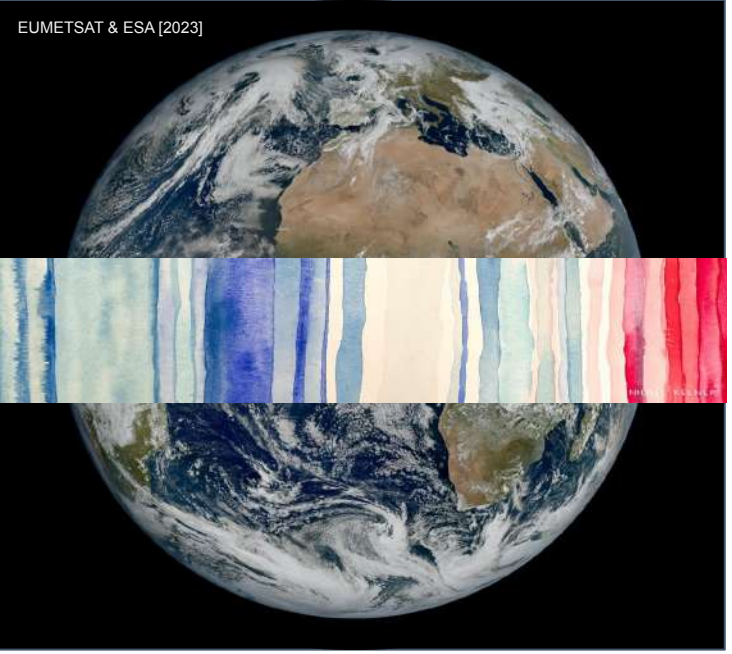


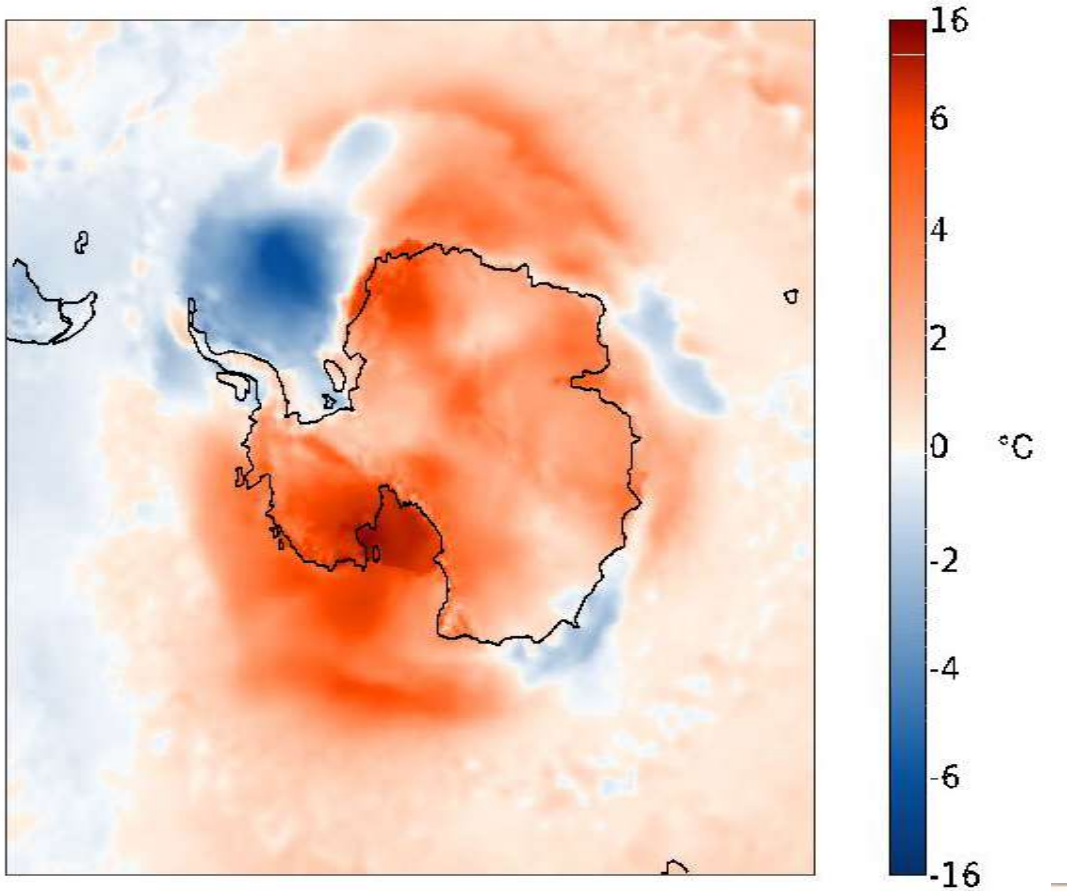

# Antarctica InSync Sea Ice:

Petra Heil
Australian Antarctic Division
Australian Department of Climate Change, Energy, The Environment & Water
&
Australian Antarctic Program Partnership
University of Tasmania, Australia
&
Snow and Avalanche Institute,
WSL Institute for Forest and Snow Research, Switzerland

Why?

# Antarctica InSync

Surface air temperature anomaly for Sep 2023



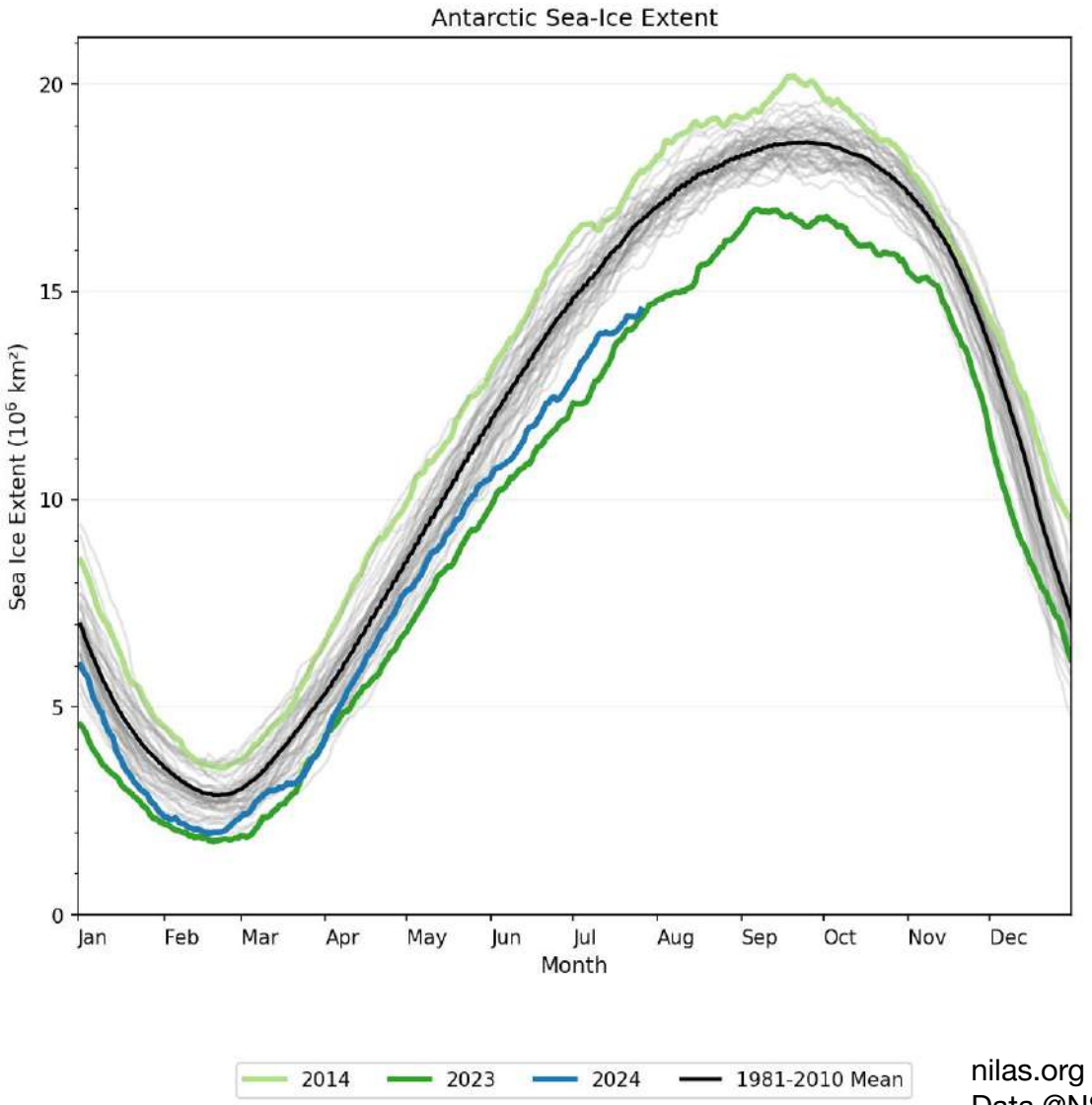

(Data: FRA5. Reference period: 1991-2020. Credit: C3S/ECMWF)

PROGRAMME OF THE EUROPEAN UNION

Copernicus

ECMWF

Climate Change Service




nilas.org
Data @NSIDC


PROGRAMME OF THE EUROPEAN UNION
Copernicus
ECMWF
Climate Change Service

2014 2023 2024 1981-2010 Mean

nilas.org
Data @NSIDC

Why?

# Antarctica & the Southern Ocean feel the heat

**Polar amplification:** Extreme heatwaves becoming more frequent and severe.

**Melting Ice:** Rising temperatures  → Decline in sea ice  & melt of glaciers and ice sheets  → Increasing sea-level rise  threatening coastal communities worldwide.

