Global Data Assimilation of Virtual SWOT data in CaMa-Flood

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1. SWOT DA Overview
2. Method for DA
3. Results and Discussions
4. Future Steps
1. SWOT DA Overview

Get Better Estimation by merging “data” into “simulation”
1. SWOT DA Overview

**SWOT**
Daily SWOT Observation Coverage is Limited

**River Model CaMa-Flood**
Simulation has Full Area Forecast

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Data Assimilation

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<table>
<thead>
<tr>
<th>day 1</th>
<th>day 2</th>
<th>day 3</th>
<th>day 4</th>
</tr>
</thead>
<tbody>
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<td>19</td>
<td>27</td>
<td>36</td>
<td>27</td>
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<td>19</td>
<td>27</td>
<td>36</td>
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</table>
1. SWOT DA Overview

**SWOT**
Daily SWOT Observation Coverage is Limited

**River Model CaMa-Flood**
Simulation has Full Area Forecast

**Objective**

- ✓ To Develop a Global Framework of SWOT Data Assimilation
- ✓ Evaluated the Effectiveness Before Launch
2. Method of Data Assimilation

**SWOT**

Not launched until **2021**

Used **Virtual SWOT**
(virtual observation data made from river model)

**River Model CaMa-Flood**

and did **Virtual Experiment**
2. Method of Data Assimilation

Virtual Experiment

Virtual SWOT and Simulation must be apart

Virtual SWOT

Virtual Observation Data made from River Model

Simulation

Artificially and Purposely Error Corrupted Simulation
2. Method of Data Assimilation

Virtual Experiment

we did 2 Different Patterns (Experiment) for making them apart

(A) -25% Experiment
- Runoff (Input)
- Reduce 25%
- 25% Reduced Runoff (Input)

(B) Blind Runoff Experiment
- 1991 Runoff
- 1990 Runoff

Virtual SWOT

Corrupted Simulation
2. Method of Data Assimilation

Virtual Experiment

we did 2 Different Patterns (Experiment) for making them apart

(A) -25% Experiment  (Andreadis et al., 2007)

Runoff (Input) → CaMa-Flood → True Simulation → Water Surface Elevation

Planned SWOT Orbit Data → SWOT Coverage Mask → add Measurement Error → Virtual SWOT
2. Method of Data Assimilation

Virtual Experiment

we did 2 Different Patterns (Experiment) for making them apart

(A) -25% Experiment (Andreadis et al., 2007)

Runoff (Input) → CaMa-Flood → True Simulation → Water Surface Elevation

Reduce 25% → 25% Reduced Runoff (Input) → CaMa-Flood → -25% Simulation

← Roughly 25% Smaller
2. Method of Data Assimilation

Virtual Experiment

We did 2 different patterns (Experiment) for making them apart.

(A) -25% Experiment
- Runoff (Input)
  - Reduce 25%
  - 25% Reduced Runoff (Input)
- Water Surface Elevation
  - Virtual SWOT
  - -25% Simulation
- Corrupted Simulation

(B) Blind Runoff Experiment
- 1991 Runoff
  - 1991 Simulation
- 1990 Runoff
  - 1990 Simulation
- Corrupted Simulation
2. Method of Data Assimilation

Virtual Experiment

we did **2 Different Patterns (Experiment)** for making them apart

(B) Blind Runoff Experiment

seasonal difference

Simulation

SWOT

1991 Runoff

Virtual SWOT

1990 Runoff

Corrupted Simulation
2. Method of Data Assimilation

Virtual Experiment

we did 2 Different Patterns (Experiment) for making them apart

(A) -25% Experiment
Runoff (Input)
Reduce 25%
25% Reduced Runoff (Input)

Water Surface Elevation
Virtual SWOT

-25% Simulation
Corrupted Simulation

(B) Blind Runoff Experiment
1991 Runoff

1991 Simulation
Virtual SWOT

1990 Runoff

1990 Simulation
Corrupted Simulation
2. Method of Data Assimilation

Virtual Experiment

Data Assimilation

Ensemble Kalman Filter (EnKF)
Implemented with LETKF (Local Ensemble Transformation Filter)

