Ocean: CMIP6 model evaluation needs

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• Specific challenges in ocean model evaluation
• Surface fluxes
• Sea level height, ocean color
• Sea surface salinity
• Looking ahead

Thanks to
Jacqueline Boutin, Paul Durack, Peter Gleckler, Steve Griffies, Andrew Wittenberg

Obs4MIP meeting - Washington DC - April/May 2014
Specific challenges in ocean model evaluation

- Long time scales, small spatial scales, difficult to observe
  - Evaluation for last 5-6 decades is a challenge (data missing)
  - Continuity vs. mean climate /uncertainty/biases challenge
- Surface vs. depth (integrated or not) different issues
- Ocean integrals as important as budgets/transports at choke points and key sections (ACC, …)
- Observations from space:
  - surface and indirect sub-surface (opaque, sea level)
  - Complement in situ, TAO, ARGO, XBTs
- Coherent products (SST, turbulent/radiative fluxes,…)
  hold value for process understanding (e.g. TAO)
- OGCMs higher resolution than AGCMs
Example: where do ocean reanalysis agree?

- Agree where in situ observation exist
- Forcing fields play a key role
- Cannot be used to validate models in most of the ocean

SODA-ORAS4 correlation 1958-2001

SODA-ORAS4 wind forcing correlation 1958-2001
SST

- Extensively used for coupled model evaluation
- Well observed by satellite since 1979
- Routine calibration (mostly for NWP)

Longer “climate quality” time series via reanalysis (ERSST, HadISST, KAPLAN…)
  - agree on the larger/global scales
  - some regional discrepancies in multi-decadal trends

Obs4mip challenges (variability and trend):
  - need to better document reanalysis differences < 1979
  - higher resolution than typical 1 deg
  - Higher time sampling (diurnal cycle, intraseasonal)
  - work with ana4MIP and data assimilation community

Deser et al. 2010
Surface fluxes

- Key variables: drive o(0) ocean circulation
- Observation-based estimates are hugely uncertain relative to what they need to be to help model development (long standing problem)
- Bulk formulae based ocean-only simulations choice approach for ocean model developers (not yet in CMIP)
- Splicing of different satellite data into coherent products
- Turbulent fluxes:
  - Wind stress, LH, SH
  - reanalysis key but must be fed/validated by satellite obs
- Radiative fluxes
  - Splicing and continuity issue
- Diurnal cycle and smaller scales may provide process-based evaluation (still untapped ?)
Estimated zonal wind stresses
(equatorial Pacific, running annual mean)

Extended from Wittenberg (J. Climate, 2004)

- Substantial impact on the equatorial thermocline slope, currents, and upwelling in ocean-only simulations, ocean state estimates, and ocean initializations
- Which observation for model evaluation?

Near-term challenges for satellite observations:
  - continuing lack of convergence among the various wind stress products
  - gaps between satellite missions (e.g. due to the loss of QSCAT)
  - the recent crisis of the TAO array, in particular near the equator, whose anemometers and thermocline measurements are critical for ground-truthing the satellite estimates
Zonal wind stress in CMIP

Zonal Mean

Along Equator

Observational constraint strong

Observational constraint weak

IPCC AR5 WG1 Figs 9.19 and 9.20
Meridional heat transport

- Key integrated variable for model evaluation
- Direct measurements scarce
- Integration of “observed” surface heat flux used as proxy
- Requires ad hoc corrections to account for uncertainty in measurements

IPCC AR5 WG1 Fig 9.21
Sea level height

- Since 1992 and T/P, sla provides a depth integrated circulation product
- Largely influenced by wind stress
- Higher resolution simulations will need higher observation resolution
- AVISO is being used increasingly to evaluate eddying ocean simulations. The new AVISO product is 1/4 degree and daily, though the actual resolution is coarser (currenty 1 degree in obs4MIP).

IPCC AR5 WG1 Fig 9.16
Ocean color

- Satellite observations since 1997 (SeaWiFS, MODIS, …)
- Validation of biogeochemical models
- Used for GCM model evaluation?
Sea surface salinity

- Satellite products since 2010 (SMOS and AQUARIUS)
- Can evaluate mean state, annual cycle, smaller scale features
- Time integrates E-P: potential to reduce obs uncertainty on E-P
- Calibration with in situ also key
- Again sustained observation is highly desirable
- Do models provide the same physical field or do we need a SSS simulator?

Durack et al. 2013

Density of in situ salinity profiles
SMOS SSS available since 2010

RMSE Difference (SMOS SSS \(1 \text{ MONTH or } 10 \text{ days} - 100 \times 100 \text{KM}^2\)) – IN SITU SSS

- Gulf stream – 10 days
  Reul et al. GRL 2014
- Hernandez et al. 2014
  After correcting Large scale seasonal Biases
- Hasson et al. 2014
  Islands + RFI?
- Amazon Plume
  10 days - Reul et al.
- 1 month-200km
  Durand et al
- Hasson et al. 2013
  ‘OTT’ Bias corrected region

Courtesy Jacqueline Boutin
• SMOS (2010-now) detects mesoscale variability
• precision ~.2 (1 month-100 km), ~.3-.5 (10 day-100 km)
• although large scale regional biases still remain to be empirically adjusted
• Not yet suited to large scale model evaluation (i.e. vs ARGO)?

Reul et al. GRL in press 2014
Amazone plume (Reverdin et al. 2013)

Kolodziejczyk et al., 2014, in rev, JGR
Looking ahead

• **Satellite observations for ocean model evaluation**
  1. Coherent long time series needed
  2. Small scale features need to be evaluated
  3. Importance of in situ calibration (e.g. TAO)
  4. Space and time covariance of different fields

• **CMIP6 Metrics (Metrics Panel and WGOMD)**

• **What are the o(0) observational constraints (e.g. wind stress) ?**

• **Opportunities to better evaluate mean state, smaller scales (eddy, DC), ocean-atmosphere interface, transports (Drakkar validation tool)**

• **Better entrain ocean modellers in CMIP:**
  • Few outcomes of CMIP5 comparison studies directly help the process physicist (mean state errors)
  • Consider intermediate configurations (e.g. nudged atmosphere simulations), include CORE3 in CMIP6

• **Observation experts + modellers work groups (e.g. GOOS/TPOS)**
Recommendations: New requirements for TPOS 2020

Resolving the Atmosphere/Ocean interface

• Higher vertical resolution of temperature, salinity, velocity resolving the diurnal cycle across regimes
• Expand the number of locations where the full energy, water and momentum exchanges are monitored.

Boundary regions

• Define requirements for sustained observations of equatorial, eastern and western boundary regions.
• Task NPOCE, SPICE, ITF TT, Eastern Boundary regional nations/alliances to assess requirements for observations in sustained mode (e.g. Sustained array for ITF based on INSTANT )

Deep Ocean

• Extend observations to the deep ocean as part of a global Deep Ocean Observing Strategy (DOOS)
Ocean model initialization

Goal is to drive the model towards the observed trajectory

Many different ways to do this as it is a difficult problem:
- Not enough quality 4D ocean observations
- Hard to distinguish internal vs. forced variability
- Model errors
- 4D var data assimilation of coupled ocean-atmosphere system not possible (yet?)