A data assimilation framework for ocean-sea-ice prediction

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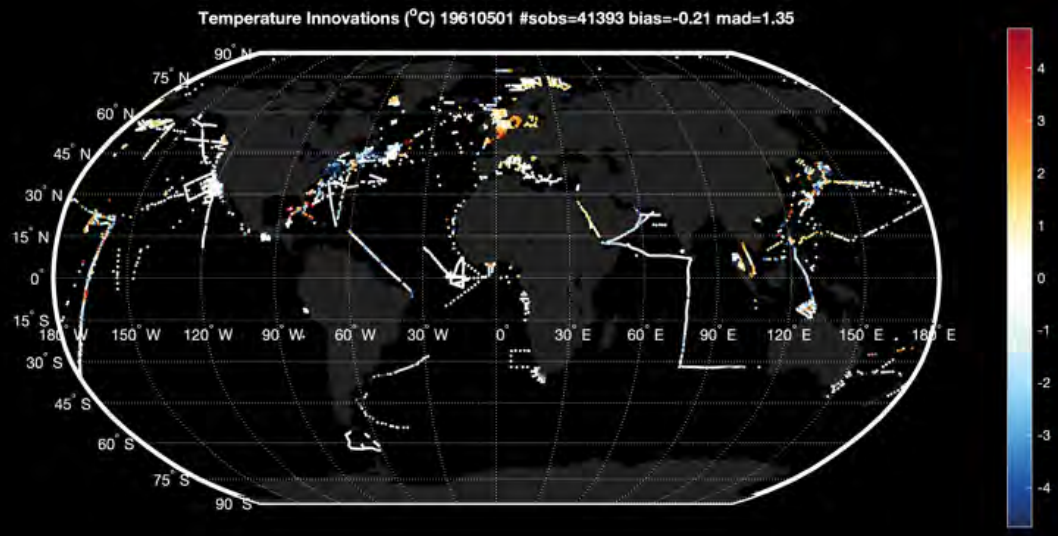
EnKF Coupled Data Assimilation (CDA) System

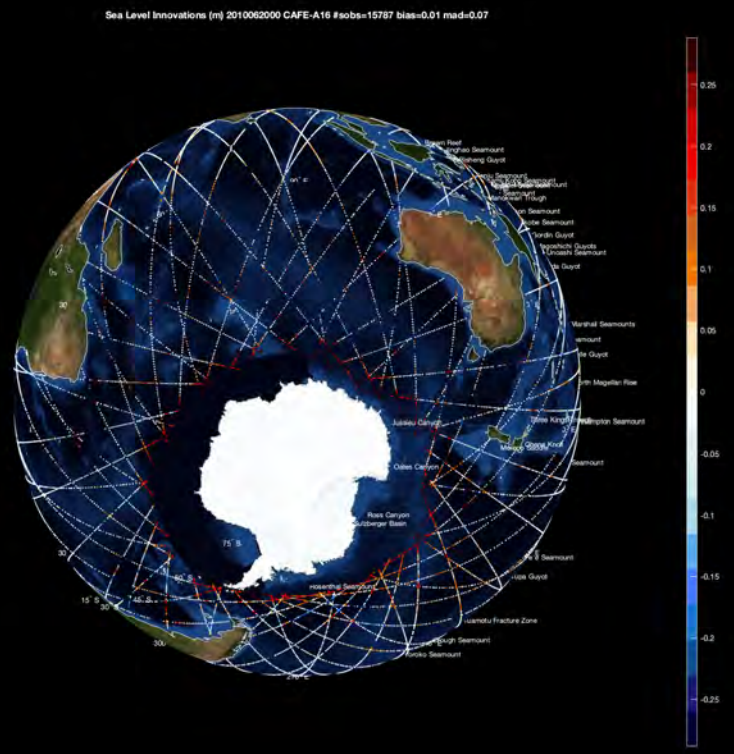
- DA for any coupled modelling system
- Scalable to relatively large models and ensemble sizes
- Parameter estimation, bias correction, asynchronous assimilation, sub-grid observation errors, footprint matching, CDA domains
- Framework for both prediction and verification using system wide consistency measures

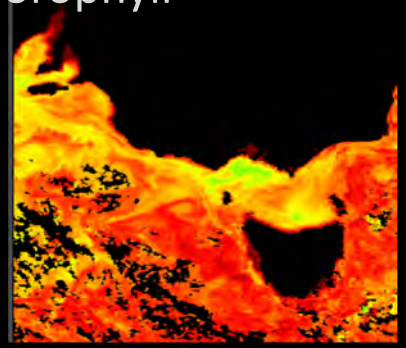
Observations

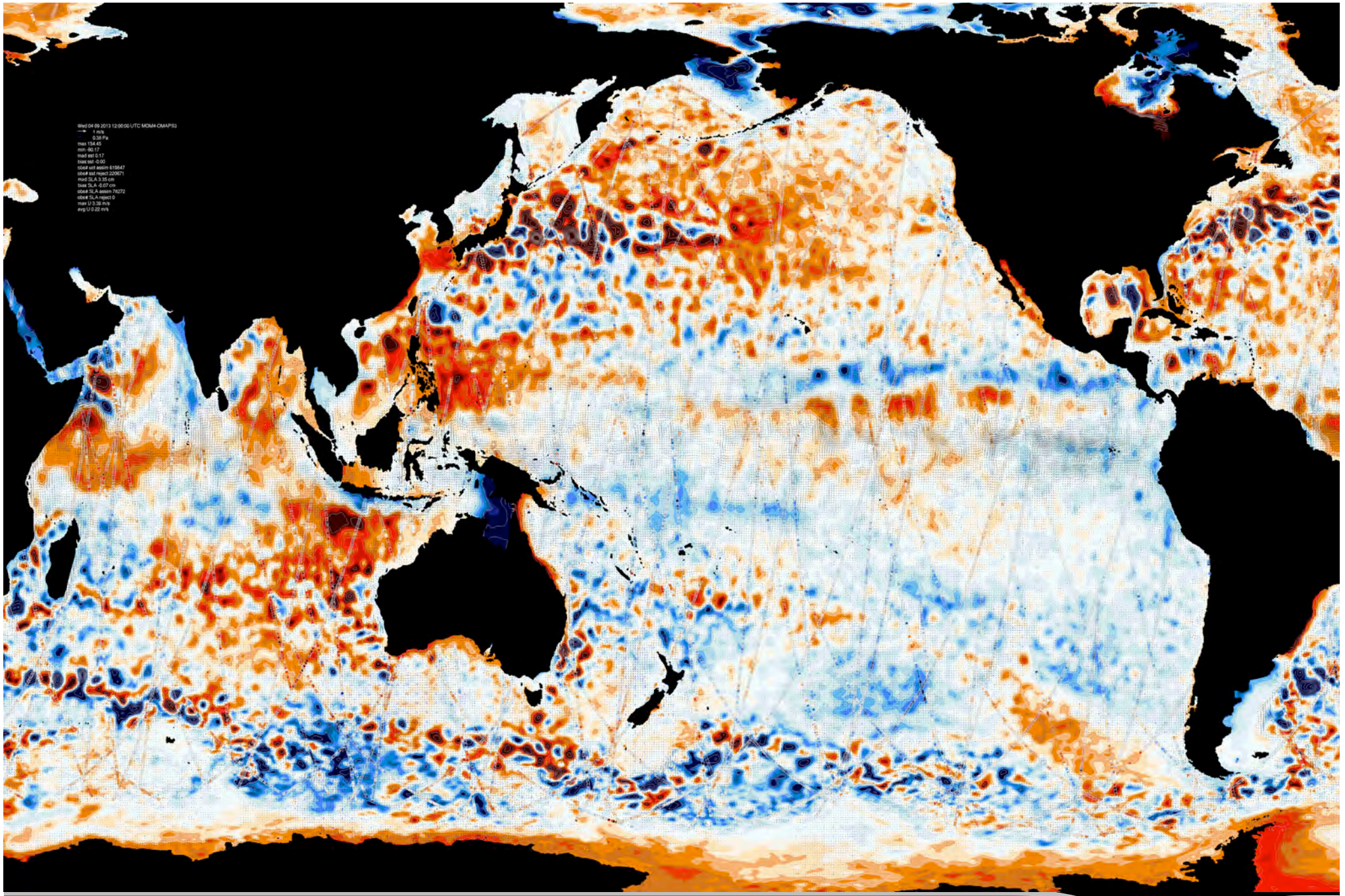
- JRA55 atmospheric reanalysis - daily
- Reynolds OISST or HadiSST2 prior to 1993
- Satellite SST from 1993 – NAVO-AVHRR, AMSR-E, AMSR-2, WindSat, PATHFINDER, VIIRS
- RADS altimetry from 1993
- In-situ T/S from **CORA5.0** including gliders, drifters, profilers, RV-CTD, XBT, MBT, XCTD, bottles, CTD, XBT, moorings, marine mammals etc.
- OSISAF sea ice concentration
- Remotely sensed chlorophyll

