CESM Earth System Prediction Working Group
Winter Meeting
January 27, 2021

Seasonal-to-Multiyear Large Ensemble (SMYLE):

A new Earth system prediction dataset using CESM2

CGD-ESP & CESM ESPWG Co-chairs

NCAR

NSF

This material is based upon work supported by the National Center for Atmospheric Research, which is a major facility sponsored by the National Science Foundation under Cooperative Agreement No. 1852977.

Motivation

- Relatively unexplored gap between seasonal and decadal prediction despite evidence of promise

  - Luo et al., 2008: Extended ENSO Predictions Using a Fully Coupled Ocean–Atmosphere Model, *J Clim*, doi:10.1175/2007JCLI1412.1.

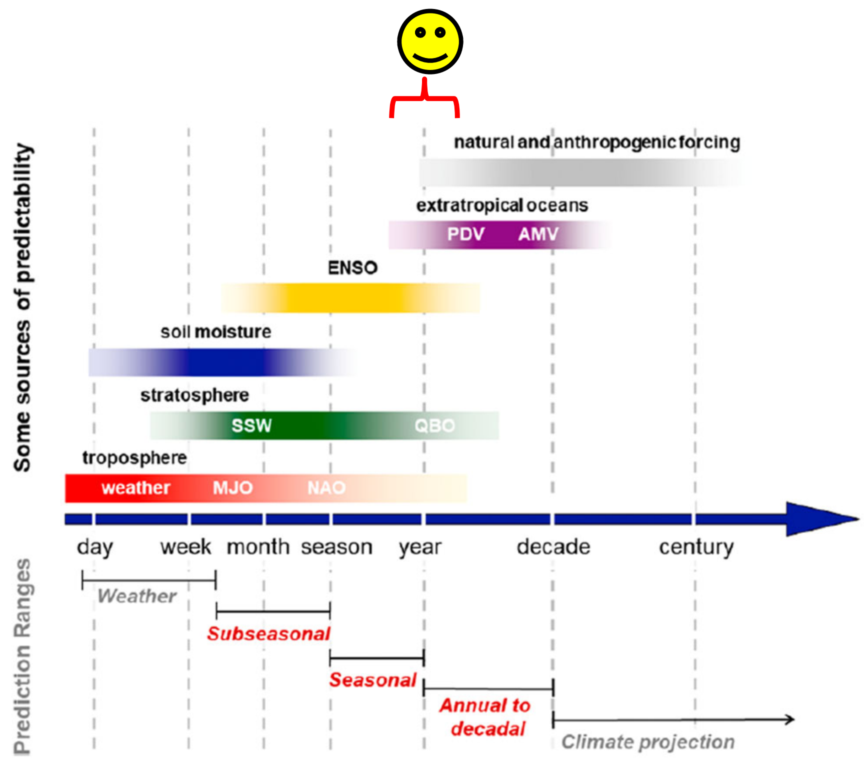
  - Dunstone et al., 2016: Skilful predictions of the winter North Atlantic Oscillation one year ahead, *Nat Geosci*, doi:10.1038/NGEO2824.

  - DiNezio et al., 2017: A 2 Year Forecast for a 60–80% Chance of La Niña in 2017–2018, *GRL*, doi:10.1002/2017GL074904.

  - Dunstone et al., 2020: Skilful interannual climate prediction from two large initialized model ensembles, *ERL*, doi:10.1088/1748-9326/ab9f7d.

  - Lovenduski et al., 2019: Predicting near-term variability in ocean carbon uptake, *Earth Syst Dynam*, doi:10.5194/esd-10-45-2019.

