Evaluating the Fidelity of a Community Coupled Model DA System (CESM-DART)


The National Center for Atmospheric Research

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Existing DART setups for CESM components

- **CAM-DART**
  - atmosphere component
  - Raeder et al. (2012), *J. Climate*

- **POP-DART**
  - ocean component
  - Karspeck et al. (2013), *J. Climate*
Defining the Terminology for our Framework

**Ideal Target**

*Cross-component Coupled model DA*

“Assimilation into a coupled model where observations in one medium are used to generate analysis increments in the other”

(from M. Rienecker, WMO CAS Workshop, Dec. 2010)
Motivation for a CDA Framework

- **Seamless prediction – days to decades**
  - unify short to long term forecasting systems
  - highly balanced coupled initial states

- **Accurate representation of short-term and long-term coupled phenomena**
  - short-term – MJO
  - extreme events – tropical cyclones

- **Improve use of near surface observational data**
  - strong initial transients in these quantities
  - capture the diurnal cycle in atmosphere-ocean interactions
Multi-component Coupled Model Data Assimilation

- Coupler exchanges fluxes and other necessary information between component models
- Several other models that are active – Sea-ice, Land-ice, River runoff, etc.
Estimated Model States

- Suite of variables from atmosphere, ocean, land and other model components
- Quantitative examination ongoing
  - need a larger timespan of runs to assess any systematic drifts
  - qualitatively fields for the first few months look ok!
Evaluating Performance in Observation Space

- Ensemble analysis provides an estimate of analysis and forecast uncertainty
  - (Top Panel) evolution of prior and posterior RMS error
  - (Bottom Panels) profile of time-averaged prior and posterior RMS error, total spread and bias relative to the actual radiosonde T observations
Multi-component Coupled Model DA

- Initial Conditions
  - 30 member ensemble
  - 20th century control run from ~1° CESM

- Atmosphere (CAM)
  - COUPLER
  - DART Atm. Obs.

- Land (CLM)
  - COUPLER
  - ensemble members

- Ocean (POP)
  - COUPLER

Time:
- 00Z
- 06Z
- 12Z
- 18Z
- 24Z

DART Atm. Obs.
- Land Obs.
- Ocean Obs.
Ocean-component Coupled Model DA

- Initial Conditions
  - 30 member ensemble
  - 20th century control run from $\sim 1^\circ$ CESM

- Atmosphere (CAM)
- Land (CLM)
- Ocean (POP)

- Ensemble members

- 00Z, 06Z, 12Z, 18Z, 24Z

- DART
- Ocean Obs.
Difference in 6-hourly Sea Surface Potential Temperature

- Large differences in the Gulf Stream
- Phase differences in tropical instability waves/shift in ITCZ
- Bias correction in SH
- Related to
  - Forcing fields
  - Ensemble spread

January 2004 to April 2004, 6-hr frames
Impact of Changes in Forcing fields

- Differences in SST corresponds to differences in surface heat flux, sea surface height → changes in wind fields
Impact of an Unconstrained Atmosphere

Evaluation in observation space of the prior and posterior RMS error and the ensemble spread

- Tropical Pacific (5S-5N, 85-105W)
In Search of MJO…

- Hypothesis: improvements to the model mean state in the multi-component case will better capture MJO signal

- Showing state of the MJO as a point in the two-dimensional phase space of Real-time Multivariate MJO Series 1 (RMM1) and Series 2 (RMM2)
  - (Top Panel) for Multi-component coupled model DA
  - (Bottom Panel) for Ocean-component coupled model DA
Ongoing Activities

- For all experiments
  - short-term: multi-year simulations, seasonal forecasting (e.g. ENSO)
  - long-term: decadal forecasting (e.g. AMOC)

- ‘True’ reference experiment
  - no data assimilation for any component
  - Challenge – instabilities develop rapidly (in fact DA stabilizes the model states)

- Improving data assimilation schemes for each individual component
  - e.g. ocean - accounting for representativeness error (poster H-p13)
  - e.g. land – model PFT, localization issues (posters F-p02, F-p05)
Summary

- Successful implementation of CESM-DART
  - multi-component coupled model framework
  - test-bed for transitioning to cross-component coupled model scheme

- Results from initial implementation
  - demonstrates differences in multi-component vs. single-component
  - demonstrates “impact” in atmosphere-ocean interaction, forcing fields at the boundary

- Community-oriented development
  - CESM model is publicly available (http://www2.cesm.ucar.edu)
  - Data Assimilation scheme (DART) is publicly available (http://www.image.ucar.edu/DARes/DART/)
  - CESM-DART codes to be released soon (later this month)
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[Logos of NCAR, Carnegie Institution for Science, and NSF]
QUESTIONS?

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CESM Model Components

- All active components (B COMPSET)
- Present day with CAM5 physics (CAM5 FV core)
- Horizontal Res: Nominal ~1
- Vertical Discretization:
  - CAM – 30 levels
  - POP – 60 levels with 10 m resolution in the upper 200 m, gradually expanding to 250 m resolution below 3000 m depth

CESM Components – High Level Diagram  The coupler is in the middle and communicates with all other components (adapted from - https://summerofhpc.prace-ri.eu)
CESM Model Bias

**SST**

- **b40_20th_1d_b08c5cn_139jp (yrs 1981-2000)**
  - Sea surface temperature: mean = 20.11
  - **ANN**
    - Min = -0.27 Max = 29.38
  - **HadiSST (climatology)**
    - Sea surface temperature: mean = 20.31
    - Min = 0.10 Max = 29.60
  - **b40_20th_1d_b08c5cn_139jp - HadiSST (climatology)**
    - mean = -0.20 rmse = 0.97
    - Min = -5.32 Max = 8.54

**Surface Stress**

- **b40_20th_1d_b08c5cn_139jp (yrs 1981-2000)**
  - Surface stress: mean = 0.07
  - **ANN**
    - Min = 0.00 Max = 0.28
  - **NCEP**
    - Surface stress: mean = 0.06
    - Min = 0.00 Max = 0.25
  - **b40_20th_1d_b08c5cn_139jp - NCEP**
    - Surface stress: mean = 0.00
    - Min = -0.14 Max = 0.07
Methodological Considerations ➔ Cross-comp. CDA

- Development of coupled error covariances
  - cross-component coupled model DA
  - Challenge – demonstrate an effective localization technique, esp. relevant for near surface observational fields

- Understanding and dealing with model biases
  - bias errors in coupled models difficult to estimate, and attribute
  - working more carefully with land, sea-ice, land-ice and river runoff model components in CESM