Challenges of forecasting surface currents

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Outline

- **Motivation**
- State-of-the-art in surface current prediction
- Gap in forecast skill for surface currents
- Opportunities

Applications: SAR+

Examples:

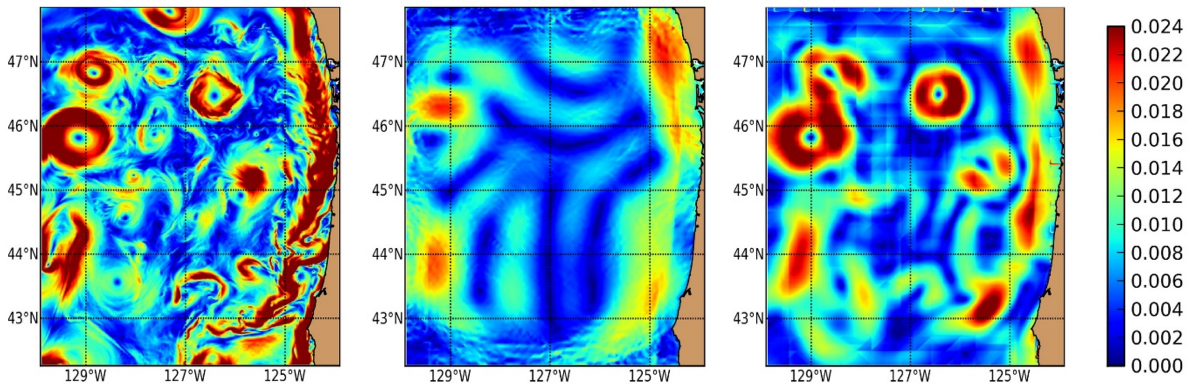
- Search and rescue at sea;
- Oil spills;
- Oceanographic experiments in the Lagrangian framework;
- Fisheries and resource management (e.g. larvae dispersal);
- Counter-mine warfare.

Properties:

- Event driven and local in space;
- Might be away from permanent observing infrastructure (including HF-Radars);
- Escalation of observing effort (drifter deployment, image acquisition).

Chemistry world, NPR

Application: constraining ocean (sub)-mesoscale activity



(a) True surface velocity field from a twin model.

(b) Mapped velocity field from current (nadir-looking) altimeter.

(b) Mapped velocity field from a SWOT-like altimeter.

Problem:

- Global surface currents are poorly constrained with existing observations.

Examples of Applications:

- Real-time ocean forecasts (from global ocean to regional OOS);
- Ocean and coupled global re-analysis;
- Scientific analysis of ocean-atmospheric fluxes.

Properties:

- Often relevant to global ocean;
- Has to rely on routine observing platforms;
- Effort measured in terms of continuous improvements in forecast (5 days +).

