NOAA RESEARCH • ESRL • PHYSICAL SCIENCES DIVISION

Understanding Atmospheric Forcing of Arctic Sea Ice through Surface Energy Fluxes

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Take-Away Points

a)PSD measuring/analyzing ALL surface energy budget (SEB) terms

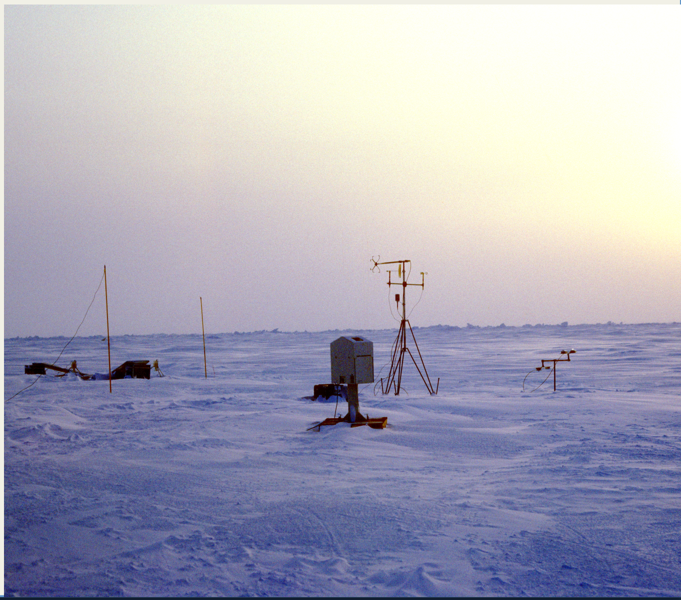
- SEB simple but powerful tool
- reveals process relationships
- used for model/reanalysis validations

b)Synoptic events

- large, important energy flux variability
- trigger melt-season transitions

c)Compensatory energy flux effects

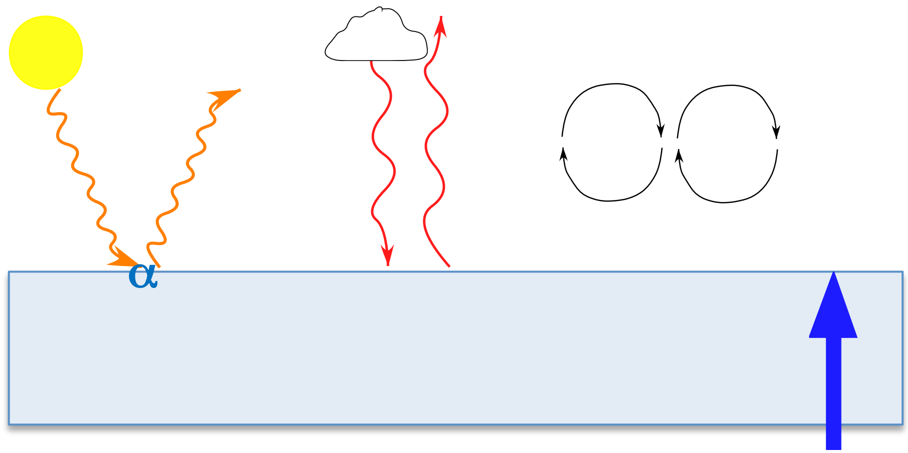
- damp energy flux/T changes during non-melt season
- non-existence during summer allow stronger melt

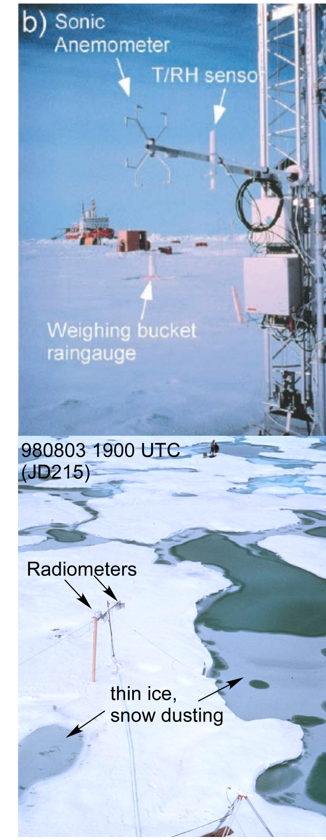


Surface Energy Budget over Sea Ice (SEB)

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

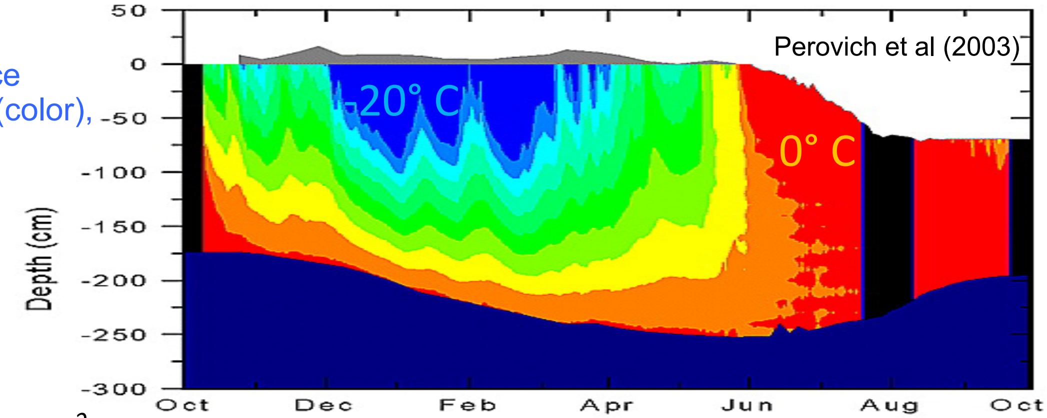
Changes in one term often produces compensatory changes in other terms