**Ocean Impacts:** Ice melt  → ocean salinity  → Potential to disrupt ocean circulation globally.

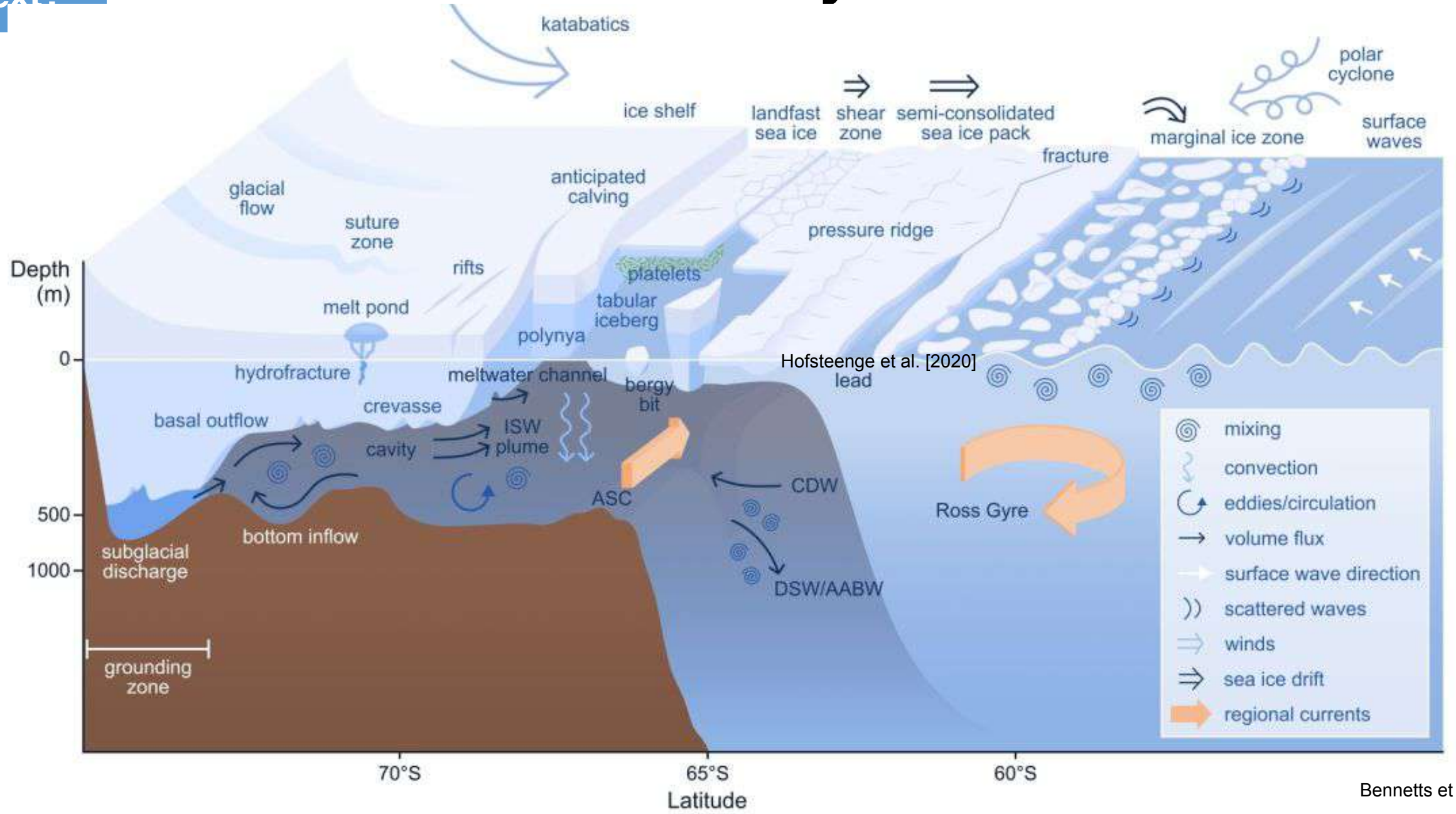
**Atmospheric Change:** Polar vortex  → … → Mid-latitude rainfall

**Tipping Points:** Antarctica may reach tipping points, where changes self-perpetuate towards a new stable level. → Ice-sheet melt could become irreversible.

**Cascading Effects:** Antarctica/SO changes may hold the trigger for a domino effect. → Climate change  → Ecosystem change  → Climate, biodiversity collapse → Human health  & cost  → … → Deep societal impacts.

Next?

# Antarctica InSync - Scales

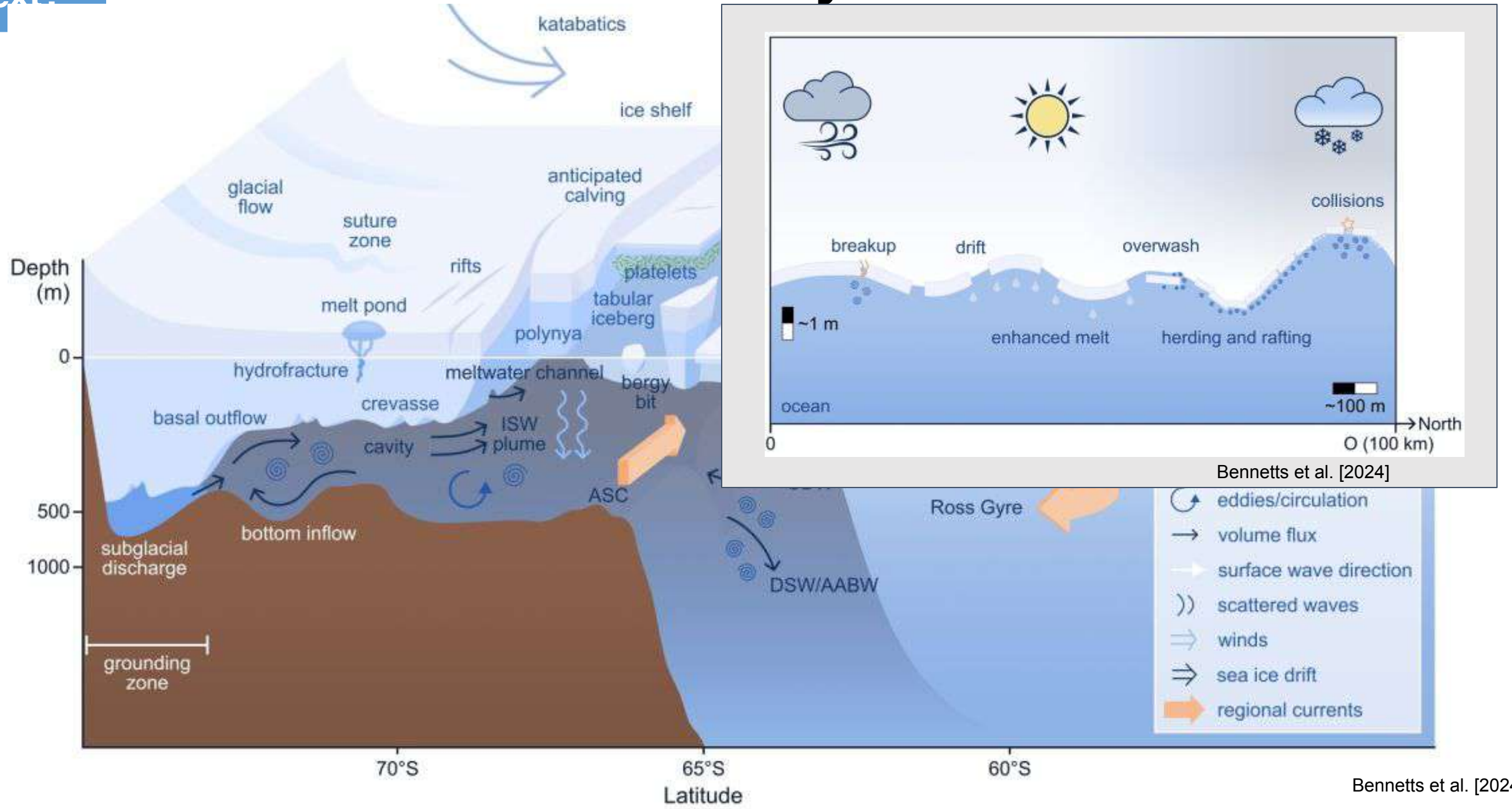



Hofsteenge et al. [2020]

Bennetts et al. [2024]

Next?

# Antarctica InSync - Scales

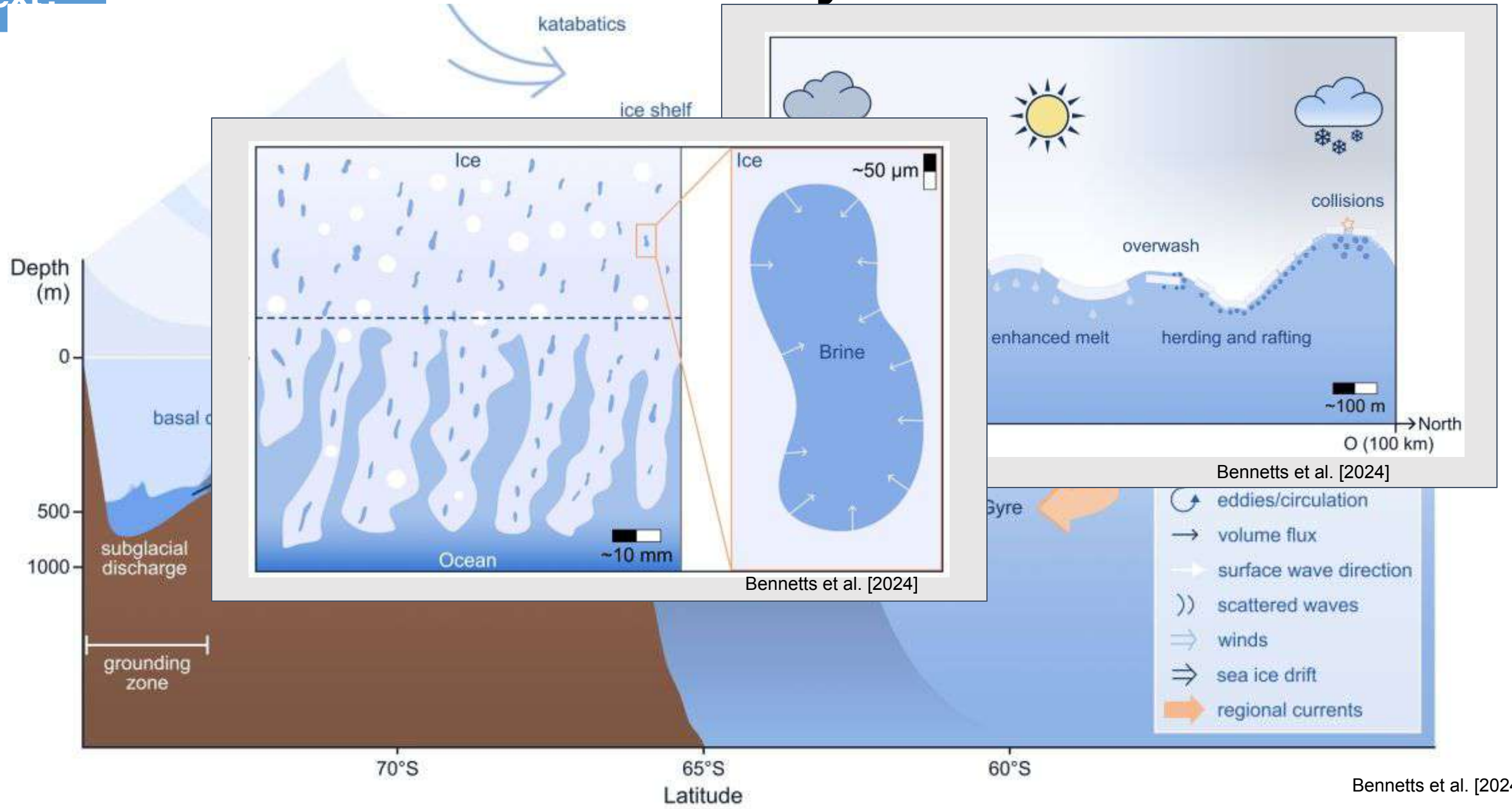



Bennetts et al. [2024]

Bennetts et al. [2024]

Next?

