Ensemble data assimilation using the CESM model

Integrating the CESM with the DART ensemble filter

CESM Tutorial

Key CGD personnel:

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Key CISL personnel:

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CGD-software engineering participants:

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Why do data assimilation with the CESM?

Climate (re)analysis

- Want to generate a historical record of the climate system (or it's components)
  - e.g.: "Has the ocean warmed in the last 50 years?"
- Want to understand physical processes in a data-constrained system

Initializing forecasts

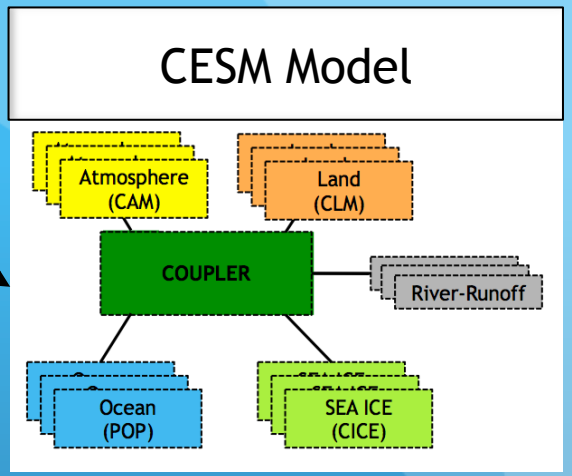
- Time scales of days to decades (atm + ocean + land + ice)

Model improvement

- Using DA increments to diagnose and try to understand(?) the biases/errors in the models

Assess an observational platform

Data Assimilation Research Testbed
Fortran code
developed/maintained in CISL

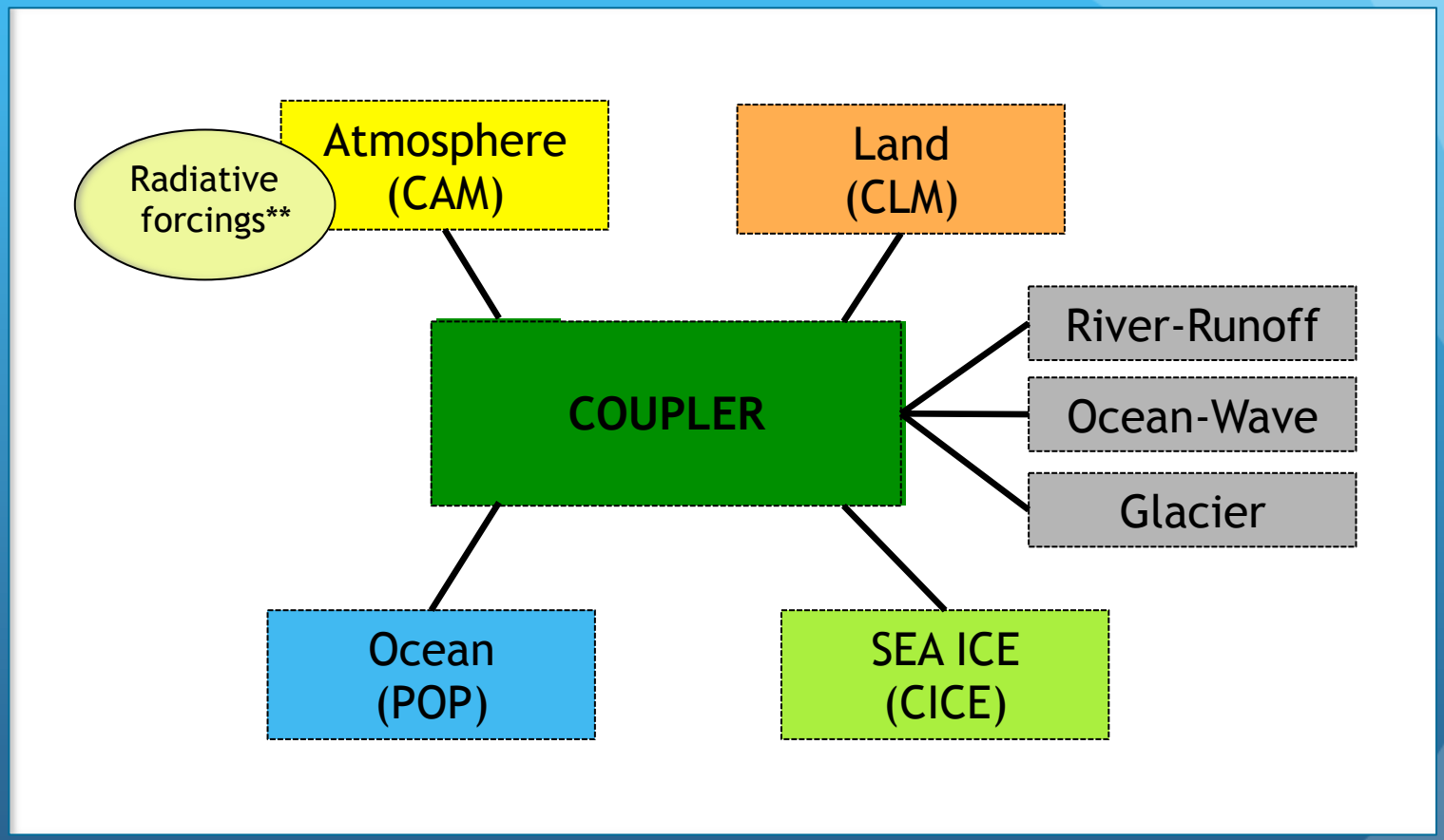


observations
of the ocean,
atmosphere,
land,etc.

