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TAKING THE PULSE OF OUR PLANET FROM SPACE

Winter and summer Arctic observational sea-ice volume budget from CryoSat2 and Polar Pathfinder data 2011-2020

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What is a sea ice volume budget?

Using observational datasets to estimate dynamic and thermodynamic changes in sea ice volume

Intensification
From concentration and thickness data.
Local rate in change in sea ice volume.

Divergence
From concentration, thickness and ice drift data.
Volume • local gradient in velocity

$$\frac{dV}{dt} = -\mathbf{u} \cdot \nabla V - V \nabla \cdot \mathbf{u} + \text{residual}$$

V: Sea ice volume

$\mathbf{u}$: Sea ice drift velocity

Advection
From concentration, thickness and ice drift data
Velocity • local gradient in volume

Residual
The part left unaccounted for.
This is from thermodynamics

We use this technique for daily CMIP6 model data, capturing the source and location of sea ice growth and melt.

Data

We use year round observation based data for Arctic sea ice

Sea ice drift vectors

- NSIDC Pathfinder daily drift product - buoy tracking, ice floe tracking

Sea ice concentration

- NSIDC NASA team daily ice concentration

Sea ice thickness from CryoSat2

- Using the new summer sea ice freeboard measurements by Dawson et al (2021)
- Interpolated to daily year round measurements of sea ice thickness from 2010-10 to 2019-09

A 10-year record of Arctic summer sea ice freeboard from CryoSat-2

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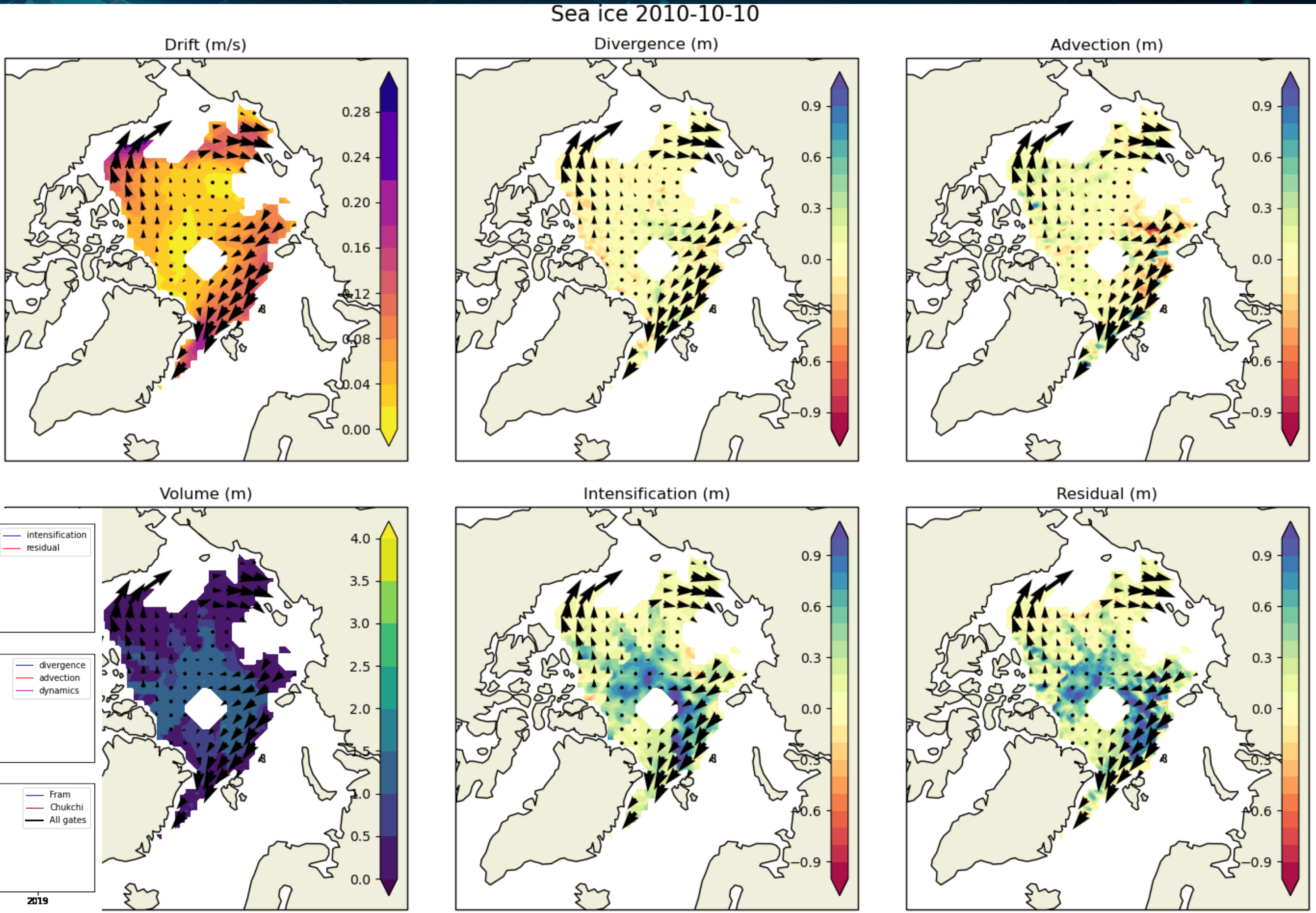
ABSTRACT

