What drives the arctic seaice, an adjoint sensitivity study

Presented by
Arash Bigdeli

INSTITUTE FOR COMPUTATIONAL ENGINEERING & SCIENCES

Why Seaice adjoint:

- Sensitivities and physics:

What are the main drivers of seaice growth ?

Get insight into expanding MIZ.

- Optimization: Both seaice area & volume. There are different in respect to information

Ice Volume —ICESat-2 / CryoSat→ **Reduced Uncertainty & improved state**

The sea ice adjoint code:

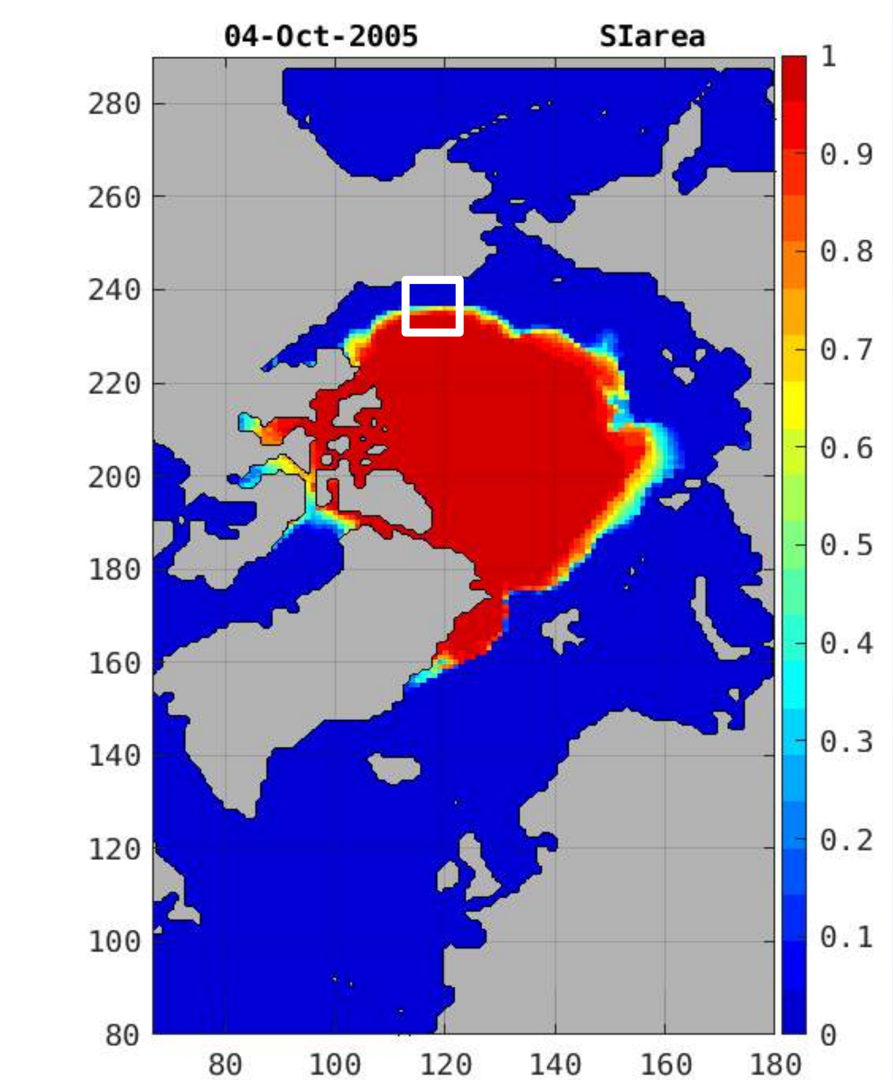
- We made Fenty's seaice growth (thermodynamic) code compatible with ECCO and ASTE /MITgcm c65q
- **Real fresh water flux + Nonlinear free surface** conventions are implemented in the code
- Closed salt, mass and heat budgets while keeping the code adjointable by introducing similar terms to MITgcm main branch seaice growth.