Gaultier 2015 J.Tech

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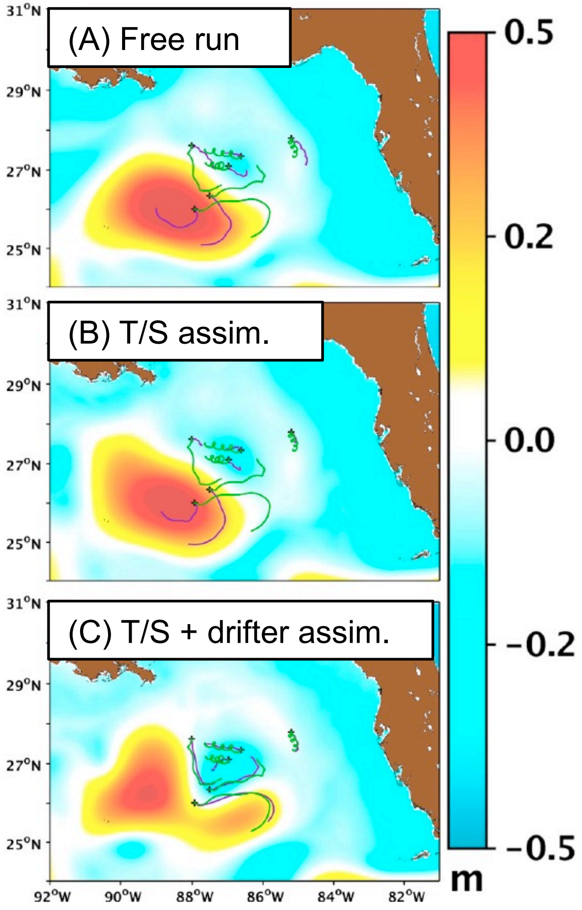
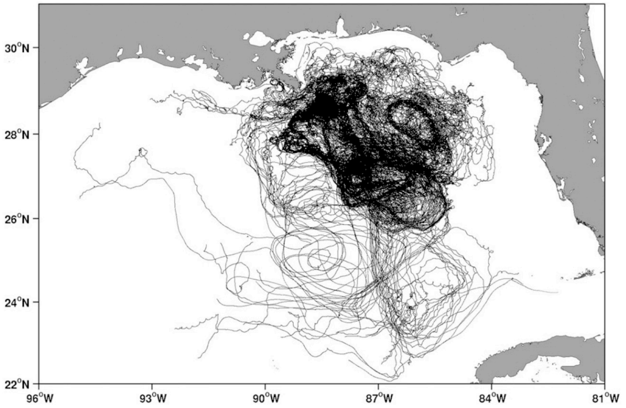
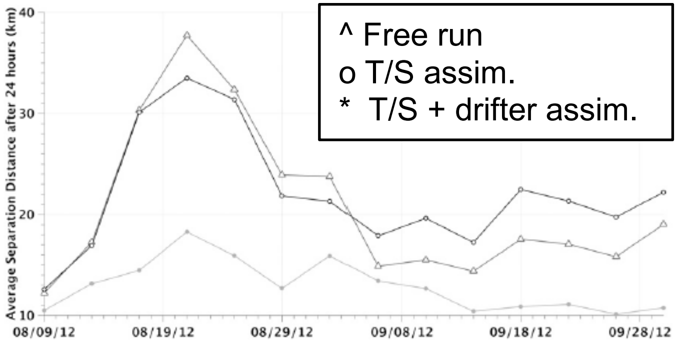
State-of-the-art: assimilation of surface drifters



SSH (color) and observed (green) and forecasted (blue) drifter trajectories.



(D) Drifter trajectories 1 Aug.- 30 Sept. 2012.



(E) Average separation of observed and simulated drifters after 24 hours.

Background:

- (D) 300 surface drifters released during GLAD/CARTHE experiment in GOM.

Results:

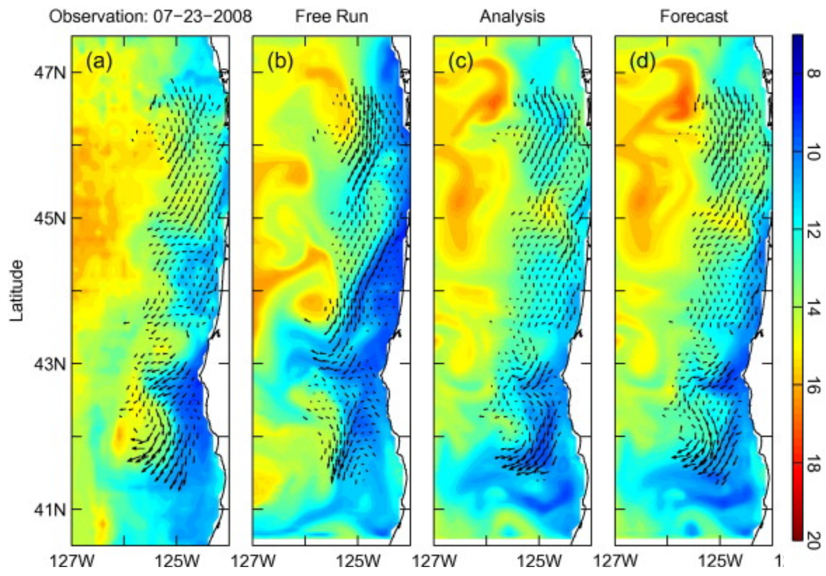
- (A and B) assimilation of T/S measurements alone is insufficient to effectively constrain lagrangian trajectories;
- (C and E) assimilation of drifter data considerably reduces drifter separation errors.

