EGU 2022 – **Display Material**

Drivers of Antarctic sea-ice advance

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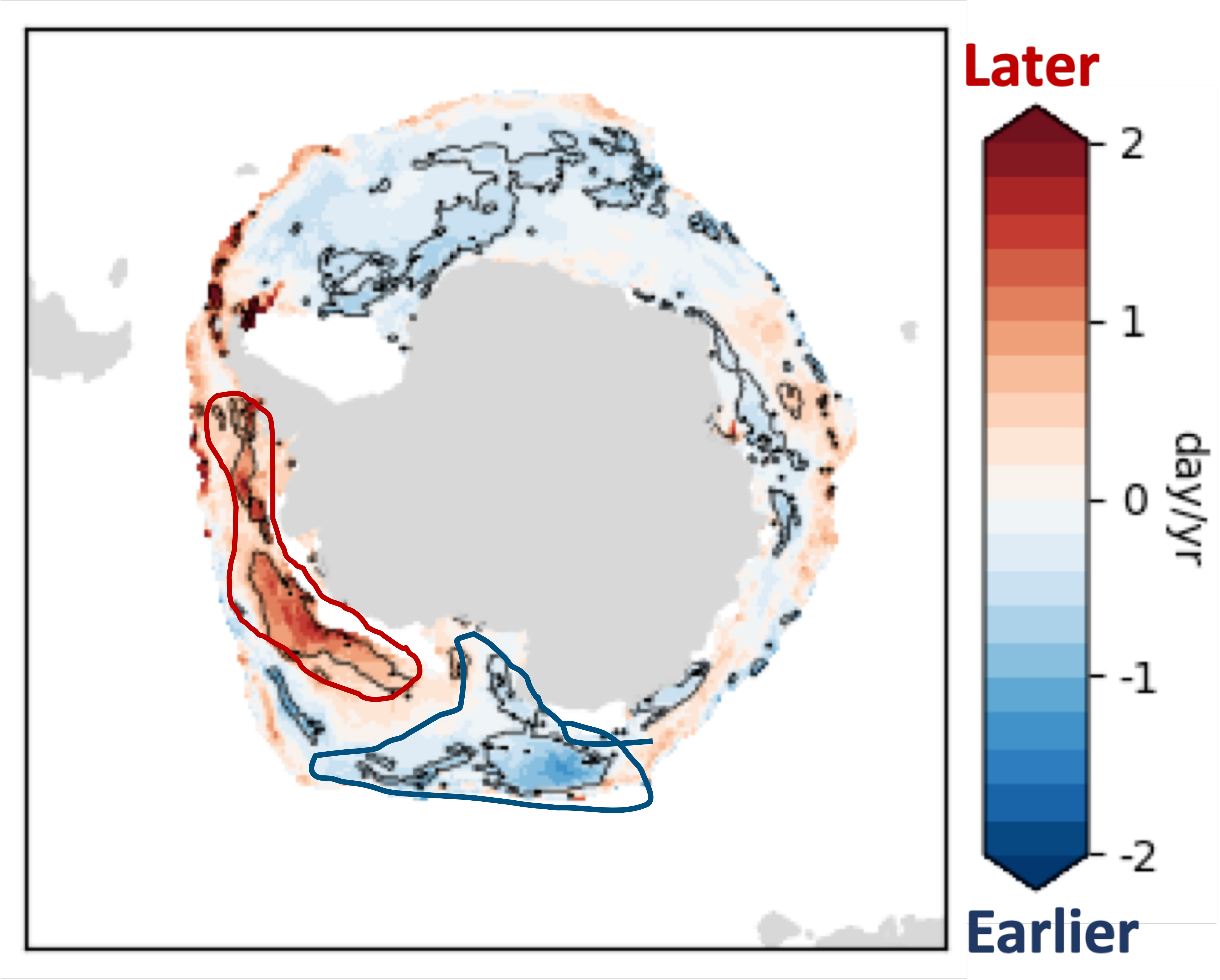
Context & questions

Drivers of observed changes in Antarctic sea-ice advance date : limited understanding

Trends on dates of advance (1982-2018)



Stammerjohn et al., 2012 (updated)