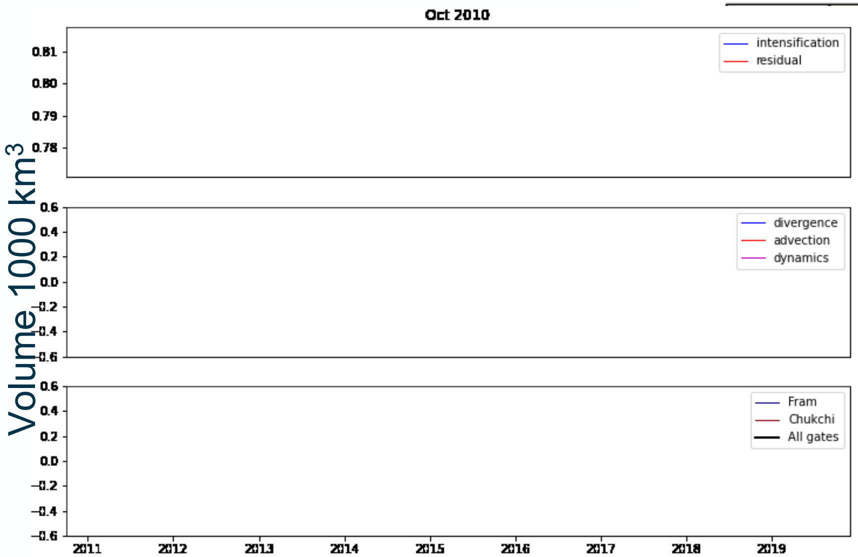
Satellite observations of pan-Arctic sea ice thickness have so far been constrained to winter months. For radar altimeters, conventional methods cannot differentiate leads from meltwater ponds that accumulate at the ice surface in summer months, which is a critical step in the ice thickness calculation. Here, we use over 350 optical and synthetic aperture radar (SAR) images from the summer months to train a 1D convolution neural network for separating CryoSat-2 radar altimeter returns from sea ice floes and leads with an accuracy >80%. This enables us

The Arctic sea ice mass budget is dominated by a long growth season followed by a short melt season

Ice divergence and advection are greatest near the Fram Strait (thicker fast drifting sea ice)

