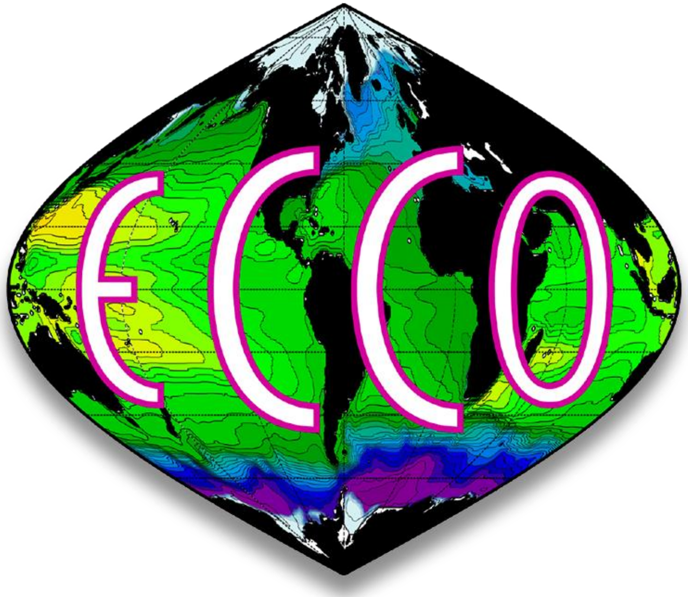
Model/Observation Comparison in Recent ECCOs:
Sea-ice Fields in Southern Ocean

Hong Zhang and Dimitris Menemenlis

JPL/Caltech



ECCO Annual Meeting UT-Austin March 20-22, 2024

OUTLINE

1. Motivation

    Two recent studies: ECCO Darwin CO_2 flux in SO (led by Dustin Carrol)

    and Evaluation of ECCOs in SO (led by Yoshi Nakayama)

2. Result

    ECCO v4r5 (+ECCO v4r4 if applicable), ECCO LLC270-alpha;

    sea-ice cover (SSM/I);

    freeboard / sea-ice thickness / snow depth (IceSat2/CryoSat2) 3.

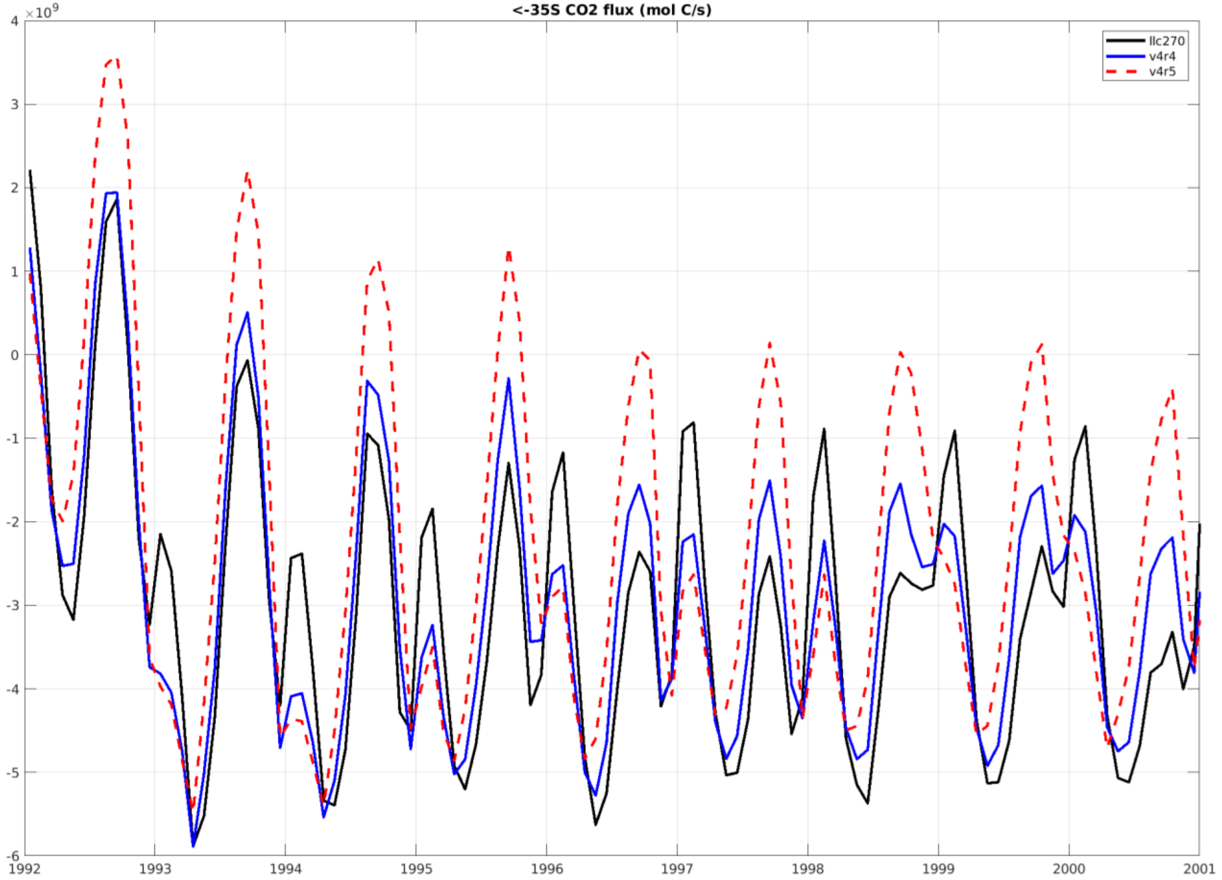
Summary

Study 1: ECCO Darwin CO_2 flux in SO

1. LLC270-alpha: ~1/3-degree, optimized over 1992-2017, extended 2018-near present
2. ECCO v4r4: ~1 degree, optimized over 1992-2017;
3. ECCO v4r5: ~1 degree, optimized over 1992-2019, extended 2020-near present

The different solutions lead to different CO_2 flux in Southern Ocean (shown right), even for the same config of Darwin model. LLC270-alpha and v4r4 have more similarity, but v4r5 are much more different.

Less sea-ice =>
    less freshwater export =>
        deeper MLD =>
            higher upwelling of pCO2



Multi-year time mean

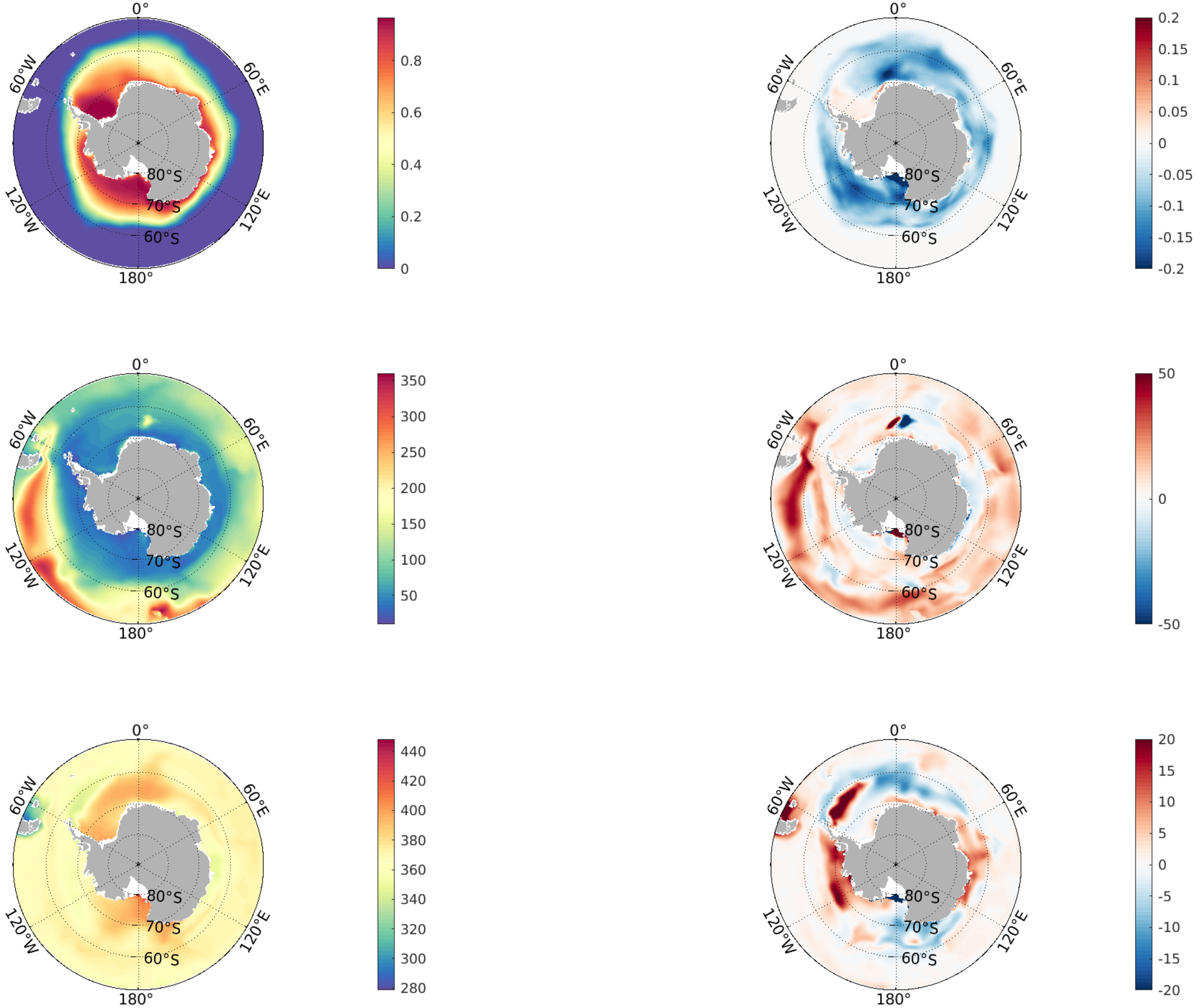
Left: v4r4

Right: v4r5-v4r4

Top: Sea-ice area

Mid: MLD

Bottom: pCO2



less ice

deeper MLD

higher upwelling of pCO2

Understanding the Southern Ocean through model-data synthesis

HE24A-2633

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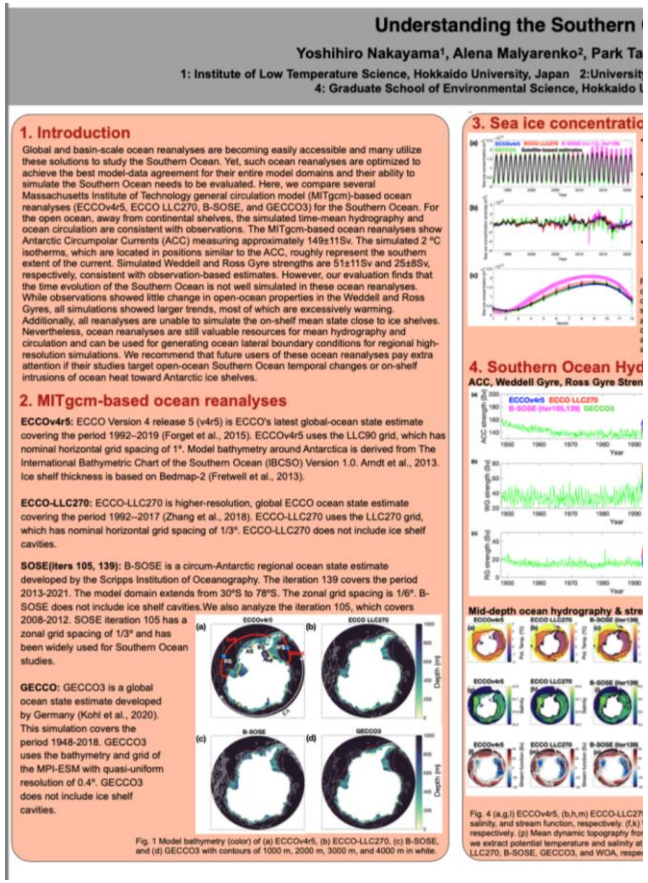
Study 2: Evaluation of ECC



Understanding the Southern

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4: Graduate School of Environmental Science, Hokkaido

1. Introduction

Global and basin-scale ocean reanalyses are becoming easily accessible and many utilize these solutions to study the Southern Ocean. Yet, such ocean reanalyses are optimized to achieve the best model-data agreement for their entire model domains and their ability to simulate the Southern Ocean needs to be evaluated. Here, we compare several Massachusetts Institute of Technology general circulation model (MITgcm)-based ocean reanalyses (ECCOv4r5, ECCO LLC270, B-SOSE, and GECCO3) for the Southern Ocean. For the open ocean, away from continental shelves, the simulated time-mean hydrography and ocean circulation are consistent with observations. The MITgcm-based ocean reanalyses show Antarctic Circumpolar Currents (ACC) measuring approximately 149±11Sv. The simulated 2 °C isotherms, which are located in positions similar to the ACC, roughly represent the southern extent of the current. Simulated Weddell and Ross Gyre strengths are 51±11Sv and 25±8Sv, respectively, consistent with observation-based estimates. However, our evaluation finds that the time evolution of the Southern Ocean is not well simulated in these ocean reanalyses. While observations showed little change in open-ocean properties in the Weddell and Ross Gyres, all simulations showed larger trends, most of which are excessively warming. Additionally, all reanalyses are unable to simulate the on-shelf mean state close to ice shelves. Nevertheless, ocean reanalyses are still valuable resources for mean hydrography and circulation and can be used for generating ocean lateral boundary conditions for regional high-resolution simulations. We recommend that future users of these ocean reanalyses pay extra attention if their studies target open-ocean Southern Ocean temporal changes or on-shelf intrusions of ocean heat toward Antarctic ice shelves.