All used for verification



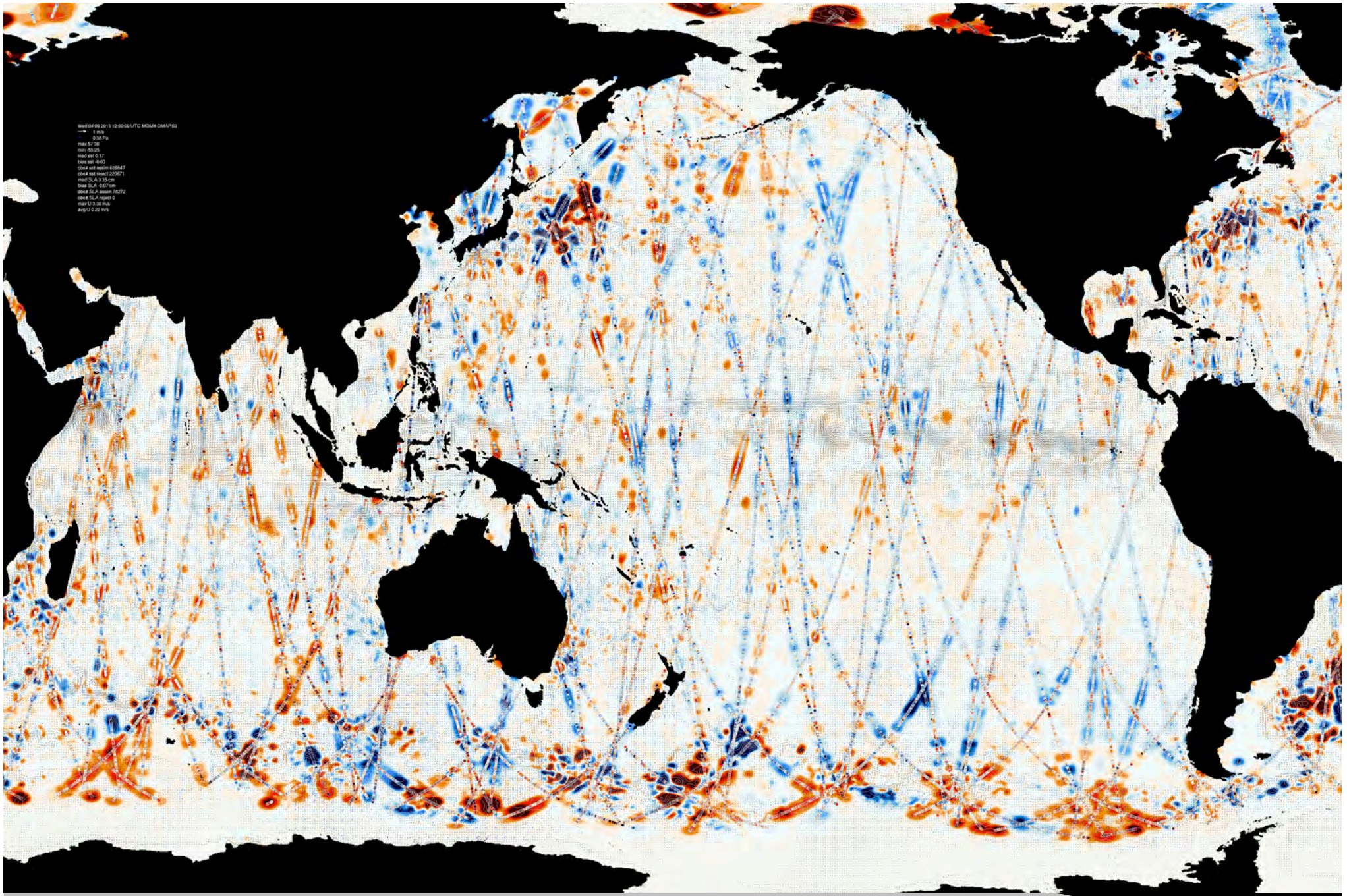






Coupled data assimilation with the EnKF

CSIRO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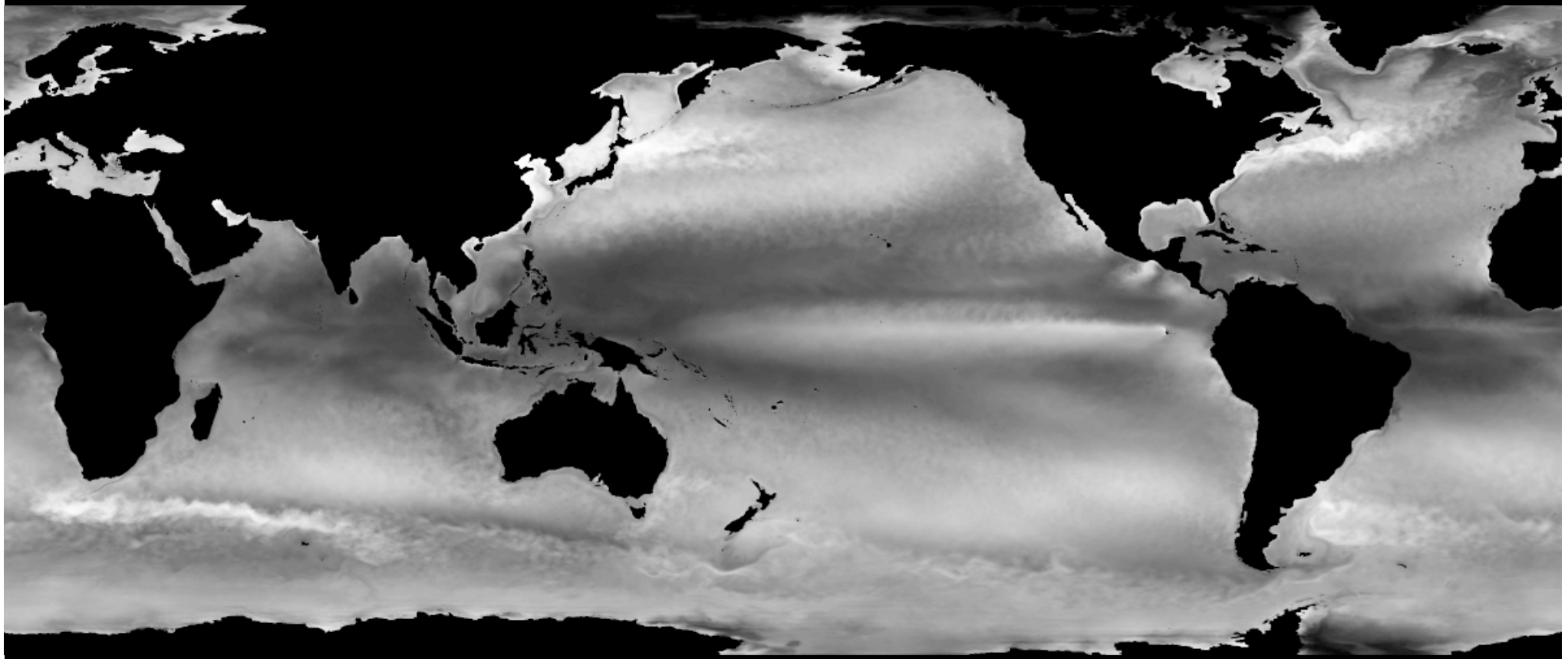
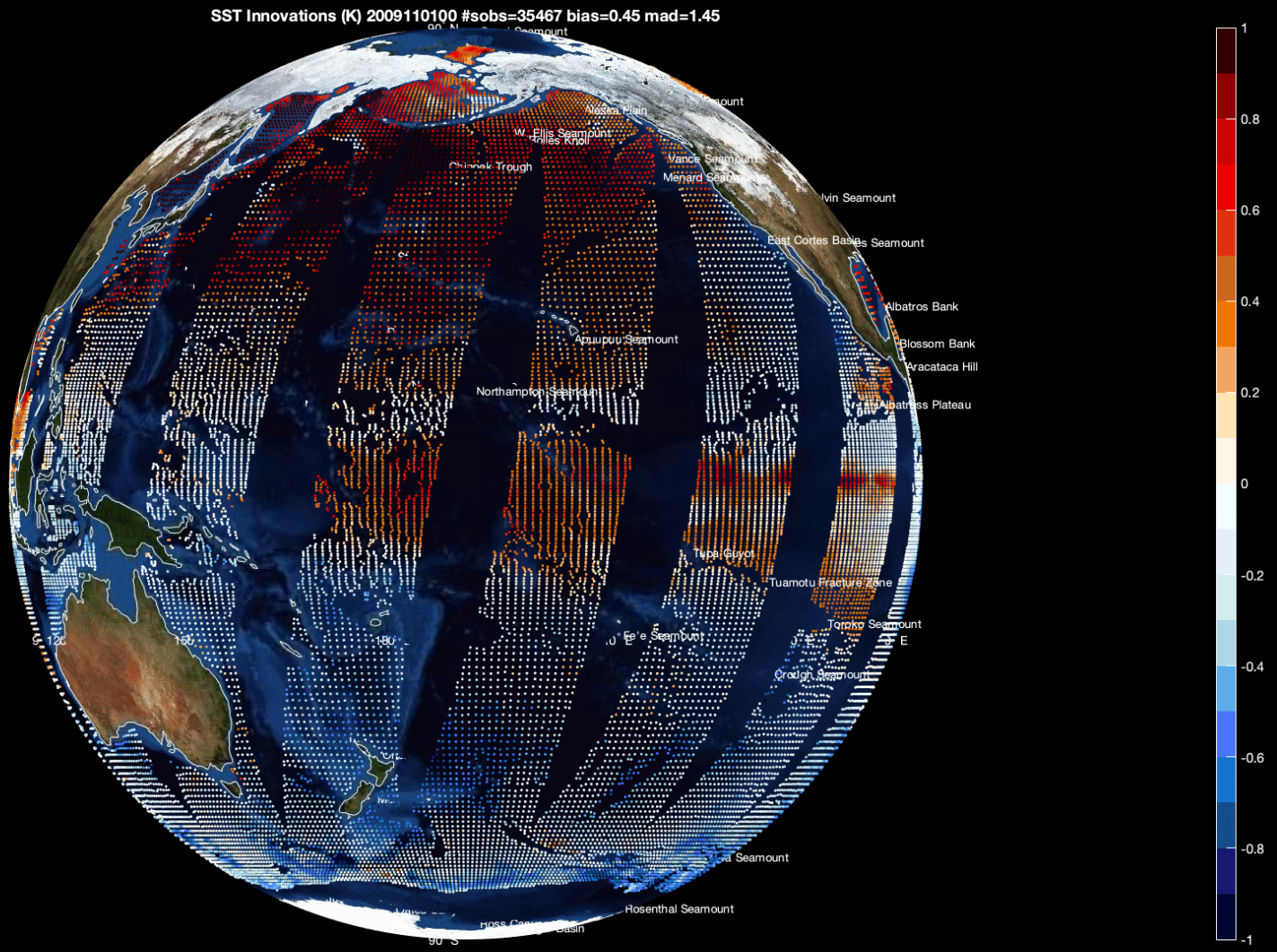
1 m/s
0.38 Pa
max 57.30
min -55.25
mad sst 0.17
bias sst -0.00
obs# sst assim 619847
obs# sst reject 220671
mod SLA 3.35 cm
bias SLA -0.07 cm
obs# SLA assim 76272
obs# SLA reject 0
max U 3.38 m/s
avg U 0.22 m/s