# Antarctica InSync - Scales



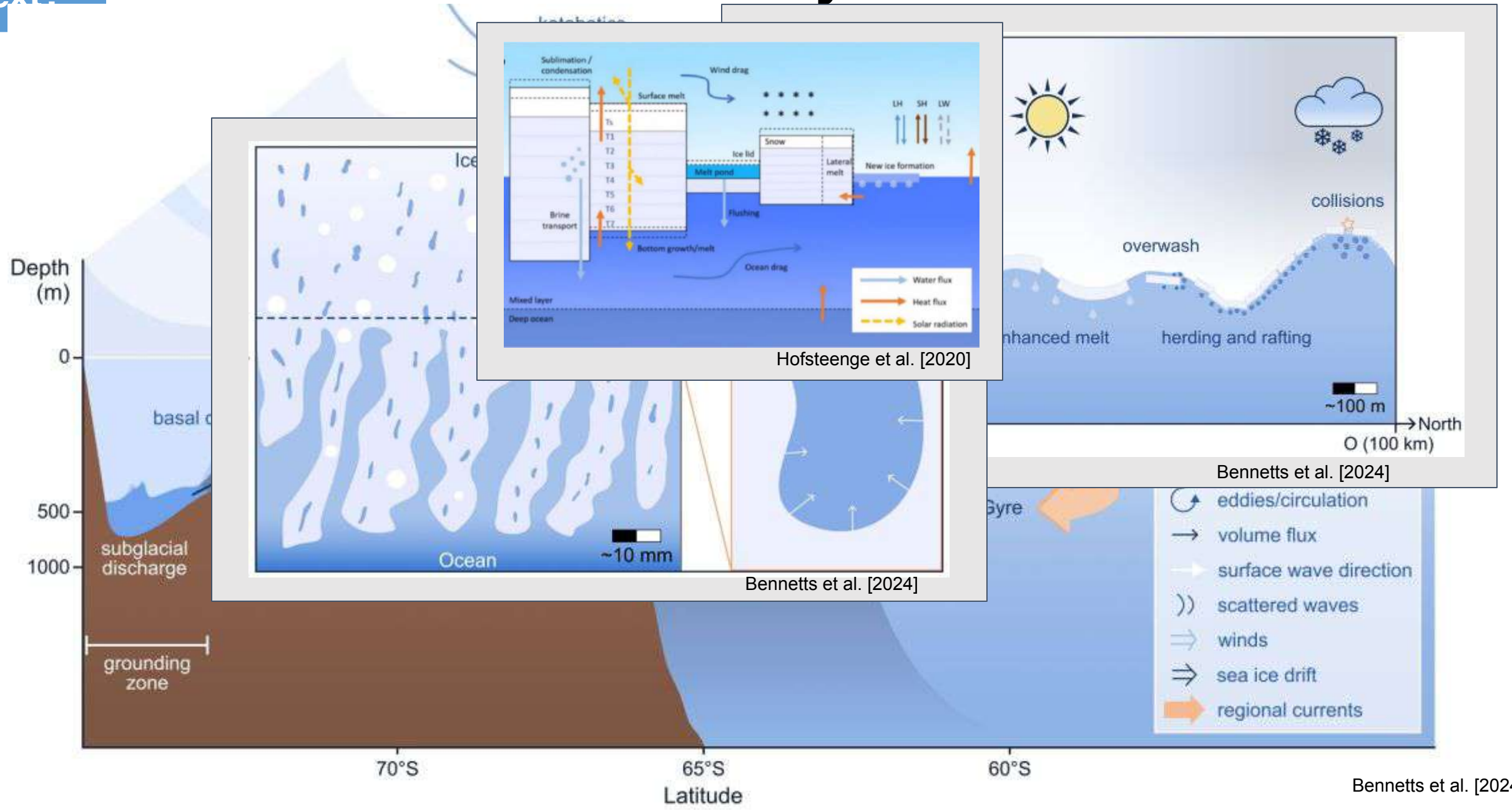

Bennetts et al. [2024]

Bennetts et al. [2024]

Bennetts et al. [2024]

Next?

# Antarctica InSync - Scales




Hofsteenge et al. [2020]

Bennetts et al. [2024]

Bennetts et al. [2024]

Bennetts et al. [2024]

What?

# Antarctica InSync

## What, where and when? Priorities?

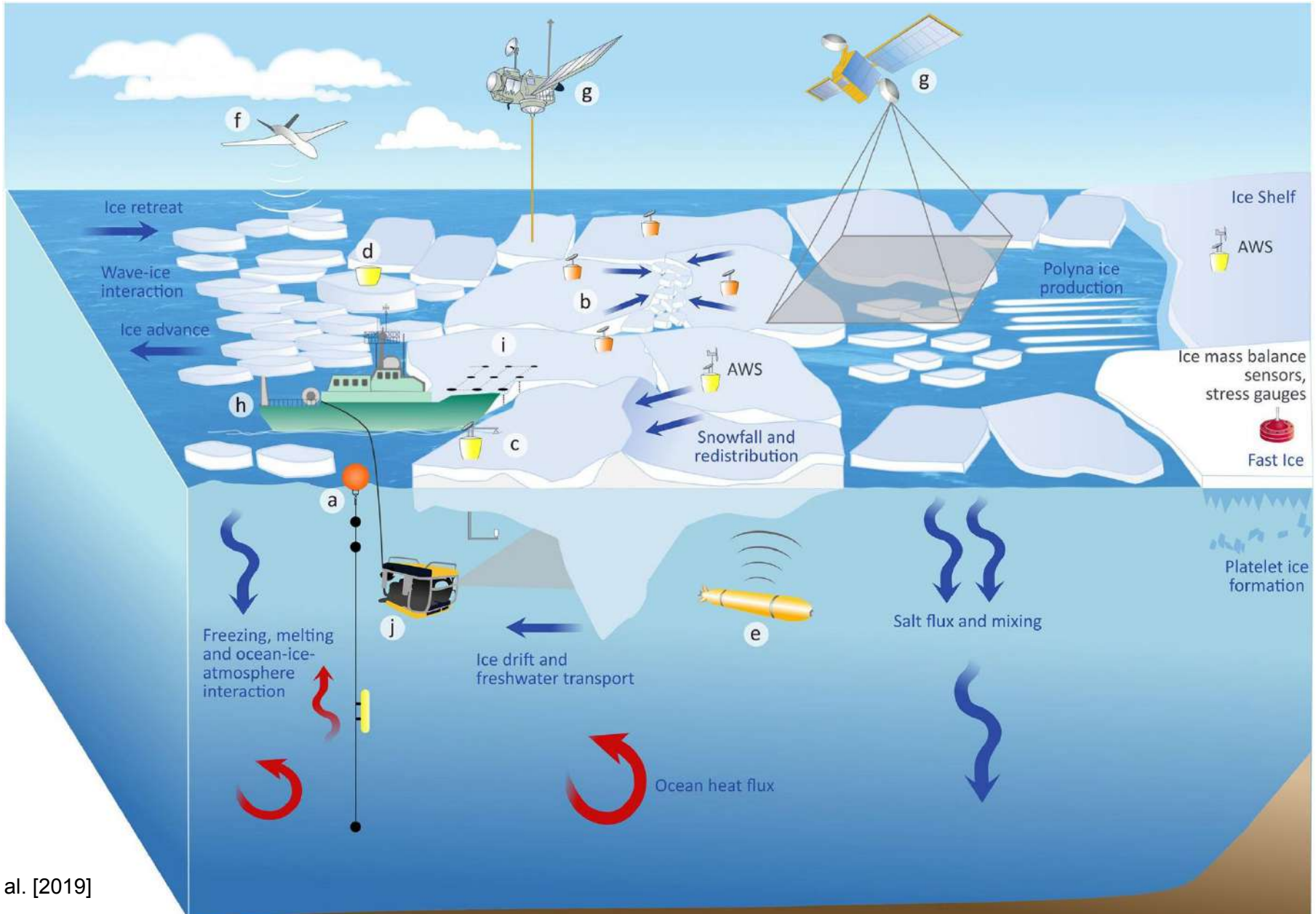
## Sea-ice ECV

| Name | Sea Ice Thickness | | | | |
|---|---|---|---|---|---|
| Definition | The vertical distance between sea ice surface and sea ice underside of the ice-covered fraction of an area. | | | | |
| Unit | m | | | | |
| Note | Sea-ice thickness is together with the sea-ice area derived from the sea-ice concentration the key ingredient to compute the sea-ice volume and mass. Long-term sea-ice volume and mass changes are considered as the integral response of climate change exerted on the polar regions. | | | | |
| **Requirements** | | | | | |
| **Item needed** | **Unit** | **Metric** | **[1]** | **Value** | **Notes** |
| Horizontal Resolution | km | | G | 1 | Required to resolve small scale impacts of deformation events on sea-ice thickness distribution for more accurate estimation of dynamics on mass balance.<br>Enables to resolve thickness distribution approaching floe scale for improved ice mass flux.<br>Needed to obtain enhanced ice-type specific ice thickness information and more accurate estimates of ice production. |
| | | | B | 25 distribution<br>25 mean & median | Required for the analysis of regional sea-ice thickness distributions<br>Needed to further develop and improve GCMs and to improve regional climate analyses<br>Needed to refine hemispheric trend analyses and to analyze basin-wide / regional sea-ice thickness and mass trends<br>Required for the evaluation of the next generation of CMIP6 GCMs |
| | | | T | 50 | Minimum useful horizontal resolution to compute hemispheric trends in sea-ice thickness and mass and to evaluate GCMs / CMIP6 |
| Vertical Resolution | | | G | - | N/A |
| | | | B | - | |
| | | | T | - | |
| Temporal Resolution | d | | G | daily year-round | To resolve ice production in polynyas and during early freeze-up<br>To resolve the impact of dynamic processes on the sea-ice thickness distribution<br>To resolve snow-ice formation |
| | | | B | weekly year-round<br>monthly year-round | To better monitor the impact of longer-lasting weather conditions on sea-ice formation and melt.<br>To better monitor the full seasonal cycle of sea-ice thickness |
| | | | T | monthly wintertime | Minimum temporal resolution required to adequately monitor the winter-time sea-ice thickness and mass increase |
| Timeliness | d | | G | 1 | Operational monitoring with climate indicators, update of reanalyses |
| | | | B | 7 | Update of monthly climate indicators |
| | | | T | 30 | |
| Required Measurement Uncertainty (2-sigma) | m | | G | 0.05 | To improve monitoring of thin ice areas and associated heat fluxes<br>To enhance sea-ice production estimation<br>To monitor diurnal changes in sea-ice thickness during growth and melt |
| | | | B | 0.1 | To monitor regional- and large-scale sea-ice thickness changes in the Arctic towards the end of the growing season and in the Antarctic. |
| | | | T | 0.25 | Minimum useful uncertainty to be able to monitor basin-wide sea-ice thickness changes at monthly scale. |
| Stability | m/decade | | B | | |
| | | | T | | |
| Standards and References | Lavergne and Kern, et al. (2022). A New Structure for the Sea Ice Essential Climate Variables of the Global Climate Observing System, BAMS, DOI 10.1175/BAMS-D-21-0227.1. | | | | |

GCOS 245 [2022]

Next?

