The influence of sea ice mean state on climate change and variability in the Community Earth System Model version 2

Jennifer Kay, University of Colorado - Boulder

Associate Professor, Dept. Atmospheric and Oceanic Sciences

Fellow, Cooperative Institute for Research in Environmental Sciences

With Patricia DeRepentigny, Marika Holland, David Bailey, Alice DuVivier, Ed BW, Clara Deser, Alexandra Jahn, Hansi Singh, Madison Smith, Melinda Webster, and Sun-Seon Lee, Nan Rosenbloom, Jim Edwards, Keith Rodgers
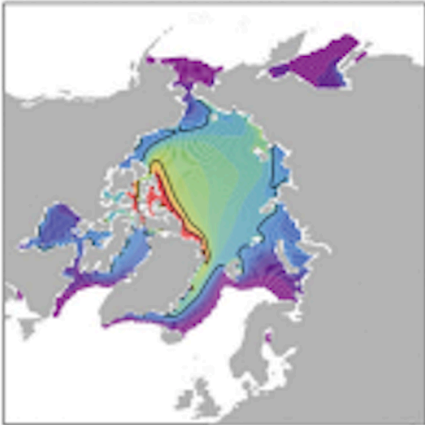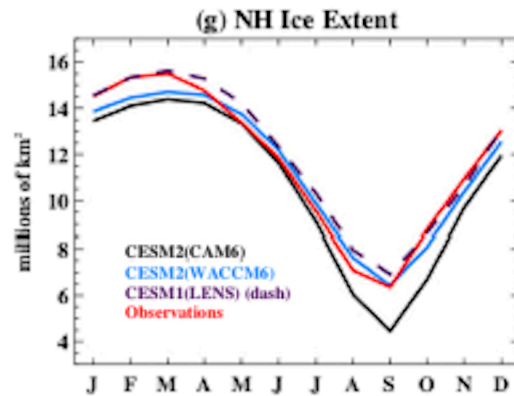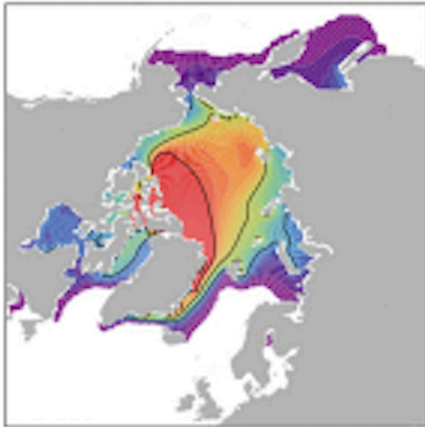
CESM PCWG Winter Meeting 2021

CESM2-CAM6 thin Arctic sea ice – Is this model "fit for task"?

(a) CESM2(CAM6) Ice Thickness

(e) CESM1(LENS) Ice Thickness

(g) NH Ice Extent

CESM2(CAM6)
CESM2(WACCM6)
CESM1(LENS) (dash)
Observations

Danabasoglu et al. 2020
CESM2 Description Paper

(a) Sept. Sea Ice Area (million km²)

NSIDC
CESM2(CAM6)
CESM2(WACCM6)
CESM-LE
CMIP6

(a)