In the remaining slides :

- Grid : ASTE based on LLC90 ~36km
- Forward mode has sea-ice dynamics, Adjoint code does not i.e. there is no $\partial(U_{ice})$

Introduction of Cost (J)

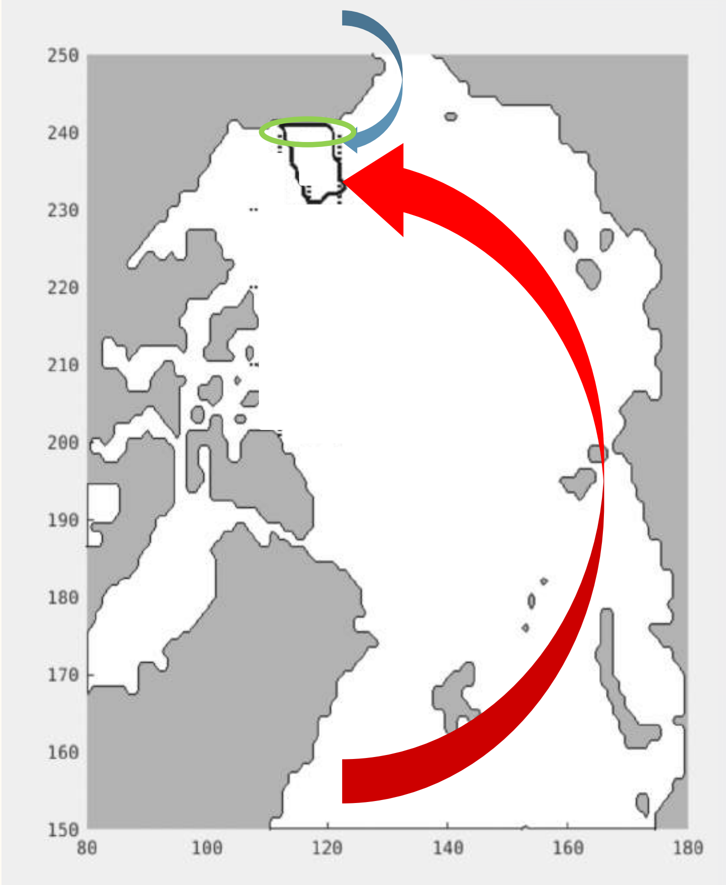
- J is defined as ”volume of sea ice between 70-75° N and 145-155° W average over Dec-2006.
- Canada Basin MIZ. The box goes through ice free to fully covered.



INSTITUTE FOR COMPUTATIONAL ENGINEERING & SCIENCES

Hydrography of the Box

- Pacific water path is toward our box
- Atlantic water clips northern part of the box
- Upwelling near Shelf , southern part of box



Setting up the sensitivities

Sensitivity = ∂(J) / ∂(variables)
The dimensions depend on variables.

