Marine Data Assimilation at JCSDA

SOCA: Sea-ice, Ocean, and Coupled Assimilation

JCSDA Core SOCA team: Travis Sluka, Guillaume Vernieres, Hamideh Ebrahimi
Many contributions from: JCSDA JEDI team, NASA/GMAO, NOAA/EMC, NOAA/ESRL
Who is JCSDA?

Joint Center for Satellite Data Assimilation

Interagency partnership hosted by UCAR dedicated to improving and accelerating use of research and operational satellite data in weather, ocean, climate and environmental analysis and prediction systems
## Who is JCSDA?

### JCSDA PROJECTS

[https://www.jcsda.org](https://www.jcsda.org)

<table>
<thead>
<tr>
<th>OBSERVATIONS</th>
<th>ALGORITHM &amp; INFRASTRUCTURE</th>
<th>APPLICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>UFO (CRTM, ...)</td>
<td>DA Algorithms (OOPS)</td>
<td>Marine (SOCA)</td>
</tr>
<tr>
<td>Diagnostics</td>
<td>B Matrix (SABER)</td>
<td>Land</td>
</tr>
<tr>
<td>Observation database</td>
<td>Infrastructure</td>
<td>Atm. Constituents</td>
</tr>
<tr>
<td></td>
<td>Coupling Methodology</td>
<td></td>
</tr>
</tbody>
</table>
SOCA (Sea-ice, Ocean, and Coupled Assimilation)

- marine data assimilation (ocean, ice, coupled)
- Focused around MOM6 model
- Built within JEDI system (Joint Effort for Data Assimilation Integration)
- Weakly coupled DA for use with NOAA’s UFS, NASA’s GEOS
Goals

• Next-generation **unified** DA system
• Increase **R2O** transition rate (academia to operations)
• Increase **science productivity** and **code performance**

Strategy

• **Modular code** for flexibility, robustness and optimization
• Mutualize **model-agnostic** component across:
  • **Applications** (atmosphere, ocean, coupled, ...)
  • **Model & grids** (operational/research, regional/global)
  • **Observations** (past, current and future)
• Collective reduction of entropy

Overview of JEDI:
https://doi.org/10.25923/rb19-0q26
SOCA: Interface to JEDI

What we **pass to JEDI**

- Interface to MOM6 model
- Observation operators (within UFO)
- Background error covariance (using SABER)

What we **get from JEDI**

Generic applications:

- **DA algorithms** 3DVAR, 3DFGAT, “4DVAR”, Hybrid-EnVAR, LETKF
- **h(x)**: Advance MOM6 over a time window and simulate observations using the generic UFO’s.
- **Perturbation of initial conditions**: B-matrix randomization.
- **Forecast**: Advance of MOM6 over a time window, driven by OOPS.
- ...
SOCA: Interface to JEDI

JCDSA Repositories

- Observations
  - UFO: Obs operators
  - IODA: Obs databases
  - CRTM
- Algorithms & Infrastructure
  - OOPS: Generic DA
  - SABER: B-matrix

External Repositories

- MOM6
- FMS
- GSW

Libraries:
- libufo.so
- libioda.so
- libcrtm.so
- liboops.so
- ...

Libraries:
- libmom6.so
- libfms.so
- libgsw.so
- ...

SOCA-MOM6: (JEDI interface)
SOCA: Interface to JEDI

UFO: Unified Forward Operators
- SST/SSS retrievals
- insitu T/S
- altimetry
  (Absolute Dynamic Topography)
- sea-ice fraction/thickness
- SST/SSS direct assimilation
  GMI/SMAP brightness temperatures using CRTM
SOCA: Interface to JEDI

