



ANTARCTICA
INSYNC

Theme II: Rapid sea ice decline and its causes and consequences

Final review

The Theme 2 white paper writing team

Theme leadership structure

PI team

Physical part: Stefanie Arndt, Ruzica Dadic

BGC part: Letizia Tedesco

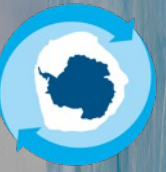
Anchor people

Modeling: Martin Vancoppenolle

Satellite remote sensing: Gunnar Spreen

Working groups

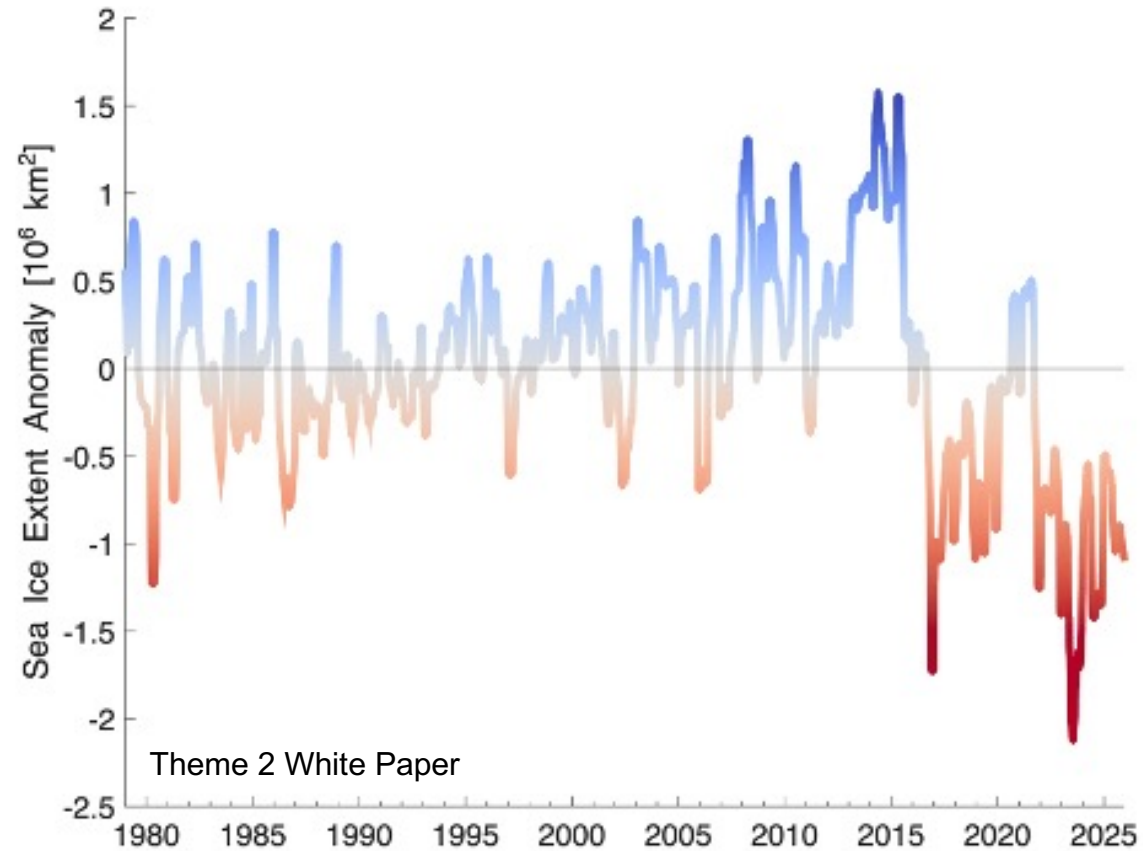
Autonomous ice-tethered platforms (person: tbd)