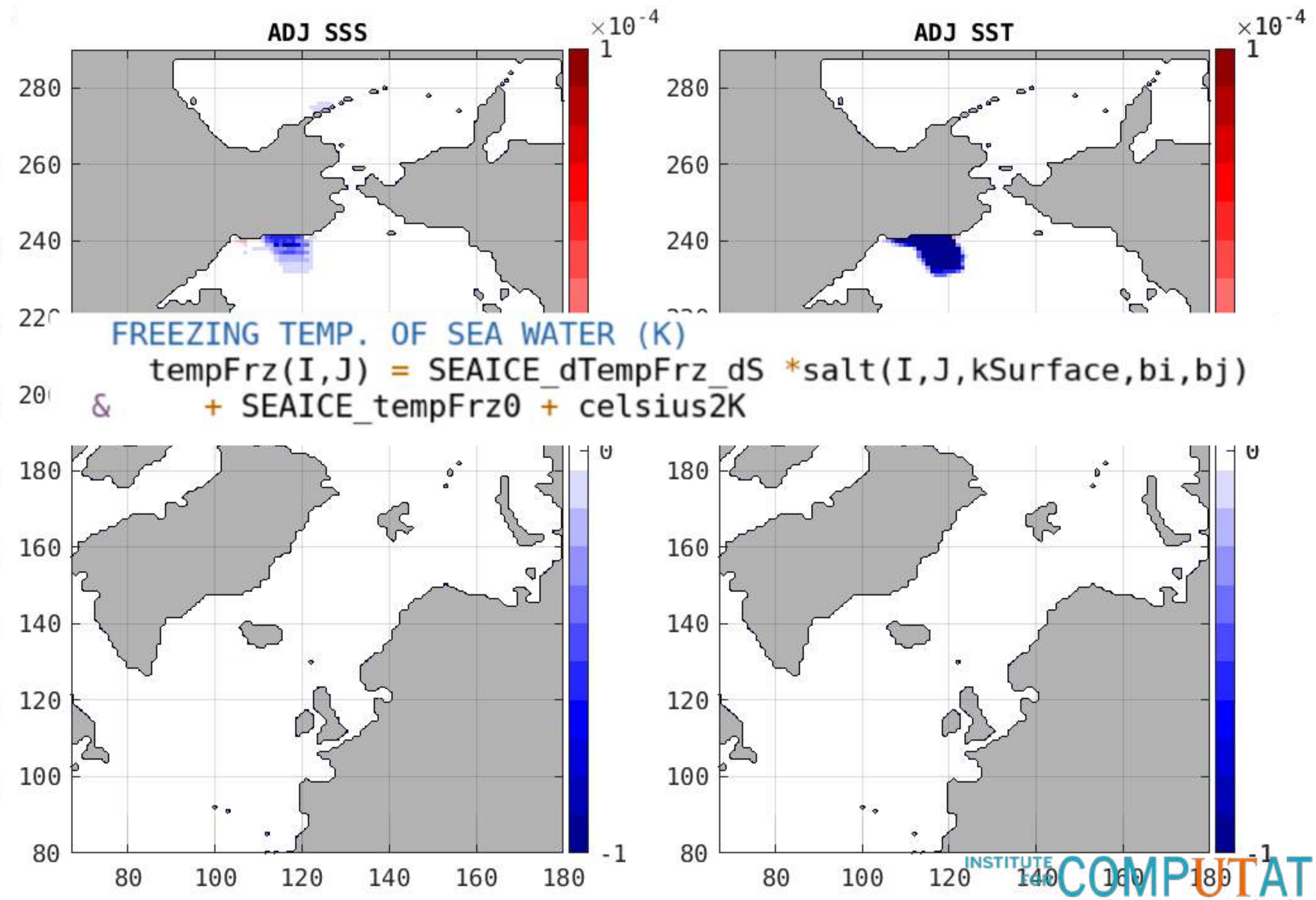
We will plot : ∂(J) / ∂(variables) * **δ** (variable)

δ(variable) is calculated from forward run.

Sensitives to ocean surface (SST SSS)

