Ocean-atmosphere coupled data assimilation efforts at NCAR:

Integrating the CESM with the DART ensemble filter

Key CGD personnel:

Alicia Karspeck, Gokhan Danabasoglu, Svetlana Karol, Steve Yeager, Joe Tribbia

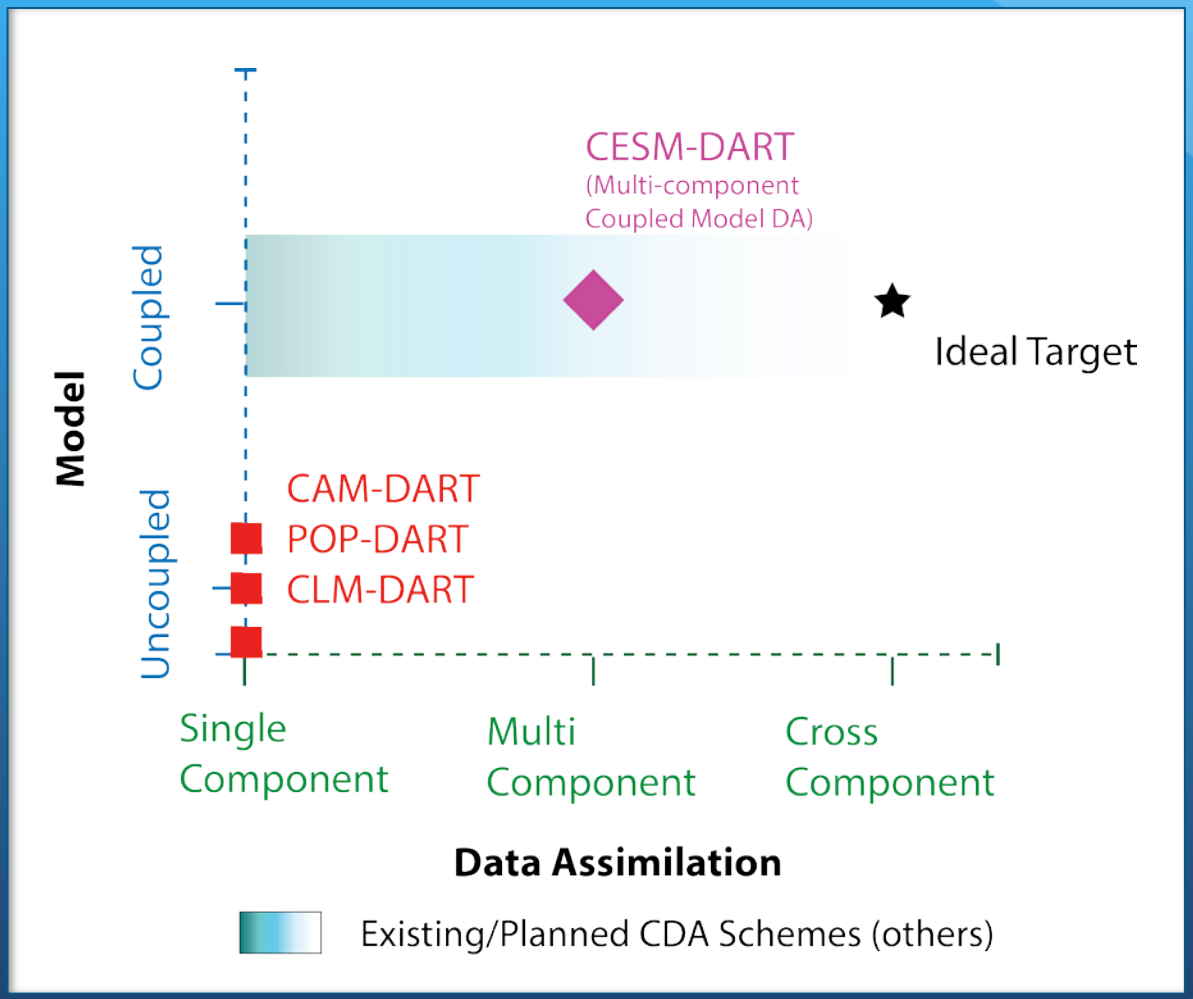
Key CISL personnel:

Jeff Anderson, Nancy Collins, Tim Hoar, Helen Kershaw, Kevin Raeder

CGD-software engineering participants:

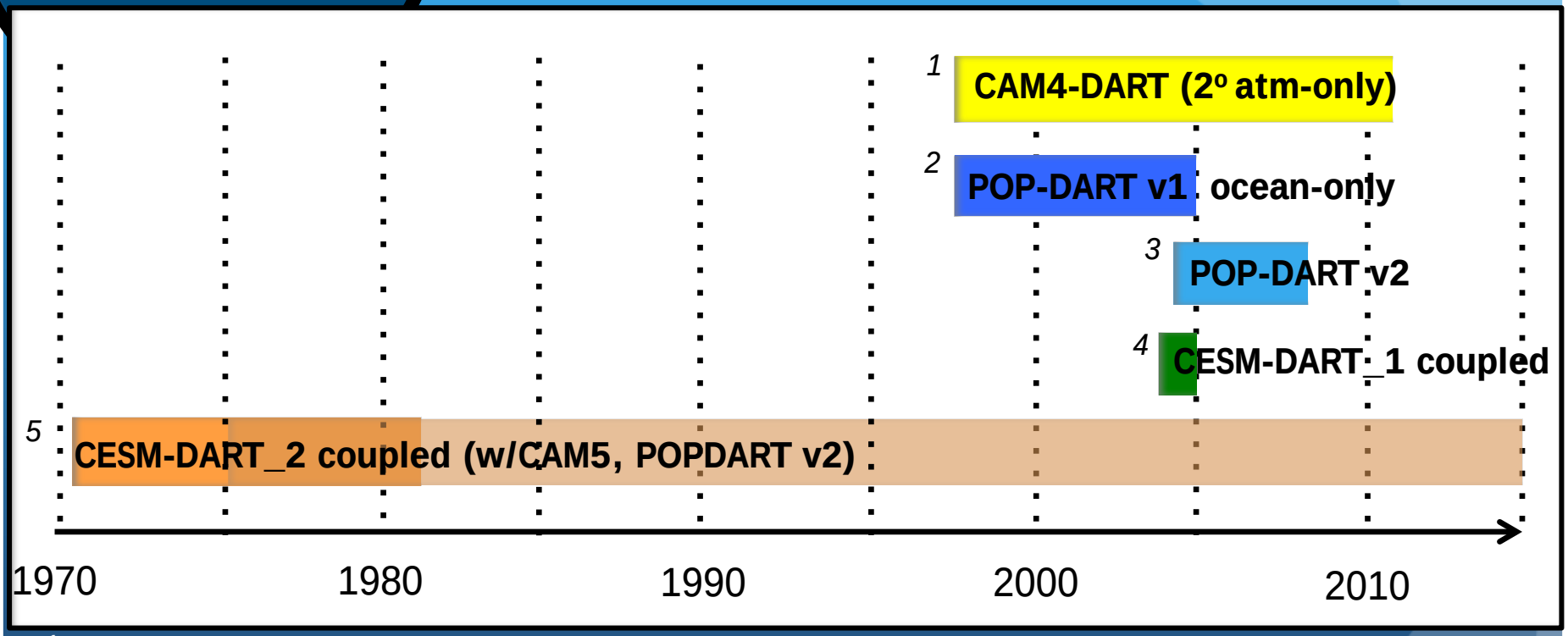
Mariana Vertenstein, Brian Eaton, Jim Edwards, Tony Craig

