Spectral coupling between the atmosphere and snow surfaces

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Danish Meteorological Institute (DMI)
44th EWGLAM and 29th SRNWP Meeting
Wednesday 2022-09-28

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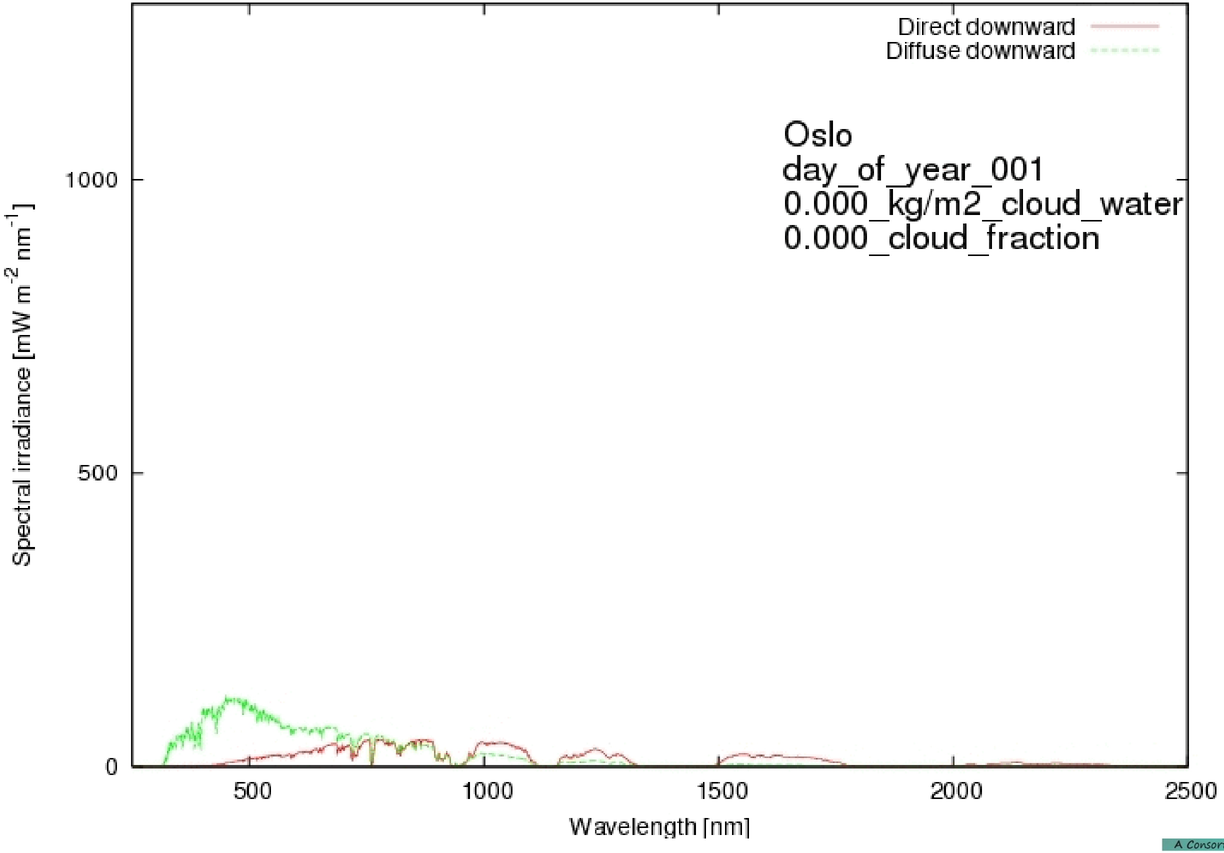
The solar spectrum



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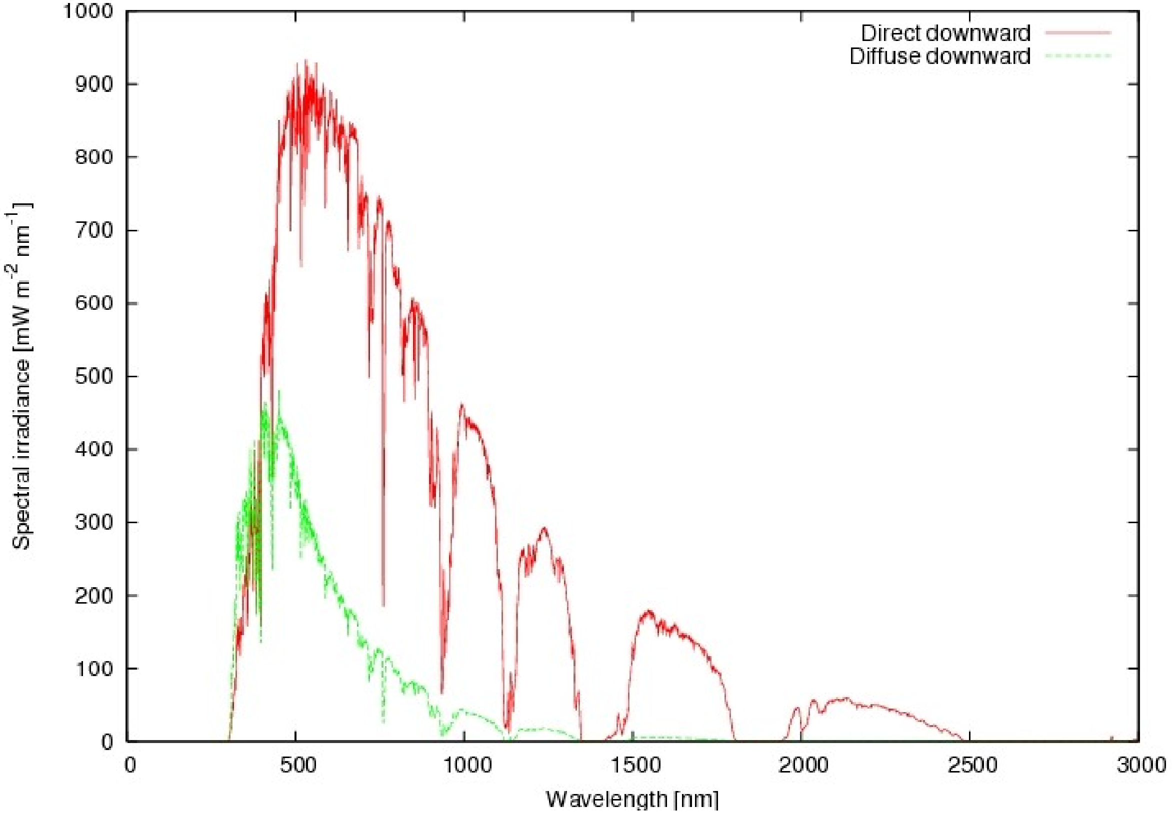
No clouds. albedo = 0.2