2. MITgcm-based ocean reanalyses

ECCOv4r5: ECCO Version 4 release 5 (v4r5) is ECCO's latest global-ocean state estimate covering the period 1992–2019 (Forget et al., 2015). ECCOv4r5 uses the LLC90 grid, which has nominal horizontal grid spacing of 1°. Model bathymetry around Antarctica is derived from The International Bathymetric Chart of the Southern Ocean (IBCSO) Version 1.0. Arndt et al., 2013. Ice shelf thickness is based on Bedmap-2 (Fretwell et al., 2013).

ECCO-LLC270: ECCO-LLC270 is higher-resolution, global ECCO ocean state estimate covering the period 1992--2017 (Zhang et al., 2018). ECCO-LLC270 uses the LLC270 grid, which has nominal horizontal grid spacing of 1/3°. ECCO-LLC270 does not include ice shelf cavities.

SOSE(iters 105, 139): B-SOSE is a circum-Antarctic regional ocean state estimate developed by the Scripps Institution of Oceanography. The iteration 139 covers the period 2013-2021. The model domain extends from 30°S to 78°S. The zonal grid spacing is 1/6°. B-SOSE does not include ice shelf cavities.We also analyze the iteration 105, which covers 2008-2012. SOSE iteration 105 has a zonal grid spacing of 1/3° and has been widely used for Southern Ocean studies.

GECCO: GECCO3 is a global ocean state estimate developed by Germany (Kohl et al., 2020). This simulation covers the period 1948-2018. GECCO3 uses the bathymetry and grid of the MPI-ESM with quasi-uniform resolution of 0.4°. GECCO3 does not include ice shelf cavities.

Fig. 1 Model bathymetry (color) of (a) ECCOv4r5, (b) ECCO-LLC270, (c) B-SOSE, and (d) GECCO3 with contours of 1000 m, 2000 m, 3000 m, and 4000 m in white.

3. Sea ice concentratio

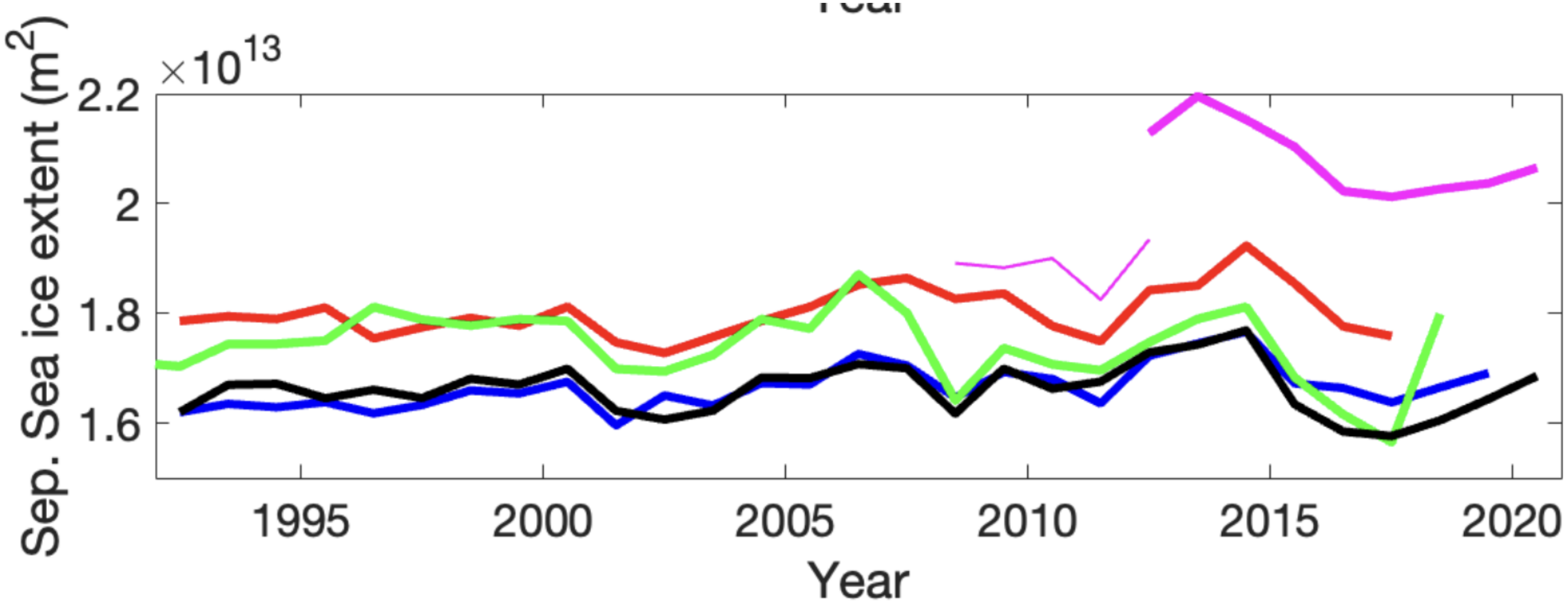
4. Southern Ocean Hyd

ACC, Weddell Gyre, Ross Gyre Stren

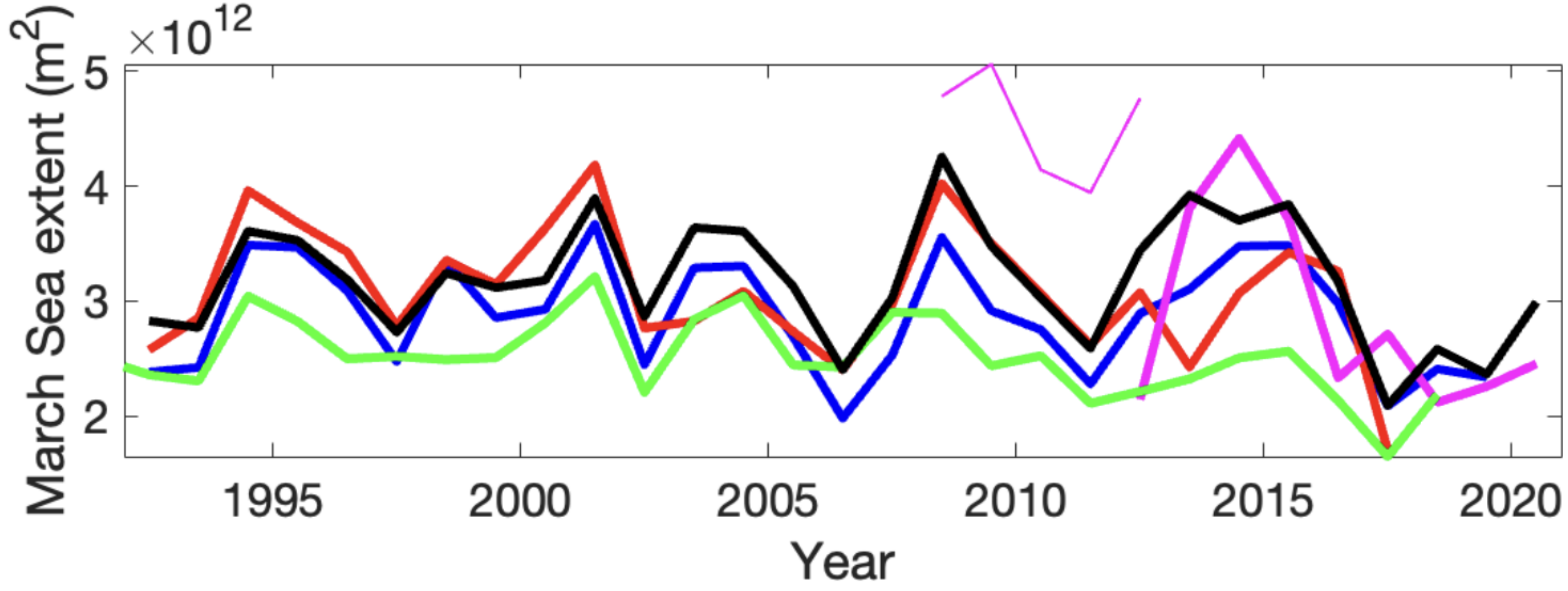
Mid-depth ocean hydrography & stre

Fig. 4 (a,g,l) ECCOv4r5, (b,h,m) ECCO-LLC27
salinity, and stream function, respectively. (f,k)
respectively. (p) Mean dynamic topography fro
we extract potential temperature and salinity at
LLC270, B-SOSE, GECCO3, and WOA, respe

(b)



(c)



OUTLINE

1. Motivation
2. Result
    - ECCO v4r5 (+ECCO v4r4 if applicable), ECCO LLC270-alpha;
    - sea-ice cover (SSM/I);
    - freeboard + sea-ice thickness + snow depth (IceSat2/CryoSat2)
3. Summary

Comparison of Southern Ocean sea ice among different ECCOs

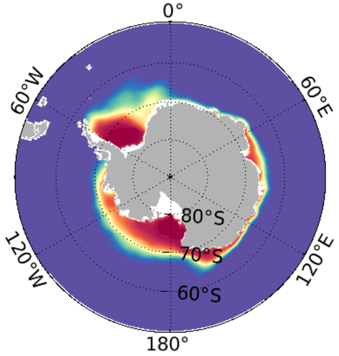
1. LLC270-alpha: ~1/3-degree, optimized over 1992-2017, extended 2018-near present
2. ECCO v4r4: ~1 degree, optimized over 1992-2017;
3. ECCO v4r5: ~1 degree, optimized over 1992-2019, extended 2020-near present

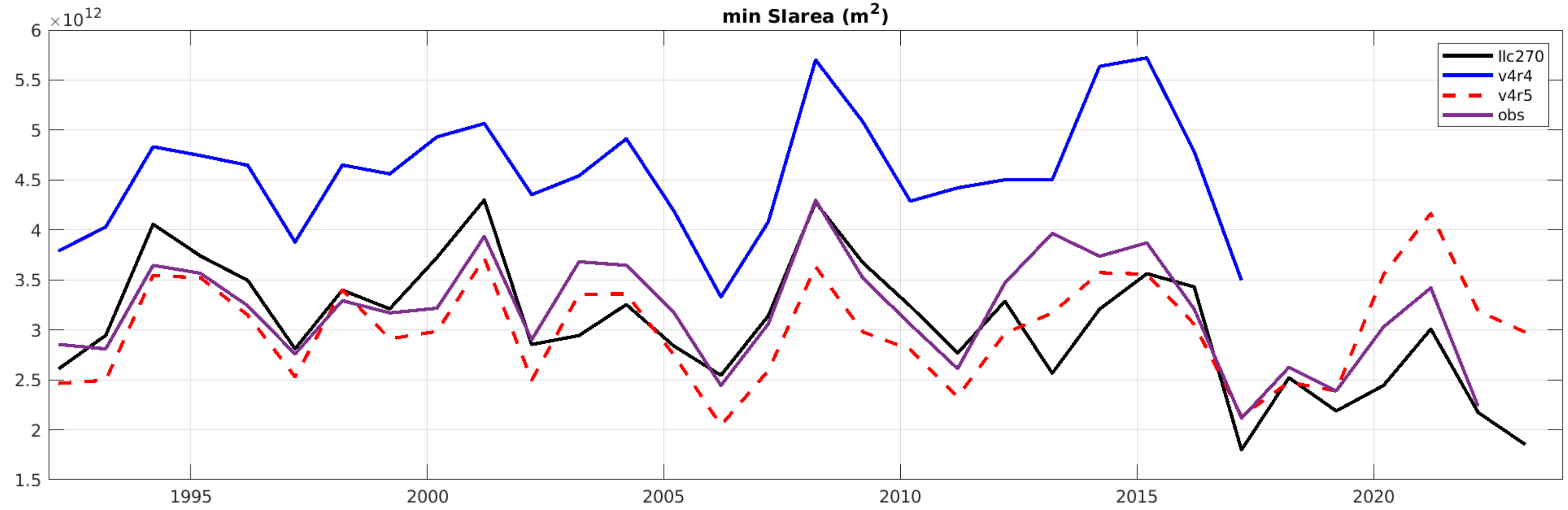
Comparison

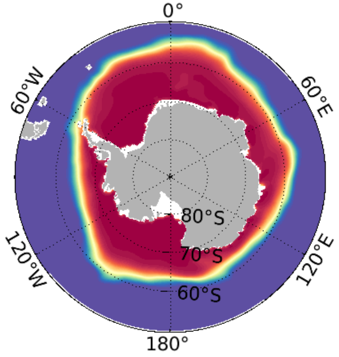
1. Time series of sea ice extent for the v4r4, v4r5, and llc270 vs SSM/I
   September (max) and March (min)