UFO: Unified Forward Operators

<table>
<thead>
<tr>
<th>RETRIEVED QUANTITY</th>
<th>SENSOR/SATELLITE</th>
<th>THINNING RATE</th>
<th>TYPICAL COUNT ASSIMILATED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea Surface Temperature from Infrared</td>
<td>AVHRR - NOAA-19</td>
<td>99.5%</td>
<td>110,000</td>
</tr>
<tr>
<td></td>
<td>AVHRR - METOP-A</td>
<td>99.5%</td>
<td>150,000</td>
</tr>
<tr>
<td></td>
<td>VIIRS - NPP</td>
<td>99.5%</td>
<td>250,000</td>
</tr>
<tr>
<td></td>
<td>ABI - GEO5-16</td>
<td>Monitoring</td>
<td>Monitoring</td>
</tr>
<tr>
<td>Sea Surface Temperature from Microwave</td>
<td>GMI - GPM</td>
<td>75.0%</td>
<td>110,000</td>
</tr>
<tr>
<td></td>
<td>AMSR2 - GCOM-W1</td>
<td>75.0%</td>
<td>130,000</td>
</tr>
<tr>
<td></td>
<td>WindSat</td>
<td>75.0%</td>
<td>100,000</td>
</tr>
<tr>
<td>Sea Surface Salinity</td>
<td>SMAP Radiometer</td>
<td>0.0%</td>
<td>450,000</td>
</tr>
<tr>
<td>Absolute Dynamic Topography</td>
<td>Jason-2</td>
<td>0.0%</td>
<td>240,000</td>
</tr>
<tr>
<td></td>
<td>Jason-3</td>
<td>0.0%</td>
<td>240,000</td>
</tr>
<tr>
<td></td>
<td>Sentinel-3a</td>
<td>0.0%</td>
<td>240,000</td>
</tr>
<tr>
<td></td>
<td>Cryosat-2</td>
<td>0.0%</td>
<td>240,000</td>
</tr>
<tr>
<td></td>
<td>SARAL</td>
<td>0.0%</td>
<td>240,000</td>
</tr>
<tr>
<td>Ice Fraction from Microwave</td>
<td>F17 &amp; F18</td>
<td>95.0%</td>
<td>100,000</td>
</tr>
<tr>
<td></td>
<td>Total: 1.640,000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

obs used in a typical SOCA DA cycle
SOCA: Interface to JEDI

UFO: Generic Quality Control

- a bunch of quality control filters
  (track check, background check, buddy check, …)

- thinning
  (Gaussian temporal / spatial …)

- variational bias correction
  (in development by JEDI team)

no coding required, just configuration files!
SOCA: Interface to JEDI

OOPS: Assimilation methods
- 3DVAR
- 3DVAR-FGAT
- EDA
- LETKF
- 4D Hybrid EnVAR
- 4DVAR

SOCA Implementation at NOAA/EMC (Hybrid-GODAS)
SOCA: Interface to JEDI

SABER: System Agnostic Background Error Representation

BUMP: (Background error on Unstructured Mesh Package)

calculation and application of univariate or multivariate correlation / localization
SOCA: Static B-Matrix

\[ B = K D C_v^{\frac{1}{2}} C_h^{\frac{1}{2}} C_h^T \frac{T}{2} C_v^T D K^T \]

Example of parametric background error “D”

SABER/BUMP (Benjamin Menetrier) Correlation on the ¼ degree MOM6 tripolar grid
SOCA: Static B-Matrix, variable xforms

\[ B = K D C_v \frac{1}{2} C_h \frac{1}{2} C_v \frac{T}{2} C_v \frac{T}{2} D K^T \]

Application example:
Altimeter assimilation

Multivariate increment for T and S using balance operators in the B-matrix

---

Weaver et al, 2006

\[ K = \begin{bmatrix} I & 0 & 0 & 0 \\ K_{ST} & I & 0 & 0 \\ K_{\eta T} & K_{\eta S} & I & 0 \\ K_{cT} & 0 & 0 & I \end{bmatrix} \]

Trocoli and Haines, 1999

\[ \delta S_B = \frac{\partial S}{\partial T} \delta T \]

Cooper and Haines, 1999

\[ \delta c_B = \frac{\partial c}{\partial T} \delta T \]

\[ \delta \eta_B = - \int_{\text{Bottom}}^{0} \frac{\delta \rho(T, S, z)}{\rho_0} dz \]
Realtime SOCA
(CI/CD Testbed)

http://soca.jcsda.org
Realtime SOCA: Motivation

• A goal of JEDI: **accelerate R2O transition and code development**

• Development is **fast paced**, JEDI components are often updated daily.

• With SOCA, we want the latest JEDI code, and we also want it to always work.