Conclusions:

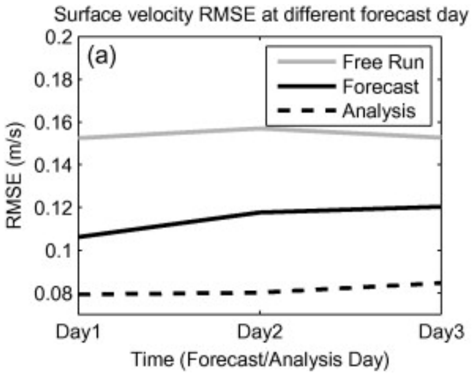
- Augmenting routine measurements with lagrangian data is effective during SAR+ operations.

Muscarela et.al. 2015 MWR

Assimilation of HF-Radar data



(A) Daily-average currents and SST on July 23, 2008.



Background:

- Considerable research on assimilation of surface currents since wide deployment of HF-Radars along the U.S. coasts.

Results (e.g. Yu 2012):

- Assimilation of HF-Radar data improves prediction of mesoscale-driven currents in the coastal ocean;
- Assimilation is more effective when direct measurements of radial currents is assimilated.

Conclusions:

- HF-radar is effective(but geographically very limited) tool that can improve analysis and prediction of surface currents.

Yu 2012, JGR

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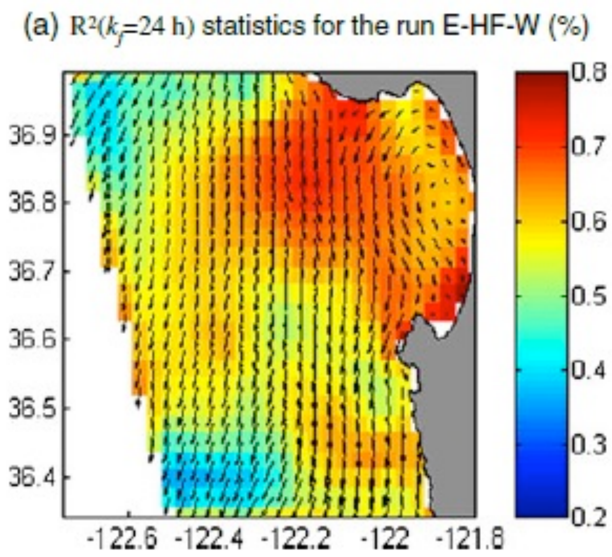
Gap between empirical and dynamic models



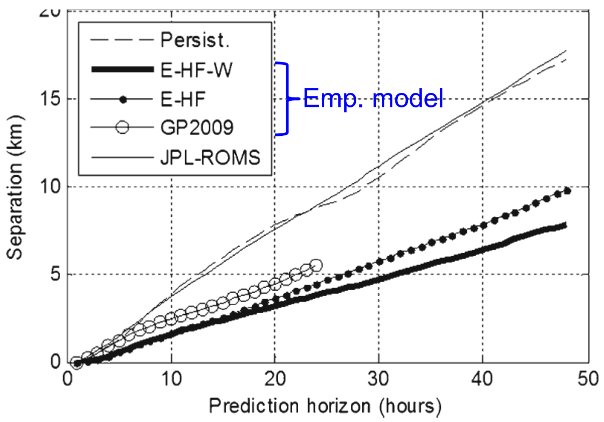


Fig. 10 Average separation between simulated drifters for four models and a persistence. Errors were computed for the test period from 10/4/2010 to 10/30/2010

Background:

- Archives of HF-Radar measurements have been used to develop empirical models of surface currents (i.e. machine learning).

Results (e.g. Frolov et.al. 2012):

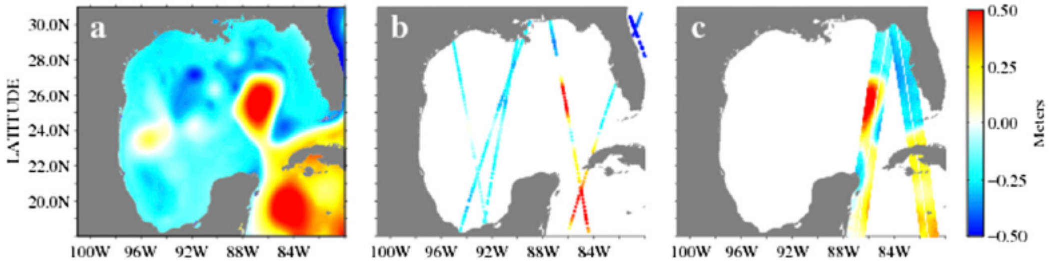
- When compared against persistence, empirical models significantly outperform dynamical models that assimilate the same HF-Radar data.