Frameworks for data assimilation



Schematic courtesy of A. Chatterjee

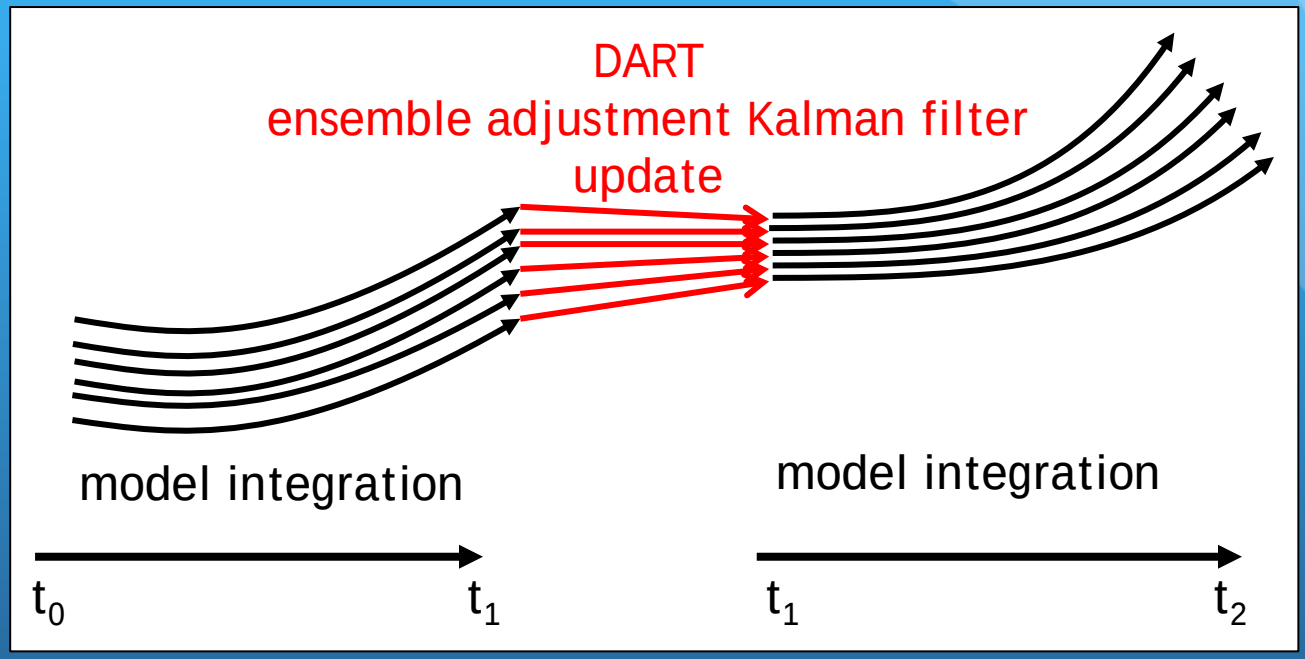
POP/CAM/CESM-DART: experimental climate reanalyses



[1] Kevin Raeder (DAReS-CISl)
[2] Alicia Karspeck (Ocean-CGD)
[3] Alicia Karspeck (Ocean-CGD)
[4] Abhishek Chatterjee(CGD/DAReS-CISL)
[5] Alicia Karspeck (Ocean-CGD)

All methods use the "model agnostic" DART implementation of the Ensemble Adjustment Kalman Filter

Data Assimilation Research Testbed

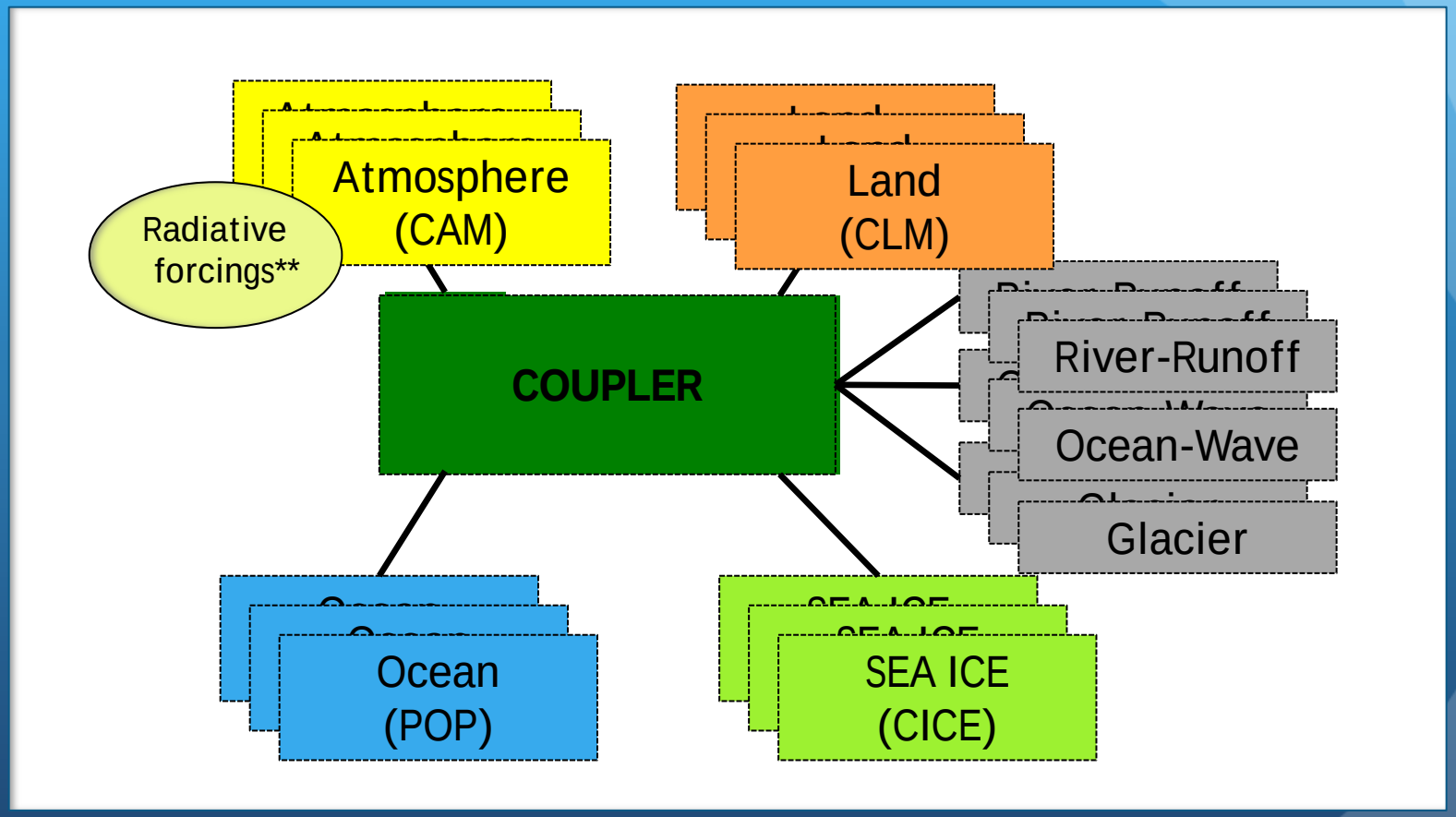


DART is a generic ensemble filter; necessary ingredients:

- ***Model forecasts***
  - In a coupled framework -- model state can be defined independently for each component or jointly across components.
- ***Forward operators*** to map from the model state vector to the observation space
- ***Observations***

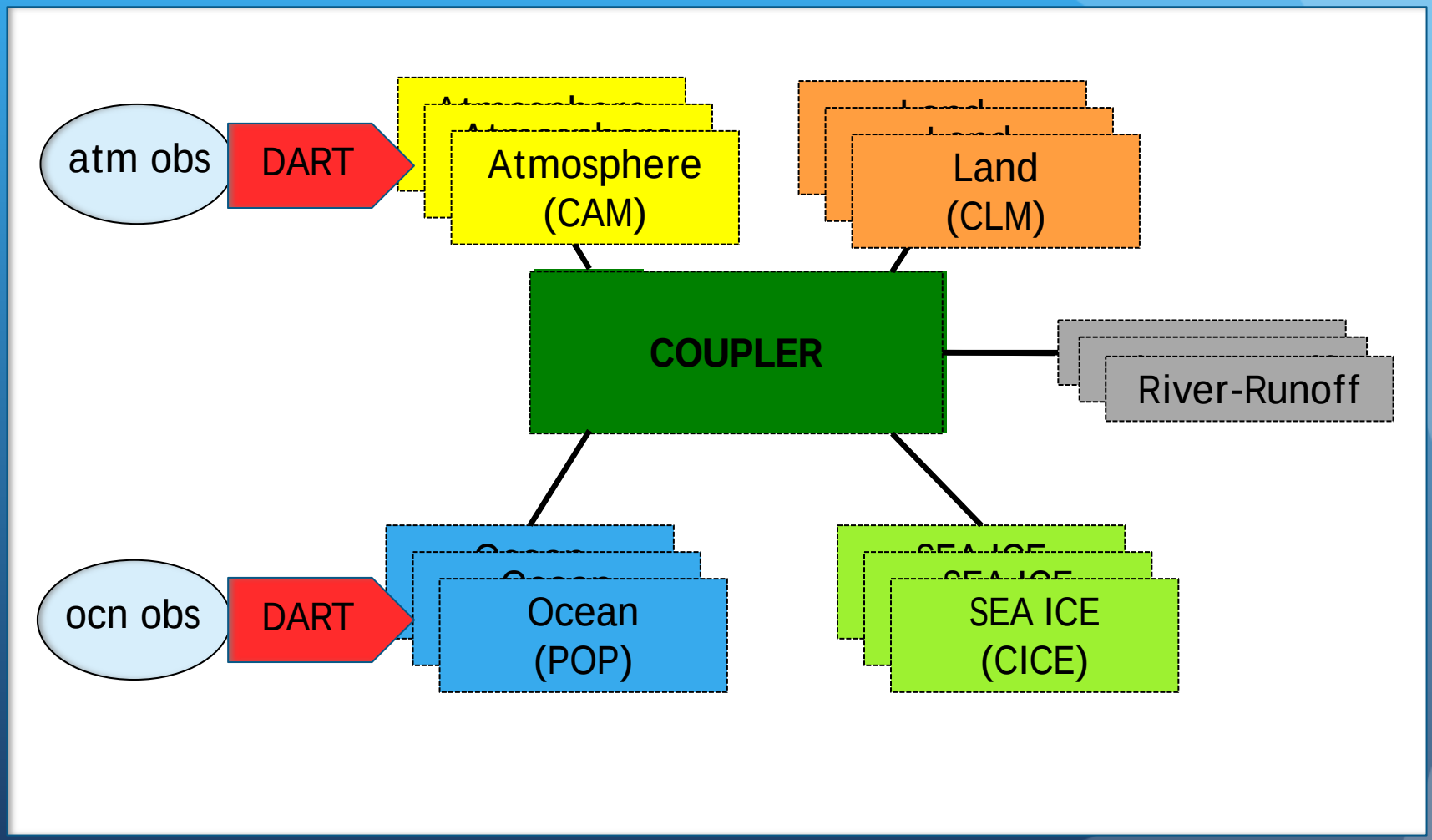
(http://www.image.ucar.edu/DAReS/DART)