Growth (and melt) rates show annual regional variations



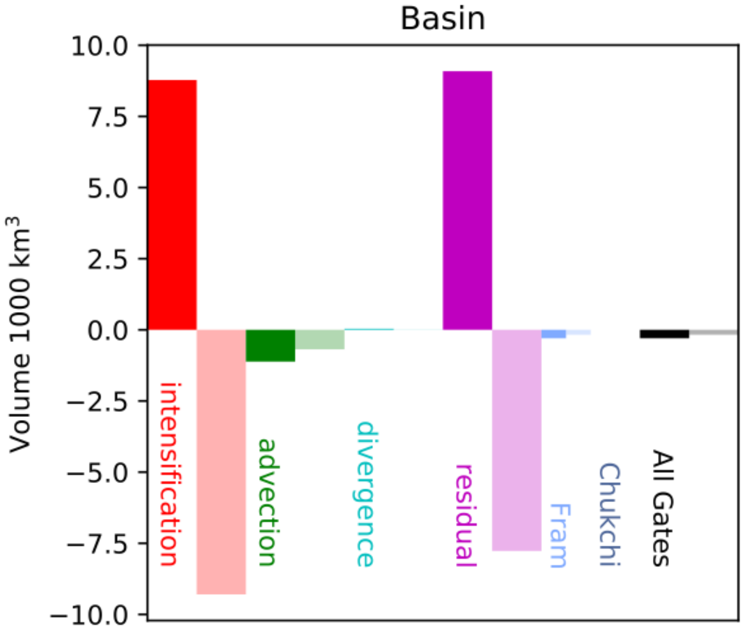


The Arctic seasonal sea ice volume balance

Considering the whole Arctic basin (excluding the Greenland Sea)

The majority of sea ice volume is accounted for from thermodynamics

Ice is lost in divergence and through the Fram Strait, although variability (and uncertainty) is high



