Global Data Assimilation of Virtual SWOT data in CaMa-Flood

Tokyo Institute of Technology
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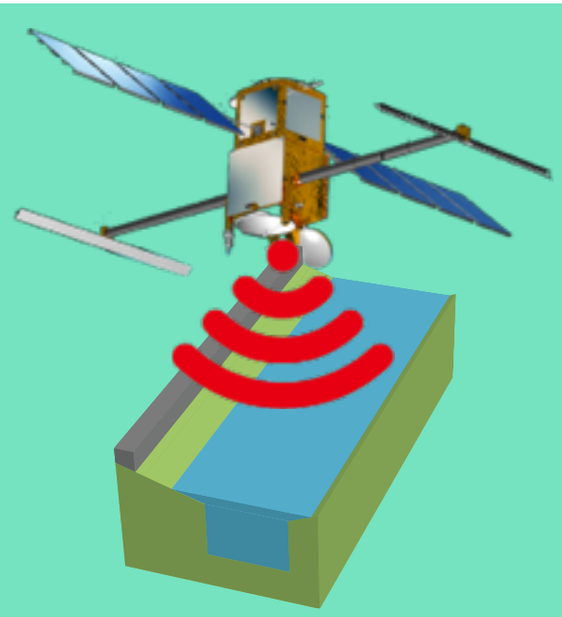
Apr. 17th, 2017 SWOT Teleconference

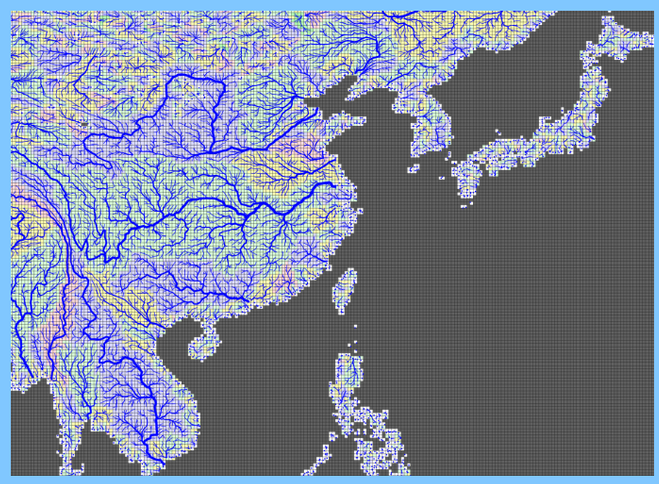
1. SWOT DA Overview
2. Method for DA
3. Results and Discussions
4. Future Steps

1. SWOT DA Overview

SWOT



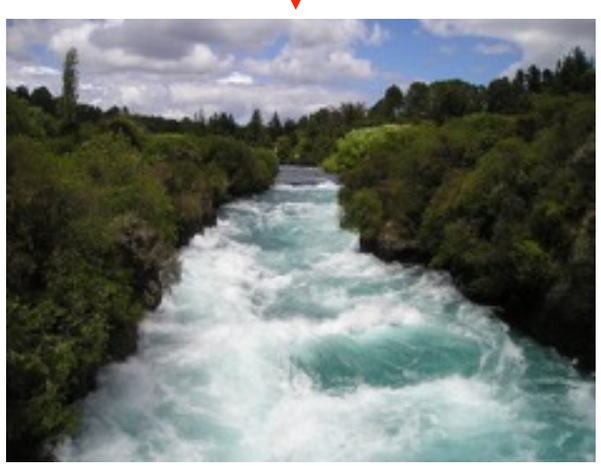
Water Surface Elevation



River Model
CaMa-Flood

Model Forecasted Discharge
etc...

Data Assimilation



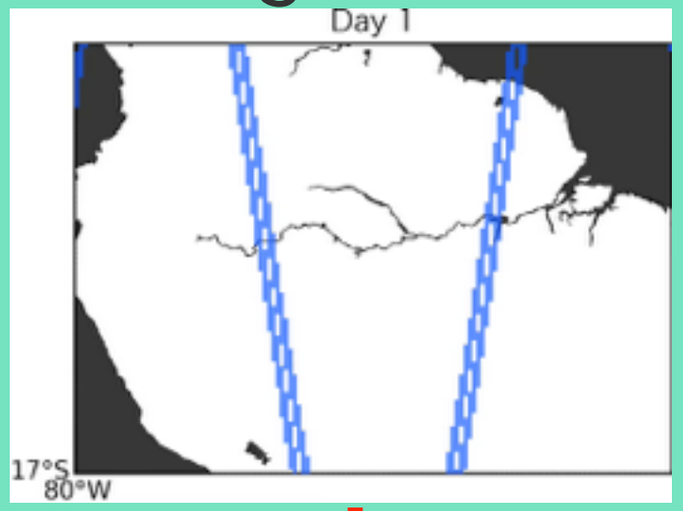
River
Discharge

Get Better Estimation by merging “data” into “simulation”

1. SWOT DA Overview

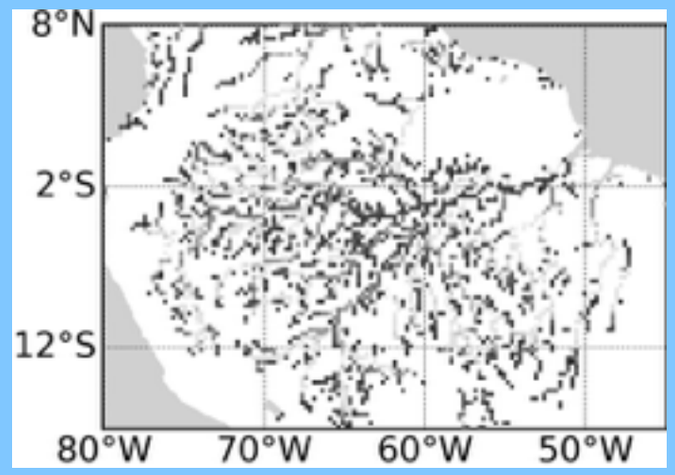
SWOT

Daily SWOT Observation
Coverage is Limited

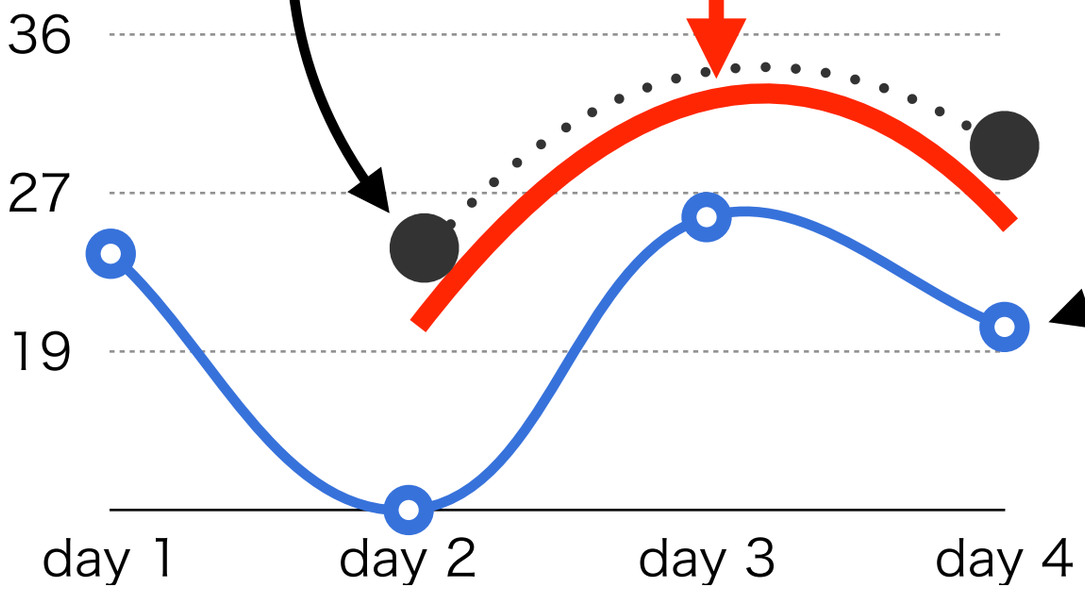


River Model CaMa-Flood

Simulation has
Full Area Forecast



Data Assimilation



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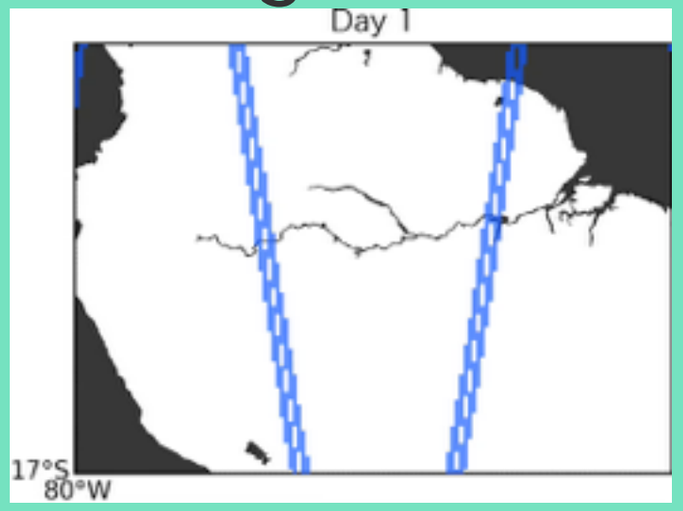

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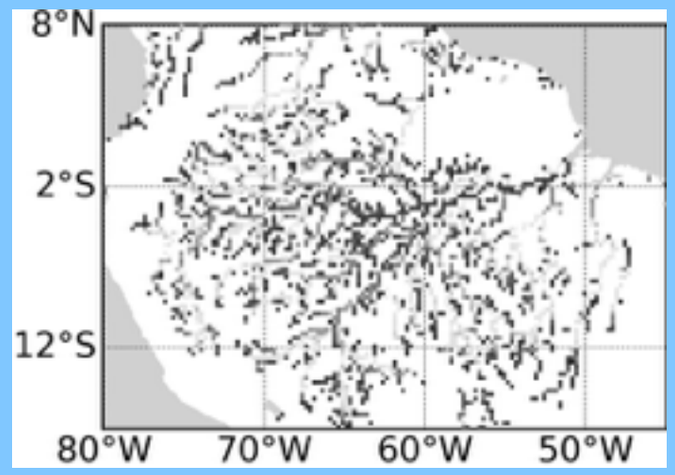


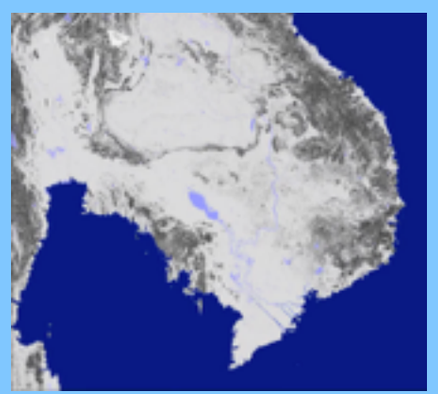
Objective

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

2. Method of Data Assimilation

SWOT

River Model CaMa-Flood



Not launched until <u>2021</u>

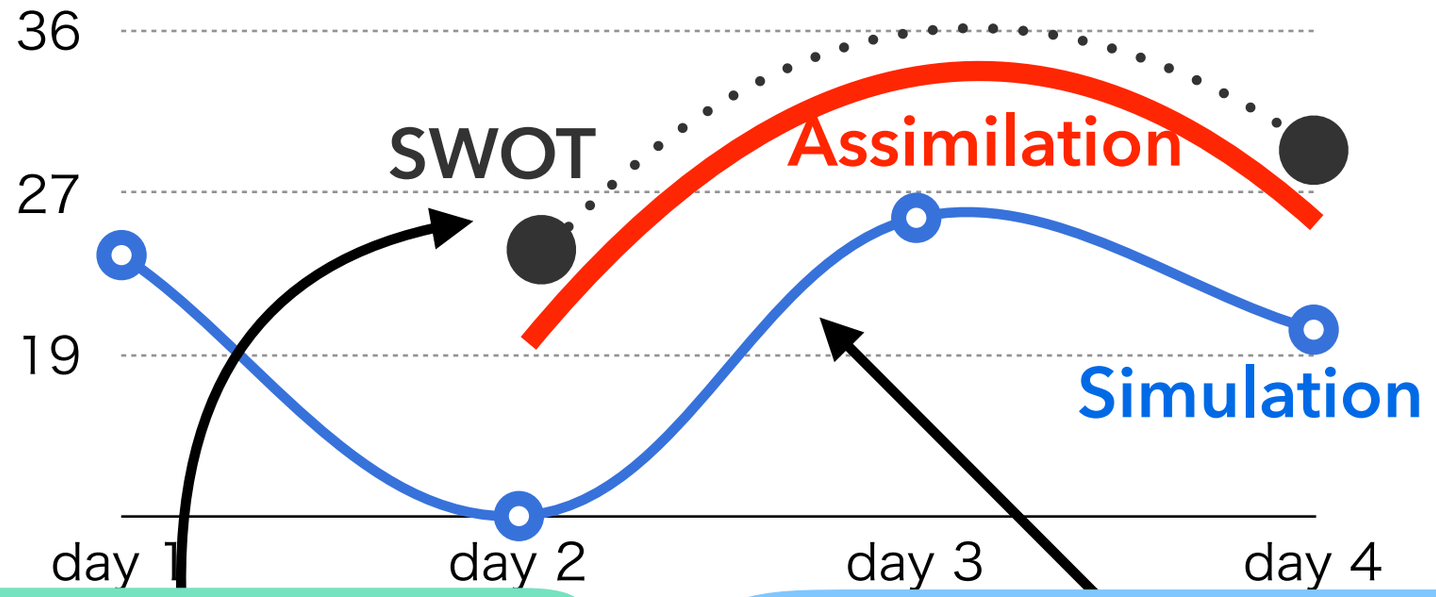
Used **<u>Virtual SWOT</u>**
(virtual observation data made
from river model)

and did **<u>Virtual Experiment</u>**

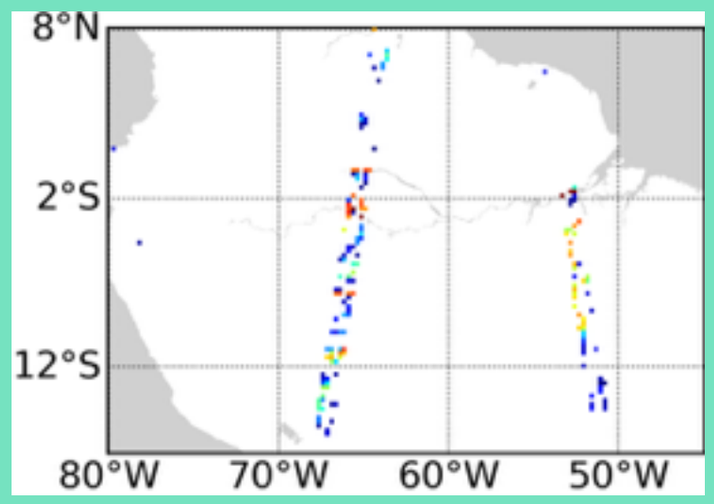
2. Method of Data Assimilation

Virtual Experiment

Virtual SWOT and **Simulation** must be apart

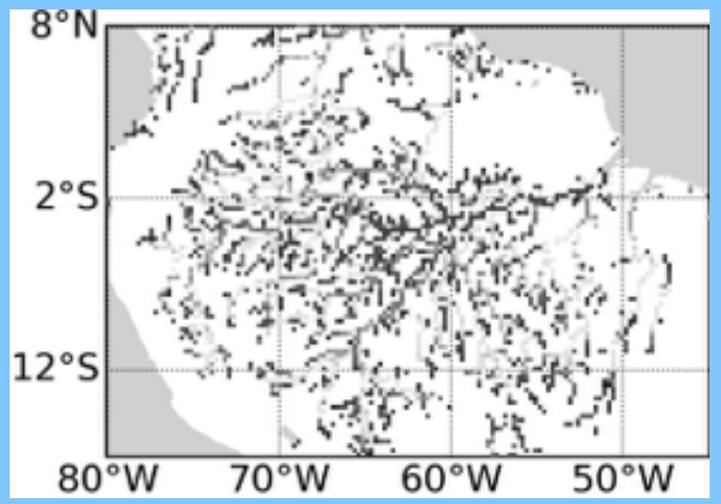


Virtual SWOT



Virtual Observation Data made from River Model

Simulation



Artificially and Purposely Error Corrupted Simulation

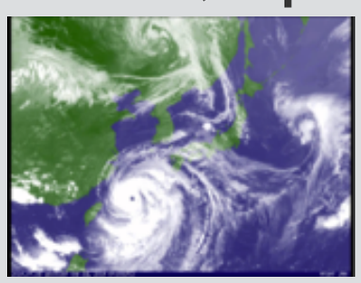
2. Method of Data Assimilation

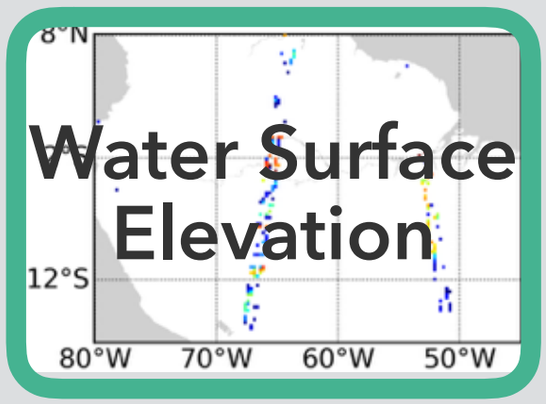
Virtual Experiment

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

(A) -25% Experiment

Runoff (Input)