SST Spread from OFAM3-EnKF



CAFE-EnKF

SPINUP of coupled DA system from CAFE-60 (monthly perturbations) to 7-day assimilation cycle



Coupled data assimilation with the EnKF

CAFE-88

Coupled atmosphere-ocean-sea-ice prediction and reanalysis system from 1988-2019+

GFDL CM2.1

1º ice and ocean (SIS + MOM5 ACCESS configuration)

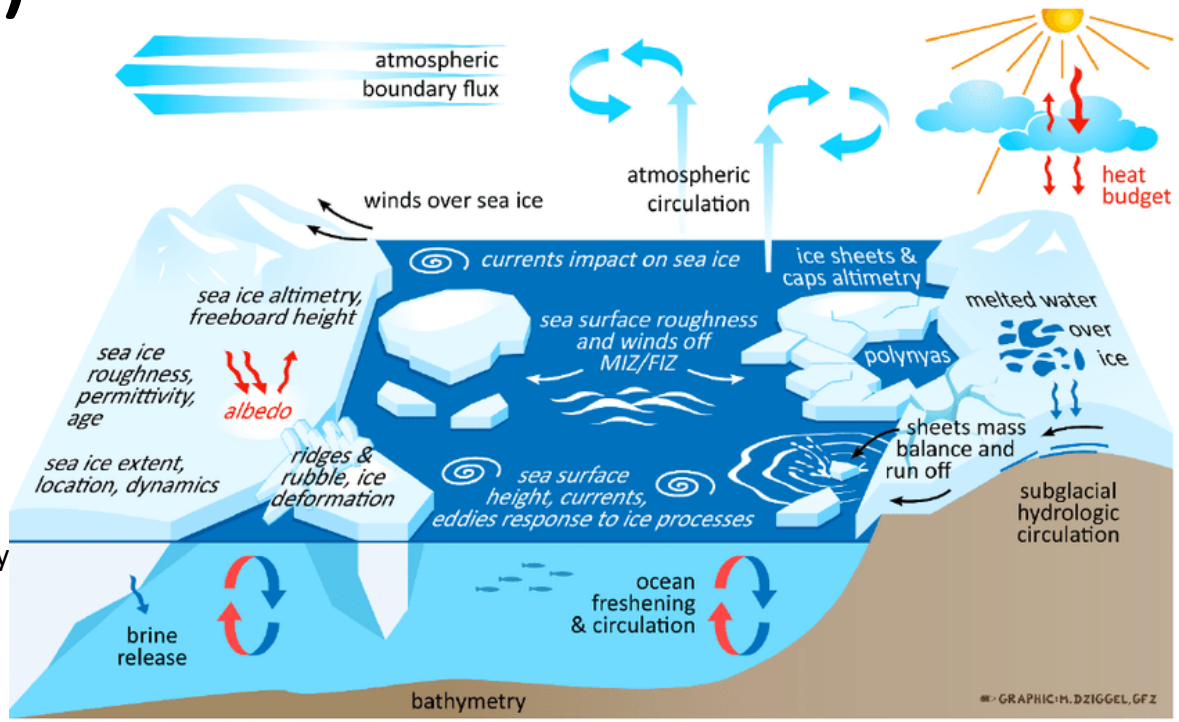
2º atmosphere (AM2)

- 96 member ensemble
- 1 day assimilation cycle
- Coupled state vector

ATM
U-wind
V-wind
Air temperature
Specific humidity
Pressure

ICE
Concentration
Thickness cats.
U-velocity
V-velocity

OCN
Sea-level-anomaly
Temperature
Salinity
U-velocity
V-velocity



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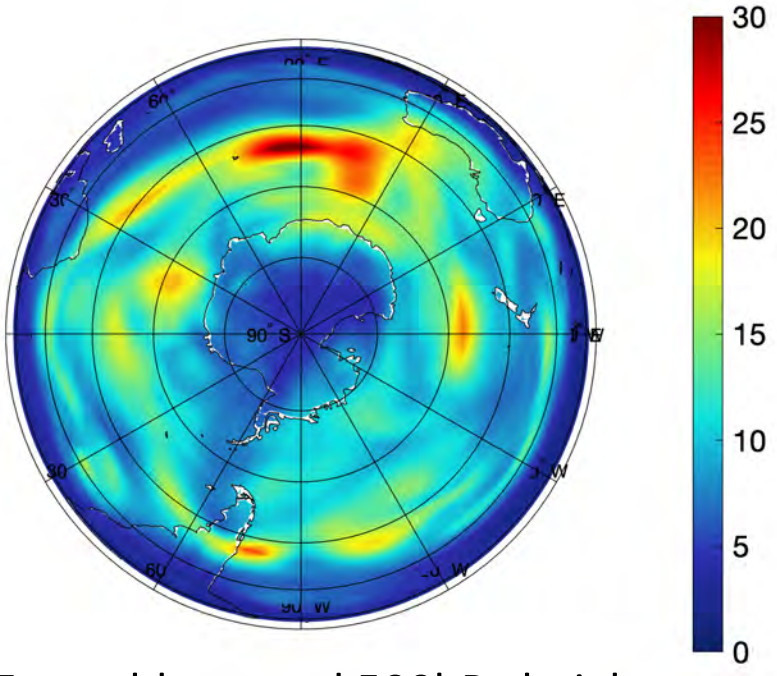
ATM	U-wind V-wind Air temperature Specific humidity Pressure
ICE	Concentration Thickness cats. U-velocity V-velocity
OCN	Sea-level-anomaly Temperature Salinity U-velocity V-velocity