Community Earth System Model
"multi-instance"

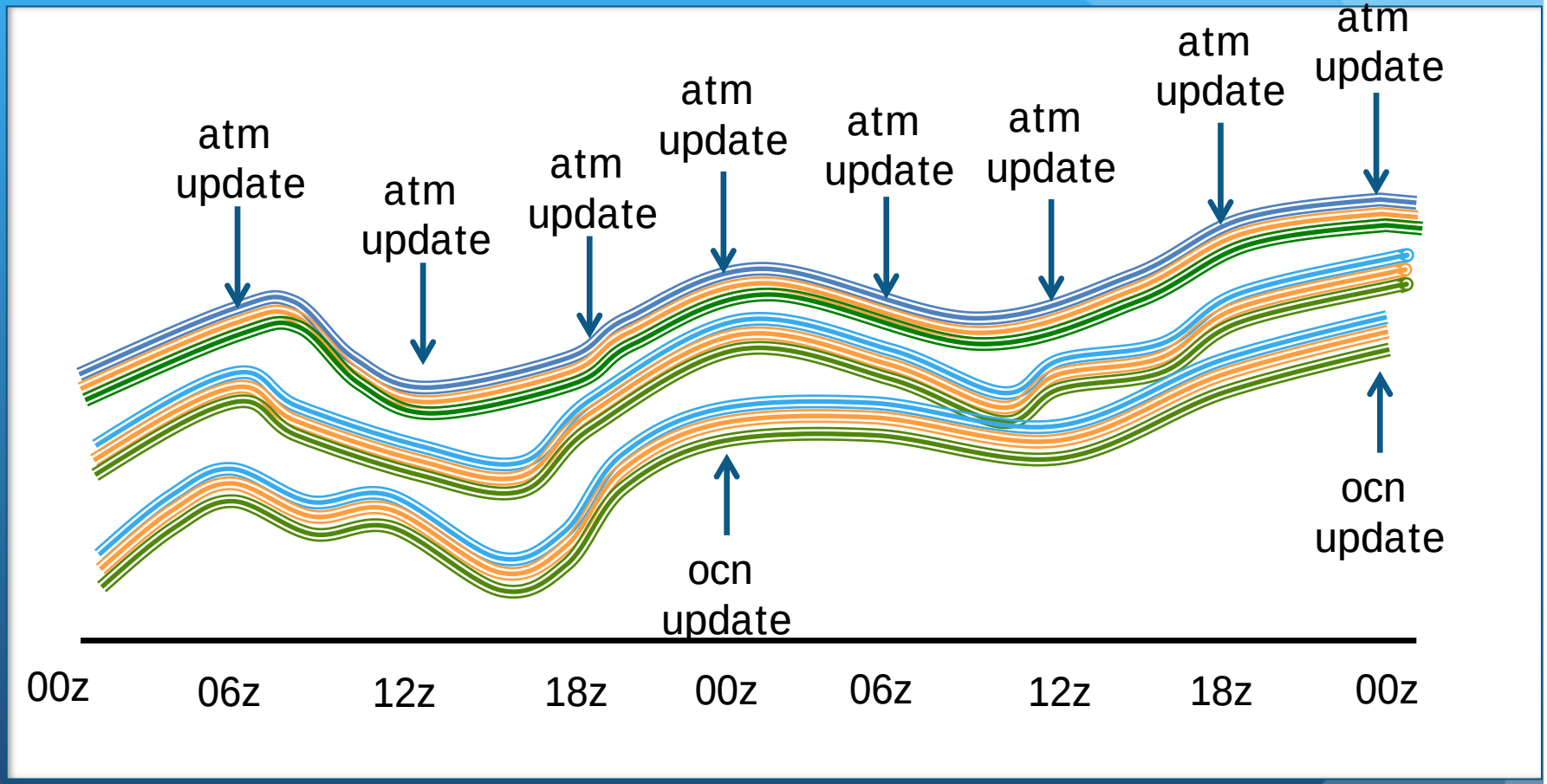


** Greenhouse gases, anthropogenic aerosols, volcanic eruptions, solar variability

Community Earth System Model interfacing with DART in a "multi-component" DA coupled framework



CESM-DART
coupled data assimilation (time-view)



- Coupler exchanges fluxes and other necessary information between component models at equal or higher frequency than assimilation update

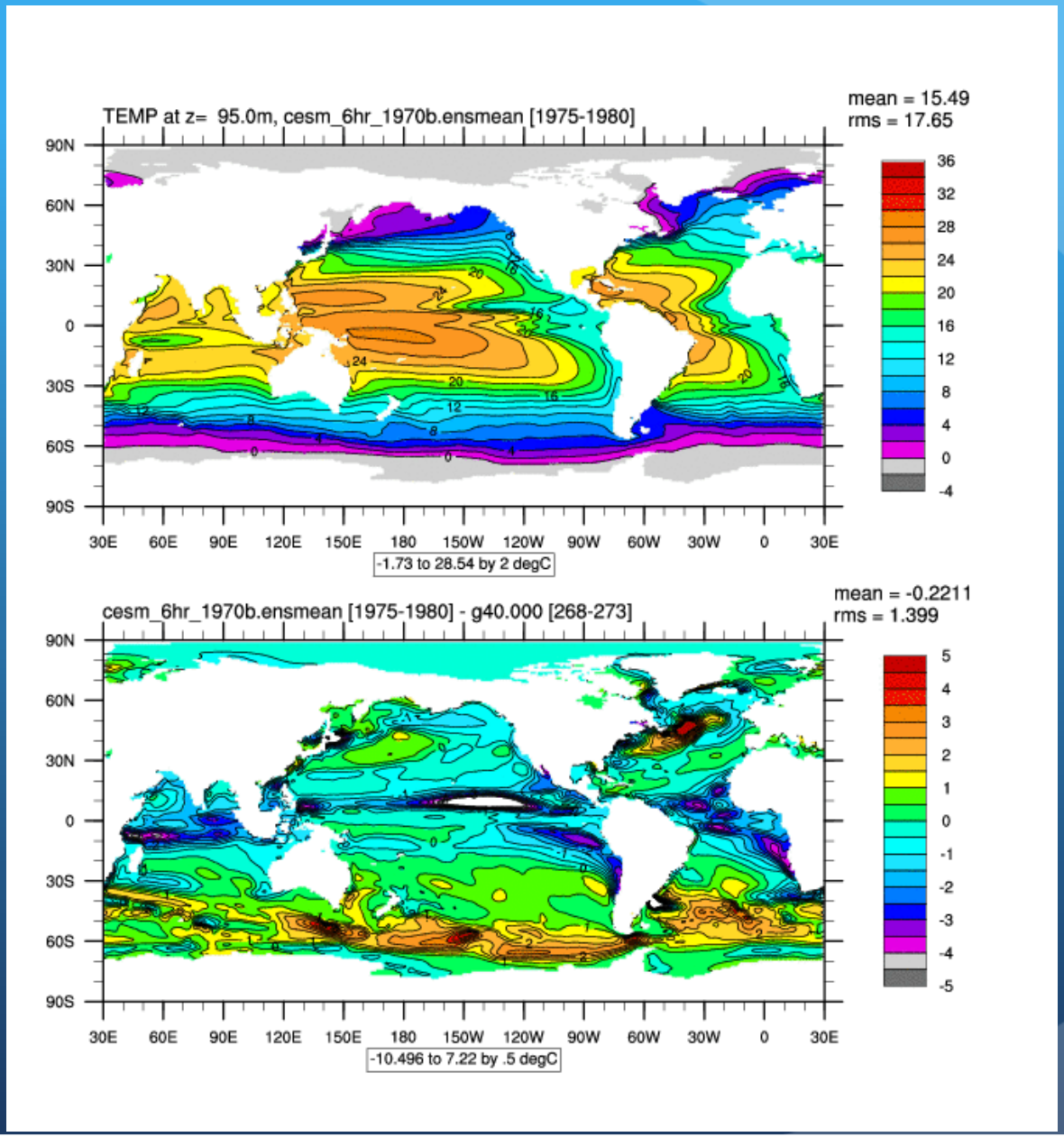
- Multi-component: assimilation of observations independently in each component