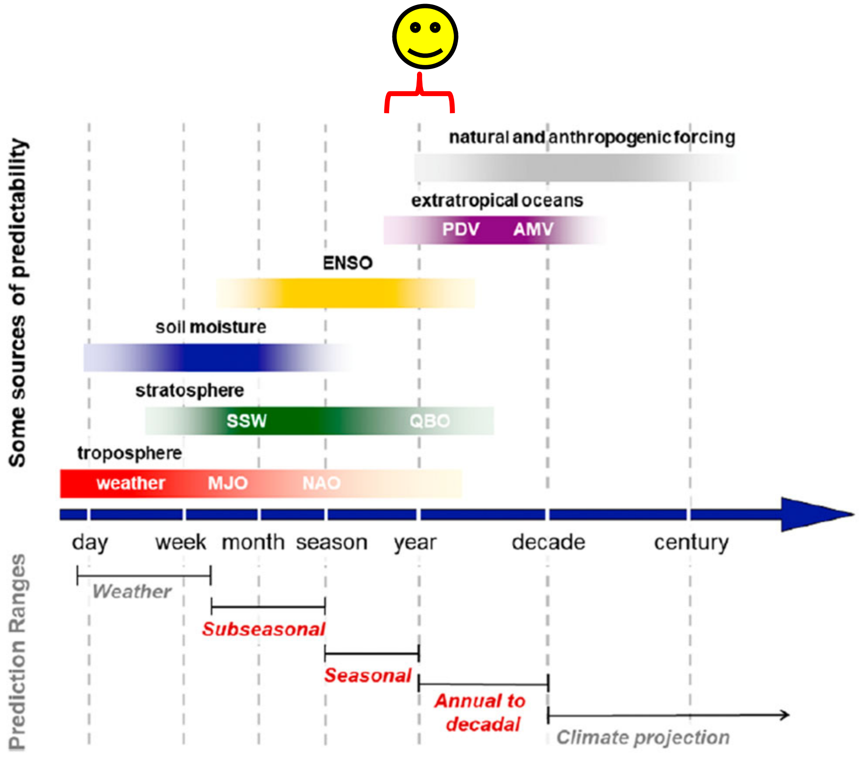
  - Kumar et al., 2021: Multi-Seasonal to Multi-Year Soil Moisture Drought Forecasting, *npj Clim Atm Sci*, in revision.



Merryfield et al. (2020)

Motivation

- Relatively unexplored gap between seasonal and decadal prediction despite evidence of promise
- Upgrade S2D ESP efforts to CESM2
- Establish a new Control for future ESPWG experimentation
- Lay the foundation for a seamless prediction system using CESM2 that spans S2D timescales



Merryfield et al. (2020)

SMYLE Experiment Design

- MODEL: CESM2 [CAM6, CICE5, CLM5, POP2 w/ MARBL] @ 1°
- START TIMES:
  - 4x/year (Nov 1, Feb 1, May 1, Aug 1) from 1970-2019
  - initial conditions should be extensible both backwards (pre-1960) and forwards (to near real time)
- ENSEMBLE: 20
  - random field perturbation method used in subseasonal (Richter et al. 2020)
- INTEGRATION LENGTH: 24 mos
- COST:
  - (200 starts) x (20 members) x (2 years) = 8,000 sim-years
  - 8000 sim-years x 3500 = 28M core-hours
  - 18M core-hours (CISL NSC) + 10M core-hours (ESPWG Year 1)
- FUTURE EXTENSION(S):
  - 9M core-hours (ESPWG Year 2)
  - Increase ensemble size? Expanded Seasonal? Extended multiyear? Decadal?

Initialization

- Component initial states derived from JRA55 Reanalysis (Kobayashi et al. 2015)
  - 1958-present
  - relatively high-res (~55km)
  - Basis of new JRA55-do forcing for CMIP6-OMIP2 (Tsujino et al. 2018)

✓ ATM: JRA55 analysis fields directly interpolated to CAM FV0.9x1.25_L32 grid

✓ LND: "SMYLE-Trendy", CLM5 simulation (1850 spinup to equilibrium, then 1850-2019) using CRU-JRA forcing (from TRENDY protocol)

✓ OCN/BGC/ICE: "SMYLE-FOSI", cycle 6 of OMIP2-style* forced ocean sea-ice simulation using JRA55-do (BGC tracer forcing aligned with cycle 6 calendar)

