Masking of snow albedo by forests in JULES and other models

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Snow albedo masking by forests

Data from Alan Barr and Paul Bartlett, Environment Canada
Snow albedo masking by forests

Maximum albedo


JULES nlt fraction

CLM nlt fraction
Snow albedo in CMIP models

Average albedo of snow covered regions

Sensitivity of albedo to temperature

Albedo masking model option 0: do nothing

– a really bad idea

March – April 1996

March – April 1997

ECMWF 850 hPa temperature day 5 error

Albedo masking model option 1: weighted average

\[ \alpha = (1 - f_s) \alpha_0 + f_s \alpha_s \]

Snow-free albedo \( \alpha_0 \) and deep-snow albedo \( \alpha_s \) depend on vegetation type weighted by snow cover fraction.

e.g. HadCM3, JULES |_spec_albedo = F
Albedo masking model option 2: gap fraction

- pretty simple, many variants

Albedos for snow-free and snow-covered ground and canopy weighted by ground snow cover fraction, canopy snow cover fraction, canopy gap fraction

\[
\alpha = f_g[(1 - f_s)\alpha_{g0} + f_{sg}\alpha_{sg}] + (1 - f_g)[(1 - f_{sc})\alpha_{c0} + f_{sc}\alpha_{sc}]
\]

\[\text{Snow cover fraction} \begin{array}{c}
0  \quad  0.2  \quad  0.4  \quad  0.6  \quad  0.8  \quad  1 \\
\end{array}\]

\[\text{Ground snow mass} \begin{array}{c}
0  \quad  0.2  \quad  0.4  \quad  0.6  \quad  0.8  \quad  1 \\
\end{array}\]

\[\text{Canopy snow mass} \begin{array}{c}
0  \quad  0.2  \quad  0.4  \quad  0.6  \quad  0.8  \quad  1 \\
\end{array}\]

\[\text{Canopy gap fraction} \begin{array}{c}
0  \quad  0.2  \quad  0.4  \quad  0.6  \quad  0.8  \quad  1 \\
\end{array}\]

\[\text{LAI} \begin{array}{c}
0  \quad  0.2  \quad  0.4  \quad  0.6  \quad  0.8  \quad  1 \\
\end{array}\]

e.g. CLASS, ECHAM
Albedo masking model option 3: two-stream approximation

– quite complicated, quite a lot of parameters, quite common

Radiative transfer equations for scattering between downwards and upwards beams of diffuse radiation in an isotropic random medium

\[-\mu \frac{dI^\uparrow}{d\Lambda} + [1 - (1 - \beta)\omega]I^\uparrow - \omega \beta I^\uparrow = \omega \mu k \beta_0 \exp(-G\Lambda / \cos \theta)\]

\[\bar{\mu} \frac{dI^\downarrow}{d\Lambda} + [1 - (1 - \beta)\omega]I^\downarrow - \omega \beta I^\downarrow = \omega \bar{\mu} k (1 - \beta_0) \exp(-G\Lambda / \cos \theta)\]

e.g. CLM, JULES | _spec_albedo = T
Albedo masking model option 4: ray tracing

– way too complicated for large-scale modelling
Snow cover and albedo simulation
Maximum albedo

Observed

Option 1

Option 2

Option 3
Maximum albedo

Observed  Option 1  Option 2  Option 3

Diagram showing the observed and predicted maximum albedo across different longitude ranges.
Sensitivity of albedo to seasonal temperature cycle

Option 1 simulation and observed

-\Delta \alpha / \Delta T (\% / K)

J  F  M  A  M  J  J  A  S  O  N  D
Conclusions

• surprisingly little difference between albedo models of differing complexity

• despite IPCC concerns, masking of snow albedo by forests can be simulated well by existing models

• good vegetation maps are required

• deep-snow albedo for shrub pft is probably too low (Cécile has a solution)

• deep-snow albedo for larch is probably too high

• JULES canopy albedo isn’t too bad, but canopy transmission isn’t consistent with it. We need `can_model = 5`