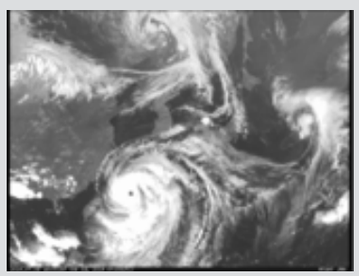


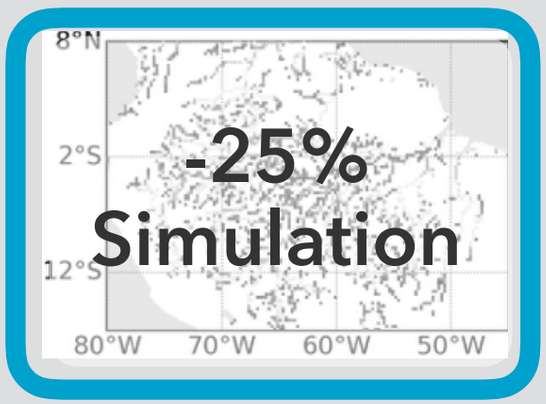


Virtual SWOT

Reduce 25%

25% Reduced Runoff (Input)

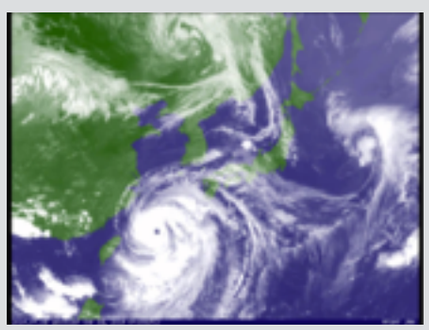


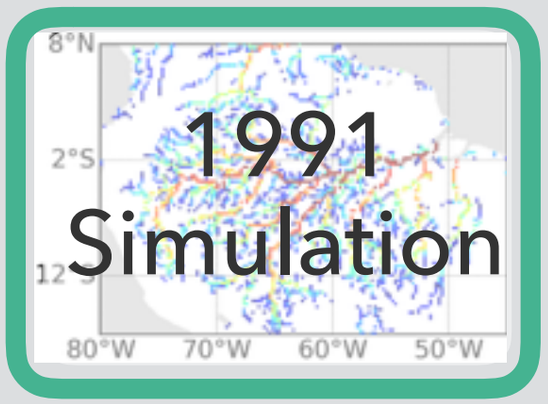


Corrupted Simulation

(B) Blind Runoff Experiment

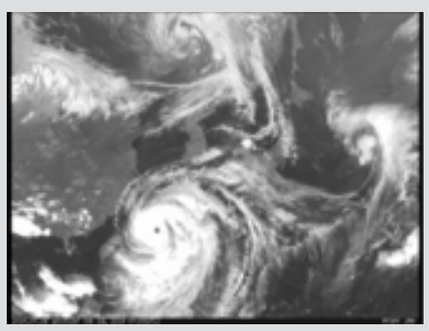
1991 Runoff

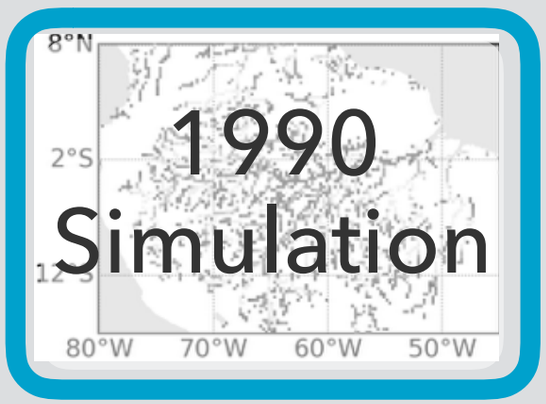




Virtual SWOT

1990 Runoff





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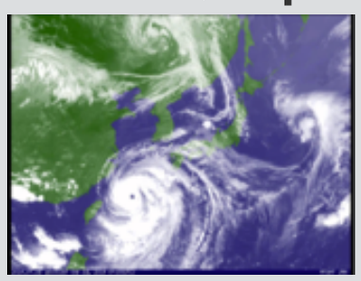
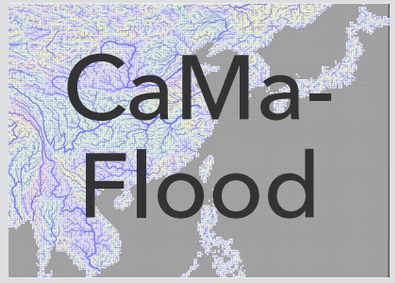
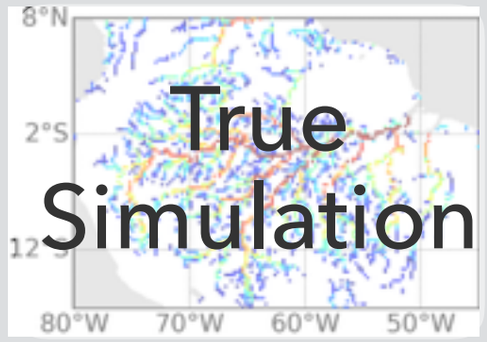
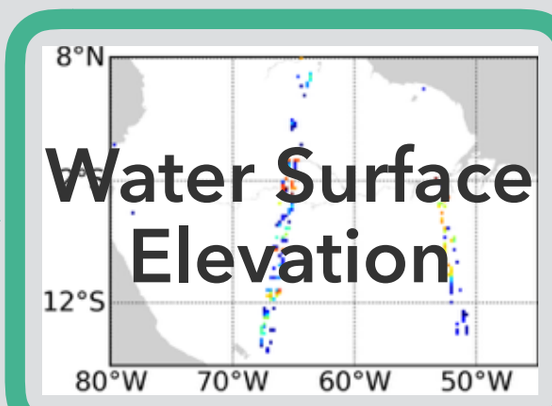


CaMa-Flood





True Simulation



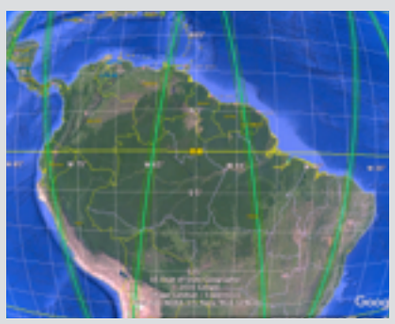
Water Surface Elevation

Virtual SWOT

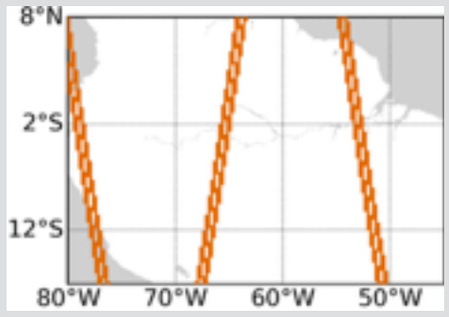
mask out

add

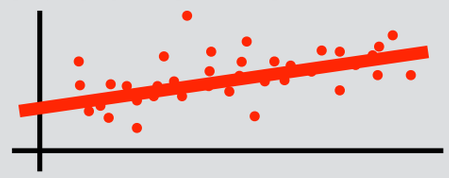
Planned SWOT Orbit Data



SWOT Coverage Mask



Measurement Error



2. Method of Data Assimilation

Virtual Experiment

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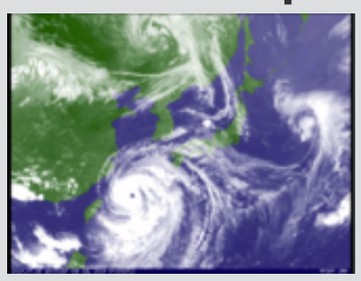
(A) -25% Experiment (Andreadis et al., 2007)

Runoff (Input)



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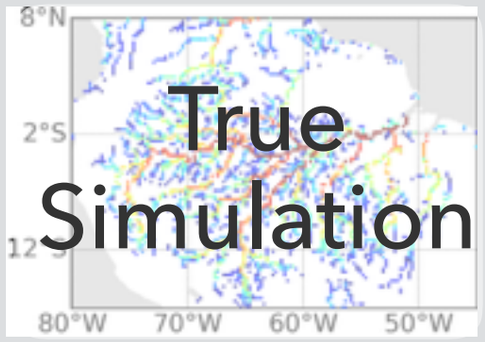

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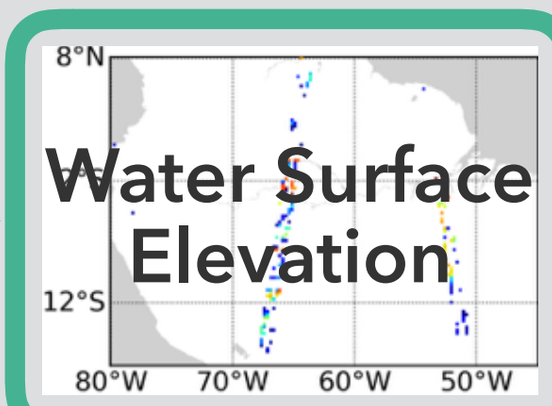
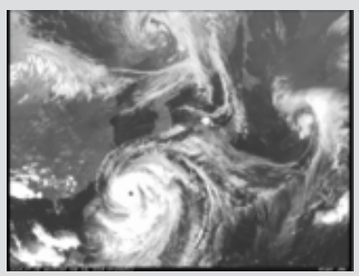


Water Surface Elevation

Virtual SWOT

Reduce 25%

25% Reduced Runoff (Input)



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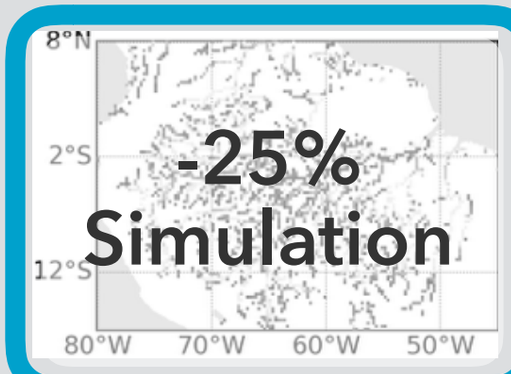

-25% Simulation

Corrupted Simulation

← Roughly 25% Smaller

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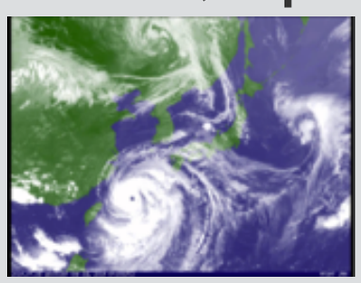
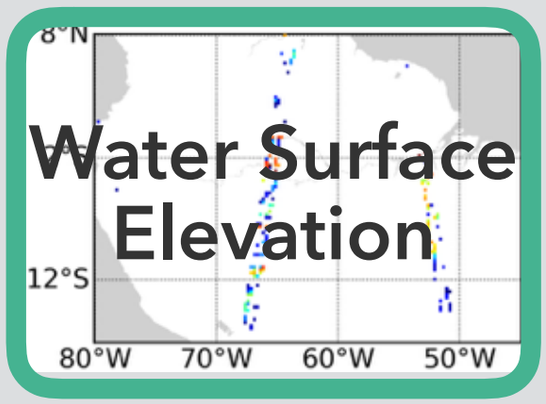
Runoff (Input)





Virtual SWOT

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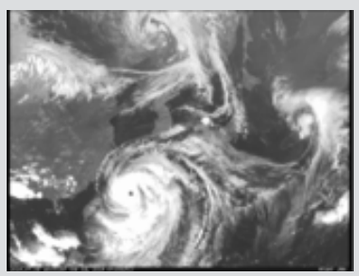
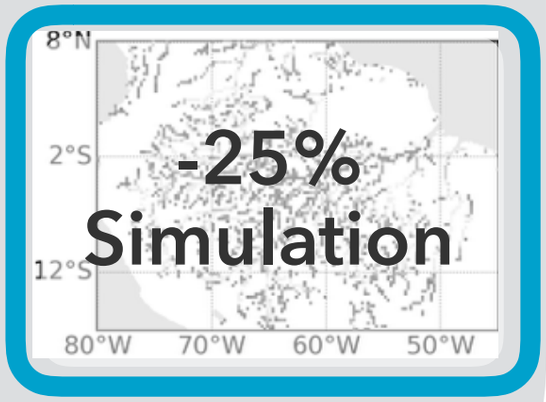
25% Reduced Runoff (Input)

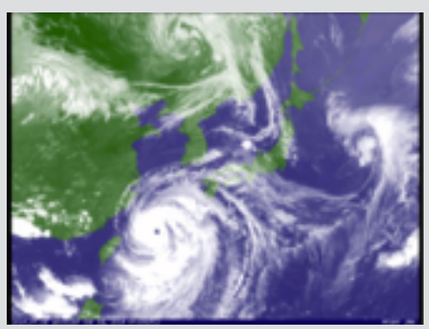


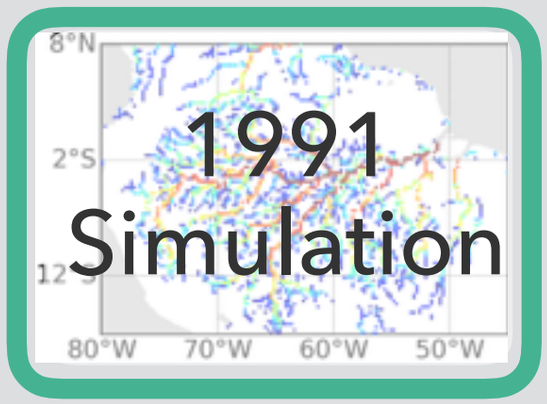


Corrupted Simulation

(B) Blind Runoff Experiment

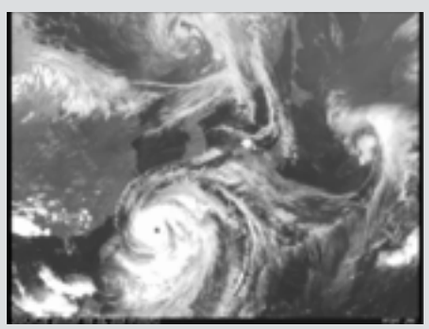
1991 Runoff

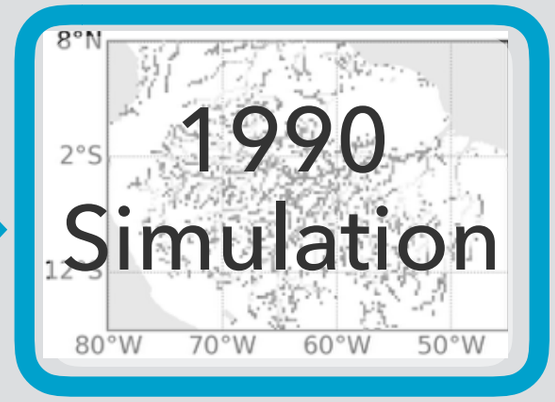




Virtual SWOT

1990 Runoff





Corrupted Simulation

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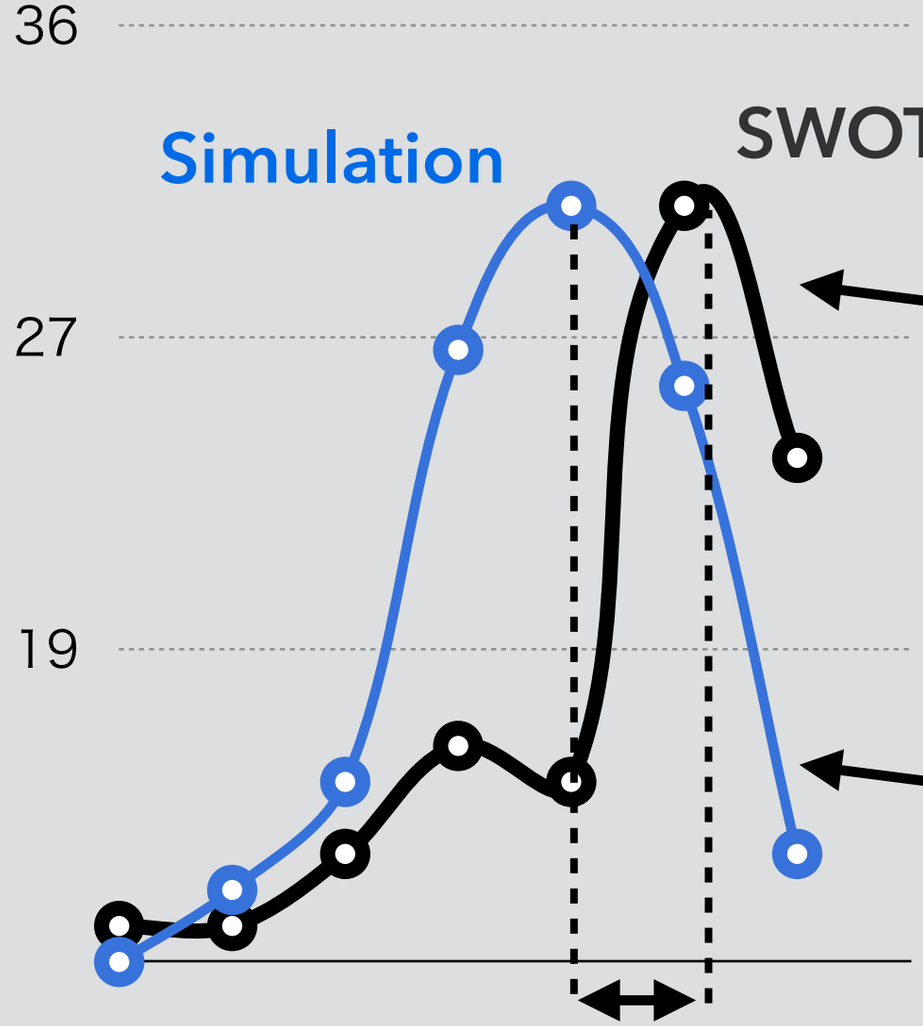