SSP5-8.5
SSP3-7.0
SSP2-4.5
SSP1-2.6
Historical

CESM2(CAM6)
CESM2(WACCM6)
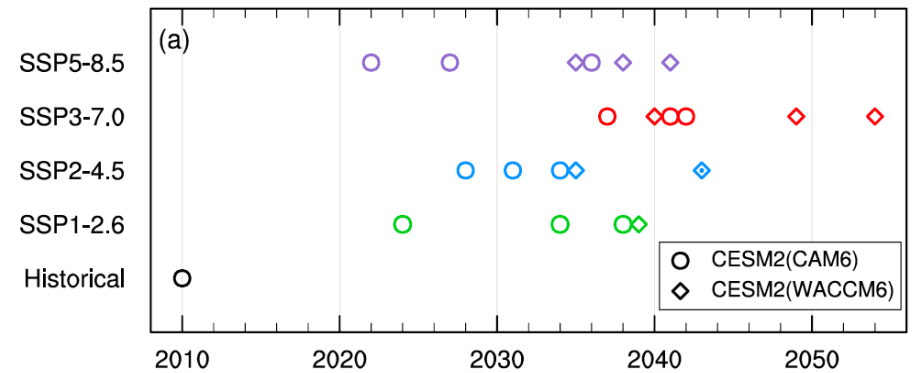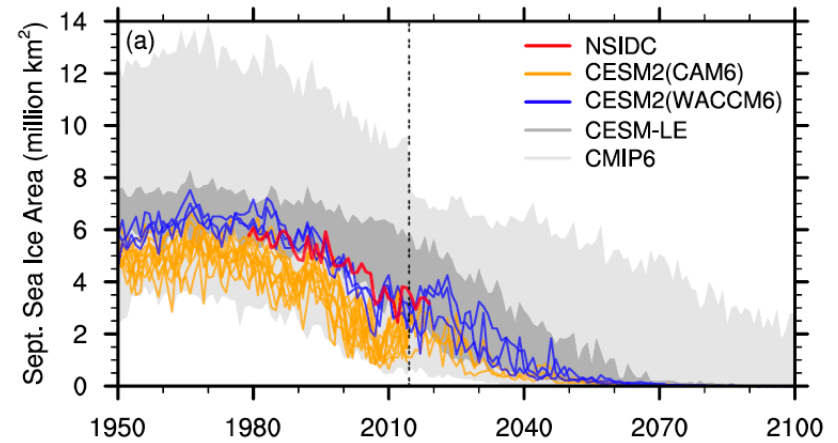
DeRepentigny et al. 2020
CESM2 Arctic Sea Ice Projections Paper

Should we "street tune" CESM2 sea ice?

(remember context: CESM2 Labrador sea ice expansion! Very little interest in sea ice expansion/tuning after CESM2 development...)

A **street tune** is tuning in the cars actual environment, on the street in actual driving conditions.

CESM2-tunedice experiments have:

1) r_snw = 1.5 (from 1.25) → slightly smaller snow grain radius and higher snow on sea ice albedo,

2) dt_mlt = 1.0 (from 1.50) → the melt onset temperature is 0.5 C higher.

No other tuning was done.

| Name	Description	Reference	# Ensemble Members 1920-2100	Length 1850 Pre-industrial Control
CESM2	CESM2 Large Ensemble and CMIP6 PI control run (same model version as CMIP6 CESM2-CAM6)	Rodgers et al. (in prep), Danabasoglu et al. 2020	50 1-10 "macro", 11-20 "micro1", 21-30 "micro2", 31-40 "micro3", and 41-50 "micro4"	1300 (more years available but CMIP6 on disk only goes to 1200…)
CESM2-tunedice	CESM2 with tuned sea ice as described in text	(this work)	4	550