Ocean heat feedbacks

Perovich et al., 2007;
Stammerjohn et al., 2012

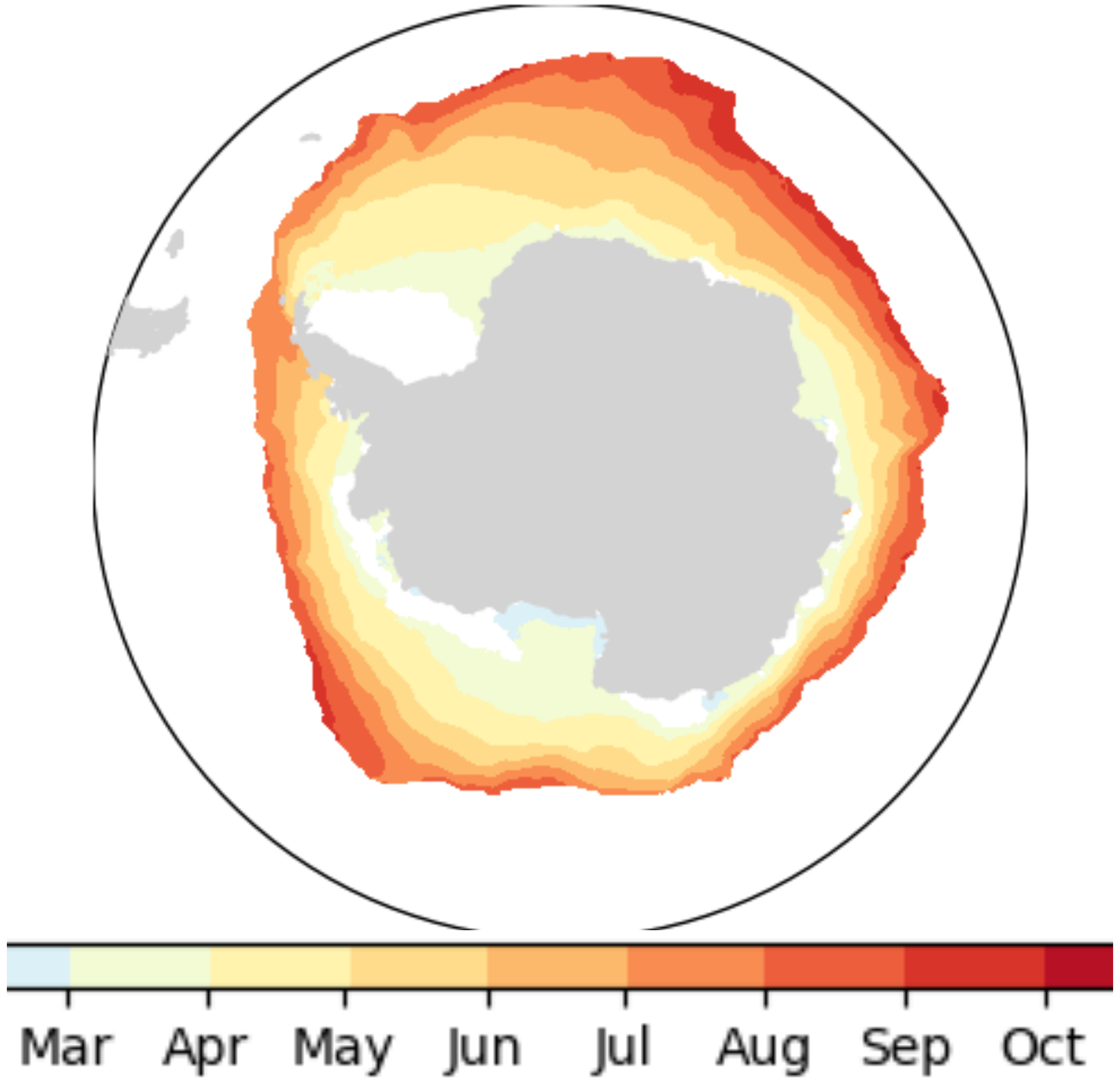
Wind-driven ice transport changes

Holland & Kwok 2012
Stammerjohn et al., 2008; 2012

What drives the observed climatology of Antarctic sea ice advance ?

PMW
1st day ice conc. > 15%
1982 - 2018 climatology

Dates of advance



1. **Which role for upper-ocean thermodynamics ?**

2. **Which role for sea-ice transport ?**

Data & methods

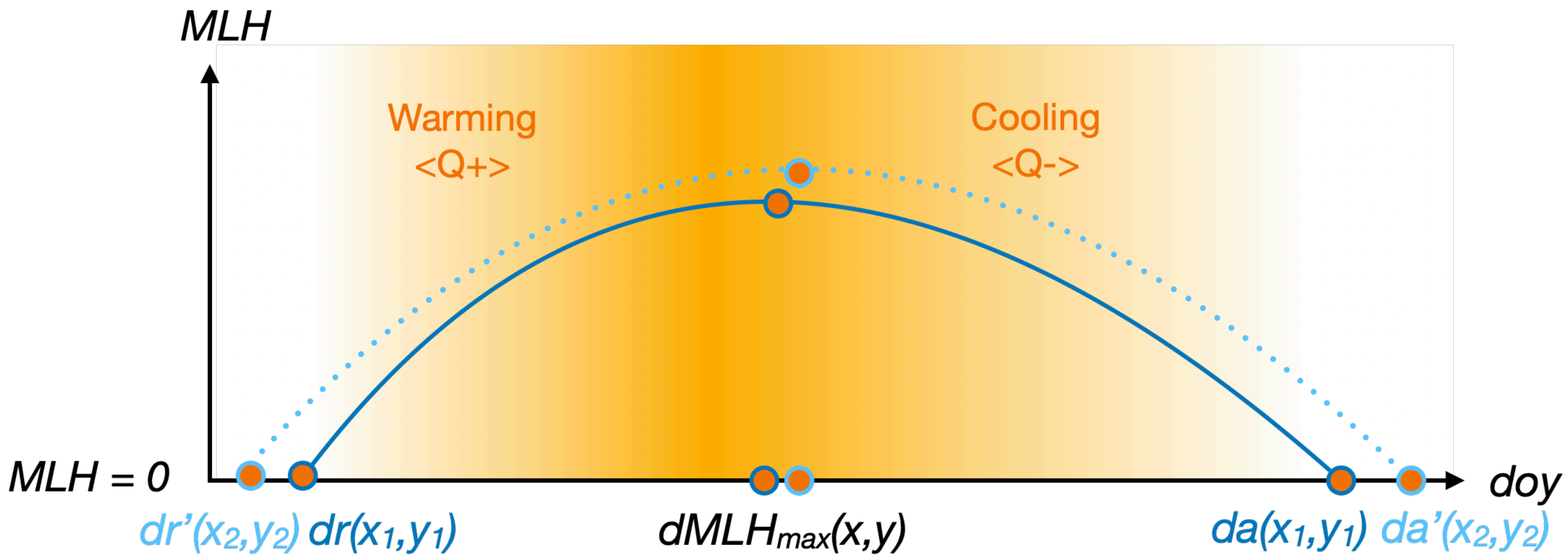
Data sources

- **Passive microwave satellite sea ice concentration (SIC)**
  - **SIC**: daily 1979-2018, 25 km resolution, SMMR/SSMI data, OSI-SAF algorithm
  - **SIC budget decomposition**: daily climatology 2003-2010, 12.5 km resolution, AMSR-E data , NASA team and cross-correlation algorithms (Holland & Kimura 2016)
- **Sea surface temperature (SST)**
  - **ESA CCI SST**: daily climatology 1982-2018, 0.05° (Good et al., 2020)
- **Mixed layer depth (MLD):** monthly climatology 1970-2018, daily interpolation, 0.5° (Sallée et al., 2021)

All data interpolated on OSI-SAF grid : Lambert Azimuthal Equal Area, 25km

Role of upper ocean thermodynamics – Method (1)

Analysis based on conceptual models of upper ocean thermodynamics:



*Mixed Layer Heat content (**MLH**)*

$$MLH = MLD.(SST - T_f)$$

Varying-depth conceptual model

*Constant **total** heat fluxes in the ML, no sea ice dynamics*

Linear relationships

$d_r \rightarrow MLH_{max} \rightarrow d_a$

Constant-depth conceptual model

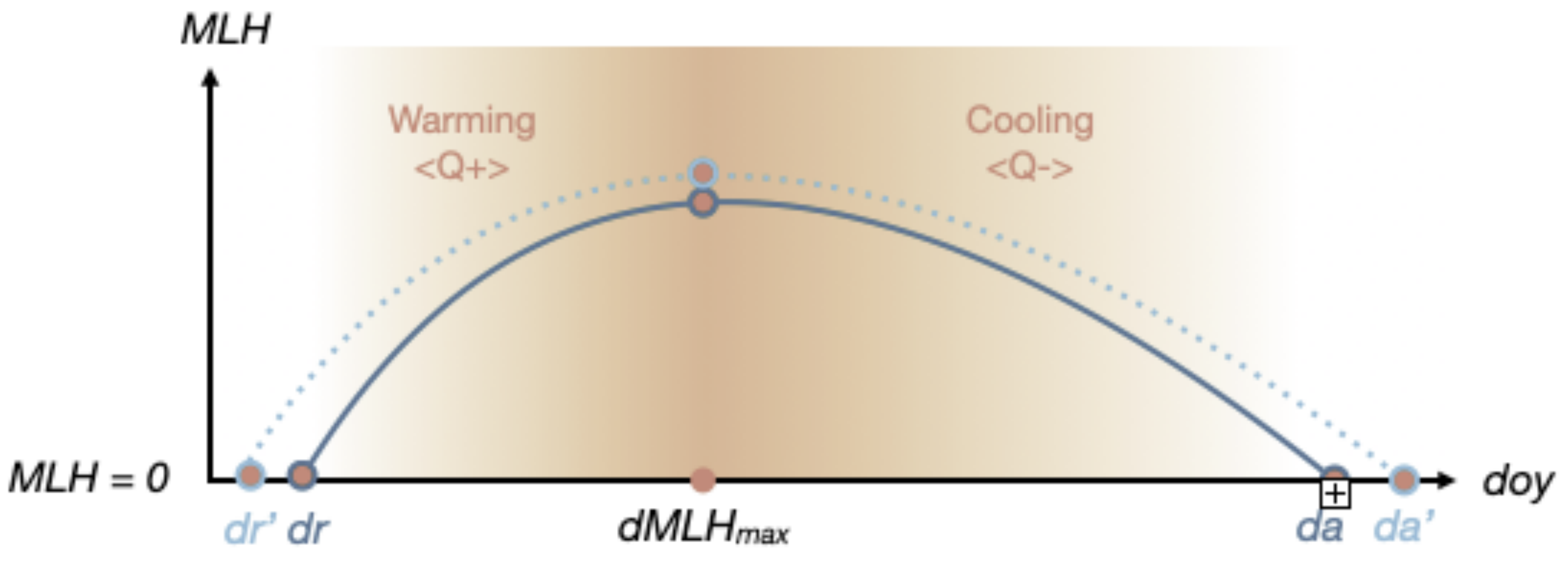
+ constant MLD (Lebrun et al., 2019)