• But... manually testing every upstream change is not humanly possible
Realtime SOCA: Motivation

CI/CD to the rescue!

**Continuous Integration (CI)**
automating the process of integrating code from multiple contributors
- Already implemented for most JCSDA repositories

**Continuous Delivery (CD)**
Code changes are automatically prepared, tested in a production-like environment, and ready for release
- Where "production" is our new real-time testbed system
CD pipeline

- Code changes are automatically prepared, tested, and ready for release into “production”
- Where “production” will be our real-time monitoring/forecasting testbed
Realtime SOCA

Model
- MOM6 1 deg (for now) / 75 hybrid lvls

Observations
- Latest available SST/ADT (from NESDIS) Insitu T/S (from USGODAE)

SST
VIIRS, AVHRR

1 day of observations

Insitu T/S
Argo, XBT, CDT, MRB

ADT
Cryosat-2, Sentinel-3a/3b, Jason3, SARAL

SSS
SMAP
Realtime SOCA

Forcing

- Latest 6 hour fields from operational NOAA Global Forecasting System

Cycling

- 24 hour cycle, run nightly
- 15-day reanalysis on new code changes

Complete workflow is part of CD pipeline, from obs and forcing retrieval to DA post processing
Realtime SOCA

Nightly evaluation posted to http://soca.jcsda.org

- Latest master and nightly CD release candidate available for comparison

- In process of adding more useful diagnostics: (obs space stats, model space stats, run timings, scorecards …)
Benefits of CI/CD

• Automation keeps up with fast paced changes
• Building, testing, releasing is less work for the humans (once it’s setup), because don’t those human have enough work as it is??
• The latest version of code always works
• Code changes can make it into production **on the same day**
System is publicly available, **BUT**…

- This CI/CD pipeline intends to test the **software engineering** (make sure upstream code doesn’t break SOCA)
- Real-time product **not** really intended for use by others (We are not an operational center: no guarantee of quality or timeliness)

**Key to success:** good tests/metrics, full automation (Future upgrade to **continuous deployment**)
SOCA

Ongoing activities
OSSEs at NOAA/CPC

Jieshun Zhu
CPC/NCEP/NOAA and ESSIC / UMD, College Park

Ocean observing system simulation experiments (OSSEs)

• Current configuration of in-situ observations (e.g., TAO, Argo)

• Proposed configurations by the TPOS 2020 project

DA system: 1° MOM6Solo + 3DVar
Atmospheric forcing: daily from Nature run
Synthetic Obs. sampling: TAO/Argo with current configurations; from Nature run
- TAO is sampled every 24 hours (vs. 10min in reality)
- Argo is sampled every 3x3 box every 10 days within TP
OSSEs at NOAA/CPC

Jieshun Zhu
CPC/NCEP/NOAA and ESSIC / UMD, College Park

Ocean observing system simulation experiments (OSSEs)

• Current configuration of in-situ observations (e.g., TAO, Argo)

• Proposed configurations by the TPOS 2020 project

Results: (2) Comparison of Low-frequency component ($V^{LF}$)

- Temp.: Both TAO and Argo improve the estimate of its LF component
- Salinity: Argo presents the same improvement as in Temp., but TAO presents some improvement only over the upper ocean
SOCA: Ongoing Activities

Biogeochemistry (Xiao Liu)

- BLING model added to MOM6
- chlorophyll tracers
- ocean color observations (from VIIRS and MODIS)
SOCA: Ongoing Activities

Radiance Assimilation
(Hamideh Ebrahimi)
- direct assimilation of SMAP brightness temperatures
- using CRTM, with addition of RSS model
SOCA: Ongoing Activities

SMAP Retrievals
(Francois Chabannes)

Using machine learning trained on collocated insitu S observations, convert SMAP brightness to SSS
SOCA: Ongoing Activities

Regional Marine DA*
(just got the funding for this!)

• initialization of the EMC Hurricane Analysis and Forecast System (HAFS)
• Based on MOM6 interface to JEDI
• support will also be provided for encapsulation of ROMS
Marine Data Assimilation at JCSDA

SOCA: Sea-ice, Ocean, and Coupled Assimilation

Travis Sluka
tsluka@ucar.edu

http://soca.jcsgda.org