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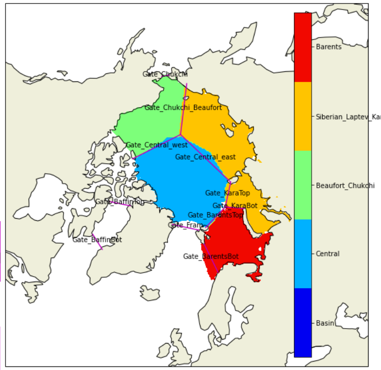
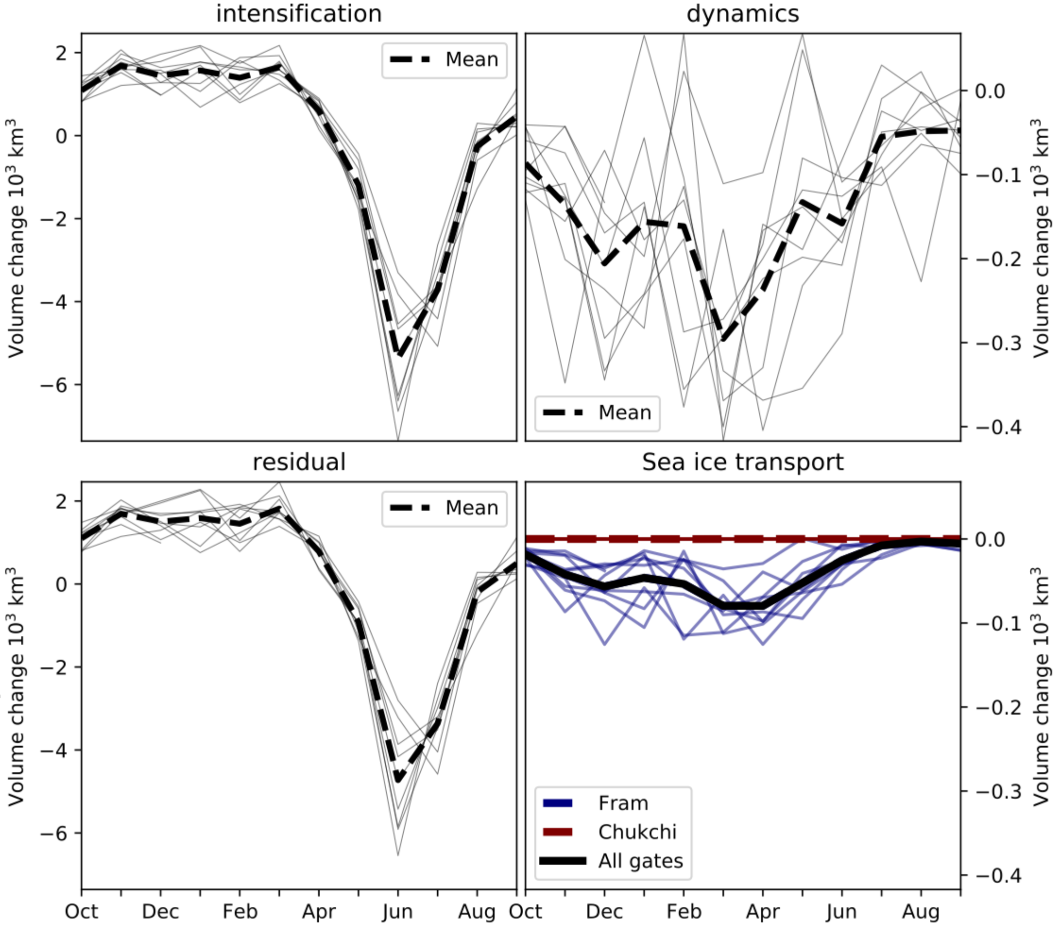
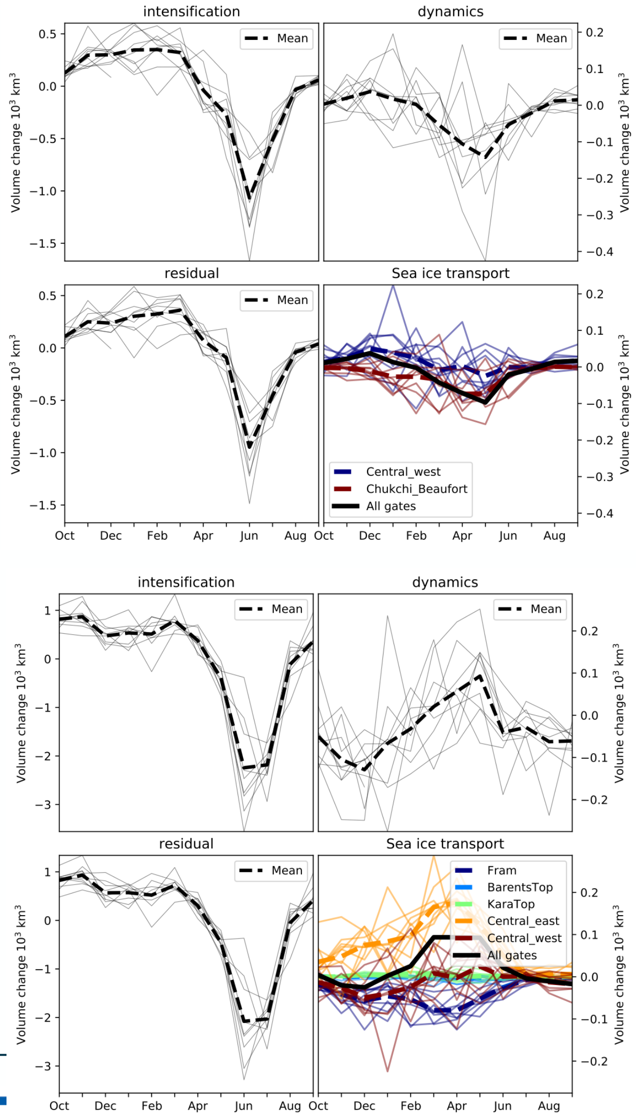