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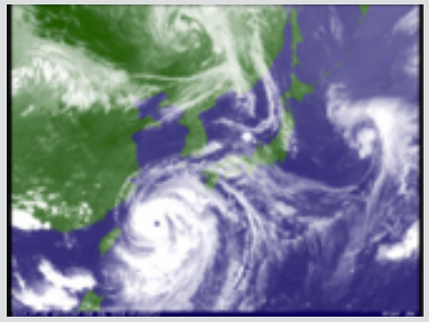
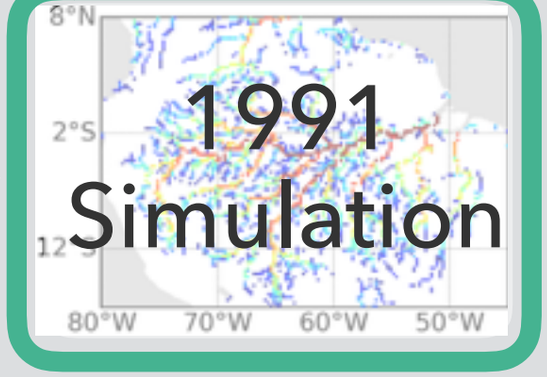
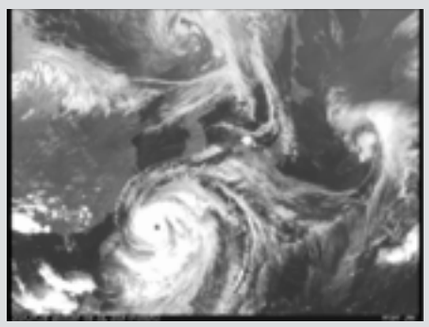
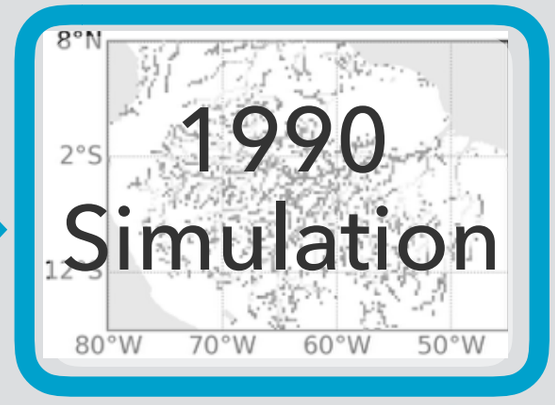




Virtual SWOT

1990 Runoff





Corrupted Simulation

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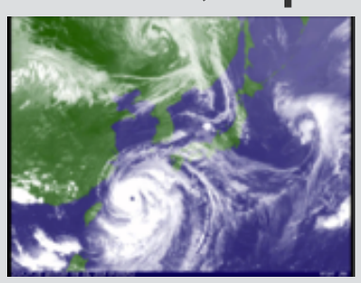
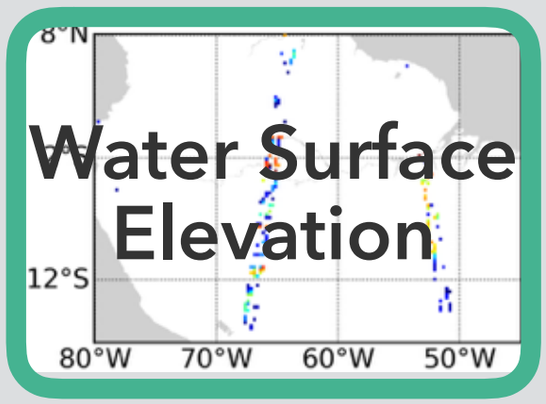
(A) -25% Experiment

Runoff (Input)

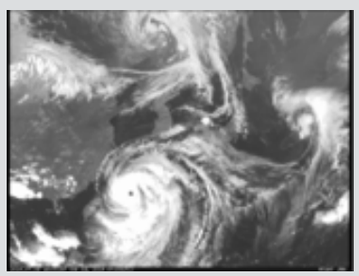


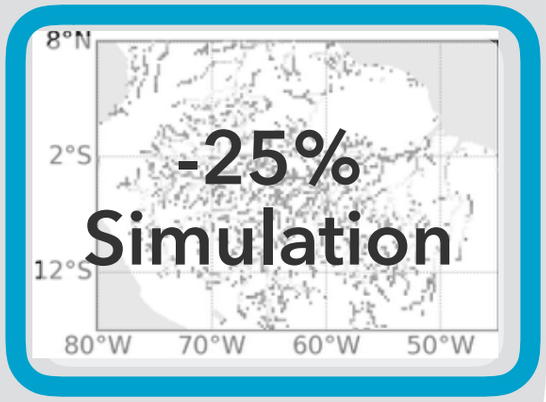


Virtual SWOT

Reduce 25%

25% Reduced Runoff (Input)

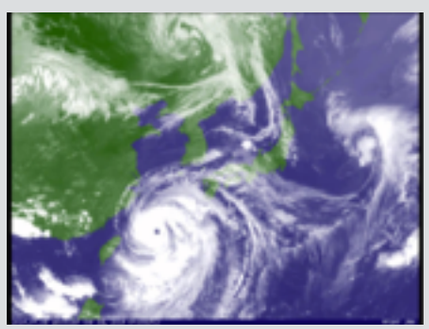


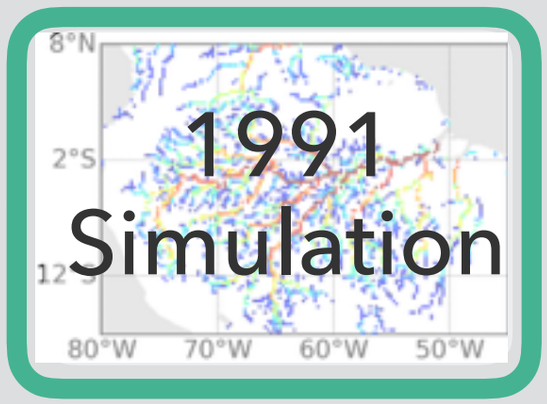


Corrupted Simulation

(B) Blind Runoff Experiment

1991 Runoff





Virtual SWOT

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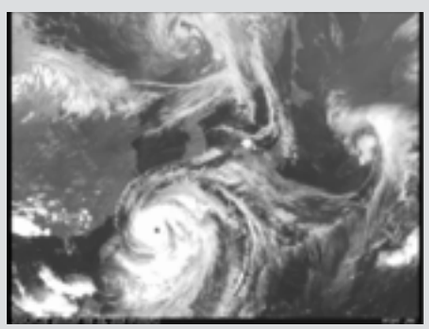

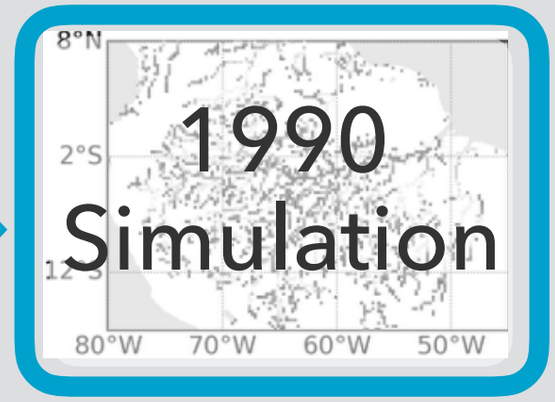

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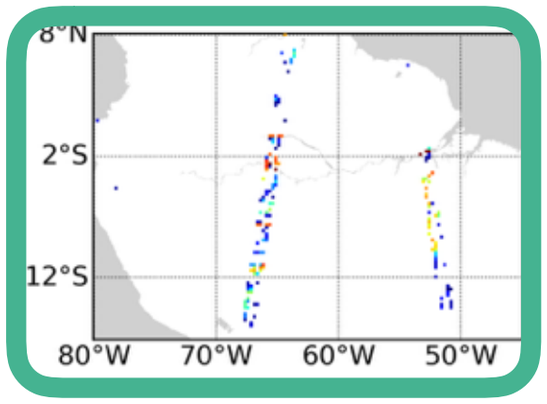

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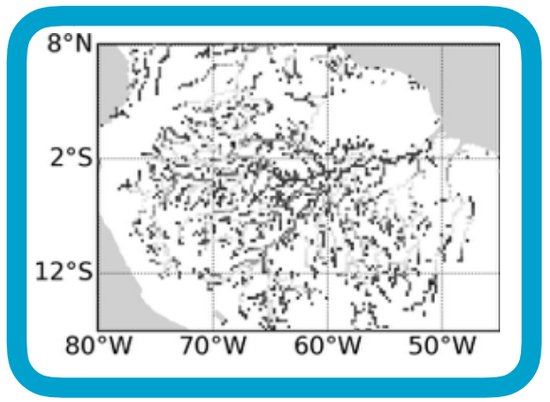
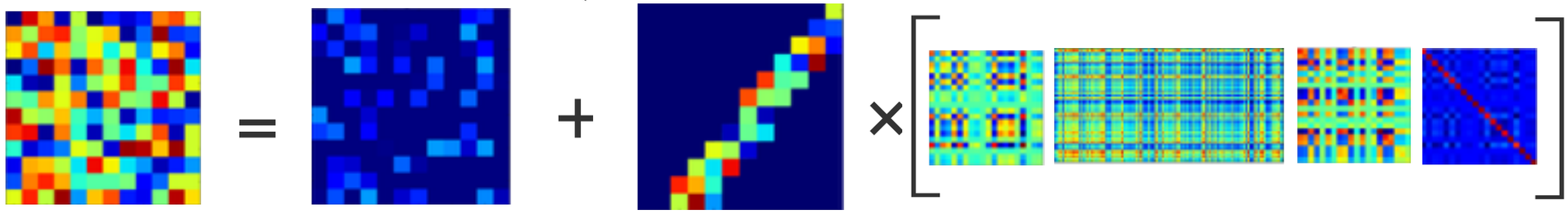


Corrupted Simulation

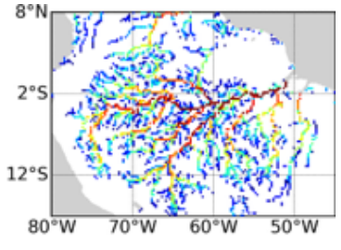
Data Assimilation

Ensemble Kalman Filter (EnKF)

Implemented with LETKF (Local Ensemble Transformation Filter)

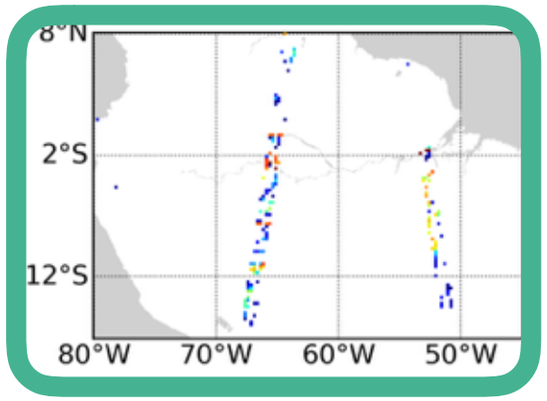


Assimilation = Simulation + Observation × Ensemble Statistics



Assimilated Estimation

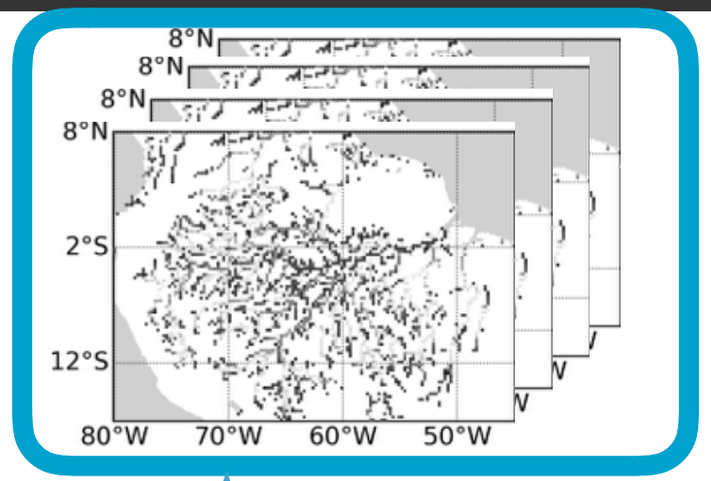
2. Method of Data Assimilation



Virtual SWOT

Virtual Experiment

Ensemble
are needed→



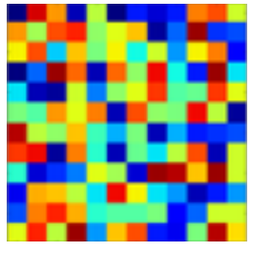
Corrupted Simulation

Data Assimilation

Ensemble

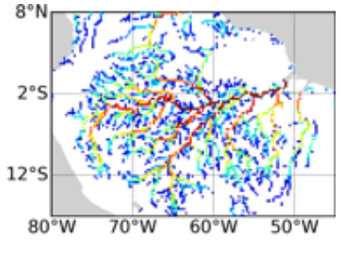
Implement

Transforma

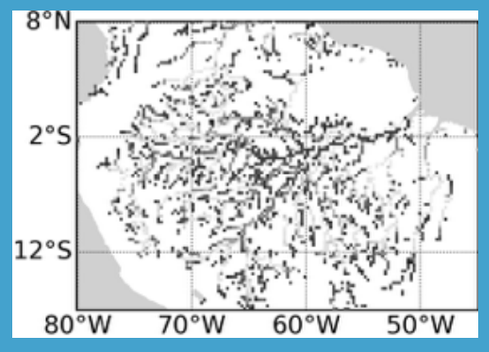


=

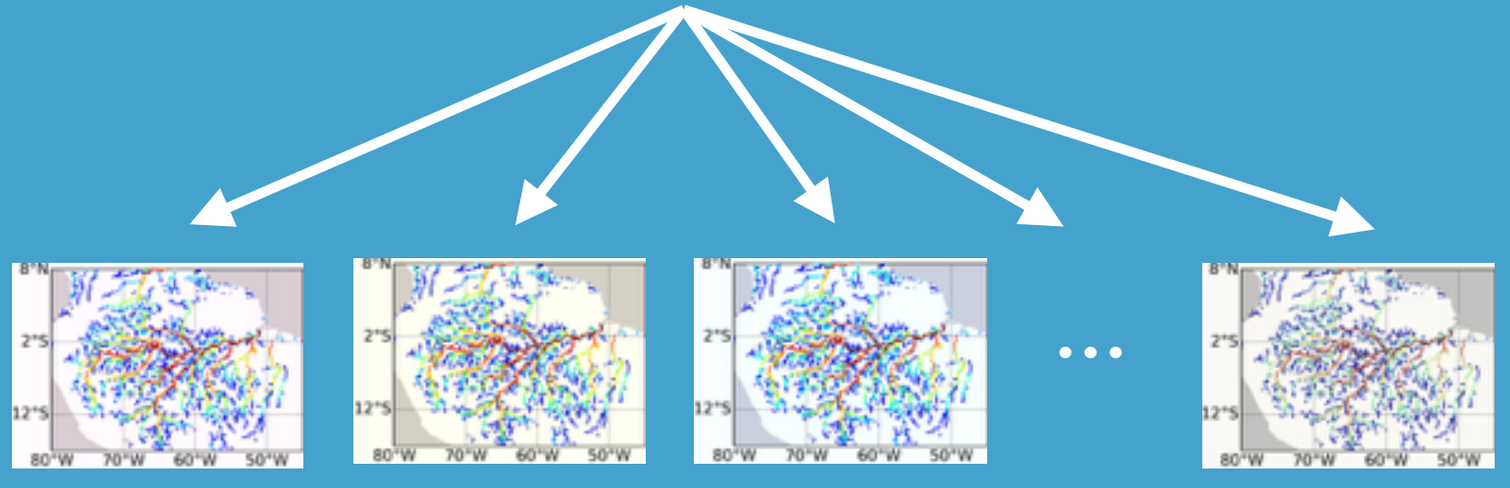
Assimilation



Assimila

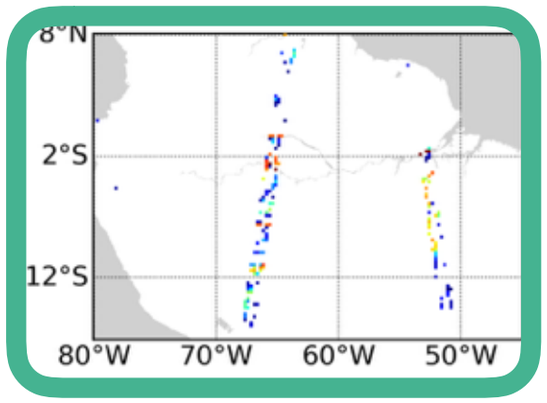


Corrupted Simulation



Made 20 Ensemble Members (using Gaussian Noise)