Ensemble spread 500hPa height

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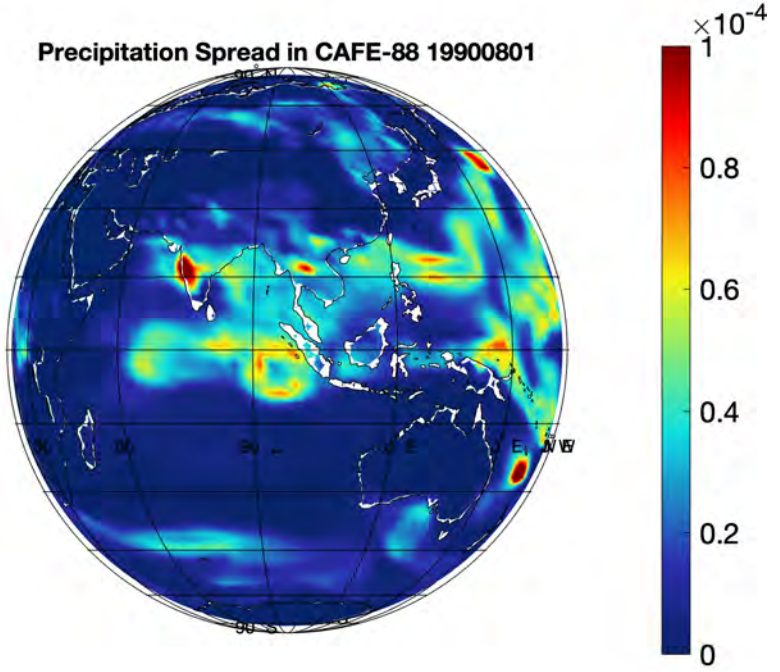
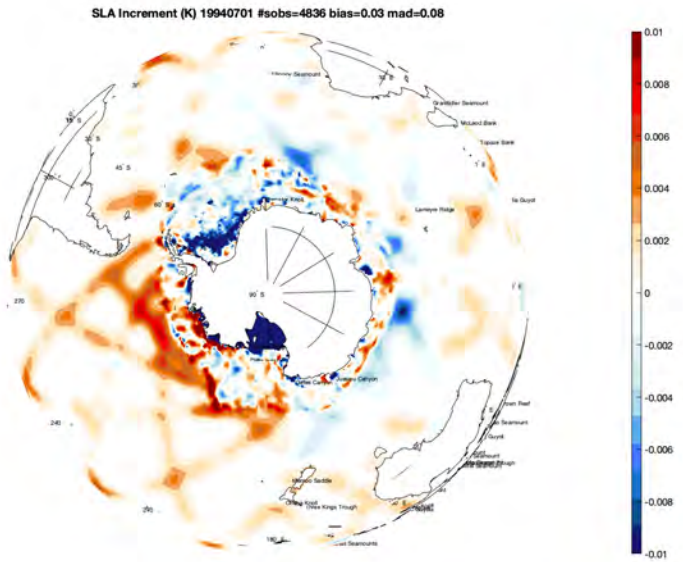
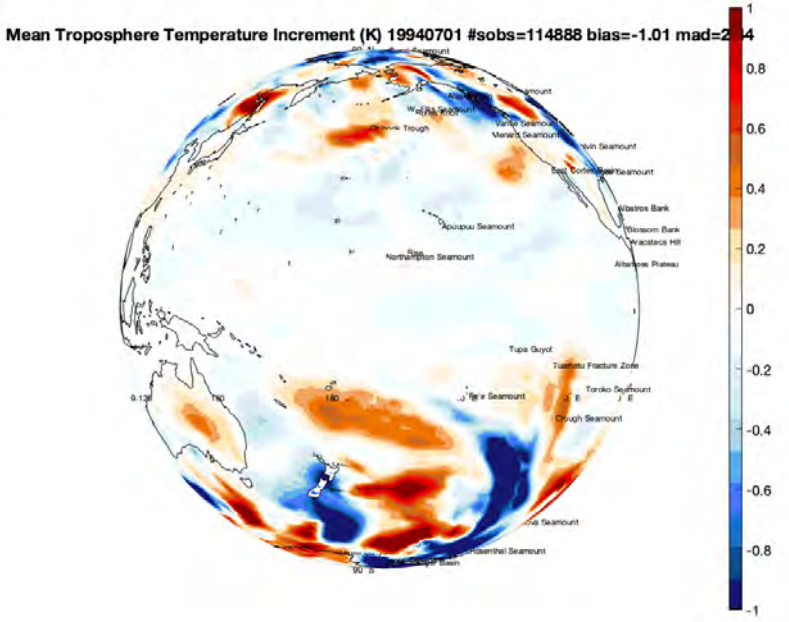
ICE	Concentration Thickness cats. U-velocity V-velocity
OCN	Sea-level-anomaly Temperature Salinity U-velocity V-velocity



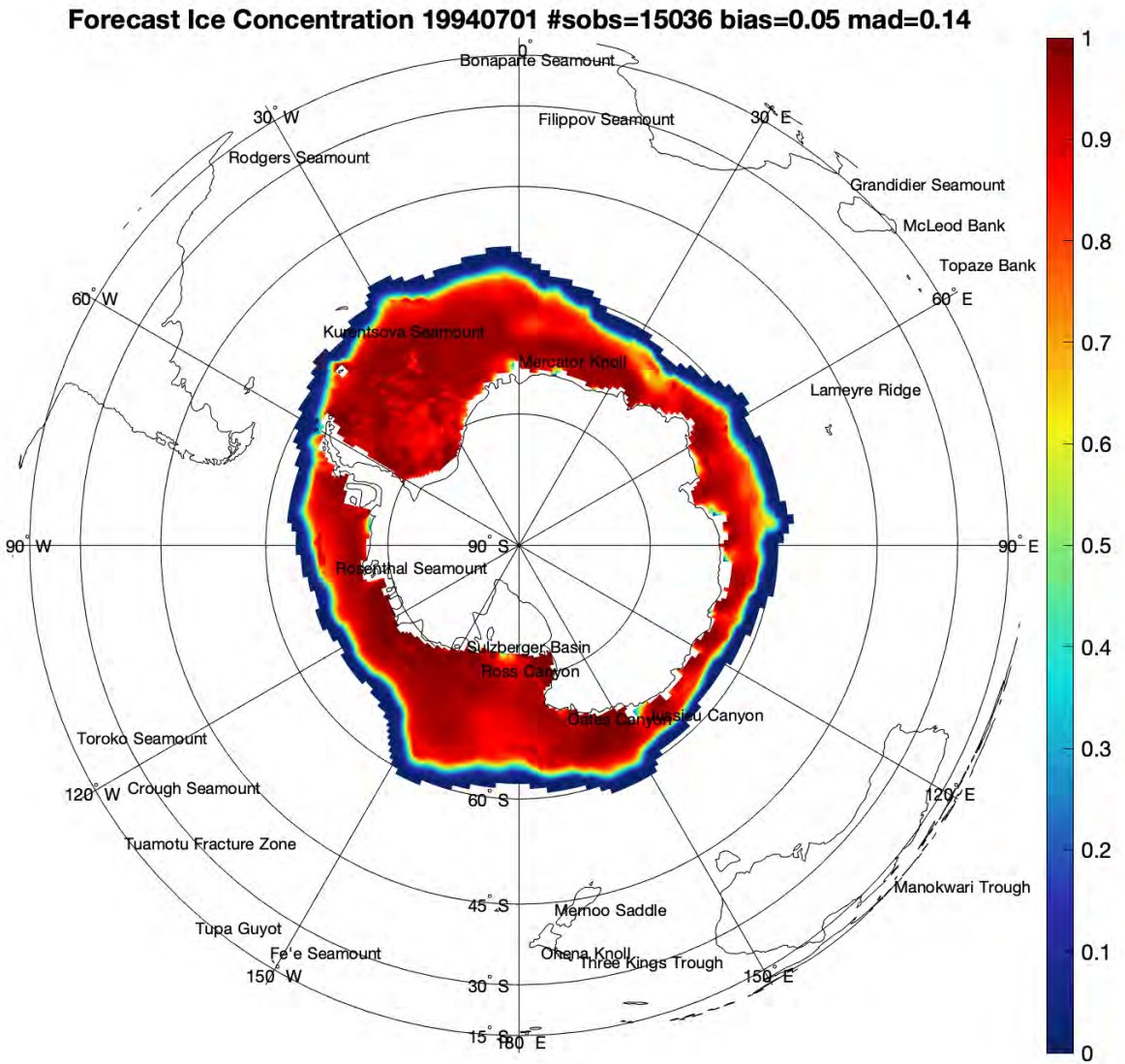
Polar regions – predictability challenge