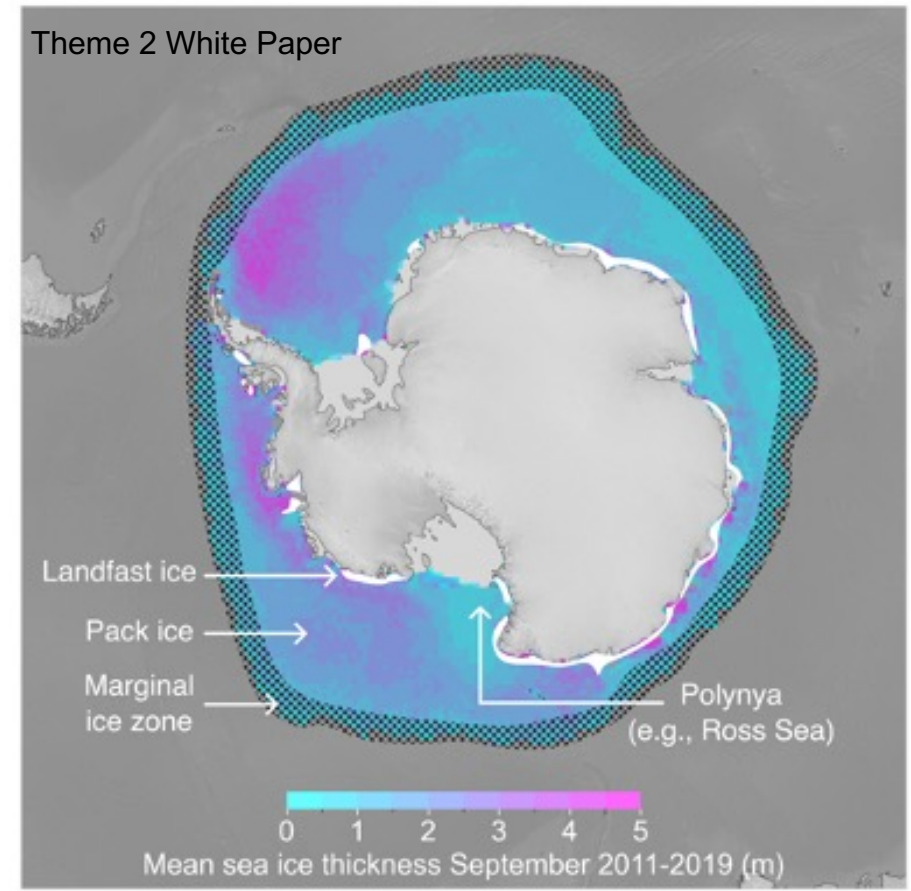
White paper



Theme 2: Rapid sea ice decline and its causes and consequences



Rapid sea ice decline since 2015



Key regions and satellite September sea ice thickness



White paper | Guiding research questions

Section 2: Knowledge gaps and research needs

Sea Ice Mass Balance and Dynamics

RQ1. What coupled (thermodynamic and dynamic) processes and feedbacks are responsible for rapid sea ice decline, and how do they vary around Antarctica and over time?

Coupled Ocean–Sea-Ice–Atmosphere–Ice Sheet Interactions

RQ2. How do exchanges of mass, heat, and momentum between sea ice and other components of the Earth System (ocean, atmosphere, ice sheet) drive rapid sea ice decline?

Ecosystem and Biogeochemical Responses

RQ3. What are the consequences of rapid sea ice decline on the ecosystem dynamics and biogeochemical processes in the Southern Ocean?

Climate Implications and Feedbacks

RQ4. How does the rapid sea ice decline impact the global climate system and amplify climate change?