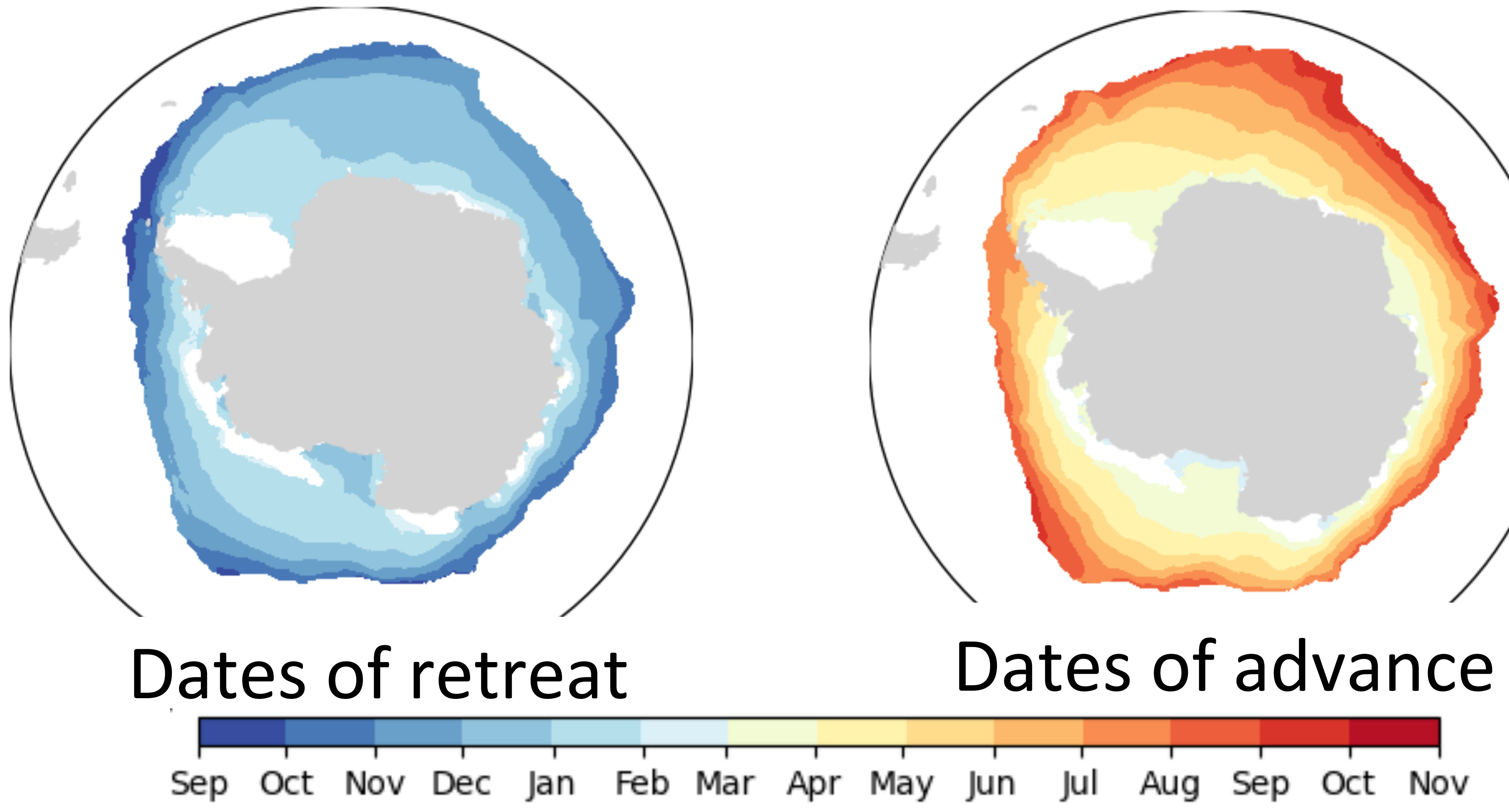
Linear relationships

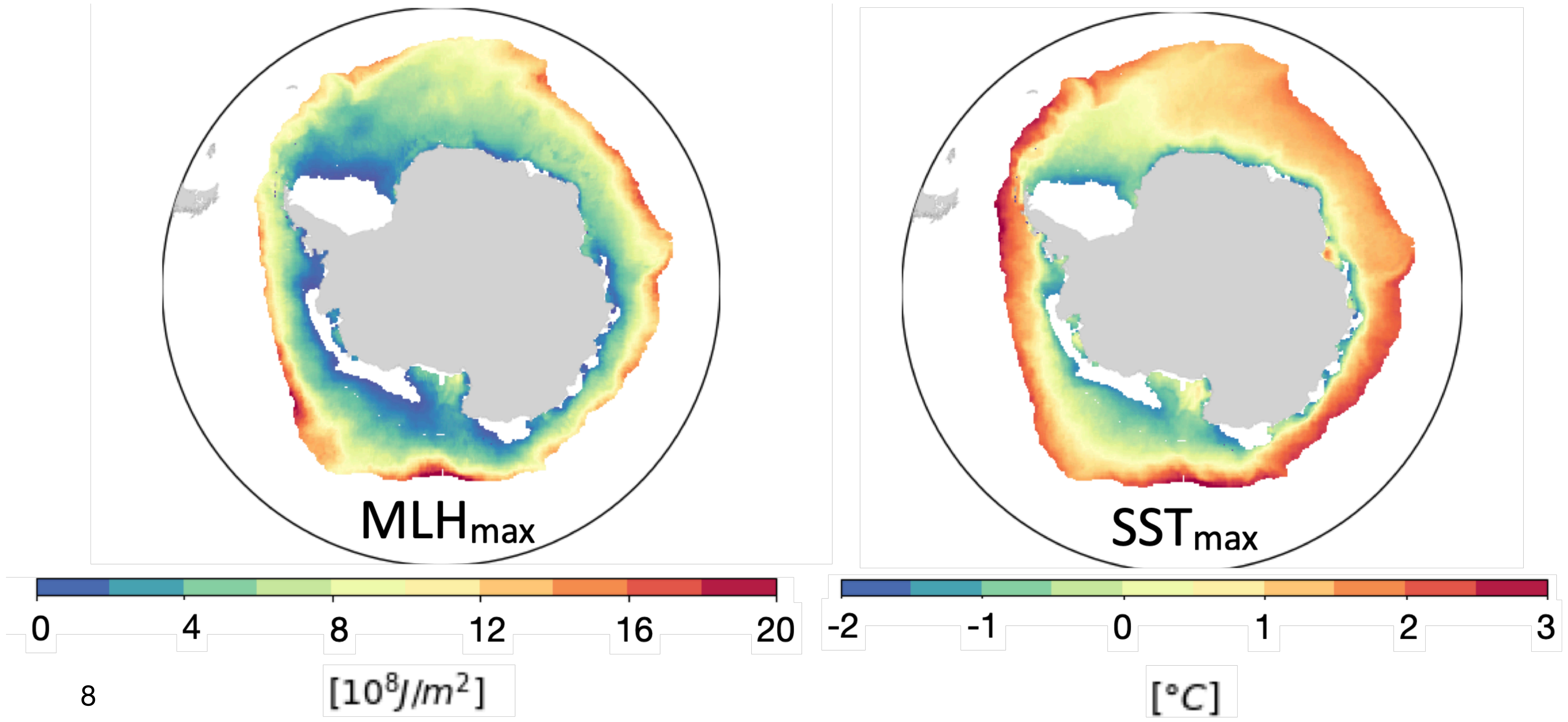
$d_r \rightarrow SST_{max} \rightarrow d_a$