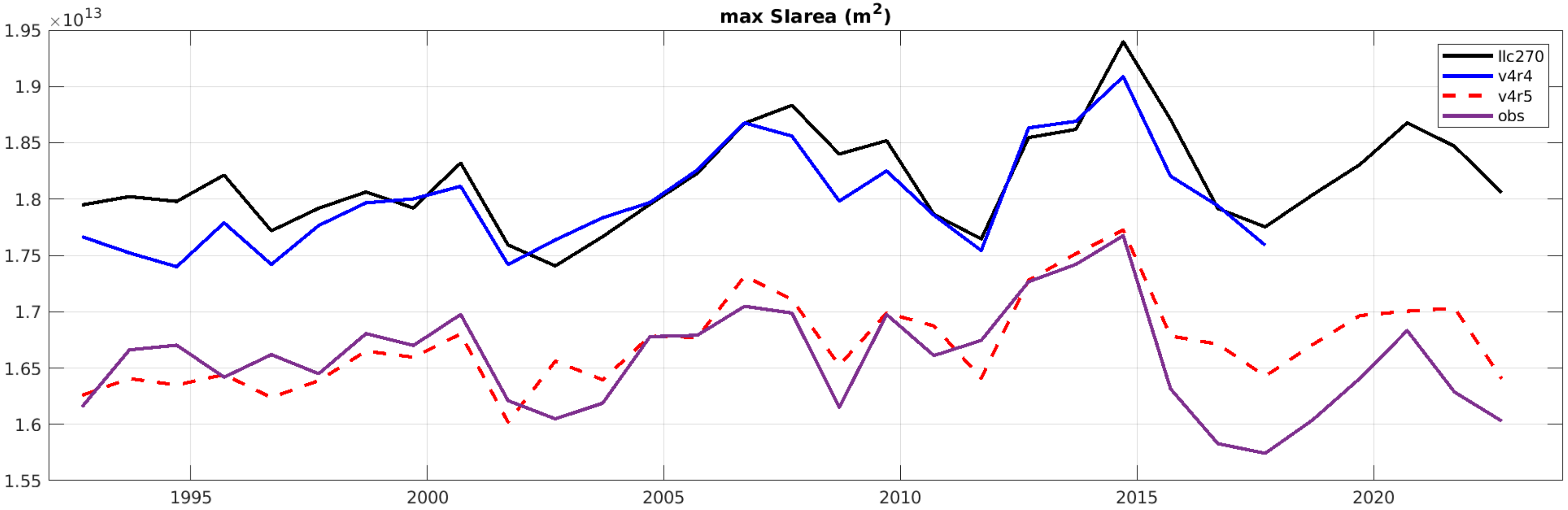
2. 2019-2022 period September and March mean
   sea-ice area,
   sea-ice freeboard,
   sea-ice thickness, and
   snow depth
   monthly mean and its anomaly pattern wrt 4-year mean
   observation: sea-ice cover from SSM/I (NSIDC);
      sea-ice freeboard from IS2 (courtesy of Ian Fenty@JPL)
      sea-ice thickness, snow depth from IS2/CS2 (courtesy of Sahra Kacimi@JPL)

Time series of sea-ice extent in SO



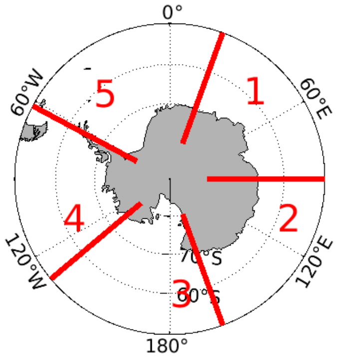


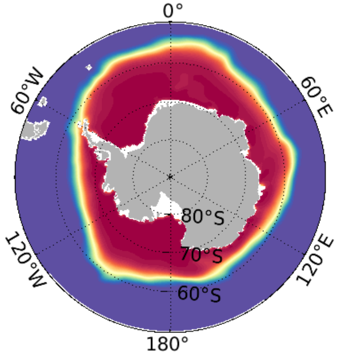


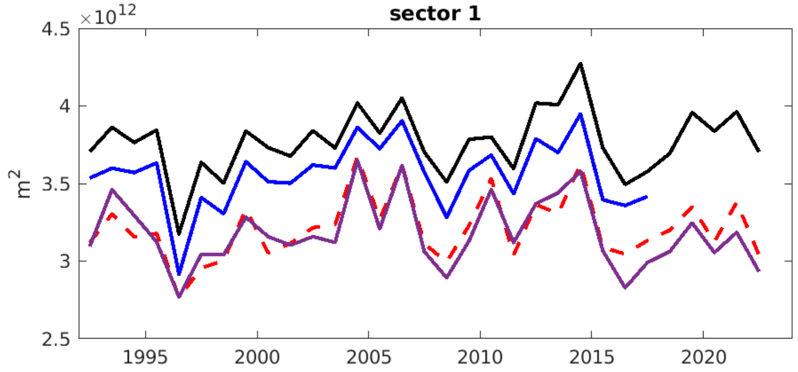


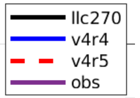
Time series of sea-ice extent in SO sectors

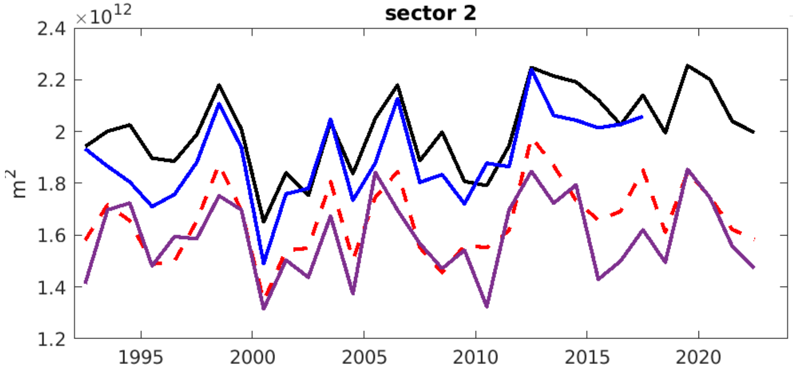
Sept mean

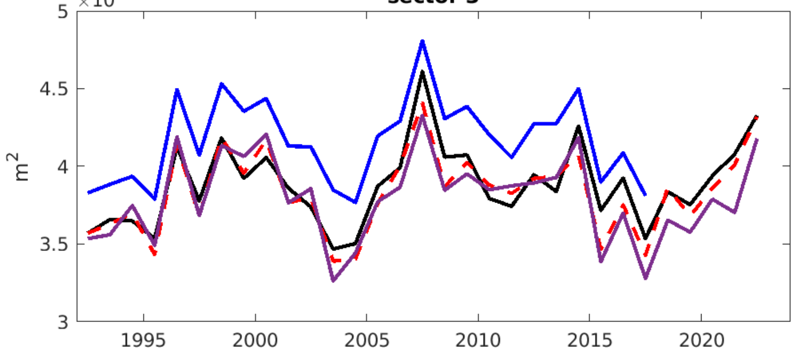


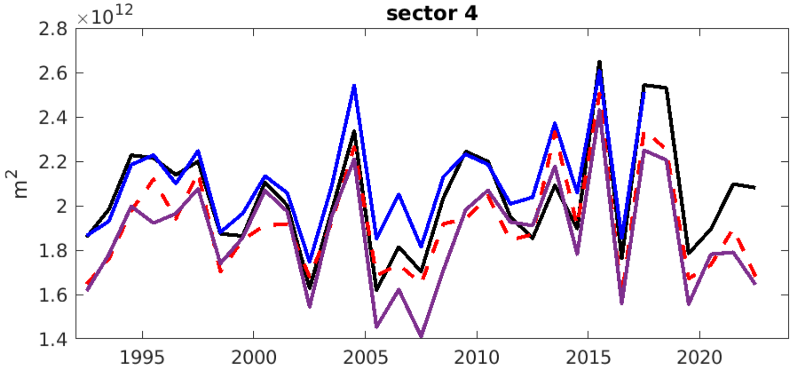


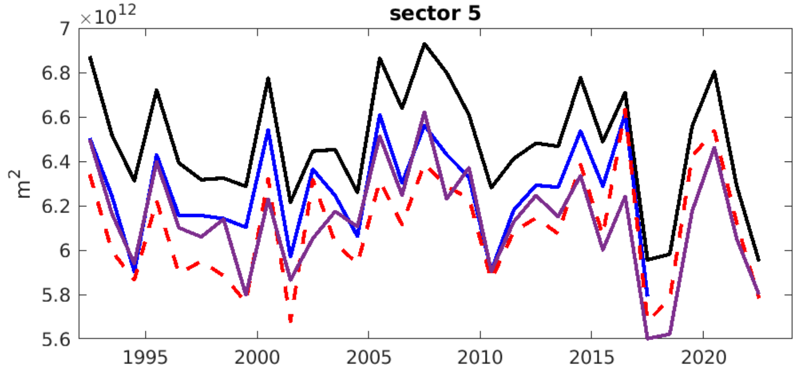






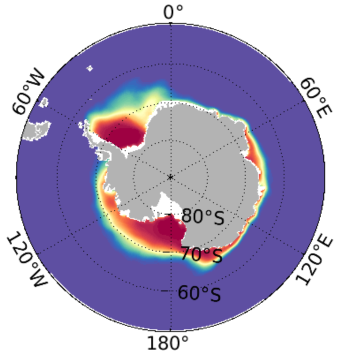


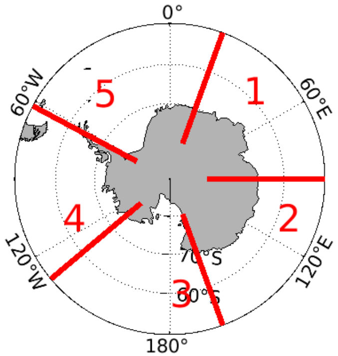


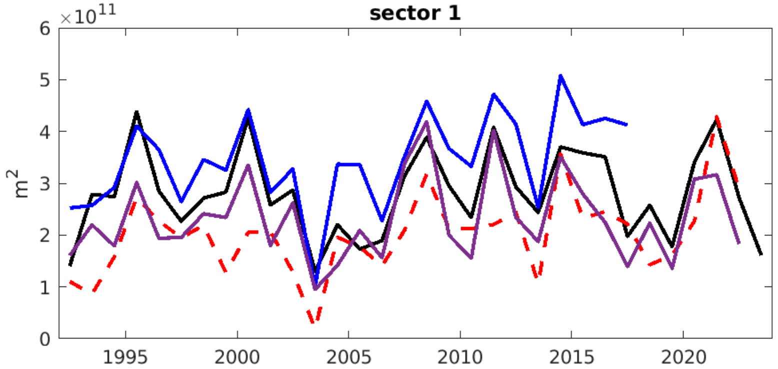


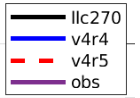
Time series of sea-ice extent in SO sectors