Data assimilation capabilities for CESM are based on the DART ensemble filter

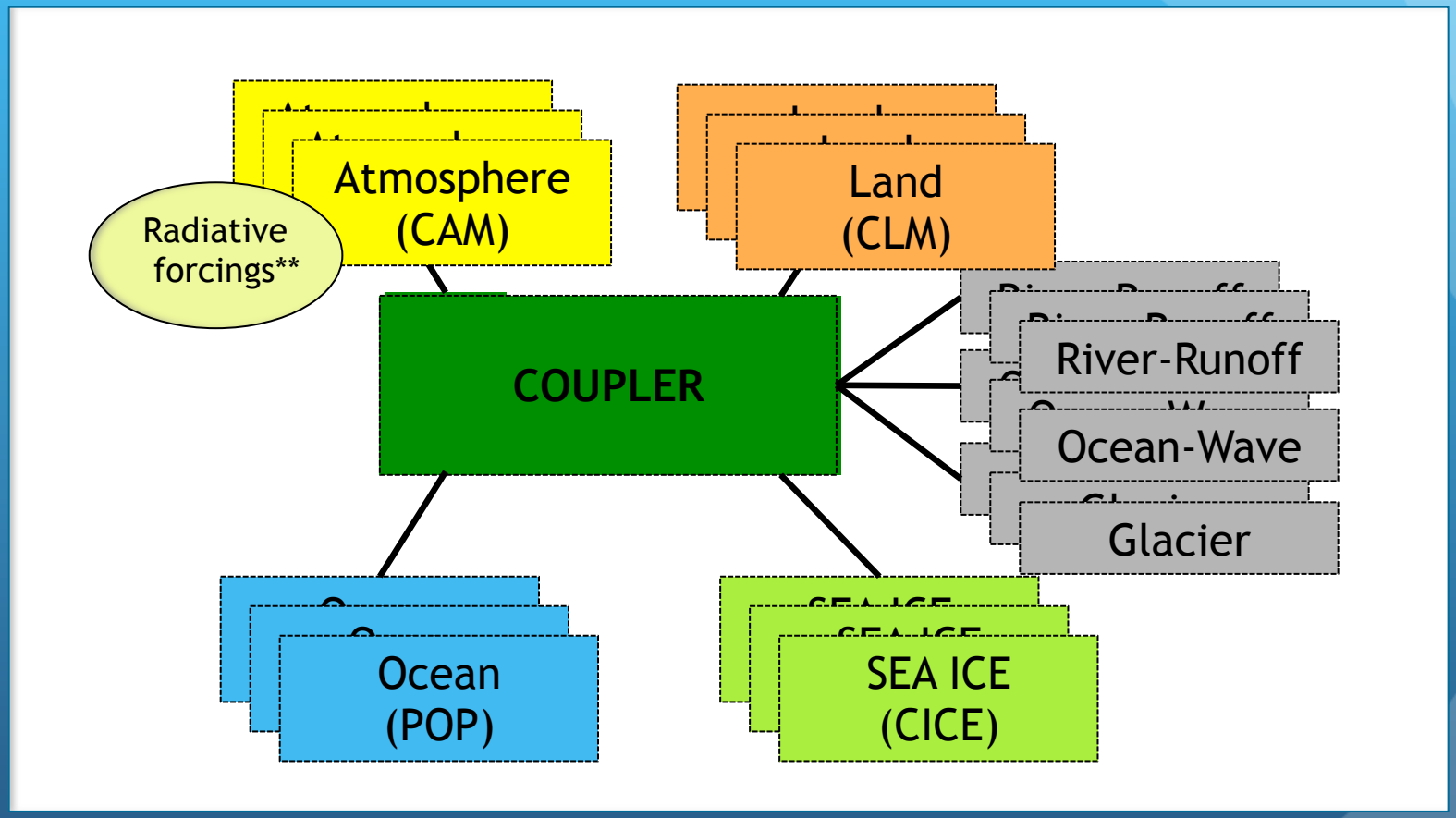
We have working systems for
+ CAM assimilation
+ POP assimilation
+ CLM assimilation