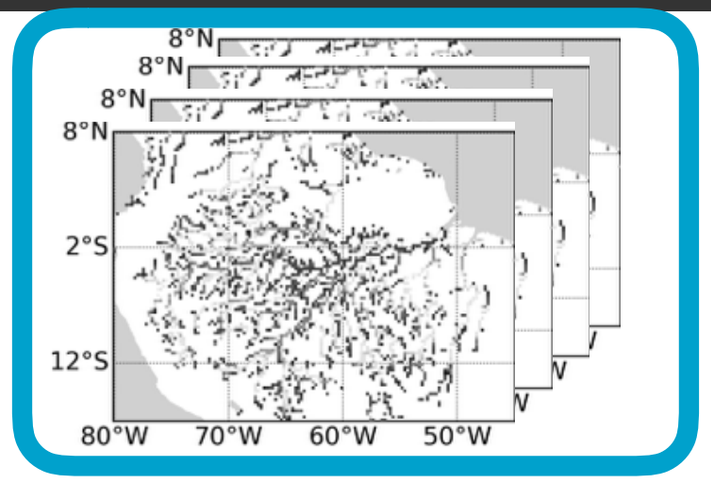
2. Method of Data Assimilation



Virtual SWOT

Virtual Experiment

Ensemble are needed→

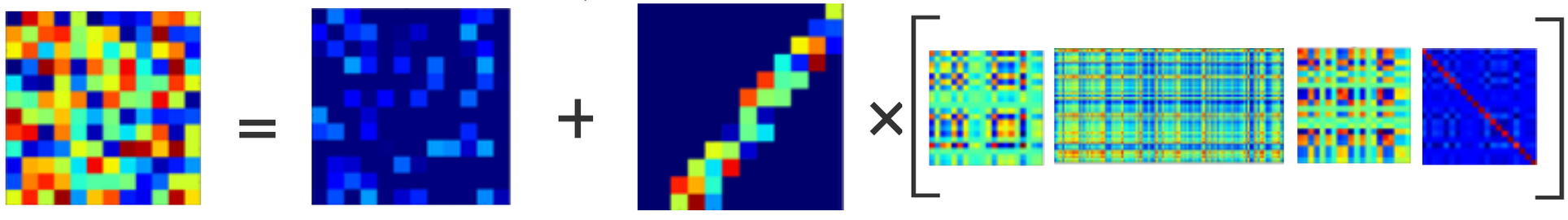


Corrupted Simulation

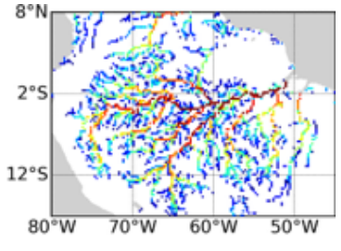
Data Assimilation

Ensemble Kalman Filter (EnKF)

Implemented with LETKF (Local Ensemble Transformation Filter)

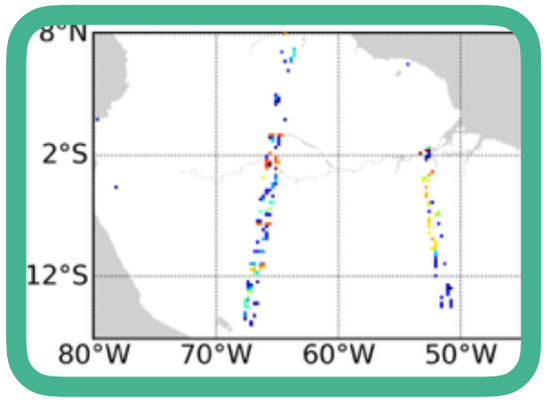


Assimilation = Simulation + Observation × Ensemble Statistics



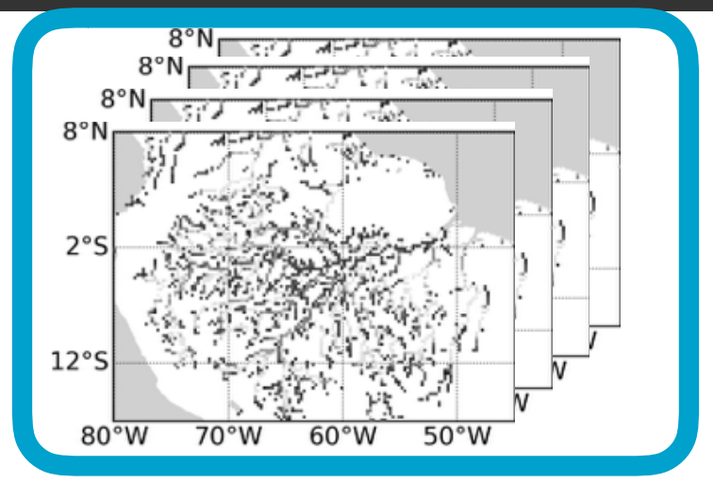
Assimilated Estimation

2. Method of Data Assimilation



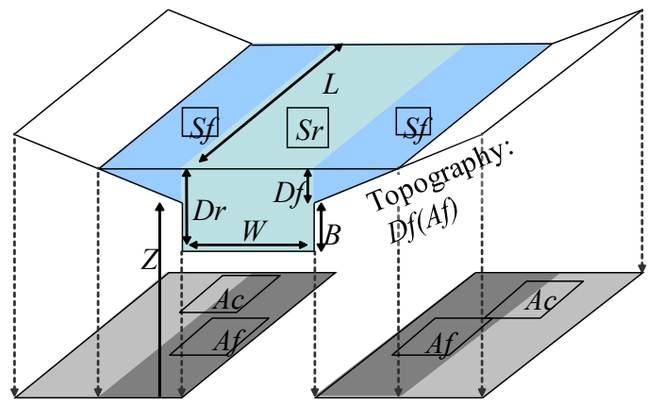
Virtual SWOT

Virtual Experiment



Corrupted Simulation

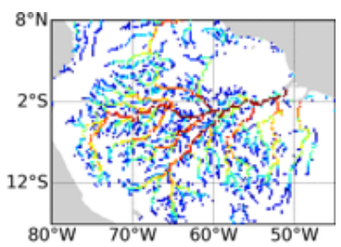
Water Surface Elevation (WSE)



Many Variables

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

Data Assimilation



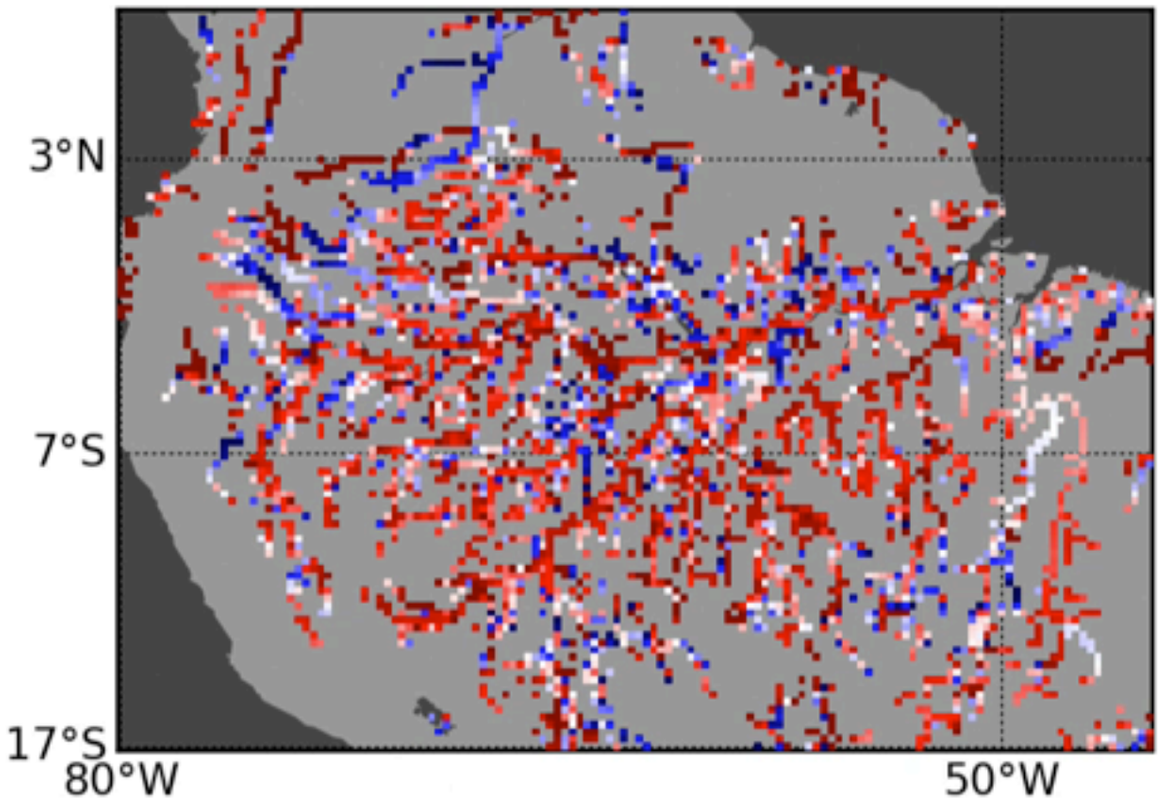
Assimilated Estimation

3. Results and Discussions

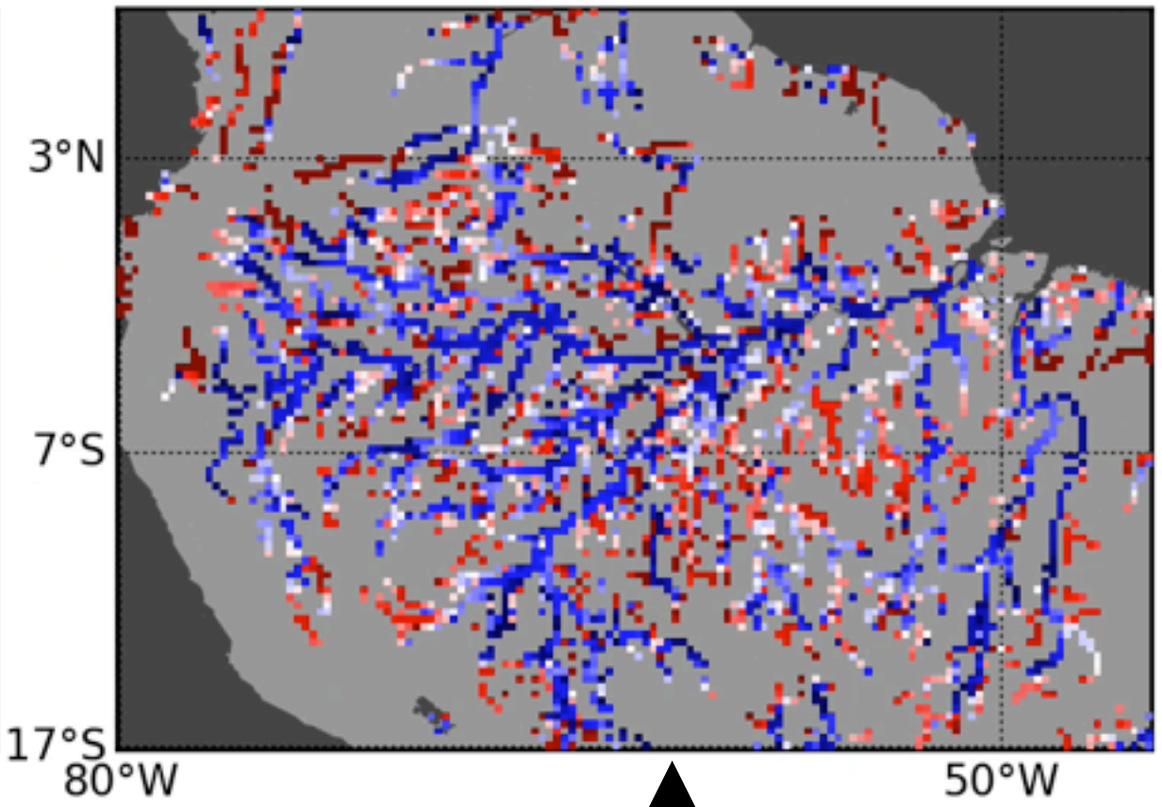
(A) -25% Experiment

absolute Error Rate of **River Discharge**

Corrupted Simulation



Assimilation



Error Decreased

the Amazon River

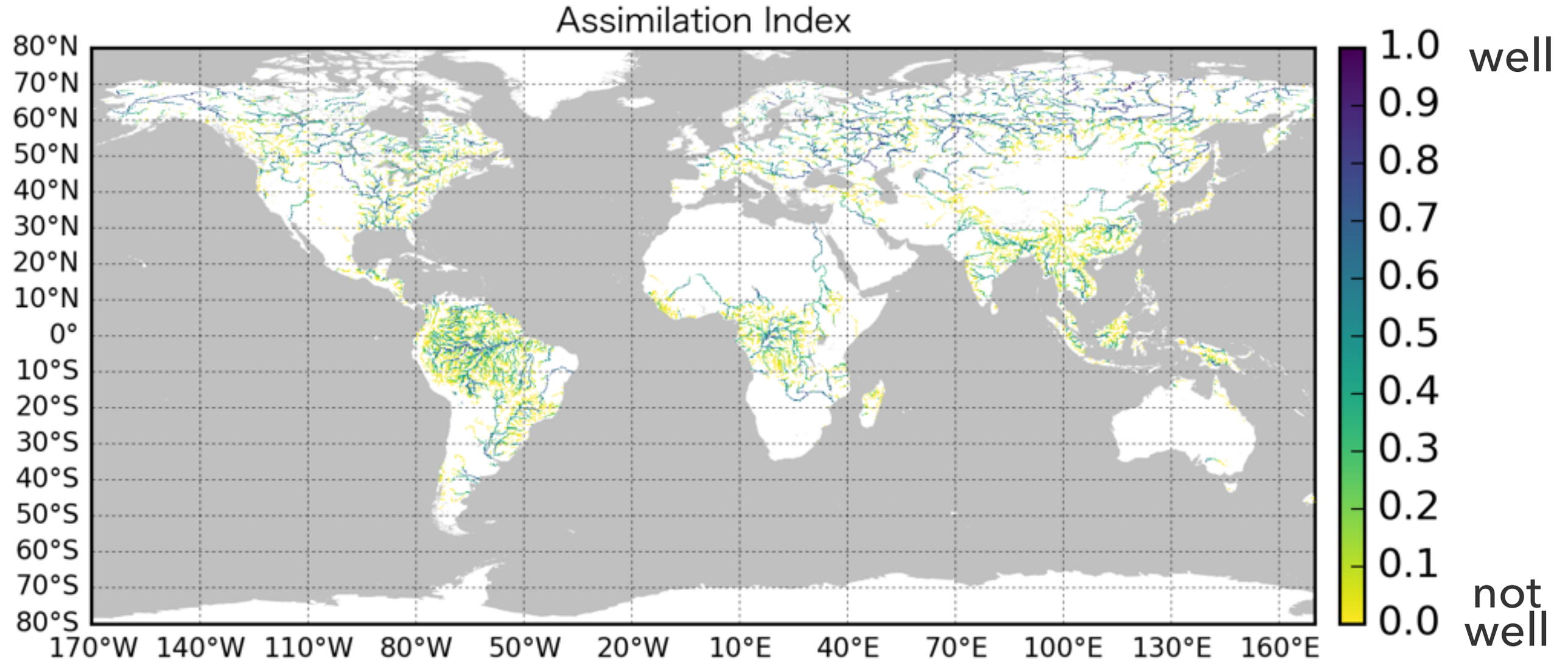
3. Results and Discussions (B) Blind Runoff