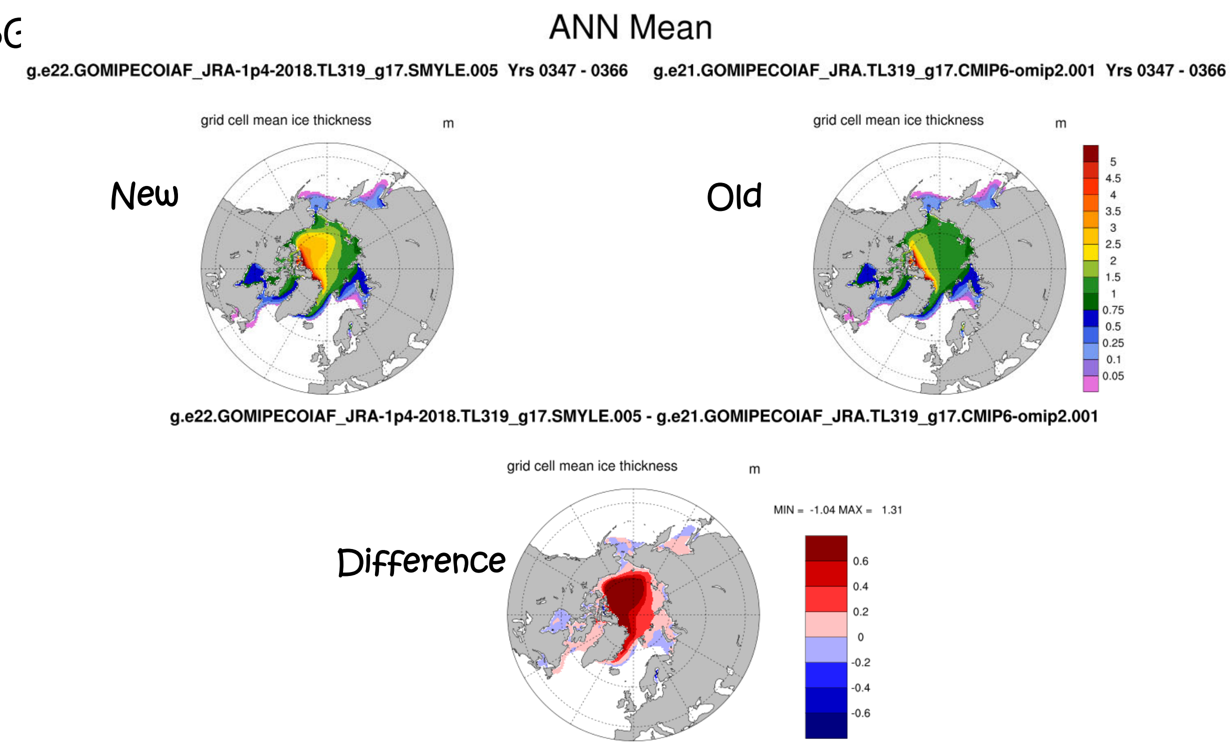
*modified BGC tunings, sea ice albedo, & under-ice SST restoring

SMYLE-FOSI

- Equivalent to CMIP6 OMIP2 *except*

- strong SST restoring under sea-ice (to improve sea ice)
- (max) sea-ice albedo mods (to improve sea ice)
- reduced deep isopycnal diffusion (to improve BG