Community Earth System Model



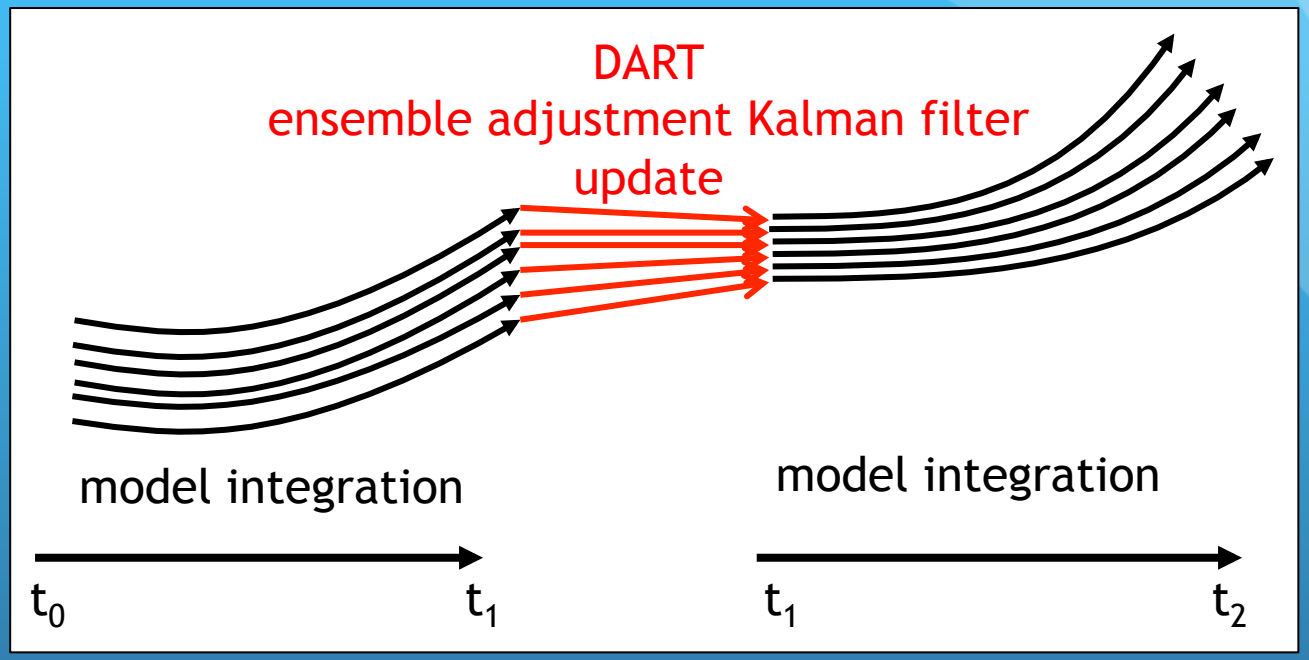
** Greenhouse gases, manmade aerosols, volcanic eruptions, solar variability

Community Earth System Model
"multi-instance"



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

Data Assimilation Research Testbed

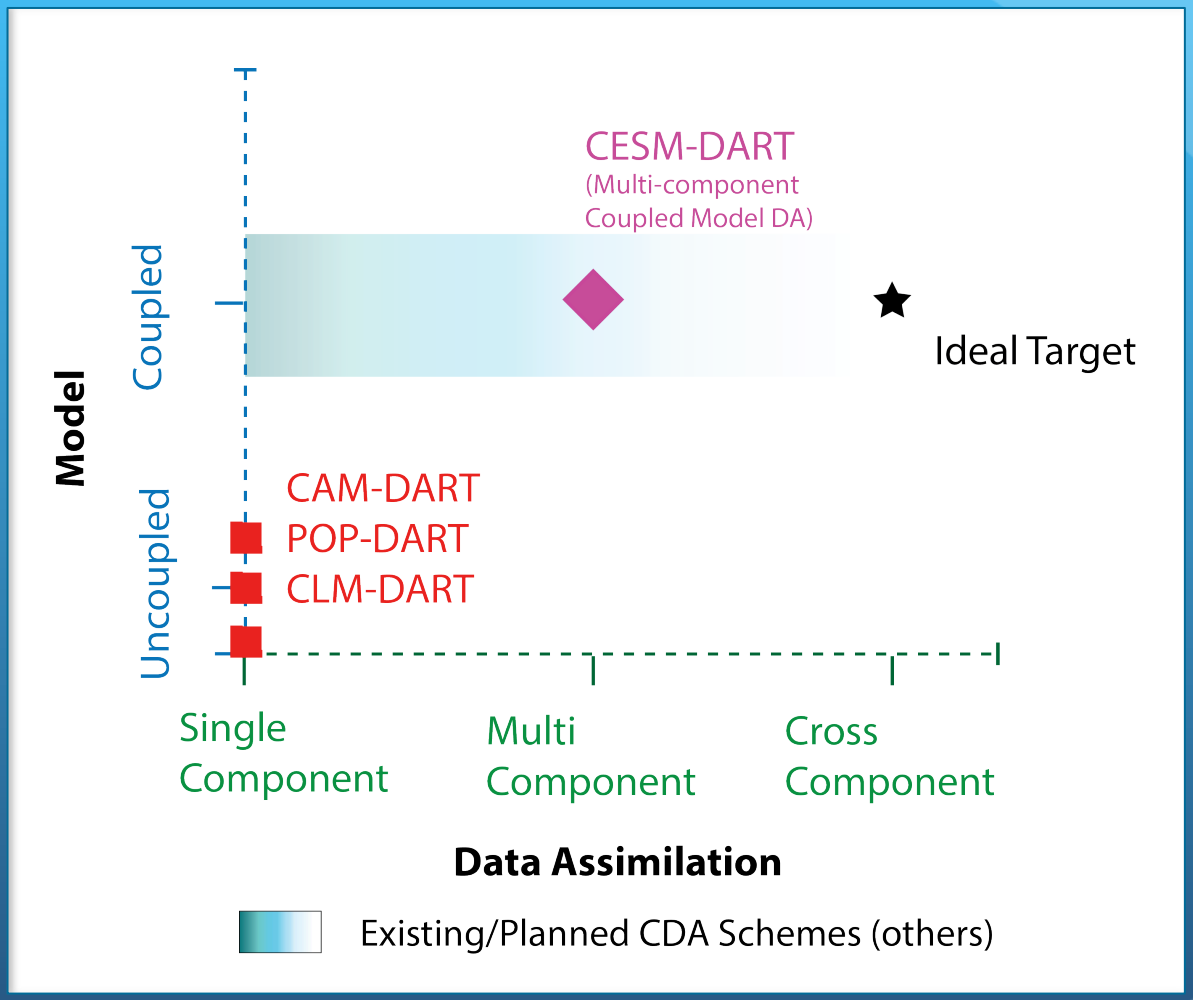


DART is a model-agnostic ensemble filter for data assimilation;
Necessary Ingredients:

- ***Model forecasts***
  - 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***

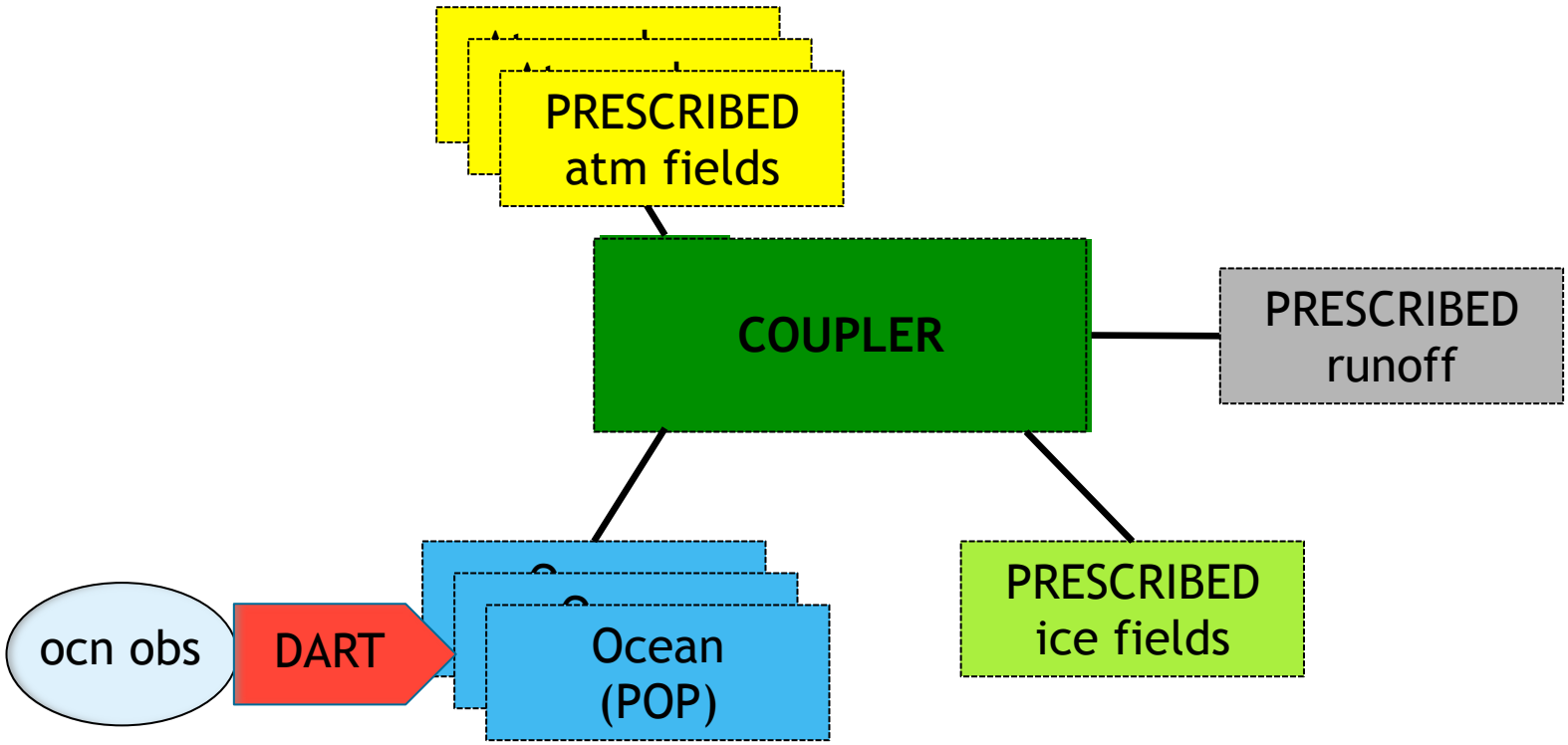
(http://www.image.ucar.edu/DAReS/DART)