Summary info on the CESM-DART coupled assimilation system

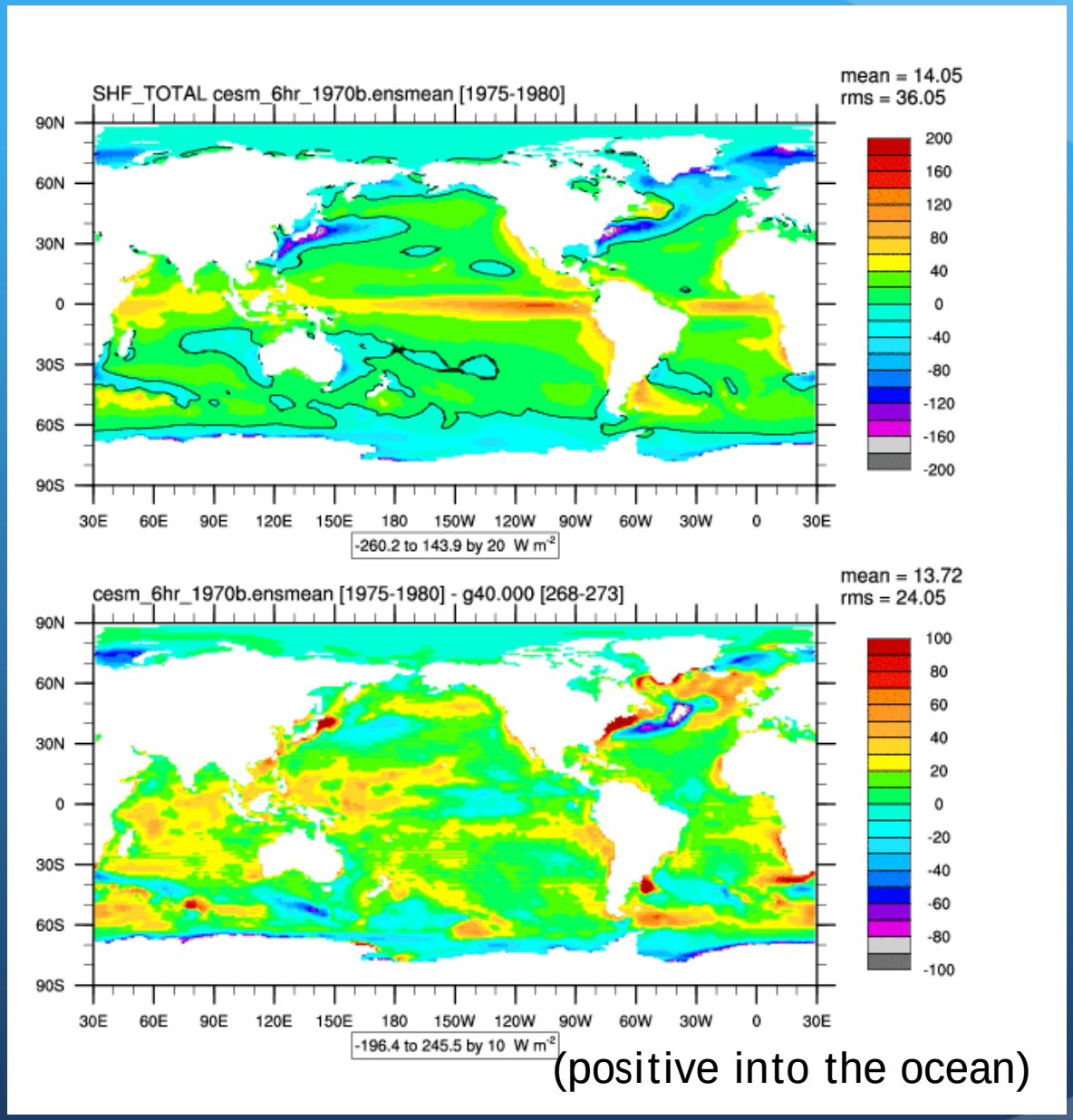
Model:	CESM1 global coupled ocean/atm/ice/land Horizontal resolution: nominal 1^{o} Vertical resolution: CAM5 30 levels (~2hPa) POP2 60 levels (10 m upper to ~250m deep) 6 hour ocean/atm coupling
DA method:	30 member DART ensemble adjustment Kalman filter (EAKF)
Ocean obs:	In-situ temp and salinity (XBT, MBT, CTD, drifters, floats, moorings, ARGO floats, ocean station; **no SST, no altimetry**) (assimilated daily)
Atm obs:	temp and winds (radiosondes, aircraft, satellite drift winds, GPSRO-COSMIC, ACARS; currently no moisture, surface pressure, or radiometer retrievals)(assimilated 6 hourly)

Some early results from the CESM-DART coupled assimilation

Some ocean results: 100 m temp relative to COREII-hindcast

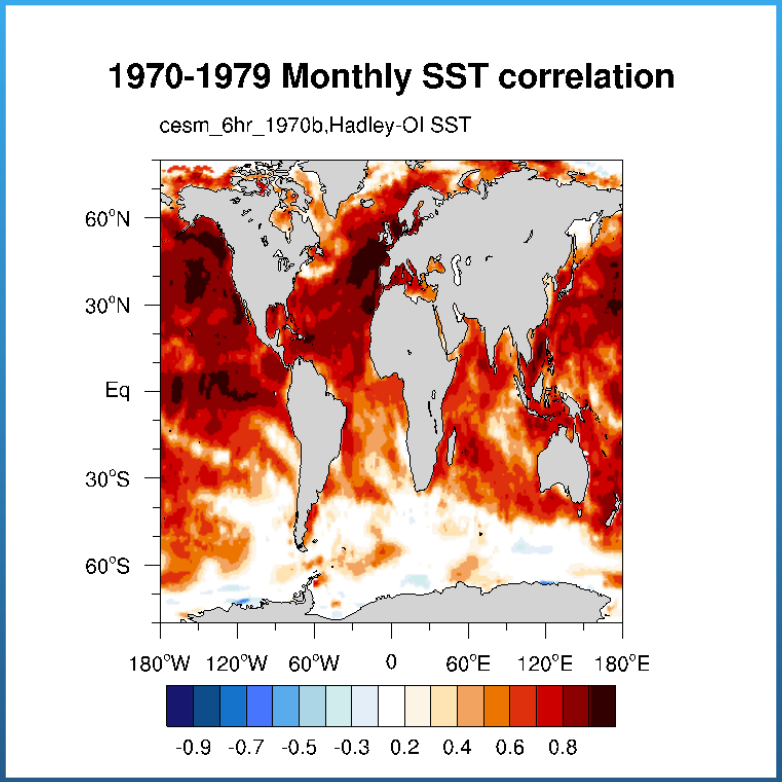


Some ocean results: Surface Heat Flux relative to hindcast

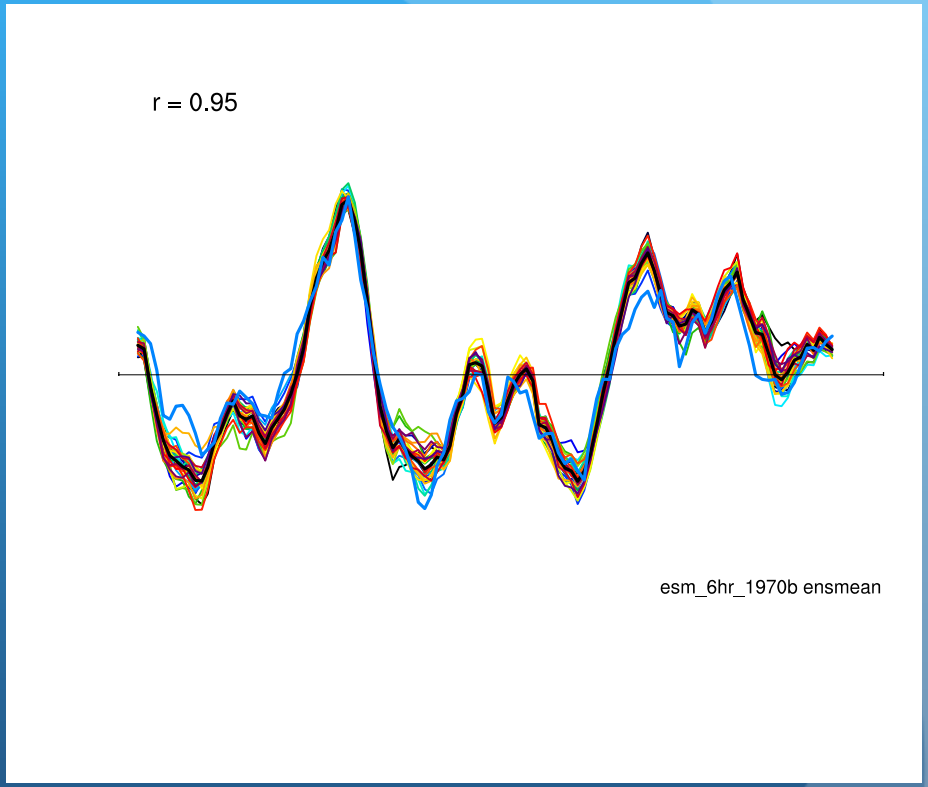


(positive into the ocean)