- Substantially thicker sea-ice in both hemispheres

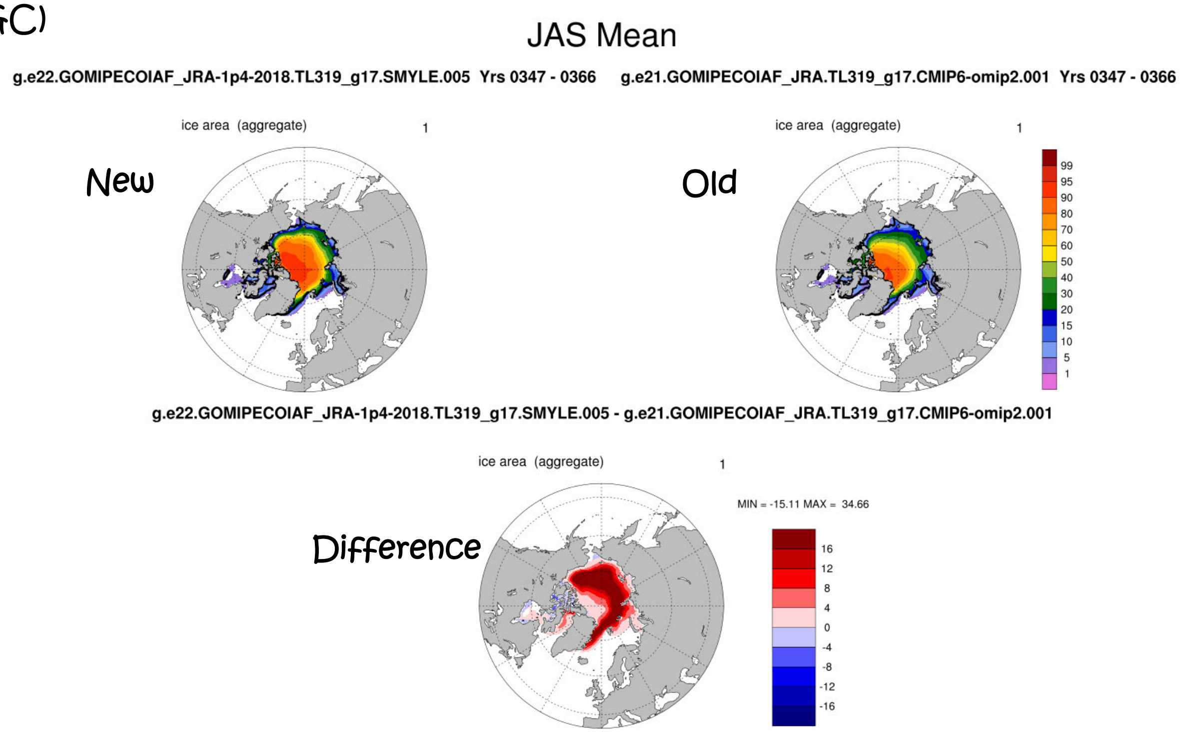


SMYLE-FOSI

- Equivalent to CMIP6 OMIP2 *except*

- strong SST restoring under sea-ice (to improve sea ice)
- (max) sea-ice albedo mods (to improve sea ice)
- reduced deep isopycnal diffusion (to improve BGC)

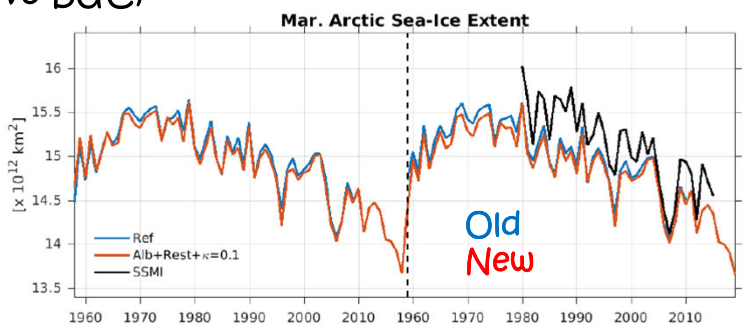
- Substantially thicker sea-ice in both hemispheres
- More realistic summer sea-ice extent