-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

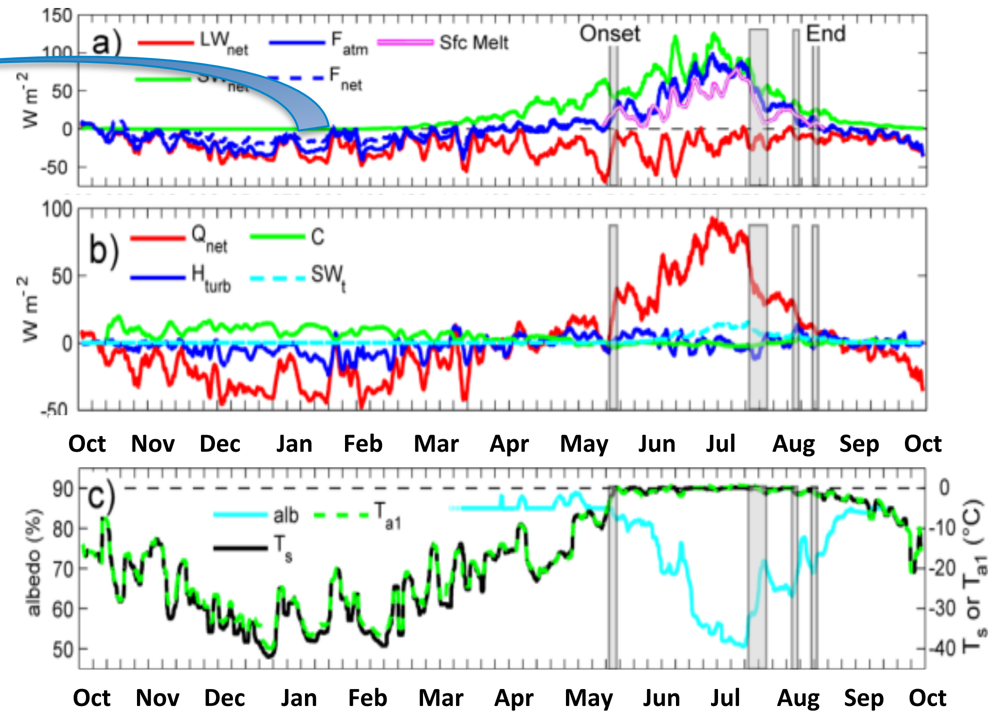
Mass: bottom freeze, top snowfall, surface melt, later bottom melt

T_{ice}: large T gradient in winter, ~isothermal in summer (at melting point)

Synoptic F_{net} Variability ~10-20 W m^{-2}

SEB terms, ice-surface melt

sfc T, air T, albedo



Persson (2012)