Some ocean results: SST variability



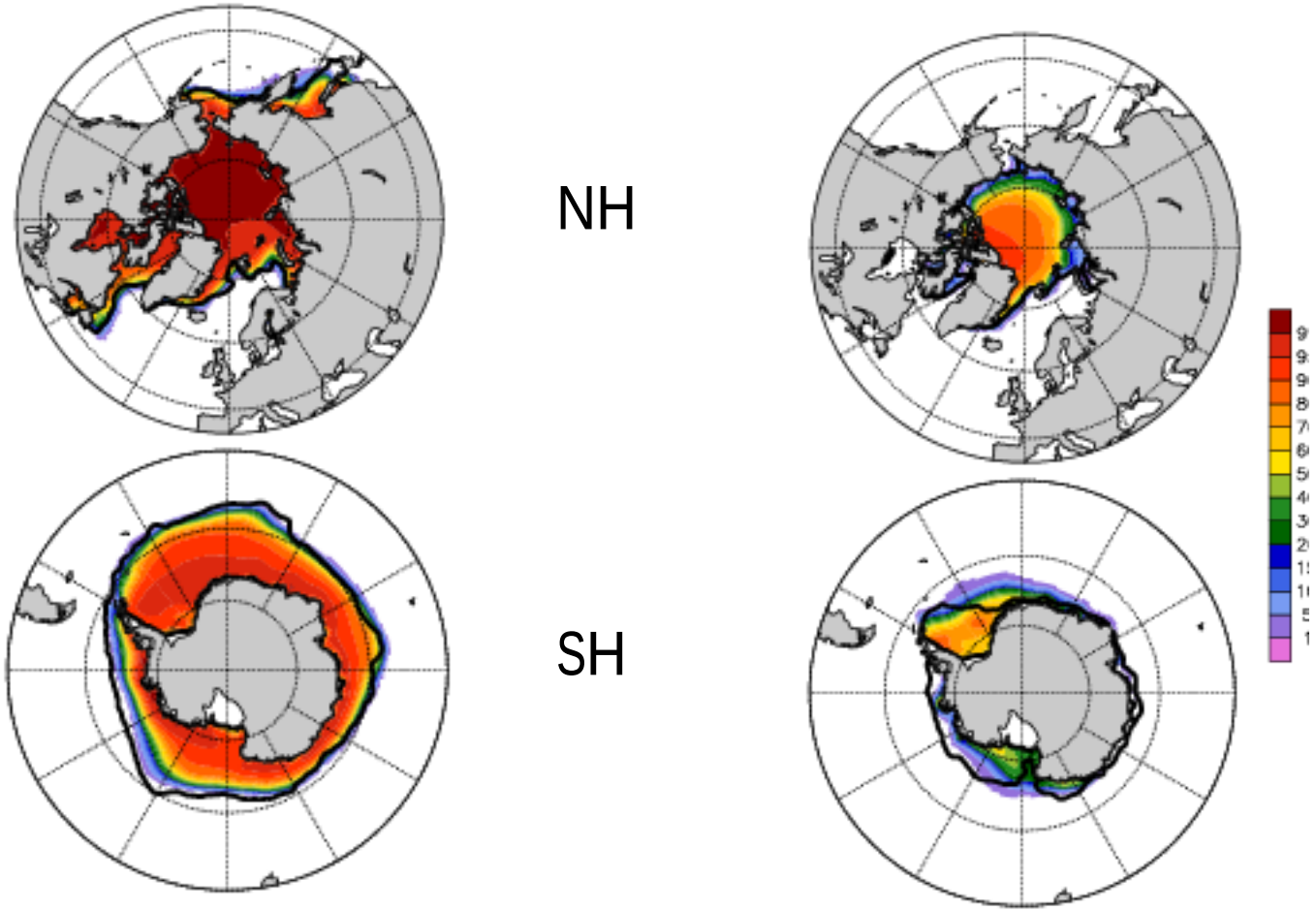
Generally high correlation with HADISST



1972-73 El Nino event simulated

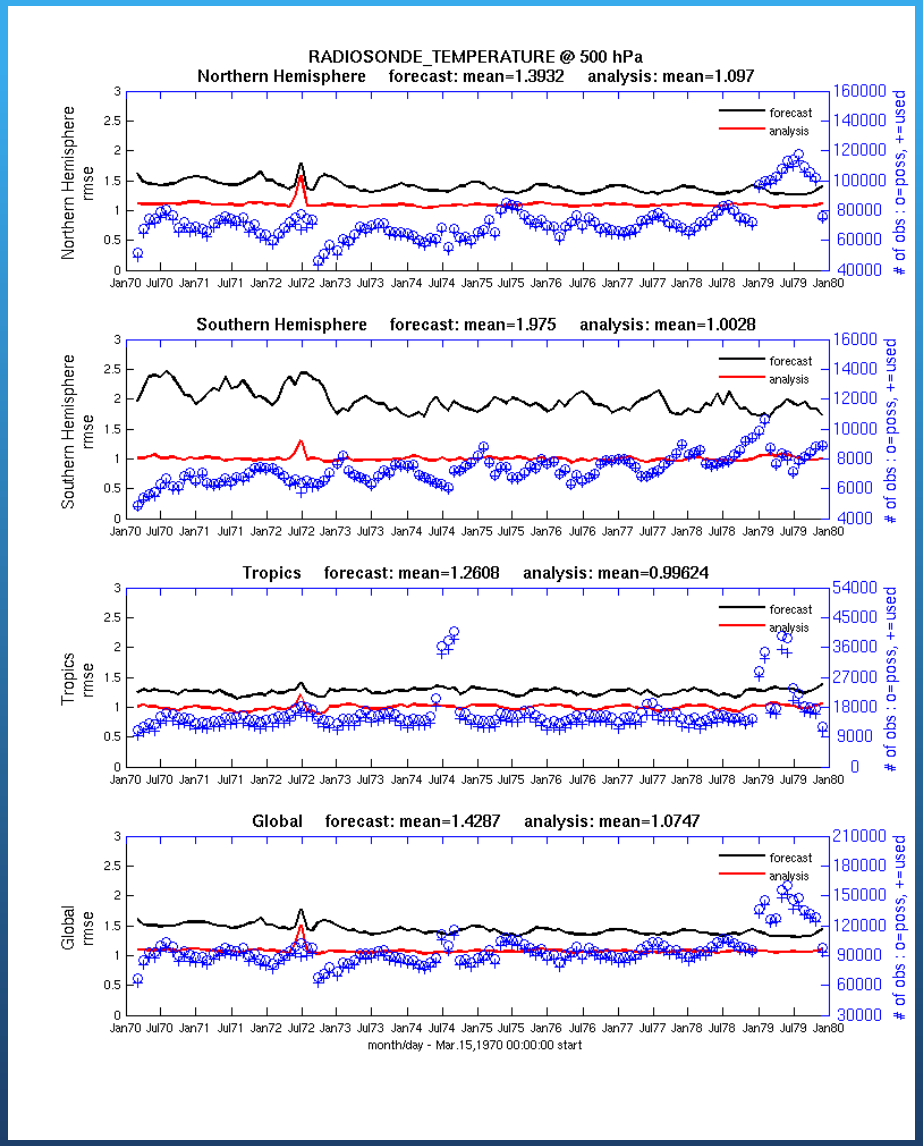
Plots courtesy of S. Karol

Early results from the CESM-DART coupled assimilation: ice area

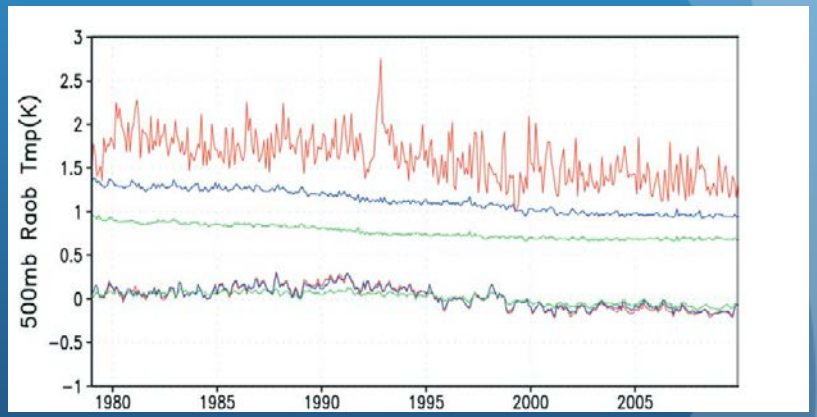


Plots courtesy of S. Karol

Early results from the CESM-DART coupled assimilation: RMS errors in 6 hour