Assimilation Index(AI): relative Assimilation Achievement

$$AI = 1 - \left| \frac{Assim. - Corrup.}{True - Corrup.} - 1 \right|$$

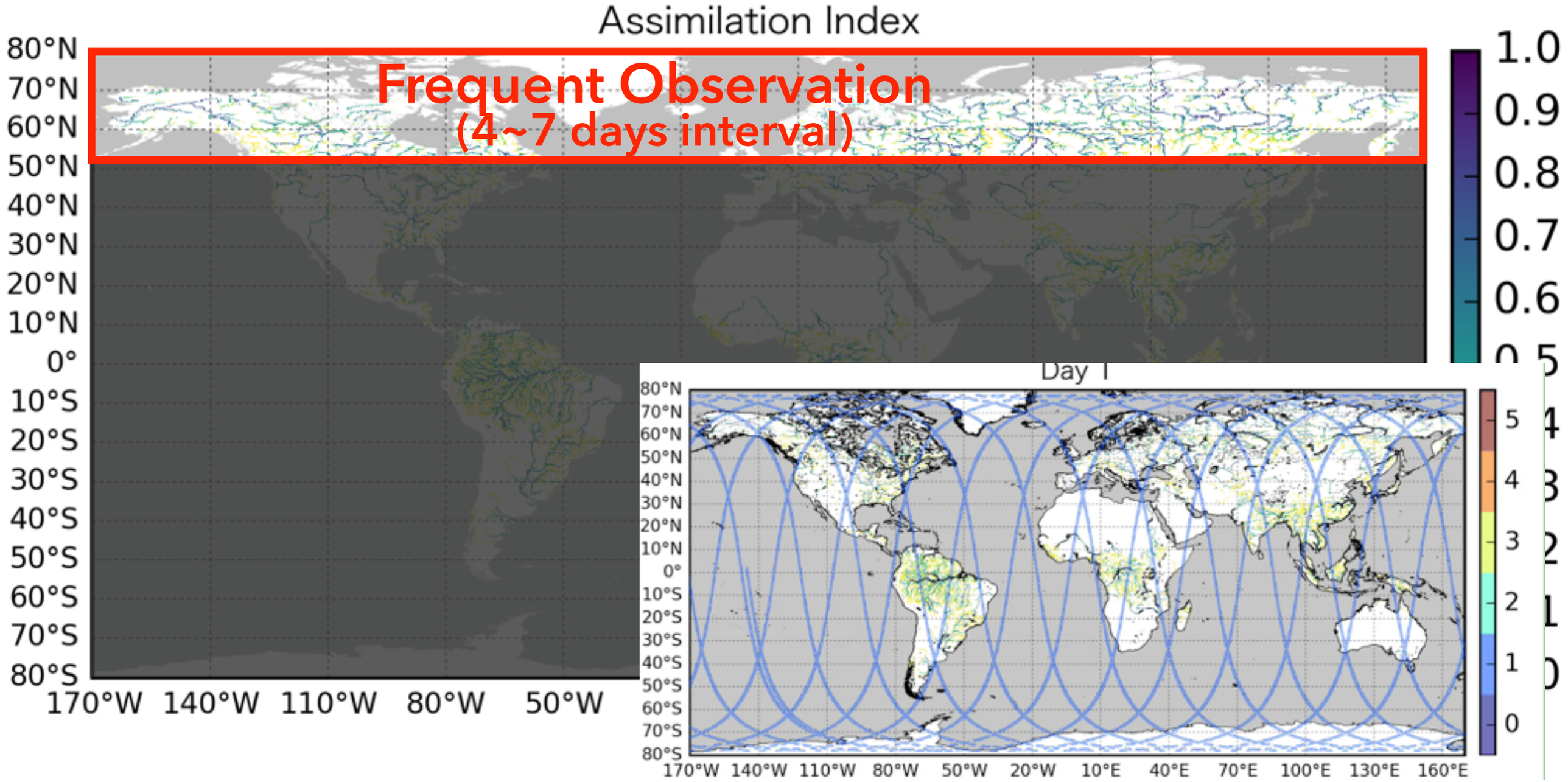
AI=1: done well

AI=0: not well



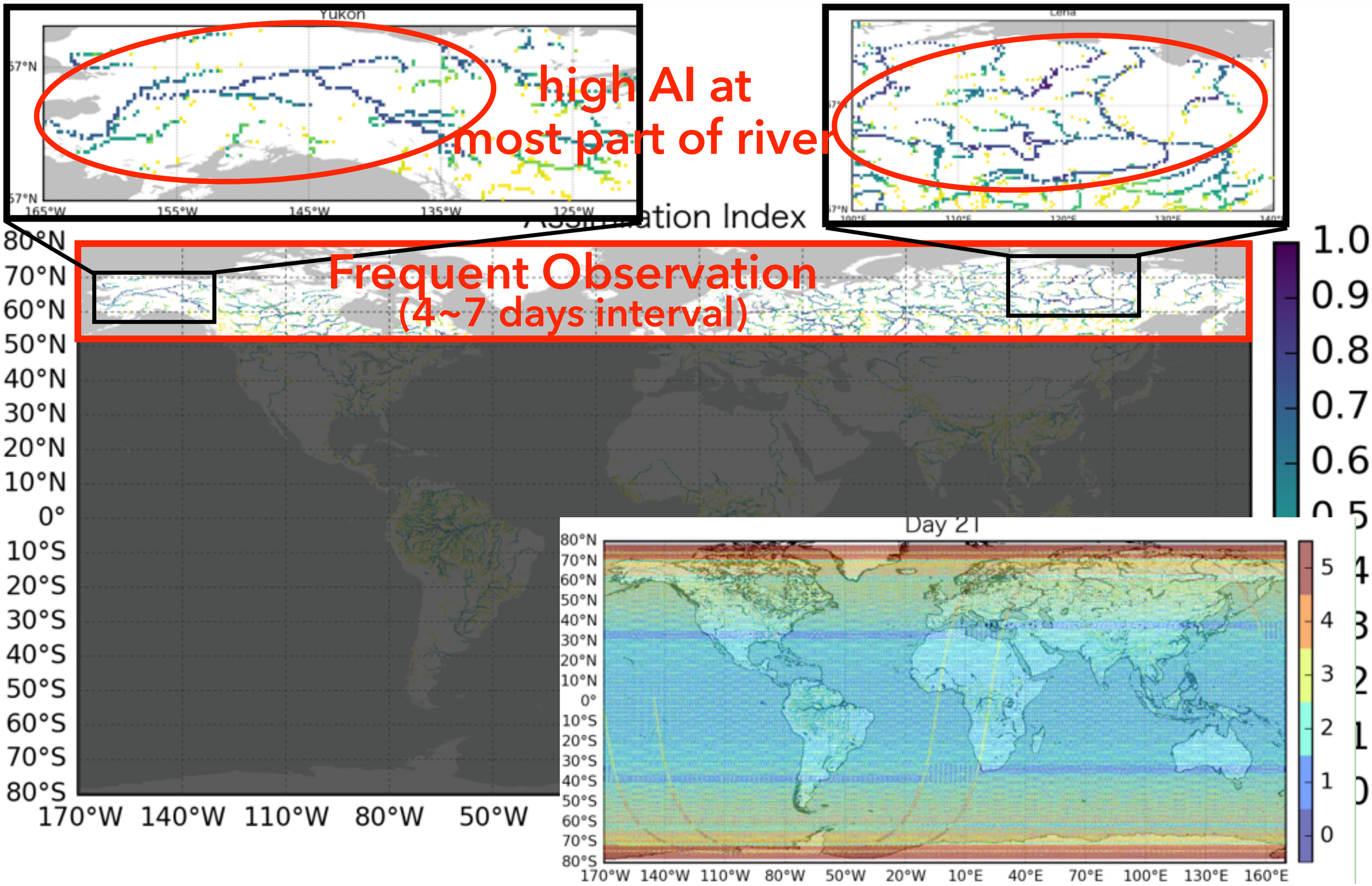
3. Results and Discussions

(B) Blind Runoff

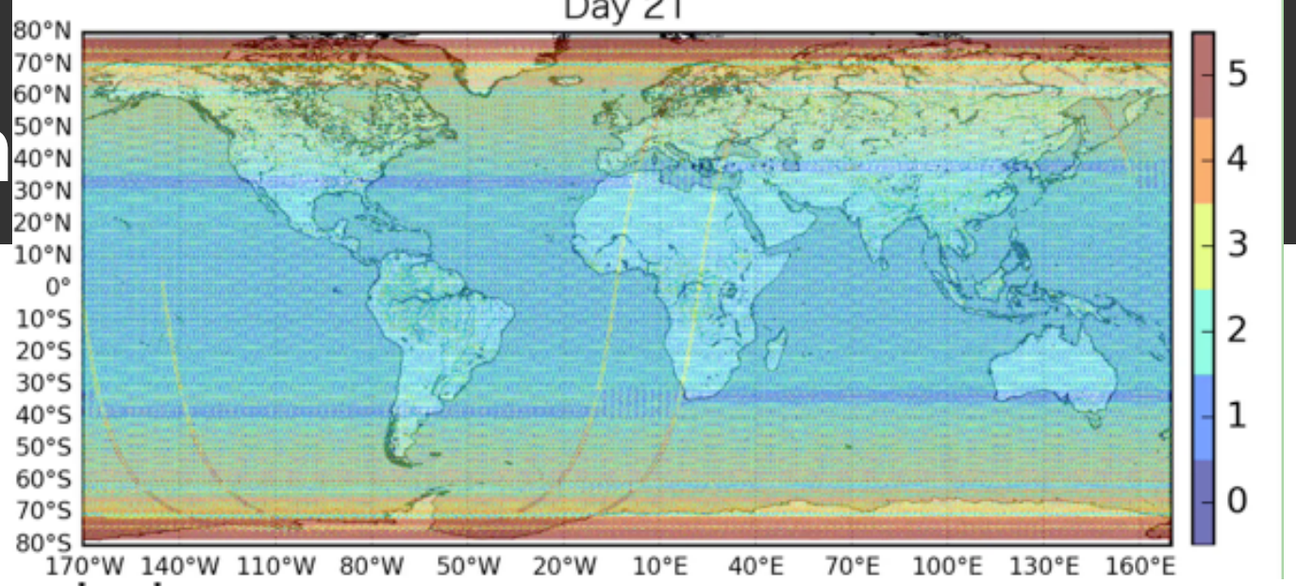


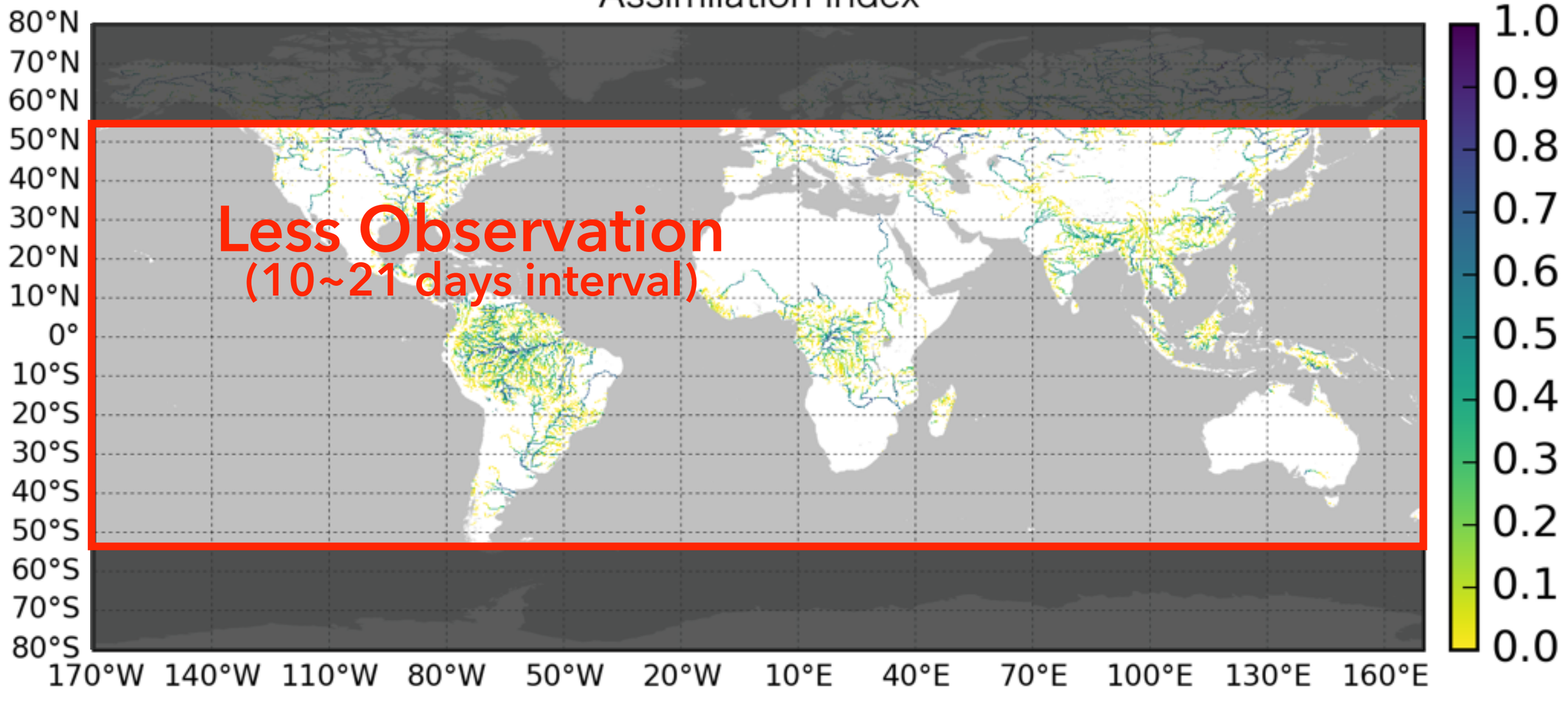
3. Results and Discussions

(B) Blind Runoff

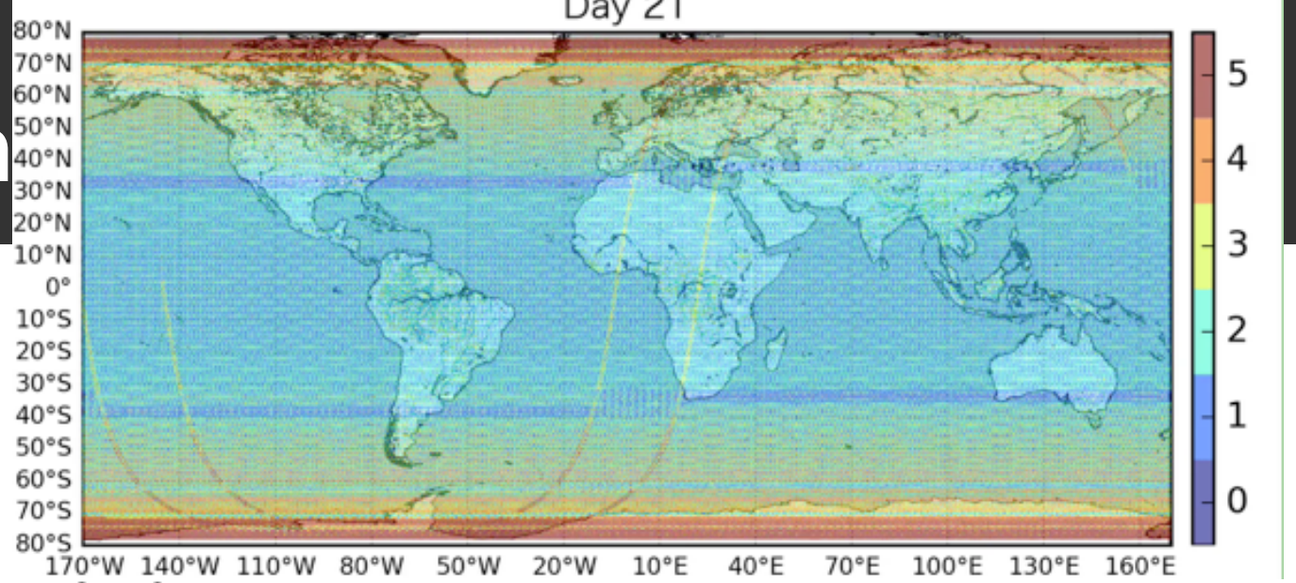


