

Methods note · Sea ice and ocean

From ocean heat flux to a conditional melt bound

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Fictional author and institute · Editorial demonstration, not peer reviewed

ABSTRACT

Converting an ocean heat flux into centimetres of ice can check physical scale without predicting sea-ice loss. This methods note uses published ocean-ice heat-budget research and the TEOS-10 framework to derive a conditional latent-melt equivalent. A hypothetical flux of ten watts per square metre over thirty days supports approximately 8.6 centimetres under explicitly simplified property and energy-allocation assumptions. Further cases show how conductive export, duration, area denominator, and reduced winter growth change the interpretation. The note distinguishes a bound on one specified energy contribution from an unconditional bound on total melt. It does not estimate a present Arctic flux or attribute observed retreat. Its reporting framework keeps system boundaries, counterfactuals, thermodynamic approximations, and unmeasured transport beside the calculation.

Keywords: ocean heat flux · latent heat · energy budget · melt equivalent · winter growth

A source-based editorial text, not a report of original Still North research. Examples and imagery are illustrative.

An upward heat flux of 10 watts per square metre sounds modest until it is integrated over a month. Yet converting that energy into centimetres of ice does not predict how much sea ice will disappear. The calculation can answer a useful, smaller question: how much phase change could a specified energy supply support under stated assumptions? Keeping that question intact prevents a correct unit conversion from becoming an unsupported forecast.

This methods note develops a conditional latent-melt equivalent using published ocean-ice heat-budget work and the TEOS-10 thermodynamic framework. It does not estimate a present Arctic flux or attribute an observed ice-loss event. All numerical cases below are deliberately hypothetical, using rounded constants to make the accounting visible. The aim is a reusable diagnostic for reading claims, checking model output, and deciding what additional measurements an actual mass-balance estimate needs.

Name the surface crossed by the energy

A flux is a rate of energy transfer per unit area. Ten W/m² means ten joules each second through each square metre of the specified surface. The location matters: shortwave radiation entering the upper ocean, heat transported through an ocean gateway, and turbulent heat delivered to an ice base are different budget terms. Energy entering a water column may be stored or advected away before reaching ice. It must not be counted once at ocean entry and again at the ice interface as two independent supplies.

Krishfield and Perovich distinguish estimates based on ocean temperature and ice-ocean motion from heat flux inferred as a residual of ice mass balance. Their analysis demonstrates that the relevant transfer depends on both thermal conditions and turbulent exchange. A warm reservoir is not a measured boundary flux. It also shows why a residual flux inherits uncertainty from the other heat-budget terms rather than constituting an independent measurement of each.

The simplest calculation, with its conditions attached

For a fixed area, a constant hypothetical flux F acting for time t supplies energy per area $Q = F \times t$. If every joule is assigned to melting ice already at its phase-change condition, the equivalent thickness is $h = Q / (\rho \times L)$, where ρ is ice density and L is latent heat per unit mass. Use compatible units: seconds, joules, kilograms, and metres. The equation is bookkeeping for an explicitly restricted energy allocation.

Take $F = 10 \text{ W/m}^2$ for 30 days, or 2,592,000 seconds. The energy supply is 25,920,000 J/m², approximately 25.9 MJ/m². Choose rounded teaching constants $\rho = 900 \text{ kg/m}^3$ and $L = 334,000 \text{ J/kg}$. Their product is 300.6 MJ/m³. Dividing gives $h = 0.0862 \text{ m}$, about 8.6 cm. This is an equivalent thickness over the same area used for the flux, not a measured thinning, a change in extent, or a forecast of open water.

Hypothetical allocation over 30 days	Energy per area	Latent-melt equivalent
All of 10 W/m ² allocated to melt	25.9 MJ/m ²	8.6 cm
Only 6 W/m ² available after an assigned 4 W/m ² export	15.6 MJ/m ²	5.2 cm
10 W/m ² acting for 15 days	13.0 MJ/m ²	4.3 cm

The second row is another invented budget, not an empirical correction factor. It shows that the bound is conditional on what the named flux includes. If 10 W/m^2 was already a net energy supply after conductive removal, subtracting that removal again would be wrong. State whether the input is a gross ocean-to-ice transfer, a net interface balance, or a flux anomaly relative to a baseline. An anomaly gives a counterfactual energy difference, not automatically the total melt.