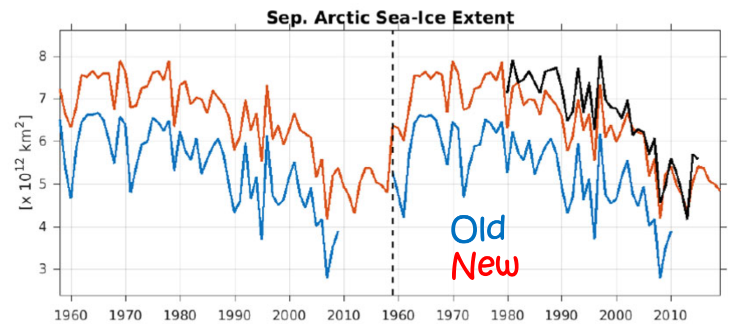


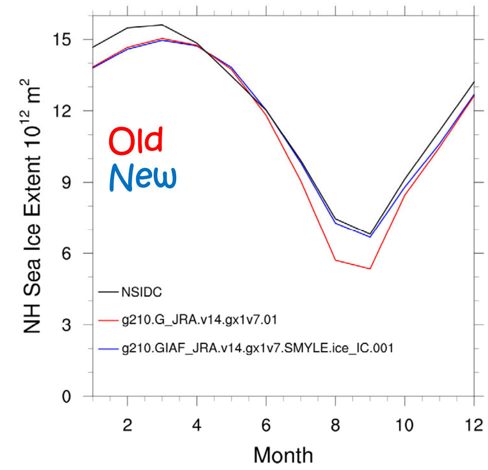
SMYLE-FOSI

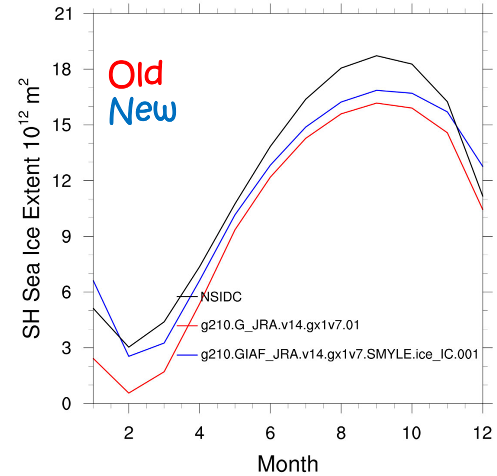
- Equivalent to CMIP6 OMIP2 *except*

- strong SST restoring under sea-ice (to improve sea ice)
- (max) sea-ice albedo mods (to improve sea ice)
- reduced deep isopycnal diffusion (to improve BGC)









- Substantially thicker sea-ice in both hemispheres
- More realistic summer sea-ice extent
- Better match to observed sea-ice seasonal/interannual variability

SMYLE-FOSI

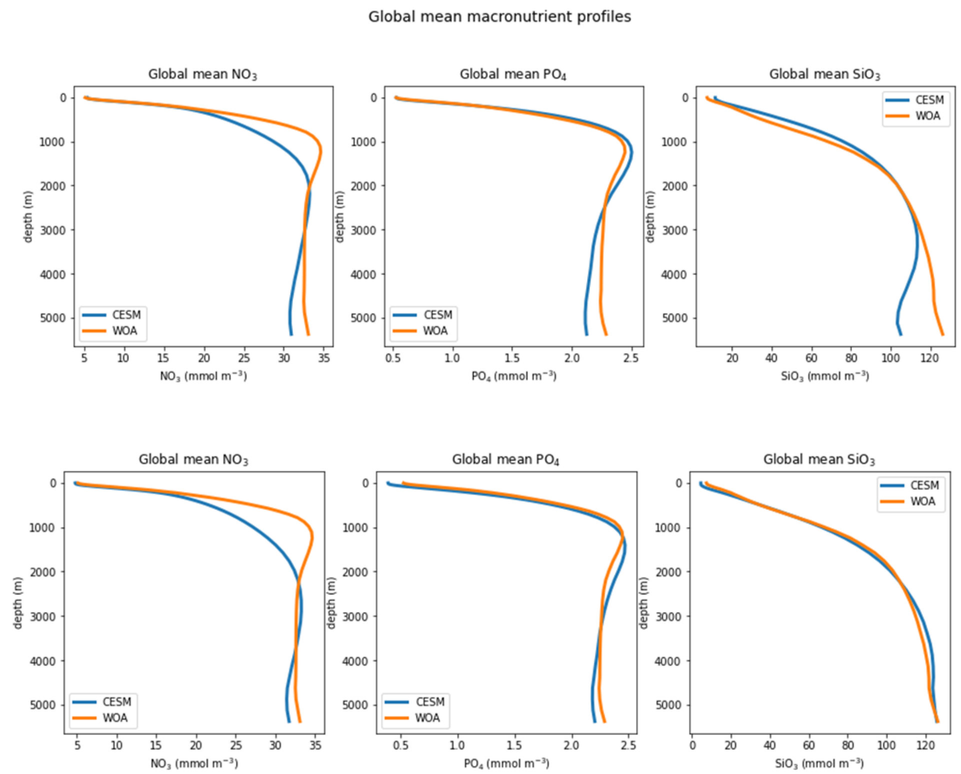
- Equivalent to CMIP6 OMIP2 *except*

- strong SST restoring under sea-ice (to improve sea ice)
- (max) sea-ice albedo mods (to improve sea ice)
- reduced deep isopycnal diffusion (to improve BGC)