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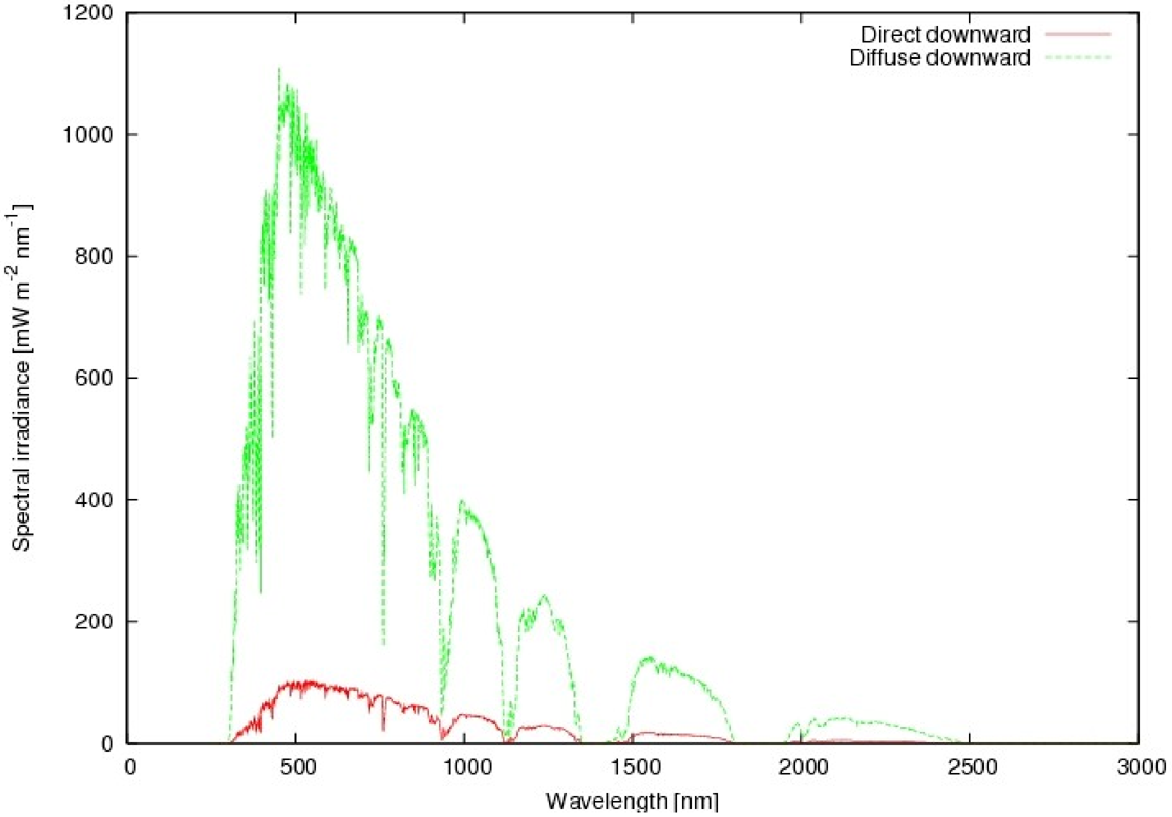
+ 10 g/m^2 cloud water load