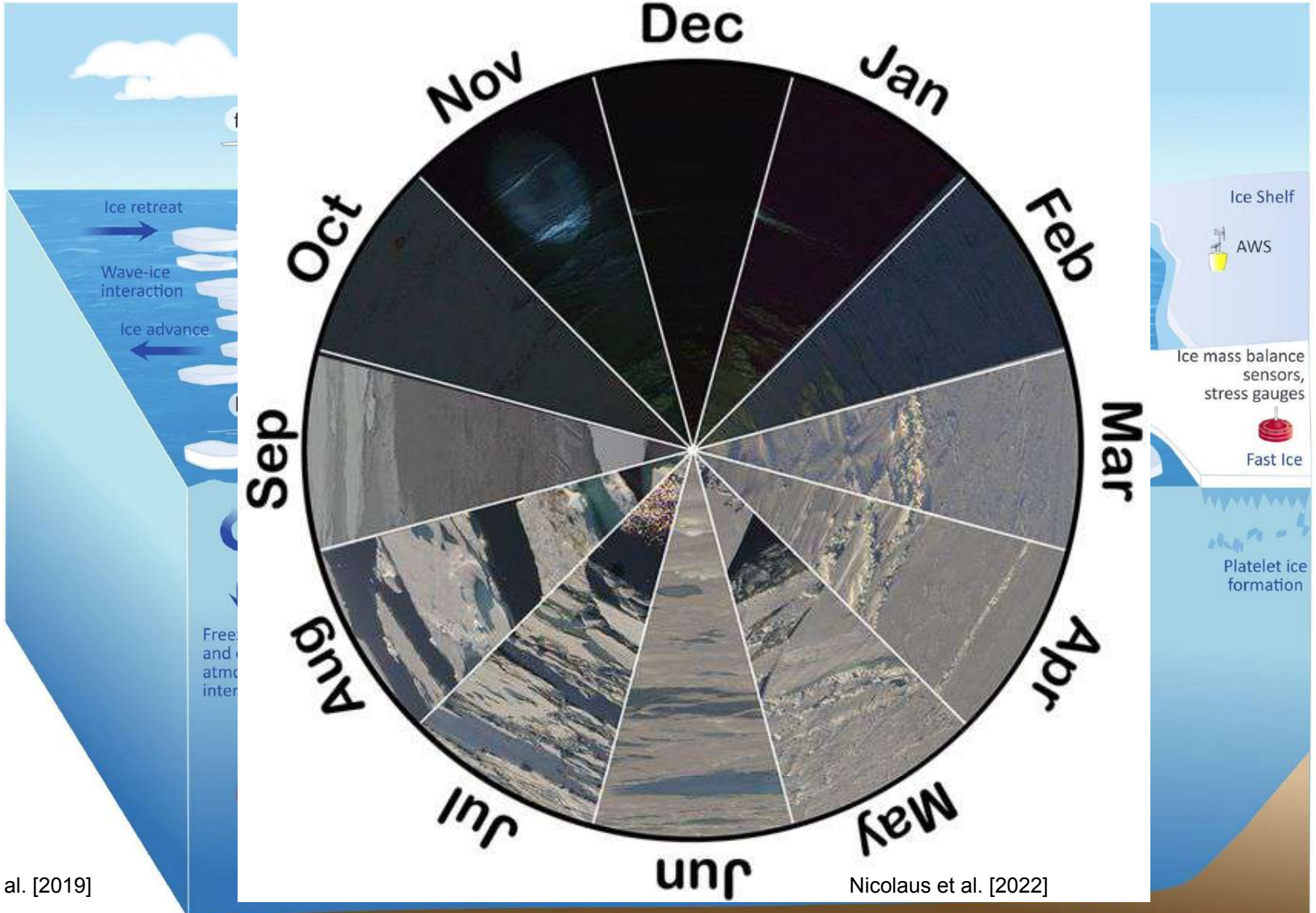
# Antarctica InSync - Strategy




Newman et al. [2019]

Next?

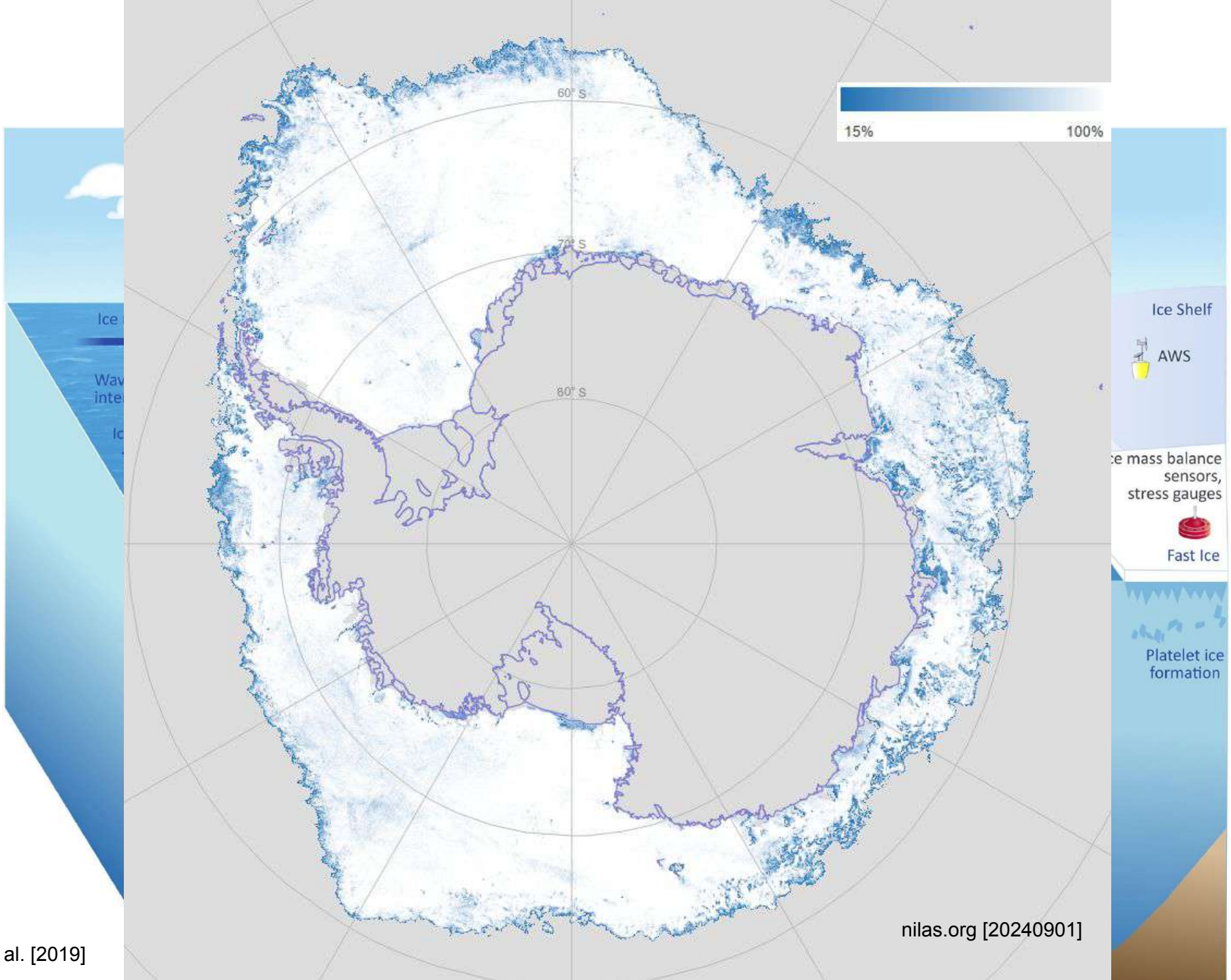
# Antarctica InSync - Strategy




Newman et al. [2019]

Nicolaus et al. [2022]

# Next?

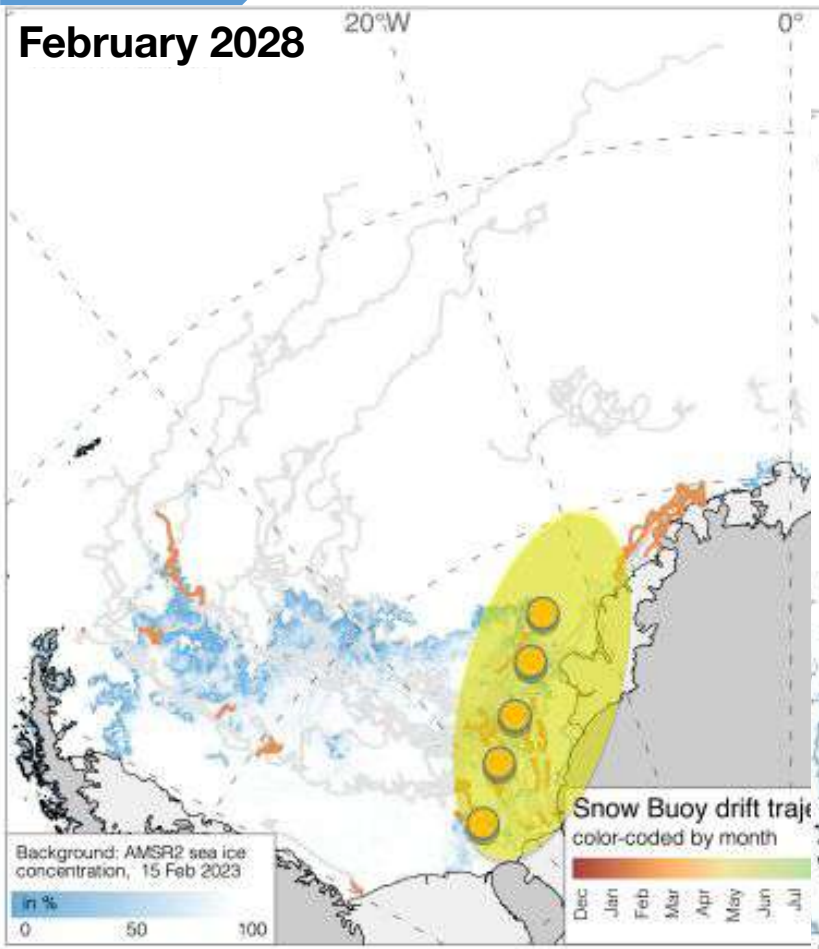



Newman et al. [2019]

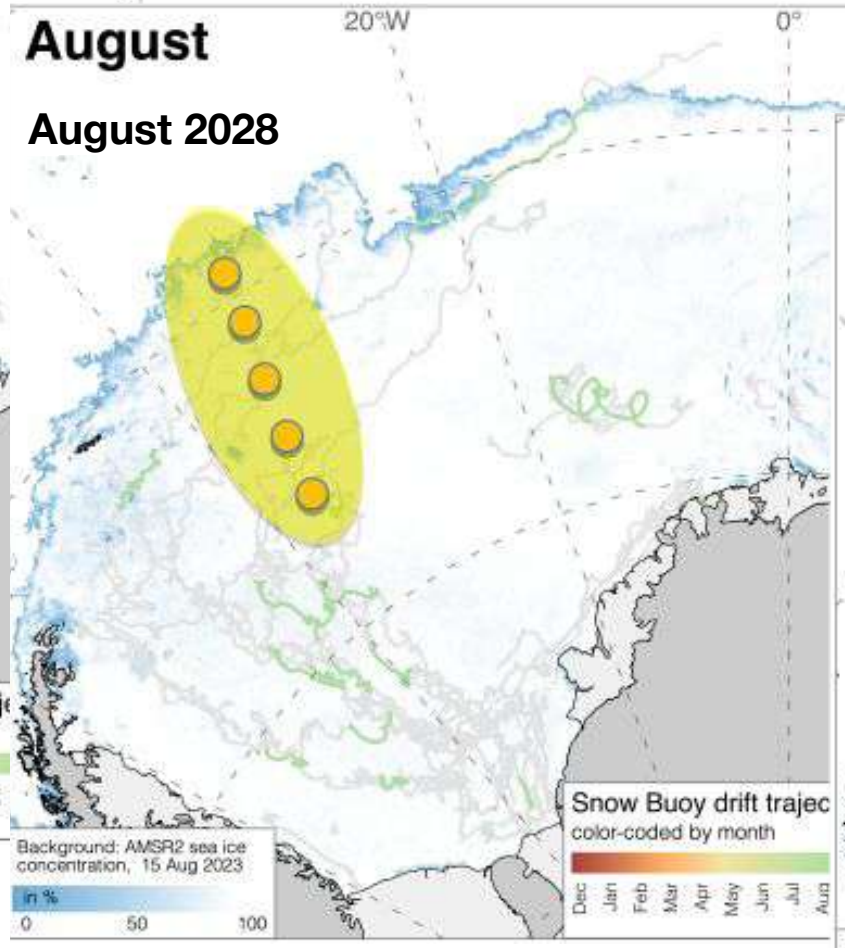
nilas.org [20240901]

