Data assimilation for discharge
Ob river example

Purpose of the study

• SWOT will measure water elevations, not discharge.

• Assimilation combine SWOT observations and modeling -> best discharge estimates.

• Study different satellite orbits -> impact on high latitude rivers
SWOT virtual mission on the Ob

Inputs

“True” river modeling

“Truth”

Corrupted inputs

River modeling with errors

SWOT simulator

Orbit & instrument (swath, error) parameters

SWOT observations

Filter

Corrected states

Model states

Quantify benefits of assimilation
Outline

1. Arctic river modeling
2. Virtual SWOT observations
3. Assimilation scheme
4. Results
River modeling

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Quantify benefits of assimilation
River modeling

- Atmospheric forcing
  - ISBA
  - Runoff
  - TRIP

Lateral inflows to the river

Floodplain topography
- River center, width and depth
  - LISFLOOD
  - River and floodplain Manning coefficients (friction)

Water depth & discharge

River model

Sept. 22, 2010

SWOT Hydrology Virtual Mission Meeting
Virtual SWOT observations

- Inputs
  - "True" river modeling
  - "Truth"
  - SWOT simulator
    - Orbit & instrument (swath, error) parameters
- Corrupted inputs
  - River modeling with errors
- SWOT observations
- Filter
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  - Model states

Quantify benefits of assimilation
Virtual SWOT observations

3 days repeat period

- Fast sampling orbit 1
- Fast sampling orbit 2
- Fast sampling orbit 3

22 days repeat period

- Nominal orbit

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Virtual SWOT observations

- Orbit parameters
- Swath parameters
- Model

Swath mask

Instrument error (2 cm white noise)

Water elevation in the swath

Water elevation

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Assimilation scheme

- Inputs
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- Filter
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  - Model states

- Quantify benefits of assimilation
Assimilation scheme

- Local Ensemble Kalman Smoother (LEnKS) with constant time-lag:
  - Localization: avoid long range spurious correlation in model error covariance matrix (no impact of observation at distance > 22 km).
  - Ensemble: approximation of the model error covariance matrix.
  - Smoother: assimilation at observation time + extent the correction to previous time steps (on a constant time frame).
Corrupted ensemble

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Quantify benefits of assimilation

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Corrupted ensemble

- Errors only from ISBA inputs: air temperature and total precipitation (rain+snow).
- Methodology:
  \[ P_{\text{corrupt}}(i,t) = \overline{P}(i).\varepsilon_m + \sum_{j=1}^{N} \varepsilon_j\alpha_j(t)\phi_j(i) \]
  - Corrupted atmospheric field
  - Initial temporal mean
  - Gaussian error \(\varepsilon_j \sim N(1,0.20)\)
  - Temporal EOF \(j^{th}\) mode
  - Spatial EOF \(j^{th}\) mode
- The first \(N^{th}\) EOF modes explained 95% of the variance (\(N=187\) for precipitations and \(N=8\) for air temperature).
- Size of the ensemble: 20 members.
Results

Inputs

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“Truth”

Corrupted inputs

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Quantify benefits of assimilation
Results for nominal orbit

Assimilating SWOT data for nominal orbit (22 day, 78°):

- Truth
- No assimilation

Water depth (m)
Distance along the river (km)
Year 1993

upstream
downstream

upstream
downstream
Results for fast-sampling orbits

Assimilating SWOT data for calibration orbits (3 day, 78°):
Water depth (m)/Orbit 1
Water depth (m)/Orbit 2
Water depth (m)/Orbit 3
## Errors after assimilation

### Nominal orbit:

<table>
<thead>
<tr>
<th></th>
<th>Mean spatial RMSE (m)</th>
<th>Mean temporal RMSE (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No assimilation</td>
<td>0.80</td>
<td>1.11</td>
</tr>
<tr>
<td>LEnKS (3 days)</td>
<td>0.33 (59%)</td>
<td>0.38 (66%)</td>
</tr>
</tbody>
</table>

### Fast-sampling orbits:

<table>
<thead>
<tr>
<th></th>
<th>Mean spatial RMSE (m)</th>
<th>Mean temporal RMSE (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No assimilation</td>
<td>0.80</td>
<td>1.11</td>
</tr>
<tr>
<td>LEnKS (2 days)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orbit 1</td>
<td>0.57 (29%)</td>
<td>0.51 (54%)</td>
</tr>
<tr>
<td>Orbit 2</td>
<td>0.40 (50%)</td>
<td>0.44 (60%)</td>
</tr>
<tr>
<td>Orbit 3</td>
<td>0.17 (79%)</td>
<td>0.10 (91%)</td>
</tr>
</tbody>
</table>
Conclusions and perspectives

- **Modeling error decreased** after assimilation -> better water depth and discharge estimates.
- For Arctic rivers, similar results between nominal and fast sampling orbits.
- Need to take into account other **modeling errors** (ISBA and LISFLOOD parameters, bathymetry, roughness, ...).
- Need to take into account other **SWOT errors** (satellite motion, wet troposphere, ...).
Thank you!