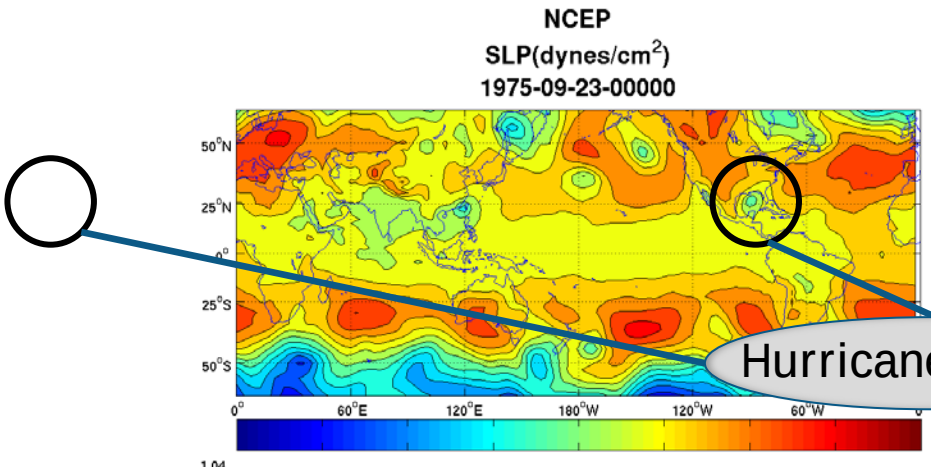
NCEP RMS errors (radiosonde temp)



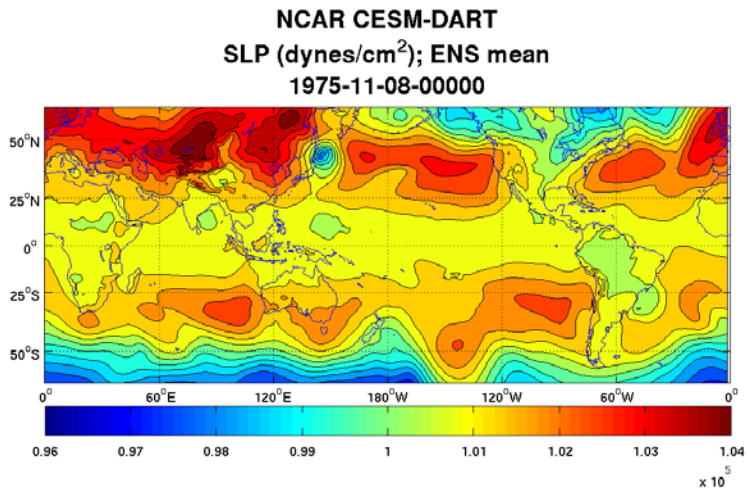
From Saha et al 2010 (blue line is forecast error)

More early results from the CESM-DART coupled assimilation atm

6hr snapshots of sea level pressure from CAM5

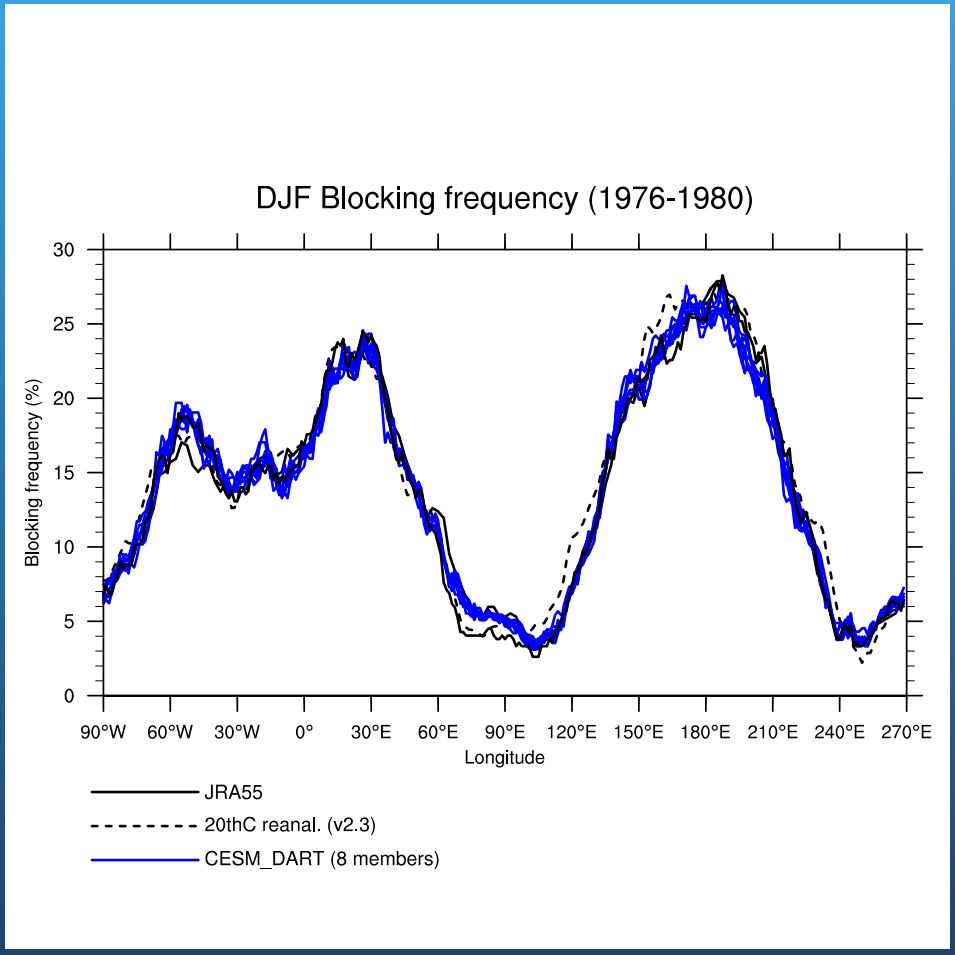


NCEP



Other users looking at atmospheric output from CESM-DART:

Plot from Rich Neale (NCAR)