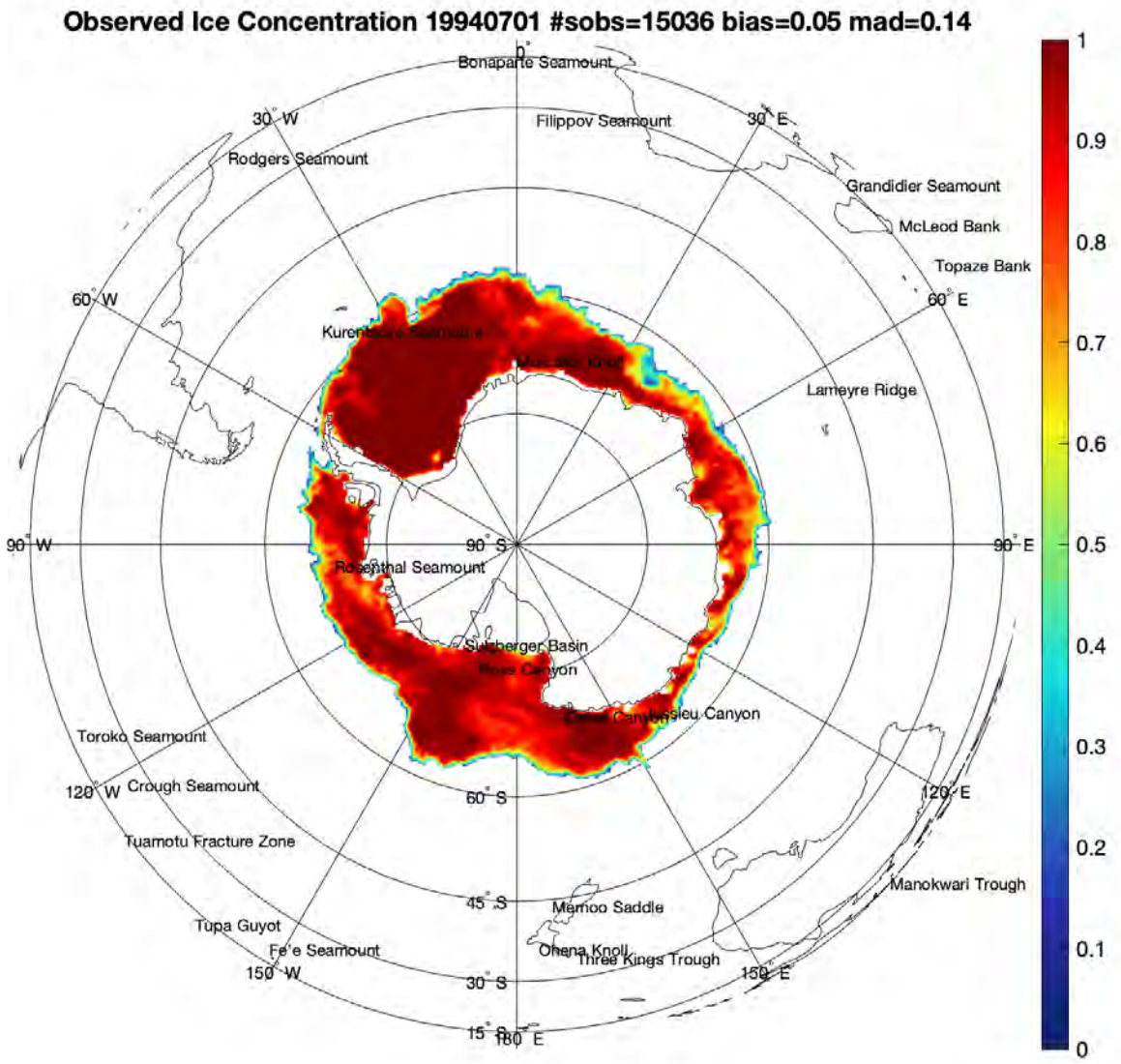
- All prediction systems have largest errors over poles
- Polar regions source of predictability for mid-latitudes – observations!