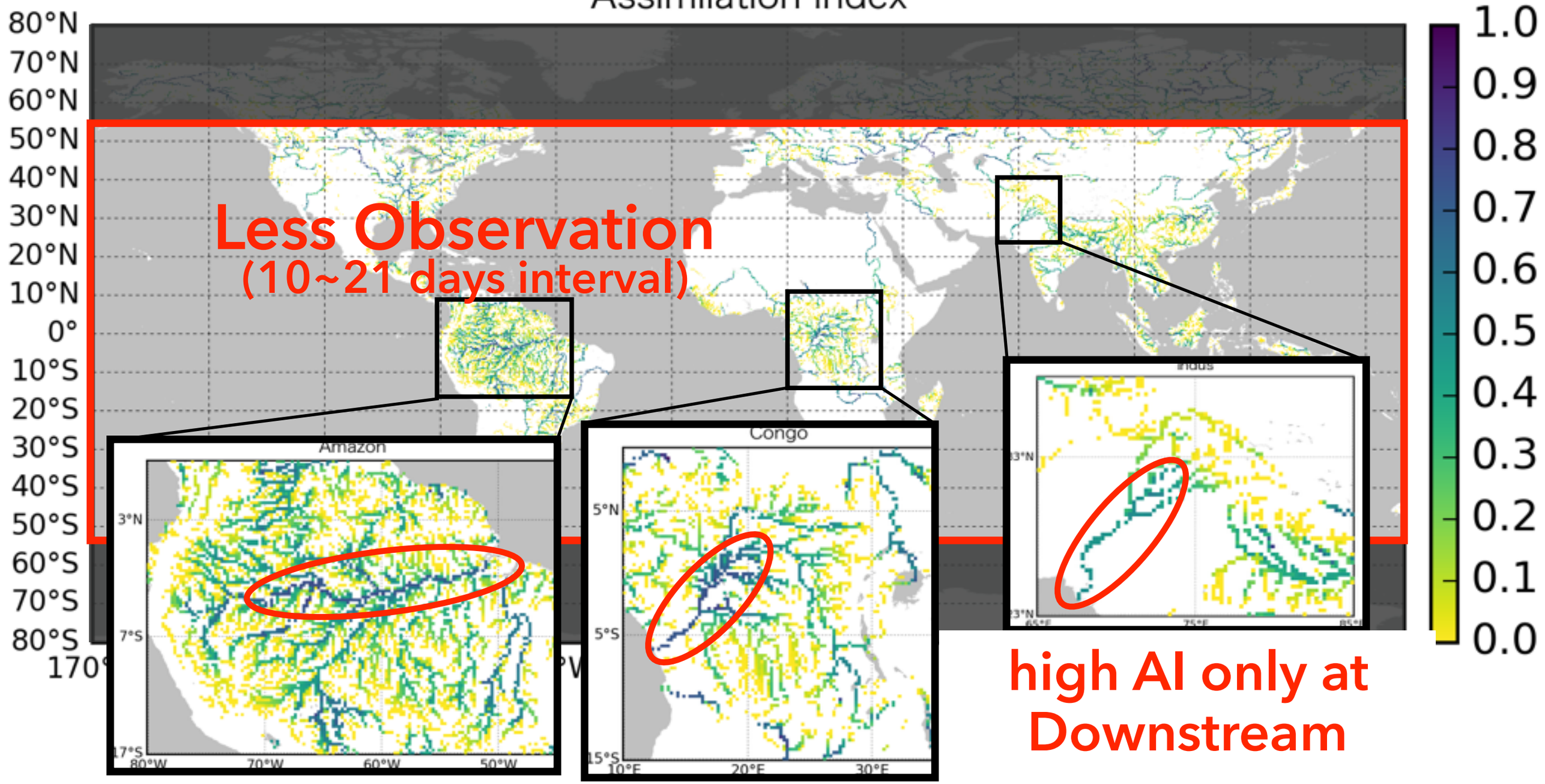
3. Results and Discussion



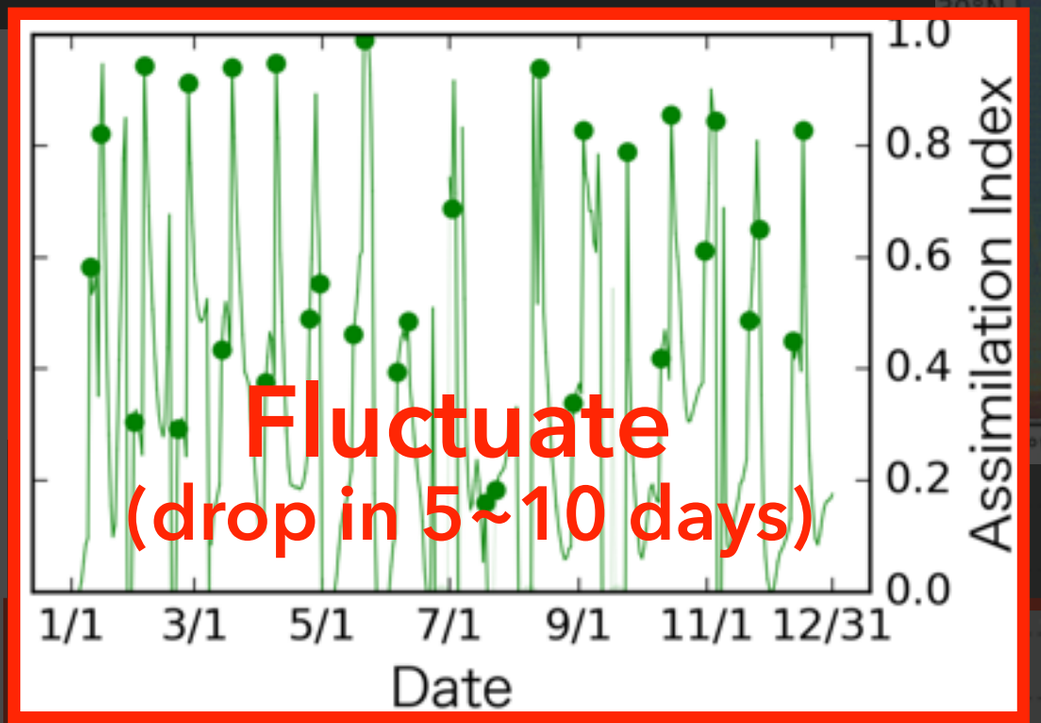


3. Results and Discussion

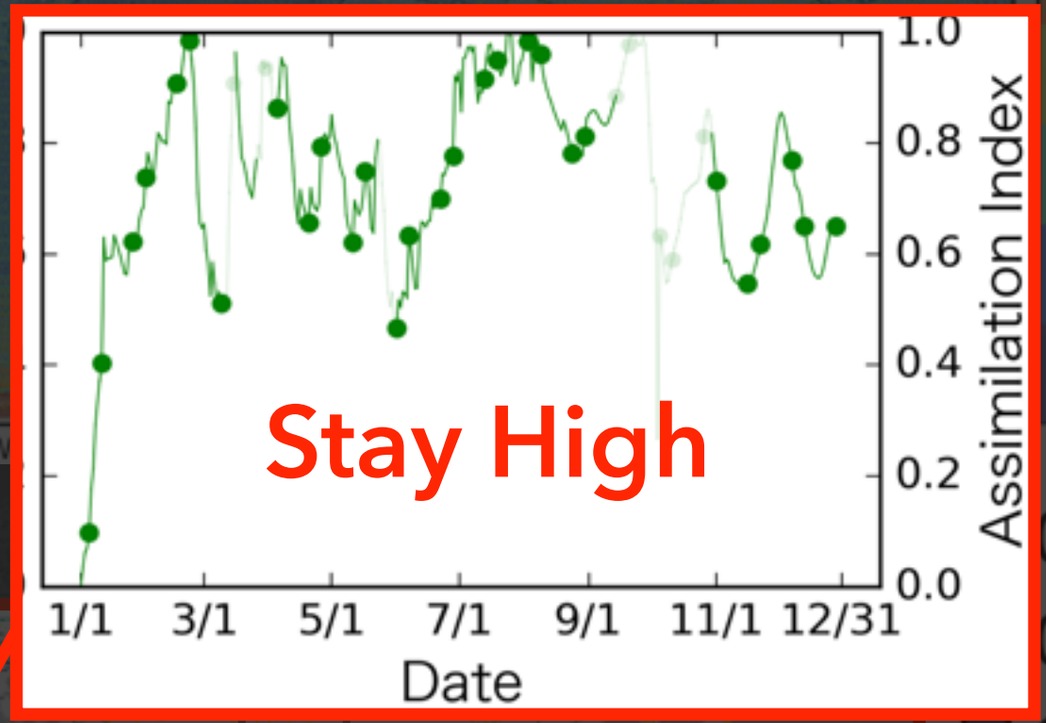


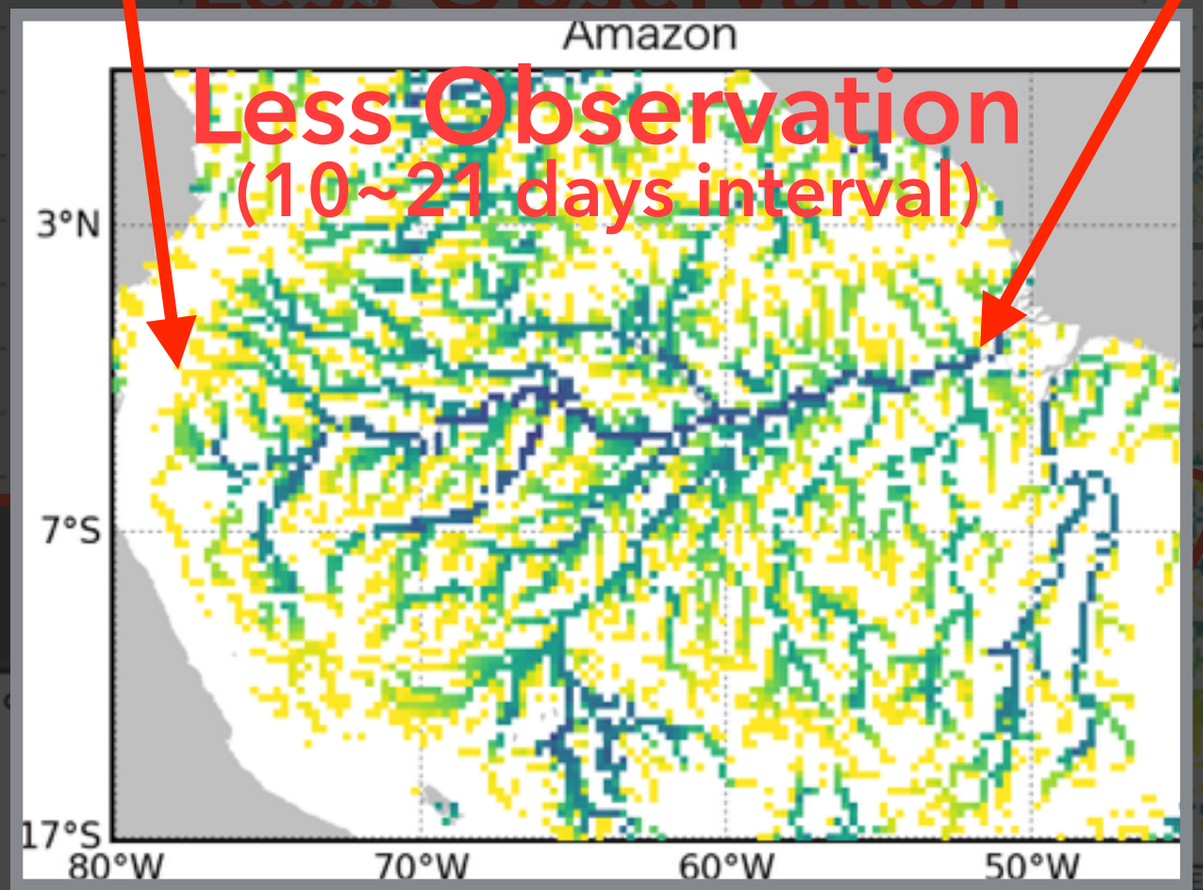


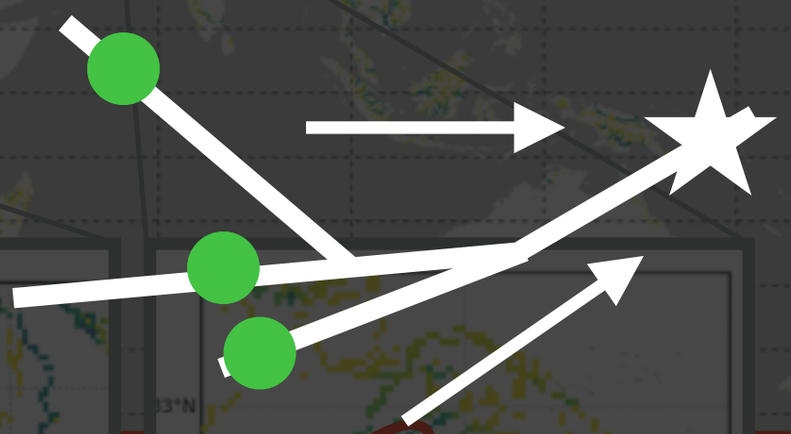
Upstream



Downstream

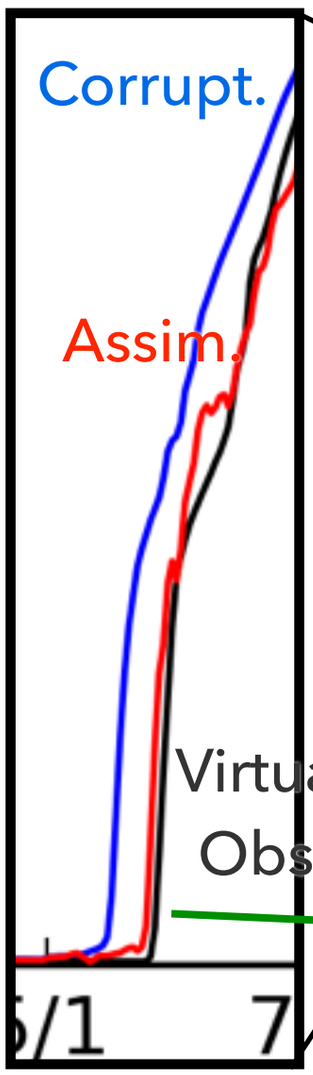


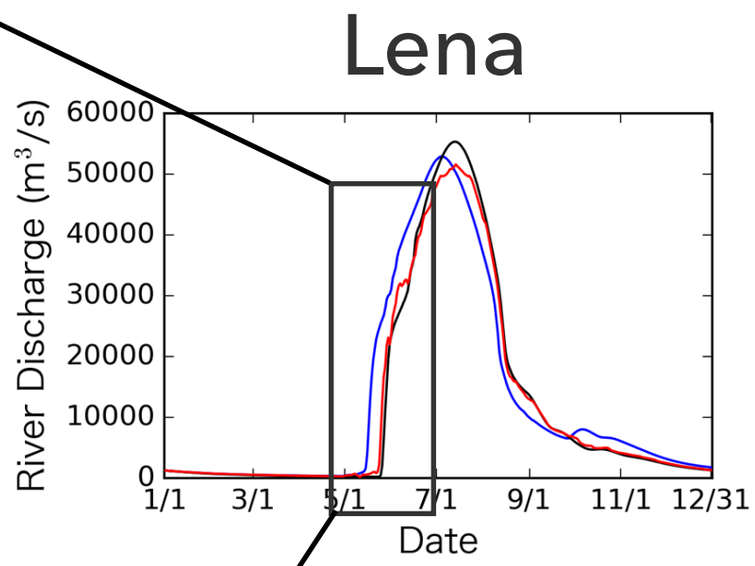




Assimilated Discharge
Inflowed
(6,000,000 km^2)

