Neige 5ème partie

Métamorphisme de la neige et climat

* Impact des conditions du métamorphisme sur la surface spécifique et l’albédo

* Impact des conditions du métamorphisme sur la conductivité thermique

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Physical properties of the snowpack

Albedo: 0.8 to 0.9
Energy budget of the surface

Energy budget of the soil
Permafrost extent
Sea ice growth

T waves
Heat conductivity
Snow metamorphism ⇒ modification of physical properties

Albedo = 0.90
Heat conductivity = 0.05 W m$^{-1}$ K$^{-1}$

Albedo = 0.84
Heat cond. = 0.08

Albedo = 0.86
Heat cond. = 0.23

Albedo = 0.82
Heat cond. = 0.53

Albedo = 0.79
Heat cond. = 0.04

Temperature
T-gradient
Wind
Climate, metamorphism and snow physics

Global warming

- Temperature +
- T gradient -
- Windspeed ?
- Grain size
- Heat conductivity

Albedo

Sea ice & permafrost extent

feedback + or - ??

feedback + or - ??
Albedo determined by:
- Scattering: increases with decreasing grain size
- Absorption: increases with increasing impurity content

Calculation of scattering:
uses the equivalent size sphere = sphere of equal $S / V$

$S / V$ related to Specific Surface Area

Surface area accessible to gases per unit mass

$$SSA = S / \rho \quad (cm^2/g)$$
Relationship Albedo- Specific Surface Area

Calculations

SSA measurements using CH₄ adsorption

Figure after A. Kokhanovsky

Domine et al., CRST 2006
Experimental approach

Heat conductivity measurements

Cold room, -5 to -25°C

Insulation

Sampling for SSA measurements

Heated area, 0 to -5°C

Heated needle probes

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SSA decay rate

Empirical parametrization of SSA decay derived from both field and lab data:

\[ SSA = f(t, SSA_0, T_{\text{mean}}) \]

\[ SSA = A - B \ln (t + \Delta t) \]

2 regimes observed:

ET regime, \( \text{grad}(T) < 10^\circ \text{C m}^{-1} \):

\[ SSA(t) = A_{\text{ET}}(SSA_0, T_{\text{mean}}) - B_{\text{ET}}(SSA_0, T_{\text{mean}}) \ln(t + \Delta t_{\text{ET}}) \]

TG regime, \( \text{grad}(T) > 20^\circ \text{C m}^{-1} \):

\[ SSA(t) = A_{\text{TG}}(SSA_0, T_{\text{mean}}) - B_{\text{TG}}(SSA_0, T_{\text{mean}}) \ln(t + \Delta t_{\text{TG}}) \]

Taillandier et al., JGR in press
Effect of $T$ on SSA decay rate, under TG conditions

$T \Rightarrow SSA \Rightarrow \text{albedo}$

-25°C, gradient
-15°C, gradient
-5°C, gradient

Taillardier et al., JGR in press
SSA decay rate

Increase in T (and in precipitation) \( \Rightarrow \) gradient (TG) \( \rightarrow \) “isothermal” (ET)

?? Effect of T increase and of a change in metamorphic regime from TG to ET ??

Taillandier et al., JGR in press
Quantifying the snow-albedo feedback

Incoming solar flux: 100 W m\(^{-2}\)

SSA change: 100 → 200 cm\(^2\)/g

⇓

Albedo: 0.75 → 0.79

Forcing = -4 W m\(^{-2}\) ⇒ Climate effect ??

Modeling soot effect on snow:

Forcing of +1.5 W m\(^{-2}\) due to soot

⇓

T change of +1 to 2 °C at high latitude

⇓

Effect of change in SSA could reach 3-4°C (cooling)

Hansen and Nazarenko, PNAS, 2004
This wonderful science generously supported by:

EXSO
Heat conductivity, $k_T$

With current $k_T$ parameterizations, understanding climate-$k_T$ interactions is not simple.
Heat conductivity, $k_T$

High temperature gradient conditions, 40°C/m

$T \uparrow \Rightarrow k_T \uparrow$

Isothermal conditions, 0°C/m

$T \uparrow \Rightarrow k_T \uparrow$

Warming $\Rightarrow k_T \uparrow$ in all cases

Did you think of wind changes ????
High temperature gradient conditions, 40°C/m

$k_T = 0.07 \text{ W m}^{-1} \text{ K}^{-1}$

Isothermal conditions, 0°C/m

$k_T = 0.14 \text{ W m}^{-1} \text{ K}^{-1}$
Warming AND change in metamorphic regime

Example of sea ice growth

Changes in snow physics offsets a 5°C warming!!
This cutting edge work abundantly funded by:

Captain Motors
Conclusion

Snow will save us from global warming!!

Both positive and negative snow-climate feedback exist.

They need to be studied to predict Arctic climate change.