- Substantially thicker sea-ice in both hemispheres
- More realistic summer sea-ice extent
- Better match to observed sea-ice seasonal/interannual variability
- Reduced nutrient drift at depth

Old

New

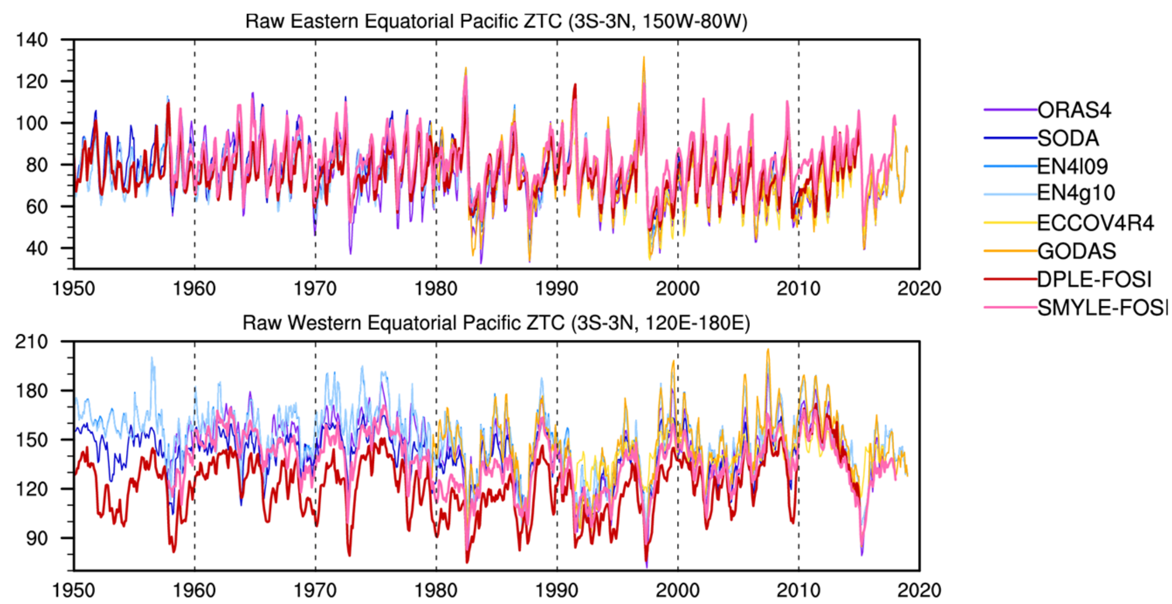


SMYLE-FOSI

- Equivalent to CMIP6 OMIP2 *except*

- strong SST restoring under sea-ice (to improve sea ice)
- (max) sea-ice albedo mods (to improve sea ice)
- reduced deep isopycnal diffusion (to improve BGC)