Frameworks for data assimilation

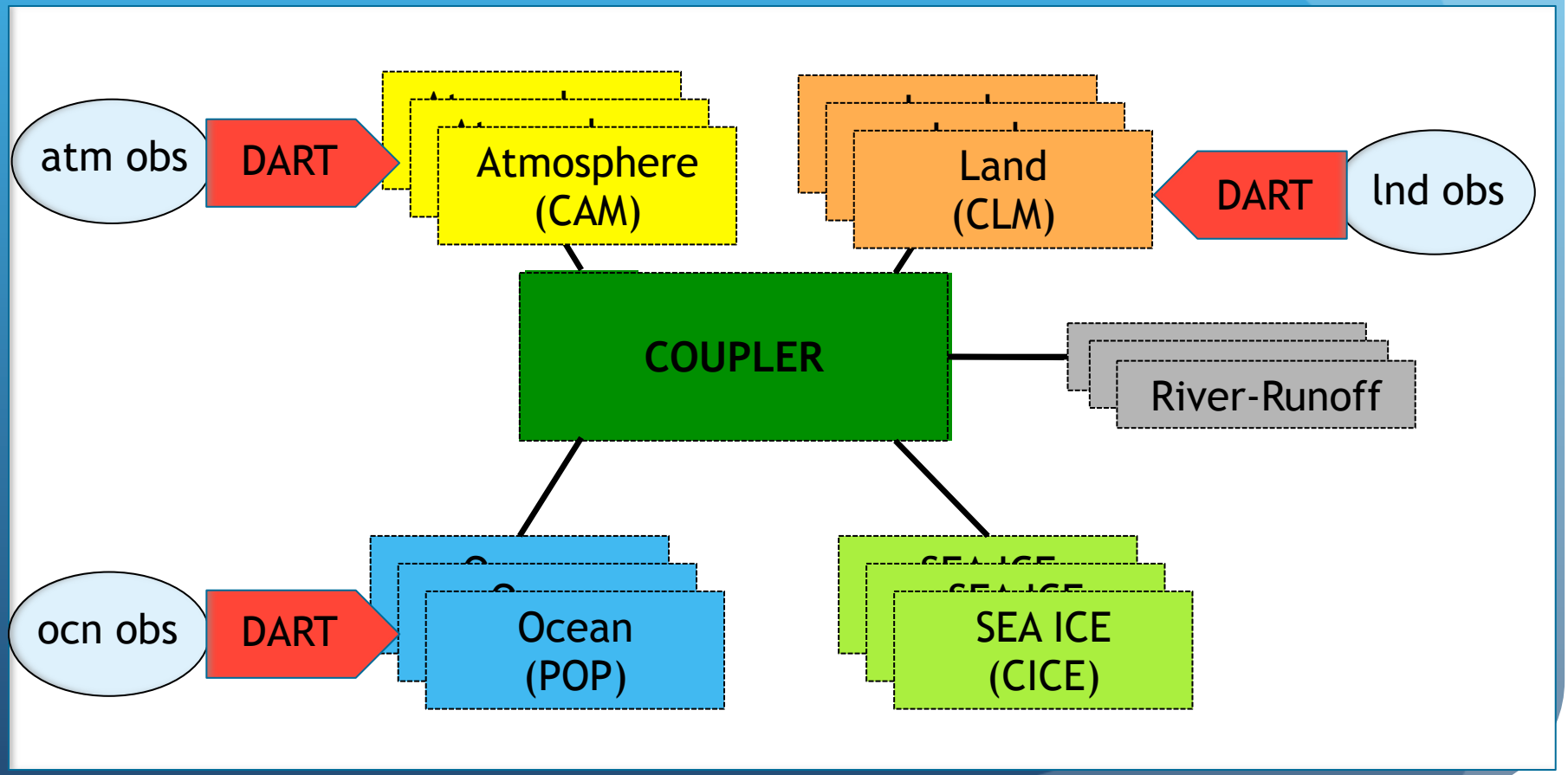


Schematic courtesy of A. Chatterjee

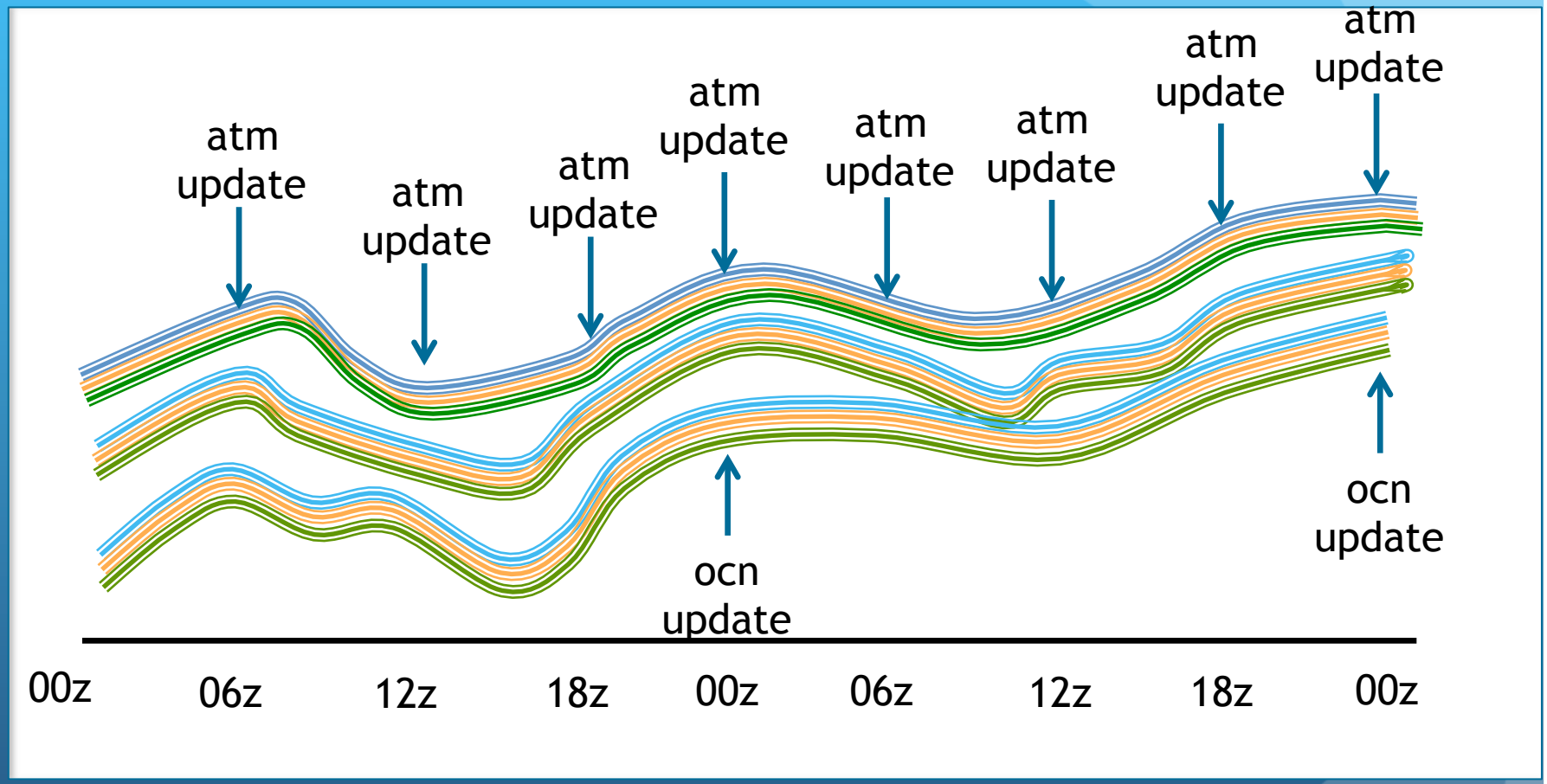
Community Earth System Model interfacing with DART in a "single-component" DA uncoupled framework