Conclusions:

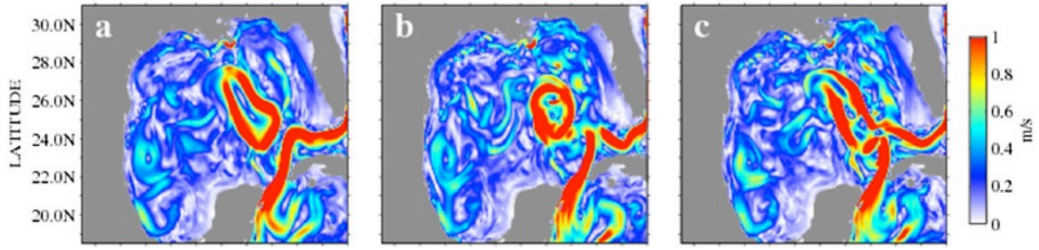
- An opportunity exists to improve assimilative dynamical models to match the skill of empirical models.

Frolov et.al. 2012 OD

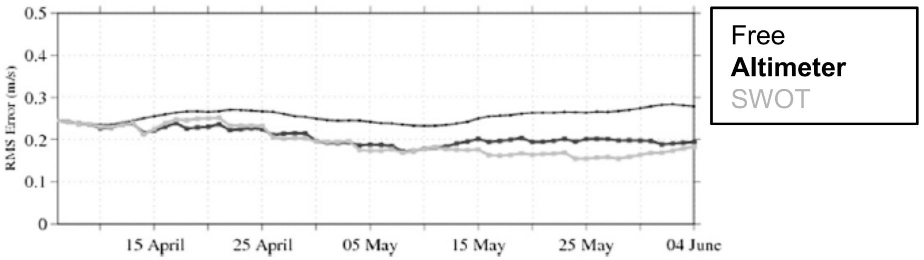
Observational gap in SSH altimetry



(1) SSH on May 2nd 2014. (a) SSH in nature run; (b) Altimeter observations; (c) SWOT observations.



(2) 96-hour forecast of surface currents 4 June 2014. (a) Nature run; (b) forecast initialized using Altimeter; (c) forecast initialized using SWOT.



(3) 96-hour surface current forecast RMSE.

Carrier et.al. 2016

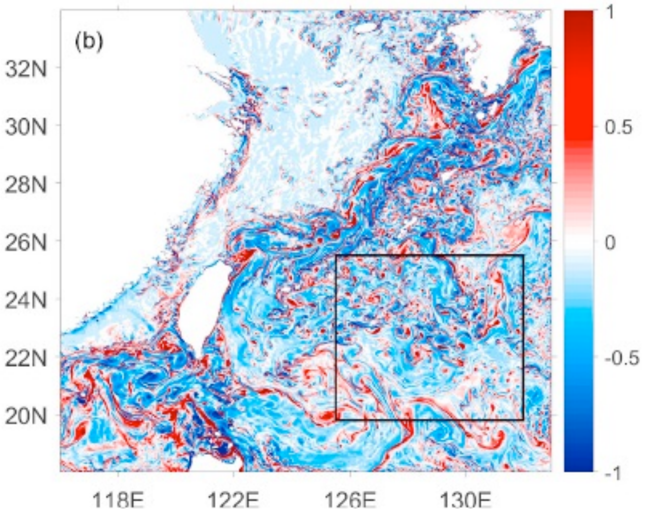
Results (e.g. Carrier et.al. 2016):

- NASA's Surface Water and Ocean Topography (SWOT) altimeter can directly observes mesoscale ocean fronts (1) and can improve the forecast of the surface currents (2).