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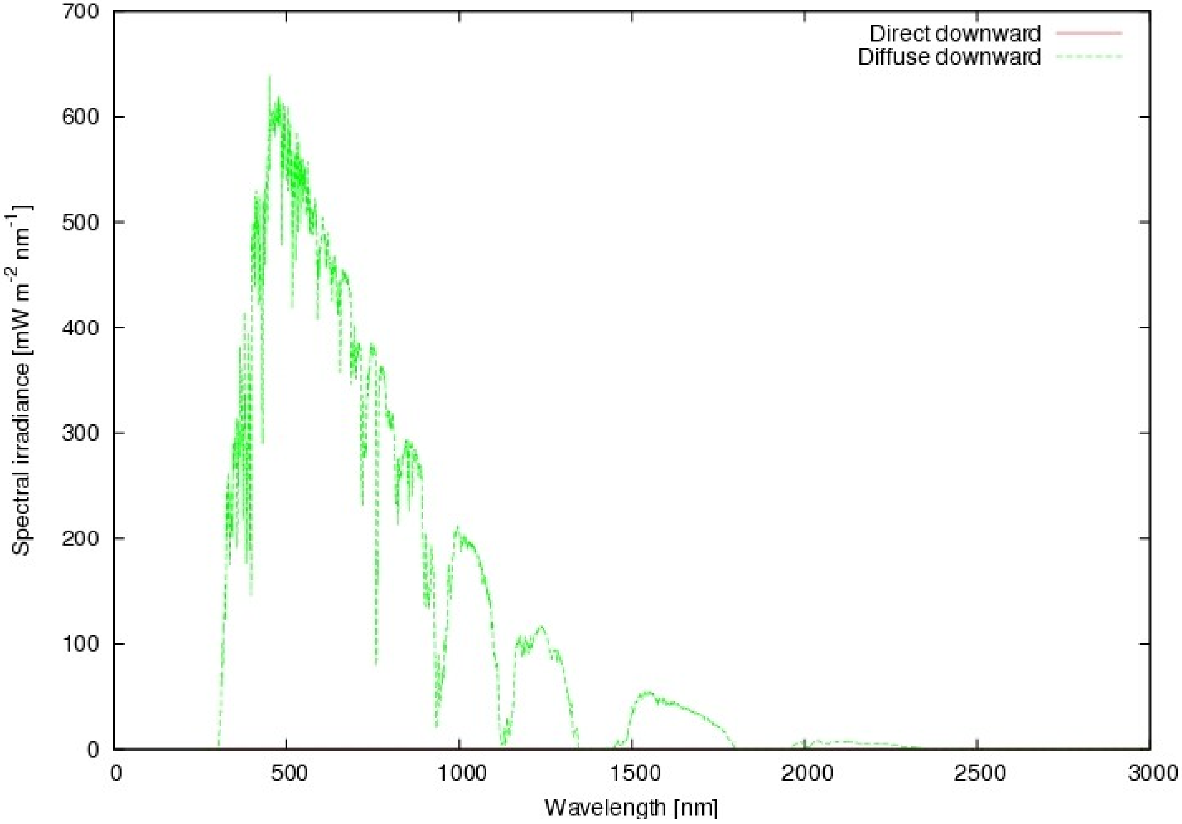
100 g/m² cloud water load



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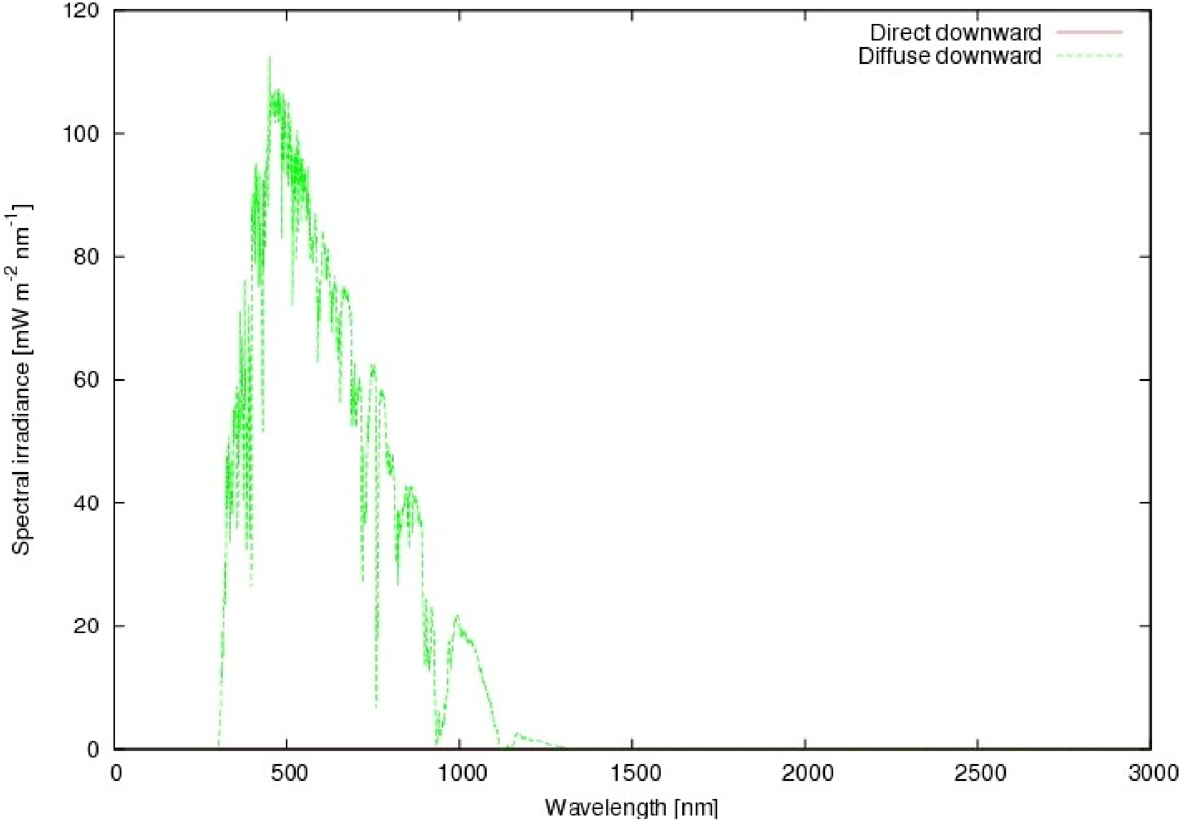
1 kg/m^2 cloud water load



