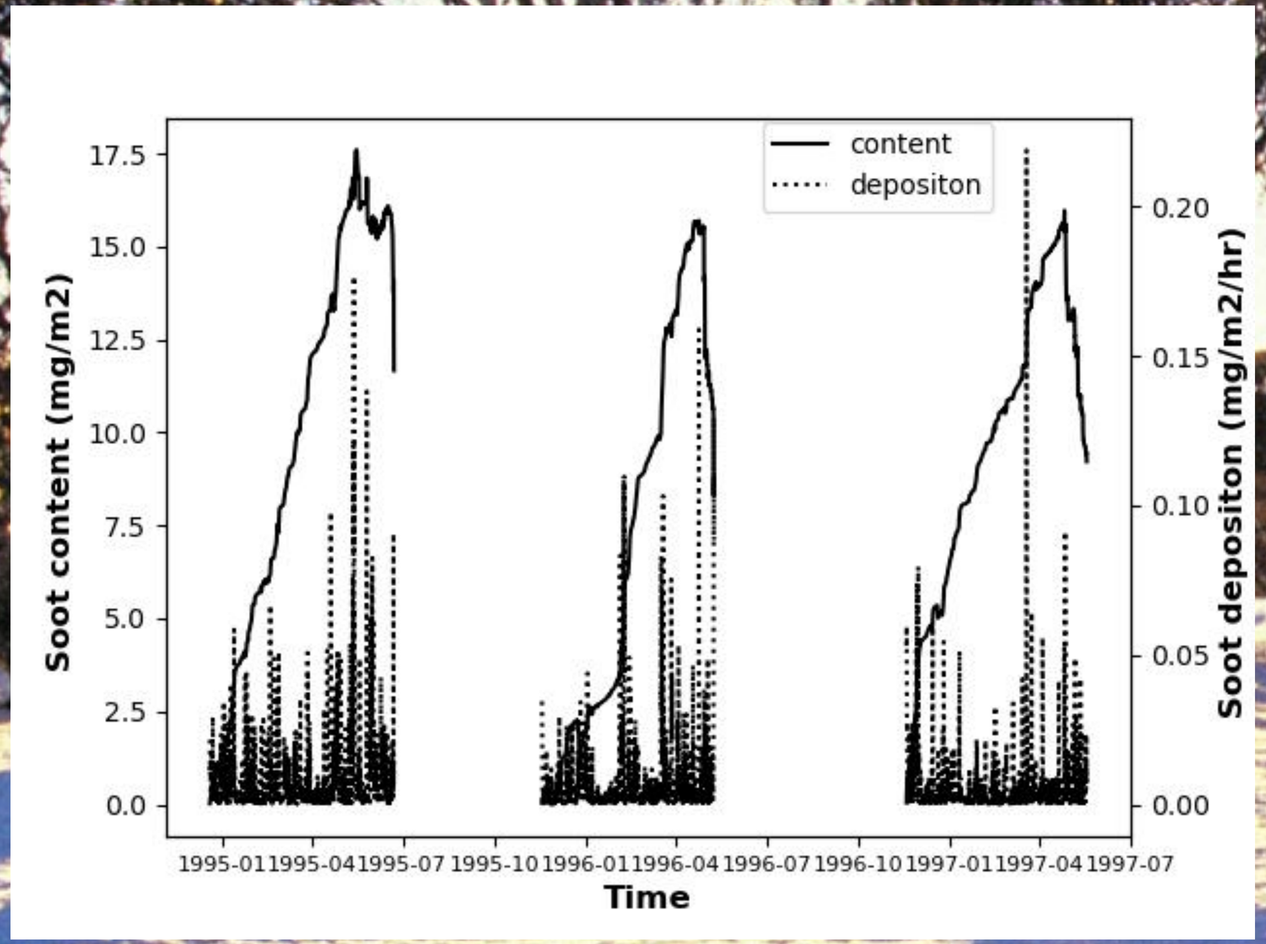
Site Simulation with ColdePorte

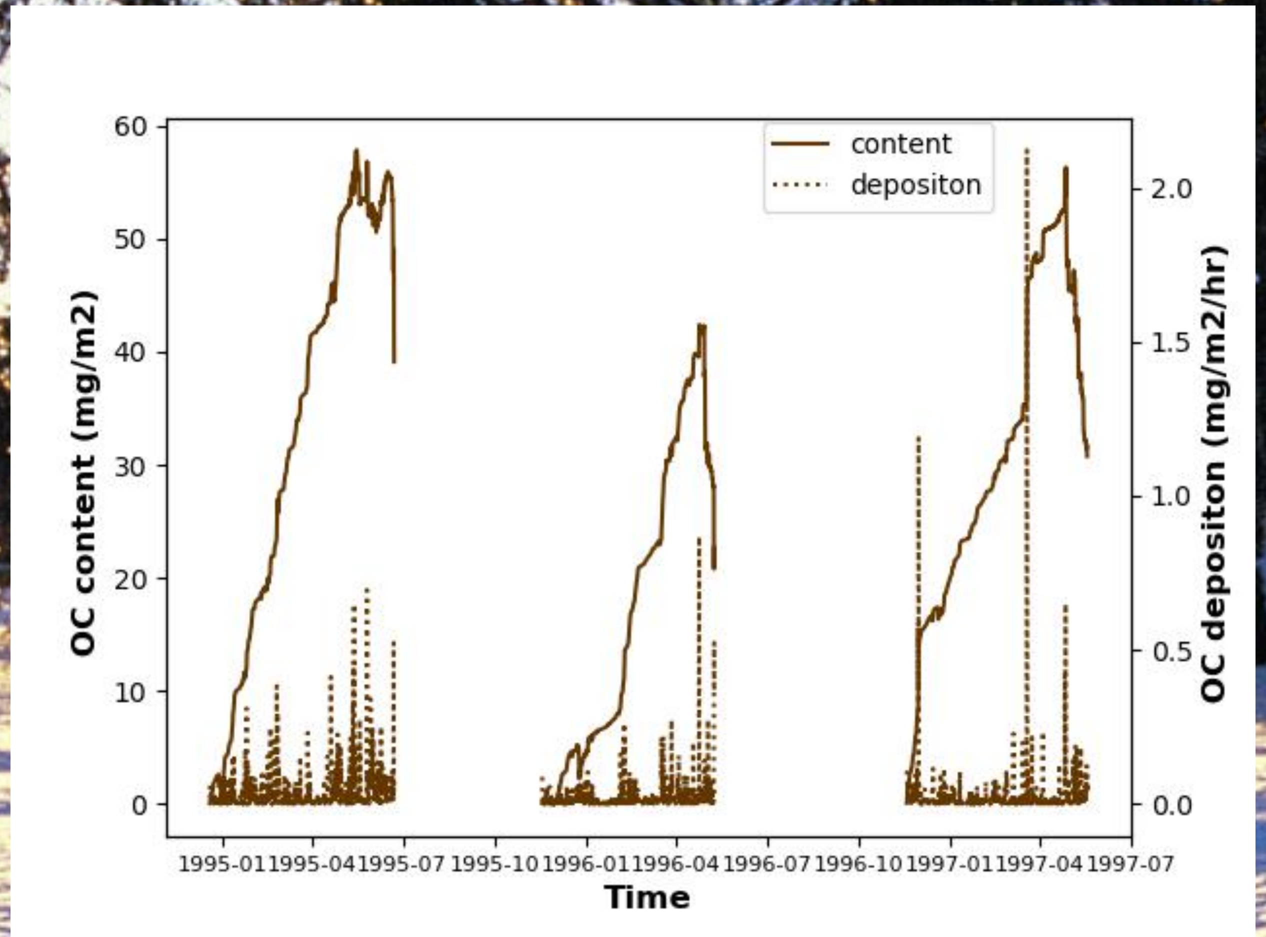
Expriment	Description
ORCHv2.2(PFT10)	ORCHIDEE 2.2 with albedo of PFT10
WW80_KSS_Puresnow	Development with Warren wiscombe radiative transfer scheme (WW80) and Kokhanswky snow optical properties and No LAP
WW80_KSS_LAPs	Same as above but with LAPs including 4 dust modes, 2 soot and 2 organic carbon (OC)