Why 'upper bound' needs a boundary

Assigning all of a positive energy contribution to latent melting gives a maximum contribution from that specified supply within the simplified model. It is not an unconditional upper bound on total melt. Additional atmospheric energy, transmitted sunlight, lateral exchange, and changes in stored heat could support more. Conversely, warming cold ice, conductive export, or energy storage can leave less of that supply available for phase change. The word bound is defensible only when the system boundary and permitted energy sources are explicit.

Real sea ice is saline and contains brine. Its enthalpy and phase state vary with temperature and salinity, so a single pure-ice latent heat is an approximation. The TEOS-10 manual provides a consistent thermodynamic treatment, including seawater, ice, freezing, and latent-heat quantities. For a real calculation, select properties appropriate to the problem rather than claiming that rounded classroom constants resolve the energy required for every change in saline ice.

Even the area denominator needs scrutiny. Suppose the hypothetical 10 W/m^2 is an average over a grid cell that is half ice-covered. If, and only if, its entire specified energy supply is delivered uniformly to that remaining ice, the equivalent per ice-covered area doubles to about 17.2 cm . If the flux was already reported per square metre of ice underside, doubling it would be an error. Grid-cell area, ice area, and open-water area should therefore accompany any flux-to-thickness conversion.

Melting and reduced growth can share an energy scale

During freezing conditions, extra upward ocean heat can reduce ice growth rather than produce net thinning. Imagine an invented winter budget in which conductive heat loss would otherwise support formation of 15 cm of ice. An additional energy contribution equivalent to 8.6 cm might leave only 6.4 cm of growth in the same simplified balance. The ice has grown, although it is thinner than in the counterfactual. Describing that as 8.6 cm of observed melt would confuse a difference between scenarios with the realised direction of change.

This distinction also matters for anomalies. A positive heat-flux anomaly does not establish that the absolute energy balance is positive for melting. Read signs consistently and specify the reference experiment or period. When the relevant comparison is modelled, preserve all changed terms: altered ice thickness can change conduction, and changed open water can change absorbed sunlight. A one-term conversion usefully checks scale but does not replace the coupled response.

A regional observation is not a conversion constant

Perovich and colleagues' study of summer 2007 links unusually strong Beaufort Sea bottom melting with enhanced solar heating of the upper ocean and a larger open-water fraction. Its importance is the observed process chain and regional heat accounting. It is not a licence to apply the same percentage attribution, flux, or melt rate to every Arctic sector, year, or season. Those require observations of the local energy pathways.

Ice thickness can also change through convergence, ridging, divergence, and advection. An Eulerian grid cell may lose ice because floes move out, while a drifting floe can thin without a corresponding reduction in regional extent. A latent-melt equivalent addresses neither geometry nor transport by itself. To attribute actual thickness change, combine thermodynamic terms with ice motion and the chosen observational frame. To infer mass, include density and area consistently; to infer extent, represent the concentration threshold and spatial arrangement.

Report a useful number, not a disguised forecast

A responsible report should state the flux definition, sign, area basis, duration, property assumptions, and neglected terms beside the equivalent thickness. For time-varying fluxes, integrate the observed series using its actual temporal support rather than multiplying an exceptional daily value by a season. Show sensitivity to plausible flux and duration ranges. Do not call a collection of illustrative scenarios a confidence interval unless the uncertainty model justifies that interpretation.

The resulting number is modest but valuable: under an explicit allocation of a specified energy supply, the latent-melt equivalent is a stated thickness. It can expose a unit error, rule out an energetically impossible attribution within the defined budget, or identify the size of a missing term. It cannot determine the Arctic's next minimum. Good energy arithmetic becomes more useful, not less, when it stops exactly where the physical evidence stops.

References

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