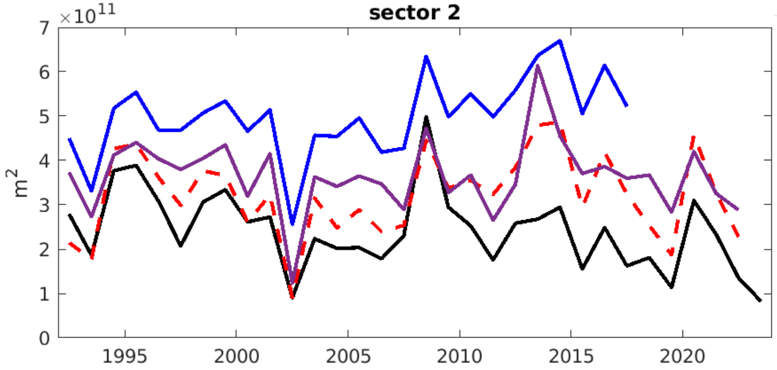
March mean

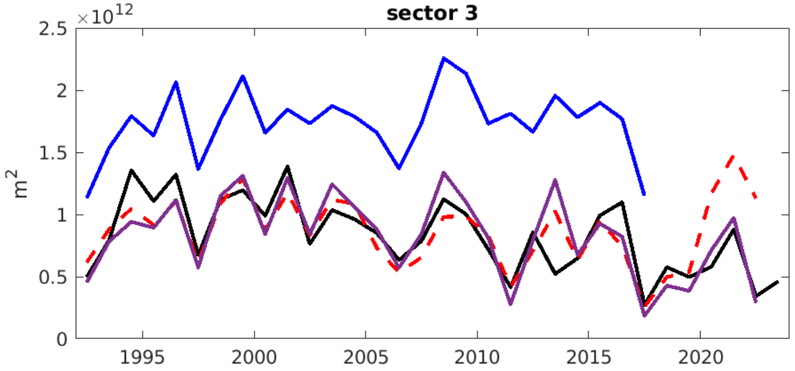


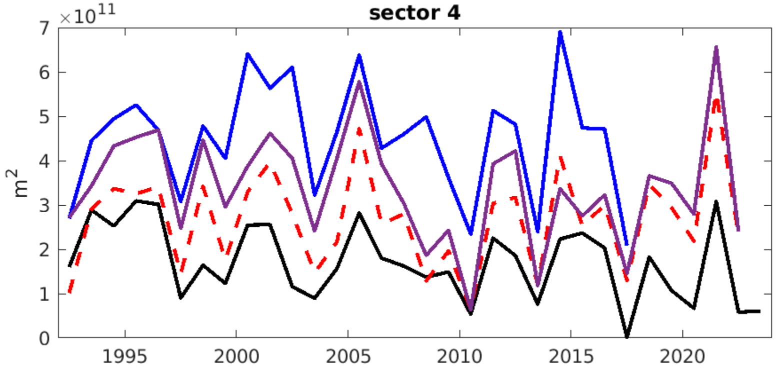


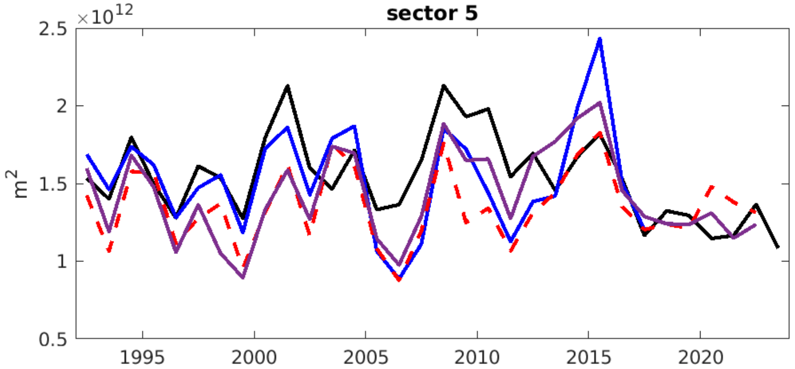






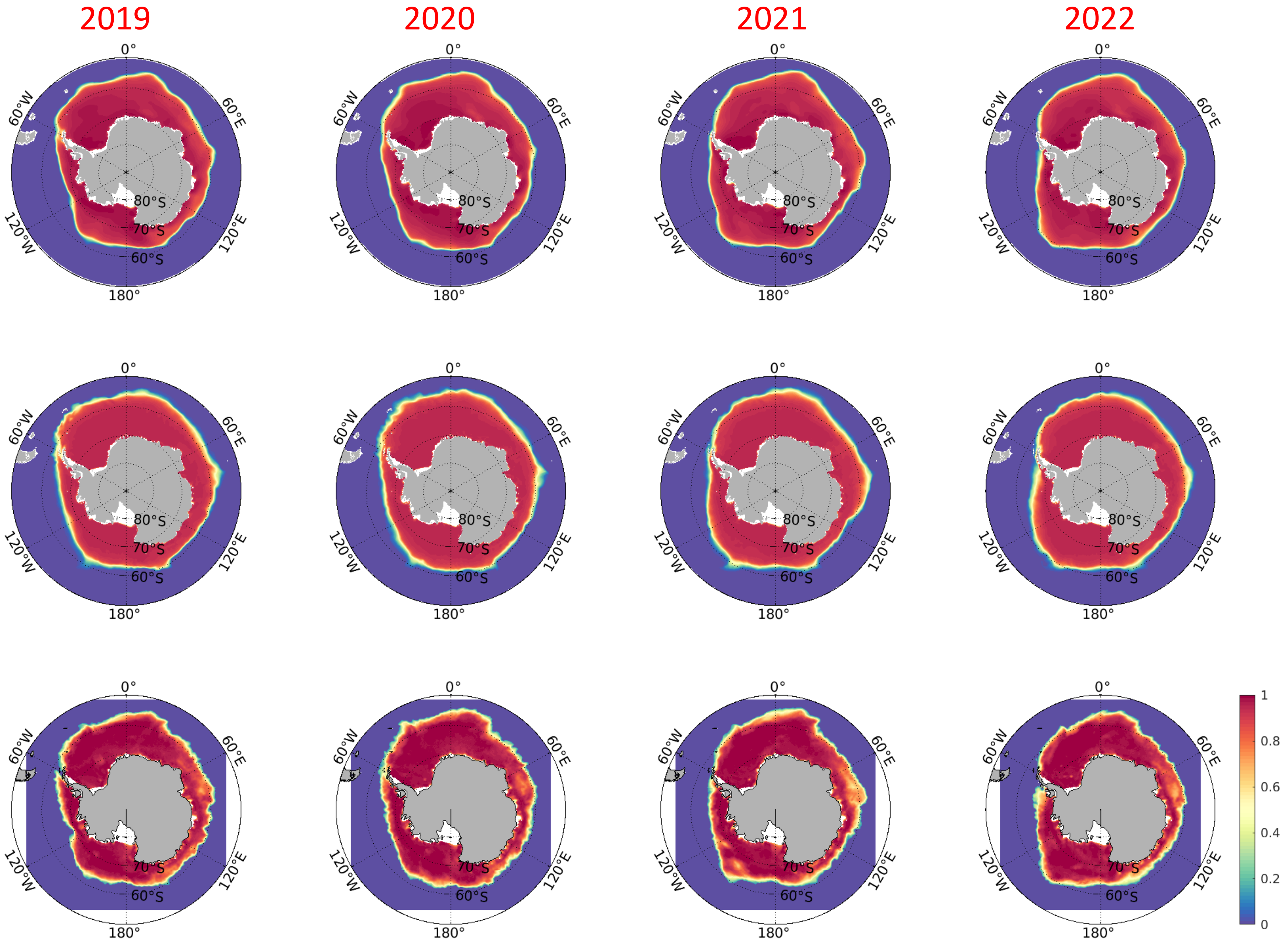






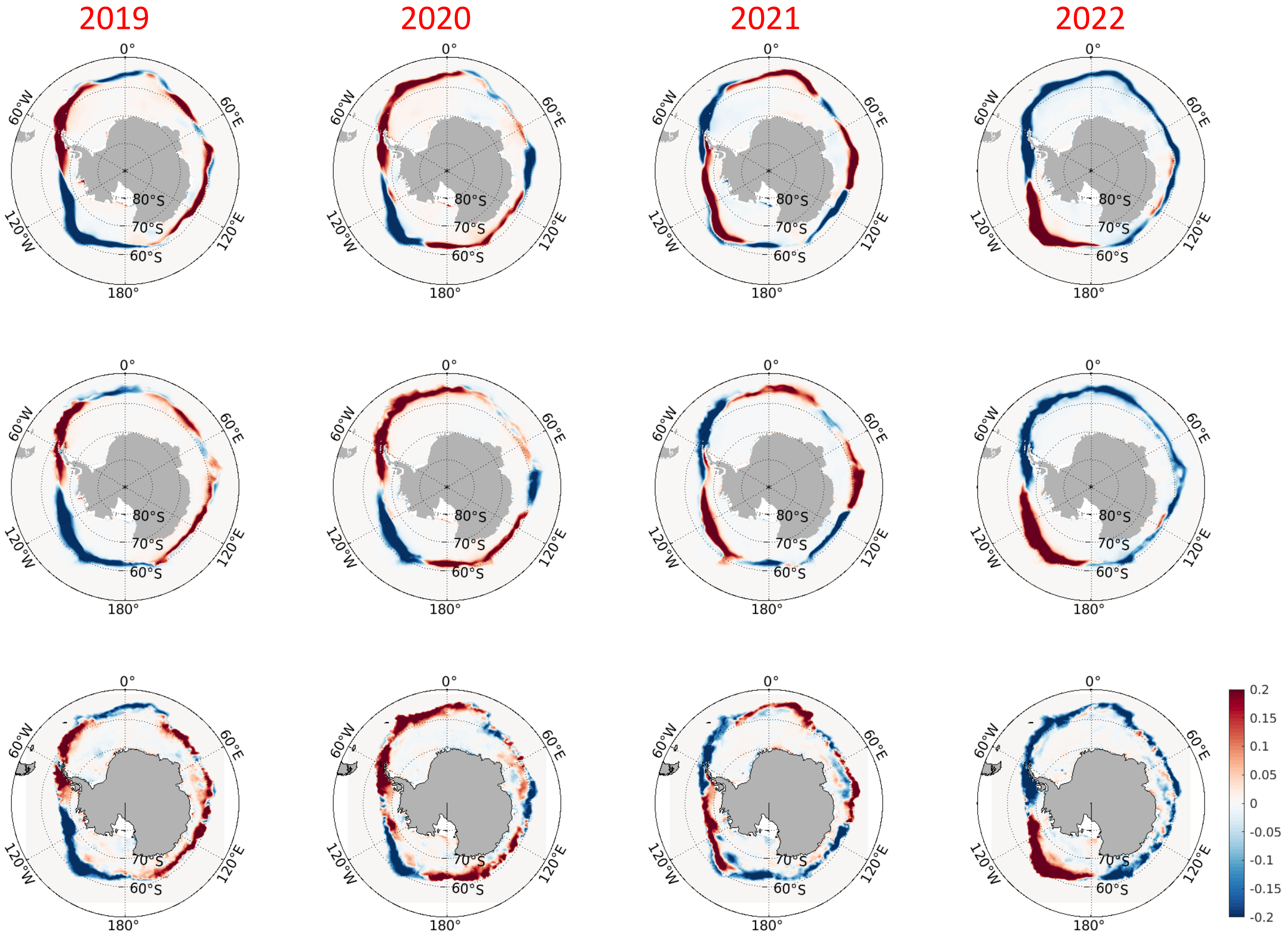
September
sea-ice area

Top: v4r5
Mid: llc270
Bottom: obs



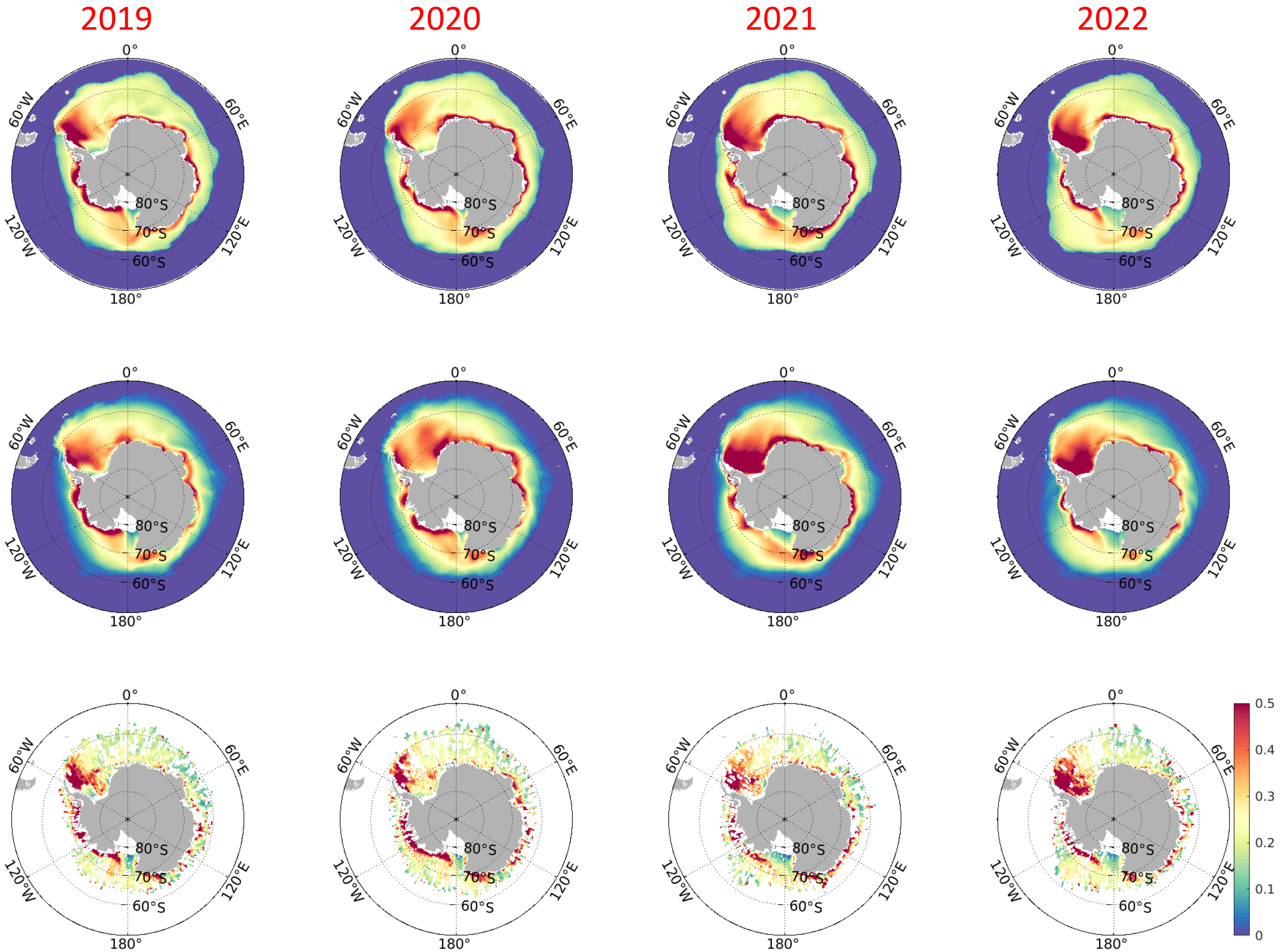
September
sea-ice area
anomaly

Top: v4r5
Mid: llc270
Bottom: obs



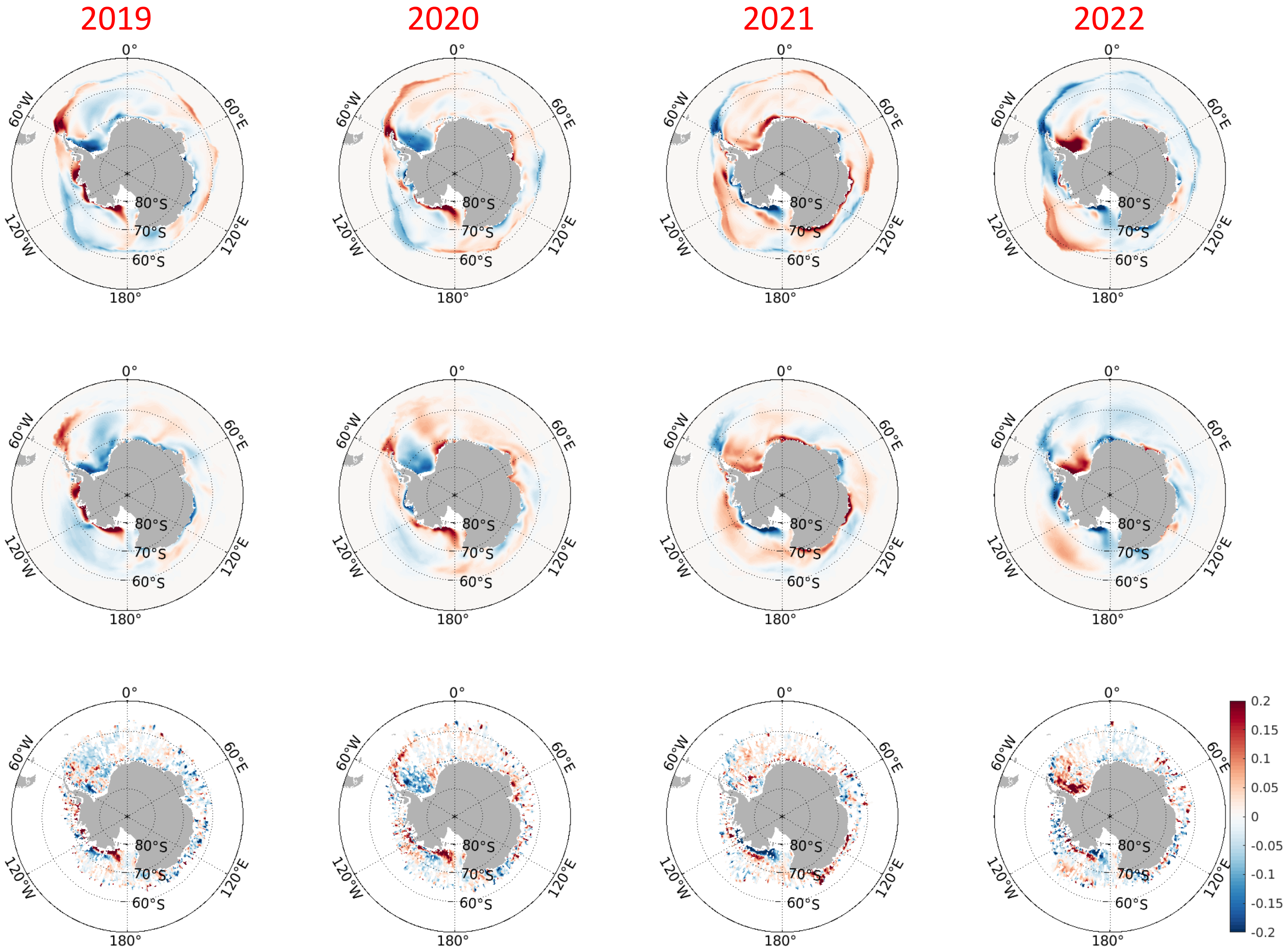
September sea-ice freeboard

Top: v4r5
Mid: llc270
Bottom: obs



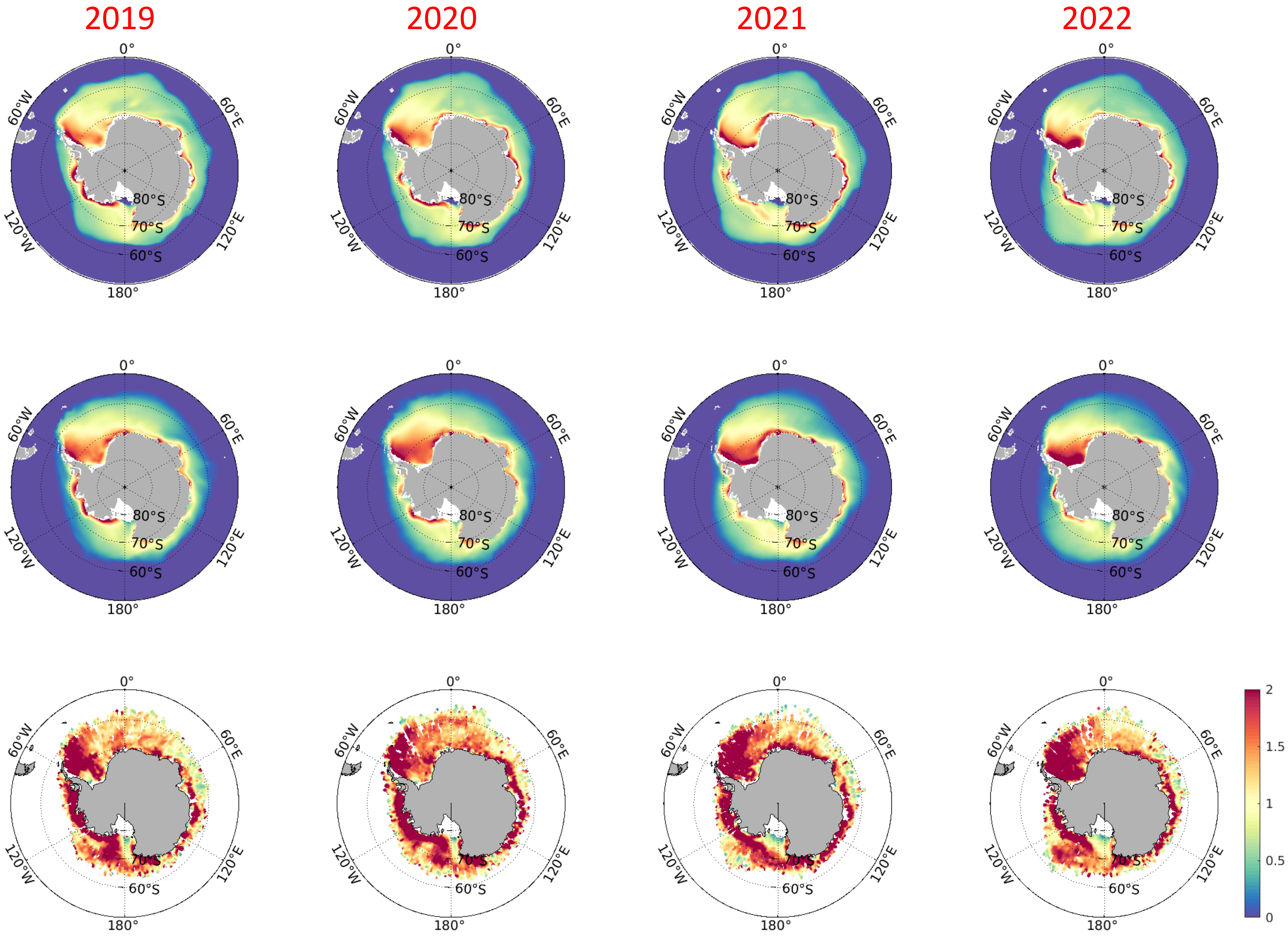
September sea-ice freeboard anomaly

Top: v4r5
Mid: llc270
Bottom: obs



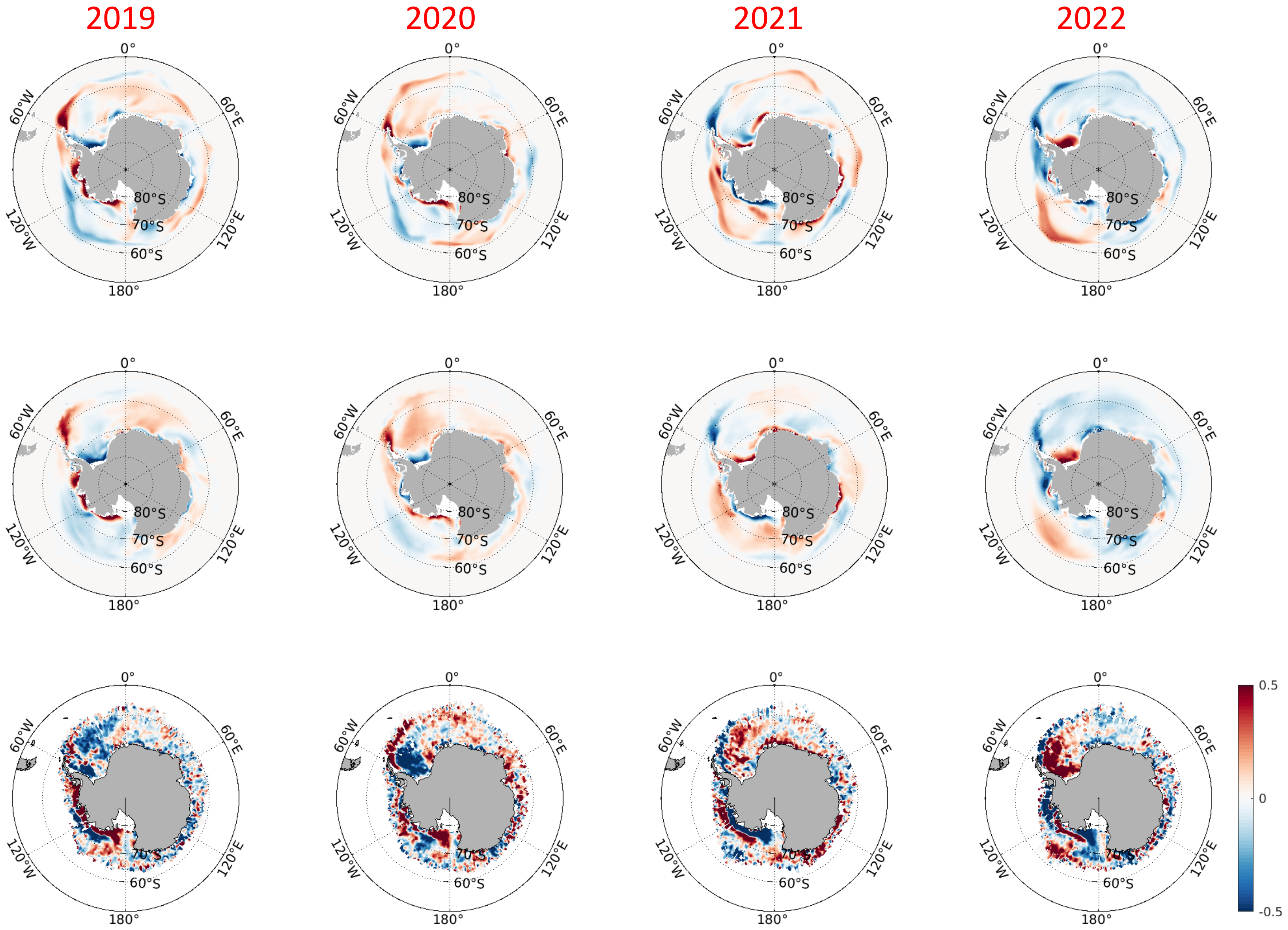
September
sea-ice
thickness

Top: v4r5
Mid: llc270
Bottom: obs



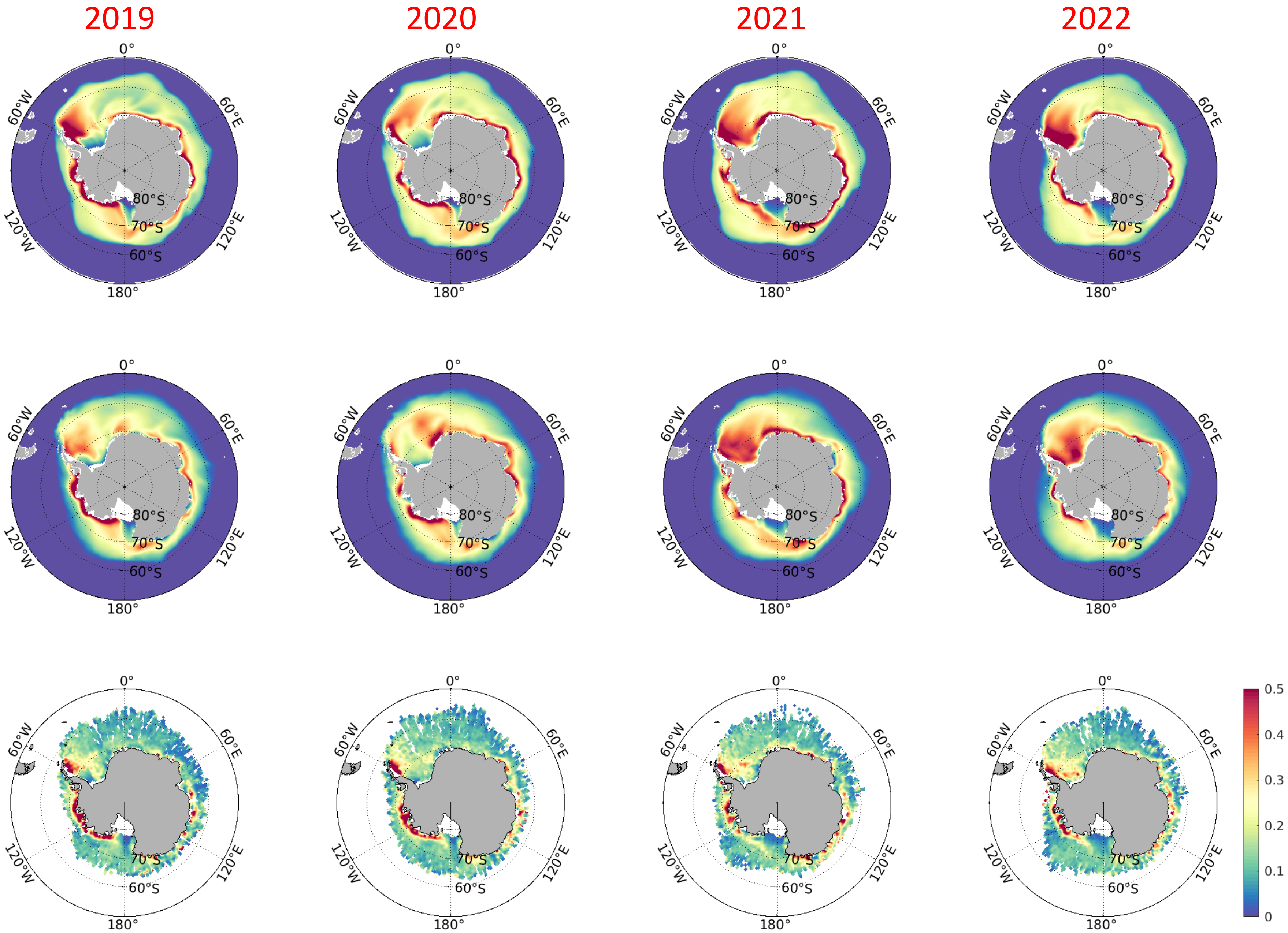
September sea-ice thickness anomaly

Top: v4r5
Mid: llc270
Bottom: obs



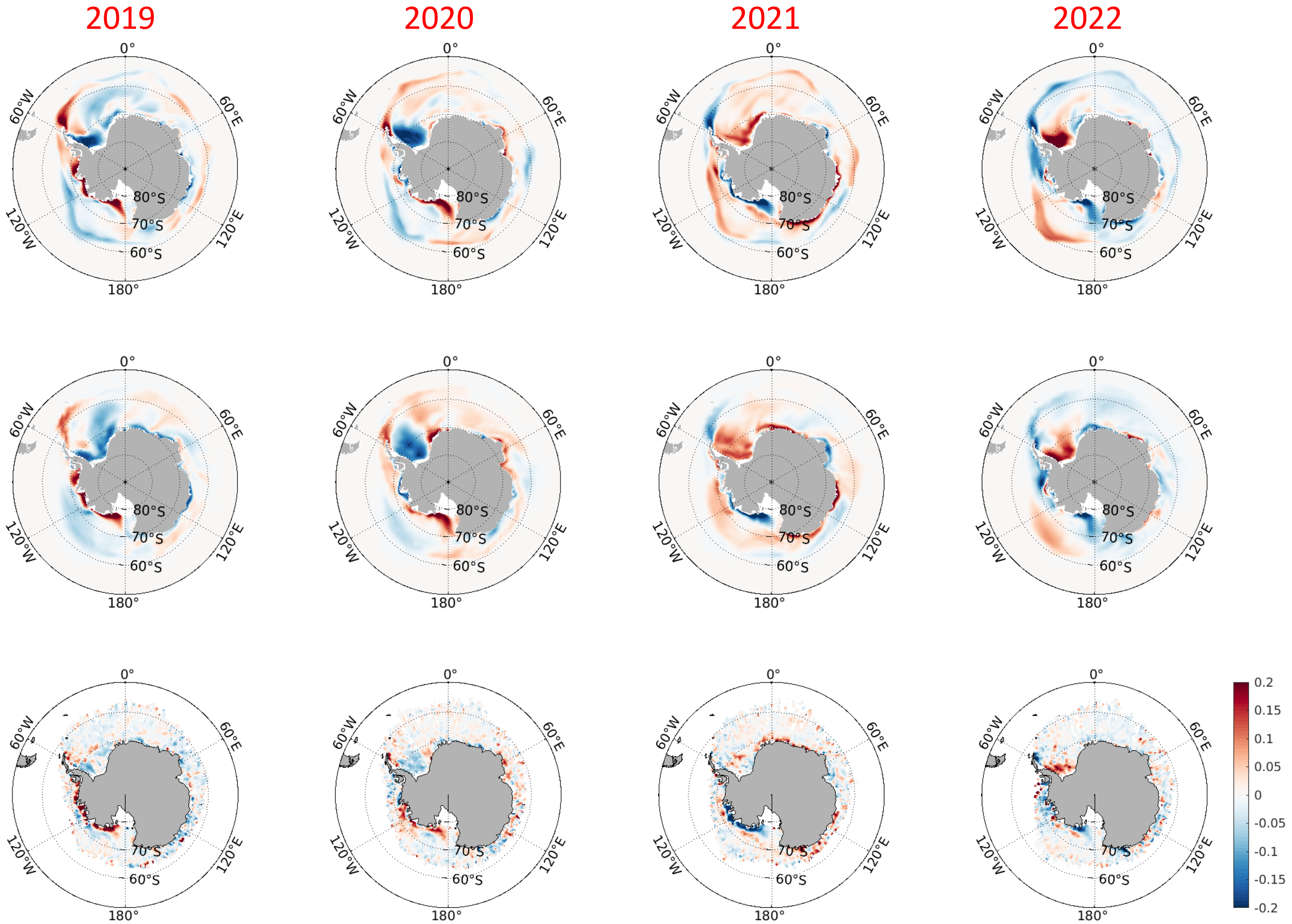
September
snow depth

Top: v4r5
Mid: llc270
Bottom: obs



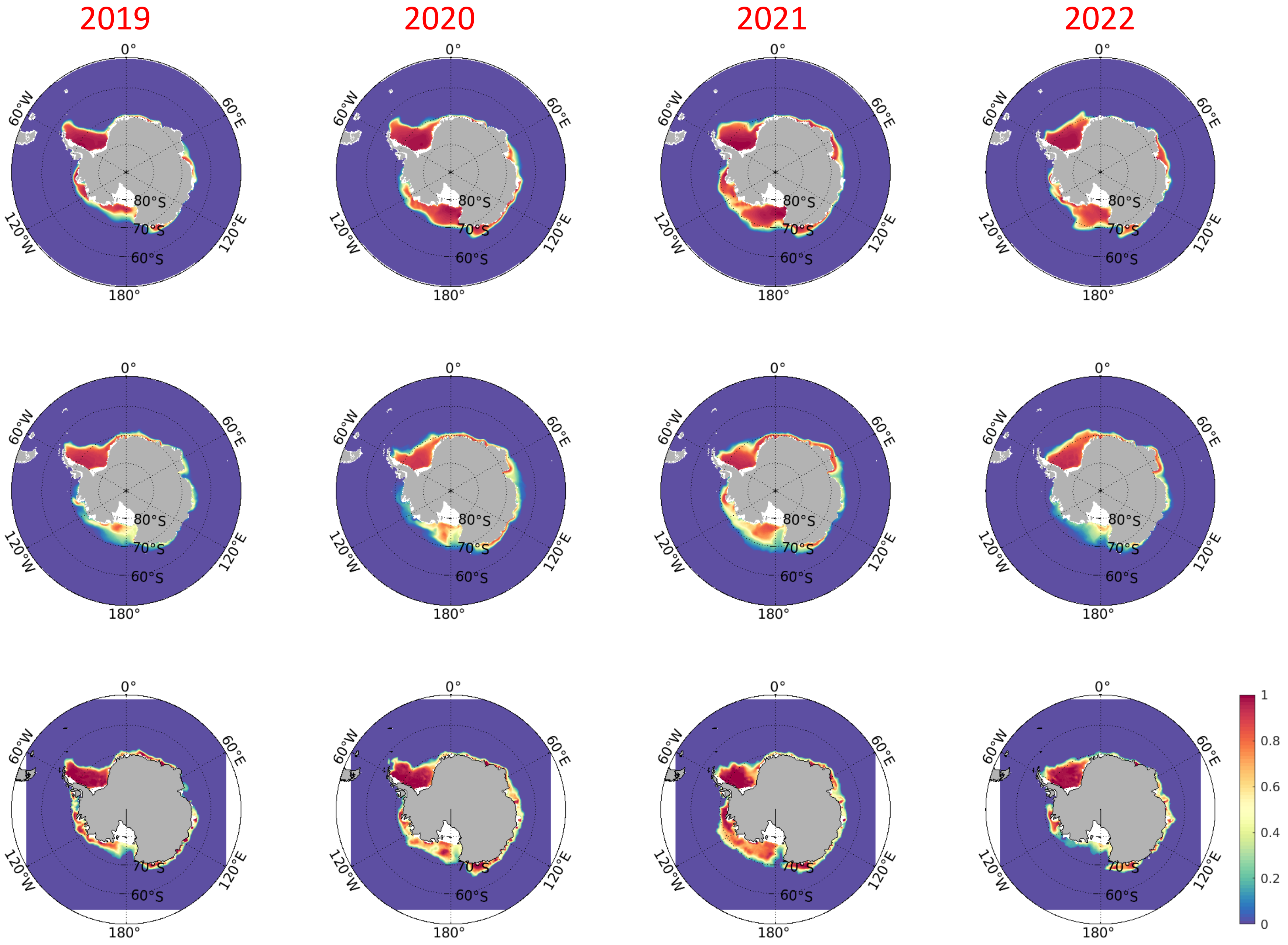
September snow depth anomaly

Top: v4r5
Mid: llc270
Bottom: obs



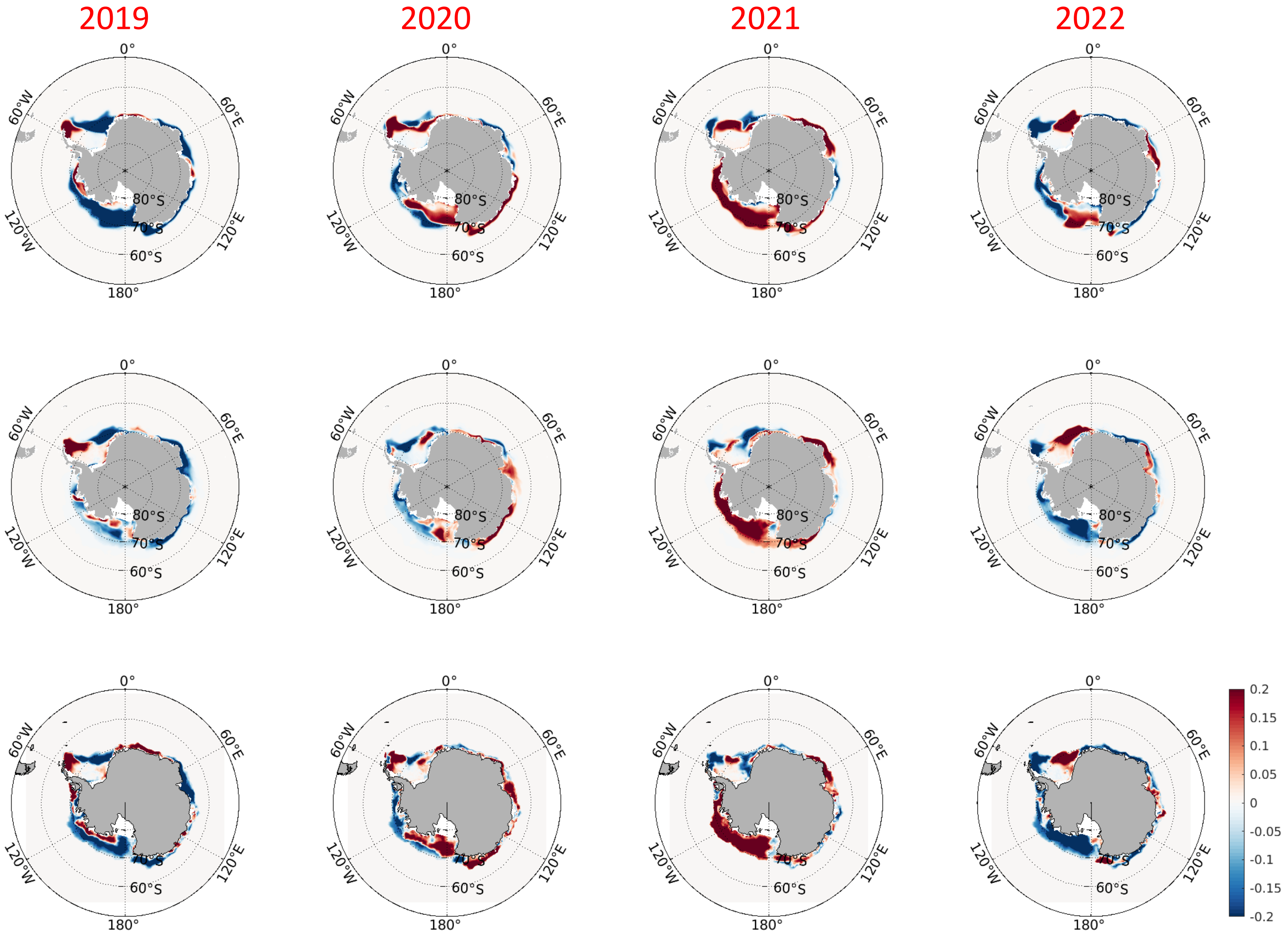
March
sea-ice area

Top: v4r5
Mid: llc270
Bottom: obs



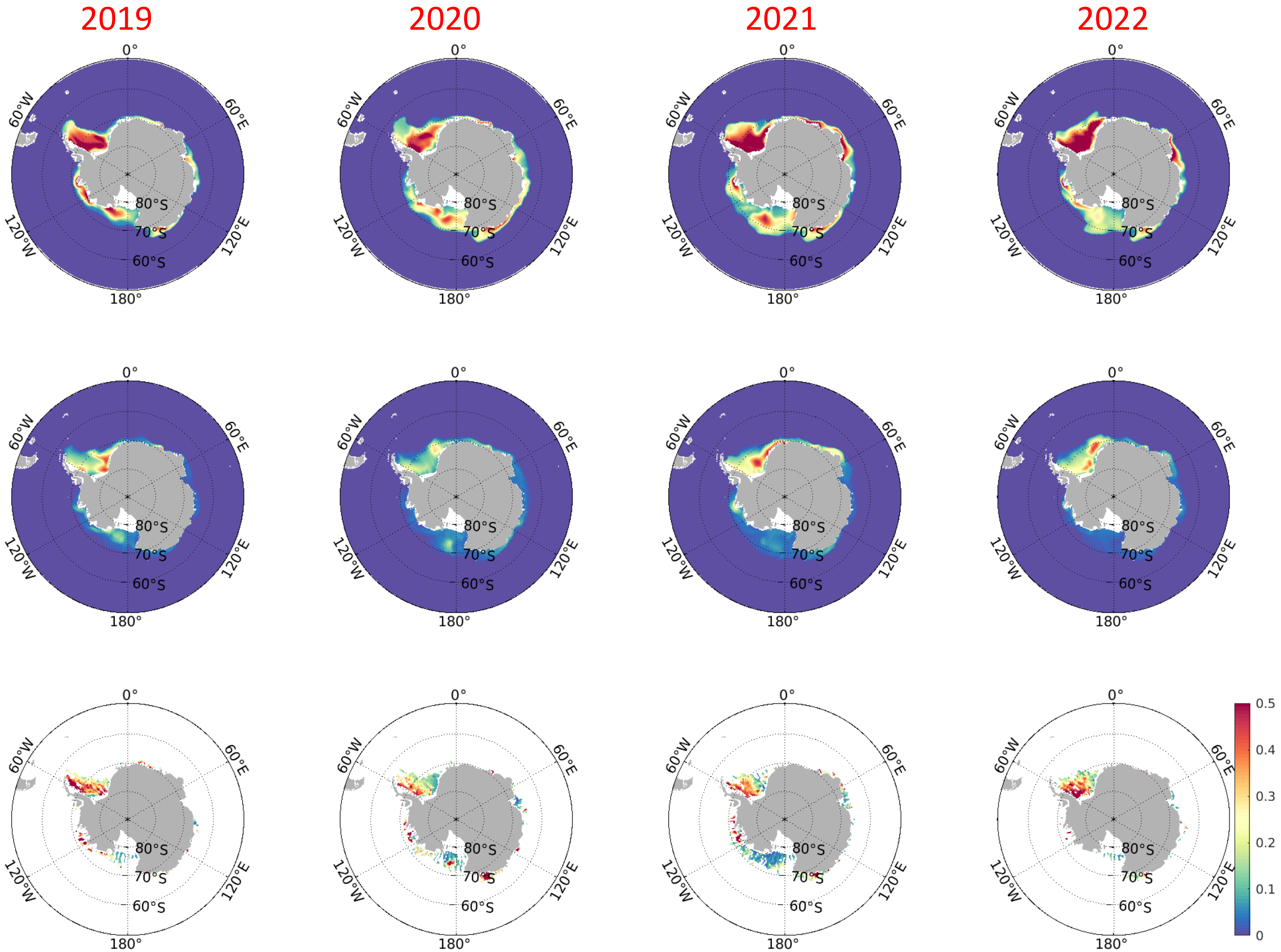
March
sea-ice area
anomaly

Top: v4r5
Mid: llc270
Bottom: obs



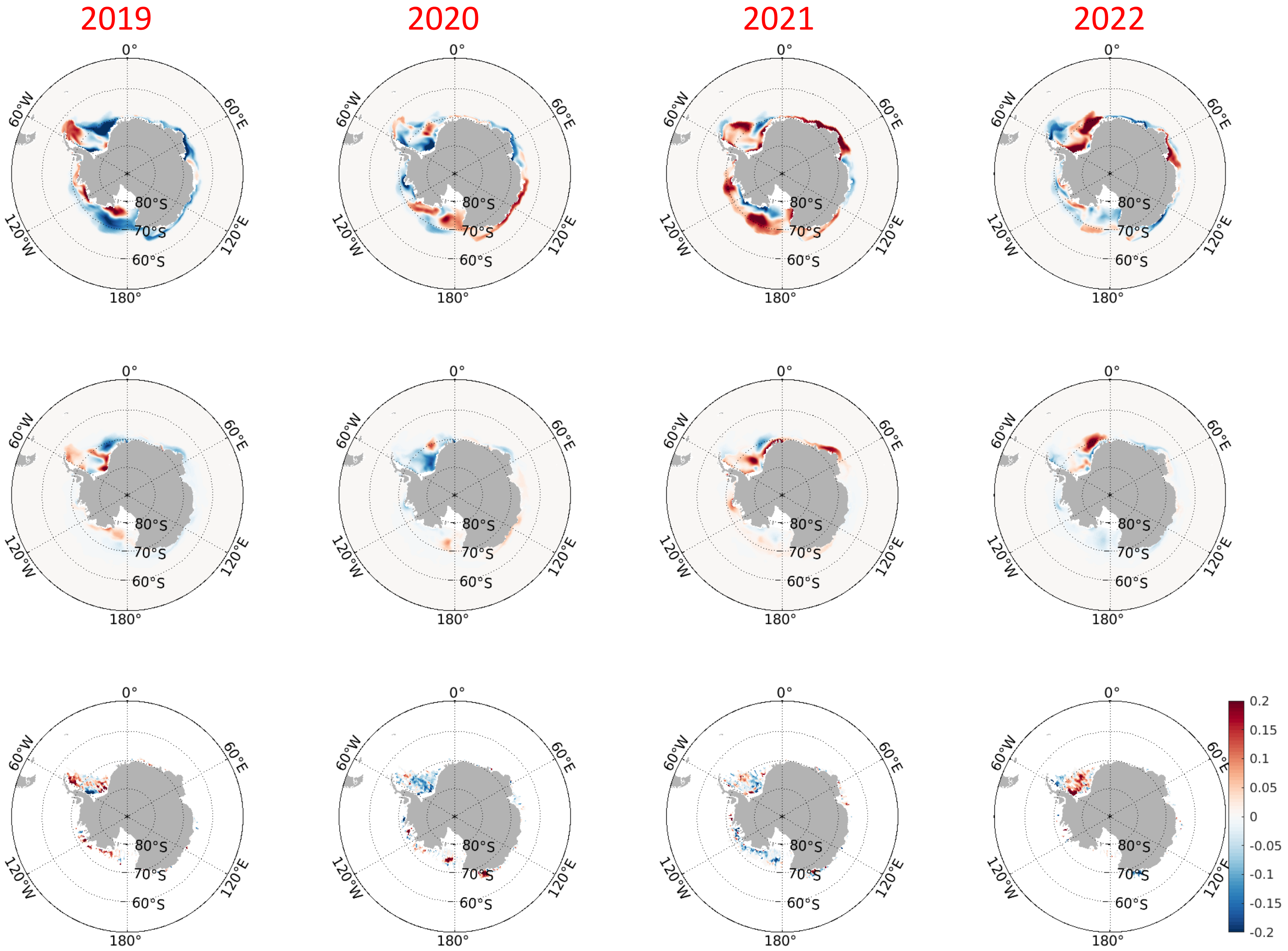
March
sea-ice
freeboard

Top: v4r5
Mid: llc270
Bottom: obs



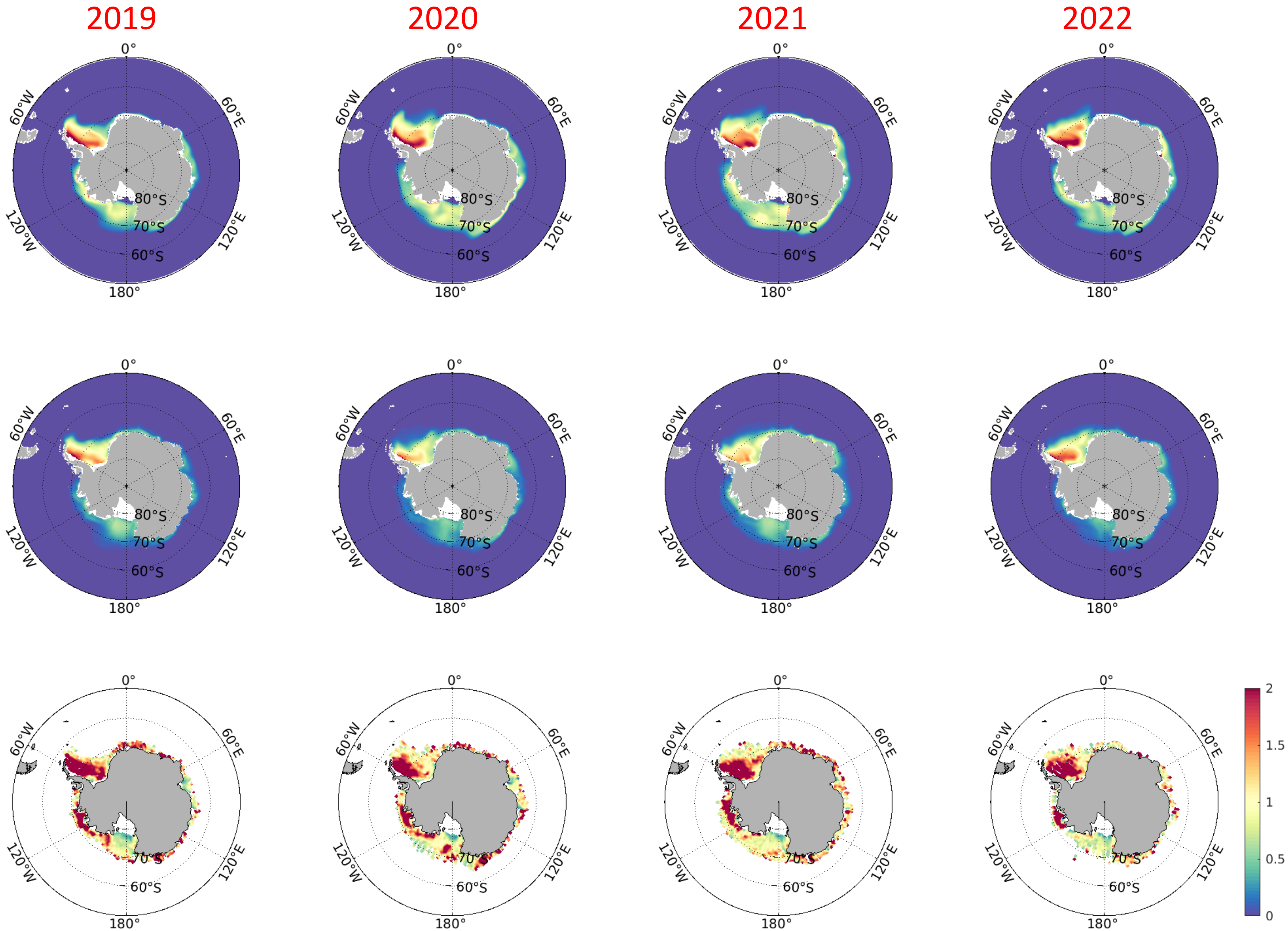
March
sea-ice
freeboard
anomaly

Top: v4r5
Mid: llc270
Bottom: obs



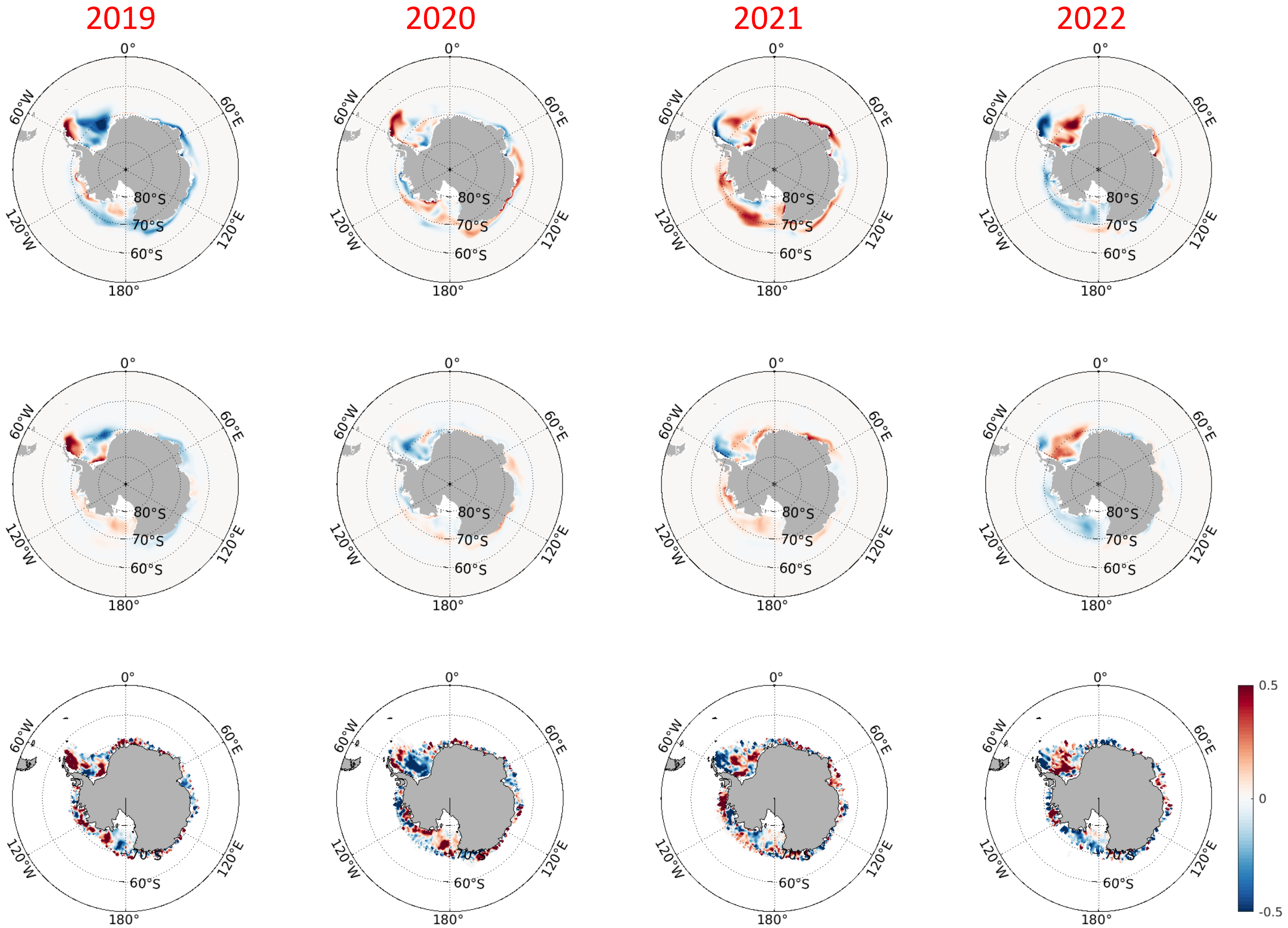
April
sea-ice
thickness

Top: v4r5
Mid: llc270
Bottom: obs