Role of upper ocean thermodynamics – Method (2)

- Can the conceptual models explain the climatology of dates of advance ?
- Spatial relationships between **climatologies ?**







Role of sea ice transport – Method (1)

Sea ice concentration budget decomposition

$$\frac{\partial C}{\partial t} = -\mathbf{u} \cdot \nabla C - C \nabla \cdot \mathbf{u} + \text{residual},$$

Dynamic — Thermodynamic

Holland & Kwok (2012); Holland & Kimura (2016)

Objective : *dynamic & thermo. contributions leading to advance*

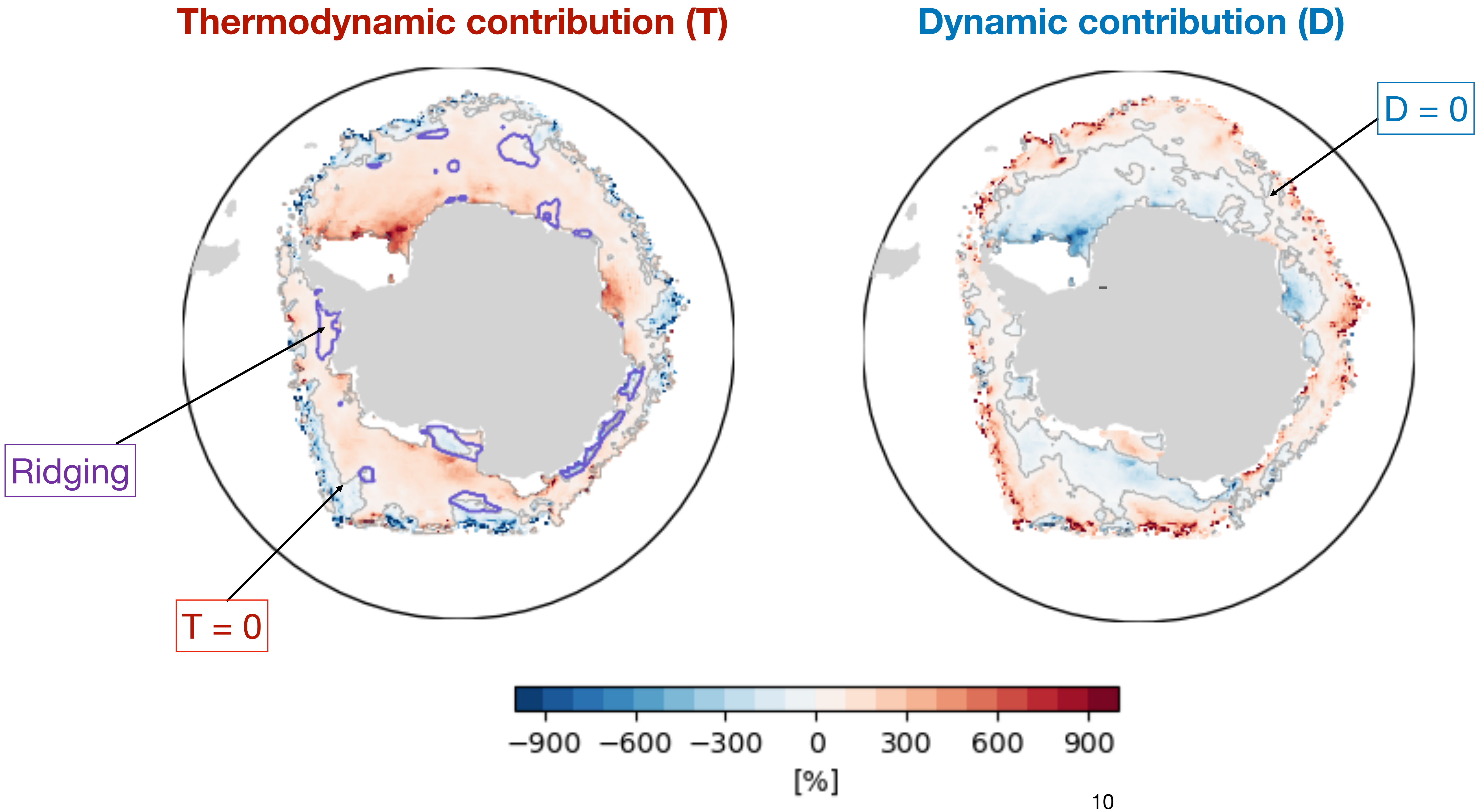
Limitation: *budget not defined below SIC=15%*

1. Integration over growth period: d_a —> Sept. 15
2. Definition of melt/growth zones & import/export zones
3. Consistency of analysis with integration time window

Role of sea ice transport – Method (2)