Regions

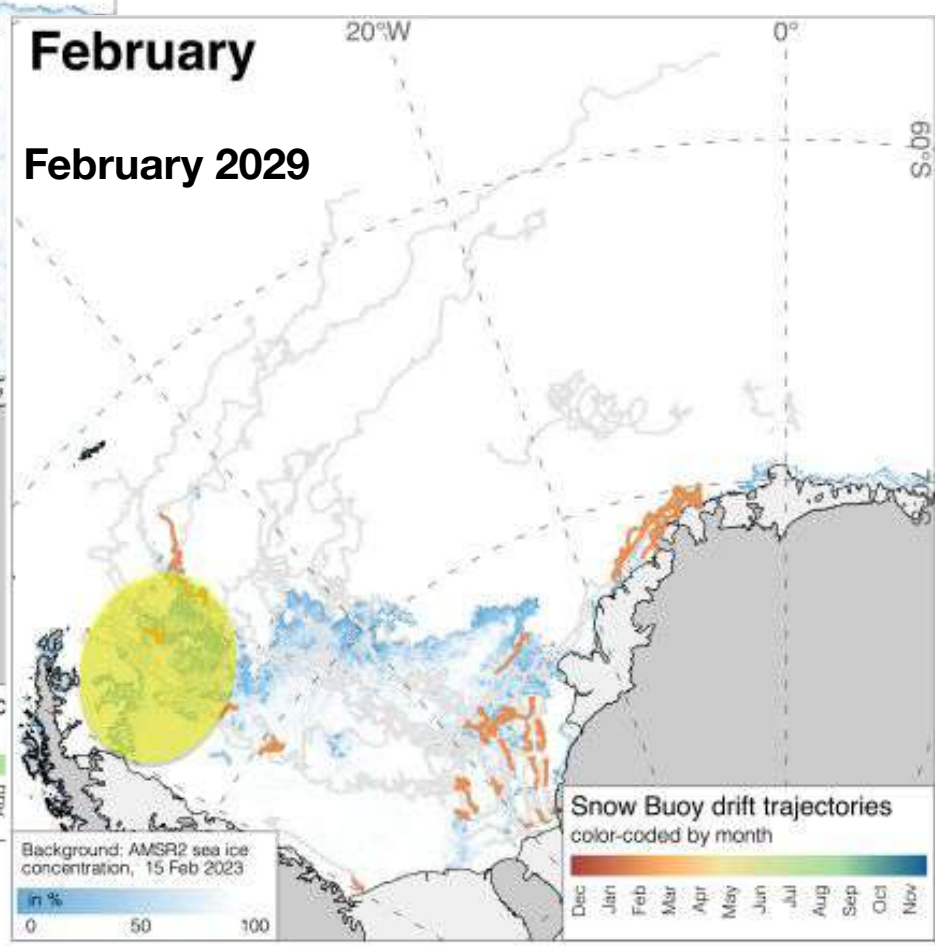
# Antarctica InSync: Deep-embayment Strategy




**Melt & metamorphism**




**Freeze, MIZ & pancakes**



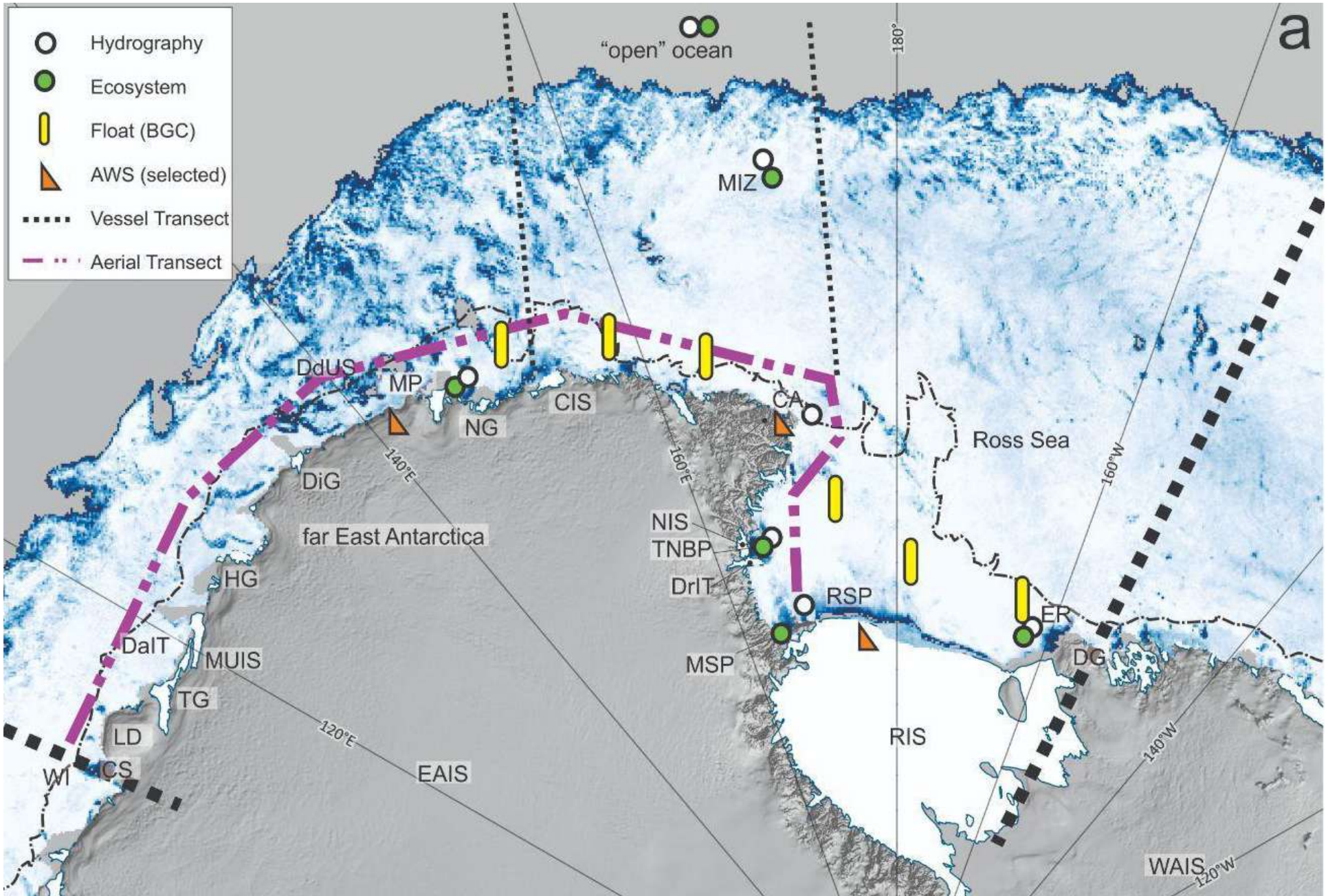

**Melt, metamorphism & full seasonal cycle**

Arndt, Nicolaus and others [dated 2024]

Regions

# Antarctica InSync: East-Antarctic Strategy

**RSfEAR: Integrated observing approach**




Heil et al. [2023]

Next?

# Antarctica InSync - Strategy:

## Multi-scale approach

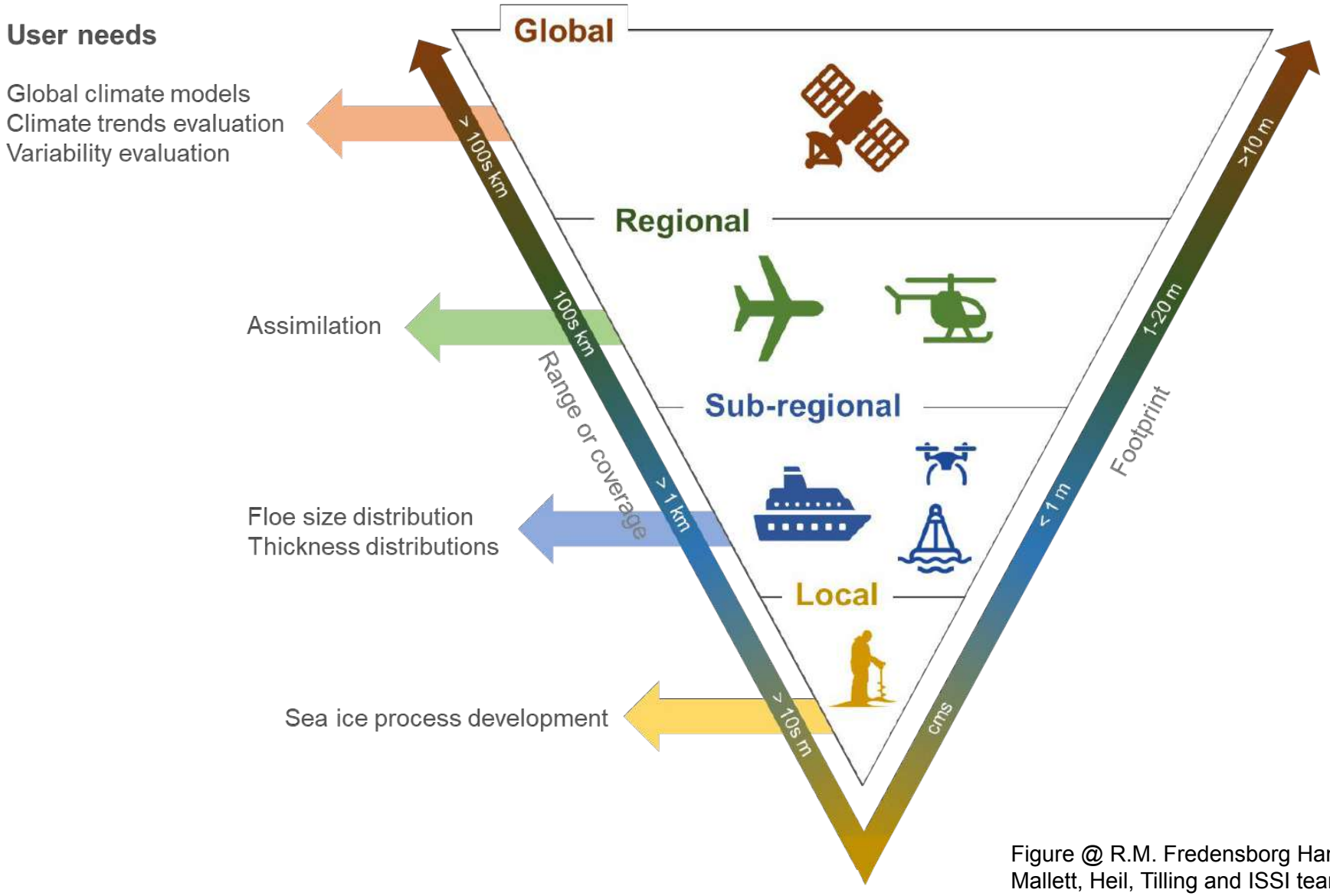



Figure @ R.M. Fredensborg Hansen
Mallett, Heil, Tilling and ISSI team [in prep]

Status Quo

# Antarctic/SO – status quo

## Starting point for Antarctica InSync:

- National programs incl. AWI, BAS, KOPRI, NSF, CPI, JARE, AAS, NZ etc.
- International organisations:
  - SCAR Expert Groups, incl. ASPeCt, BEPSII, AntClimNow
  - CCAMLR
- WMO, WCRP etc. endorsed working groups, incl.
  - IPAB
  - AFIN
  - Antarctic Regional Climate Centre (in Implementation Phase)
- International support, incl.
  - CliC
  - SOOS

United Nations Decade of Ocean Science 2021-2030 · SCAR · WMO · CCAMLR · Antarctic and Southern Ocean Coalition · COMNAP · CliC · International Science Council SCOR · SOOS Southern Ocean Observing System · COLTO · ...