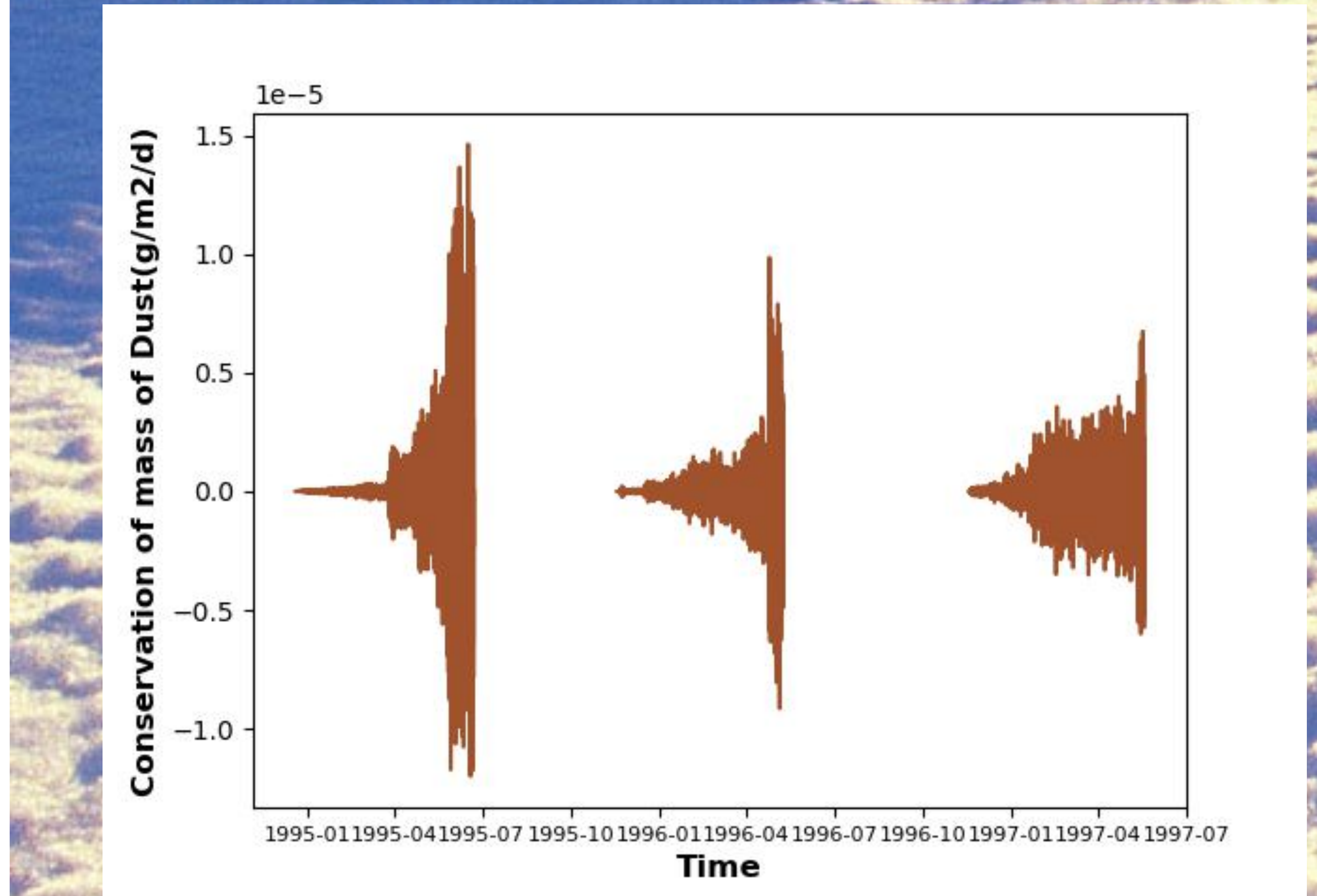
Site Simulation with ColdePorte: LAP content and mass conservation