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

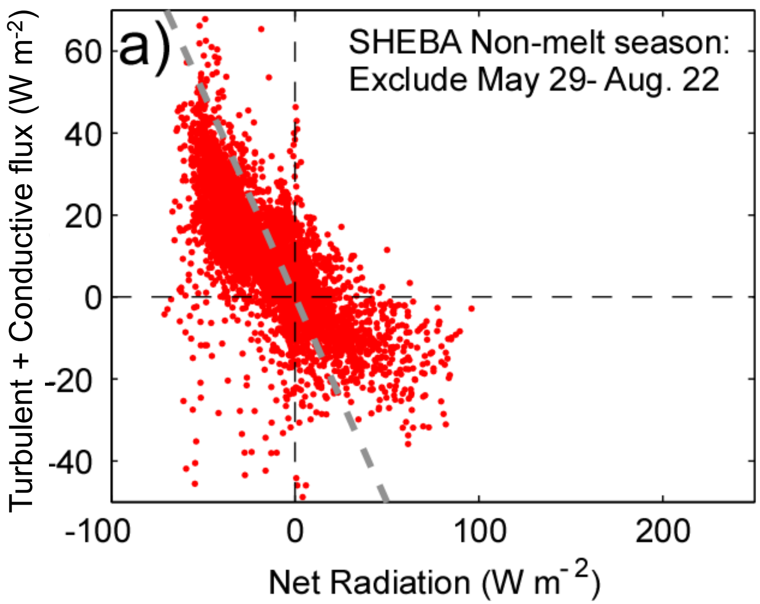
30-year ice mass loss: 1-2 W m^{-2}

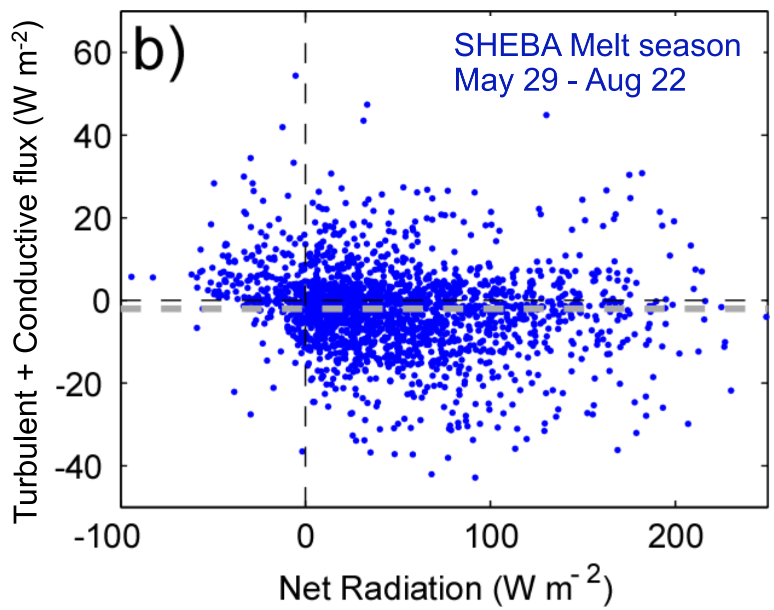
Kwok and Untersteiner (2011)

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



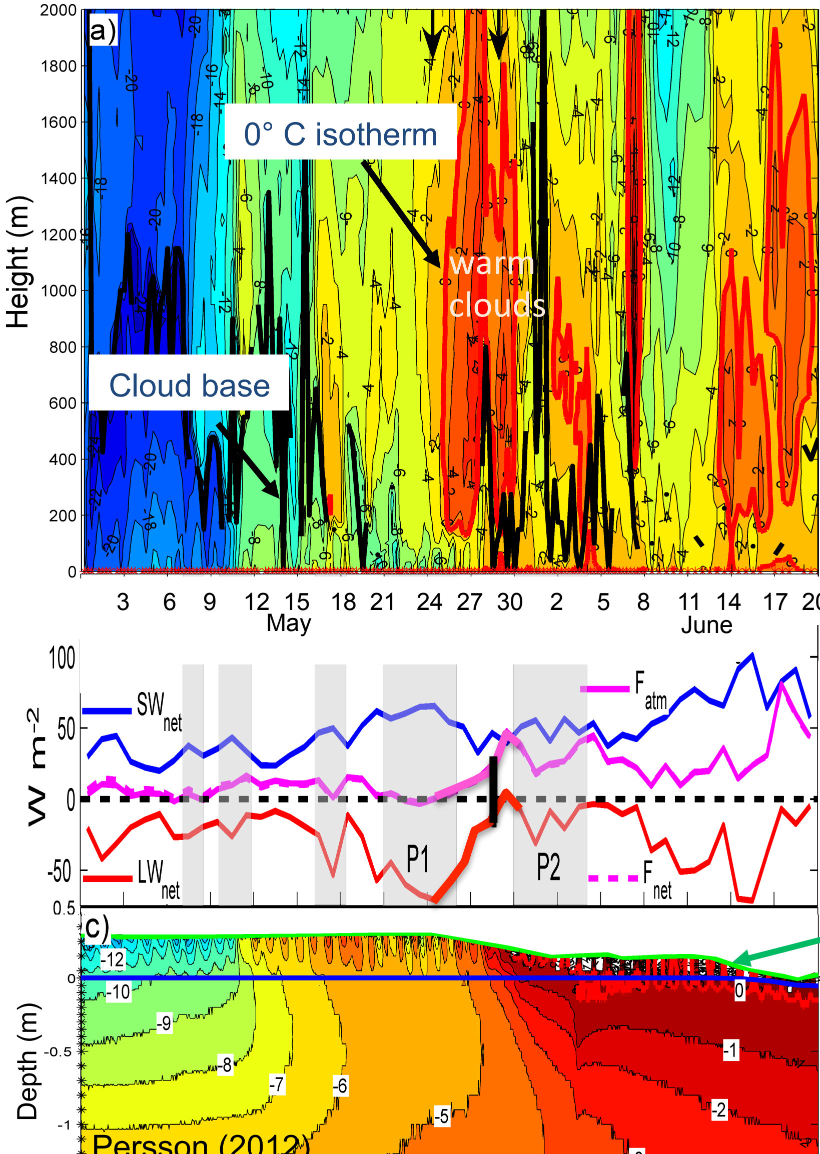


damp energy flux/T changes

non-existence allows stronger melt episodes

Persson et al (1999)

Synoptic Event Triggers Melt Onset



Atmospheric T (color) and cloud base (heavy black line)

Surface energy budget

Snow surface

Ice surface

Snow/ice T (deg C)

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 α from surface rainfall and melt

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

Summary and Future Work

Autumn freeze-up; Sep 24, 2014

Summary

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

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

c) Compensatory SEB terms impact F_{net} magnitudes
- summer non-existence contributes to large F_{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