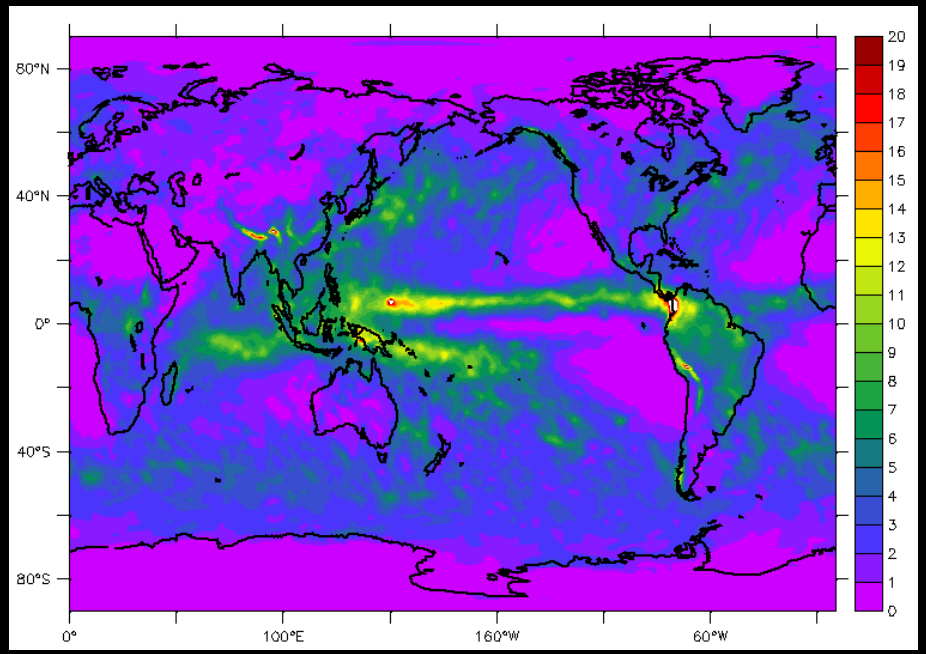


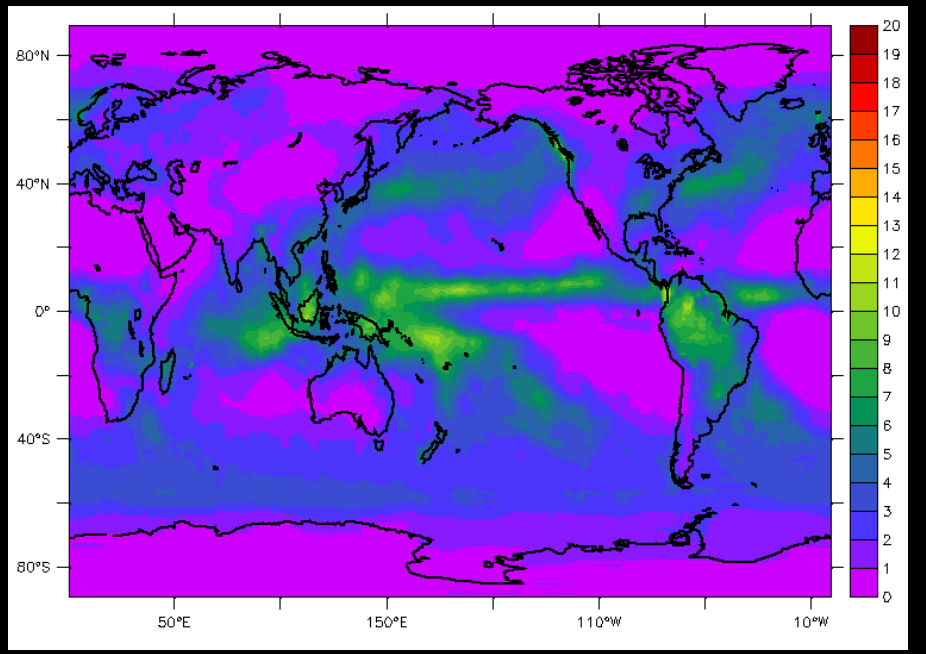
Blocking frequencies similar to 20CR and JRA55 over preliminary time-period

Other users looking at atmospheric output from CESM-DART:

Slide from Aneesh Subramanian (Oxford/Scripps):

Mean Precipitation



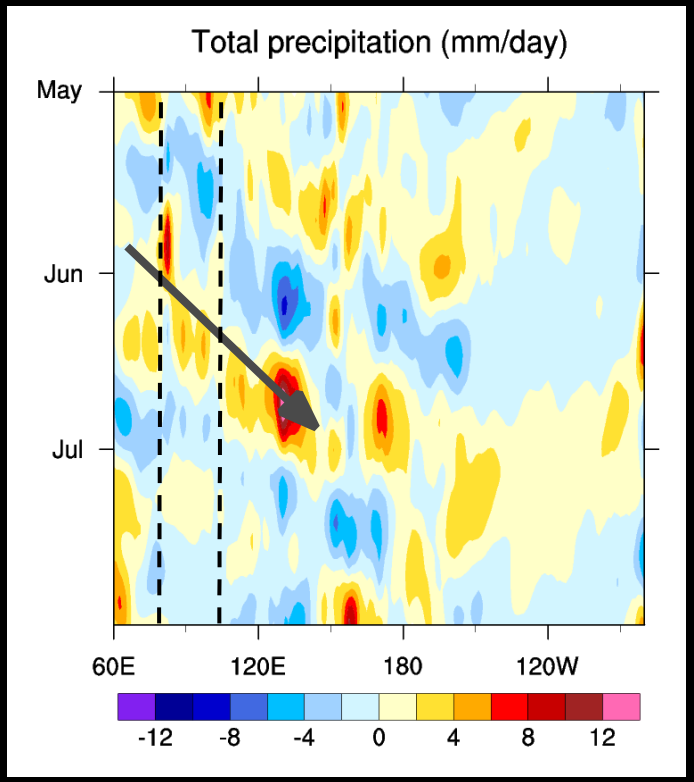


- Reduced precipitation bias in the East Pacific, south of the Equator
- Looking into analysis tendencies from DART to understand why.

Other users looking at atmospheric output from CESM-DART:

Slide from Aneesh Subramanian:

g in the posterior
during the active MJO phase in the Indian Ocean region



Major challenge for the CESM-DART project: **Computational cost**

When everything is working "just right" ~ 2 sim-years per wallclock month on Yellowstone.

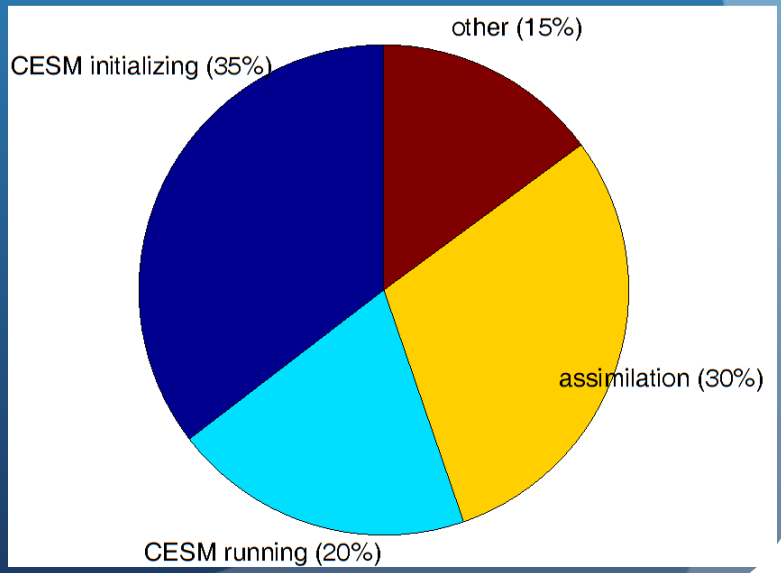
Recently ported simulation to Edison (NERSC) -- working to increase through-put on the new machine

Together with CSEG -- developed a software/infrastructure plan that can speed-up CESM/DART:

- Pause-resume capability for CESM
- Multiple couplers for multi-instance

(waiting to hear about funding)

Where does all the time go? ------→



Early results are promising, but we need more eyes on the data!

Interested in looking at preliminary results from ocean/atmosphere/land/ice components of CESM-DART? (1970 - 1980 +)

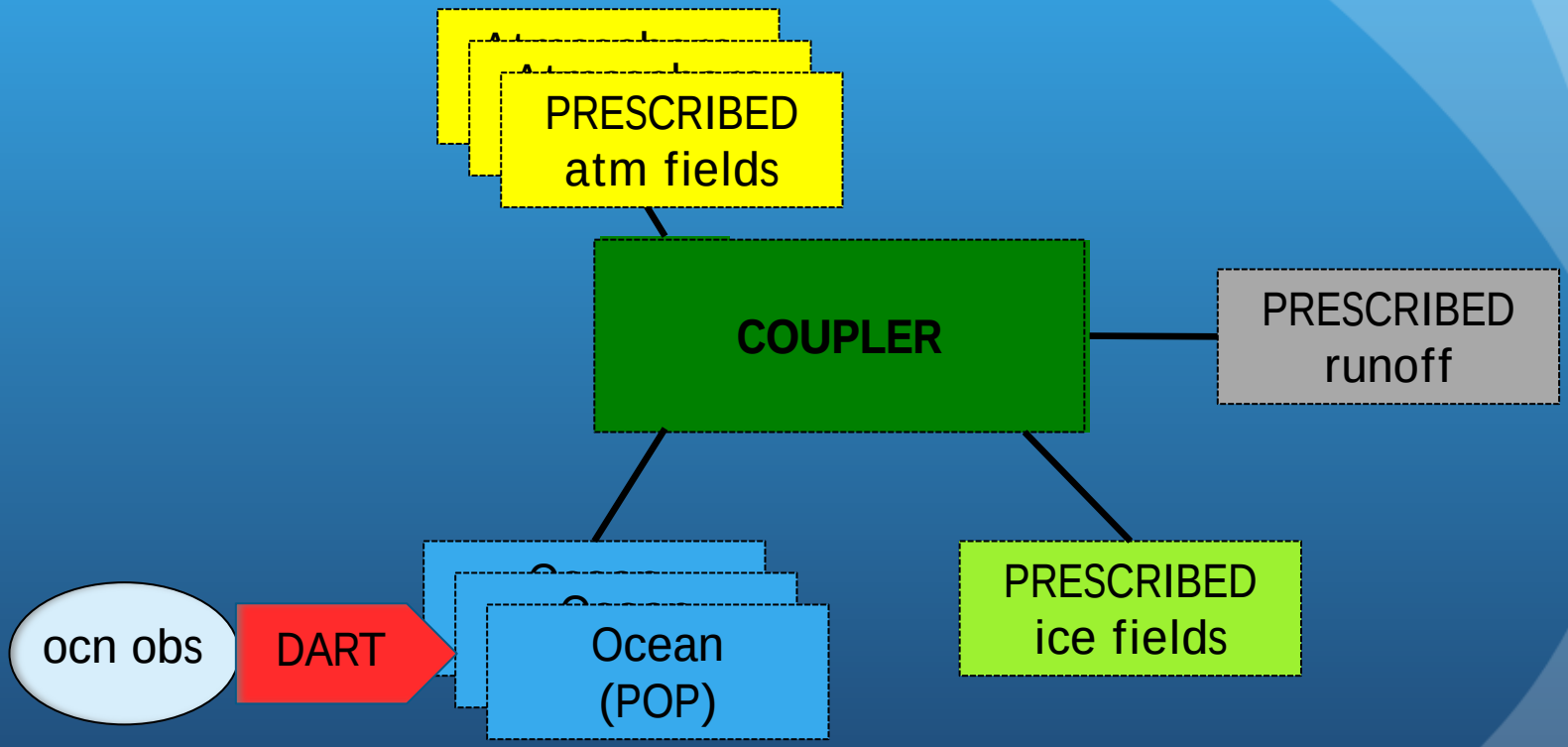
Contact: aliciak@ucar.edu

- Ocean/land/ice (monthly history files available)
- Atm (6 hourly history files available)
- Ocean (data assimilation increments available)
- Atm (data assimilation increments available)