Lag 1 mo

Dec 2006

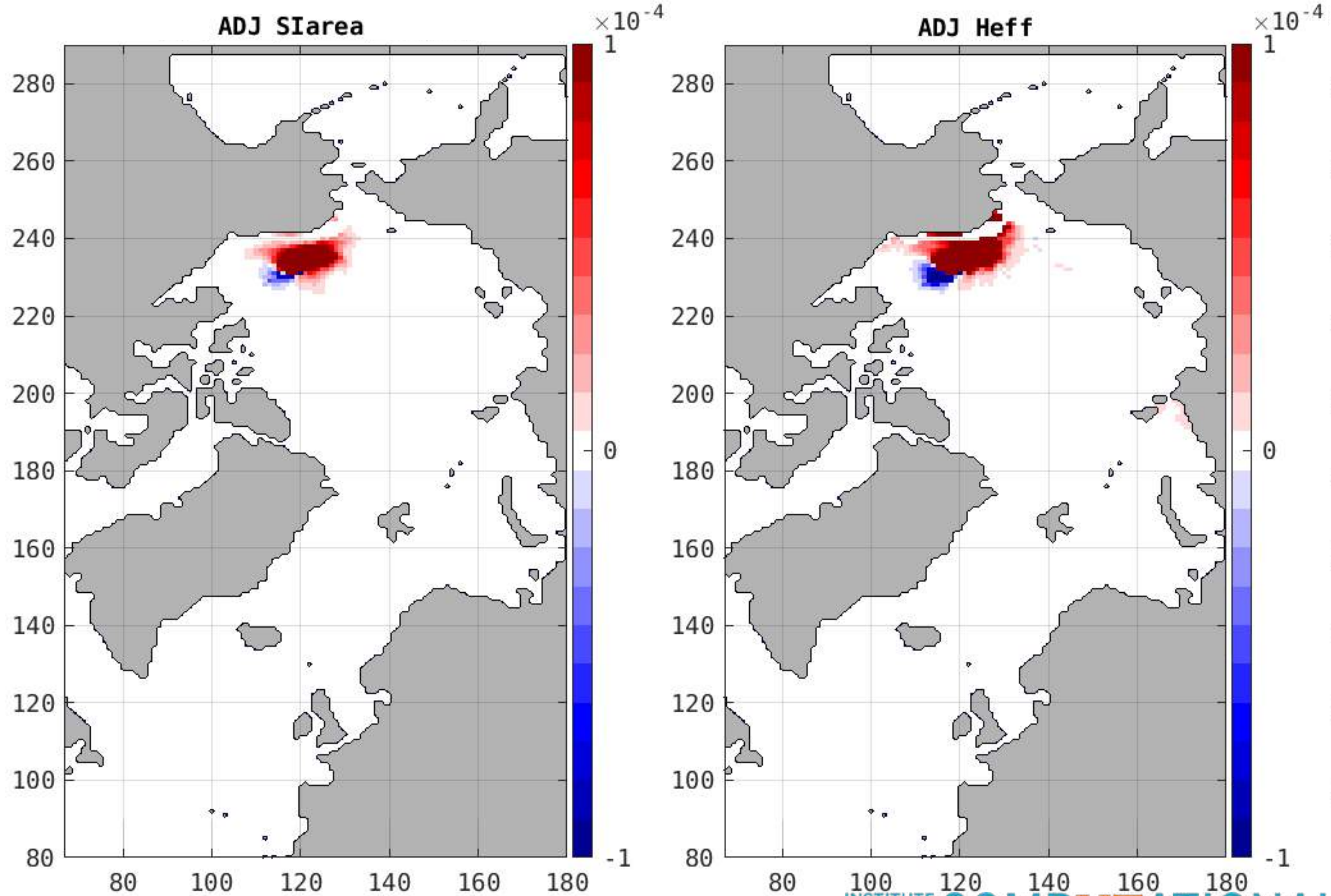



```
FREEZING TEMP. OF SEA WATER (K)
    tempFrz(I,J) = SEAICE_dTempFrz_dS *salt(I,J,kSurface,bi,bj)
&        + SEAICE_tempFrz0 + celsius2K
```

Sensitives to Area(ice cover), Heff (Ice Volume)