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

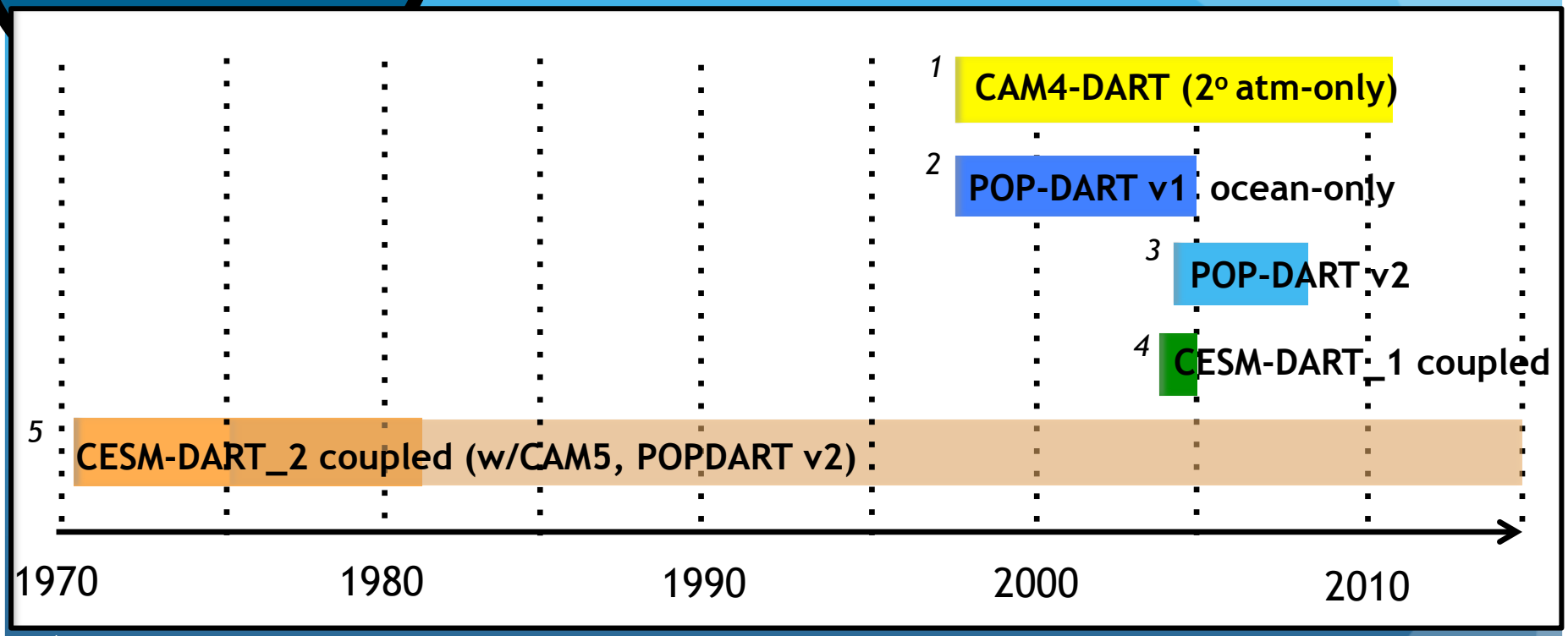


CESM-DART
coupled data assimilation (time-view)