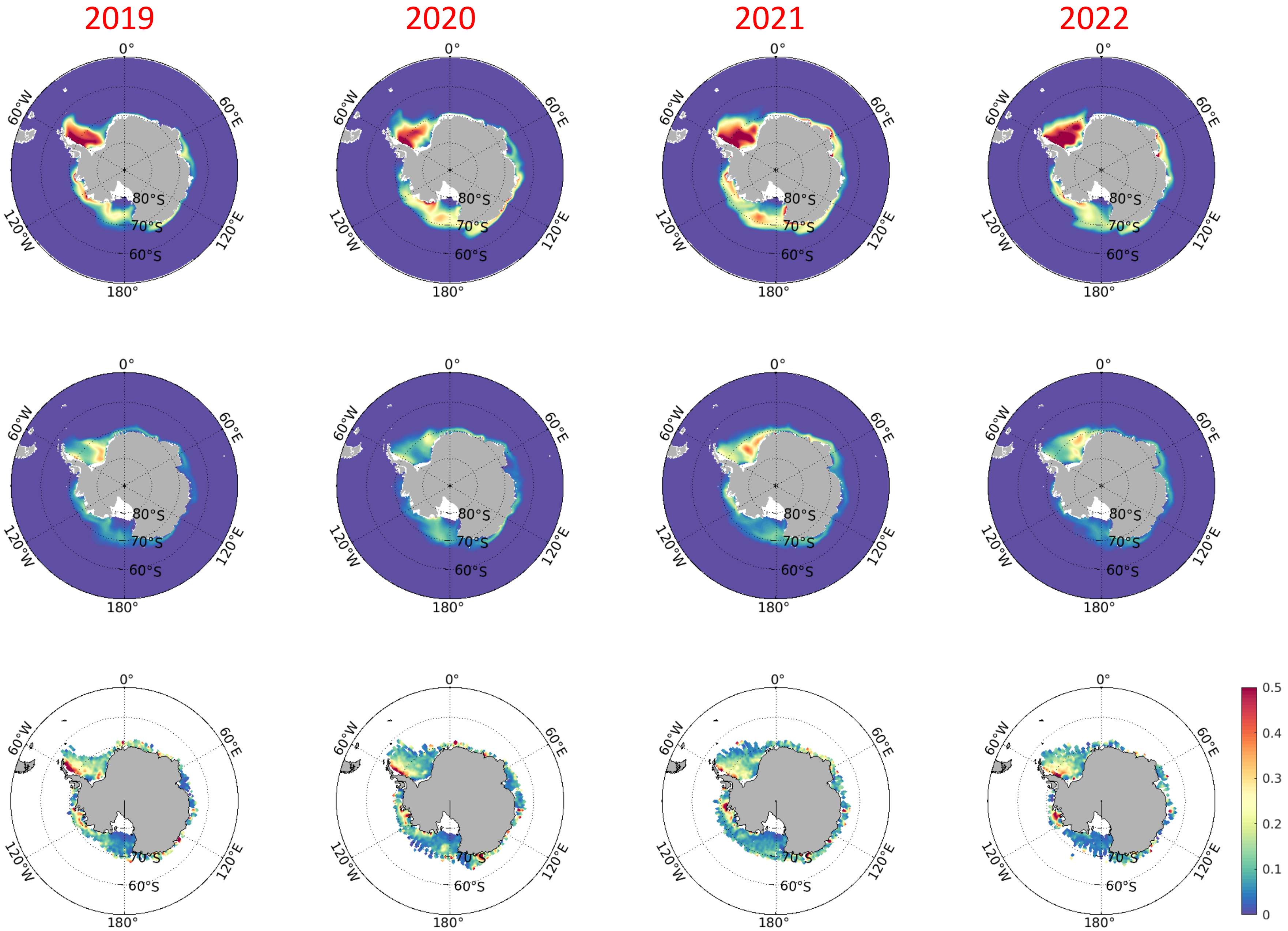
April
sea-ice
thickness
anomaly

Top: v4r5
Mid: llc270
Bottom: obs



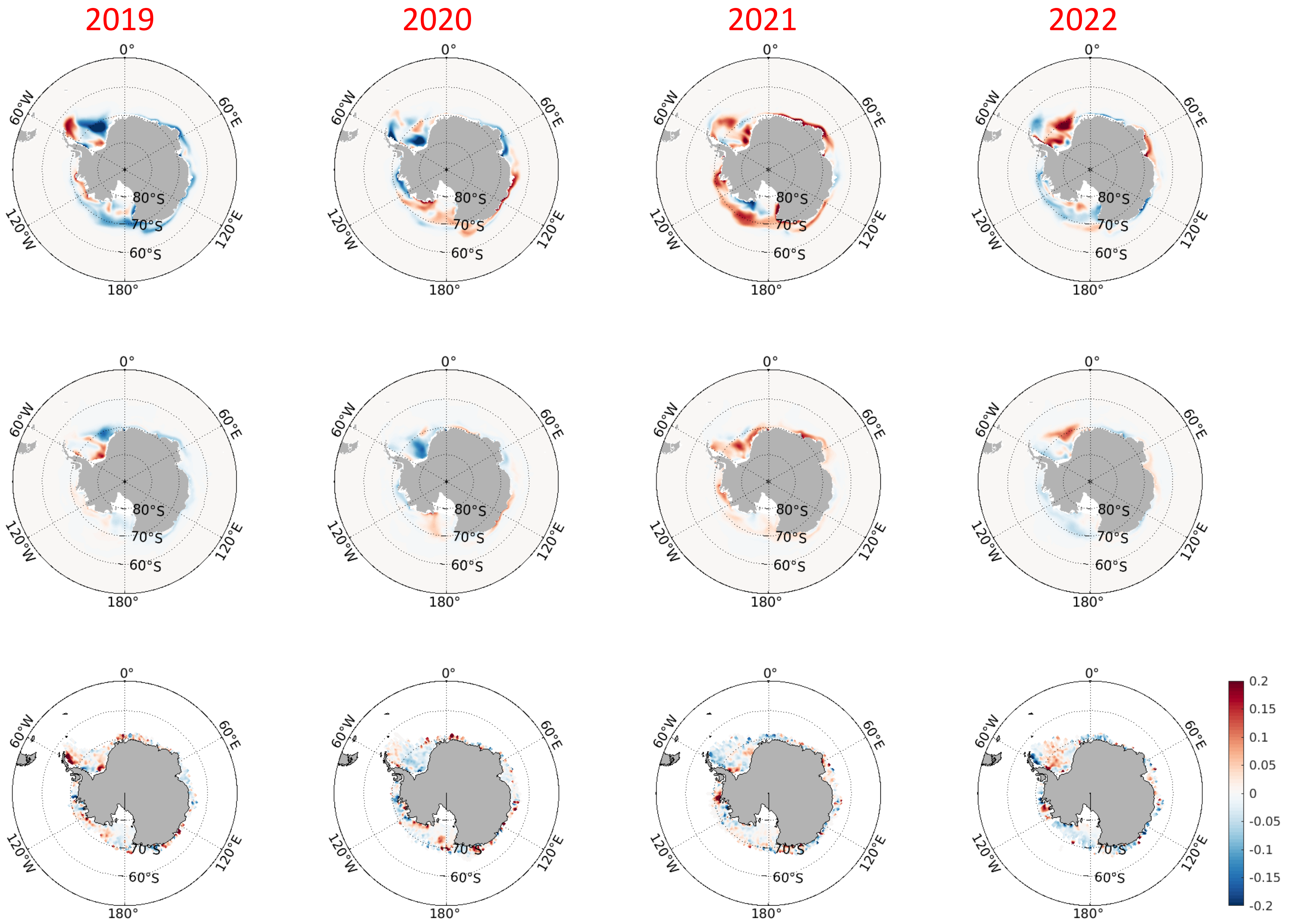
April
snow depth

Top: v4r5
Mid: llc270
Bottom: obs



April snow depth anomaly

Top: v4r5
Mid: llc270
Bottom: obs



OUTLINE

1. Motivation

2. Result

3. Summary

- ECCO-v4r5 has better agreement with satellite observation: b/c its sea-ice adjoint? Or ice-shelf package?

- “sub-optimal” extension seems working for variation of sea-ice cover: b/c realistic atmospheric re-analysis forcing? climatology adjustment?