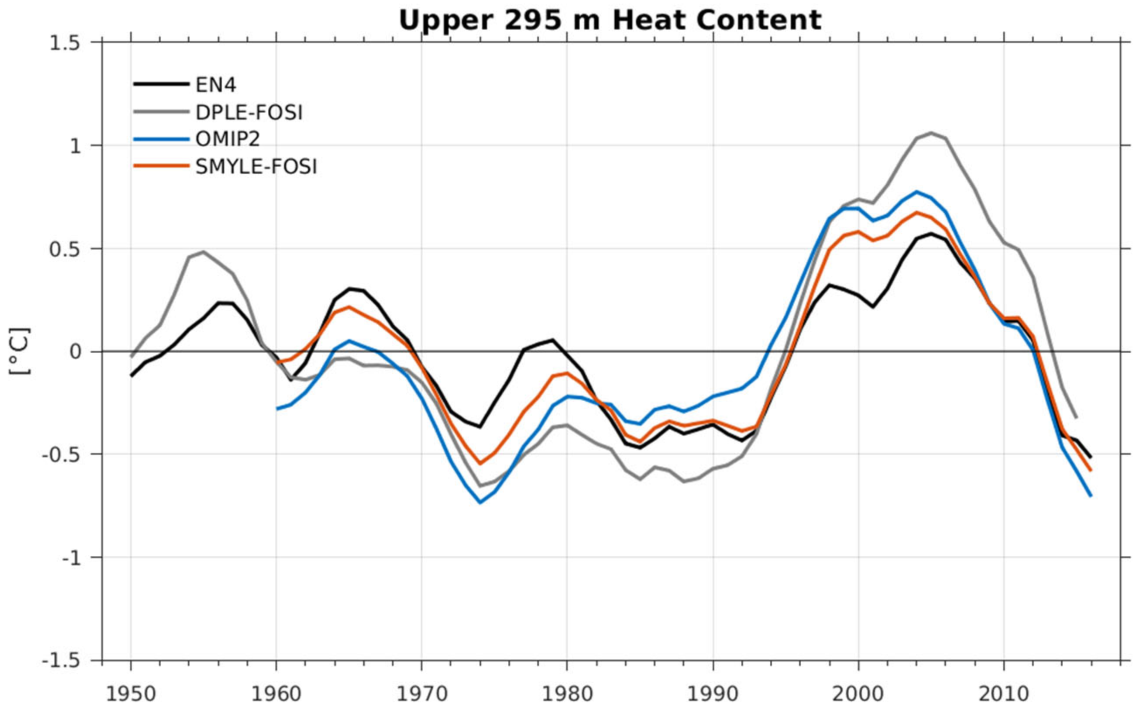
- Substantially thicker sea-ice in both hemispheres
- More realistic summer sea-ice extent
- Better match to observed sea-ice seasonal/interannual variability
- Reduced nutrient drift at depth
- Improved thermocline structure in Equatorial Pacific (compared to DPLE-FOSI)



SMYLE-FOSI

- Equivalent to CMIP6 OMIP2 *except*

- strong SST restoring under sea-ice (to improve sea ice)
- (max) sea-ice albedo mods (to improve sea ice)
- reduced deep isopycnal diffusion (to improve BGC)



- Substantially thicker sea-ice in both hemispheres
- More realistic summer sea-ice extent
- Better match to observed sea-ice seasonal/interannual variability
- Reduced nutrient drift at depth
- Improved thermocline structure in Equatorial Pacific (compared to DPLE-FOSI)
- Better match to observed heat content variability in the subpolar North Atlantic

Production Status

- Model output finalized
  - Includes select daily (all components), 6-hourly (atm), & 3-hourly (atm) fields
  - 82 GB/sim-year ➔ 656 TB (~328 TB compressed)
  - Contact me if you have questions (yeager@ucar.edu)

- Differences from CESM2-CMIP6 historical/SSP2-4.5:
  - -ocean deep isopycnal mixing (POP2)
  - -other BGC tuning params (MARBL)
  - -modified sea ice albedo (CICE5; uses CESM2 retuned sea-ice settings)
  - -crop-harvest bug fix (CLM5)
  - -smoothed BB (SMBB) forcing (Fasullo et al. 2021)

- Differences from CESM2-SMBB (CESM2-LENS members 51-100) historical/SSP2-4.5:
  - -ocean deep isopycnal mixing (POP2)
  - -other BGC tuning params (MARBL)
  - -modified sea ice albedo (CICE5; CESM2 retuned sea-ice settings)

- Production runs to begin very soon

SMYLE Analysis

- CESM data policy: http://www.cesm.ucar.edu/management/docs/data.mgt.plan.2011.pdf
  - SMYLE is a CESM Production Experiment.
  - PIs of this experiment are the CESM SSC & ESPWG Co-chairs.
  - CESM data is characterized as being Protected, CESM Access, or Public.
  - CESM Experiment data shall be available to members of any CESM Working Group (CESM Access) no later than six months following the conclusion of the Experiment integration.
  - CESM Experiment data shall become Public as soon as a scientific paper on the results has been submitted by the PIs or one year after the end of the simulation, whichever comes sooner.