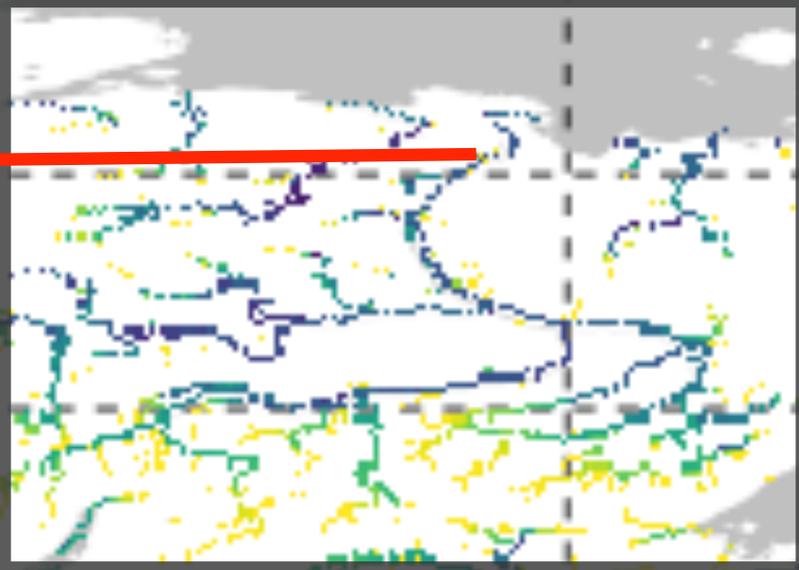
Seasonal Transition



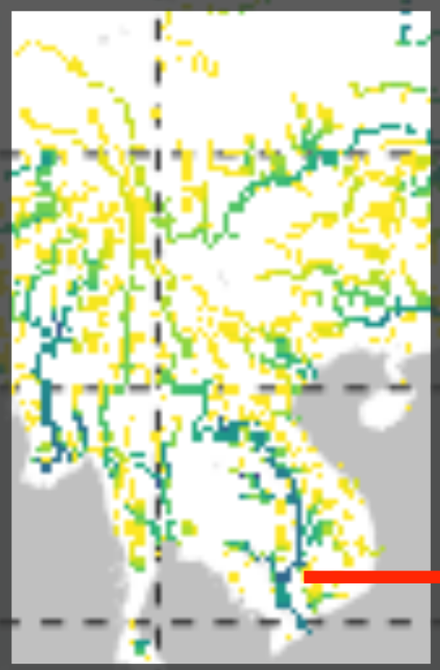


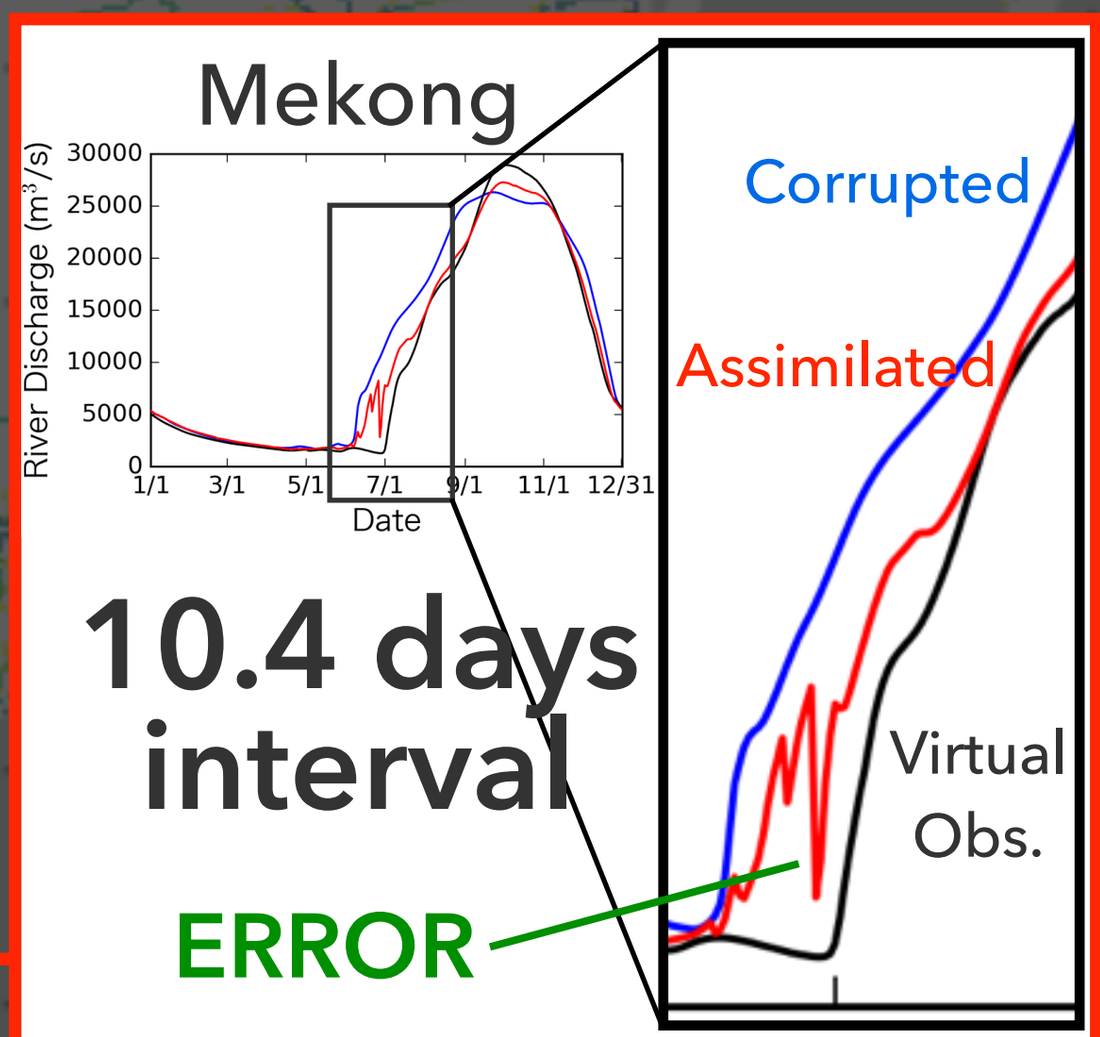
4.2 days interval

MATCH



- Inflow from Upstream
- Local and Upstream Observation
- Observation Frequency





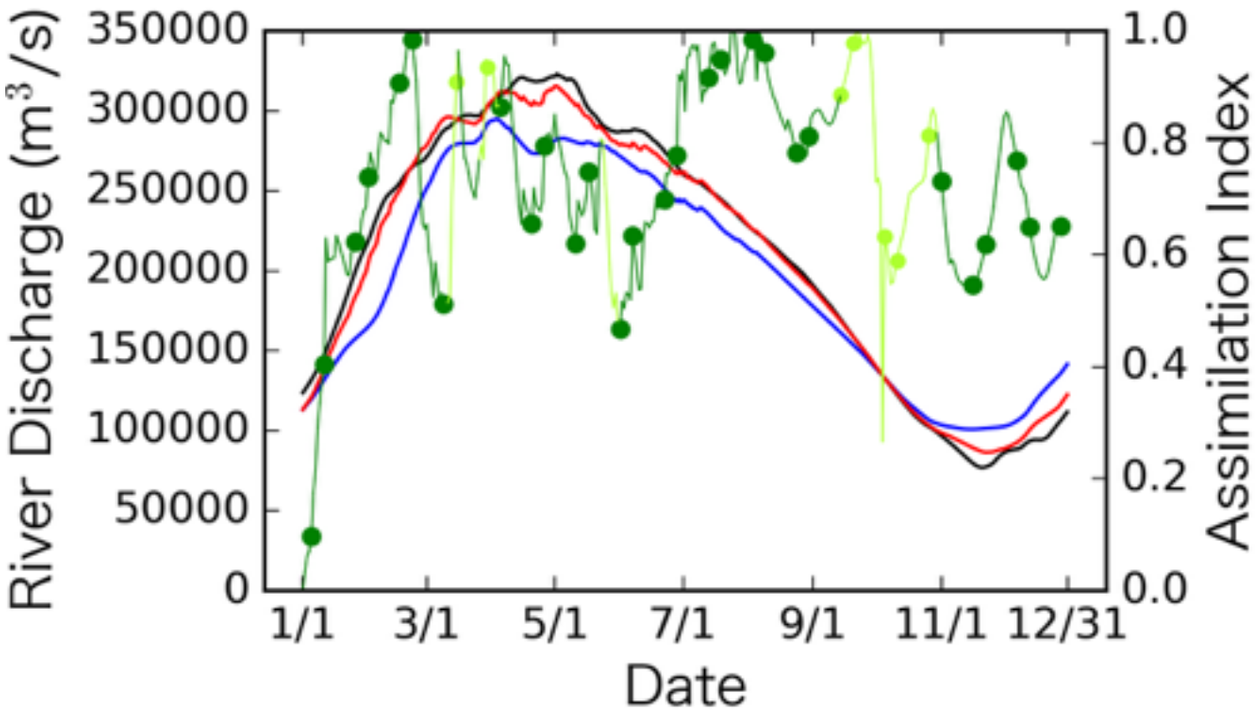
10.4 days interval

ERROR

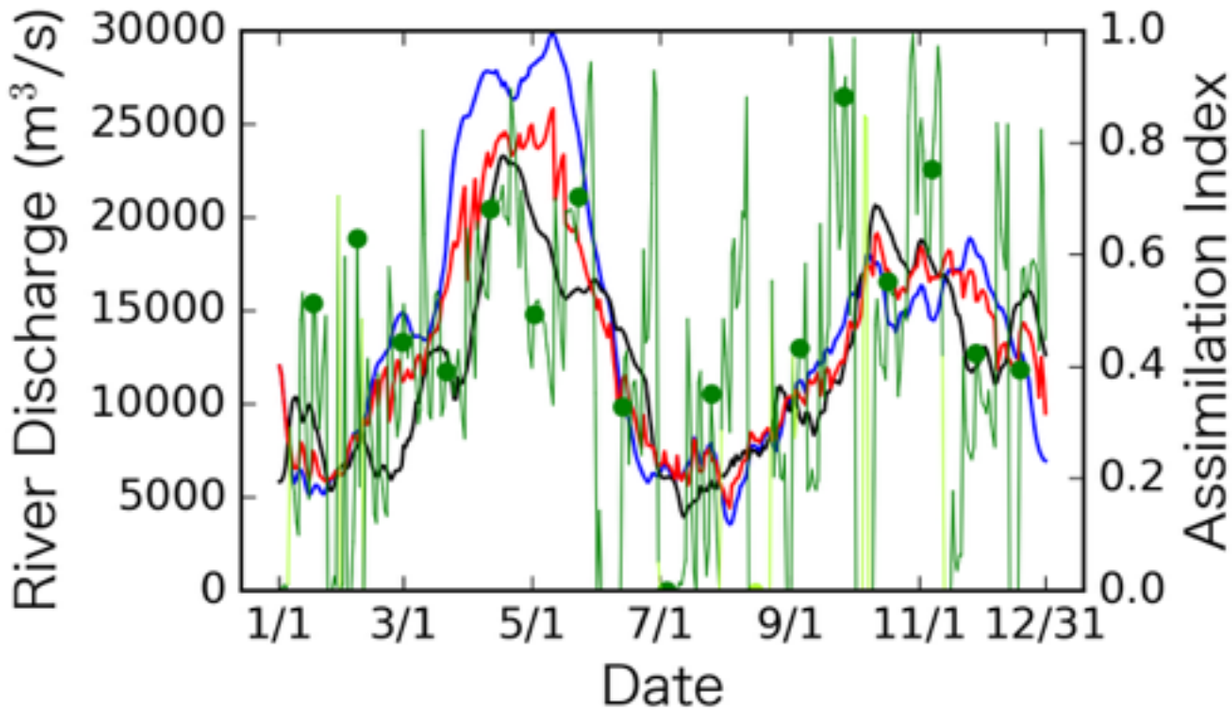
3. Results and Discussions

(B) Blind Runoff

Amazon (Downstream)



Congo (Midstream)



Discharge

Virtual Obs.

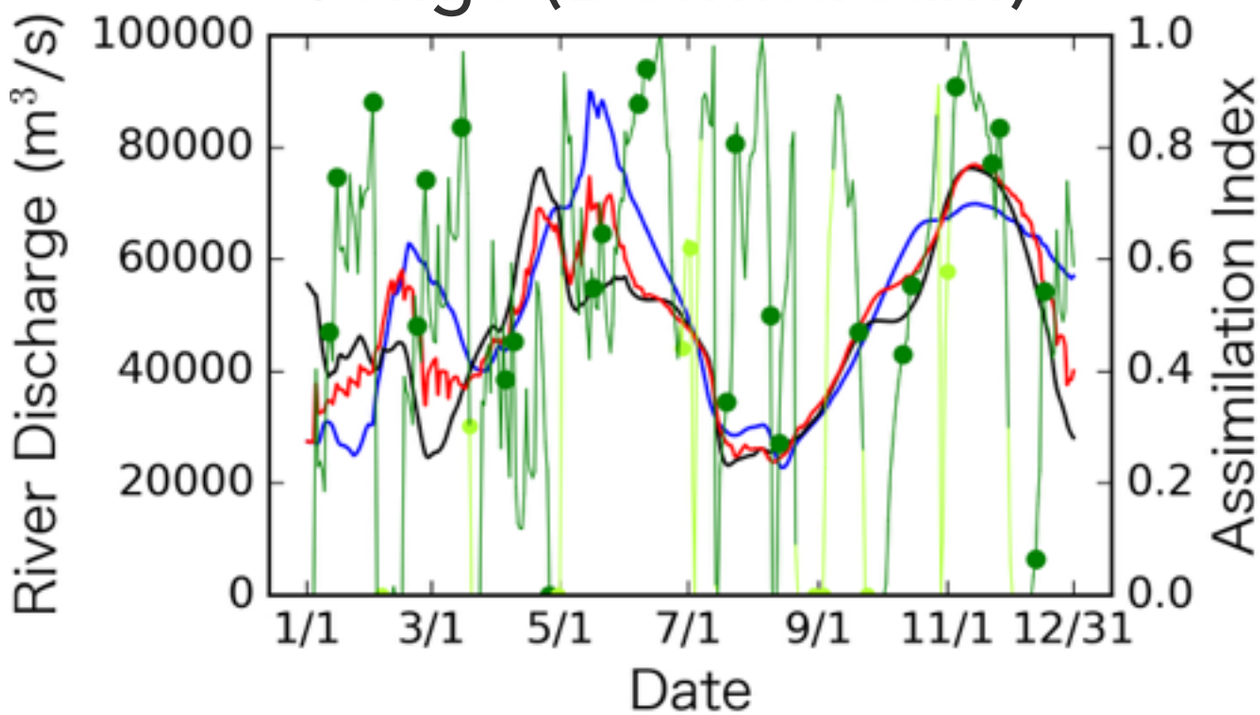
Assimilated

Corrupted

Assimilation Index

●: Observation

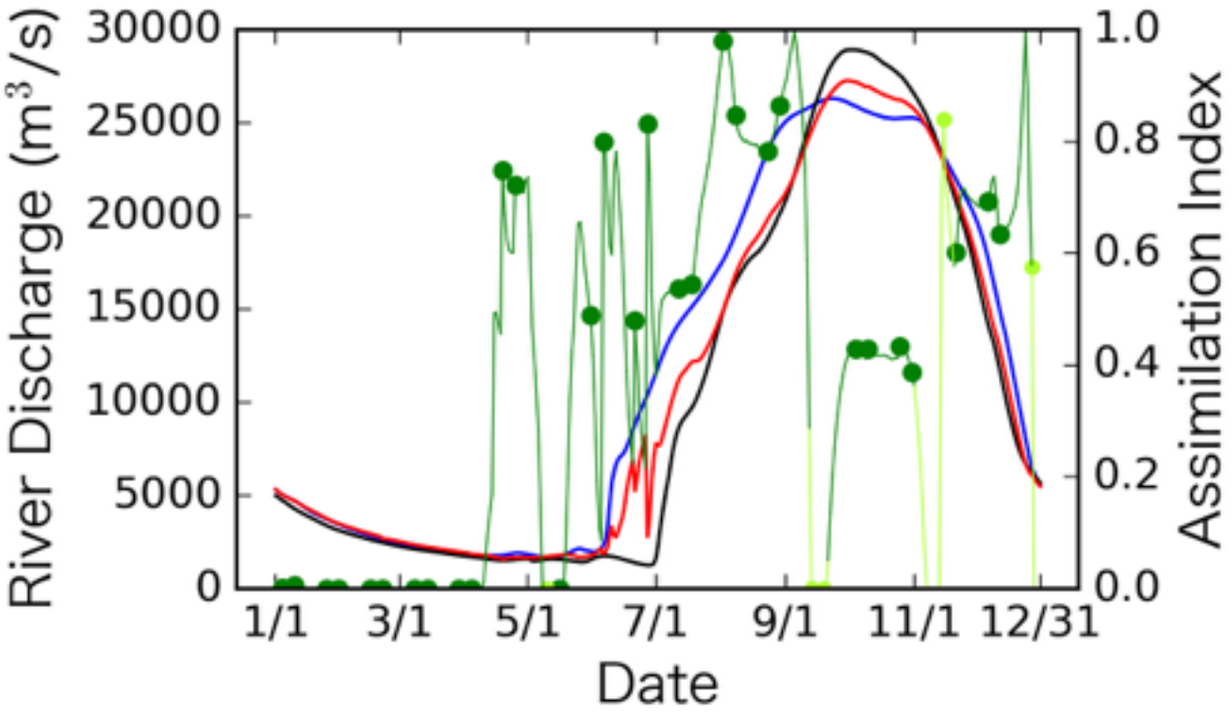
Congo (Downstream)