Lag 6 mo

Jul 2006



Reconstruction of J

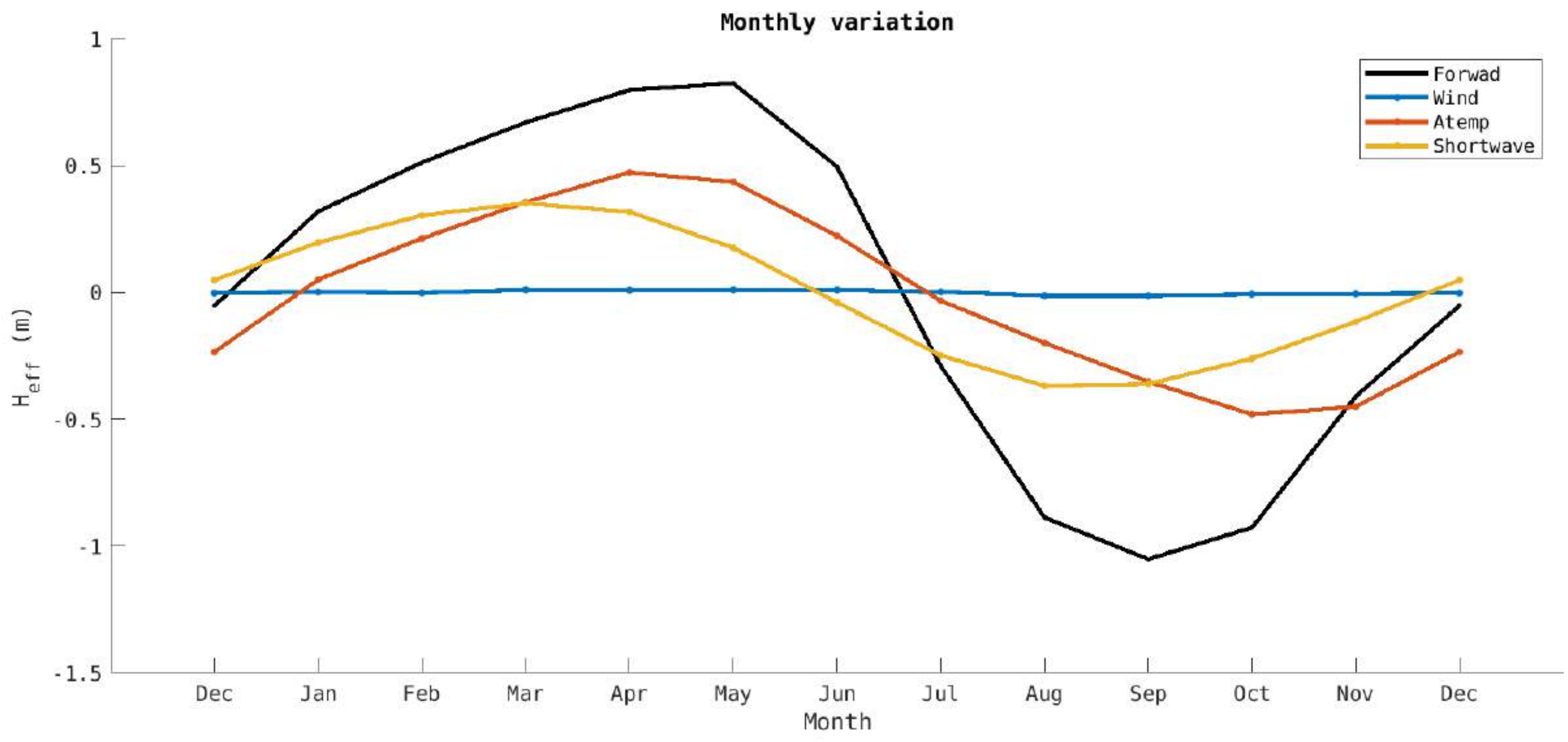
- We can reconstruct a time series of J by:

$$J_{reconstruct} = \sum_k \int_{x_1} \int_{x_2} \int_{t-t_f}^{t} \frac{\partial J}{\partial \Omega_k} (x_1, x_2, \alpha - t)\, \delta\Omega_k(x_1, x_2, \alpha) d\alpha dx_1 dx_2$$

- In a linear case, reconstructed J would match the J from forward run

- Here we chose a lag $(\alpha - t)$ of 12 month and chose air temperature, shortwave, wind as control variables.