- 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

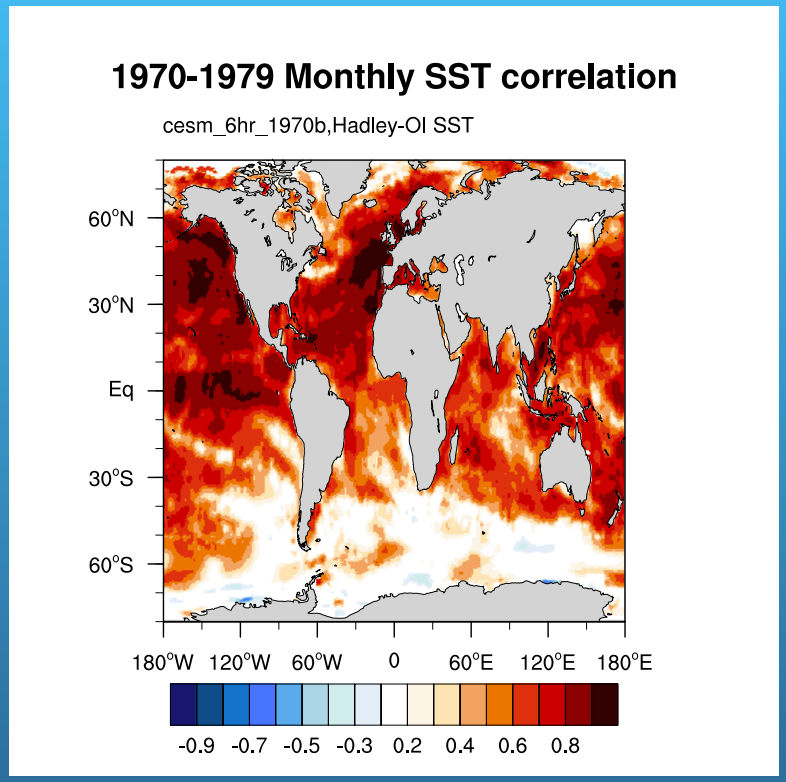
POP/CAM/CESM-DART: experimental climate reanalyses

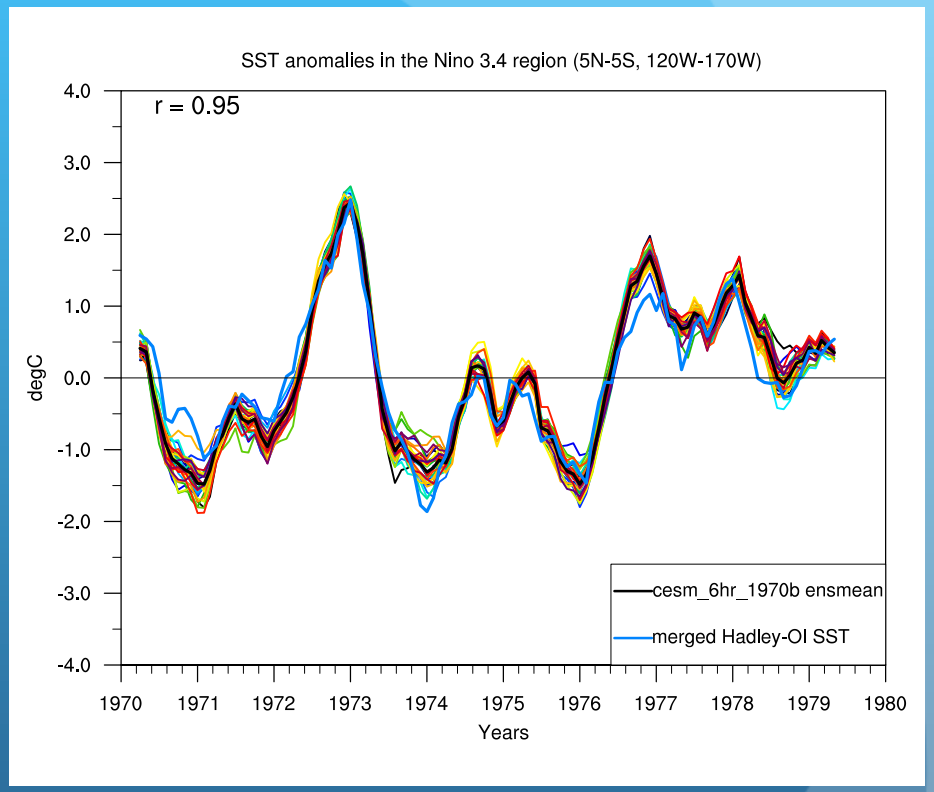


[1] Kevin Raeder (DAReS-CISl)
[2] Alicia Karspeck (Ocean-CGD)
[3] Alicia Karspeck (Ocean-CGD)
[4] Abhishek Chatterjee(CGD/DAReS-CISL)
[5] Alicia Karspeck (Ocean-CGD)