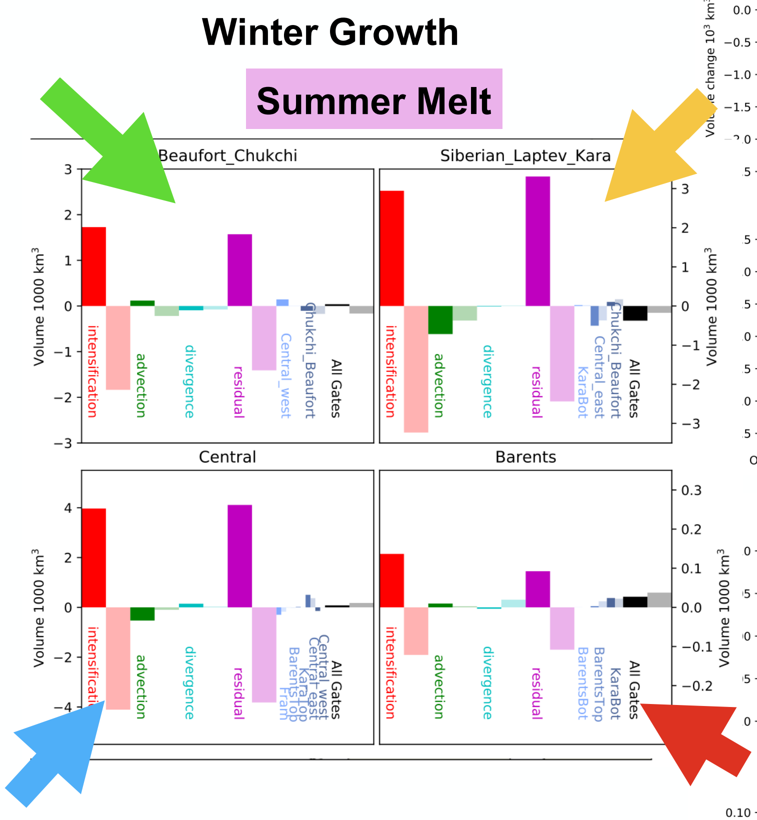
Summer

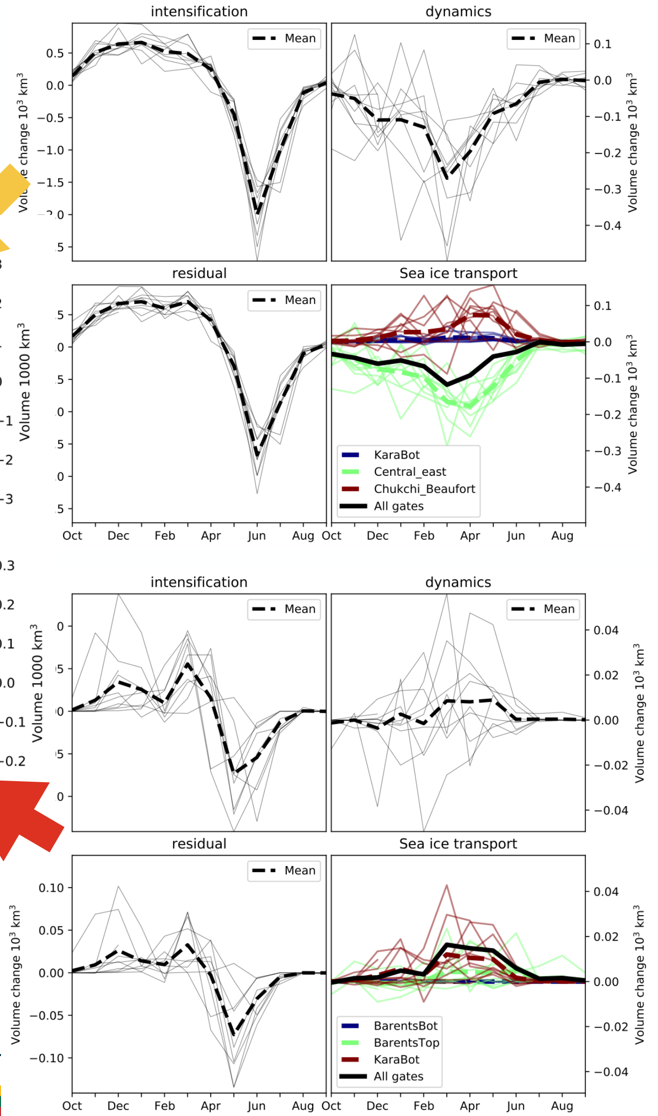


Regional seasonal cycles

- Sub dividing the whole basin into key regions
- Whilst over the whole Basin, dynamical terms typically cancel each other out, regional dynamical differences have an important role
- The uncertainty in regional dynamical terms is lower than for the whole basin
- Total ice transport typically agrees with dynamical changes to ice volume







Total seasonal change in mass

- Over the entire basin there is a net over growth of sea ice
- Large uncertainties - misrepresentation of thin ice

- The central region has an emergent inter-annual cycle of net change in mass
- Dynamic changes are highly variable

- Beaufort and Chuckchi seas are highly variable
- Some years have a balance in growth/melt, some years can be a source or sink in sea ice

- The near asian seas over-produce sea ice
- The ice is transported north to the central region

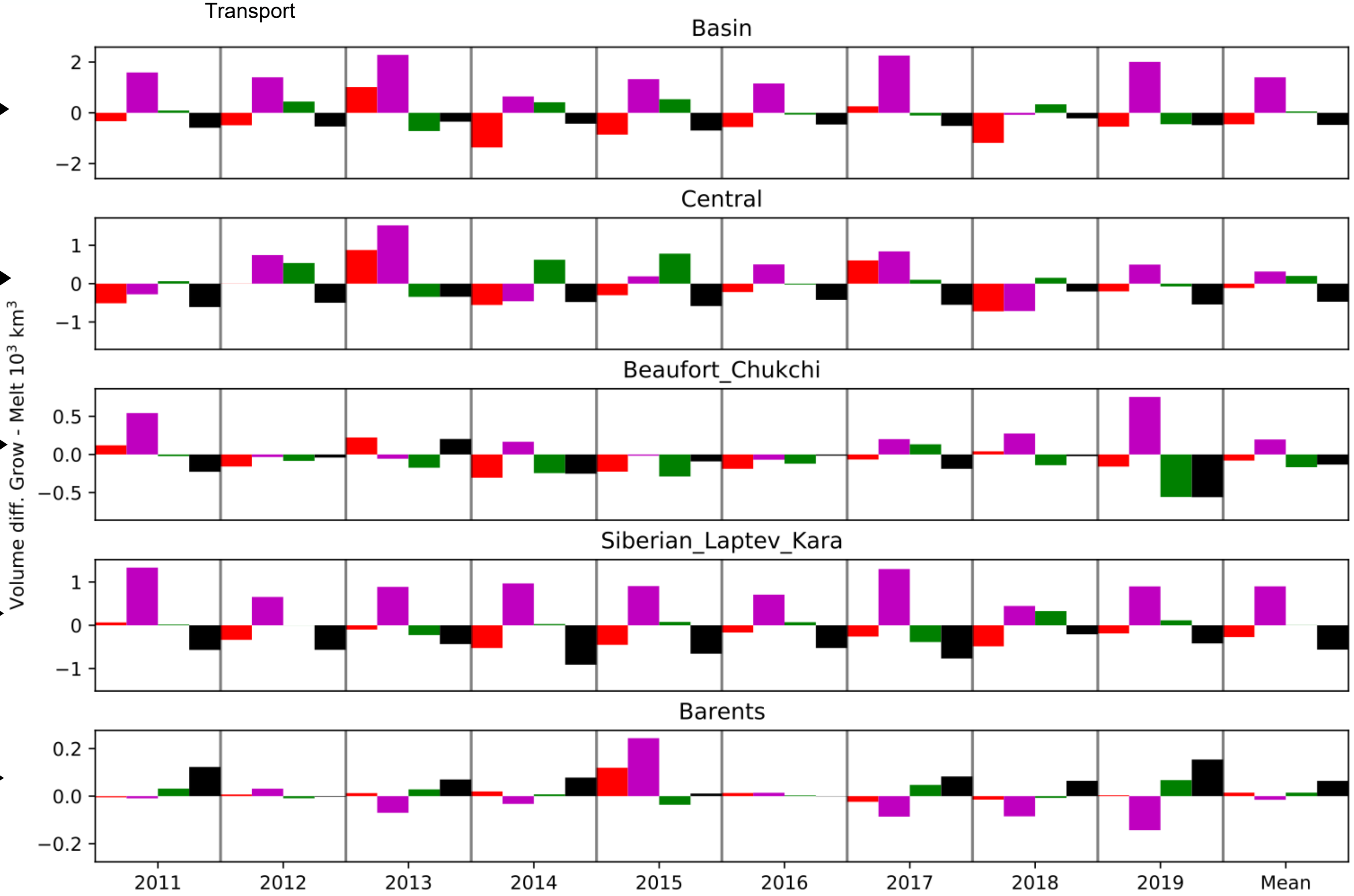
- Barents Sea is highly variable and dependent on drift patterns and sea ice extent
- 2017 - 2019 saw similar patters of drift and melt

Intensification (total change in mass)

Residual (estimated thermodynamics) +ve (more ice grows than melts)

Divergence (ridging or lead opening)

Transport



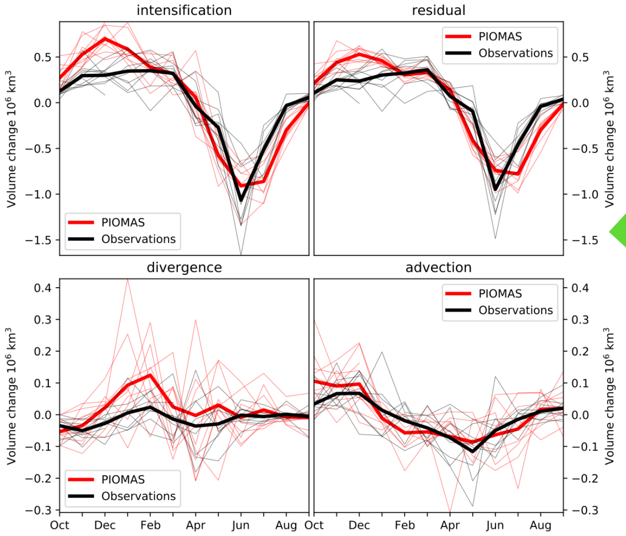
Applications - detailed model comparisons

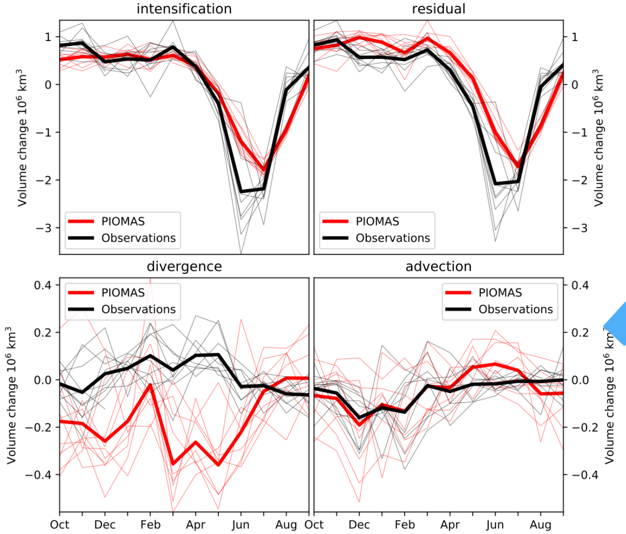
esa

We can also use this seasonal sea ice volume budget for detailed model comparisons

The timing of PIOMAS melt is later within the central region and extended with the Beaufort Sea