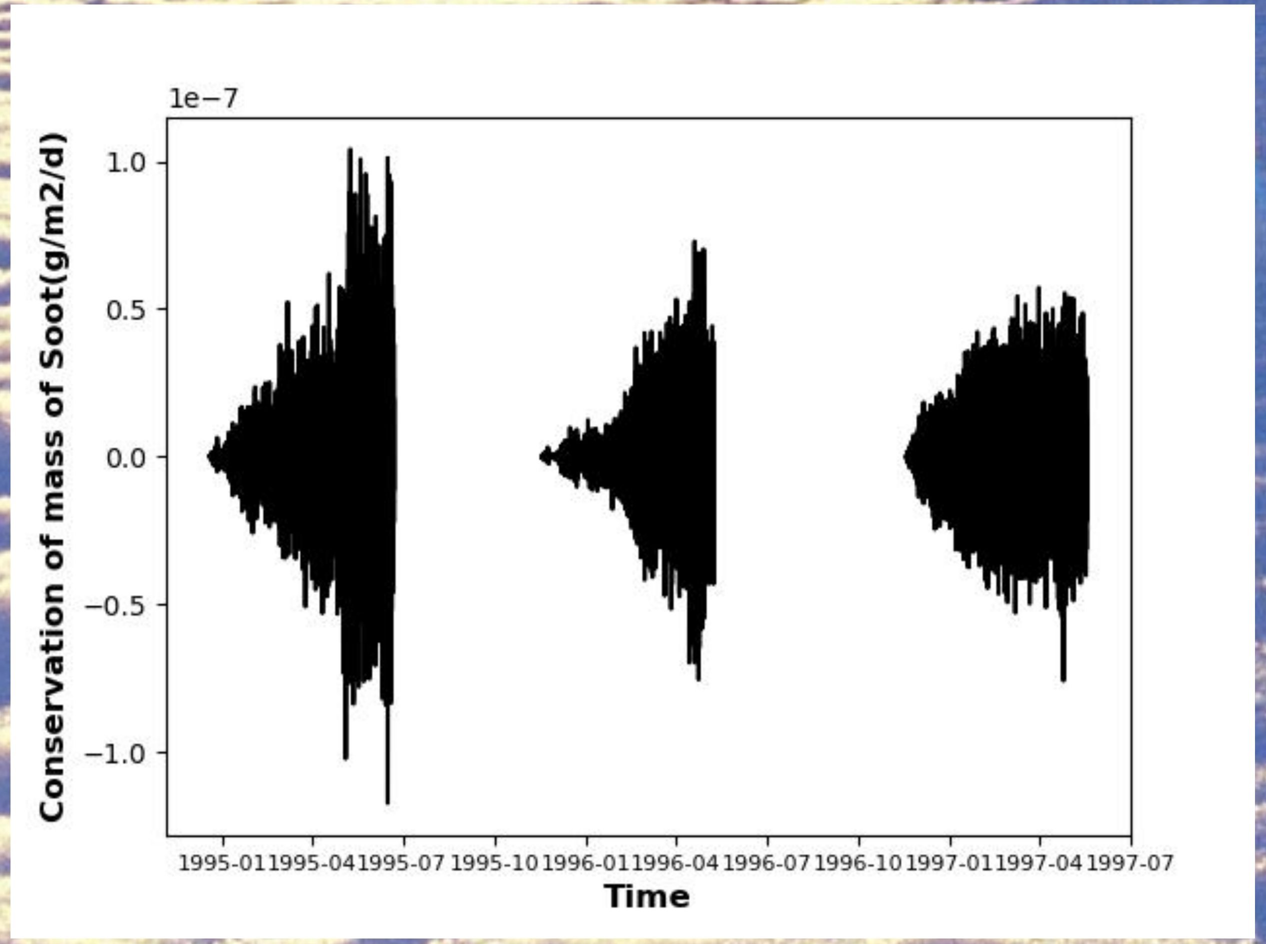
TOTAL MASS in (g/m2)