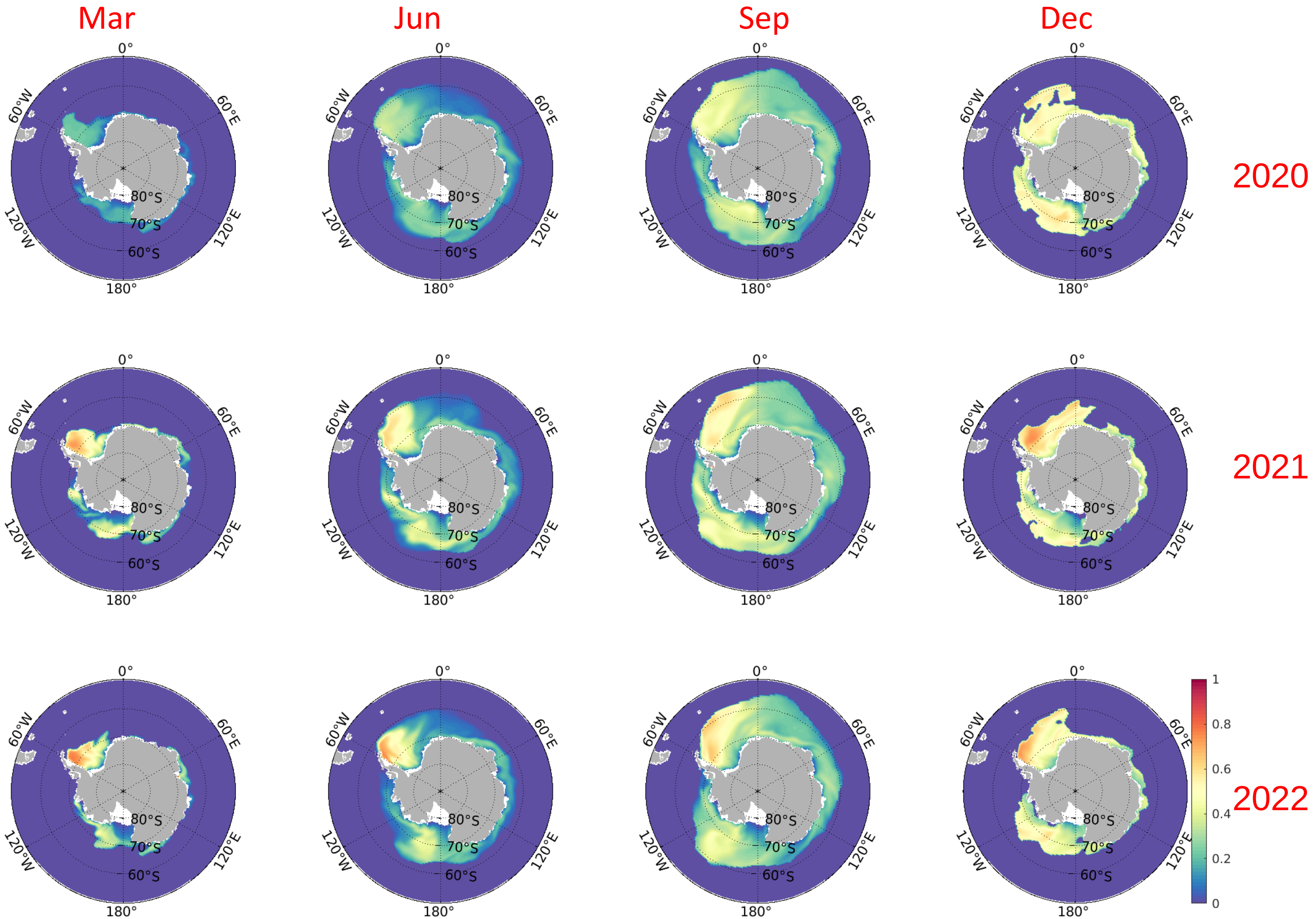
- large mismatch with observation of sea-ice freeboard, sea-ice thickness, and snow depth: including sea-ice freeboard observation (being employed in ongoing optimization) and even direct sea-ice thickness / snow depth observations for next-gen state estimate?

- additional angle: sea-ice age (MY, FY recent trend)?

extra

seasonal
sea-ice age
started from
2020/1/1

Top: Year 2020
Mid: Year 2021
Bot: Year 2022



Time series of sea-ice extent in Arctic Ocean