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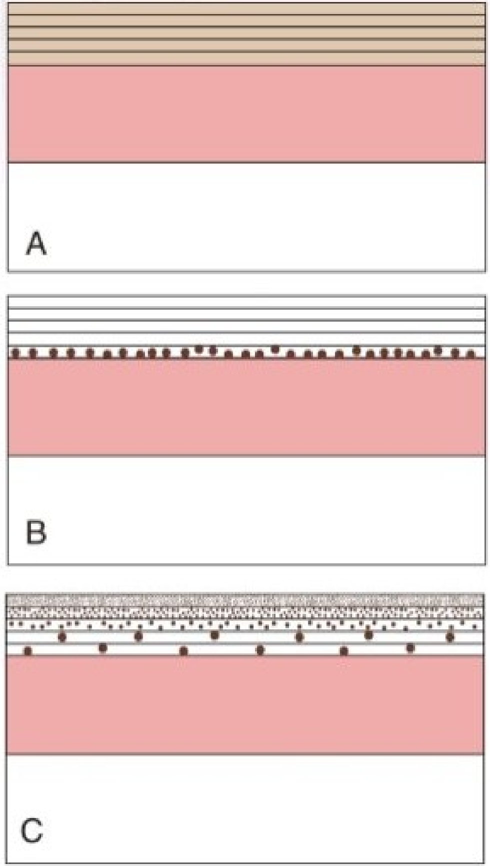
NWP radiation variables

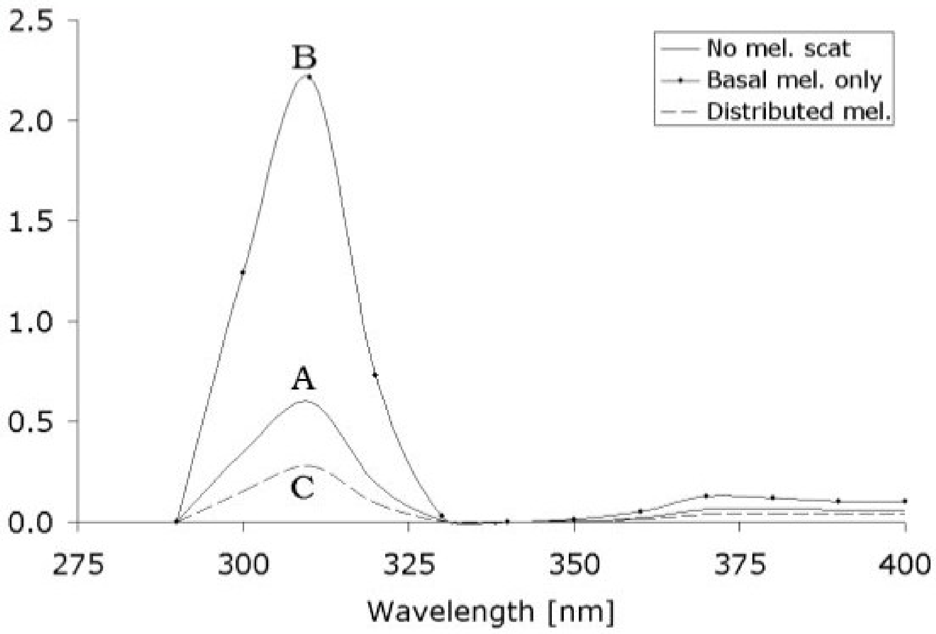
- Broadband solar at the surface and top of atmosphere

- Spectral Band data (2-3)
  - UV
  - visible (VIS)
  - solar infrared (NIR)

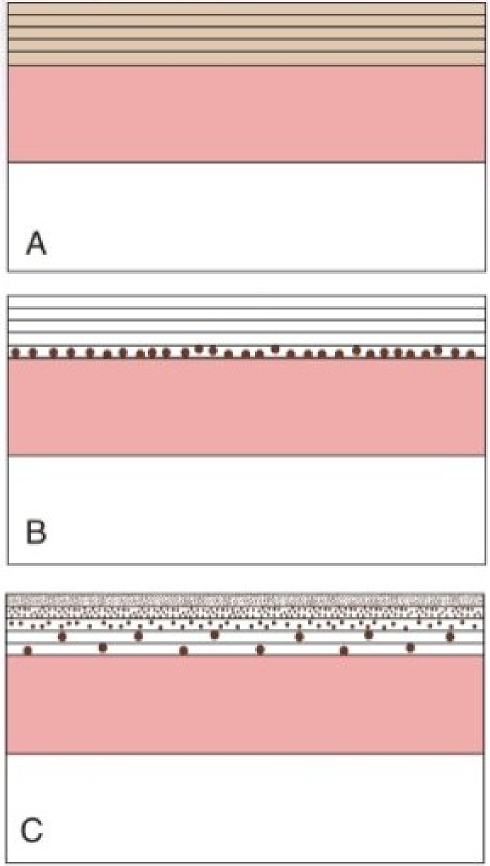
- Spectrally derived products
  - UV index
  - Photosynthetic available radiation (PAR)