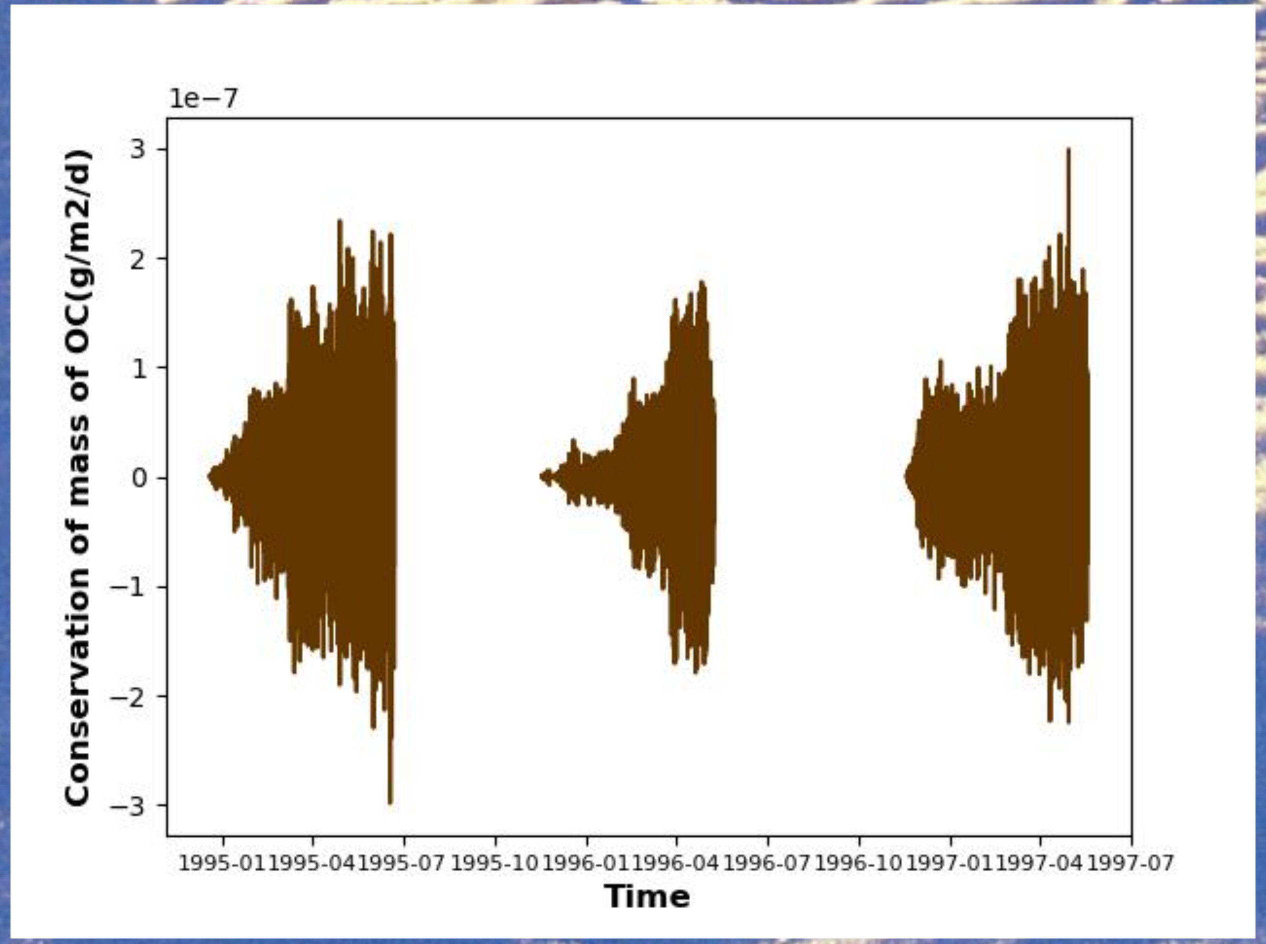












NET LAP Conservation
dM/dt-DEP+REM

Wiscombe & Warren Snow Radiative transfer scheme

➢Function of
- Solar zenith angle
- Ratio of diffuse incident flux to total (diffuse+direct) incident flux
- Albedo of surface underneath
- Optical properties of snow

➢Which are
- τ - optical depth (extinction)
- ω - single scattering albedo
- g - asymmetry factor

(Wiscombe & Warren, 1980, JGR)