- SMYLE Analysis Registry (please sign up if interested!)
  - manage early access to SMYLE output
  - facilitate coordination within ESPWG
  - https://docs.google.com/spreadsheets/d/14KbOR9ySrql_p5SKUC_aVVXeIkSXo_53IN9NGsfVFcg/edit?usp=sharing

- Presentation of preliminary results expected at the 26th Annual CESM Workshop (June 2021)

Thank You!

To everyone who has contributed to SMYLE thus far:

Dan Amrhein, Dave Bailey, Fred Castruccio, Gokhan Danabasoglu, Jim Edwards, Ethan Guttman, Cecile Hannay, Marika Holland, Who Kim, Erik Kluzek, Kristen Krumhardt, Sanjiv Kumar, Jean-Francois Lamarque, Dave Lawrence, Keith Lindsay, Matt Long, Danica Lombardozzi, Nikki Lovenduski, Jerry Meehl, Brian Medeiros, Mike Mills, Jerry Olson, Keith Oleson, Yaga Richter, Nan Rosenbloom, Christine Shields, Isla Simpson, Gary Strand, Simone Tilmes, Joe Tribbia, Will Wieder, Andy Wood, Xian Wu, …

ESPWG CSL Allocation

- Nov 1 2020 – Oct 31 2022
- 41M core-hours

	Year 1		Year 2		Totals		
	Dev	Prod	Dev	Prod	Year 1	Year 2	Y1 + Y2
Working Group							
AMWG	21.0	8.9	44.3	4.8	29.9	49.1	79.0
BGCWG	5.2	9.8	6.6	19.5	15.0	26.1	41.1
ChCWG	4.5	5.7	6.9	10.2	10.2	17.1	27.3
CVCWG		20.1		33.9	20.1	33.9	54.0
ESPWG	7.1	10.5	2.0	21.4	17.6	23.4	41.0
LIWG	6.0	9.0	9.0	16.5	15.0	25.5	40.5
LMWG	7.0	13.0	11.0	23.0	20.0	34.0	54.0
OMWG	10.9	9.1	15.3	18.6	20.0	33.9	53.9
PaleoWG	11.2	9.7	17.7	16.3	20.9	34.0	54.9
PCWG	3.0	12.0	13.9	11.6	15.0	25.5	40.5
SEWG	6.0		9.0		6.0	9.0	15.0
WAWG	9.7	17.6	12.5	14.6	27.3	27.1	54.4
Total WGs	**91.6**	**125.4**	**148.2**	**190.4**	**217.0**	**338.6**	**555.6**

ESPWG CSL Allocation

- D1.AISE (Anomaly Initialization Sensitivity Experiments): 2.06M Year 1

Case studies (e.g., mid-1990s SPNA warming; 2015 Atlantic cold blob; 97/98 El Niño) to explore benefits of anomaly initialization techniques relative to established baseline experiments (CESM1-DPLE, CESM2-SMYLE).
Leads: Yeager, Kim, Maroon, others? DiNezio

- D2.DACS (Data Assimilation Case Studies): 1.5M Year 1, 1.52M Year 2

Case studies to explore benefits of initialization using weakly-coupled ensemble DA relative to baseline experiments.
Leads: Amrhein, others?

- P1.SMYLE: 10M Year 1, 9M Year 2

Seasonal-to-multiyear large ensemble production experiment with CESM2.
Leads: ESPWG Co-chairs

- P6.DPSE (Decadal Predictability Source Experiments): 1.15M Year 2

Perform CMIP6 DCPP Component C2 sensitivity experiment (climatological initial conditions in subpolar N. Atlantic) with CESM1 for comparison to CESM1-DPLE. In collaboration with UK-NERC partners.
Leads: Yeager, Danabasoglu, Kim

Questions?