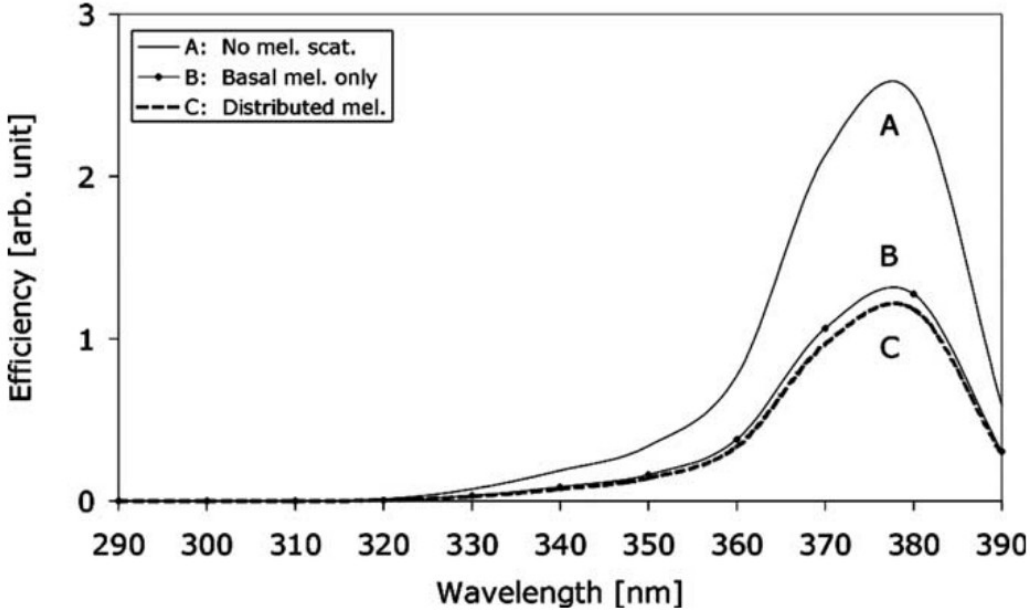
Efficiency of DNA mutation



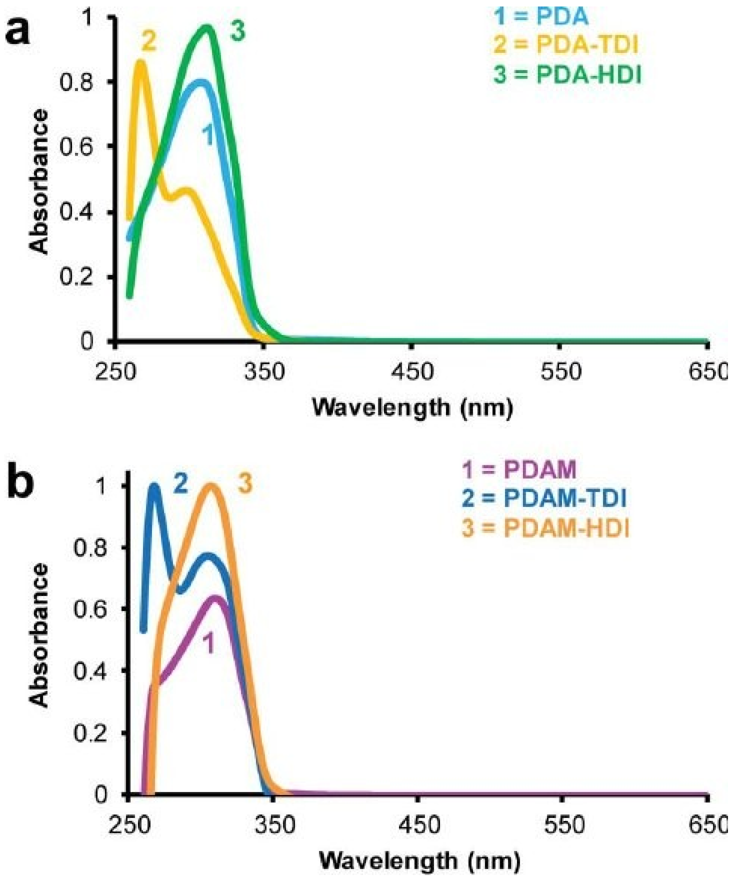


Efficiency of folate degradation



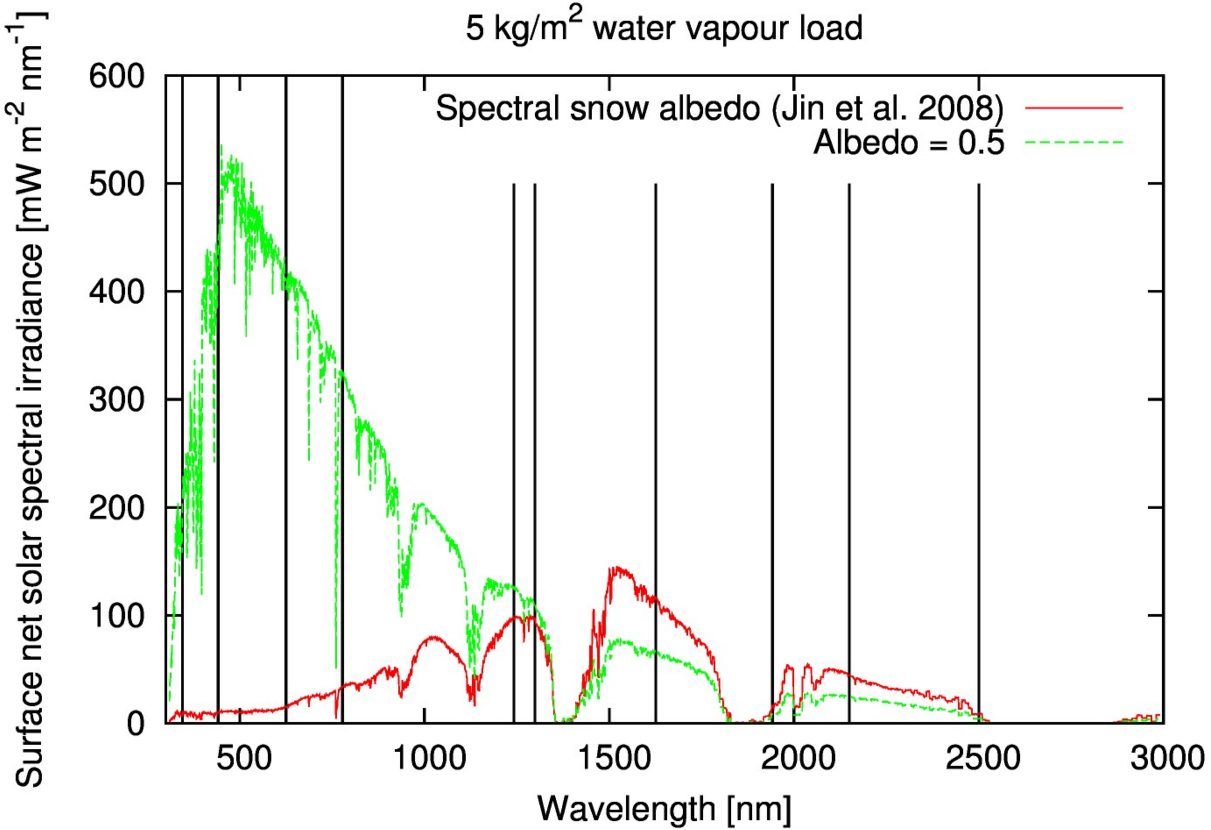


Wind turbine coating spectra



From Kamaci et al. (2015)
doi:10.1016/j.jtice.2015.08.018

+ spectral properties of snow



Green: constant surface albedo = 0.5.