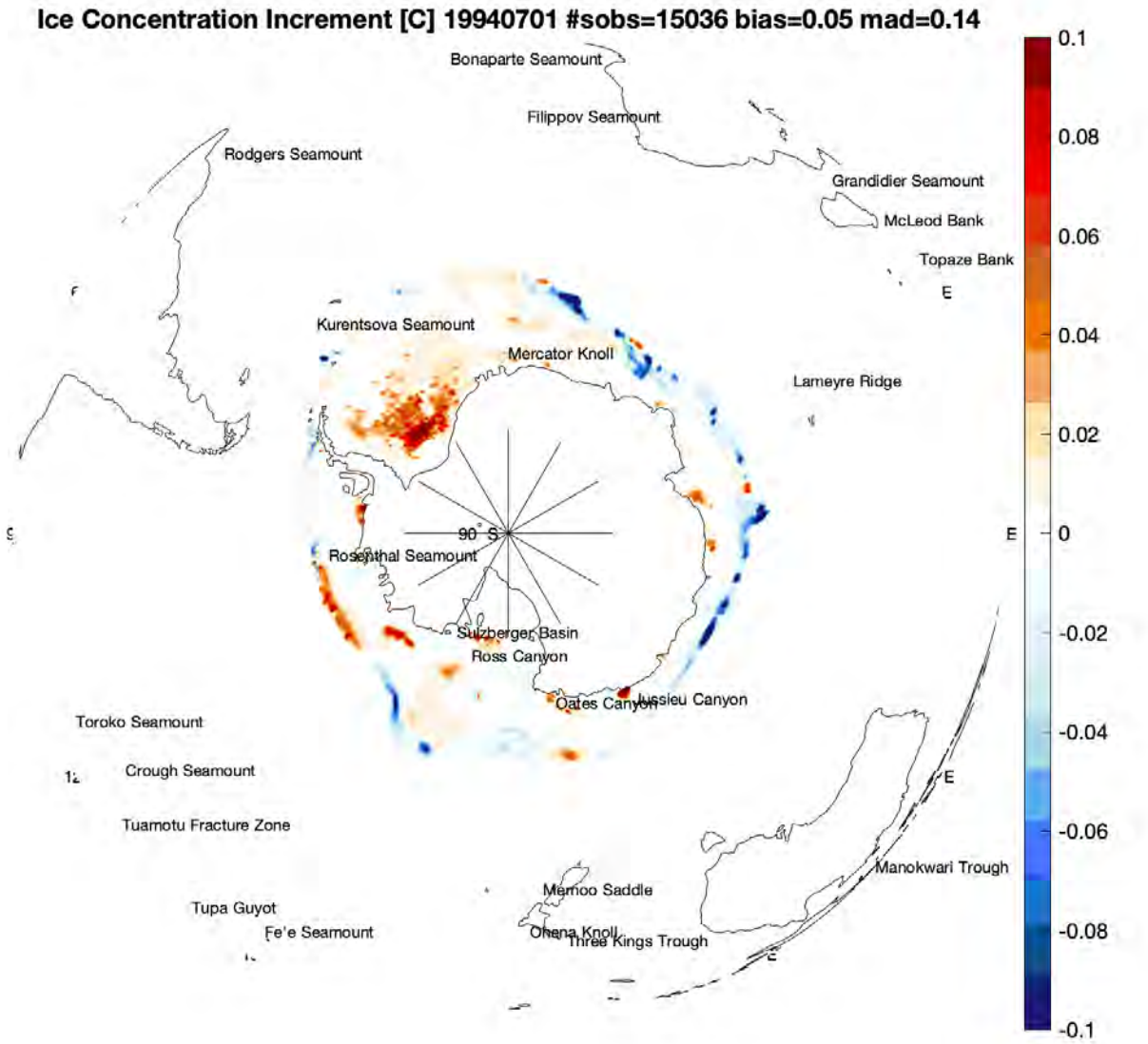


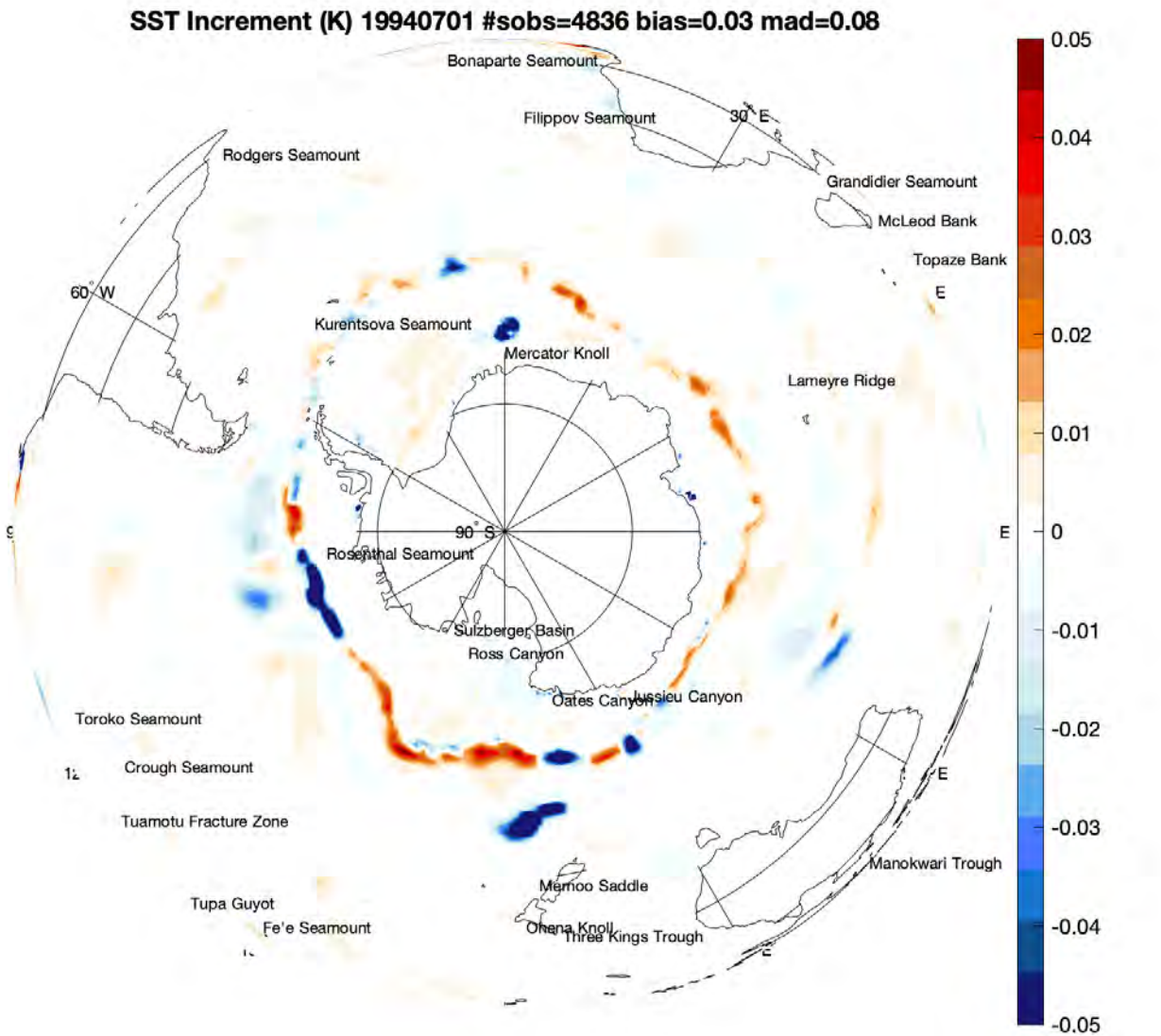


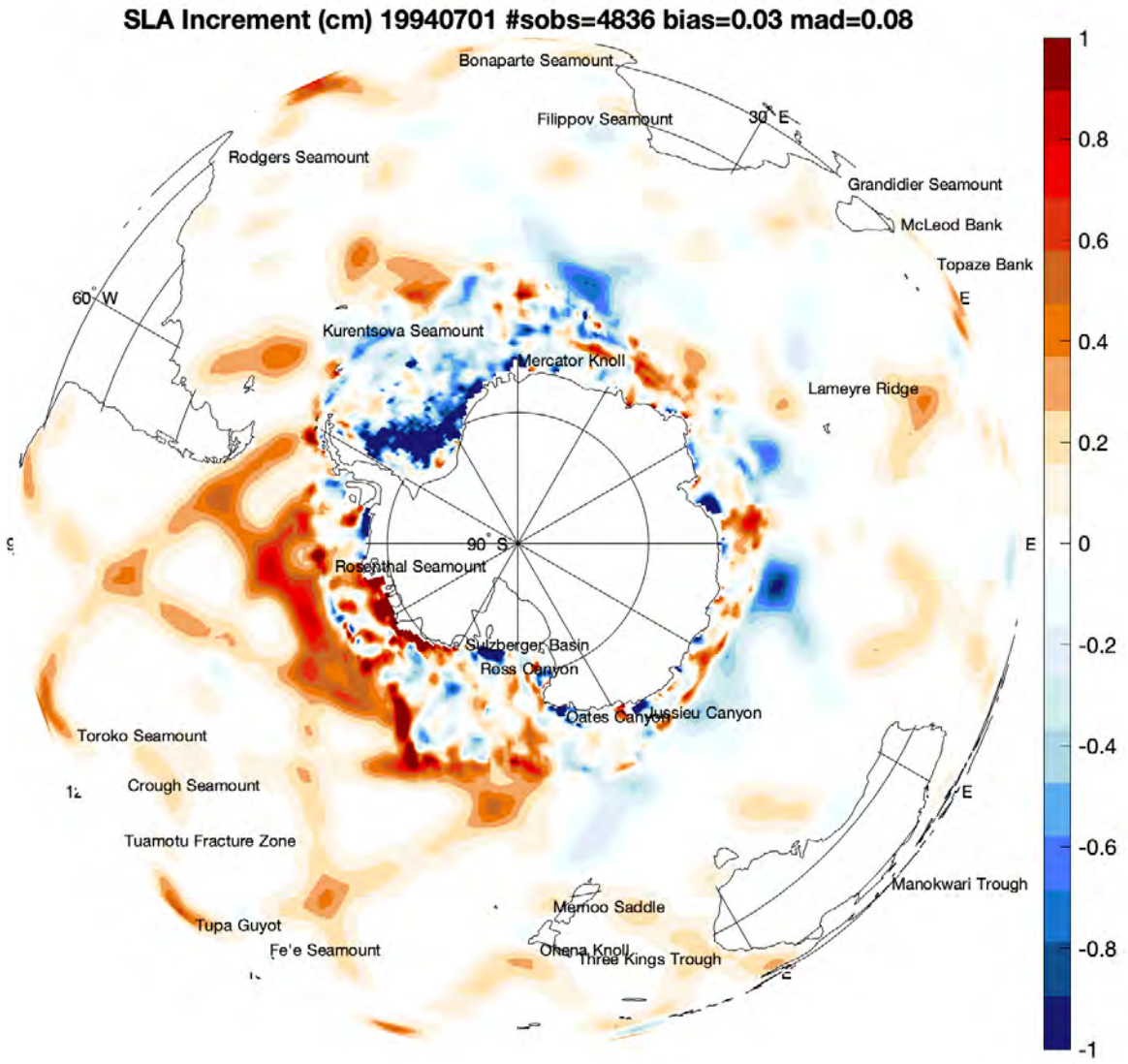
- Sea-ice challenge as mass ice has an affect similar to the inverse barometer
- 1m ice ~= 0.1m SLA!

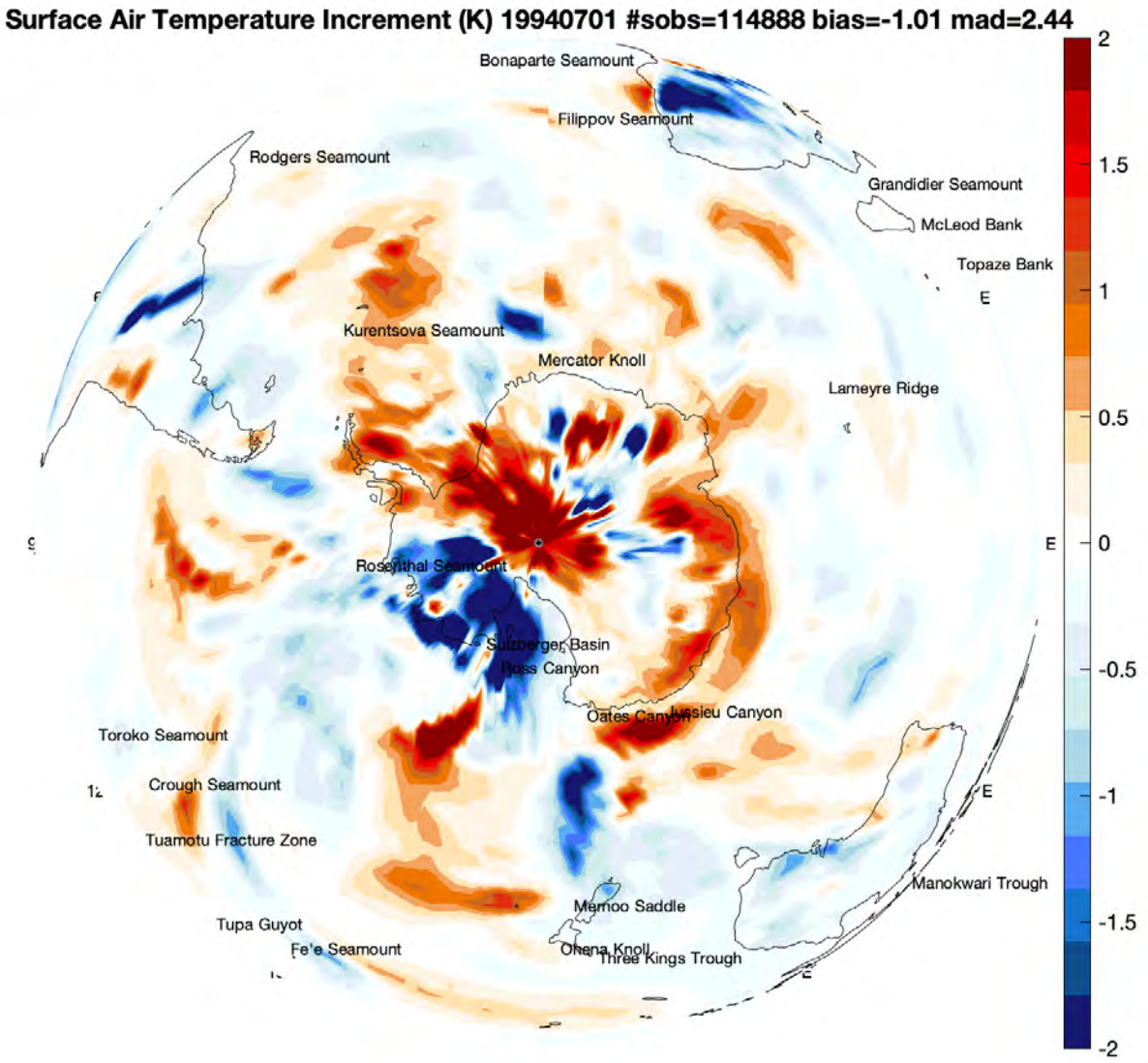

Forecast Ice Concentration 19940701 #sobs=15036 bias=0.05 mad=0.14
0°
30° W
30° E
60° W
60° E
90° W
90° E
120° W
120° E
150° W
150° E
180° E
90° S
60° S
45° S
30° S
15° S
Bonaparte Seamount
Filippov Seamount
Rodgers Seamount
Grandidier Seamount
McLeod Bank
Topaze Bank
Kurentsova Seamount
Mercator Knoll
Lameyre Ridge
Rosenthal Seamount
Sulzberger Basin
Ross Canyon
Toroko Seamount
Crough Seamount
Tuamotu Fracture Zone
Manokwari Trough
Memoo Saddle
Tupa Guyot
Fe'e Seamount
Three Kings Trough
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