Also more diagnostics available (ask me)

end

Community Earth System Model interfacing with DART in a "single-component" DA uncoupled framework

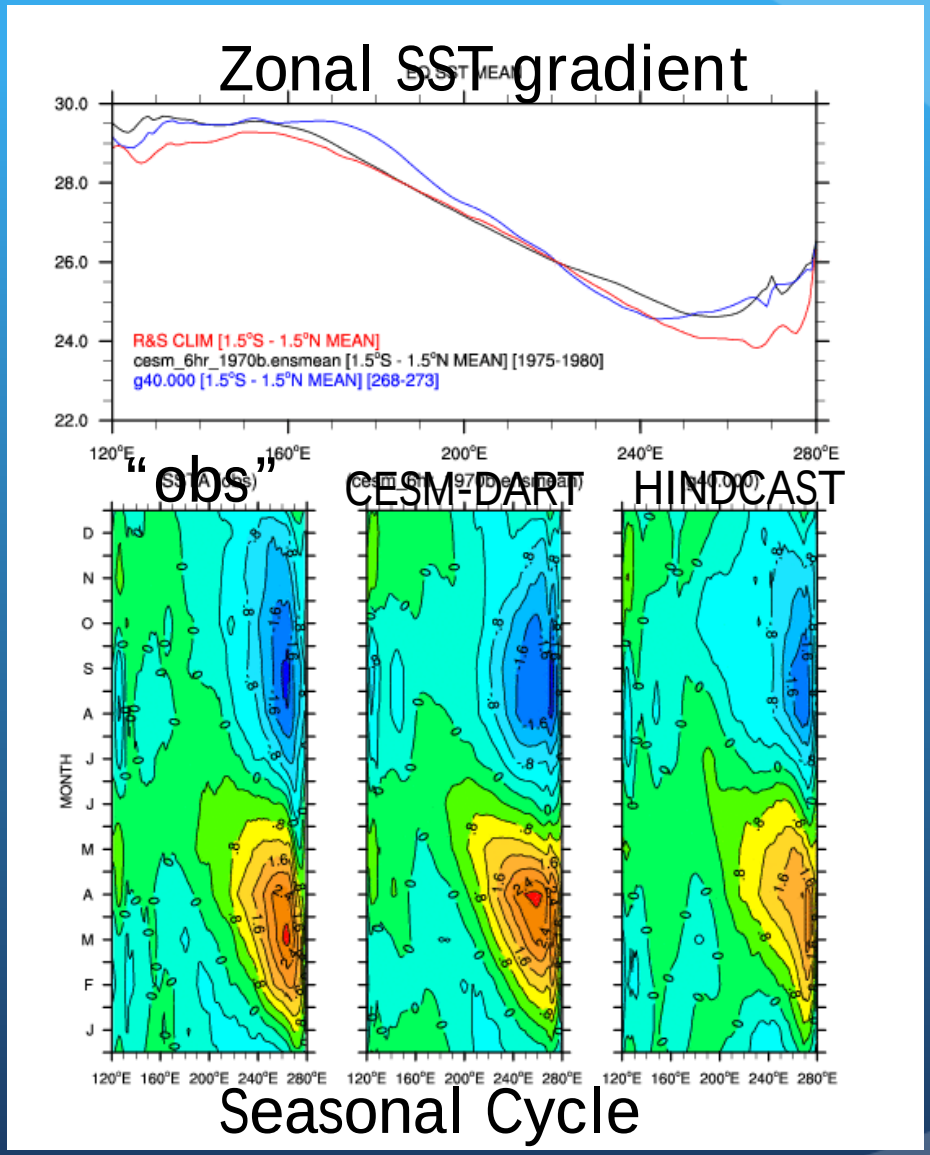


Plans for the next 5 years:

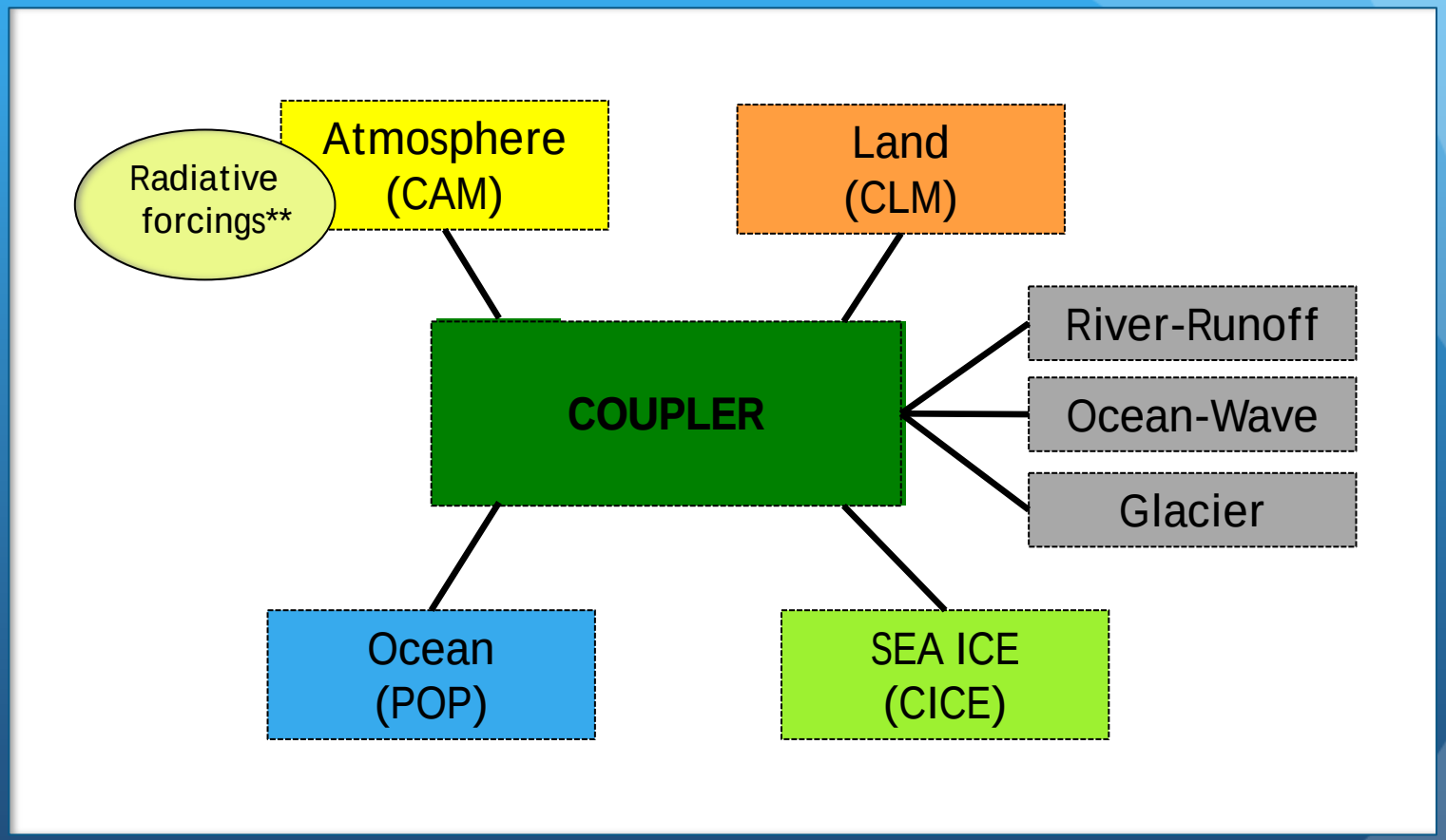
- Complete CESM ocean/atm coupled reanalysis from 1970-present (funded through EaSM-2)
- CESM and DART software advances for speeding-up the assimilation (NSF base funds/EaSM-3)
- Include altimetry in ocean assimilation (funded through EaSM-3)
- Global ocean assimilation with eddy-resolving model (funded through EaSM-3)

Investigate how coupled reanalyses may be advantageous for state estimation and prediction and engage University community in using the CESM/DART system

Some equatorial Pacific features



Community Earth System Model



** Greenhouse gases, manmade aerosols, volcanic eruptions, solar variability