Red: Jin et al. (2008) albedo spectrum of aggregate snow particles.

Vertical lines: wavelength band divisions of the IFS 14 band shortwave radiation scheme.

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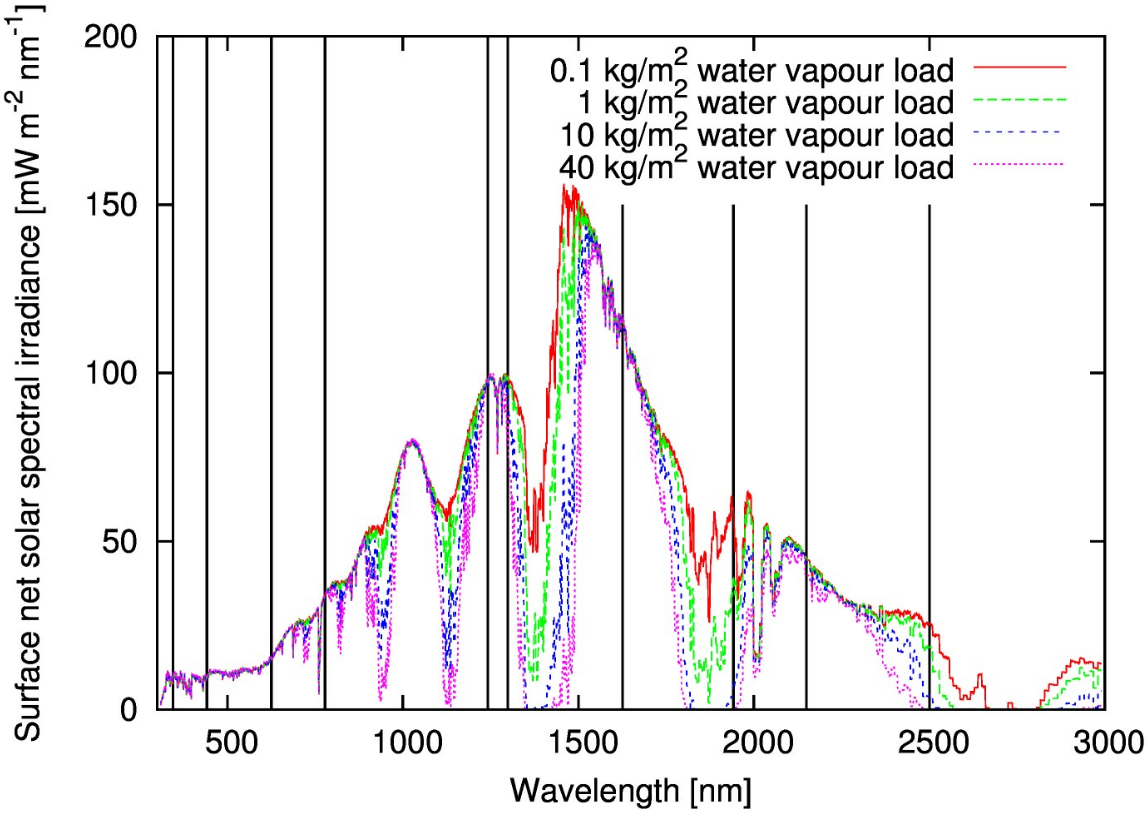
+ variable water vapour load



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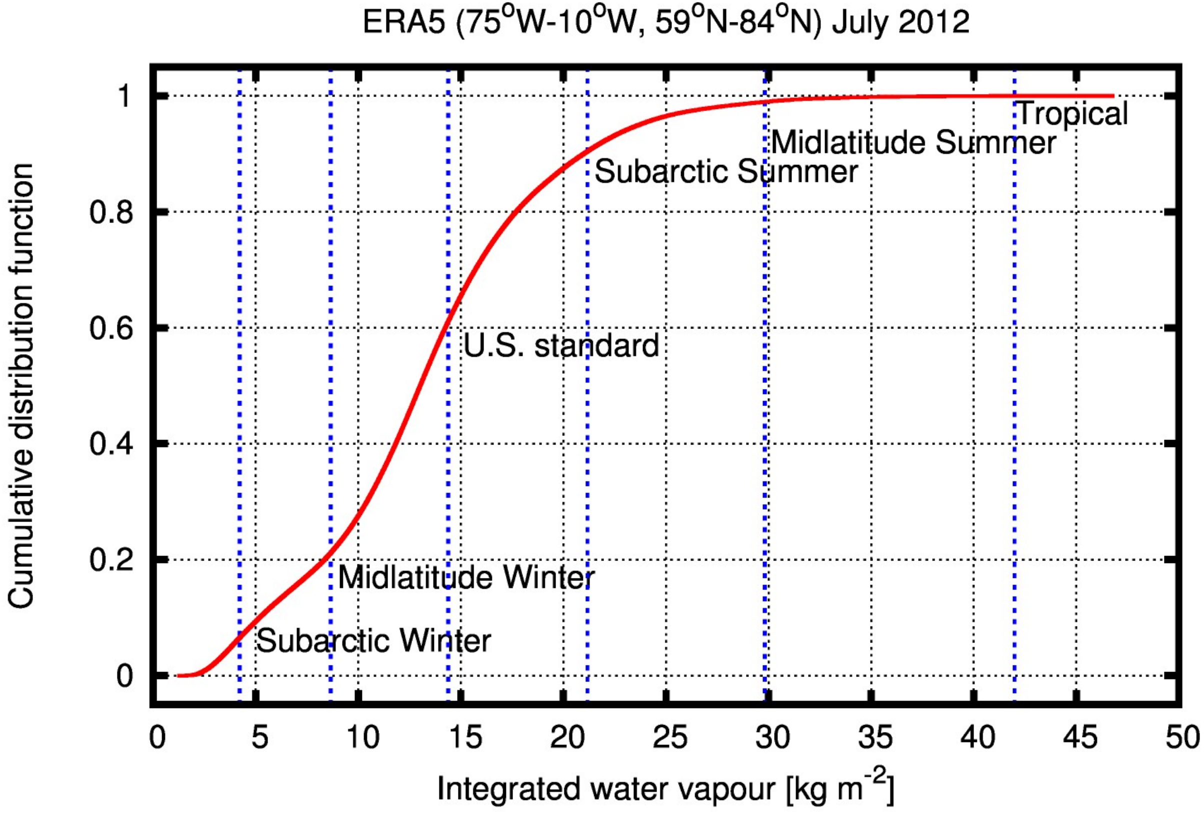
Cumulative water vapour loads