Assimilation = Simulation + Observation × Ensemble Statistics

Assimilated Estimation
2. Method of Data Assimilation

Virtual Experiment

Data Assimilation

Ensemble Kalman Filter (EnKF)

Implemented with LETKF (Local Ensemble Transformation Filter)

Assimilated Estimation

Made 20 Ensemble Members (using Gaussian Noise)
2. Method of Data Assimilation

Virtual Experiment

Ensemble Kalman Filter (EnKF)

Implemented with LETKF (Local Ensemble Transformation Filter)

Virtual SWOT

Corrupted Simulation

Data Assimilation

Ensemble Kalman Filter (EnKF)

Implemented with LETKF (Local Ensemble Transformation Filter)

Assimilation = Simulation + Observation × Ensemble Statistics

Assimilated Estimation
2. Method of Data Assimilation

Virtual Experiment

Virtual SWOT

Corrupted Simulation

Water Surface Elevation (WSE)

Many Variables

This is possible because CaMa-Flood calculates water dynamics based on WSE

Data Assimilation

Assimilated Estimation
3. Results and Discussions

(A) -25% Experiment

absolute Error Rate of *River Discharge*

**Corrupted Simulation**

**Assimilation**

Error Decreased

the Amazon River
3. Results and Discussions

(B) Blind Runoff

Assimilation Index (AI): relative Assimilation Achievement

\[ AI = 1 - \frac{Assim. - Corrup.}{True - Corrup.} - 1 \]

AI=1: done well
AI=0: not well
3. Results and Discussions

(B) Blind Runoff

Frequent Observation
(4~7 days interval)
3. Results and Discussions

(B) Blind Runoff

Frequent Observation
(4~7 days interval)

High AI at most part of river
3. Results and Discussions

(A) -25% Experiment
Less Observation
(10~21 days interval)
3. Results and Discussions

(A) -25% Experiment

Less Observation
(10~21 days interval)

high AI only at Downstream
Assimilation Index (AI)

Introduction

Method

Result/Discussion

Less Observation

(10~21 days interval)

High at Downstream

Assimilated Discharge

Inflowed

(6,000,000 km$^2$)

Upstream

Fluctuate
(drop in 5~10 days)

Stay High

Upstream

Downstream

Less Observation

(10~21 days interval)

Assimilated Discharge

Inflowed

(6,000,000 km$^2$)

high at Downstream
4.2 days interval

• Inflow from Upstream
• Local and Upstream Observation
• Observation Frequency

10.4 days interval

MATCH

ERROR
3. Results and Discussions

(B) Blind Runoff

Amazon (Downstream)

Congo (Midstream)

Virtual Obs.

Corrupted

Assimilation Index

● Observation

Discharge

Assimilated

Congo (Downstream)
3. Results and Discussions 

(B) Blind Runoff

Mekong (Downstream)

Lena (Downstream)

Ob (Midstream)

Virtual Obs.

- Assimilated
- Corrupted

Assimilation Index

\[ \text{Observation} \]

\[ \text{Discharge (m}^3/\text{s)} \]

\[ \text{River Discharge (m}^3/\text{s)} \]

\[ \text{Assimilation Index} \]

\[ \text{Date} \]

\[ 1/1 \to 12/31 \]
4. Future Steps

Enlarging Local Patch

Assimilation is possible only when there is Observation at that location.

Originally, only target pixel is calculated at Assimilation.

Using information of near-by pixel.

Assimilation Correction will be possible when there is observation at somewhere in the local patch.
4. Future Steps

Improving Ensemble Spread

- Usually, ensemble is bundled in daily step
- This is often used in Atmospheric Model, which Ensemble easily spread
- However Ensemble and Bundle at daily step is too short for River Model to spread Ensemble

Observation at Downstream is not much effective
4. Future Steps

Improving Ensemble Spread

- Usually, ensemble is bundled in daily step
- This is often used in Atmospheric Model, which Ensemble easily spread
- However Ensemble and Bundle at daily step is too short for River Model to spread Ensemble

- Only bundle when there is Observation & Assimilation (once in few days)
- This will allow the Ensemble to Spread
- This will make assimilation at downstream more effective