Methods

# ASPeCt - A SCAR Expert Group

What are the drivers for the summer and winter reductions of Antarctic sea ice?

How do the changing thickness and composition of the snowpack impact persistence and characteristics of the Antarctic sea ice?

Which aspects of the coupled Antarctic sea ice system remain poorly understood, particularly in the context of accelerated global warming and amplified polar change?

How do biogeochemistry and ecosystems link to atmosphere and cryosphere?

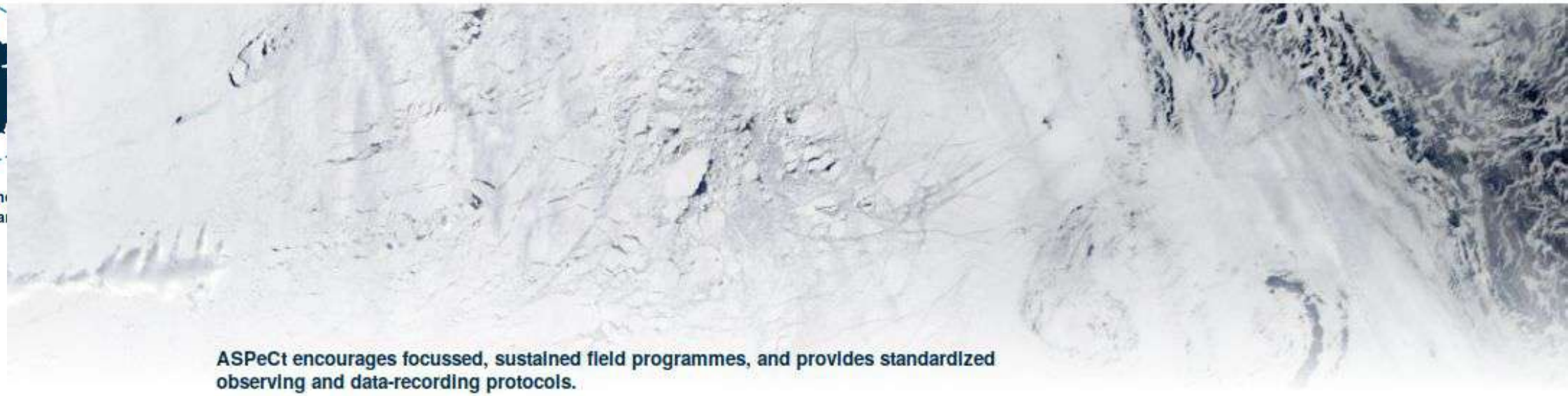
aspectsouth.org

Methods

ASPeCt
Antarctic Sea Ice Processes and Climate

ASPeCt | Science | Story of Sea Ice | ASPeCt resources | Other Resources | Photo Galleries

What are the drivers for th
winter reductions of Anta



ASPeCt encourages focussed, sustained field programmes, and provides standardized observing and data-recording protocols.

ASPeCt Sea-Ice Cards

Manual for shipboard observations of sea ice.

Icebreaking vessels are unique platforms for gathering data regarding Antarctic sea-ice thickness, distribution, and other characteristics. These data enhance our understanding of processes, validate satellite-derived products, and provide input for numerical models.

Established in 1996, Antarctic Sea Ice Processes and Climate (ASPeCt) is an expert group operating under the Scientific Committee of Antarctic Research (SCAR) Physical Sciences program and dedicated to multi-disciplinary research within the Antarctic sea ice zone.

ASPeCt sea-ice cards are an authoritative document for observing Antarctic sea ice, adhering to global observing protocols outlined by the World Meteorological Organization (WMO). The cards describe the standard procedure for conducting underway observations. They specify the variables to be observed, offer visual guidance on sea-ice types, and provide the ASPeCt data codes for recording observations.

## Shipboard observation

## *In situ* measurement

## Best Practices for sea ice

**Methods**

ASPeCt
Antarctic Sea Ice Processes and Climate

ASPeCt | Science | Story of Sea Ice | ASPeCt resources ▾ | Other Resources ▾ | Photo Galleries

Editing Observation - September 9 2007 Move Observation cancel

| | Position | | | | Sea Ice Observations | | | | | | | | | | | | | Meteorological Observations | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hr | Latitude | | Longitude | | Conc. | Ice | | | | | | | B Ice | Melt Ponds | | | | | Twater | Tair | Wind | Wind | Cloud | Visib | Weather | Commer |
| [Z] | dd°mm.sss'[S] | | dd°mm.sss'[E/W] | | [tenths] | c | ty | z [cm] | f | t | s | sz [cm] | smb | c [%] | mz [cm] | l1 [m] | l2 [m] | O/W | [°C] | [°C] | Speed [m/s] | Dir. [°] | [_/8] | | | |
| 12 | 62°06.000' | S | 128°57.000' | E | 9 | 7 | 30 | 10 | 100 | 200 | 1 | 0 | | | | | | 2 | -1.84 | -9.5 | 10 | | 1 | 97 | 2 | |
| | | | | | | 2 | 12 | 5 | 0 | 000 | 1 | 0 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |

Icebreaking vessels are unique platforms for gathering data regarding Antarctic sea-ice thickness, distribution, and other characteristics. These data enhance our understanding of processes, validate satellite-derived products, and provide input for numerical models.

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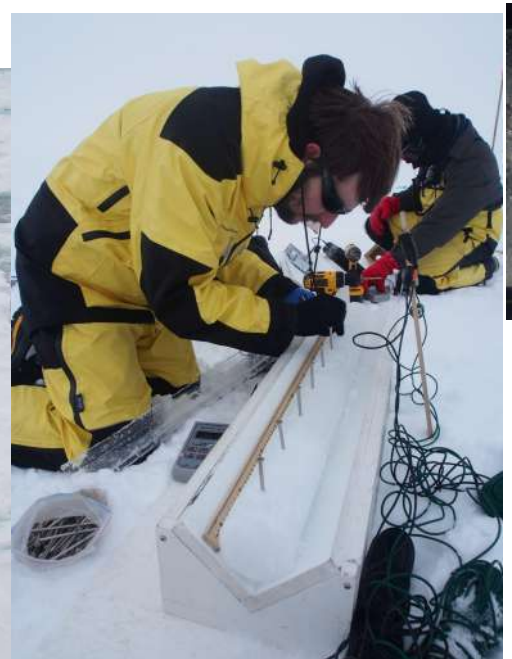
## Shipboard observation

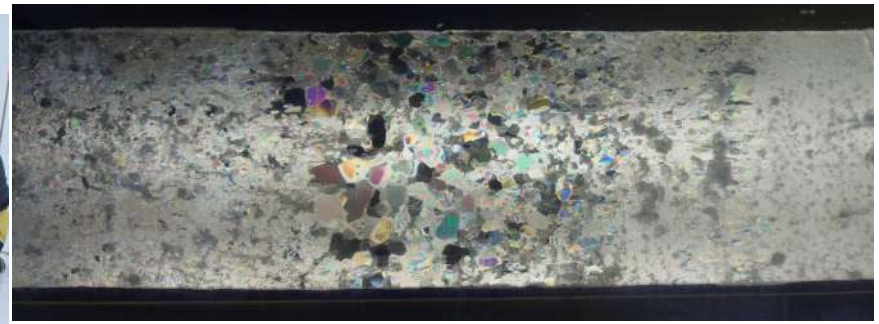
## *In situ* measurement

## Best Practices for sea ice

Methods

# ASPeCt - Examples from ice-station work



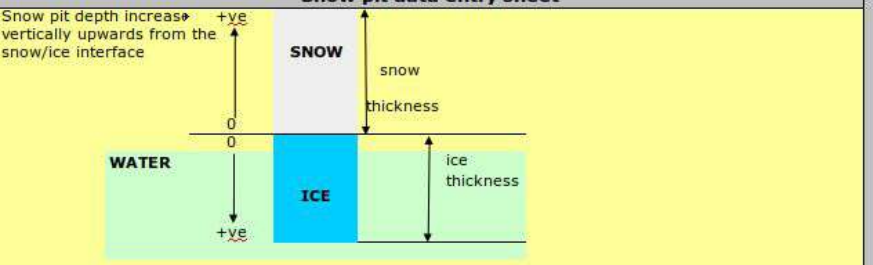


Photos courtesy S.Warren, W.Pyper, T.Worby, P.Heil, KGolden, S.Zicus

Methods

# ASPeCt - Examples from ice-station work

**Snow pit data entry sheet**




| | |
|---|---|
| **Snow pit identification (e.g. distance along transect, point on floe):** | |
| **Instrument Type/Details:** | |
| **Comments:** | |

| Height (m) | Temp (°C) | lower limit of density sample height range (m) | upper limit of density sample height range (m) | Density (kg/m³) | lower limit of salinity sample height range (m) | upper limit of density sample height range (m) | Salinity (psu) | lower limit of dielectric sample height range (m) | upper limit of dielectric sample height range (m) | Dielectric const. (20 MHz) | lower limit of wetness sample height range (m) | upper limit of wetness sample height range (m) | Wetness (vol%) | Wetness (wt%) | Lower limit of isotope sample height range (m) | Upper limit of isotope sample height range (m) | $\delta^{18}O$ (°/₀₀) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

**Table 1: Snow Symbols International Classification**

(Colbeck et al. 1990)

**Symbols for morphological classification**

The alphanumeric character to create the corresponding class type symbol in the font SnowSymbolsInt is given

**NOTE:** ACTUAL CLASS SYMBOLS NOT SHOWN

| Class | SSI Character | Description |
|---|---|---|
| 1 | 1 | Precipitation particles |
| 2 | 2 | Decomposing, fragmented particles |
| 3 | 3 | Rounded grains |
| 4 | 4 | Faceted crystals |
| 5 | 5 | Depth hoar |
| 6 | 6 | Wet grains (also refrozen) |
| 7 | 7 | Feathery crystals (surface hoar) |
| 8 | 8 | Ice masses |
| 9 | 9 | Surface deposits and crusts |

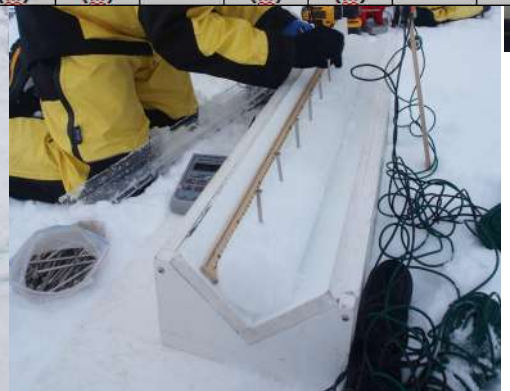
**Snow Symbol International Classification**