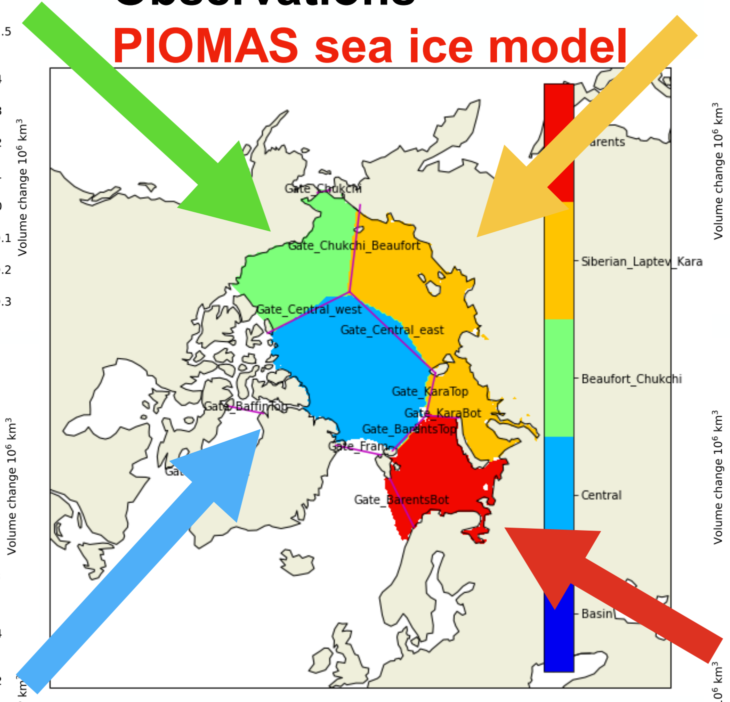
PIOMAS ice drift is faster and more divergent, with increased dynamical loss of sea ice volume in the central Arctic, and increased circulation through to the SLK seas

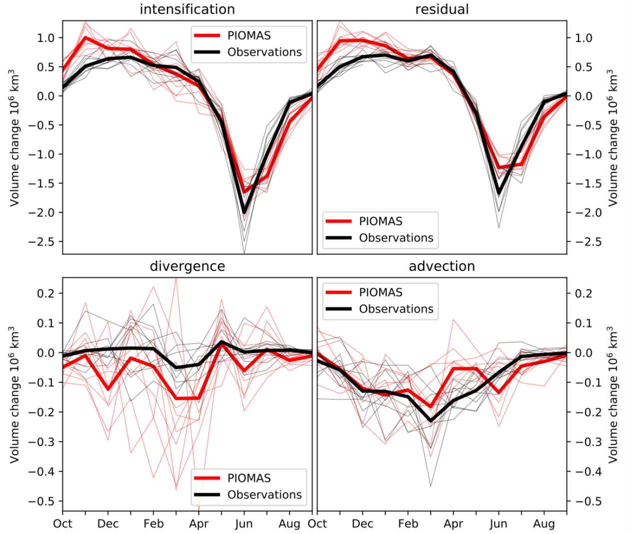


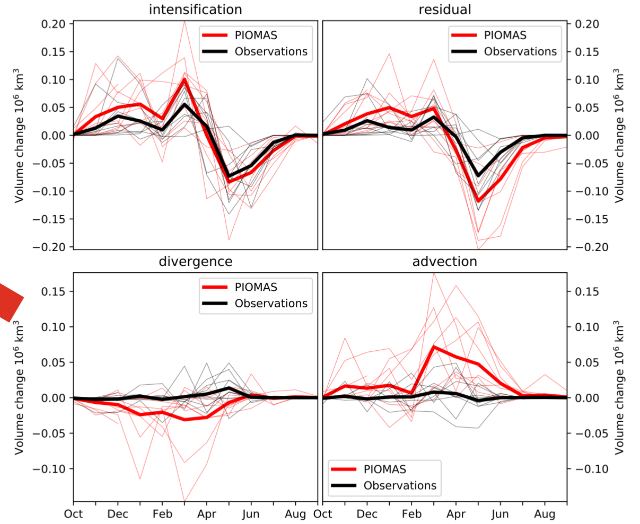


Observations

PIOMAS sea ice model







Summary

A novel Arctic summer sea ice product has been used along side sea ice drift and concentration products

We have produced purely observational based estimates of sea ice growth, melt and dynamic redistribution

Key regionally specific features of sea ice mass budget emerge

Future work

Quantify uncertainty:

- Base observational uncertainty ~10% of ice thickness measurement
- Unrepresented ice edges and thin ice
- Observed and model ice divergence rates