1. Integration over growth period: d_a —> Sept. 15
2. Definition of melt/growth zones & import/export zones

Omit ridging regions in the melt zone



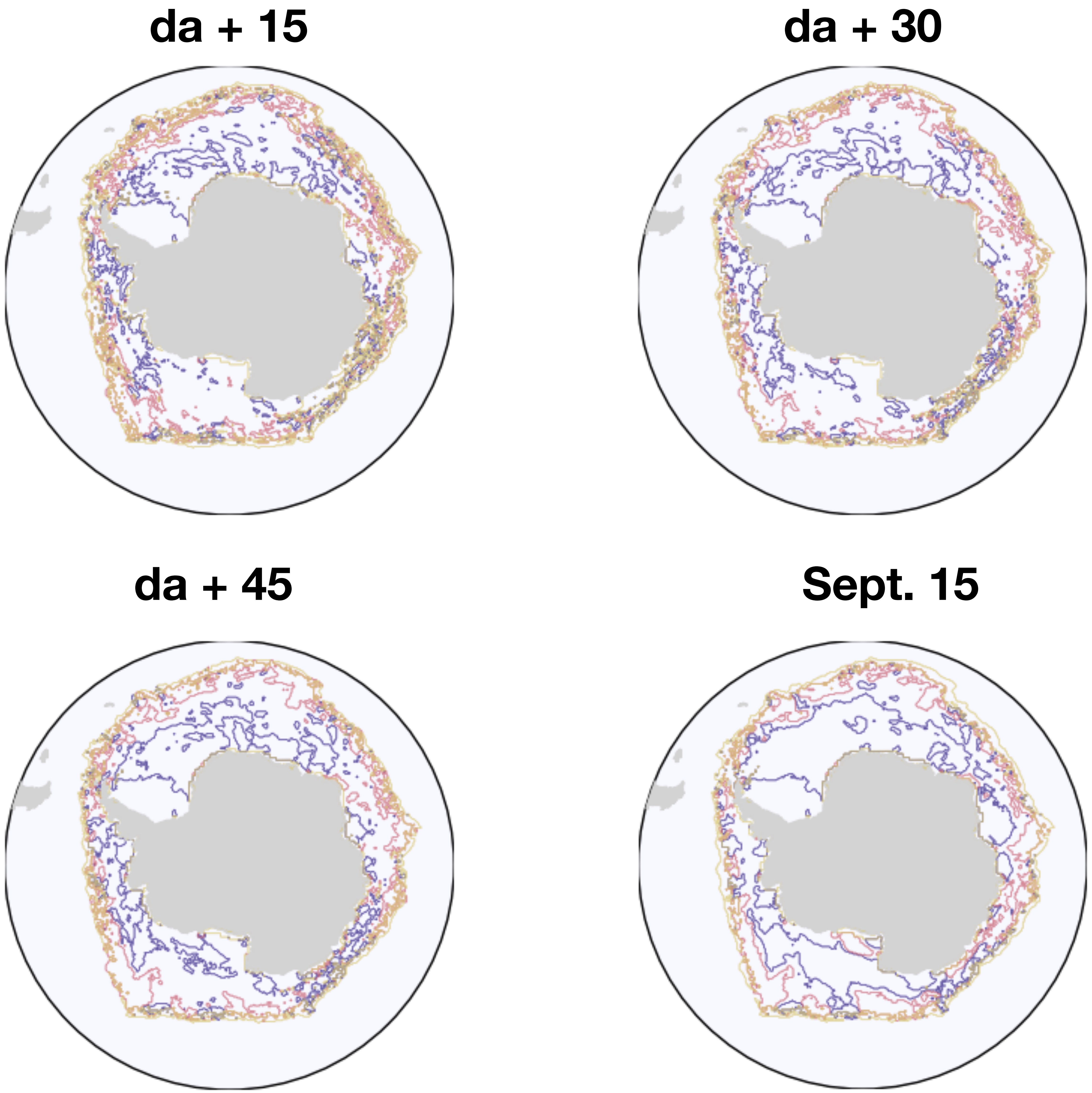
$$dSIC = \int_{d_a}^{15sep} dsic\,dt$$

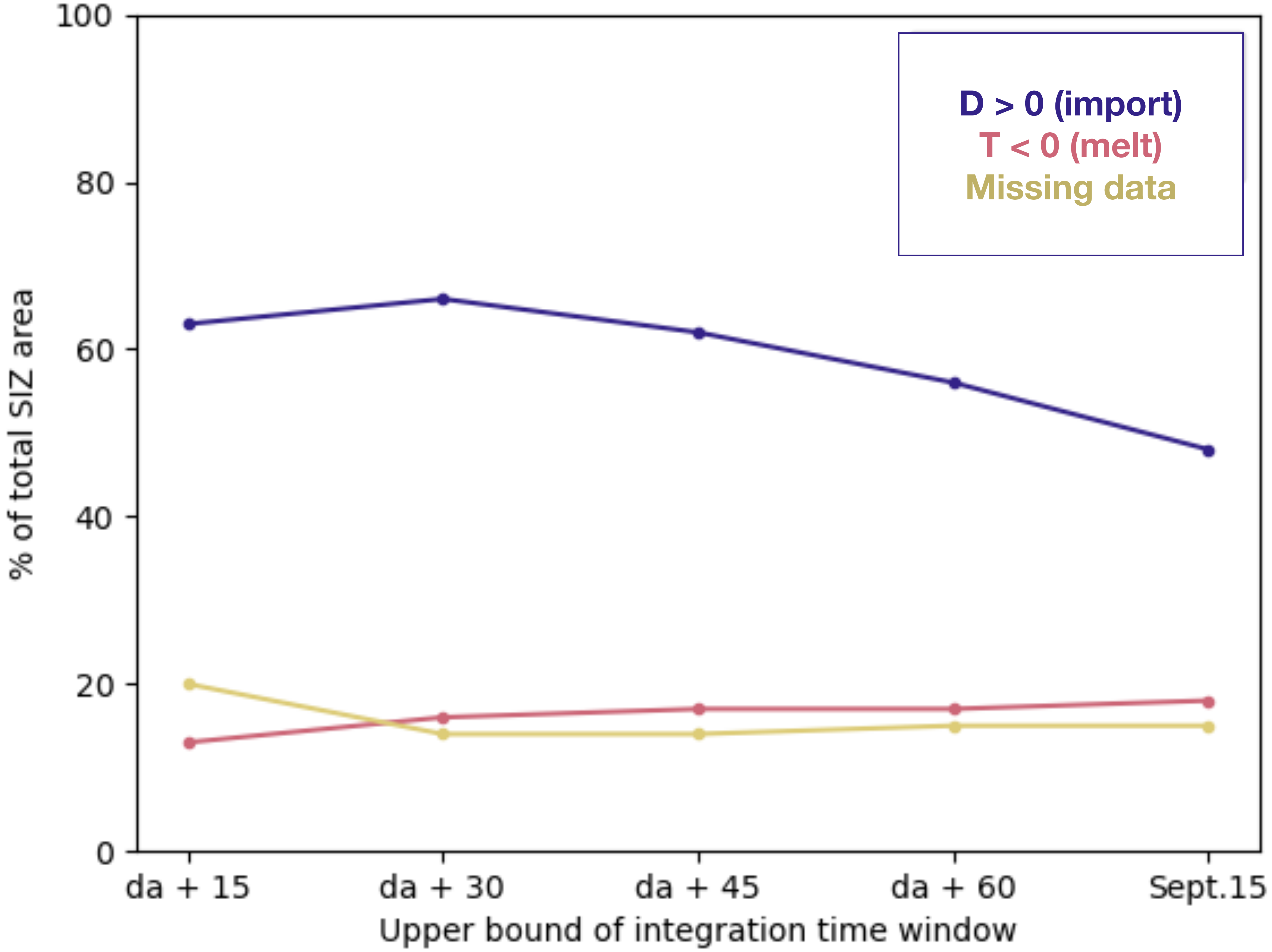
$$T = \frac{1}{dSIC}\int_{d_a}^{15sep} t\,dt$$

$$D = \frac{1}{dSIC}\int_{d_a}^{15sep} d\,dt$$

Role of sea ice transport – Method (3)