(after Colbeck et al. 1990)

| Lower limit of snow class height range (m) | Upper limit of snow class height range (m) | SSI character or 2 digit code (refer to tables 1 & 2) | Average Grain Size (mm) |
|---|---|---|---|

**Table 2: Two digit codes for SSIC sub-classes**

| Class | Sub class | Character | Description - with two digit code |
|---|---|---|---|
| 1 | a | a | Columns (1a) |
| | b | b | Needles (1b) |
| | c | c | Plates (1c) |
| | d | d | Stellars or dendrites (1d) |
| | e | e | Irregular crystals (1e) |
| | f | f | Graupel (1f) |
| | g | g | Hail (1g) |
| | h | h | Ice pellets (1h) |
| 2 | a | i | Partly decomposed precip. Particles (2a) |
| | b | j | Highly broken part. (2b) |
| 3 | a | k | Small rounded part.(3a) |
| | b | l | Large rounded part. (3b) |
| | c | m | Mixed forms (3c) |
| 4 | a | n | Solid faceted particles (4a) |
| | b | o | Small faceted particles (4b) |
| | c | p | Mixed forms (4c) |
| 5 | a1 | q | Cup crystal hollow (5a) |
| | a2 | r | Cup crystal partly solid (5a) |



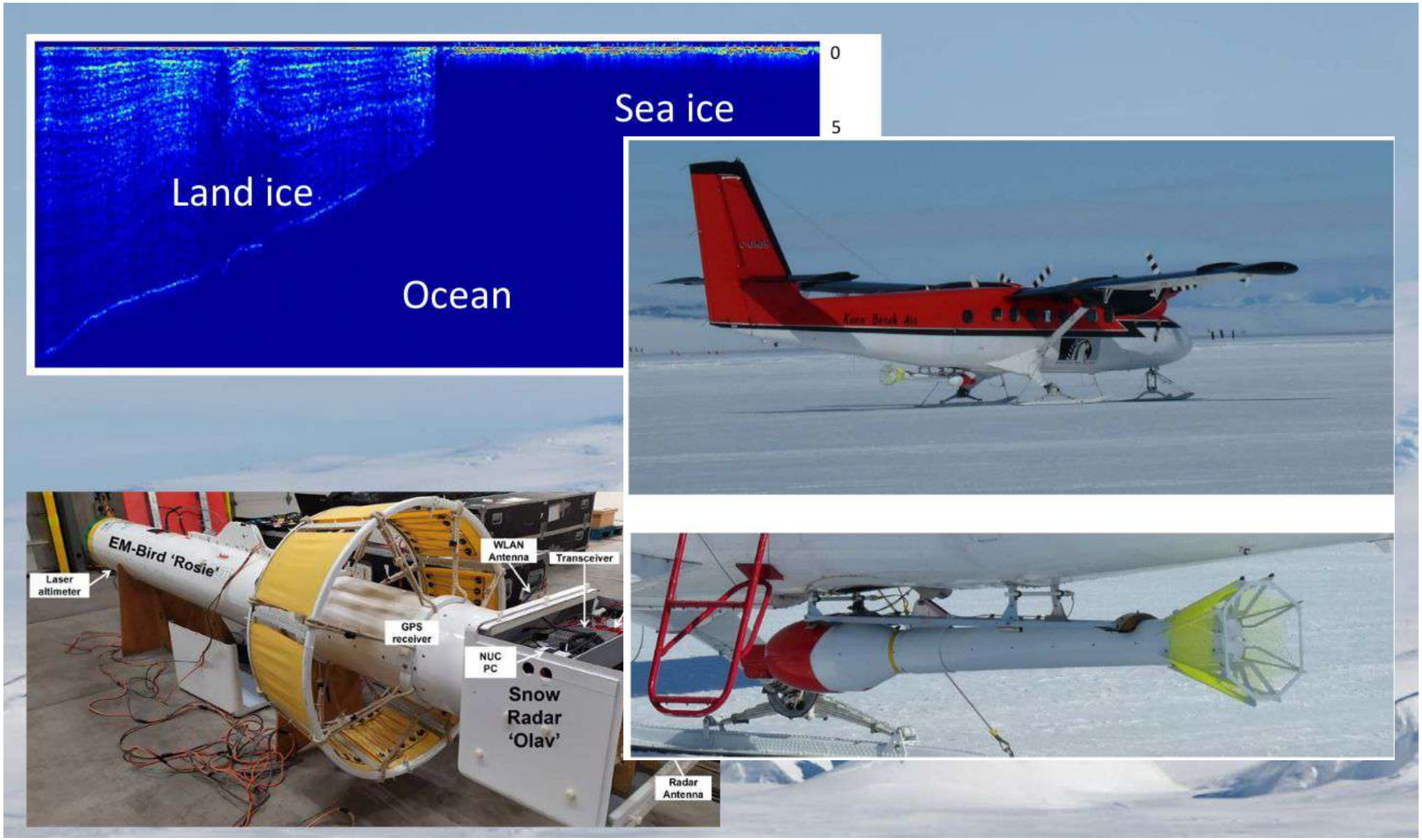
aspectsouth.org

Photos courtesy S.Warren, W.Pyper, T.Worby, P.Heil, KGolden, S.Zicus

R&D

# Antarctica InSync - Strategy

## Sensors, packages & methods




Rack et al [in prep]

# **OSIA:** Sea-ice floe size & classification

Image acquisition

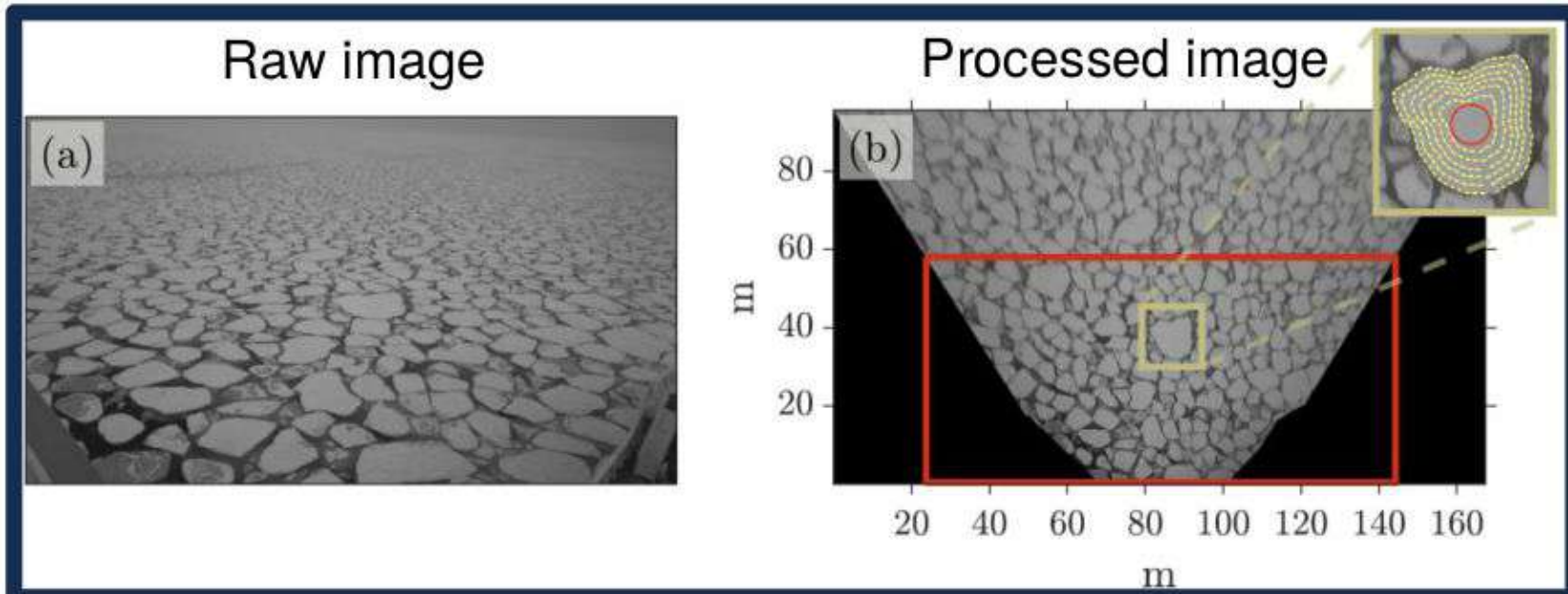
↓

Orthorectification

↓

Segmentation

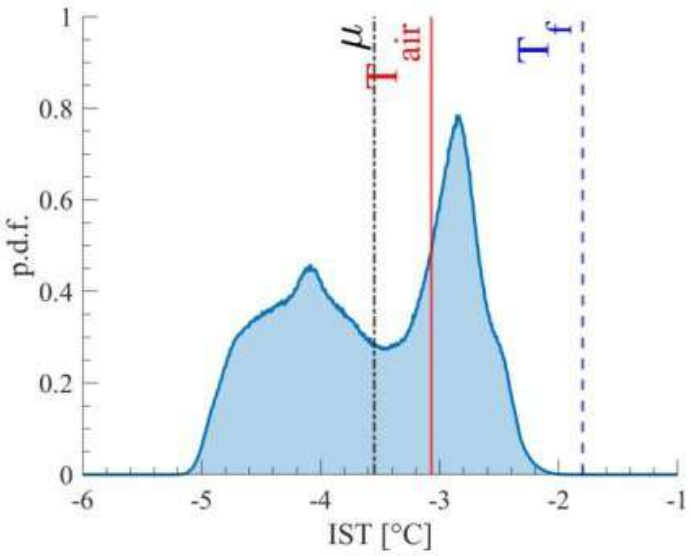
Towards a **Synthetic ASPeCt** data set




Heil, Toffoli et al. [in prep]

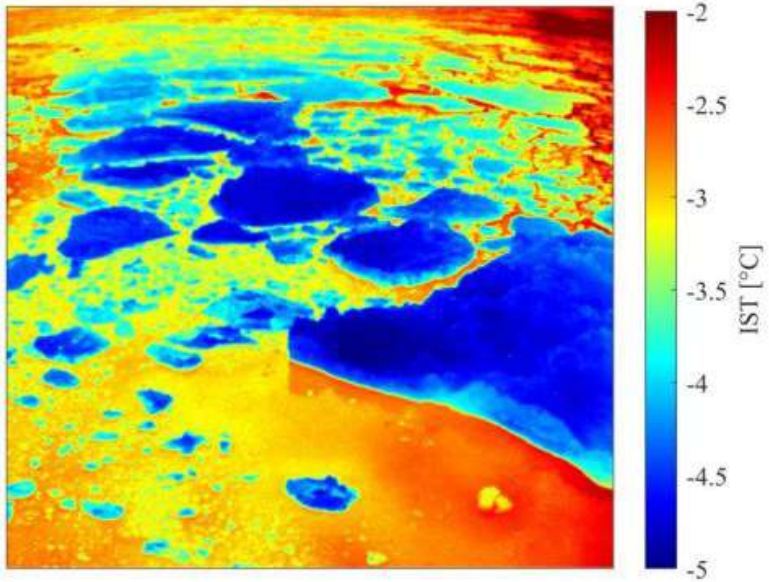
# OSIA: Thermal camera

Heil, Toffoli et al. [in prep]