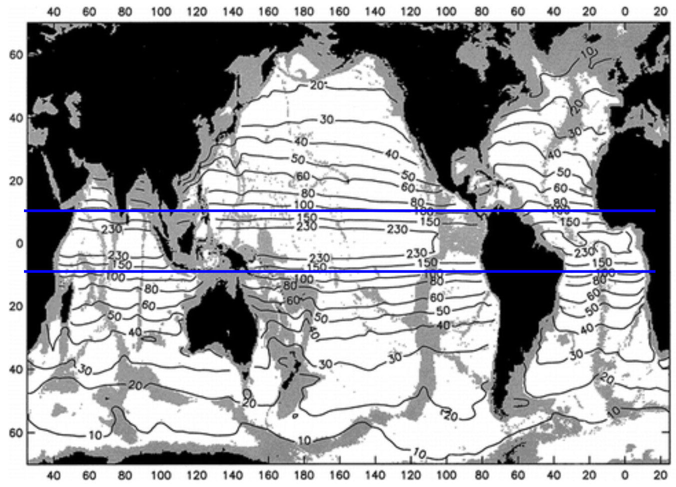
Conclusions:

- (3) However, because of the SWOT revisit times (21 days for full Earth coverage), SWOT adds only marginal improvement to the skill of the forecast currents.

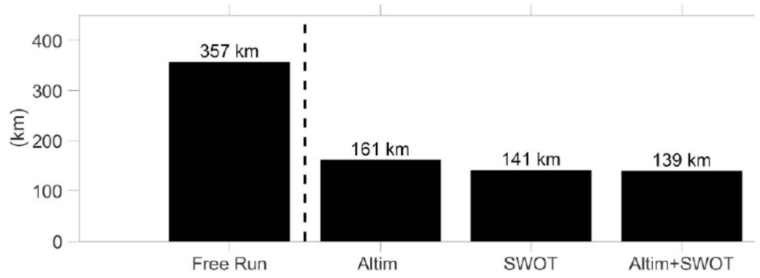
Oceanic scales constrained by current and near-future observations



(A) Surface relative vorticity normalized by the Coriolis parameter from the 1 km NATURE run on January 1, 2016.



(C) Rossby radius of deformation in km.



(B) SSH scales constrained by assimilation of Altimeter and SWOT data

- (B) Assimilation of SWOT data will improve over existing Altimeter-only observing system.
- (C) However, because of the SWOT re-visit times, oceanic mesoscale will remain unconstrained outside of the deep Tropics.

D'Addezio 2019; Chelton et.al. 1998

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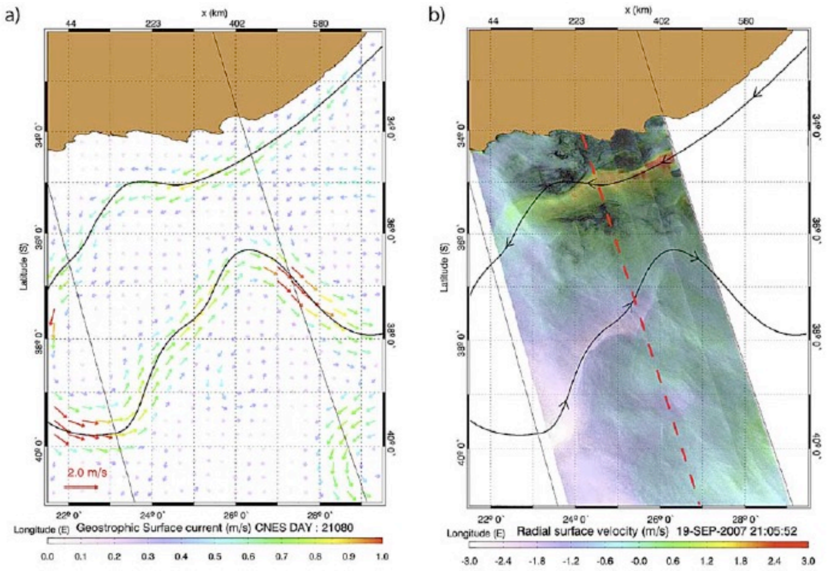
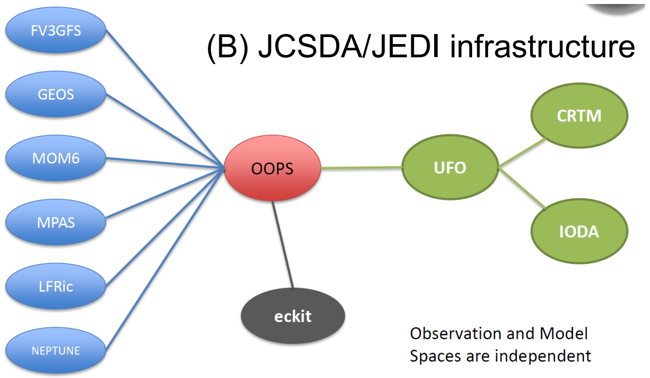


(A) Surface currents retrievals from (a) altimetry (b) ASAR. Johannessen et.al. 2008 GRL.