For the month July 2012 and a longitude-latitude region covering Greenland and surrounding areas.

Blue lines: AFGL standard atmospheres

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Snow albedo computation - 1-layer scheme

For no melt conditions (corrected from le Moigne 2018 Eq. 4.156):

$$
\begin{aligned}
\alpha_s(t) &= \alpha_s(t-\Delta t) - \tau_a \frac{\Delta t}{\tau} + \frac{P_s \Delta t}{W_{crn}}(\alpha_{s,\max} - \alpha_{s,\min}), \qquad (3)\\
&\quad (\alpha_{s,\min} \le \alpha_s \le \alpha_{s,\max})\\
\tau_a &= 0.008 \text{ day}^{-1}, \quad \alpha_{s,\min} = 0.50, \quad \alpha_{s,\max} = 0.85\\
W_{crn} &= 10 \text{ kg m}^2, \tau = 86400 \text{ s/day}
\end{aligned}
$$

For melt conditions:

$$
\begin{aligned}
\alpha_s(t) &= \left[\alpha_s(t-\Delta t) - \alpha_{s,\min}\right] \exp(\tau_f \frac{\Delta t}{\tau}) + \alpha_{s,\min} +\\
&\quad \frac{P_s \Delta t}{W_{crn}}(\alpha_{s,\max} - \alpha_{s,\min}), \qquad (4)\\
&\quad (\alpha_{s,\min} \le \alpha_s \le \alpha_{s,\max})\\
\tau_f &= 0.24 \text{ day}^{-1}
\end{aligned}
$$

For glaciers $\alpha_{s,\min} = 0.8$.

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Snow albedo computation - multi-layer schemes

Spectral band	Albedo α	Absorption coefficient β (m^{-1})
0.3–0.8 µm	$\max(0.6, \alpha_i - \Delta\alpha_{\text{age}})$ where: $\alpha_i = \min\left(0.92, 0.96 - 1.58\sqrt{d_{\text{opt}}}\right)$ and: $\Delta\alpha_{\text{age}} = \min\left(1., \max\left(\frac{P}{P_{\text{CDP}}}, 0.5\right)\right) \times 0.2\frac{A}{60}$	$\max\left(40, 0.00192\rho/\sqrt{d_{\text{opt}}}\right)$
0.8–1.5 µm	$\max(0.3, 0.9 - 15.4\sqrt{d_{\text{opt}}})$	$\max\left(100, 0.01098\rho/\sqrt{d_{\text{opt}}}\right)$
1.5–2.8 µm	$346.3d' - 32.31\sqrt{d'} + 0.88$ where: $d' = \min(d_{\text{opt}}, 0.0023)$	$+\infty$

Table 1: Temporal evolution of snow albedo and absorption coefficient β (Vionnet et al. 2012). $P_{\text{CDP}} = 870$ hPa. Spectral band weights: 71%, 21% & 8%. MEB: 48% & 52%

Differences in the actual model:

$$
\begin{aligned}
P_{\text{rel. max}} &= 1.0 \rightarrow 1.5, \quad \beta_{1.5-2.8\mu m} = +\infty \text{ m}^{-1} \rightarrow 2000 \text{ m}^{-1}, \\
\text{age, coef.}_{\text{glacier}} &= 60 \text{ day}^{-1} \rightarrow 900 \text{ day}^{-1}, \quad \alpha_{min,glacier} \rightarrow 0.8 \text{ (in Crocus)}
\end{aligned}
$$