Table 1. Community Earth System Model (CESM) version 2 model simulations used in this work. All simulations use the Community Atmosphere Model version 6 (CAM6). Thus, we refer to the two configurations as CESM2 and CESM-tunedice. *Note: The CESM2-tuned ice 1850 control run was branched from year 811 of the CESM2 1850 control run.*
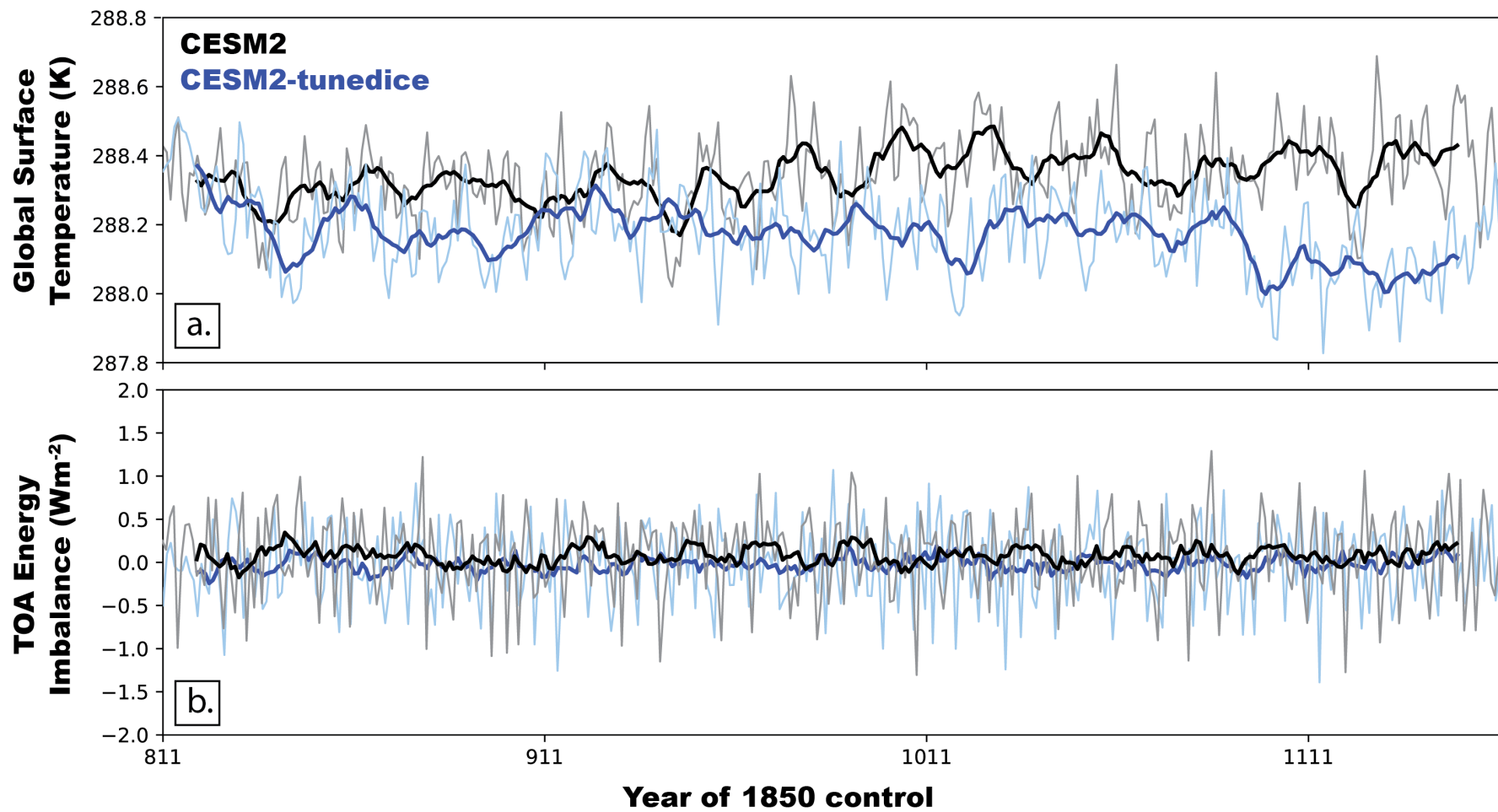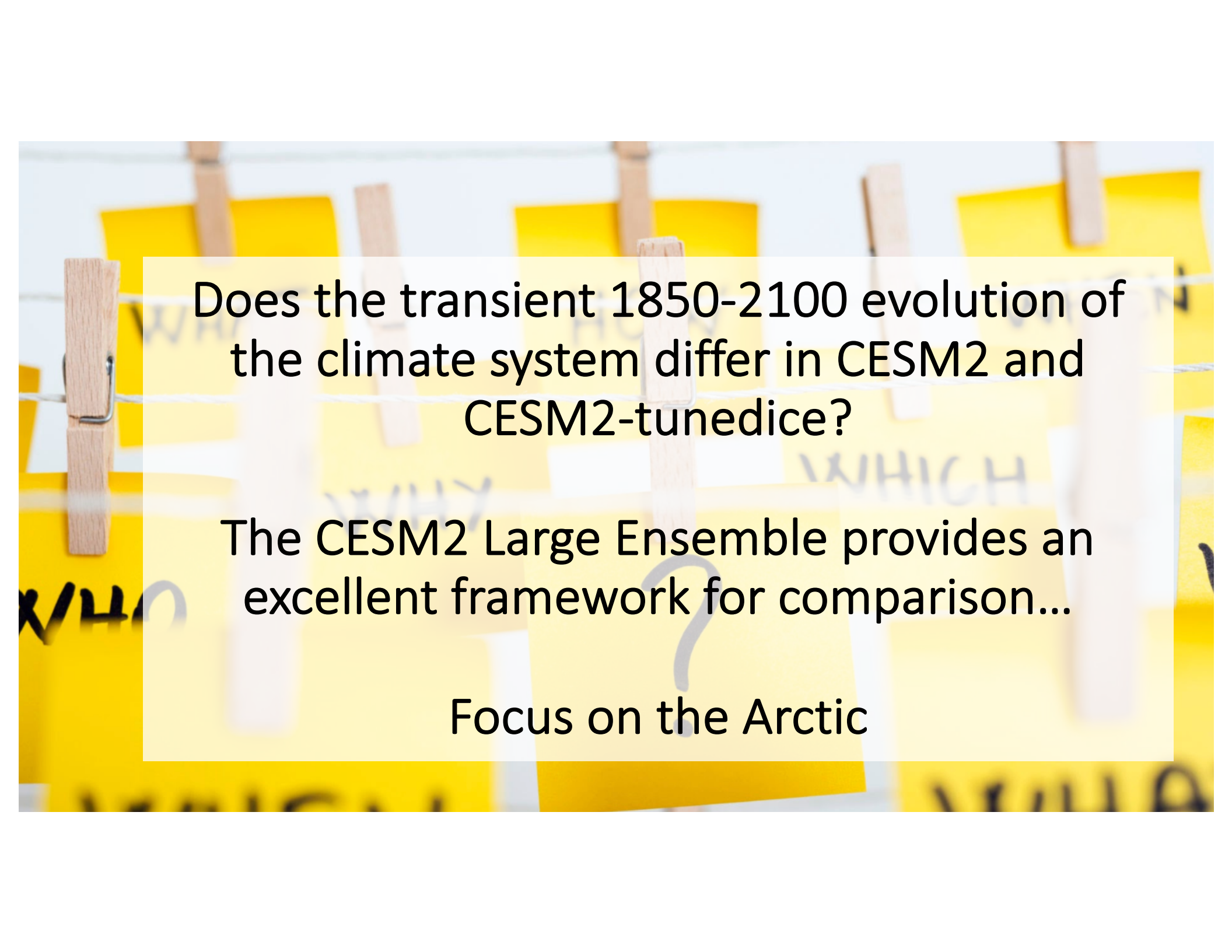
Global annual mean timeseries of overlapping years of the CESM2 and CESM2-tunedice preindustrial control runs: a) surface temperature (K), b) Top-of-model energy imbalance (Wm^{-2}). The thick lines show a 10-year running mean.