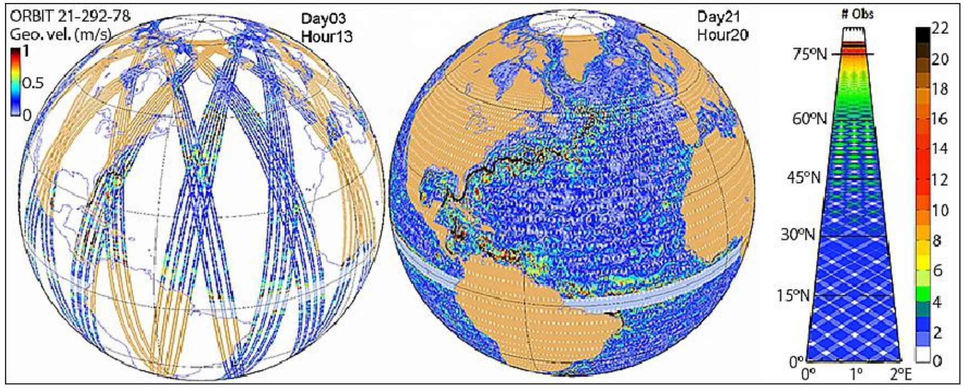
(A) Novel observations:

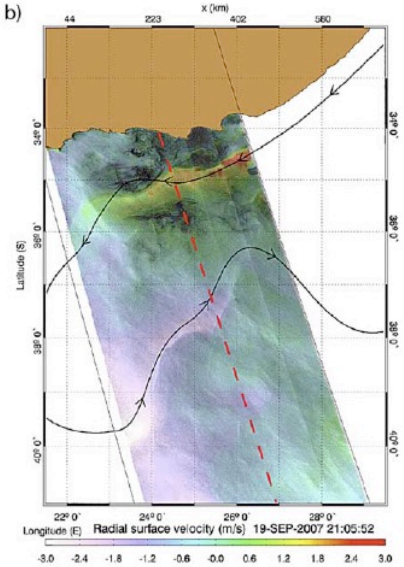
- Multiple (but unconventional sensors) provide routine (SAR, GEOS) and on-demand (SAR) observations of ocean surface and near-surface winds.
- It is possible to retrieve and assimilate highly-resolved observations of surface currents from these novel platforms.

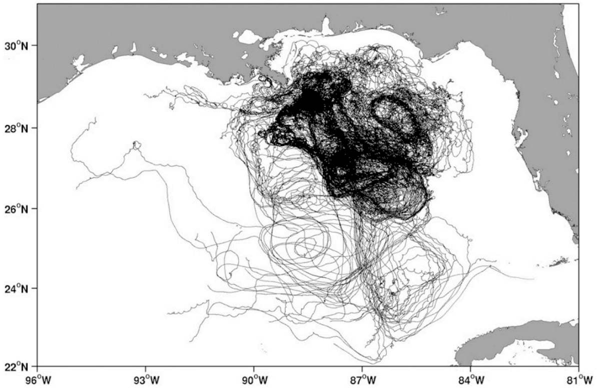
(B) New infrastructure:

- Joint Center for Satellite Data Assimilating (JCSDA) is developing a Joint Effort for Data Assimilation Integration (JEDI).
- An opportunity to foster the development that can be used across the community (NOAA, NASA, NSF, Navy, UKMO).

Johannessen et.al. 2008 GRL;







A coordinated field program/ model development:

- Massive release of lagrangian drifters similar to GLAD.
- Coincident with SWOT inaugural mission.
- Coordinated acquisition of new satellite imagery (e.g. SAR, GEO, ..?)
- Model/assimilation development effort that can be directly integrated in to the JEDI infrastructure.

End