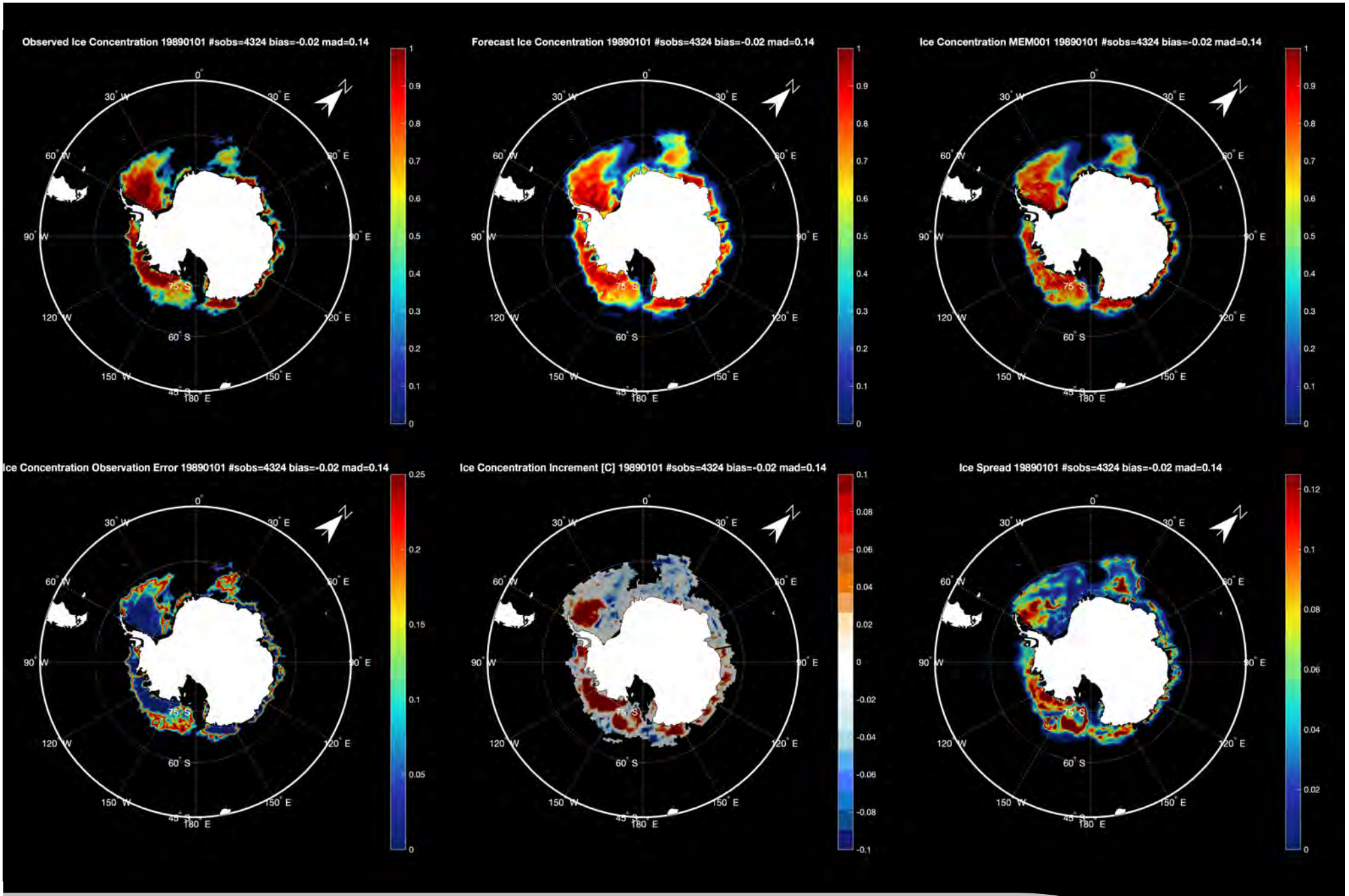

Observed Ice Concentration 19940701 #sobs=15036 bias=0.05 mad=0.14
0°
30° W
30° E
60° W
60° E
90° W
90° E
90° S
120° W
120° E
150° W
150° E
180° E
60° S
45° S
30° S
15° S
Bonaparte Seamount
Filippov Seamount
Rodgers Seamount
Grandidier Seamount
McLeod Bank
Topaze Bank
Lameyre Ridge
Rosenthal Seamount
Toroko Seamount
Crough Seamount
Tuamotu Fracture Zone
Tupa Guyot
Fe'e Seamount
Manokwari Trough
Three Kings Trough
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0


Ice Concentration Increment [C] 19940701 #sobs=15036 bias=0.05 mad=0.14
Bonaparte Seamount
Filippov Seamount
Rodgers Seamount
Grandidier Seamount
McLeod Bank
Topaze Bank
Kurentsova Seamount
Mercator Knoll
Lameyre Ridge
90° S
Rosenthal Seamount
Sulzberger Basin
Ross Canyon
Oates Canyon
Jussieu Canyon
Toroko Seamount
Crough Seamount
Tuamotu Fracture Zone
Manokwari Trough
Menoo Saddle
Tupa Guyot
Fe'e Seamount
Ohena Knoll
Three Kings Trough
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1


SST Increment (K) 19940701 #sobs=4836 bias=0.03 mad=0.08
Bonaparte Seamount
Filippov Seamount
30° E
Rodgers Seamount
Grandidier Seamount
McLeod Bank
Topaze Bank
60° W
E
Kurentsova Seamount
Mercator Knoll
Lameyre Ridge
90° S
Rosenthal Seamount
Sulzberger Basin
Ross Canyon
Oates Canyon
Jussieu Canyon
Toroko Seamount
Crough Seamount
Tuamotu Fracture Zone
Manokwari Trough
Mernoo Saddle
Tupa Guyot
Fe'e Seamount
Ohena Knoll
Three Kings Trough
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05


SLA Increment (cm) 19940701 #sobs=4836 bias=0.03 mad=0.08
Bonaparte Seamount
Filippov Seamount
30° E
Rodgers Seamount
Grandidier Seamount
McLeod Bank
Topaze Bank
60° W
E
Kurentsova Seamount
Mercator Knoll
Lameyre Ridge
90° S
E
Rosenthal Seamount
Sluzberger Basin
Ross Canyon
Oates Canyon
Jussieu Canyon
Toroko Seamount
Crough Seamount
E
Tuamotu Fracture Zone
Manokwari Trough
Mernoo Saddle
Tupa Guyot
Fe'e Seamount
Ohena Knoll
Three Kings Trough
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1