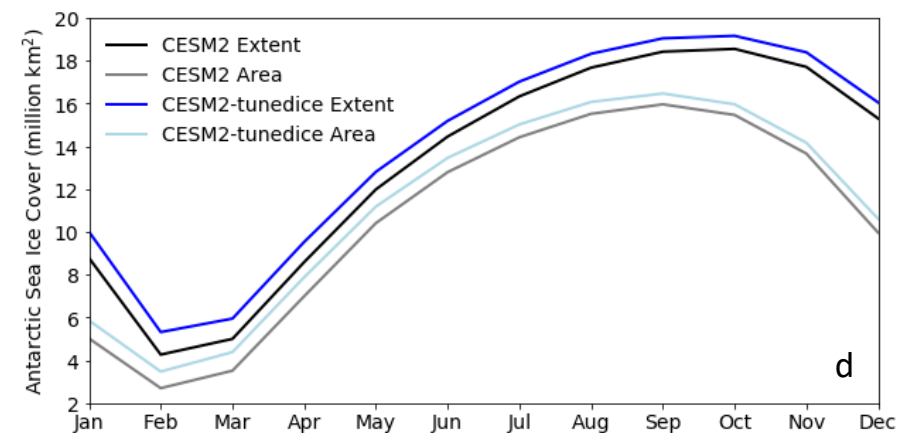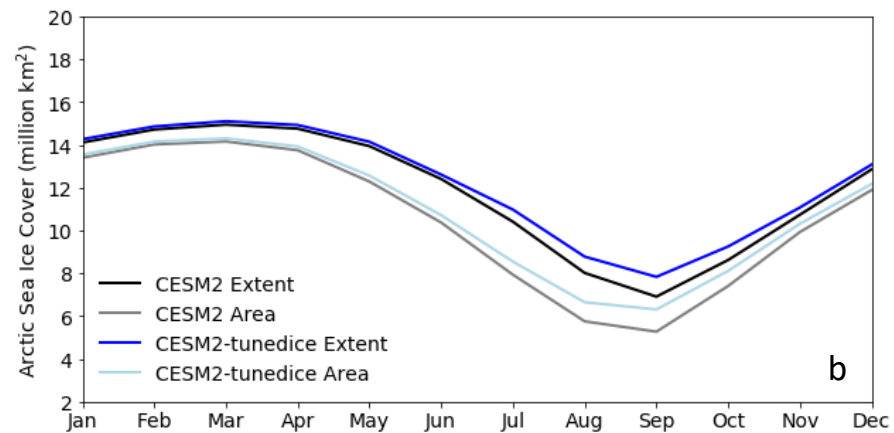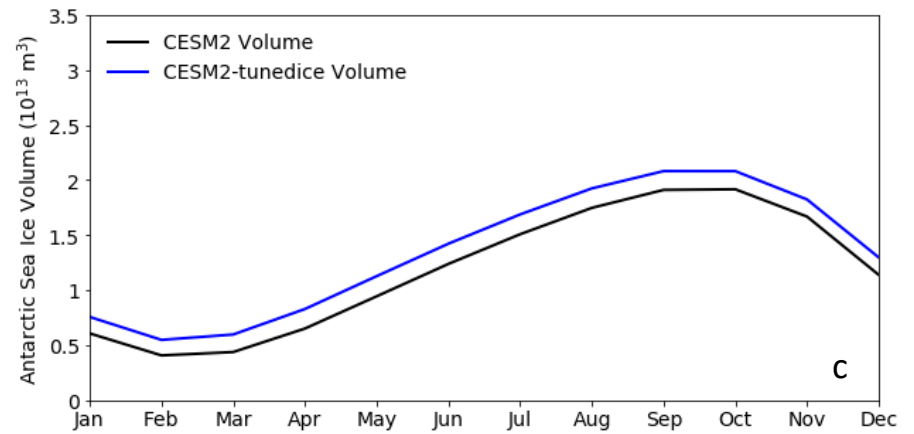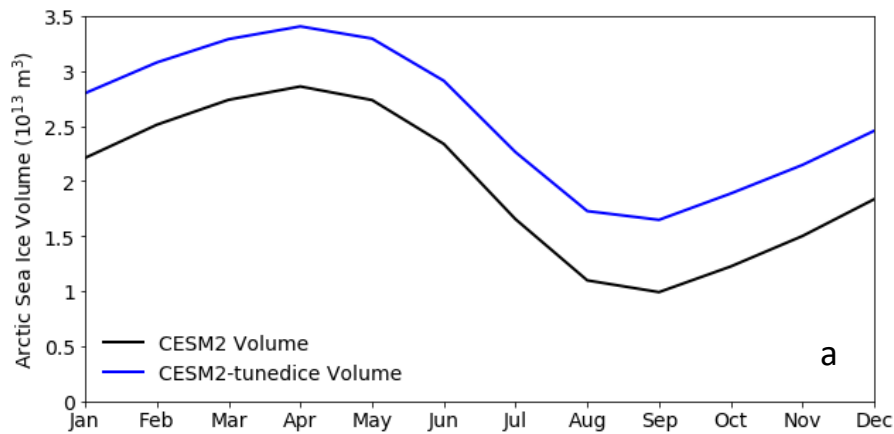
Seasonal cycle in CESM2 and CESM2-tunedice preindustrial control runs: a) Arctic sea ice volume, b) Arctic sea ice area and extent, c) Antarctic sea ice volume, d) Antarctic sea ice area and extent.
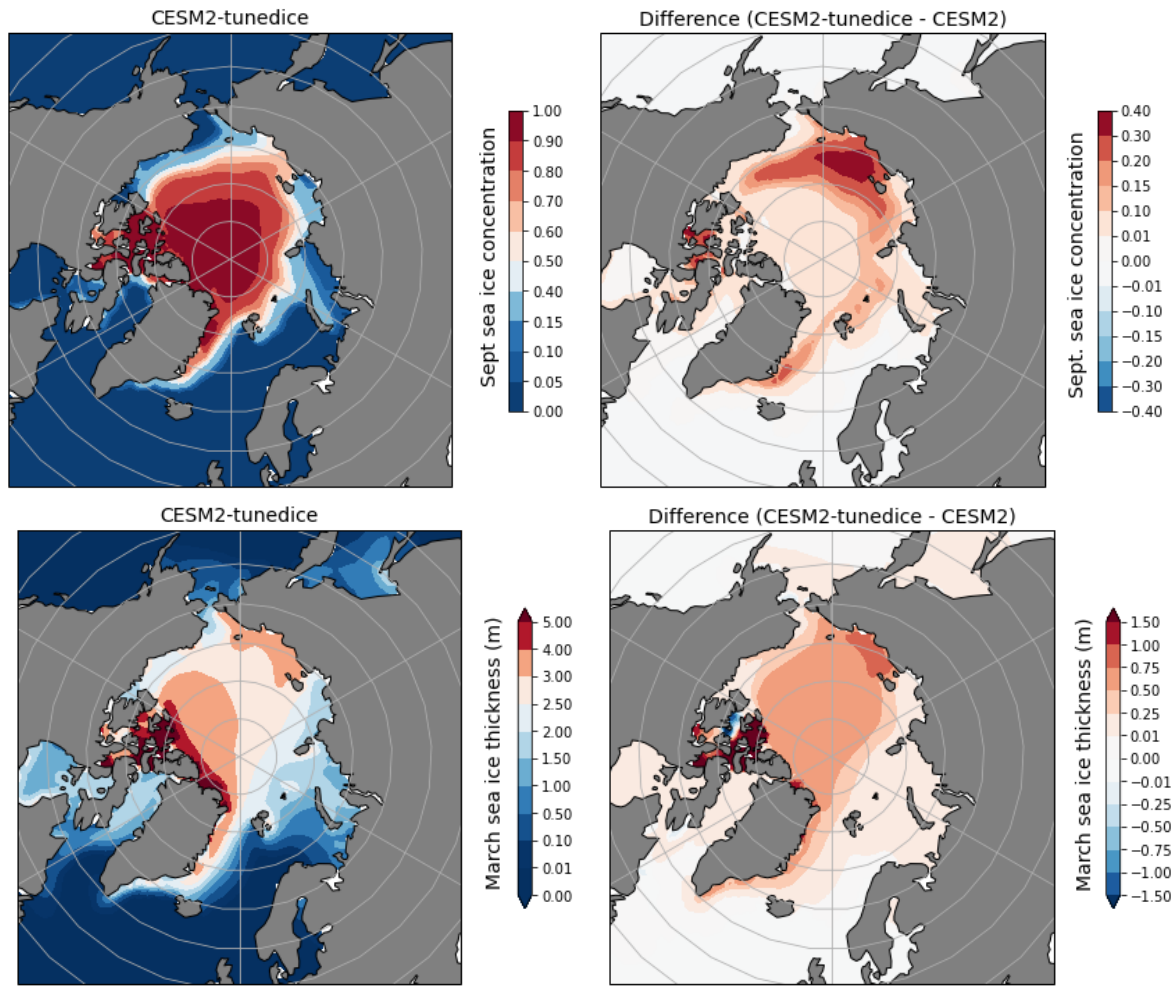
Pre-industrial Arctic sea ice in CESM2-tunedice and Difference from CESM2: top) September Arctic sea ice extent, bottom), March Arctic sea ice thickness. Values are overlapping 200-year averages (years 911-1110 of CESM2).
Note: Nonlinear color scale used to emphasize thin and low concentration ice categories.

Does the transient 1850-2100 evolution of the climate system differ in CESM2 and CESM2-tunedice?

The CESM2 Large Ensemble provides an excellent framework for comparison…

Focus on the Arctic

Slides removed.... CESM2 Large Ensemble is not yet public.

Summary – CESM2 tuned Sea Ice

CESM2 Large Ensemble simulations confirm that CESM2-CAM6 historic Arctic sea ice extent loss is earlier than observed, likely due to thin ice bias. See also *DeRepentigny et al. (2020, JGR-Oceans).*

Sea ice mean state affects CESM2 sea ice loss timing and the amount of associated warming. With thicker sea ice ice, CESM2 goes ice-free later and has more associated Arctic surface warming since 1850. Interestingly, rate of Arctic sea ice loss less affected by mean state.

Non-polar climate impacts are small.

Suggestions welcome. Simulations available soon. Cite Kay et al. (2021), to be submitted to JAMES (after CESM2 LE description paper is submitted).