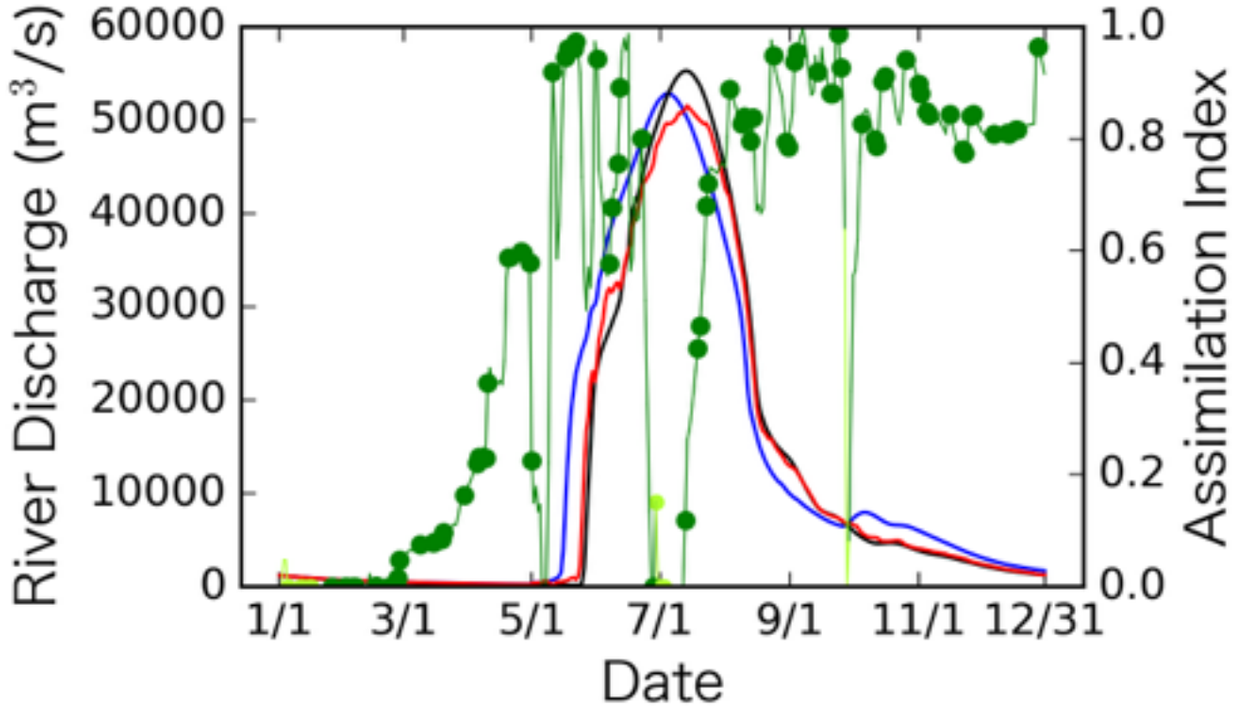
3. Results and Discussions

(B) Blind Runoff

Mekong (Downstream)

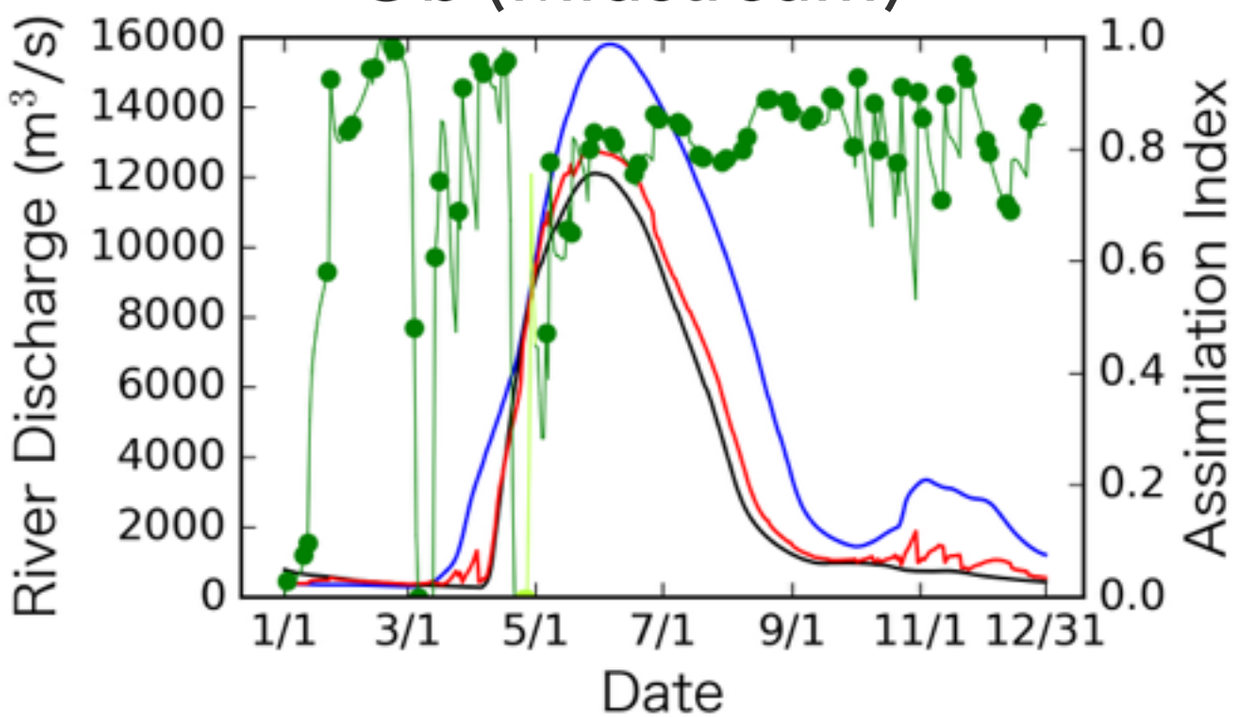


Lena (Downstream)



Discharge	Virtual Obs.
	Assimilated
	Corrupted
Assimilation Index	
●: Observation	

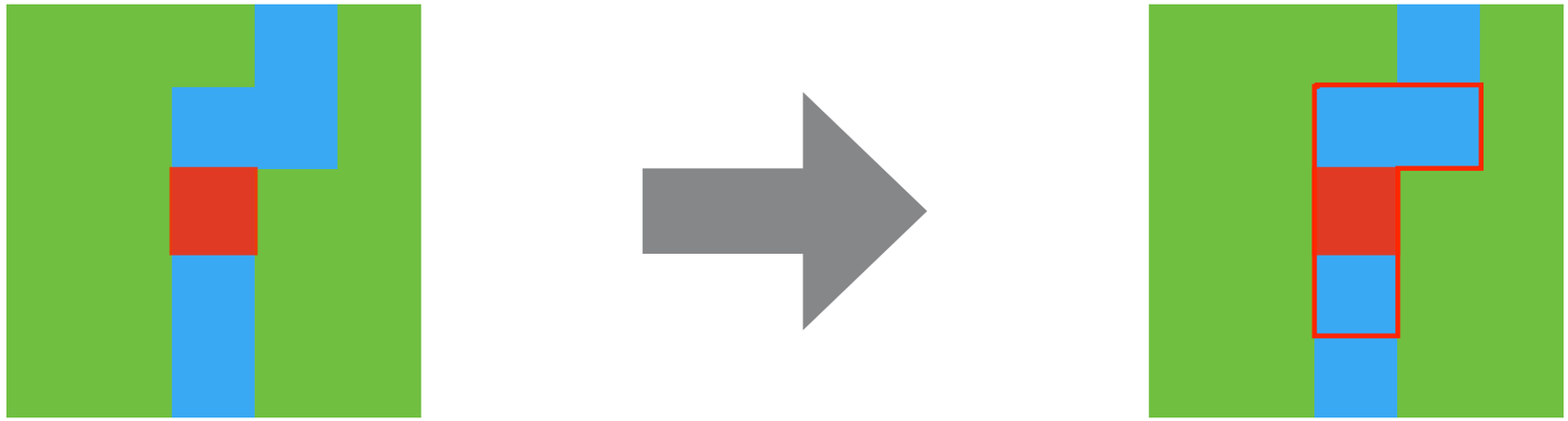
Ob (Midstream)



4. Future Steps

Enlarging Local Patch

Assimilation is possible only when there is Observation at that location



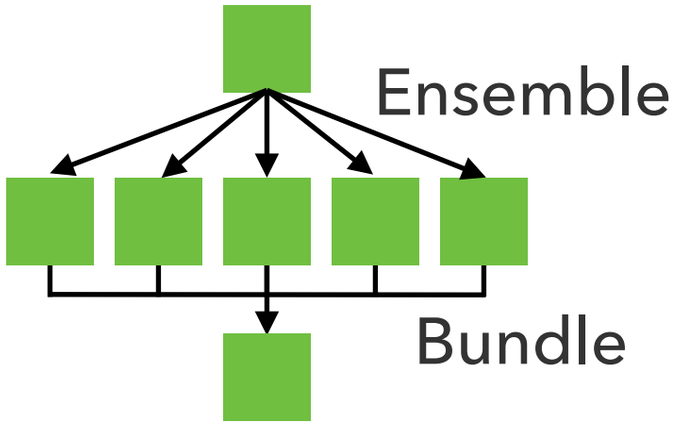
Originally, only target pixel is calculated at Assimilation

Using information of near-by pixel

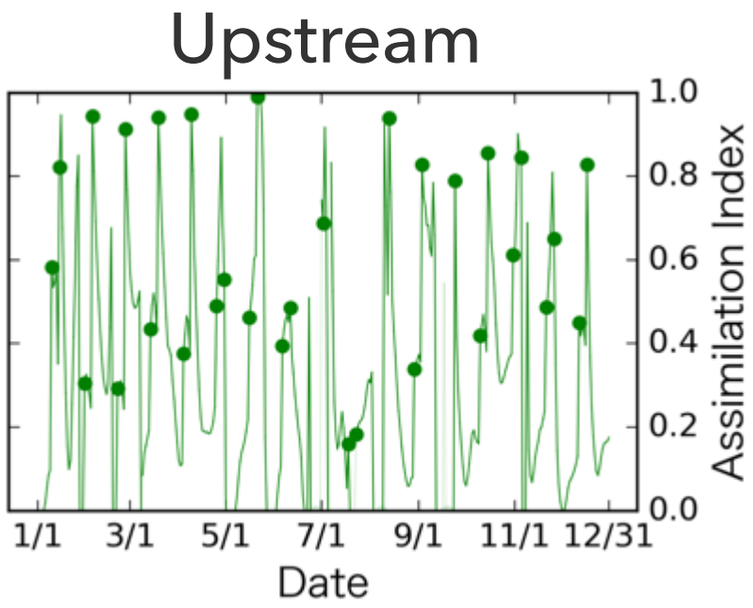
Assimilation Correction will be possible when there is observation at somewhere in the local patch

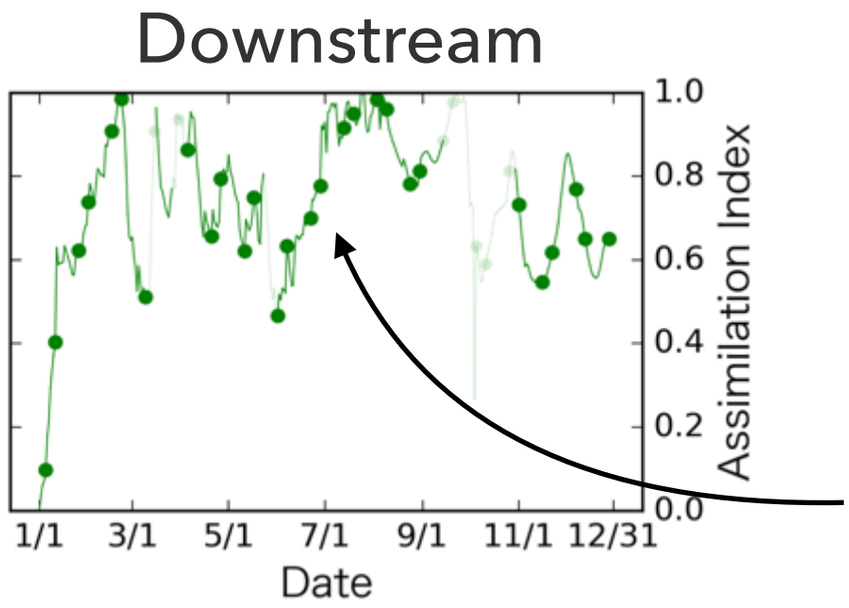
4. Future Steps

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

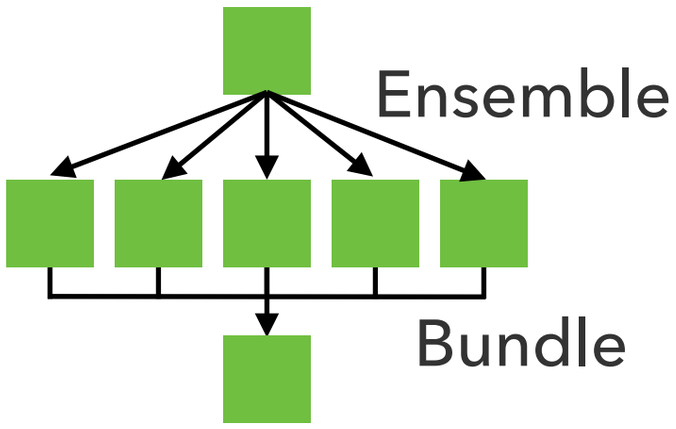




Observation at Downstream is not much effective

4. Future Steps

Improving Ensemble Spread



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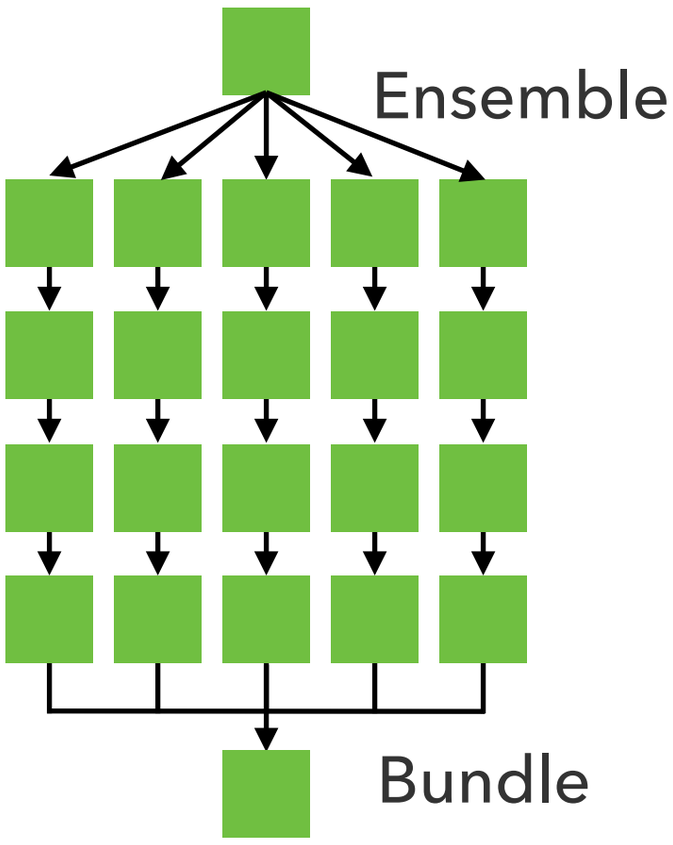
- However Ensemble and Bundle at daily step is too short for River Model to spread Ensemble



- 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