3. Consistency of analysis with integration time window



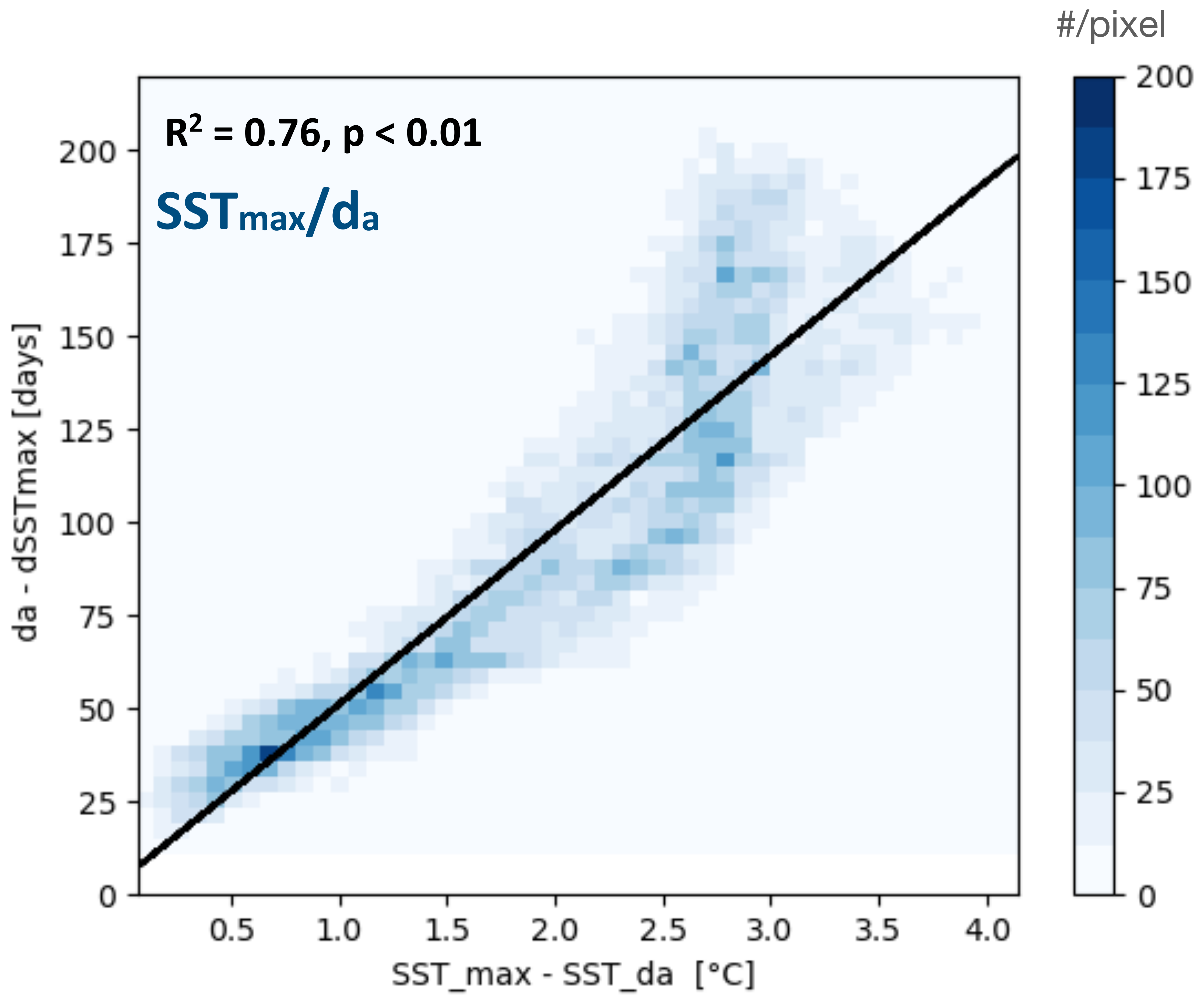


Melt / growth regions should be similar at the time of advance and during the growth period