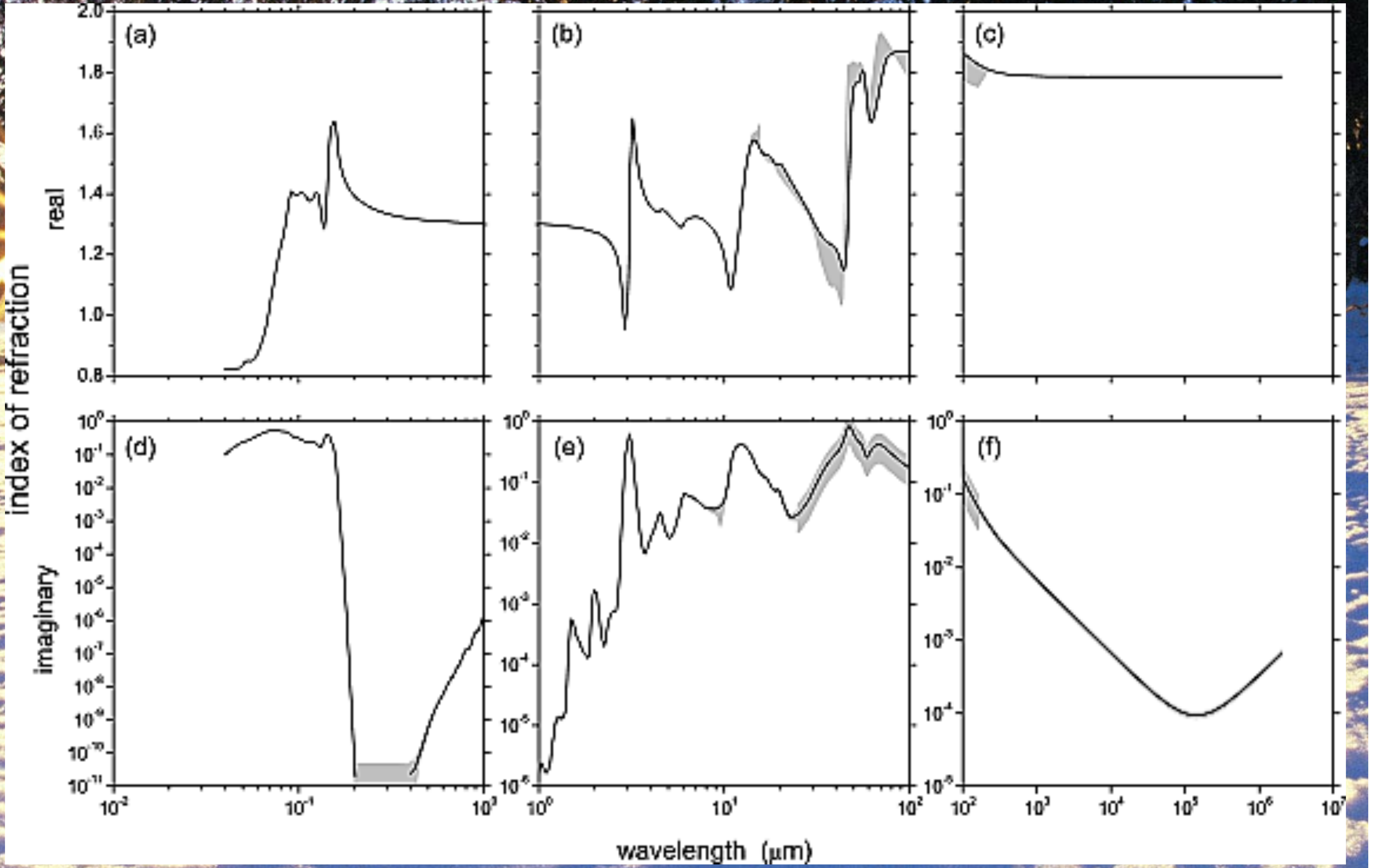
Specification of incorporation to ORCHIDEE

- **Scheme is implemented over bio PFTS**
- **Albedo is calculated for each layer of snow**
- **Direct and Diffused albedo calculations**

Snow Optical Properties from Kokhanovsky Scheme

1. Basically this scheme use refractive index of ice, that depends on wavelength (Warren & Brandt, 2008, JGR-A)
2. Correction to imaginary part for wavelength < 600nm by Picard 2016.

$$m = n - i\chi$$



Snow Optical Properties from Kokhanovsky Scheme

1. Optical depth

$$SSA = \frac{3}{r_{eff}\rho_{ice}}$$

$$\sigma_e = \frac{\rho SSA}{2}$$

$$\tau = \sigma_e z$$

3. Asymmetry Factor

$$g(n,s) = g_\infty(n) - (g_\infty(n) - g_0(n,s)) * e^{-y(n,s)c}$$

$$c = \frac{24\pi\chi}{\lambda\rho_{\text{ice}}\text{SSA}}.$$

$$g_\infty(n) = 0.9751 - 0.105(n-1.3)$$

$$g_0(n) = 0.8961 - 0.38(n-1.3)$$

$$y(n) = 0.728 + 0.752(n-1.3)$$

2. Single Scattering Albedo

$$(1-\omega) = \frac{1}{2}(1-W(n))(1-e^{-\psi(n,s)c})$$

$$\psi(n,s) = \frac{2}{3}\frac{B(n,s)}{1-W(n)}$$

$$W(n) = 0.0611 + 0.17 * (n-1.3)$$

$$B(n) = 1.22 + 0.4(n-1.3).$$

However, B0 is taken as 1.6 after Libois et al, 2014.