Surface Air Temperature Increment (K) 19940701 #sobs=114888 bias=-1.01 mad=2.44
Bonaparte Seamount
Filippov Seamount
Rodgers Seamount
Grandidier Seamount
McLeod Bank
Topaze Bank
Kurentsova Seamount
Mercator Knoll
Lameyre Ridge
Rosenthal Seamount
Sulzberger Basin
Ross Canyon
Oates Canyon
Jussieu Canyon
Toroko Seamount
Crough Seamount
Tuamotu Fracture Zone
Manokwari Trough
Mernoo Saddle
Tupa Guyot
Fe'e Seamount
Ohena Knoll
Three Kings Trough
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2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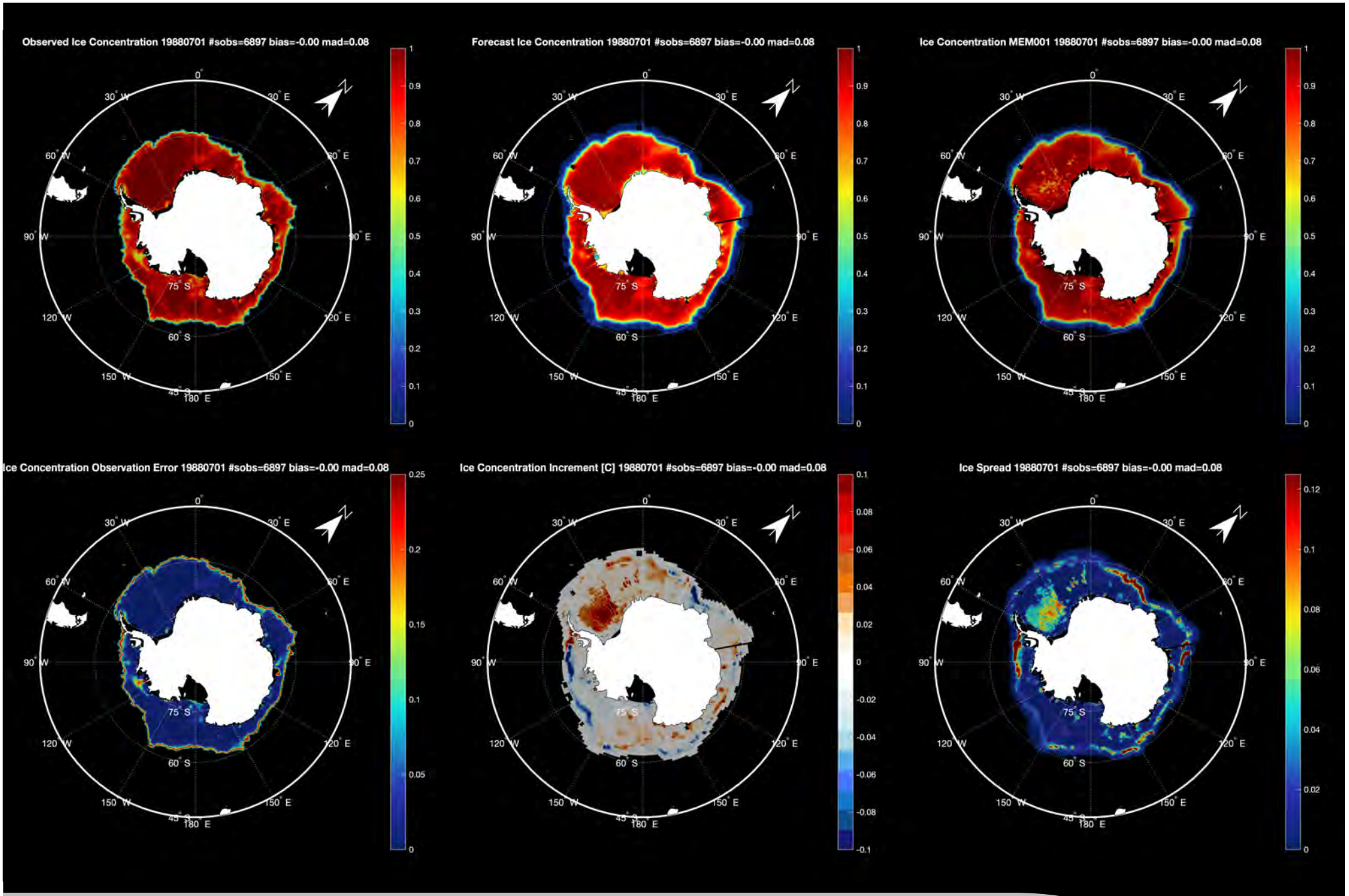
Forecast Ice Concentration 19890101 #sobs=4324 bias=-0.02 mad=0.14
Ice Concentration MEM001 19890101 #sobs=4324 bias=-0.02 mad=0.14
Ice Concentration Observation Error 19890101 #sobs=4324 bias=-0.02 mad=0.14
Ice Concentration Increment [C] 19890101 #sobs=4324 bias=-0.02 mad=0.14
Ice Spread 19890101 #sobs=4324 bias=-0.02 mad=0.14
0°
30° W
30° E
60° W
60° E
90° W
90° E
120° W
120° E
150° W
150° E
180° E
75° S
60° S
45° S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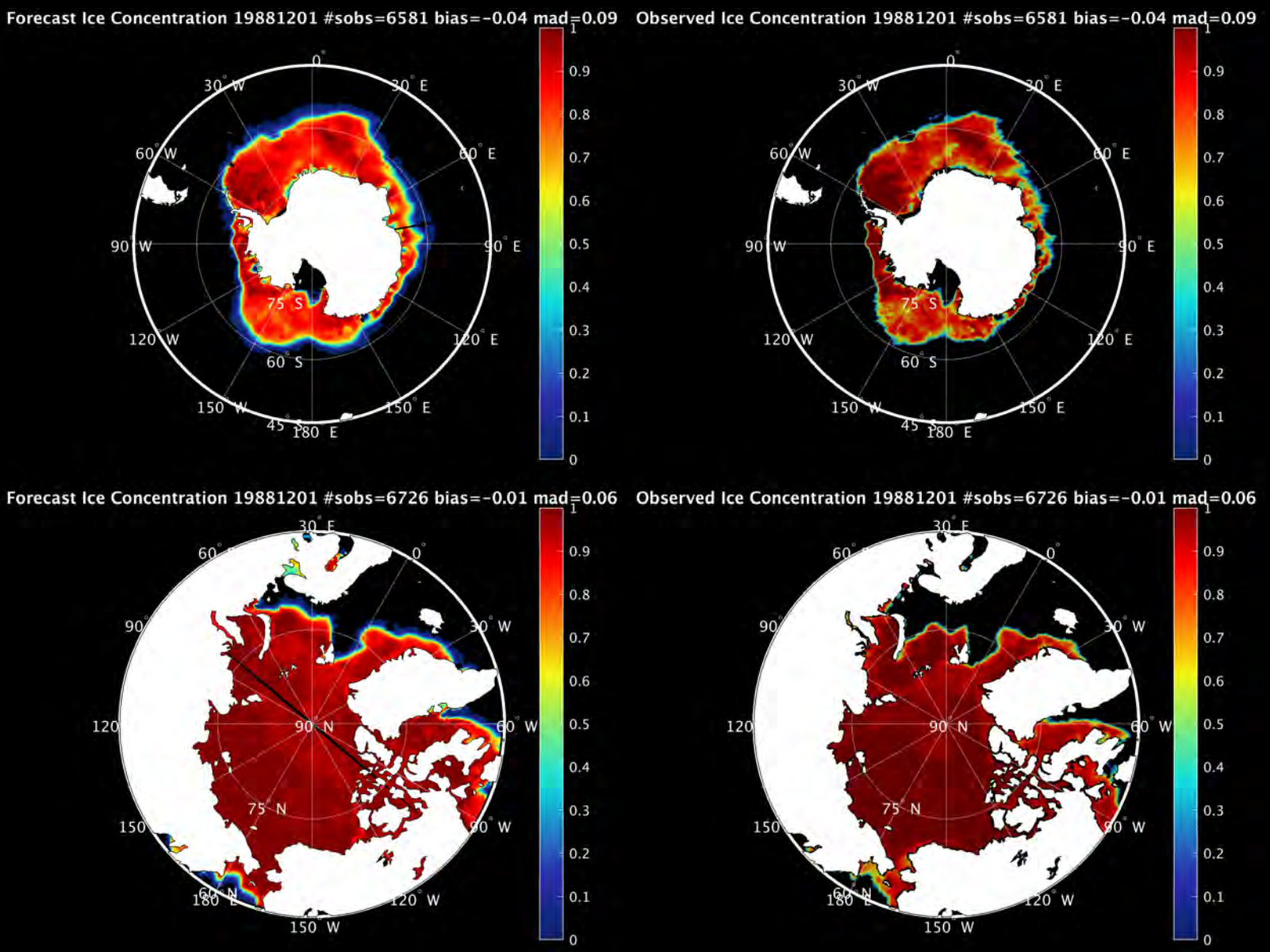
Forecast Ice Concentration 19880701 #sobs=6897 bias=-0.00 mad=0.08
Ice Concentration MEM001 19880701 #sobs=6897 bias=-0.00 mad=0.08
Ice Concentration Observation Error 19880701 #sobs=6897 bias=-0.00 mad=0.08
Ice Concentration Increment [C] 19880701 #sobs=6897 bias=-0.00 mad=0.08
Ice Spread 19880701 #sobs=6897 bias=-0.00 mad=0.08
0°
30° W
30° E
60° W
60° E
90° W
90° E
120° W
120° E
150° W
150° E
180° E
75° S
60° S
45° S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Observed Ice Concentration 19881201 #sobs=6581 bias=-0.04 mad=0.09
Forecast Ice Concentration 19881201 #sobs=6726 bias=-0.01 mad=0.06
Observed Ice Concentration 19881201 #sobs=6726 bias=-0.01 mad=0.06
0
30 W
30 E
60 W
60 E
90 W
90 E
120 W
120 E
150 W
150 E
180 E
75 S
60 S
45 S
75 N
90 N
60 N
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

- We plan to implement the CDA framework for the ACCESS-OM suite to support next generation BRAN2020 and OceanMAPS4 ocean and sea-ice forecasting.

- The CDA framework is being used carry out joint state and parameter estimation in order to find less biased forecast model.

- This becomes increasingly important for ocean, seasonal and climate prediction.