Understanding Atmospheric Forcing of Arctic Sea Ice through Surface Energy Fluxes

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Science Review
12-14 May 2015
Boulder, Colorado
Take-Away Points

a) PSD measuring/analyzing **ALL** surface energy budget (SEB) terms
- SEB simple but powerful tool
- reveals process relationships
- used for model/reanalysis validations

b) Synoptic events
- large, important energy flux variability
- trigger melt-season transitions

c) Compensatory energy flux effects
- damp energy flux/T changes during non-melt season
- non-existence during summer allow stronger melt
Surface Energy Budget over Sea Ice (SEB)

Net energy flux to ice surface, $F_{net}$

$$F_{net} = F_{atm} + F_c = SW_d (1-\alpha) + LW_d - LW_u - H_s - H_l + F_c$$

Each term associated with limited number of physical processes
(e.g. $LW_d$ affected by atmospheric temperature and cloud characteristics)

Measuring each term – links physical processes, $F_{net}$ & ice changes

Changes in one term often produces compensatory changes in other terms
- feedbacks reduce $F_{net}$, but limited by the physics of the compensatory processes
Sea Ice and Surface Energy Budget Variability
(SHEBA, multi-year ice)

Snow cover, ice temperatures (color), ice outlines

Annual cycle
Mass: bottom freeze, top snowfall, surface melt, later bottom melt
$T_{\text{ice}}$: large $T$ gradient in winter, ~isothermal in summer (at melting point)

Synoptic $F_{\text{net}}$ Variability $\sim 10$-$20$ W m$^{-2}$

SEB terms, ice-surface melt

Annual $F_{\text{net}}$: 5-10 W m$^{-2}$

30-year ice mass loss: 1-2 W m$^{-2}$
Kwok and Untersteiner (2011)

sfc T, air T, albedo

Kwok and Untersteiner (2011)


Persson (2012)
Impacts of Compensatory Fluxes

**Non-melt season:**
- $T_s$ can vary
- Net radiation changes leads to compensating responses in $H_s, H_l, F_C$
- Limits $F_{net}$ and $T$ changes

**Melt season:**
- $T_s$ fixed at 0° C
- No compensating responses to net radiation changes
- $F_{net}$/ice melt fully affected by changes in each term
- Importance of melt-season length


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Synoptic Event Triggers Melt Onset

1) Melt onset - often triggered when above-freezing air aloft coincides with liquid clouds

2) Melt onset due primarily to
   a) increase in LW$_d$ (LW$_{net}$) from warm, storm clouds and
   b) decrease in $\alpha$ from surface rainfall and melt

3) Earlier melt onset for years with melt triggered by warm-air advection events
   - Russian drifting station data
Summary

a) PSD measuring/analyzing all SEB terms
   - “truth” for validating models/reanalyses

b) Synoptic events produce large $F_{\text{net}}$ variability
   - frequency of synoptic events important for annual and climatic sea-ice changes

c) Compensatory SEB terms impact $F_{\text{net}}$ magnitudes
   - summer non-existence contributes to large $F_{\text{net}}$/melt & importance of melt-season length

d) Synoptic events trigger melt-season transitions
   - suggests melt-season lengthening due to long-range transport

Future Work

a) Measure SEB annual cycle in changing Arctic
   - over FY sea ice, emerging open water, & MIZ
   - SEB impacts of changing synoptic forcing
   - e.g., MOSAiC, other field programs

b) Autumn freeze-up
   - quantify ocean heat loss; understand processes & impacts
   - key for current NOAA research

c) Continue/improve use of observations for model/reanalysis validation & development
   - e.g., Year of Polar Prediction