g00=0.86 as per Picard et al., 2009

LAP: Optical Properties from LMDZ

- Mass extinction (MEE), single scattering albedo (w) and asymmetry factor (g) are taken from LMDZ for 6 RRTM bands 0.18-0.25 μm, 0.25-0.44 μm, 0.44-0.69 μm 0.69-1.19 μm, 1.19-2.38 μm, 2.38-4.00 μm

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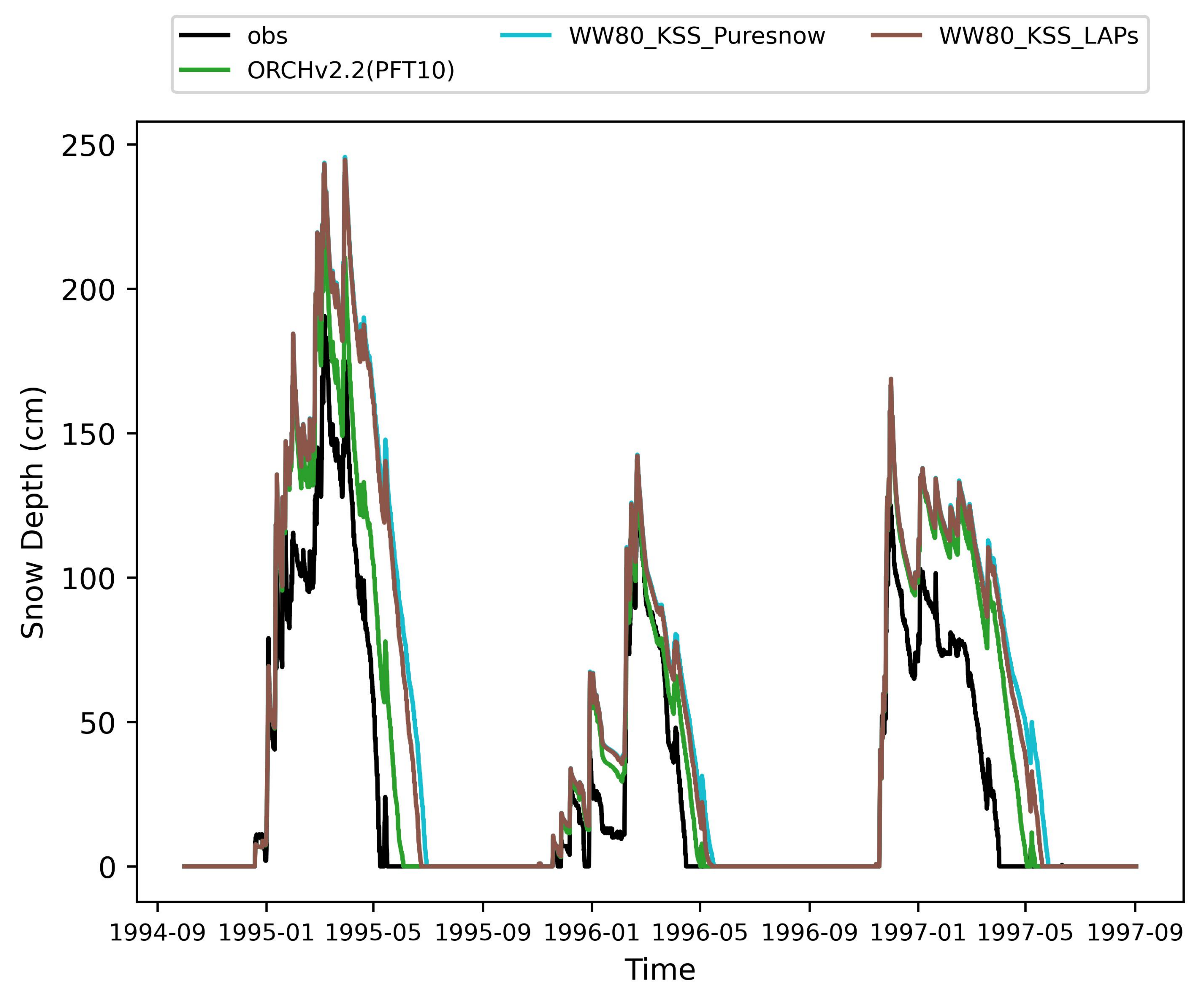