## Preliminary results

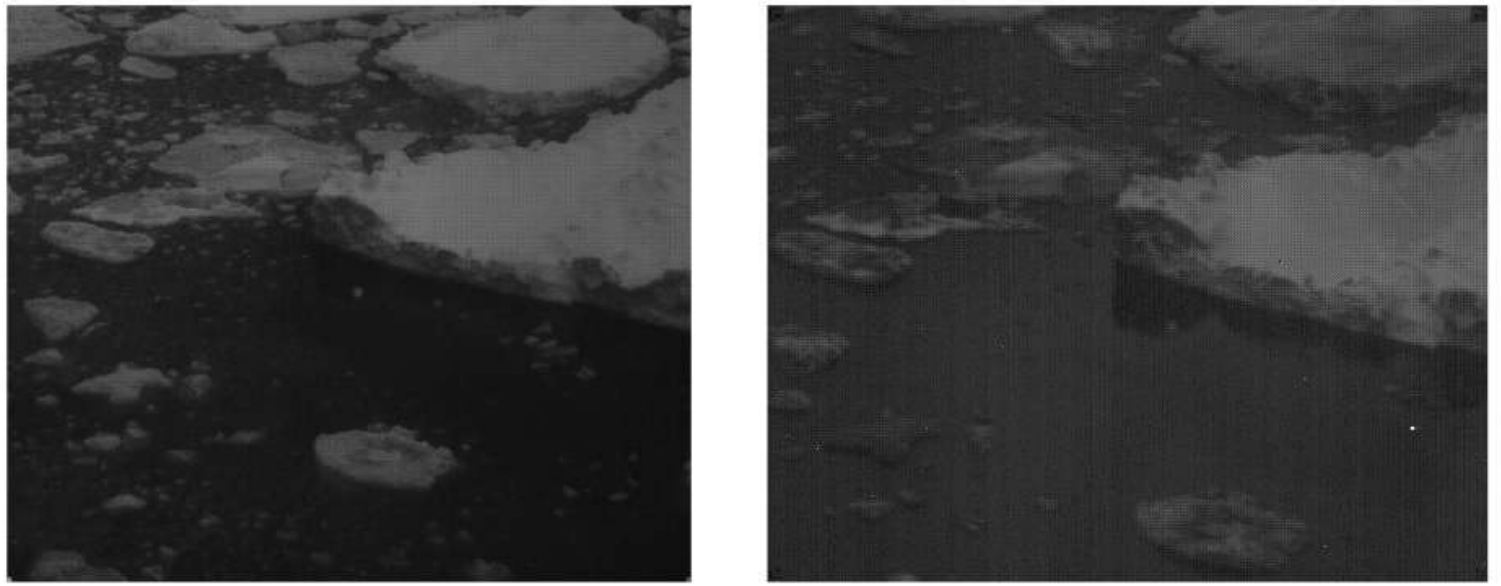
$T_a$ = air temperature -3.07 °C
$T_f$ = freezing point -1.8 °C
μ = mean IST -3.5 °C
p.d.f. = probability density function
**Bimodal distribution**



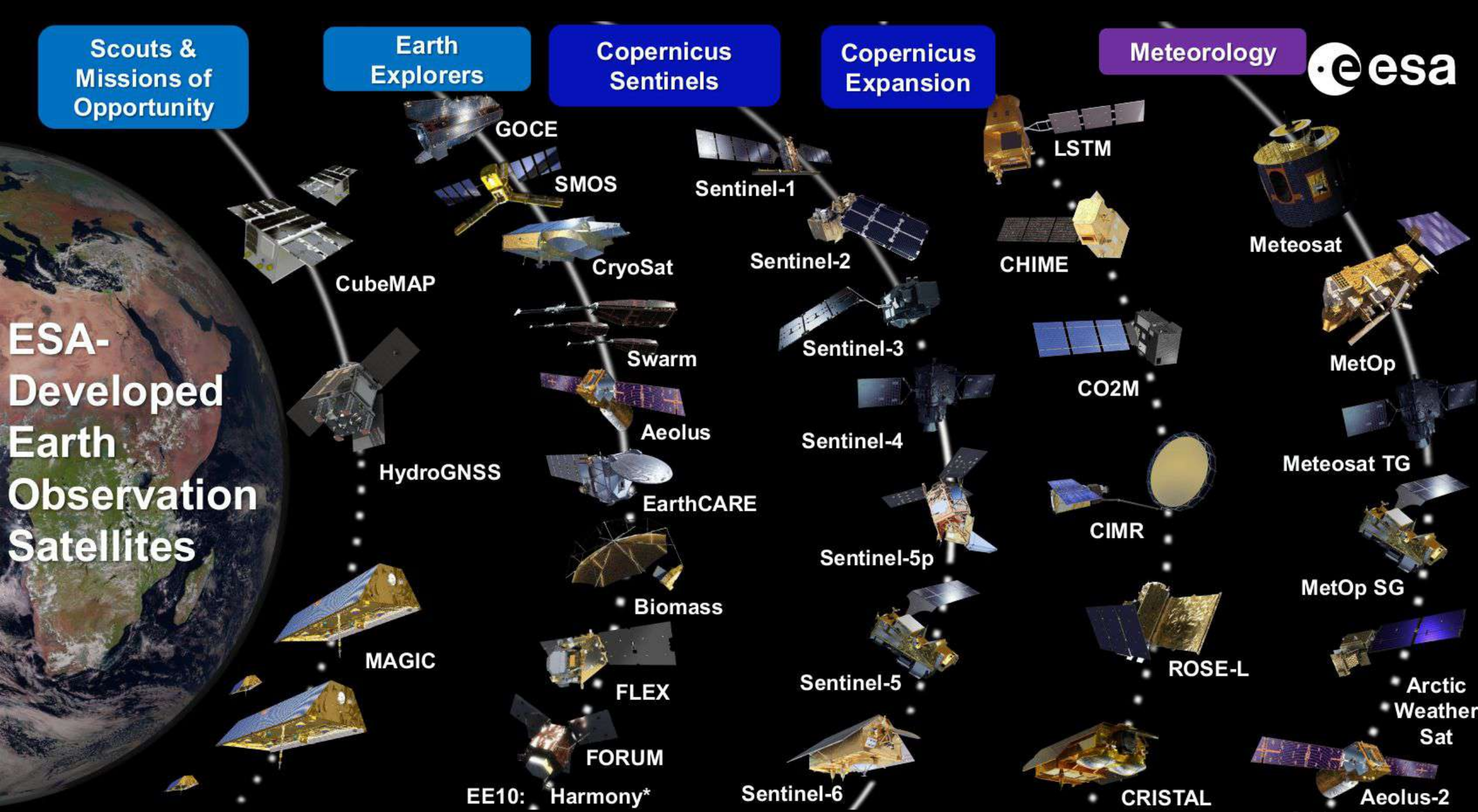

*Preliminary IR image V3*

TOUCAN:
wavelength range (400 - 900 nm)

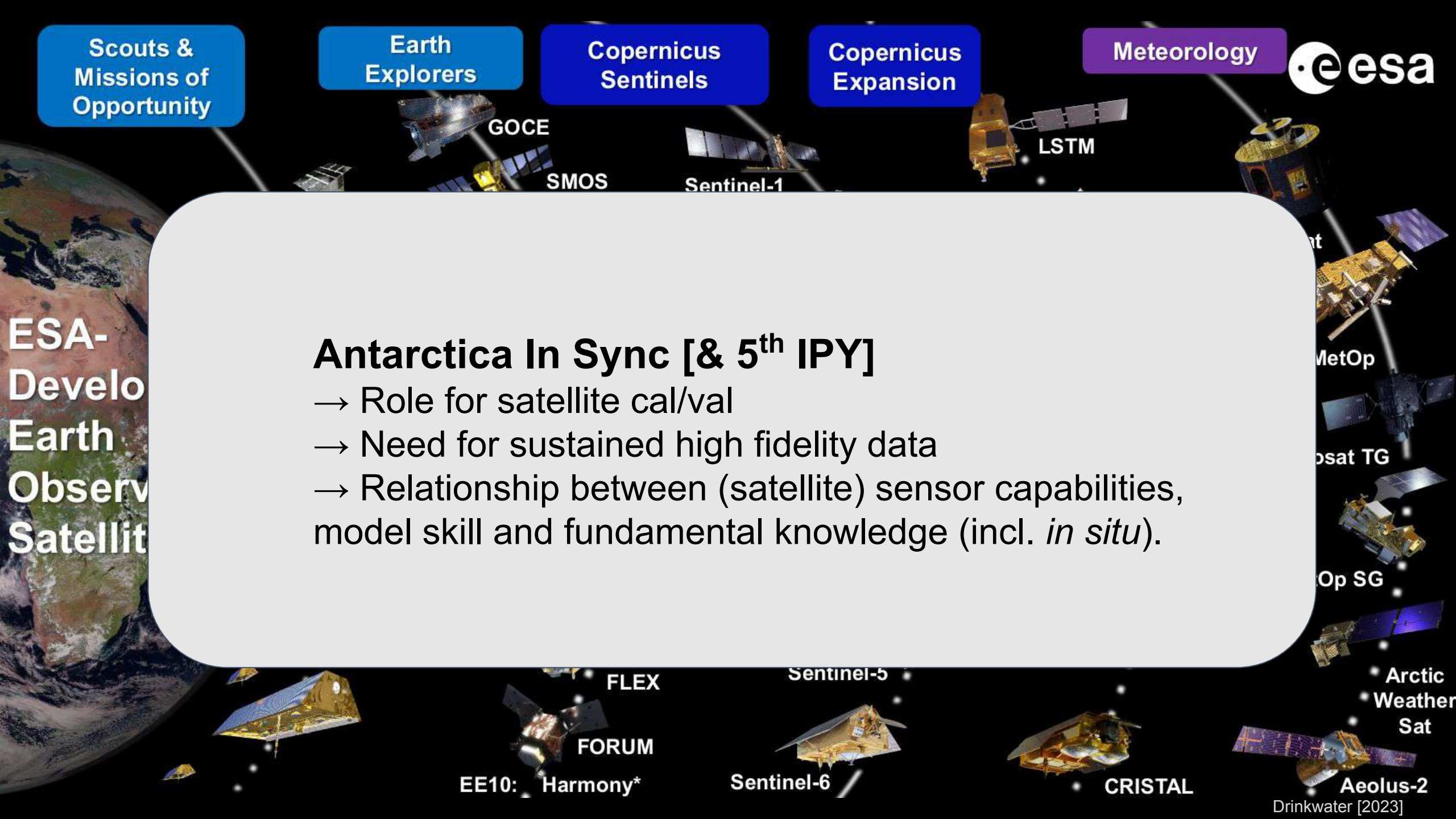
ANT:
wavelength range (1100 - 1700 nm)



*Raw multispectral images in different wavelengths*




Drinkwater [2023]




**Antarctica In Sync [& 5th IPY]**

→ Role for satellite cal/val

→ Need for sustained high fidelity data

→ Relationship between (satellite) sensor capabilities, model skill and fundamental knowledge (incl. *in situ*).

Drinkwater [2023]

Next?

# Antarctica InSync

## What is needed?

- Build national project teams & international network
- Create cross-disciplinary longitudinal
- Identify scientific hotspots#. [→ Scales, regionality, seasonality]
- Identify key variables.  [Beyond ECVs, i.e., scales & processes]
- Devise Ant InSync observational strategies#. → Resource requirements.
- Agreed observations & buy-in to measurement protocols. → Best Practices.
- Bridging observations and models.
- Quo vadis: Data “recovery” in prep phase.
- Data access.