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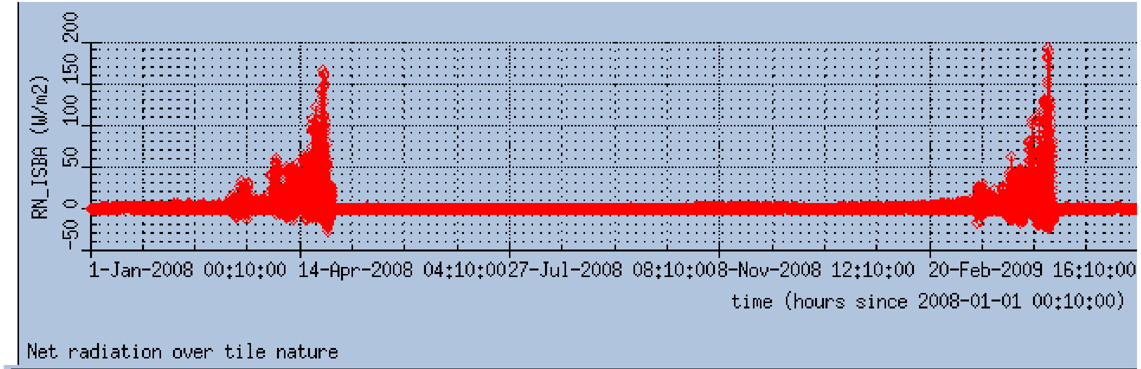
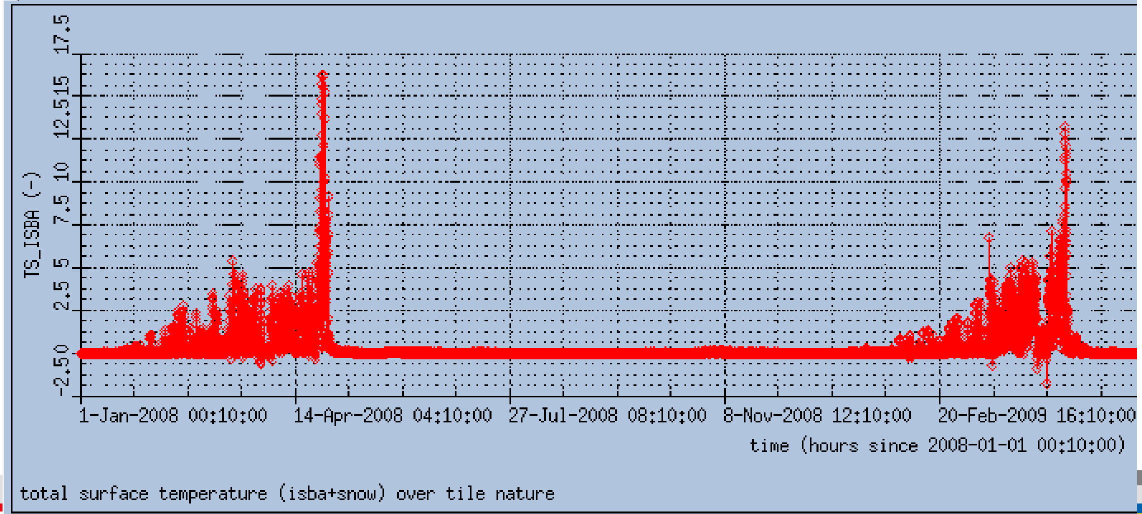
MEB albedo spectrum difference





Offline SURFEX runs

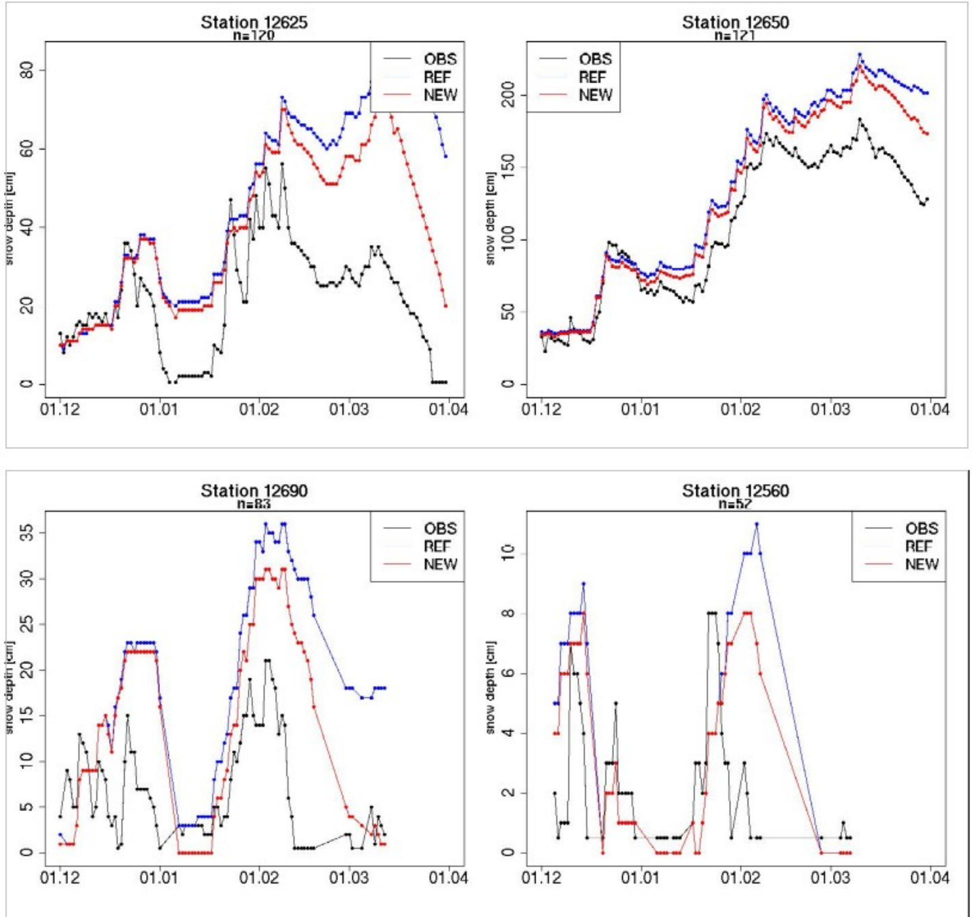
NordSnowNet 2022 meeting setup by Patrick Samuelsson

Forcing data from Sodankylä covering two winters

Top: Net radiation differences

Bottom: Skin temperature differences

Crocus experiment for Polish stations



- Test and plots by Gabriel Stachura (IMGW)
- Stations: Zakopane, Kaspowy Wierch, Lesko and Katowice

Thank you for your attention!

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