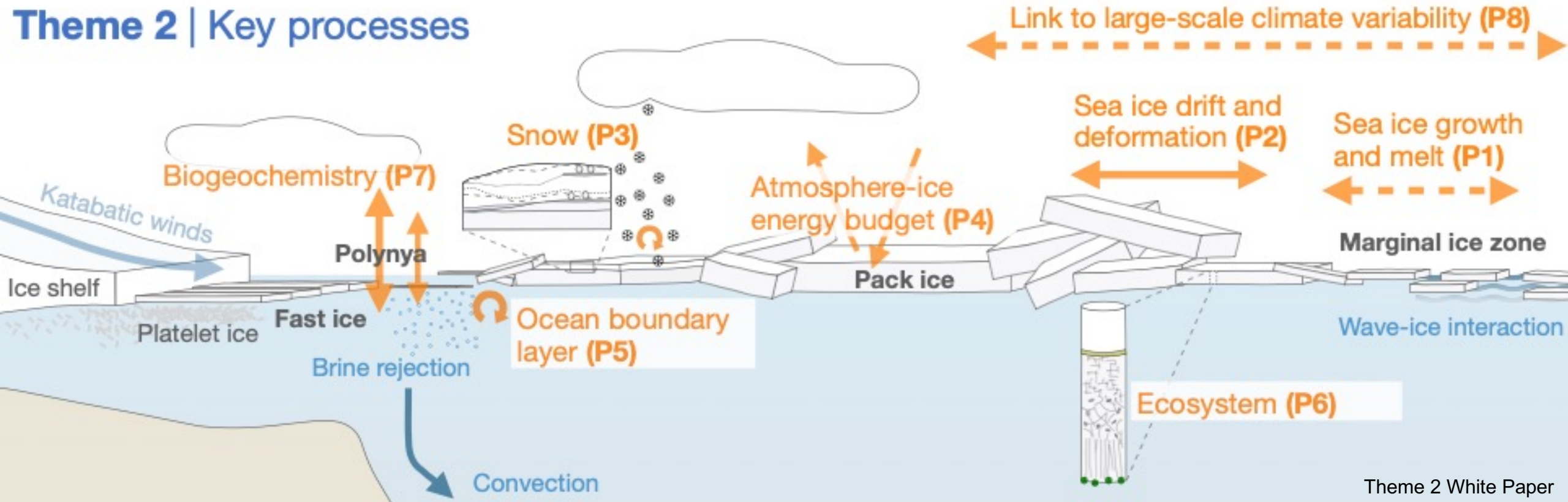
→ Urgency of Circumpolar, Year-round Observations

White paper | Key processes



Section 2: Knowledge gaps and research needs

Theme 2 | Key processes



Theme 2 White Paper

Key processes in 8 domains: Sea ice growth and melt (P1), Sea ice drift and deformation (P2), Snow (P3), Atmosphere-ice energy budget (P4), Ocean boundary layer (P5), Ecosystems (P6), Biogeochemistry (P7), Link to large-scale climate variability (P8).

White paper | Key processes and variables



RQ1. Sea Ice Mass Balance and Dynamics

Sea ice growth and melt (P1)	Sea ice area/concentration, sea ice thickness, snow depth, ice temperature , salinity, density, oxygen isotopes, crystallographic texture, meteoric ice fraction (superimposed and snow ice), ocean and surface heat fluxes, albedo, sea ice age , floe size, lead and ridge fraction
Sea ice drift and deformation (P2)	Sea ice drift vector , sea ice strain rates, internal ice stress, wind stress , ocean stress, wave height, tides, sea ice top and bottom topography, lead fraction, ridge fraction, floe size, sea ice thickness, sea ice age

RQ2. Coupled Ocean–Sea-Ice–Atmosphere–Ice Sheet Interactions

Snow (P3)	Snow accumulation, SWE, snow depth , snow density, temperature and salinity, isotopic composition, thermal conductivity, liquid water content, specific surface area (SSA), snow microstructure, meteoric ice fraction (superimposed and snow ice), surface roughness/topography
Atmosphere–ice energy budget (P4)	Longwave radiation (up/down), surface temperature, shortwave radiation (up/down), albedo, precipitation, air temperature, relative humidity, wind speed and direction, turbulent sensible and latent heat fluxes , optical snow and ice properties (SSA, density), snow microstructural anisotropy, surface topography/roughness, snow depth , thermal conductivity of snow, brine fraction, sea ice density
Ocean boundary layer (P5)	Under-ice hydrography (currents, temperature and salinity), turbulent heat and salt fluxes .