Results & discussion

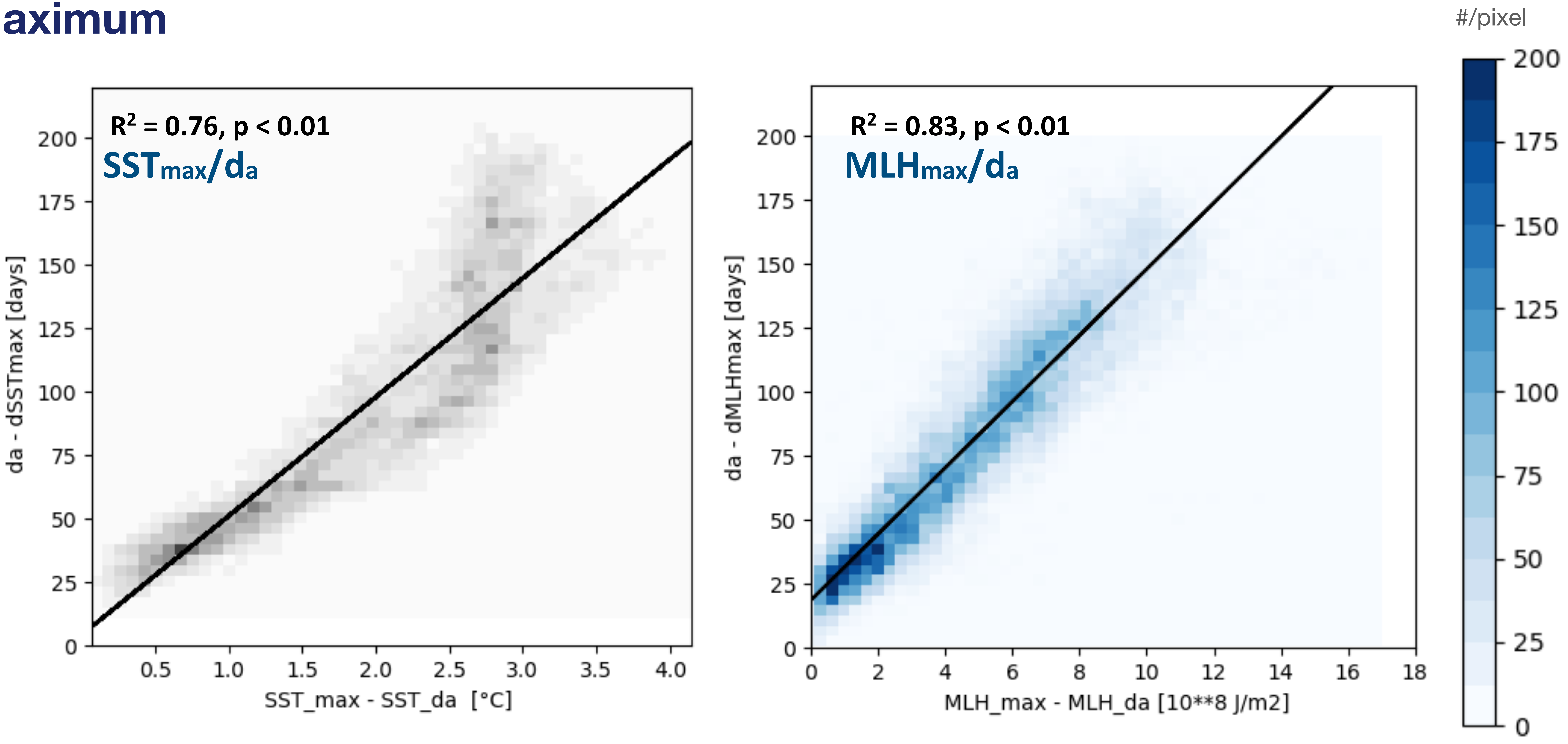
Role of upper ocean thermodynamics

Constant-depth model is too simple to explain the date of advance



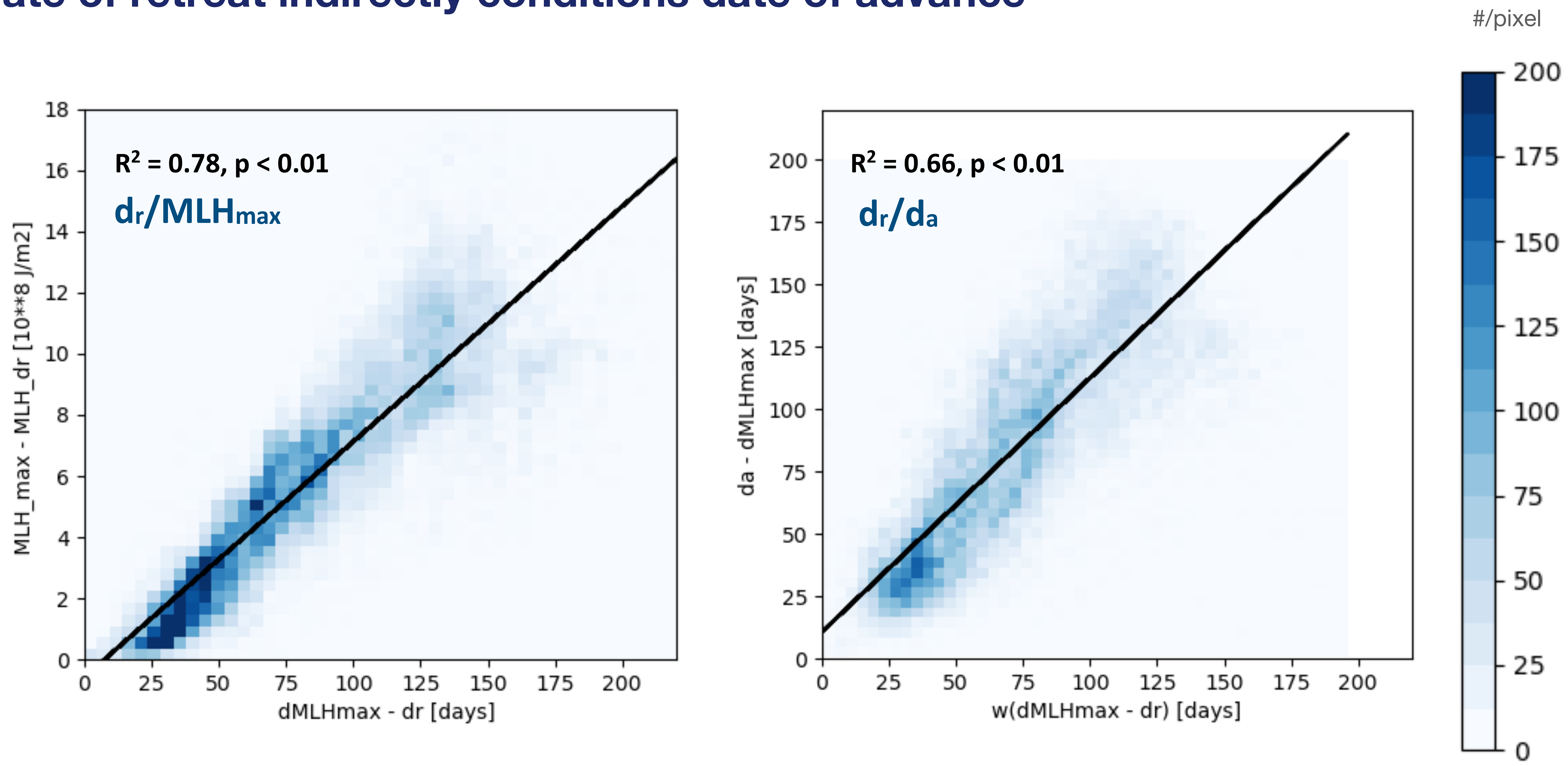
The relationship is not linear

Date of advance more related to ML heat content maximum than to SST maximum



Cooling of full MLD to near-freezing temperature needed before d_a

Date of retreat indirectly conditions date of advance

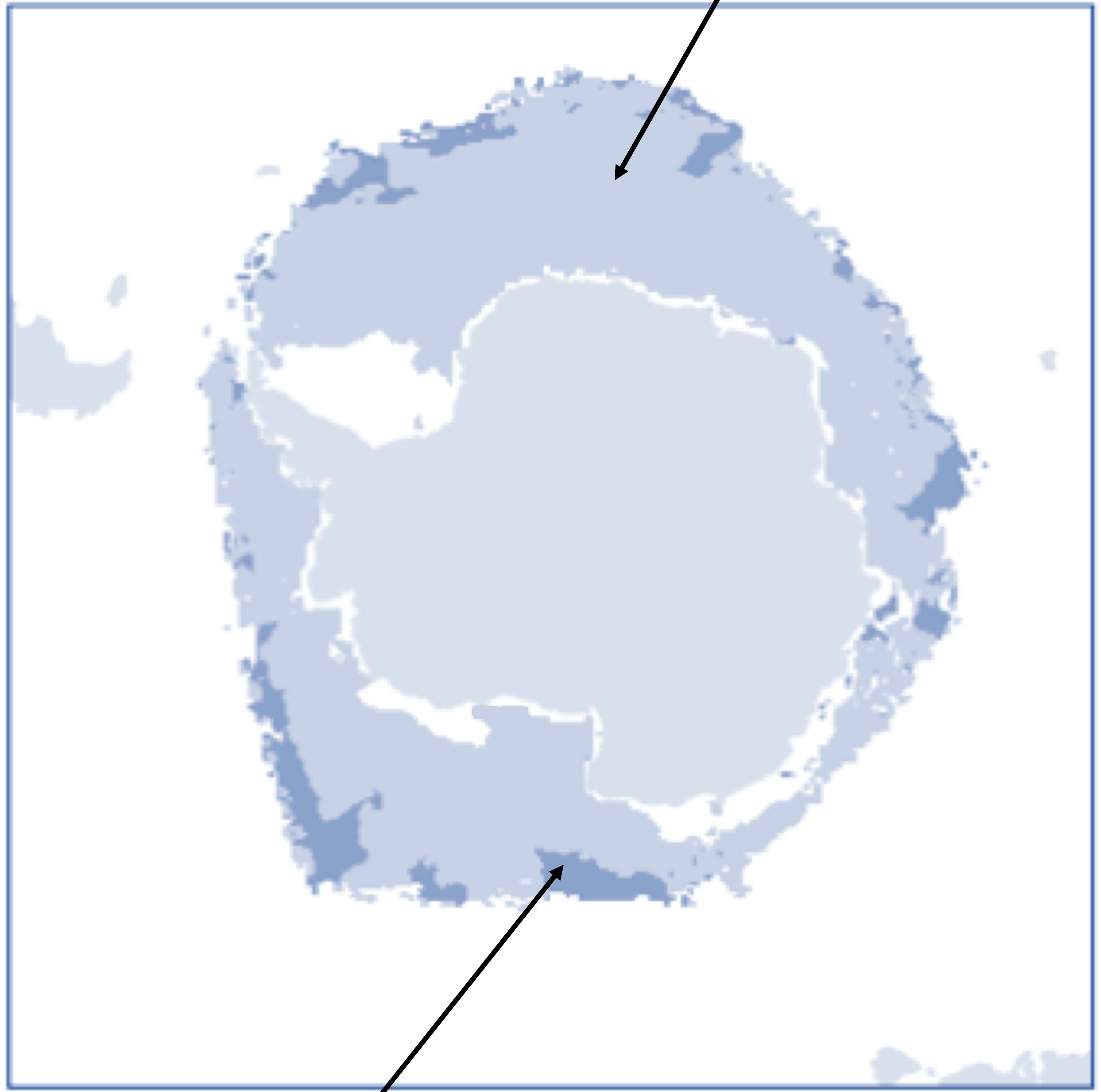


d_r-MLH_{max}-d_a **conceptual model is to a large extent supported by our analysis**

Role of sea ice transport

2 regions with distinct processes from SIC budget decomposition

1- Inner zone: *freezing & transport*

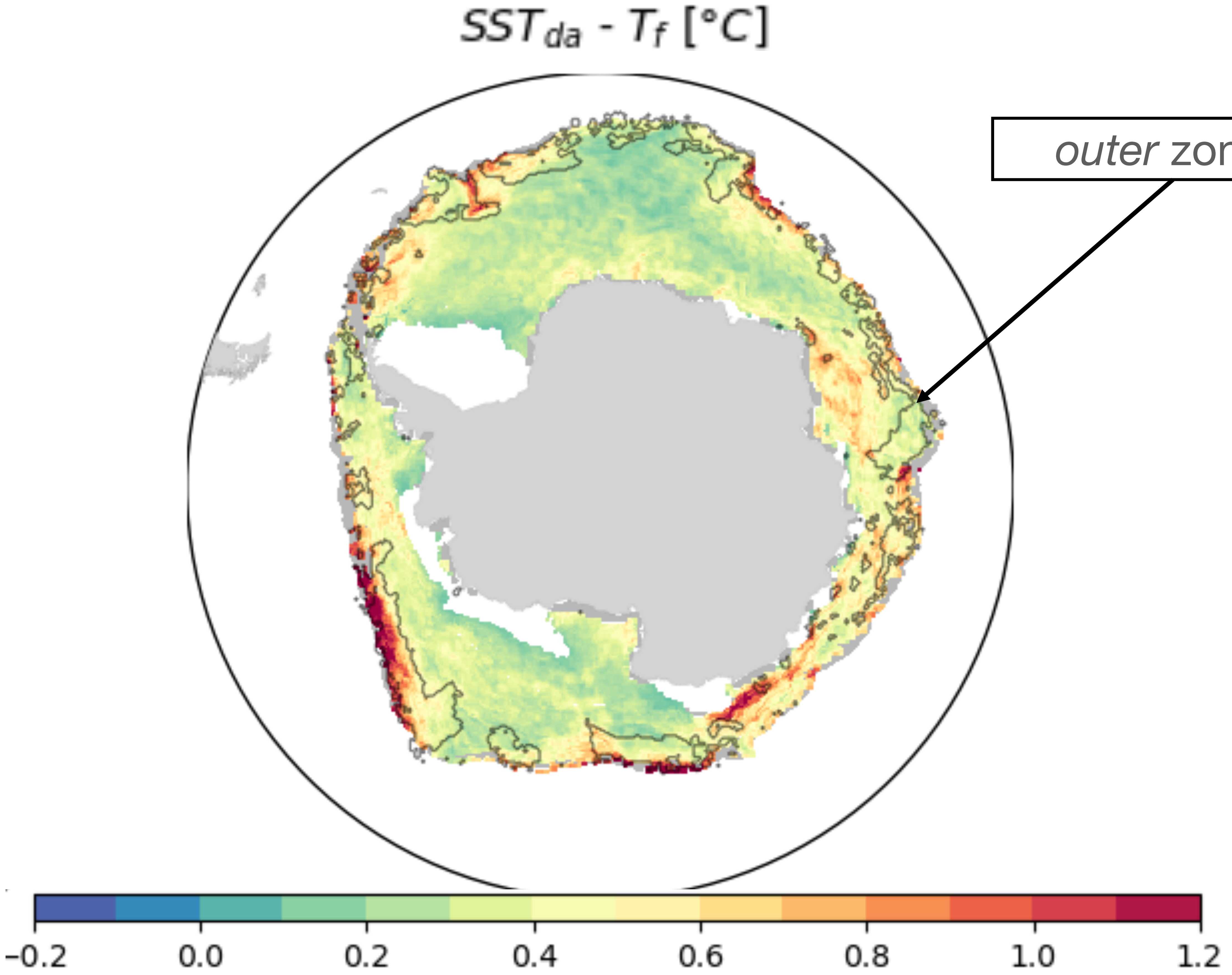


2- Outer zone: *melting & import*

MLH_{max}-d_a relationship significantly (Z-test) weaker in outer zone (R^2 = 0.62) than in inner zone (R^2 = 0.84)

No freezing occurs in the outermost ice-covered region

Highest SST@d_a –T_f correspond to region of ice melt / import



Inner zone: *freezing, driven by MLH_{max}*

Outer zone: *no freezing, ice transport only*

Only ice dynamics can drive sea-ice advance in the *outer zone*

Conclusion

The roles of ocean-sea ice processes in controlling the timing of sea-ice advance were investigated from observational data

Which role for upper ocean thermodynamics?

- Sea ice advance is mostly a thermodynamic process, as it is driven primarily by the upper ocean heat content seasonality.

- The date of advance better relates to the maximum MLH than to the maximum SST : the full mixed layer needs to approach freezing before sea-ice can advance.

- The date of retreat indirectly conditions the date of advance by constraining the radiative heat input into the mixed layer and maximum MLH.

Which role for sea-ice transport ?

- Sea-ice drift play a key role in setting the timing of advance. Around the date of advance, sea ice is redistributed all over the seasonal ice zone.

- Equatorward ice transport is the only source of sea ice in the outer 15% of the Antarctic SIZ, where the SST is the highest above the freezing point.

These findings on the spatial variability of the dates of advance climatology could have important implications on the interannual and long-term changes.