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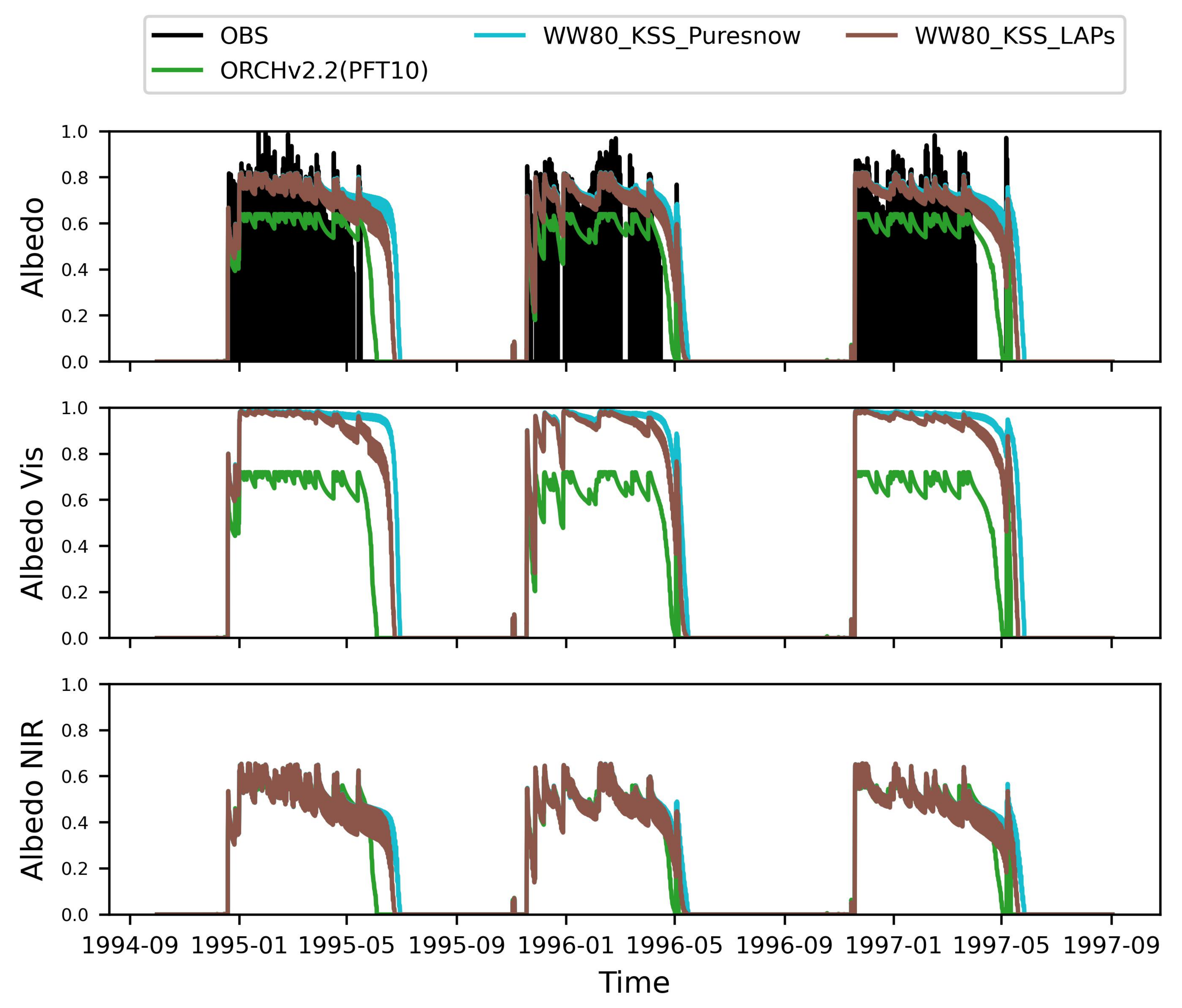

Sub snow layer Light Penetration and Absorption

Possible pathways for SW downwelling flux:

Transmission

forward scattering

Backward scattering (albedo)

absorption

Further Work

1. **Light penetration and subsurface Snow heating**

2. **Difference sensitivity experiments to quantify effects of flushing, different LAP species**

3. **1D simulation all the 8 Snow-ESMmip sites and one site over High Mountain Asia.**

4. **Coupling with LMDZ-OR-INCA6.2.2 which has four modes of Dust.**

THANK YOU