RQ3. Ecosystem and Biogeochemical Responses

Ecosystem-related processes (P6)	Biological communities (composition, abundance, biomass, phenology); Primary production (ice algal vs phytoplankton, photosynthetic efficiency, microbial growth rates) ; Carbon cycling and export (POC, DOC, carbon export fluxes, sinking aggregate fluxes, EPS concentrations, cryomineral formation rates).
Biogeochemical processes (P7)	Air-ice-ocean exchange (CO₂ fluxes, CH₄ fluxes, reactive trace gases fluxes (e.g., DMS), aerosol precursor emissions, cloud condensation nuclei concentrations); Elemental and Nutrient Cycling (DIC, nitrogen species concentrations, nutrient concentrations (NH₄⁺, NO₂⁻, NO₃⁻), phosphorous concentrations, silicate concentrations, iron concentrations and speciation, sulfur compounds); Process rates (nitrification rates, microbial metabolic rates, iron release fluxes, DMS production rates); Physical-chemical controls (snow depth, snow salinity, sea ice thickness, sea ice temperature, sea ice salinity, light transmittance, sea ice age).

RQ4. Climate Implications and Feedbacks

Link to large-scale climate variability (P8)	Sea ice concentration, sea ice thickness, sea ice drift vectors, sea ice albedo, upward/downward longwave radiation, upward/downward shortwave radiation, sensible flux, latent flux, upper ocean salinity/temperature, surface wind stress, surface moisture, sea level pressure, upper and mid-atmosphere level pressure, wind speed
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White paper | Key regions and Observing Strategies



Overarching Observing Strategies

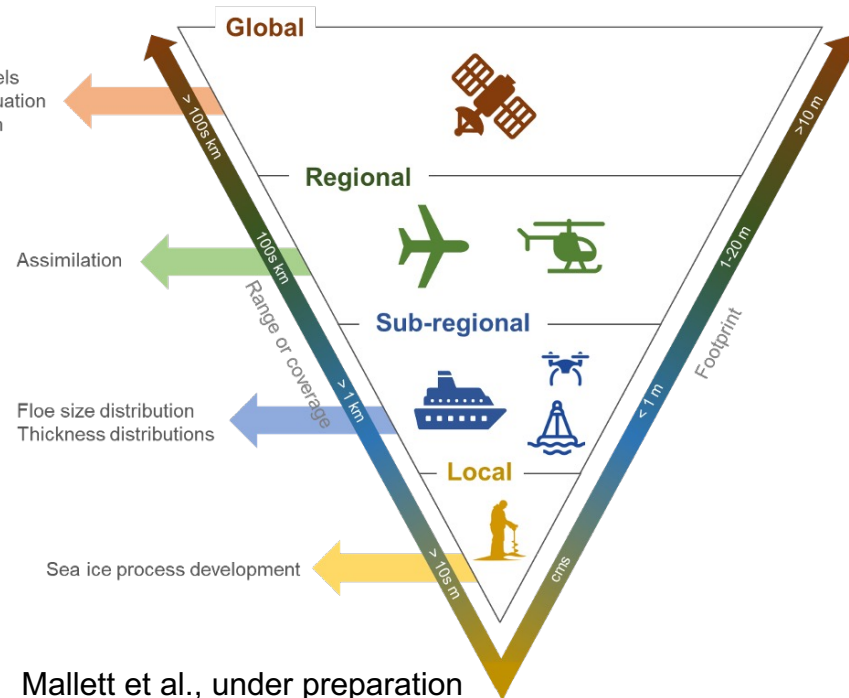
- Circumpolar and throughout all seasons
- Regular and repeated visits
- Strong international cooperation
- Satellite observations to cover all regions over longer time scales

Key regions

- Pack ice
- Landfast ice
- Marginal ice zone
- Polynyas

User needs

Global climate models
Climate trends evaluation
Variability evaluation



Theme 2 White Paper