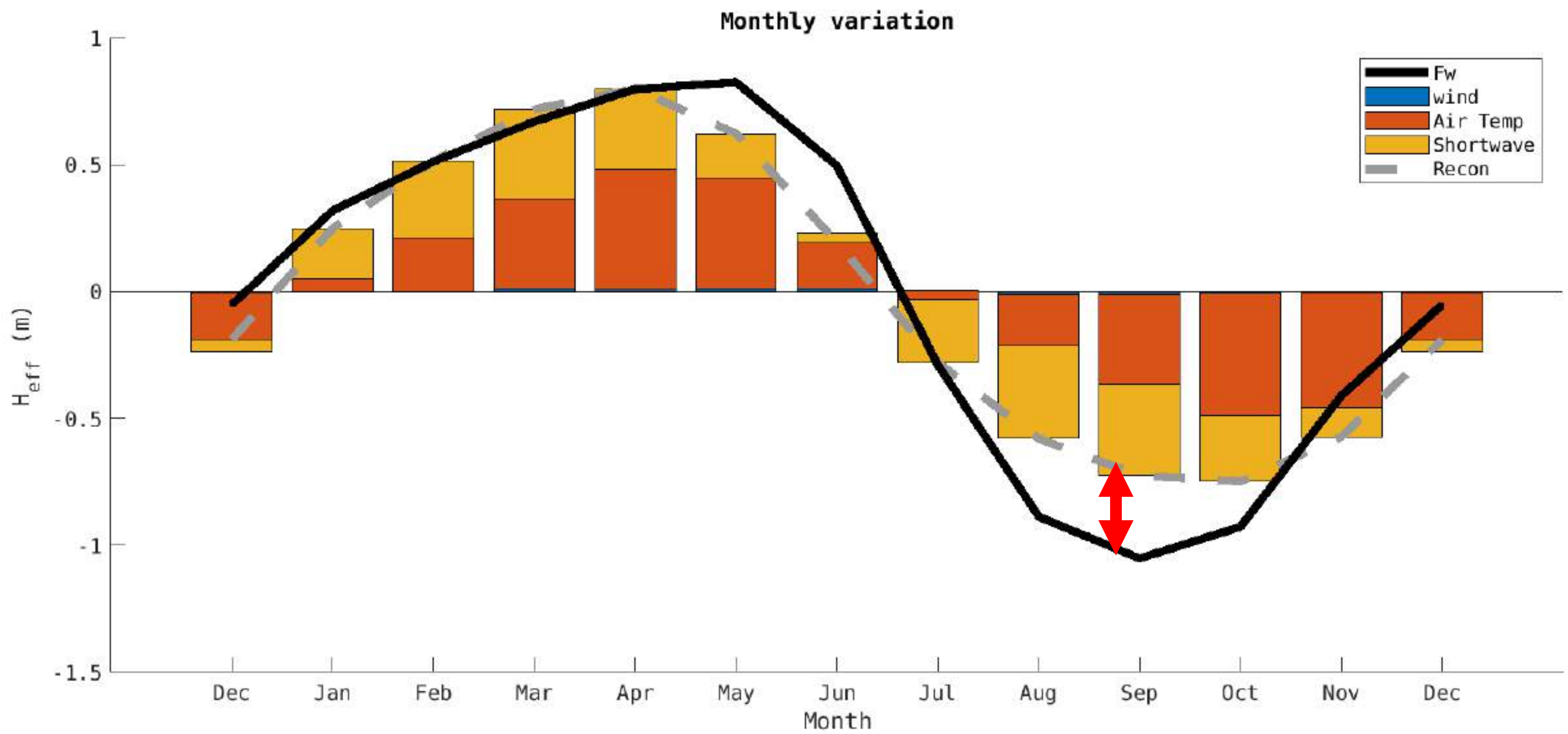
Reconstruction Results



- Wind has no contribution, in seasonal time scale. Thermodynamics only
- SW lags behind air temperature.
- Max H_{eff} matches Air Temp, a combination may explain the minumum.

INSTITUTE FOR COMPUTATIONAL ENGINEERING & SCIENCES

Reconstruction Results , need for extra variable



- We linearized around December state.
- Our assumption of linearity will not hold as well in September/Aug seaice cover.

Quantification of reconstruction.

- Correlation Coefficient (CC) and Percentage of Explained Variance (PEV) :

Full Signal: CC= 0.9 ; PEV = 80%

Monthly Variability: CC=0.96 ; PEV = 91%

- With current linearization setup due to mismatch in accuracy between melting and freezing seasons, we can’t do inter annual variability studies.
- A possible way forward is constructing an ensemble of sensitivities based on linearization around each month.

Summary

- Verified Fenty seaice thermodynamic adjoint code gives physically consistent sensitivities (with NLFS + RealFreshwater Flux)
- Successfully reconstructed the main seasonal cycle of ice volume in the MIZ of the Arctic Canadian Basin (CC=0.96) using gradients linearized around the December state.
- Code can now be integrated into the next ECCO production release