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

Some ocean results: SST variability





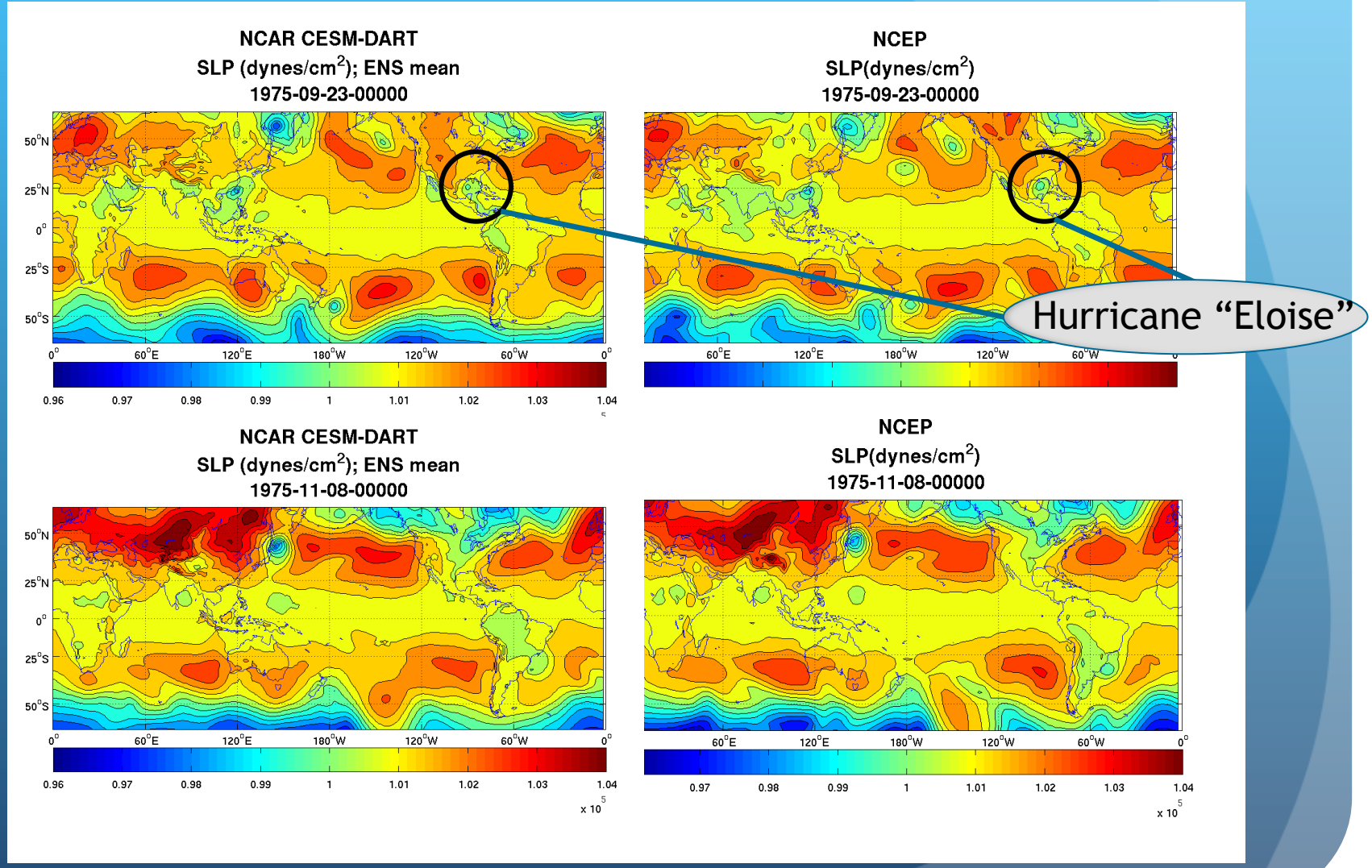
Generally high correlation with HADISST

1972-73 El Nino event simulated

Plots courtesy of S. Karol

More early results from the CESM-DART coupled assimilation atm

6hr snapshots of sea level pressure from CAM5



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How to learn more:

DART website:

- http://www.image.ucar.edu/DAReS/DART
  - Examples/papers/tutorials/etc.

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

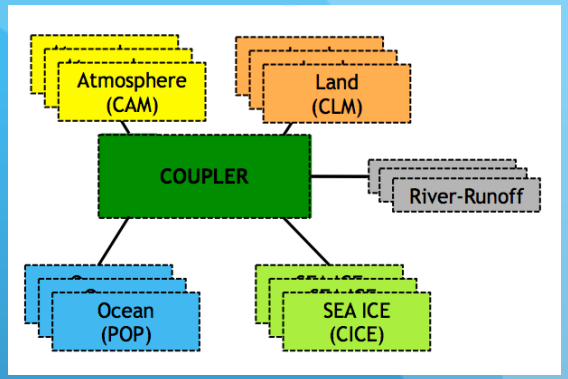
- Ocean/land/ice (monthly history files available)
- Atm (6 hourly history files available)
- Ocean (data assimilation increments available)
- Atm (data assimilation increments available)

Also more diagnostics available (ask me)

DART/DA

obs

Model/use/
obs
specific
interfaces



User jurisdiction:

- Definition of the "state"
- Observations
- Mapping from the model state to the observations ('forward operators')

DART jurisdiction:

- Implementation of DA algorithms
- Efficiency of the software
- Definition of protocols
  - observation format
  - common time/distance protocol
  - protocol for passing state vector between the model and DART
- Library of "use cases" (commonly used model interfaces, observational data sets, forward operators, diagnostic routines)

CESM jurisdiction:

- The best way to run an ensemble of simulations (speed)
- How to stop (or pause) and restart (resume) a simulation
- What model fields diagnostics are output/ saved/archived