Assimilation of Argo profiles for the Pacific Ocean

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Outline

• Motivation
• Model and assimilation method
• Results
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2. Model and assimilation method

2.1 Model

NEMO (Nucleus for European Modeling of the Ocean) v2.3

Model domain: 118°E-70°W, 60°S-60°N, surface-5250m
Experiment period: January, 2005 - December, 2007

Model resolution:
- Zonal: 2.0°
- Meridional: 0.5° → 1°
- Vertical: 31 levels
- Time: 1.5 hours
2.2 Local Ensemble Kalman filter

61 members (60 perturbed observation members + 1 unperturbed)

\[ X^a = X^f + K(d - HX^f) \]

\[ K = (\rho \circ P^f)H^* (H(\rho \circ P^f)H^* + R)^{-1} \]

\[ X = [T \quad S]^* \]

\[ \rho(x, y) = e^{-(\frac{d_x^2}{L_x^2} + \frac{d_y^2}{L_y^2})/\cos^3(y)} \]

K -- the Kalman gain matrix;
H -- measurement operator;
d -- observations;
P^f -- the ensemble covariance matrix
ρ -- a correlation function used to localize the background error covariance in P^f;
L_x=1500km, L_y=500km for T; L_x=800km, L_y=400km for S.
R -- the observation error covariance matrix.
Local analysis

30° longitude X 15° latitude x 3 neighbor levels

Schematic figure of (a) the search cuboid and (b) time window for data points used in an assimilation cycle.
The observation error variance for an individual observation is defined as (Oke et al. 2007):

\[ \varepsilon_o^2 = \varepsilon_{instr}^2 + \varepsilon_{RE}^2 + \varepsilon_{age}^2 \]

\( \varepsilon_{instr}^2 \) -- the estimated variance of the instrument error

\( \varepsilon_{RE}^2 \) -- the estimated variance of the representation error (RE)

\( \varepsilon_{age}^2 \) -- the estimated variance of the error associated with the relative age of an observation.

\[ \varepsilon_{instr}^2 + \varepsilon_{RE}^2 = 0.25 \ (°C)^2 \text{ for T} \]
\[ 0.1 \ (psu)^2 \text{ for S} \]

\[ \varepsilon_{age} = RMS_{mod} \mid t^a - t^o \mid / 10.0 \]
2.3 Data (2005-2007)

- TAO/TRITON
- XBT
- CTD
- Argo
- **NCEP** Pacific Ocean Reanalysis

10% Argo profiles for validation (randomly selected)

Scheme1: 90% Argo profiles + all other profiles (XBT, CTD, TAO/TRITON)

Scheme2: 90% Argo profiles
Distribution of (left) temperature and (right) salinity profiles within a 11-day window centered on January 16, 2007.
Spatial distribution of number of Argo profiles for 2005-2007. The number is counted at a $2^\circ \times 2^\circ$ cell, shifted over the whole domain.
**Scheme1:** Argo profiles + all other profiles (XBT, CTD, TAO/TRITON)

**Scheme2:** Argo profiles

\[ RMSE_{region} = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (T_i^{model} - T_i^{observation})^2} \]
RMSEs of temperature, as a function of depth, from analysis with assimilation (cuboids) and control run without assimilation for different regions, where RMSE is obtained using independent Argo data as observations.
RMSEs of Salinity, as a function of depth, from analysis with assimilation (cuboids) and control run without assimilation for different regions, where RMSE is obtained using independent Argo data as observations.
RMSE of temperature at 50m, calculated using all Argo data profiles for the whole period from 2005-2007.
RMSE of temperature at 200m
RMSE of Salinity at 50m
RMSE of Salinity at 200 m
Time-longitude plots of averaged temperature over top 250m along the equatorial belt of 5S-5N during 2005-2007, for (left) control run, (middles) assimilation runs, and (right) NCEP reanalysis data.
Time-longitude plots of averaged temperature over top 250m along 30N during 2005-2007, for (left) control run, (middles) assimilation runs, and (right) NCEP reanalysis data.
Time-longitude plots of zonal velocity of 15m along the equator during 2005-2007.
4. Conclusions - perspectives

• An assimilation system based on local EnKF was developed in NEMO for the Pacific Ocean. The assimilation of Argo profiles can improve effectively ocean state estimate for most regions of the Pacific ocean, especially for the southern Pacific ocean and deep ocean.

• There is no significant difference between the assimilation of all profiles and the assimilation of Argo profiles.

• The next step:
  • bias correction strategies
  • improvement of state estimate for the Northern Pacific
  • a good marriage between Argo with satellite observations (SST and SSH).
Acknowledgement: