Development of an Algorithm for Soil Moisture with High Spatial- and Temporal- Resolution

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Soil Moisture

-High spatial and temporal variability due to…

Outline

1. Introduction
2. Methods
3. Results(Temporal)
4. Results(Spatial)
5. Conclusion

1.1 Background - Microwave sensors -

Active

-Emits microwave from the sensor and measures the backscatter from land surface

ALOS PALSAR

ground

Passive

-Measures the intensity of emission from land surface

Aqua AMSR-E

ground

	Temporal	Spatial
Active	**Low(40 days)**	**High(10 m)**
Passive	**High(1 or 2 days)**	**Low(>40 km)**

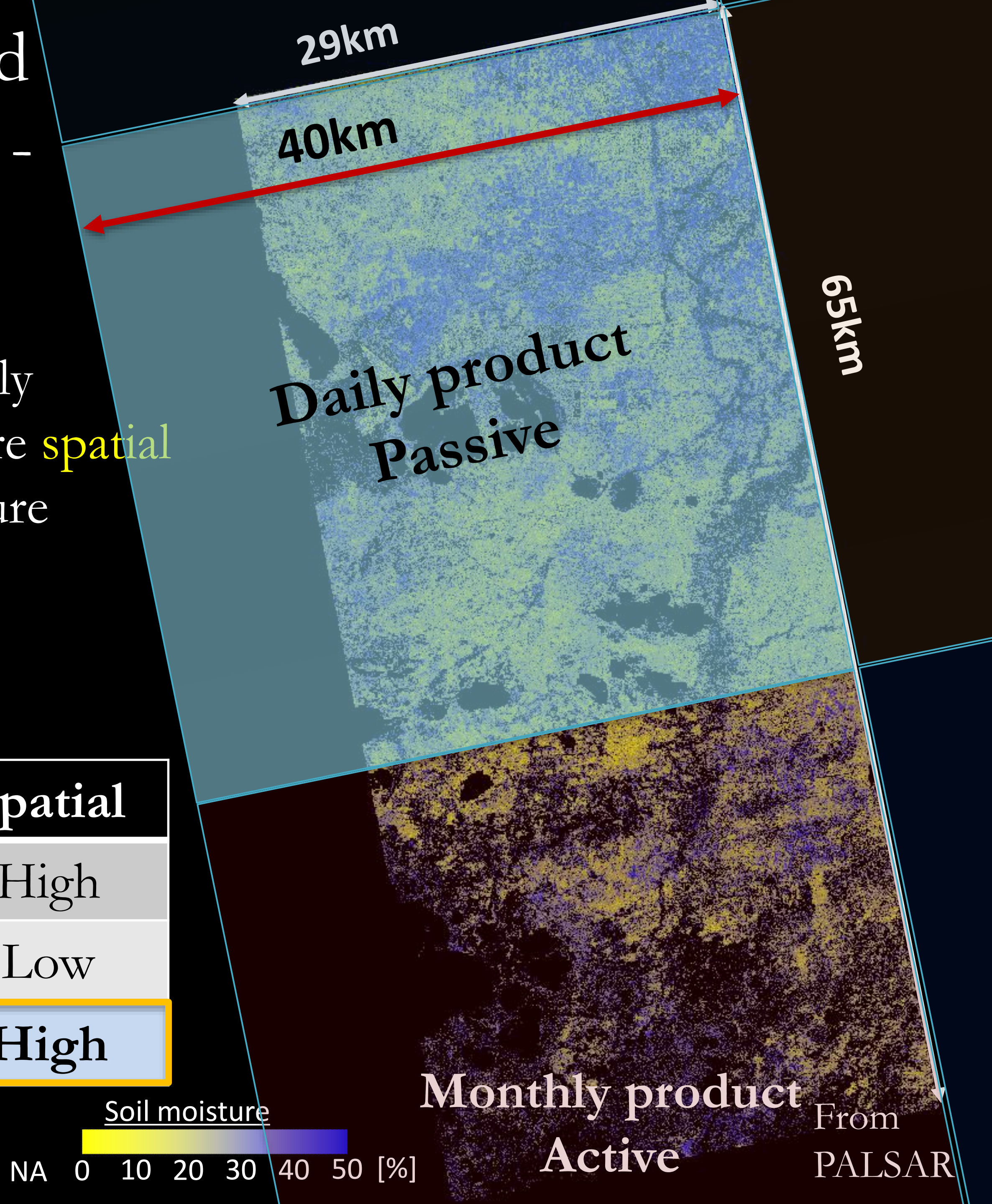
Both of microwave sensors are sensitive to soil moisture !

Source: JAXA

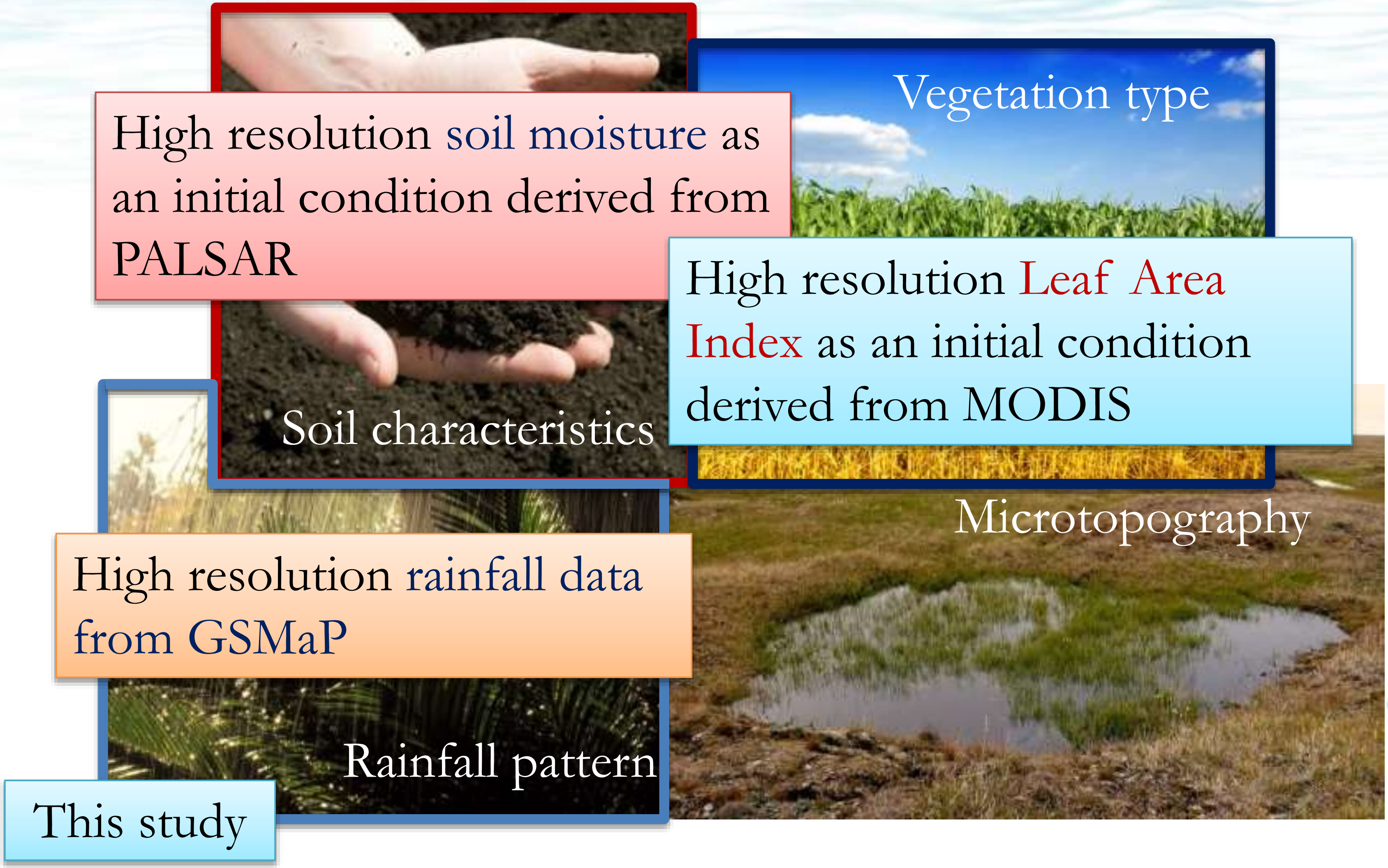
1.2 Background
- Soil moisture -

-Remote sensing is the only technique that can measure spatial distribution of soil moisture

	Temporal	Spatial
Active	Low	High
Passive	High	Low
GOAL	**High**	**High**



1.3 Introduction –factors-



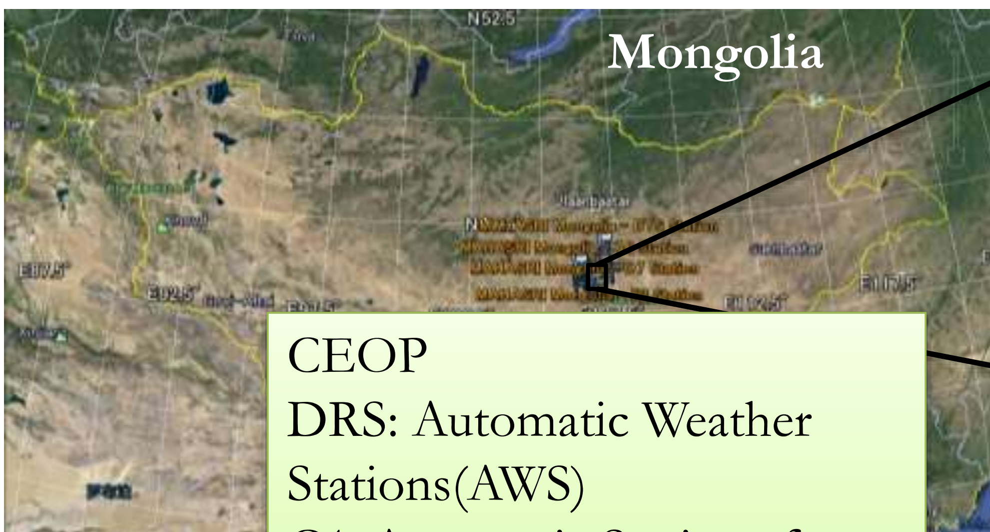
Focus on the effects of soil characteristics and vegetation type.
Additionally, focus on the effect of rainfall pattern qualitatively.

2.1 Target resolution and area

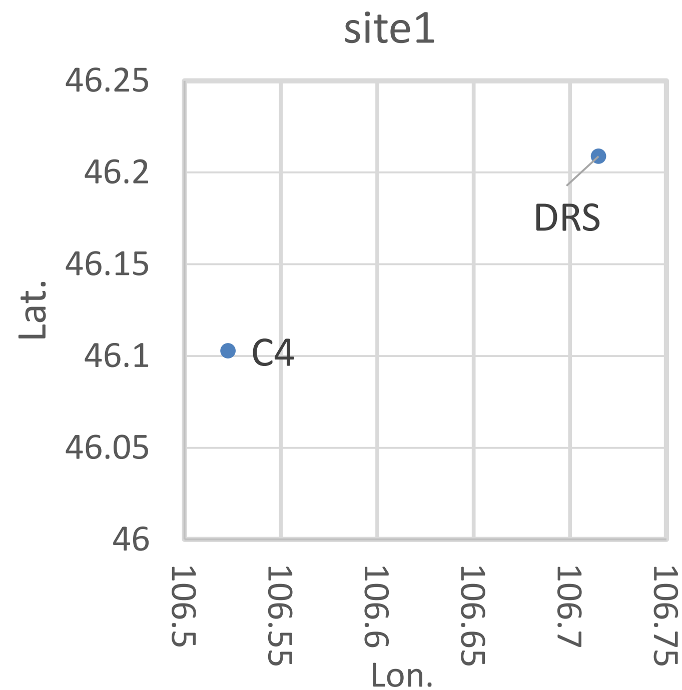
Passive: AMSR-E (resampled to 25km)

Active: PALSAR (averaged to 1km)

→ 1km resolution



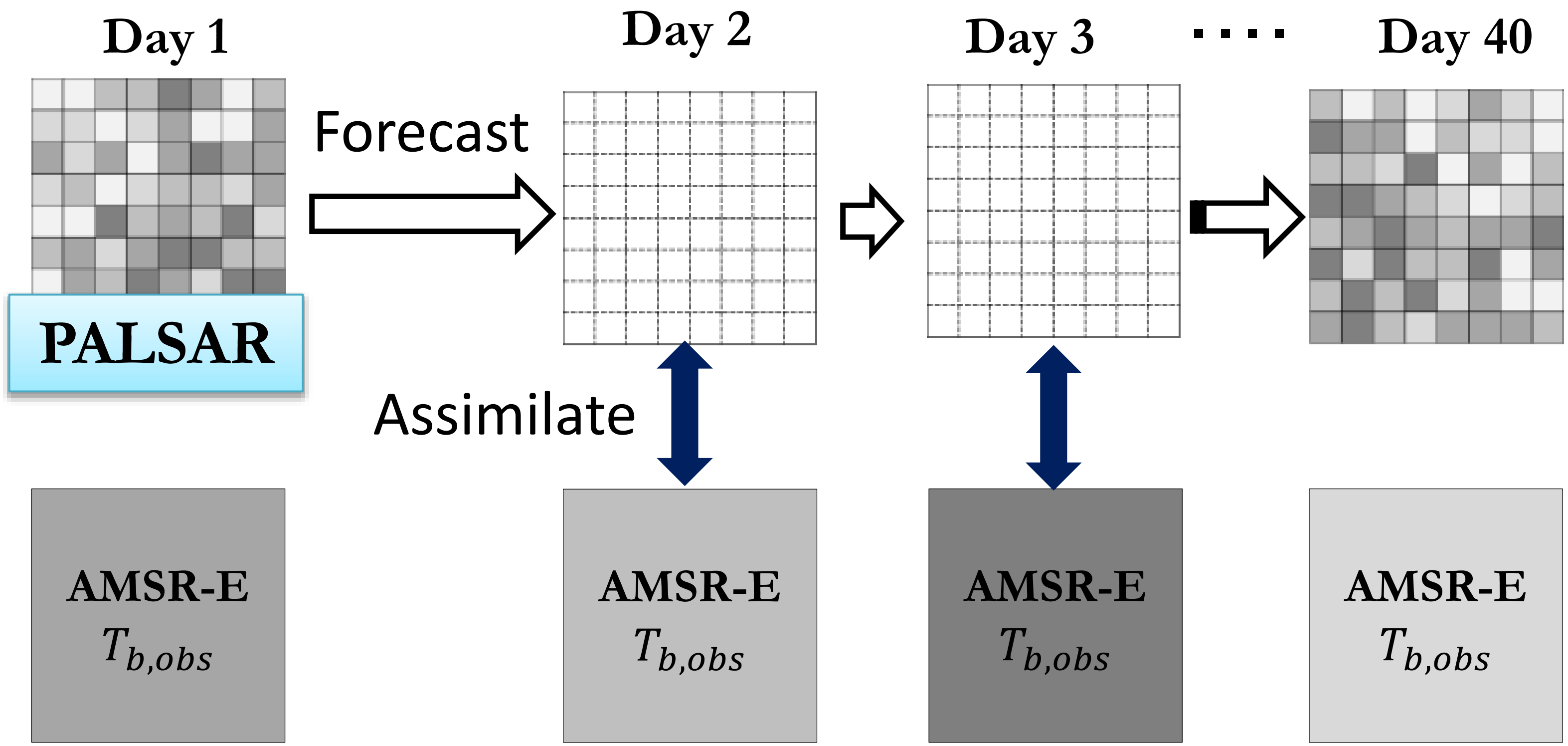
CEOP
DRS: Automatic Weather Stations(AWS)
C4: Automatic Stations for Soil Hydrology(ASSH)



2.2 Main strategies

1. Use PALSAR high spatial resolution soil moisture data as an initial condition

2. Assimilate AMSR-E brightness temperature everyday



2.3 Models

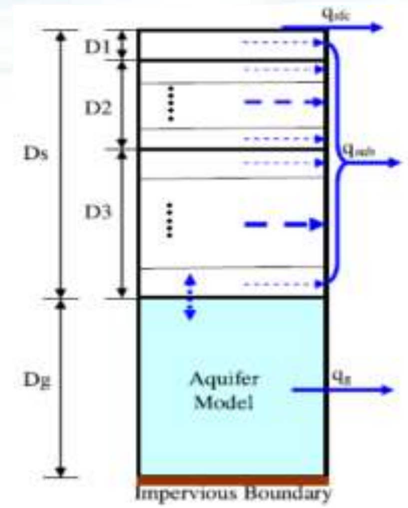
Forecast Model

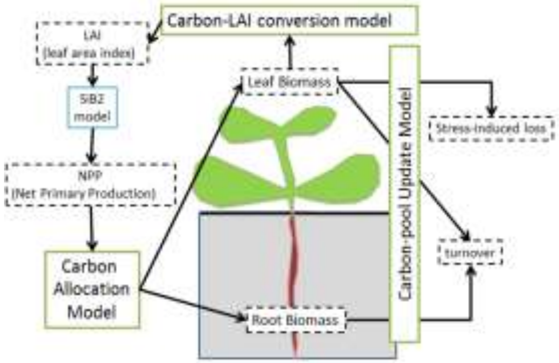
EcoHydro-Sib [Sawada and Koike, 2014]

Observation operator

Radiative Transfer Model (RTM)

[Kuria et al., 2009]





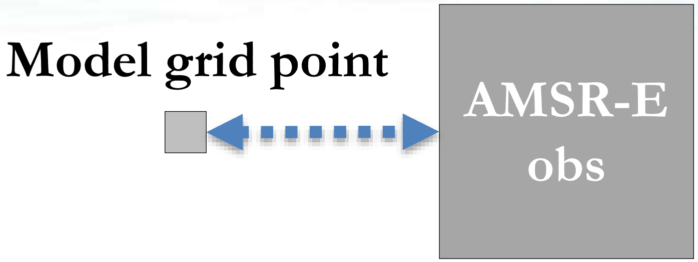
<u>Many parameters in each models</u>

1. Calibration
2. Assimilation

2.4 Steps

Step 1: Parameter optimization

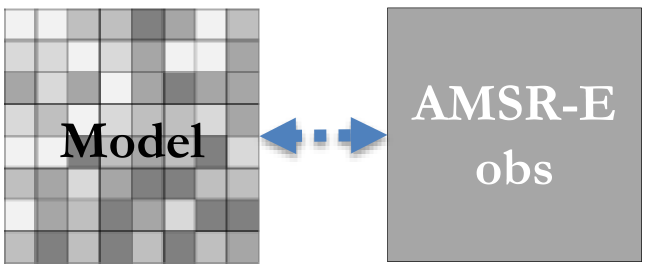
Coupled Land and Vegetation Data Assimilation System (CLVDAS)[Sawada and Koike, 2014]



However, CLVDAS assumes the sizes of model grid point and observation are same

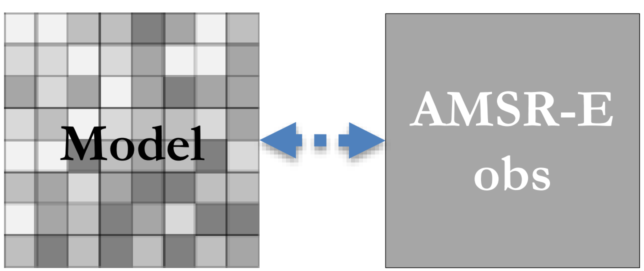
Developed in this study

Step 2: Parameter correction factors optimization



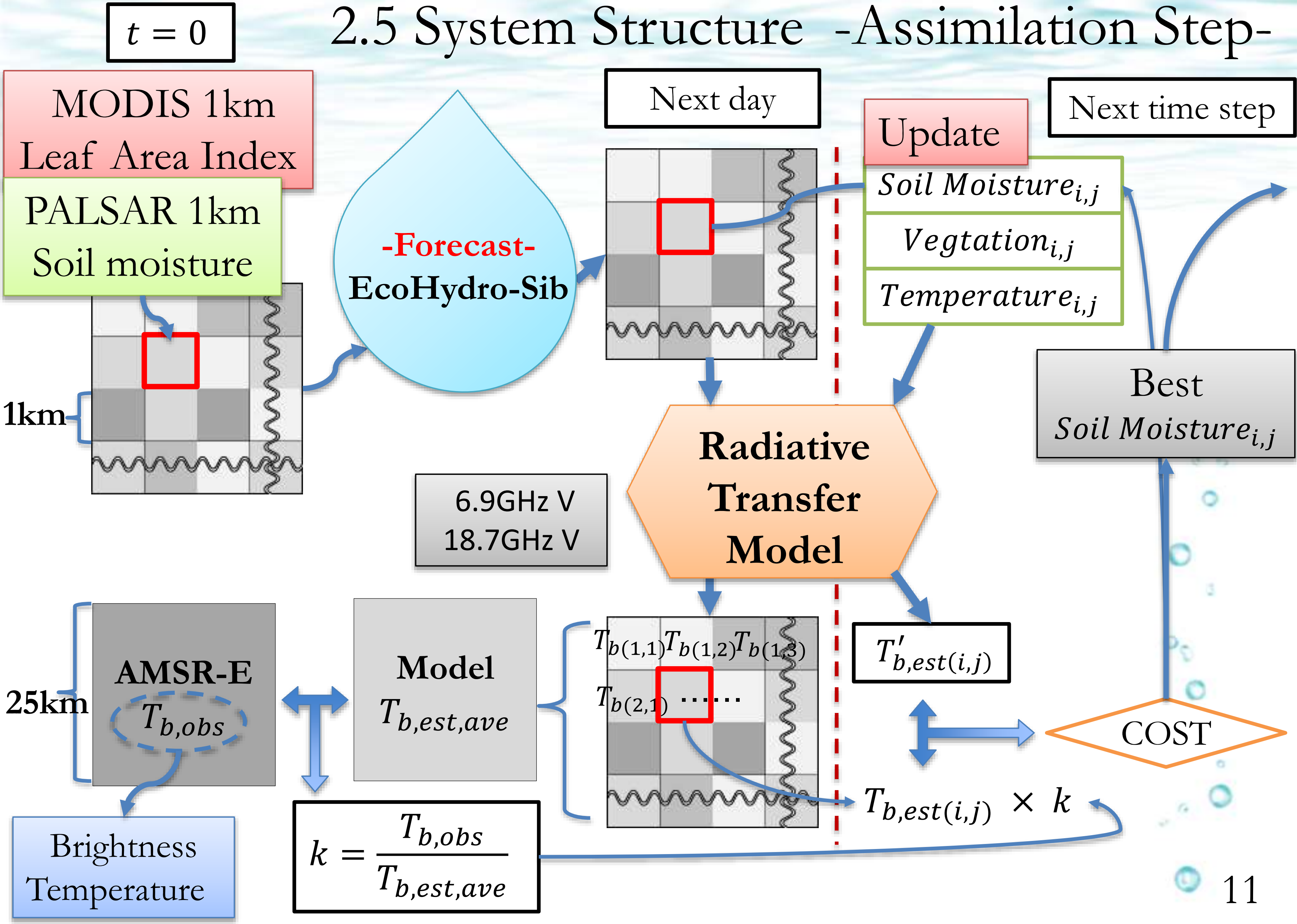
Correct model parameters at passive scale

Step 3: Data assimilation



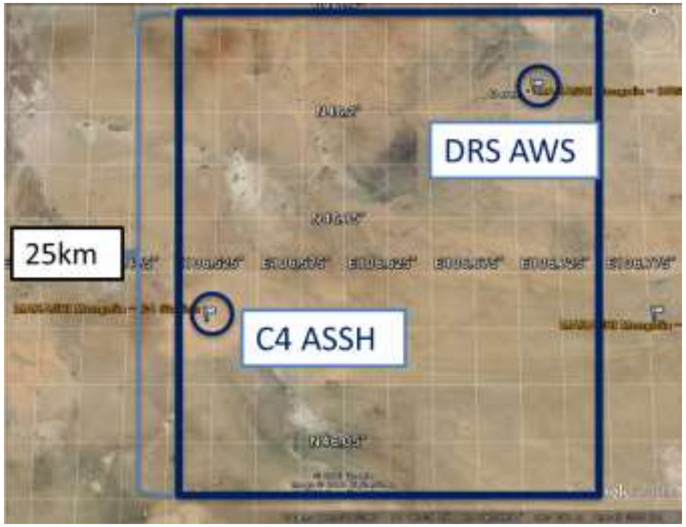
Assimilate soil moisture in each grid point

2.5 System Structure -Assimilation Step-



3 & 4 Results (Without Rainfall Pattern)

In order to minimize the effect of rainfall data error, rainfall data observed in DRS station is used

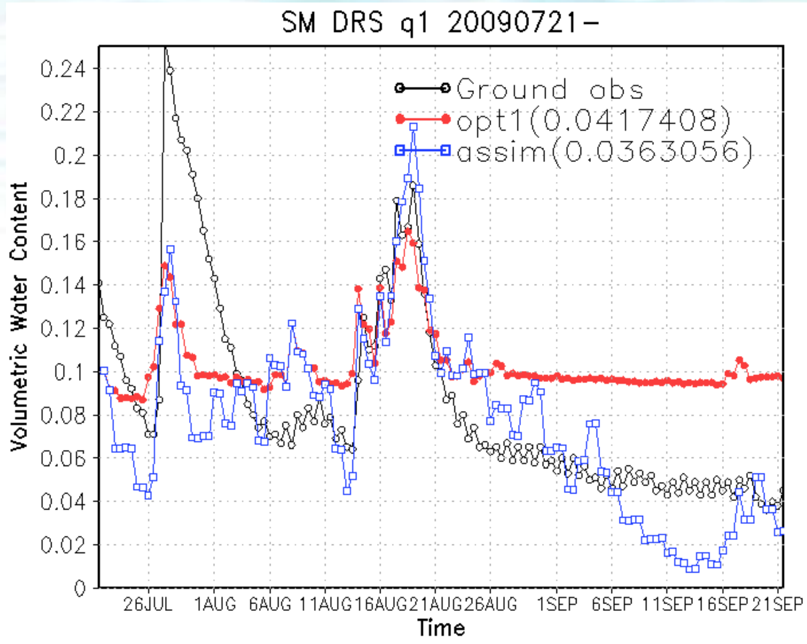


3 RESULTS(TEMPORAL)

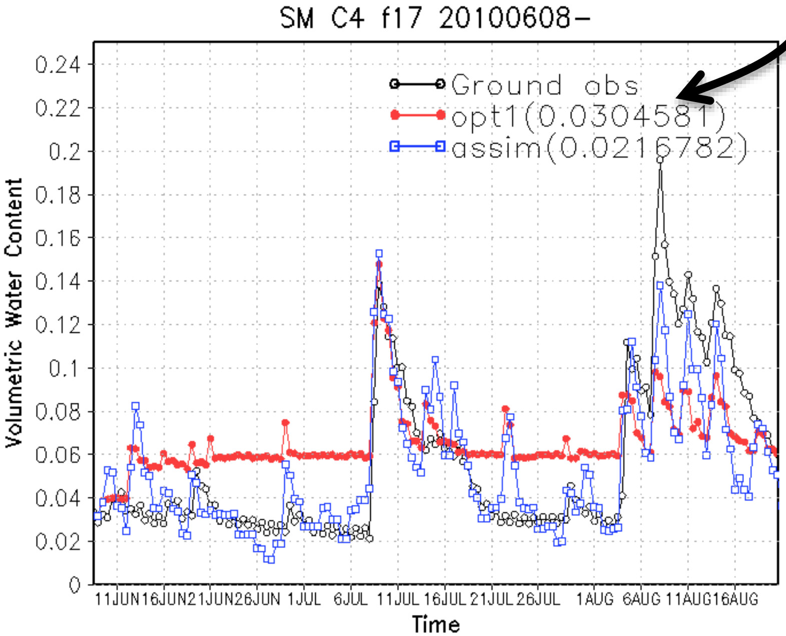
	Temporal	Spatial
Active	Low	High
Passive	High	Low
This Model	**High**	**High**

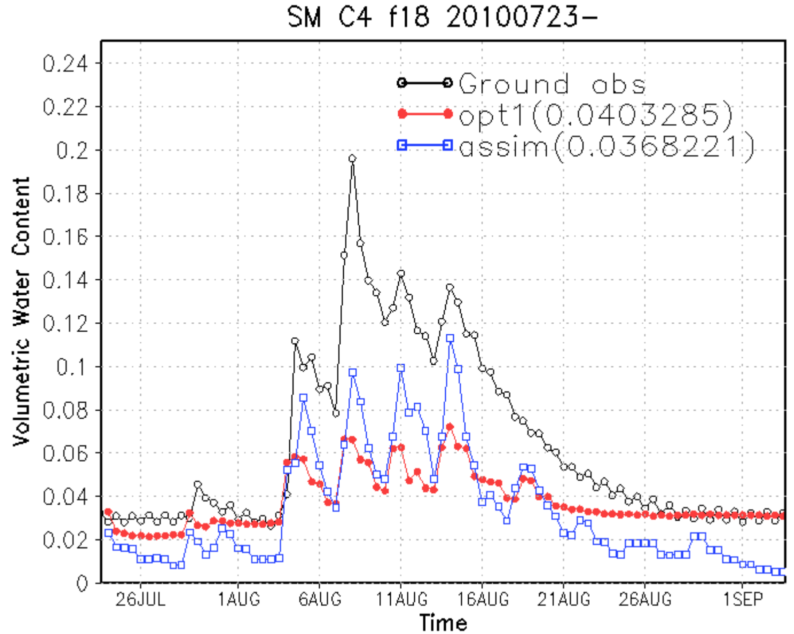
3.1 Temporal change

Black: Ground Observation
Red: Optimization (CLVDAS)
Blue: Assimilation

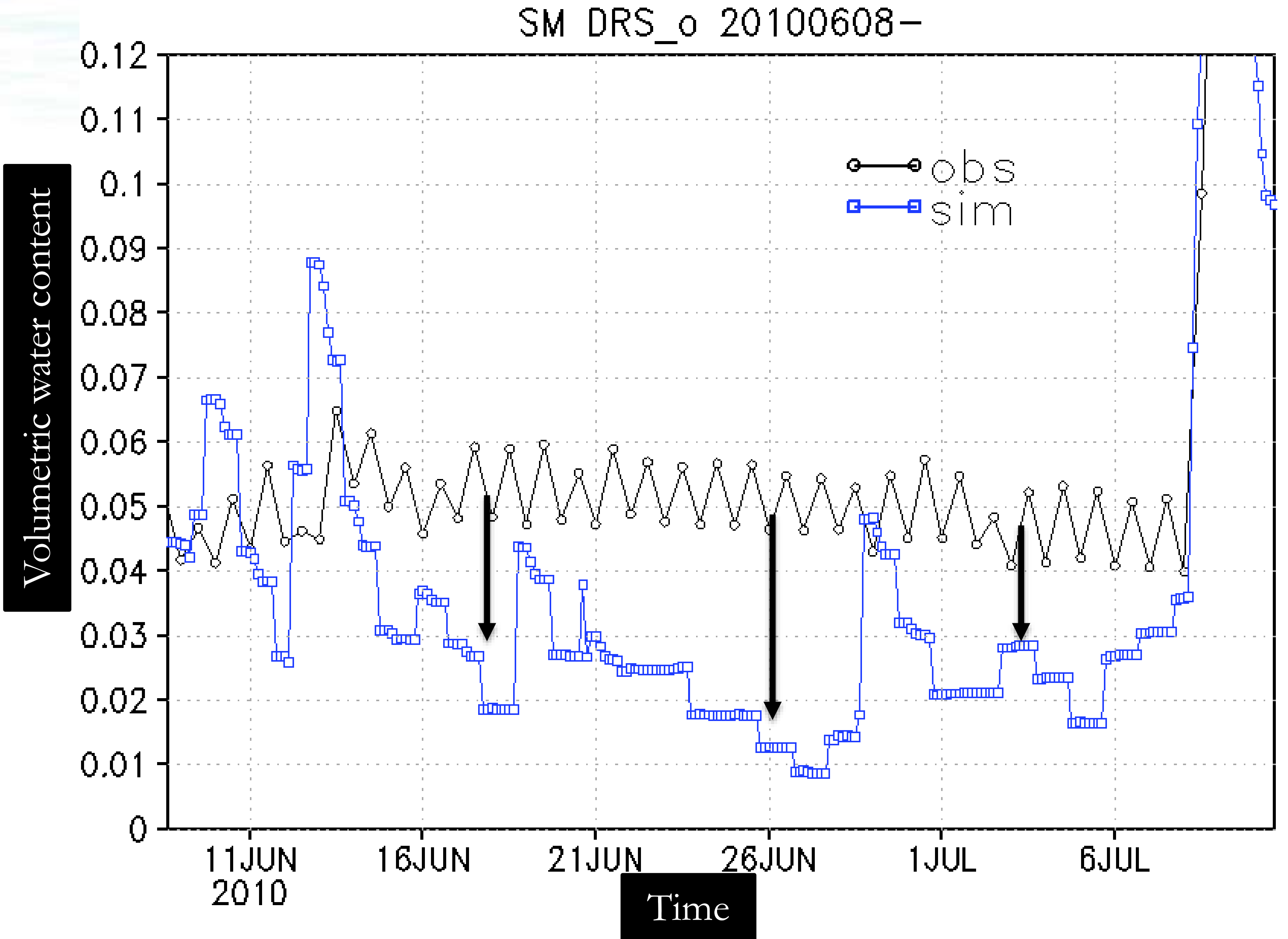


Root Mean Square Error (RMSE)



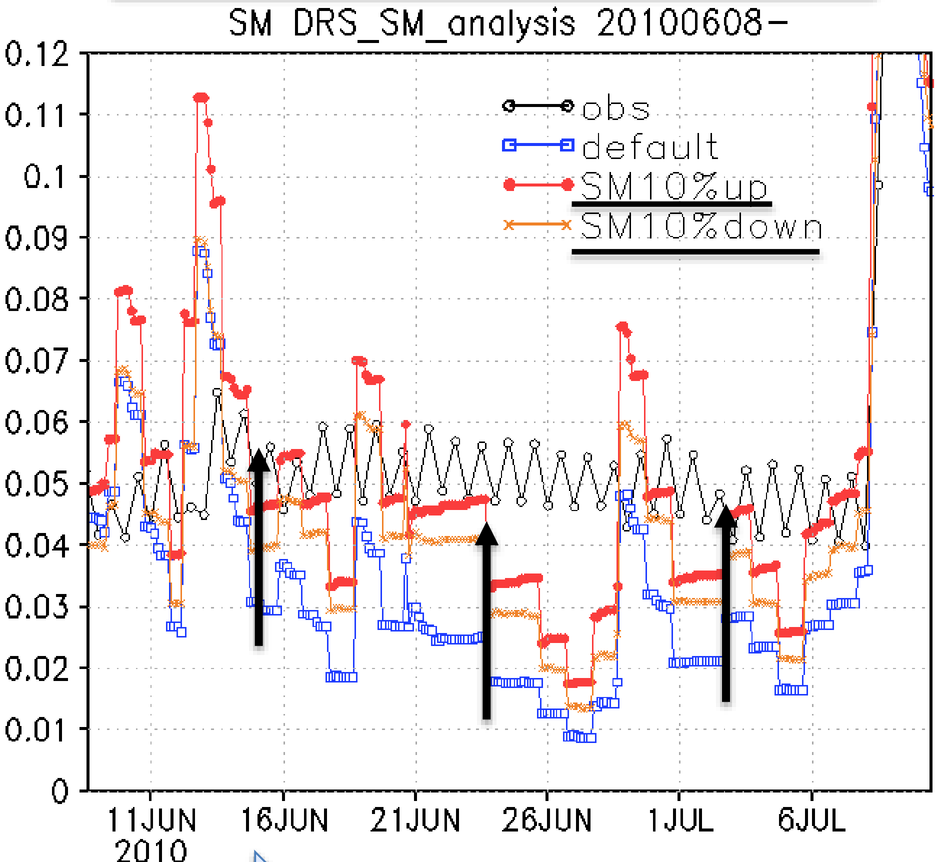


3.2 Bad case

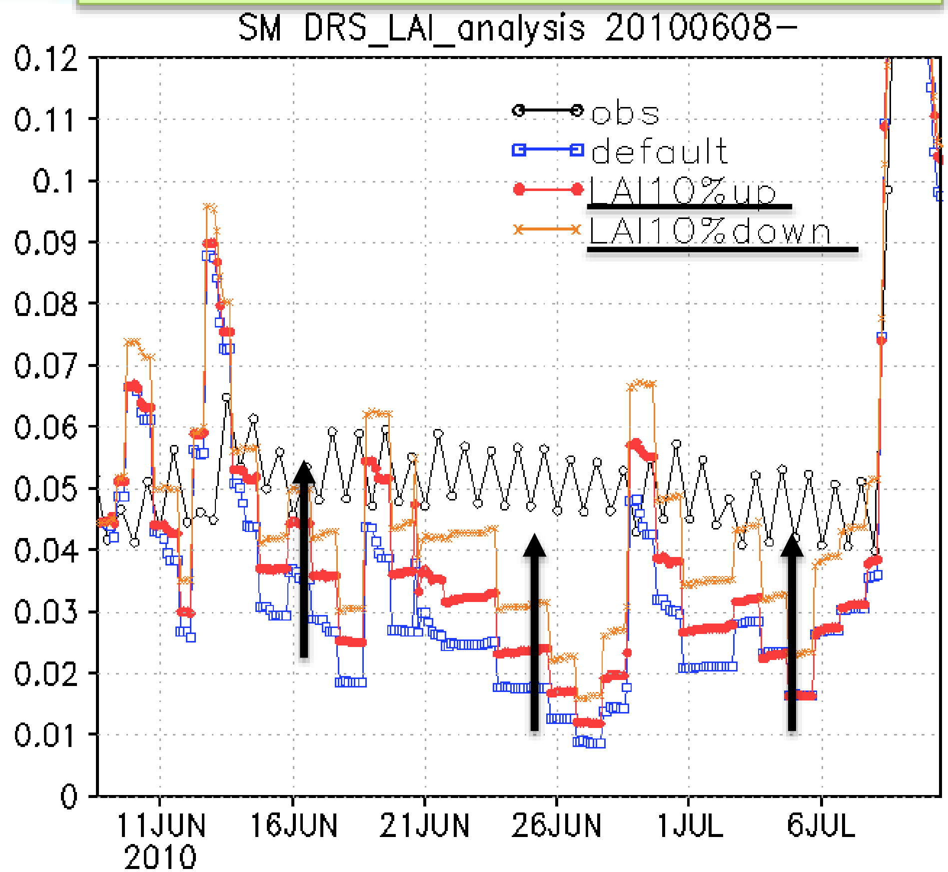

SM DRS_o 20100608-
Volumetric water content
0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
obs
sim
11JUN
2010
16JUN
21JUN
26JUN
1JUL
6JUL
Time

3.3 Sensitivity Analysis

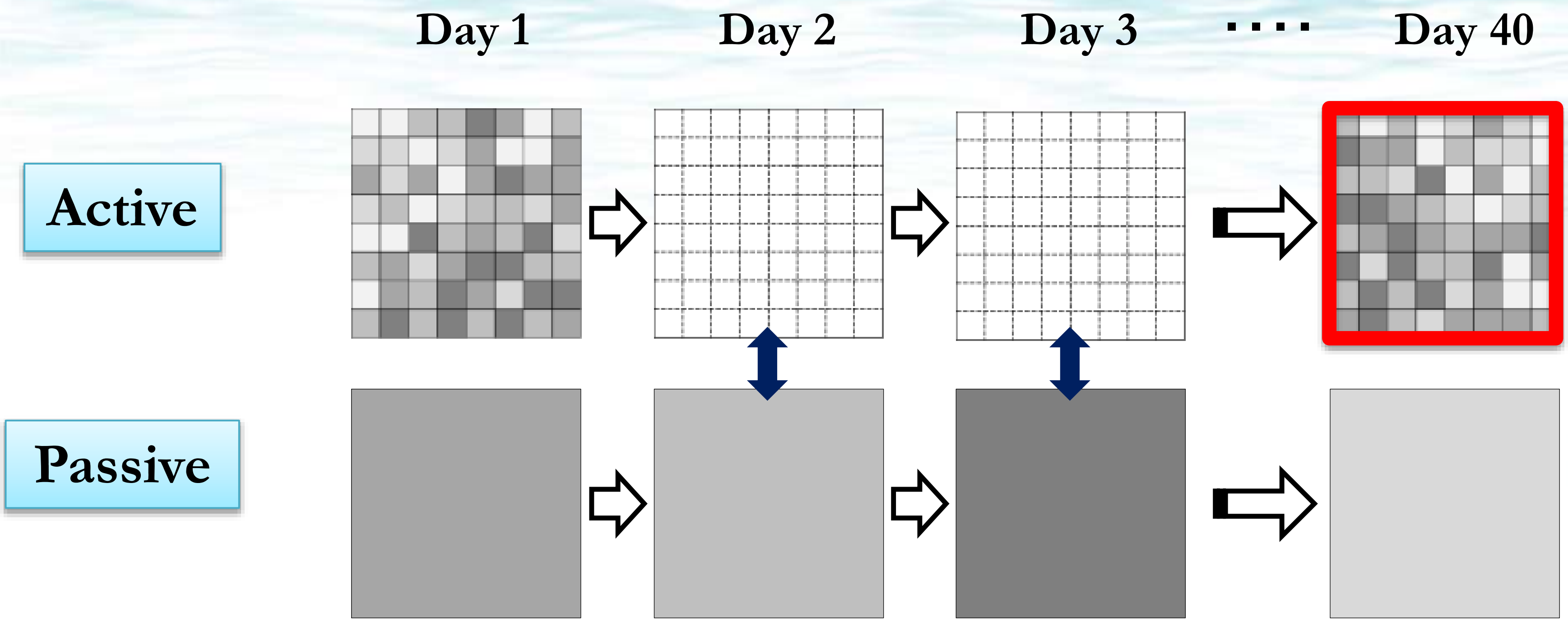
Changed initial soil moisture



Changed initial Leaf Area Index



Accuracy of initial condition is the key of this experiment.



4 RESULTS(SPATIAL)

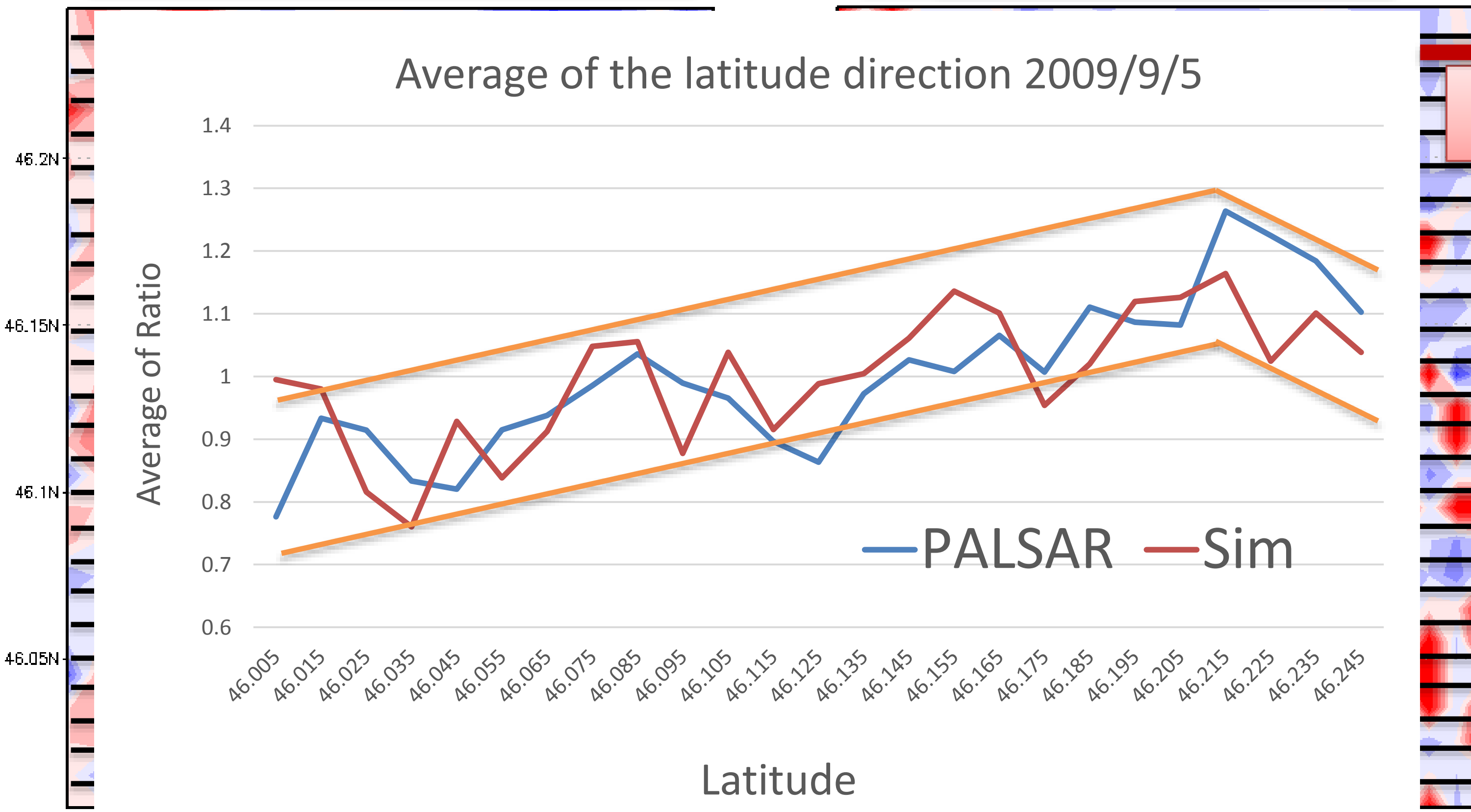
	Temporal	Spatial
Active	Low	High
Passive	High	Low
This Model	**High**	**High**

4.1 Spatial distribution

2009/9/5 15:00

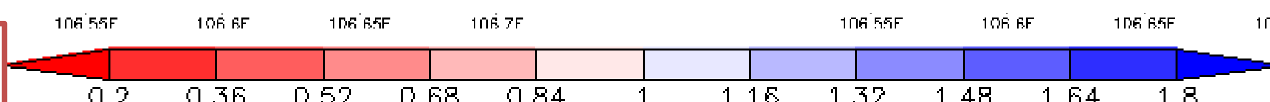
PALSAR

New MODEL



average

Dry



Wet

5 Conclusion

- We combine PALSAR soil moisture and AMSR-E brightness temperature to achieve high spatial and temporal resolution soil moisture data
- Estimation of temporal soil moisture change at fine scale is improved
- We could estimate trend of spatial heterogeneity within the AMSR-E pixel

Thank you for your kind attention!

Conclusion

-Estimation of temporal soil moisture change at fine scale is improved

-We could estimate trend of spatial heterogeneity within the passive pixel

=> Interpolation method made more accurate

Future Works

-Consider effect of microtopography by using Laser Profiler data

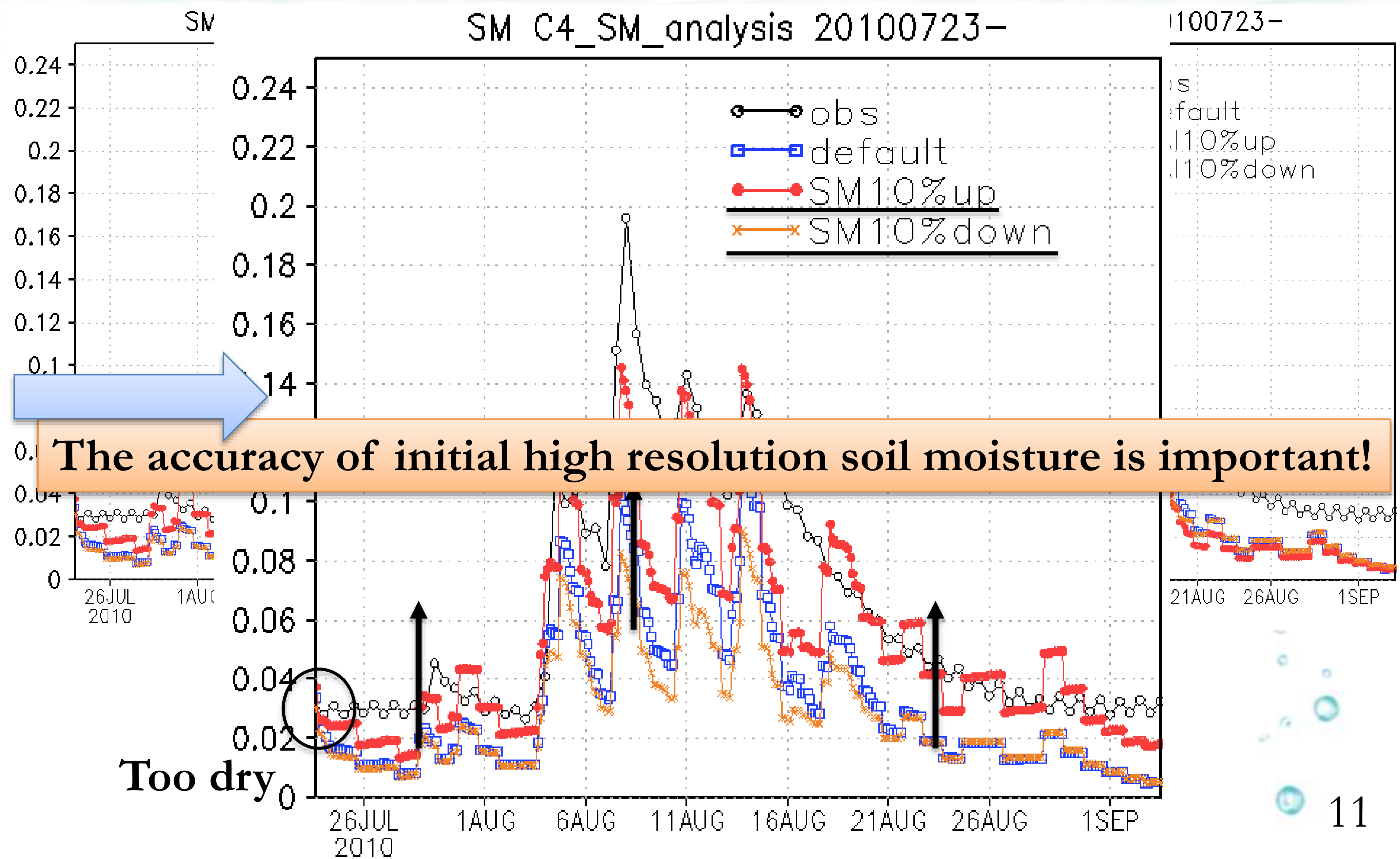
-Input high resolution soil moisture data more frequently by combining other SARs data

Thank you for your kind attention!

From sensitivity analysis

Changed initial soil moisture

Changed initial Leaf Area Index

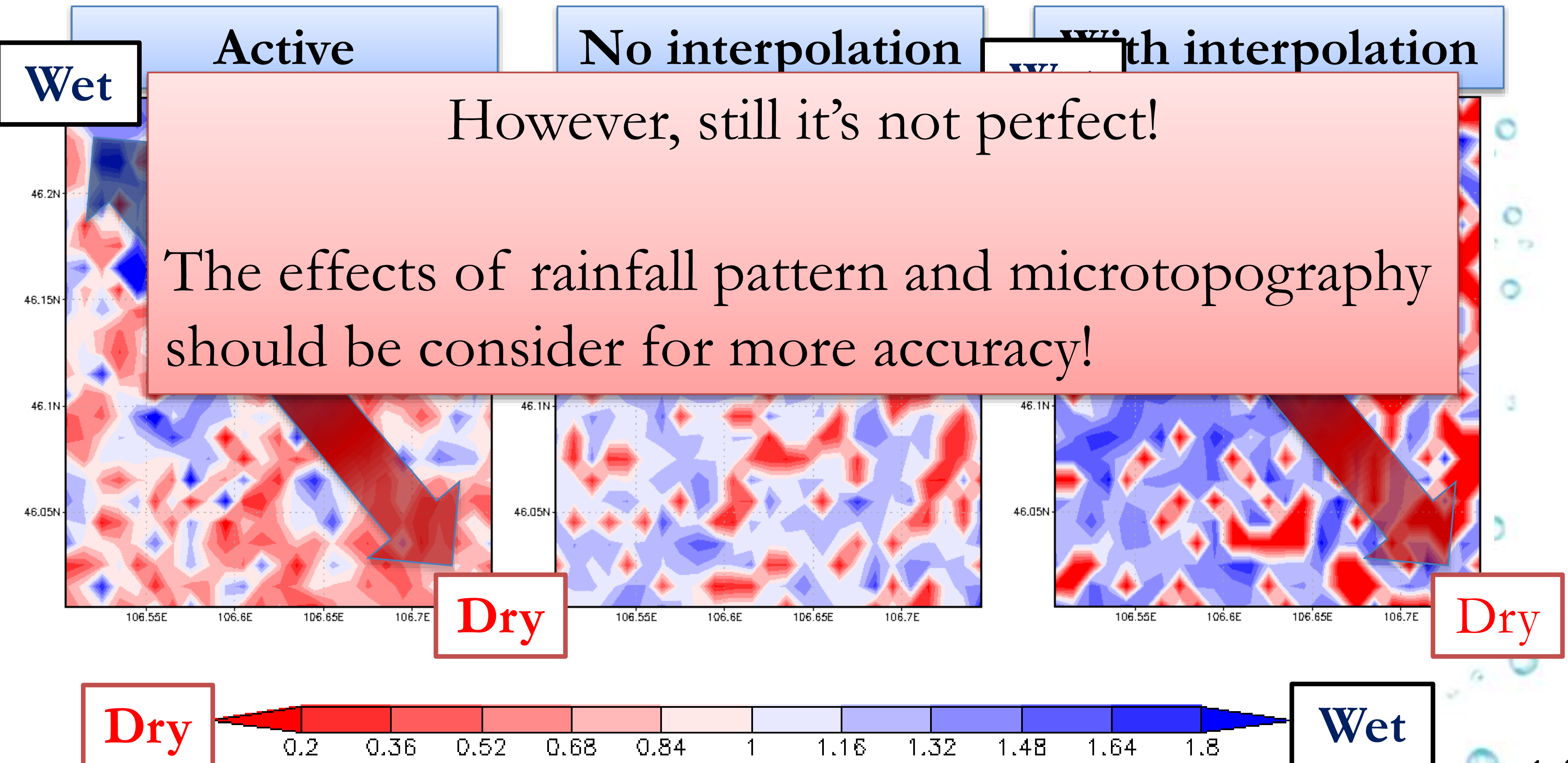


The accuracy of initial high resolution soil moisture is important!

Brightness temperature interpolation method

To improve parameter optimization step, brightness temperature was sub-gridded by interpolating passive grid data.

2010/7/23 15:00



However, still it's not perfect!

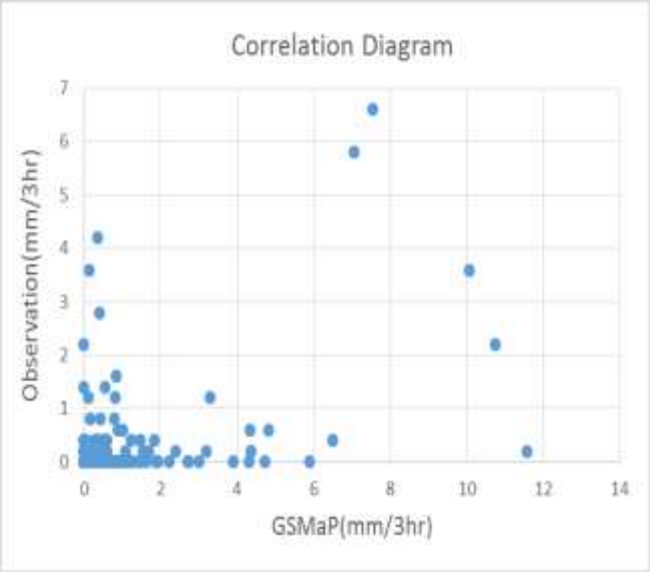
The effects of rainfall pattern and microtopography should be consider for more accuracy!

4 Rainfall pattern -GSMaP-

It is necessary to use high spatial and temporal resolution rainfall data for a more accurate soil moisture map.

Global Satellite Mapping of Precipitation (GSMaP) is introduced.

Spatial Resolution: 10km
Temporal Resolution: 1hr



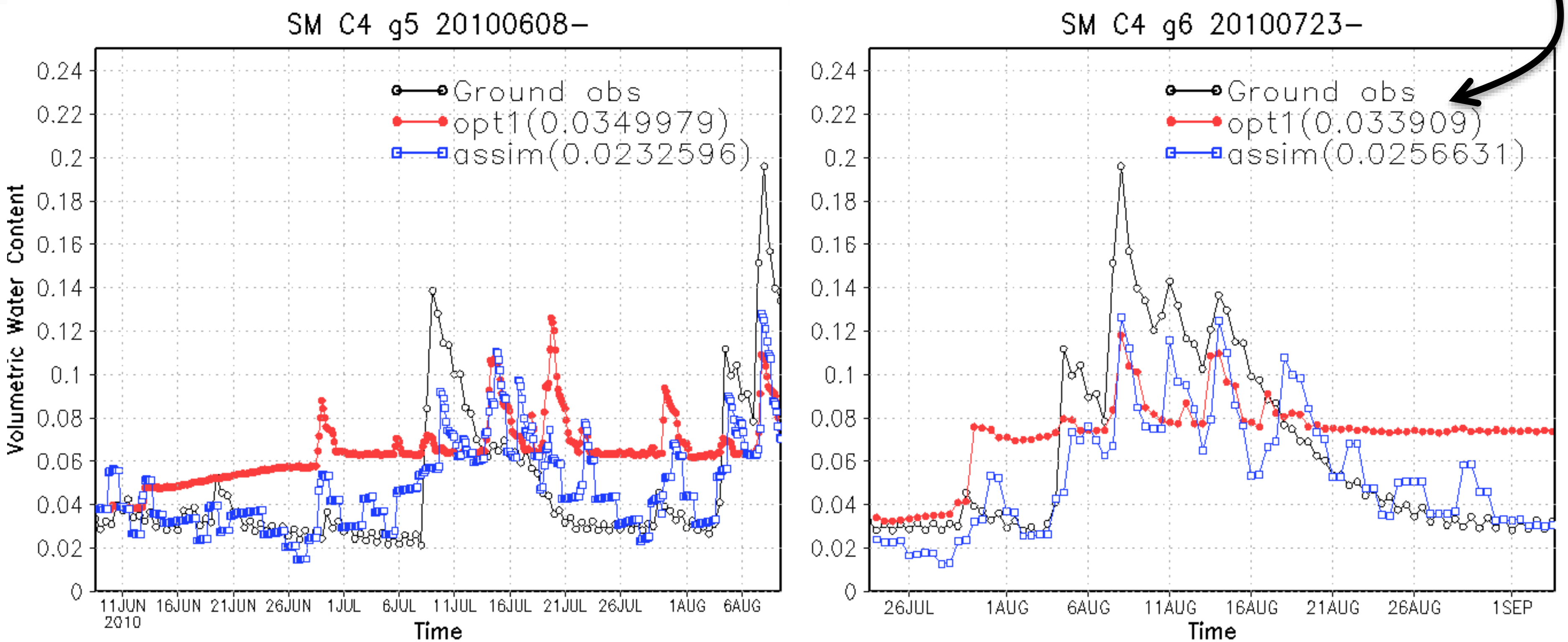
However, GSMaP rainfall data is not so reliable at this moment.

Objectives of this experiments

- present the methods to use GSMaP qualitatively
- show the robustness of this assimilation system

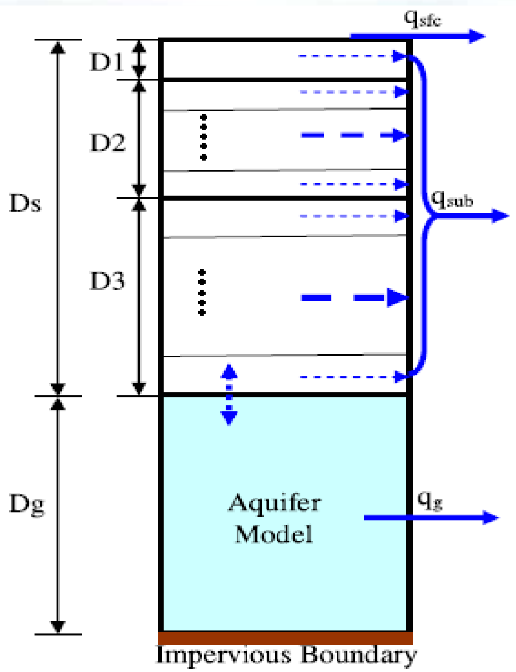
4.1 Results

Root Mean Square Error (RMSE)



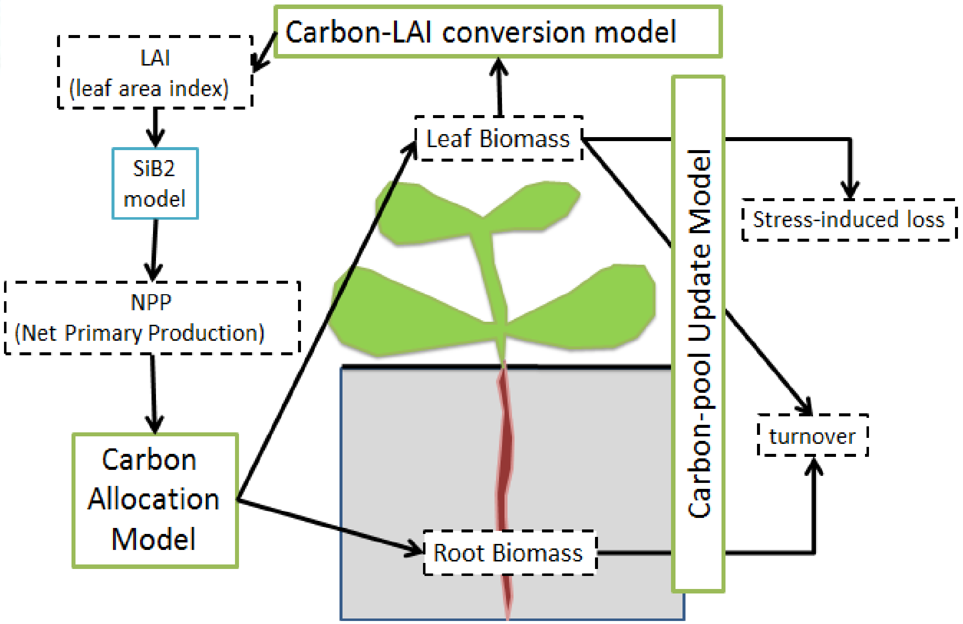
- Even if parameters are wrongly estimated, this model can reduce the error of rainfall data.

Model



hydro-SiB
[Wang et al., 2009]

+



DVM
[Sawada,2013]

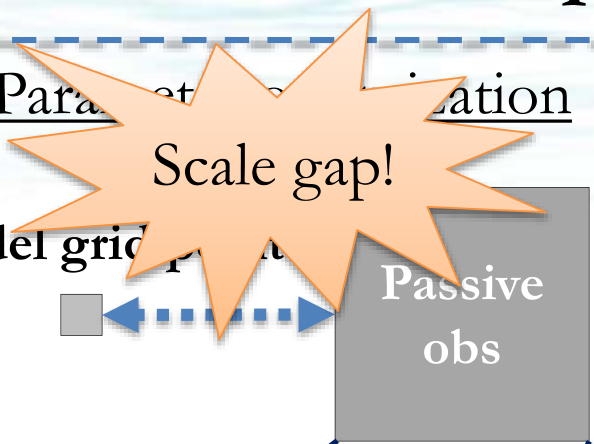
- Hydrological-Ecological Coupling model

-Calculate soil moisture and vegetation

To improve more!!

Step 1: Parameter optimization

By using CLVDAS [Sawada, 2013]

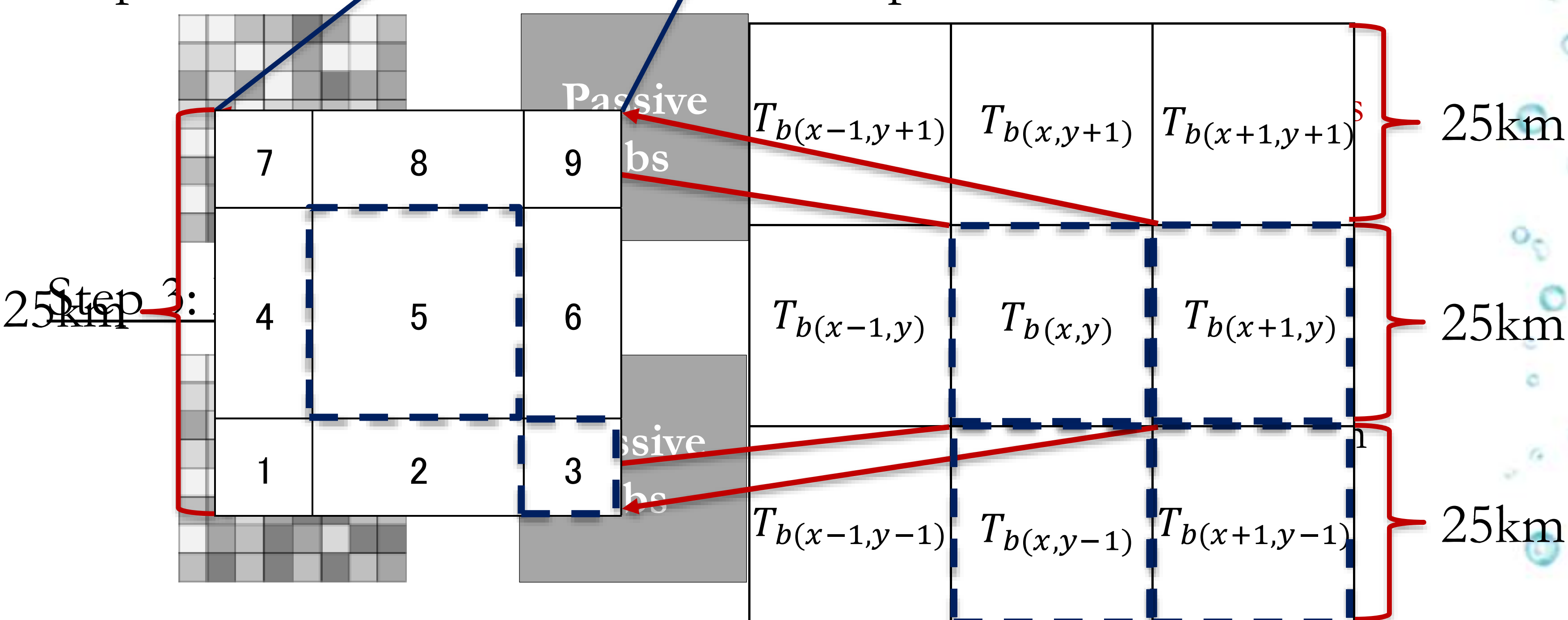


Sub-grid brightness temperature by interpolation method

Optimize model parameters in each grid point

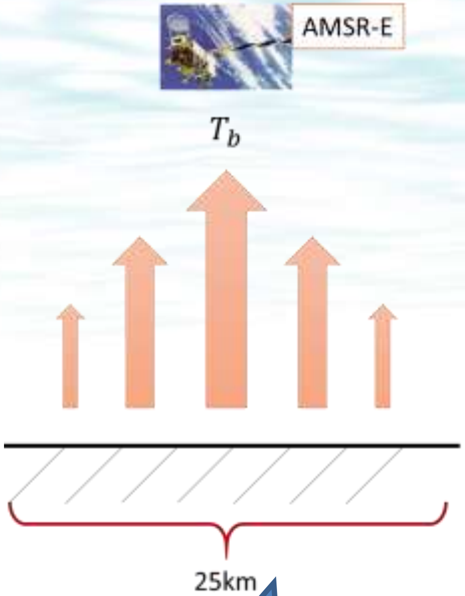
Developed in this study

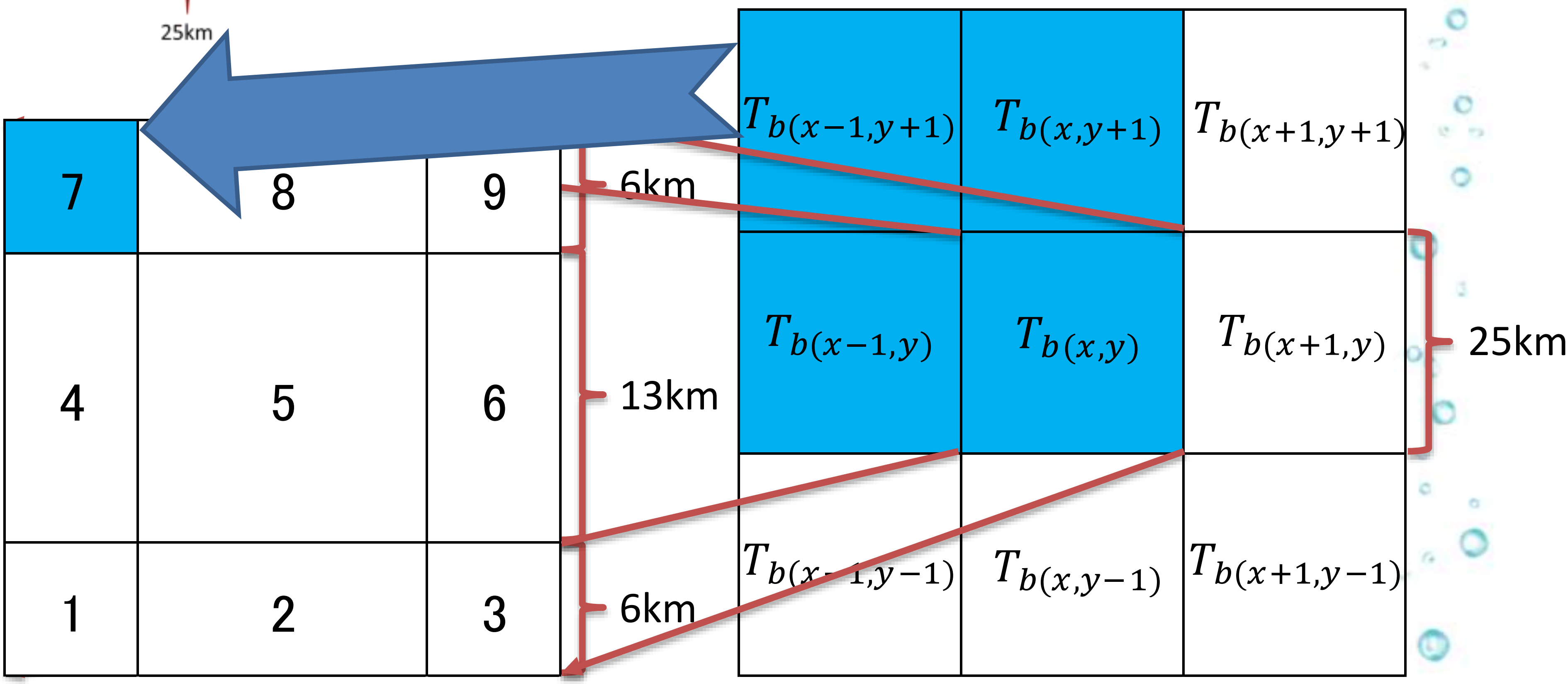
Step 2: Parameter correction factors optimization



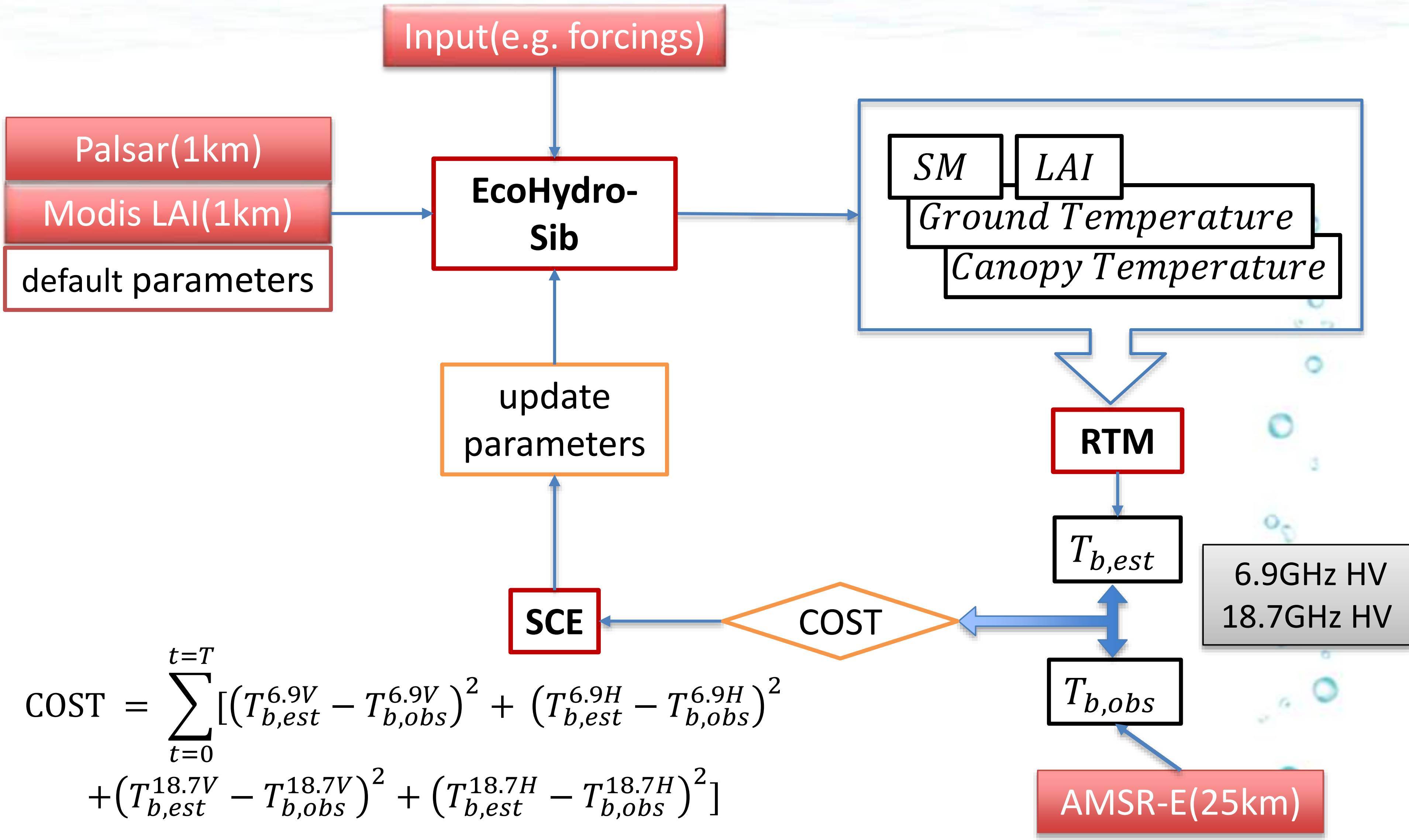
Step 3:

Interpolation method



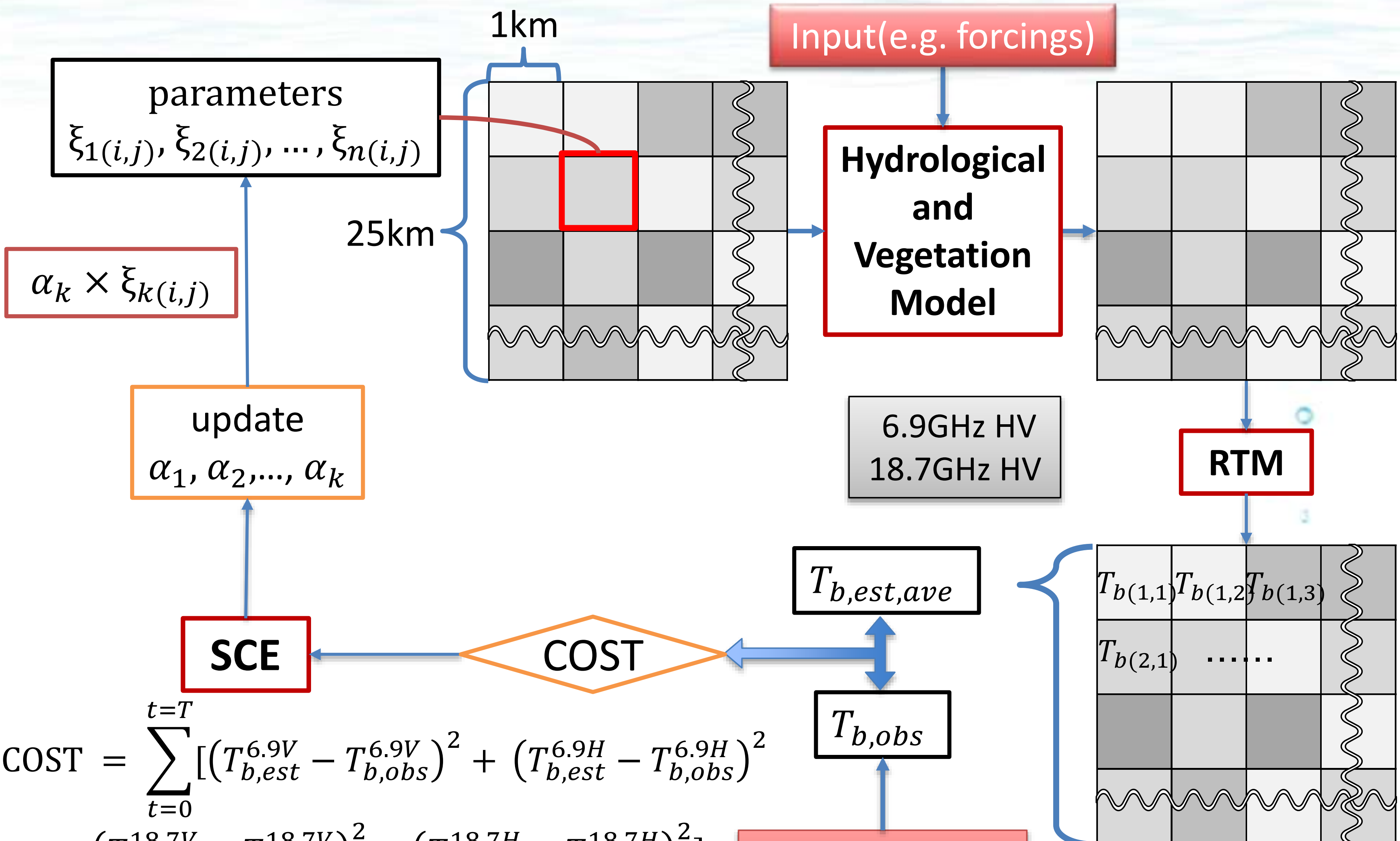


Parameter optimization



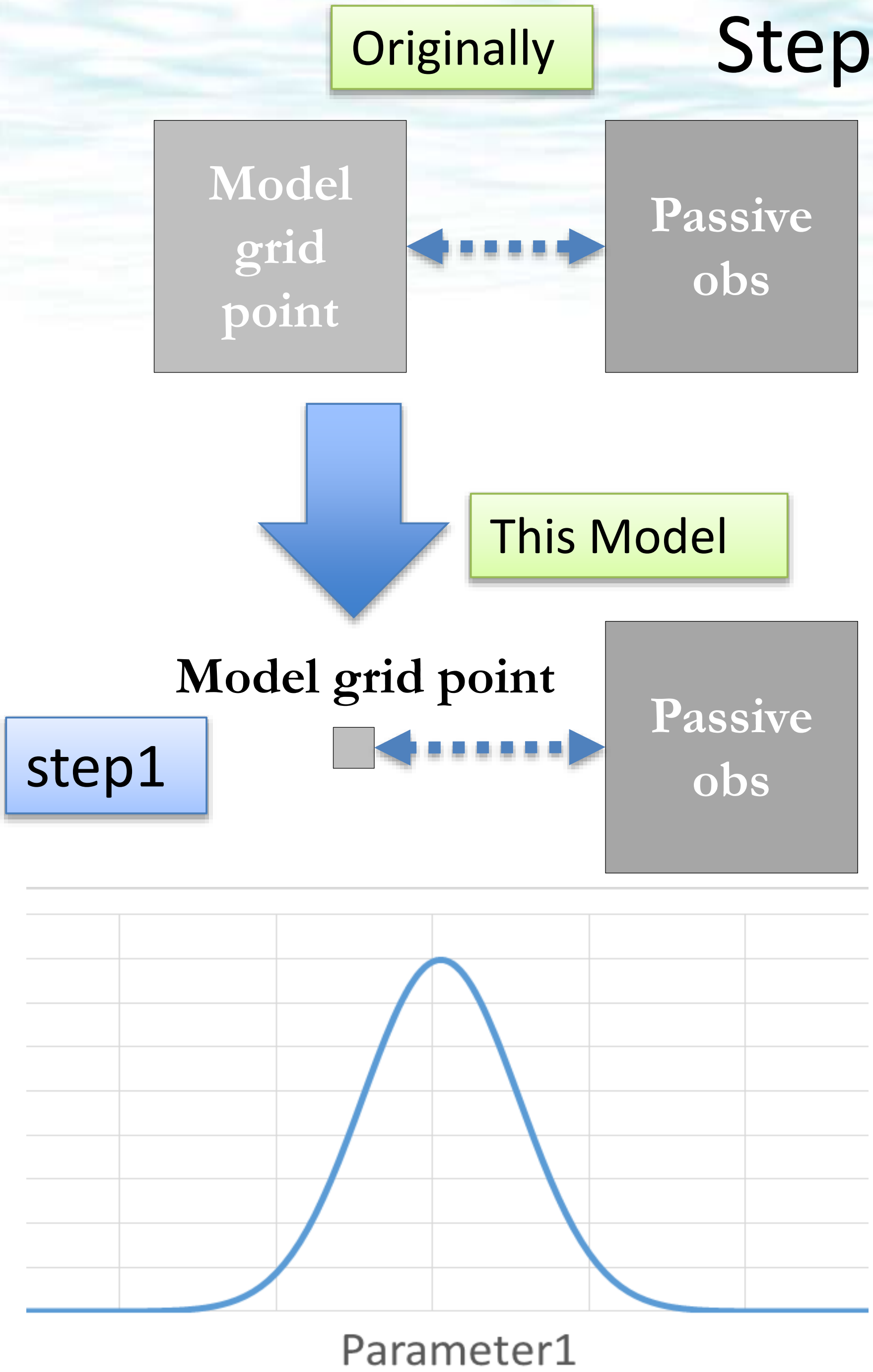
$$\mathrm{COST} = \sum_{t=0}^{t=T}\left[\left(T_{b,est}^{6.9V} - T_{b,obs}^{6.9V}\right)^2 + \left(T_{b,est}^{6.9H} - T_{b,obs}^{6.9H}\right)^2 + \left(T_{b,est}^{18.7V} - T_{b,obs}^{18.7V}\right)^2 + \left(T_{b,est}^{18.7H} - T_{b,obs}^{18.7H}\right)^2\right]$$

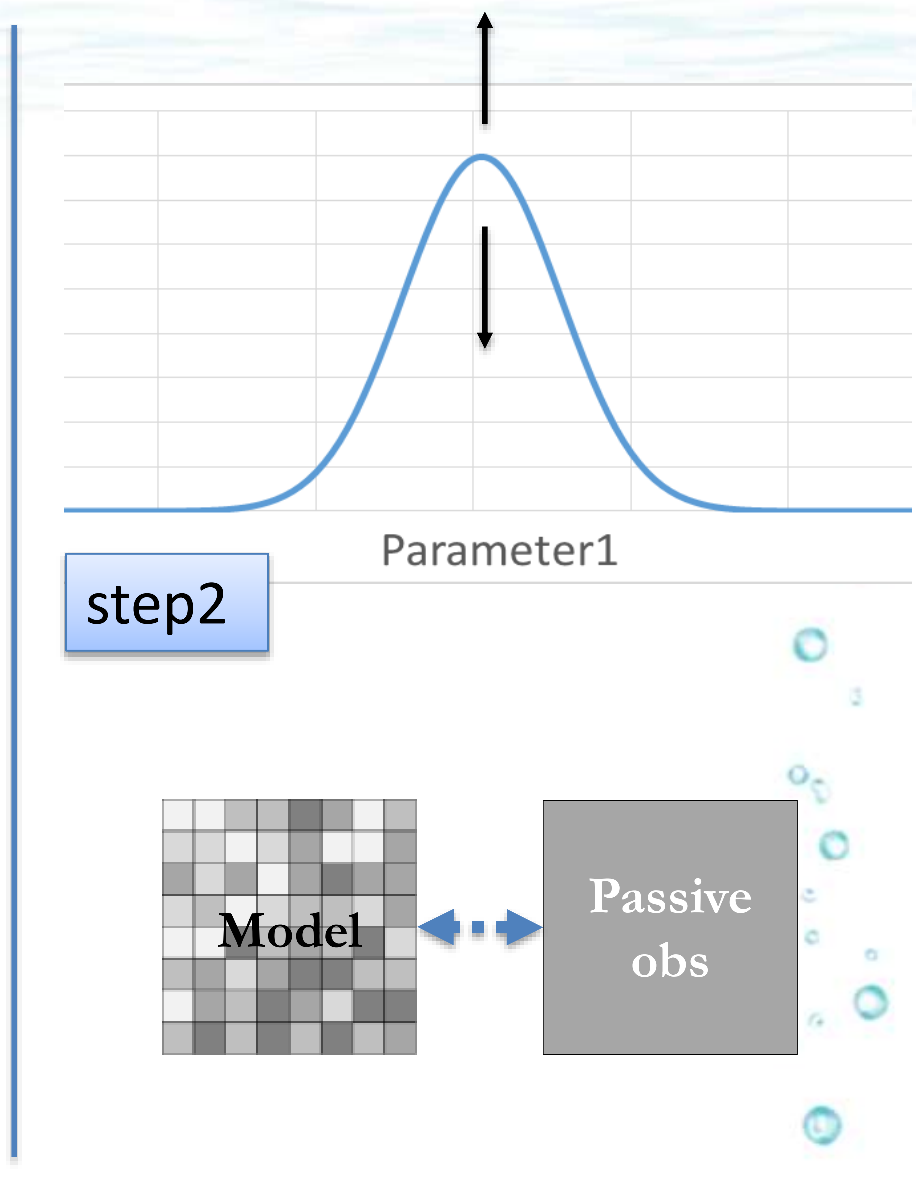
Parameter correction factors optimization



$$\mathrm{COST} = \sum_{t=0}^{t=T} [(T_{b,est}^{6.9V} - T_{b,obs}^{6.9V})^2 + (T_{b,est}^{6.9H} - T_{b,obs}^{6.9H})^2 + (T_{b,est}^{18.7V} - T_{b,obs}^{18.7V})^2 + (T_{b,est}^{18.7H} - T_{b,obs}^{18.7H})^2]$$

Step1 - step2


Originally
Model grid point
Passive obs
This Model
Model grid point
step1
Passive obs
Parameter1


Parameter1
step2
Model
Passive obs

Why downscaling

-Meteorological reasons

-Hydrological process occurs at 1km scale

-Passive scale is 40km

-Downscaling is needed for more accurate meteorological prediction.

-Agricultural reasons

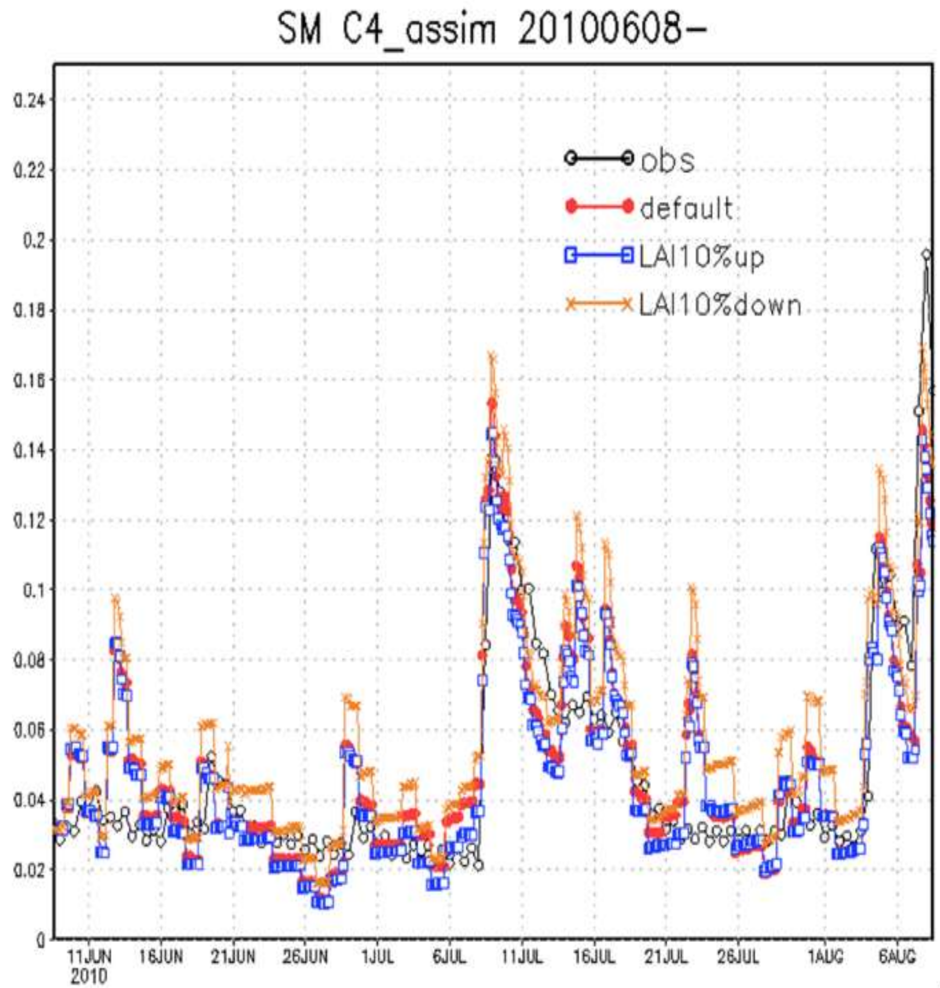
-For more accurate prediction of food production

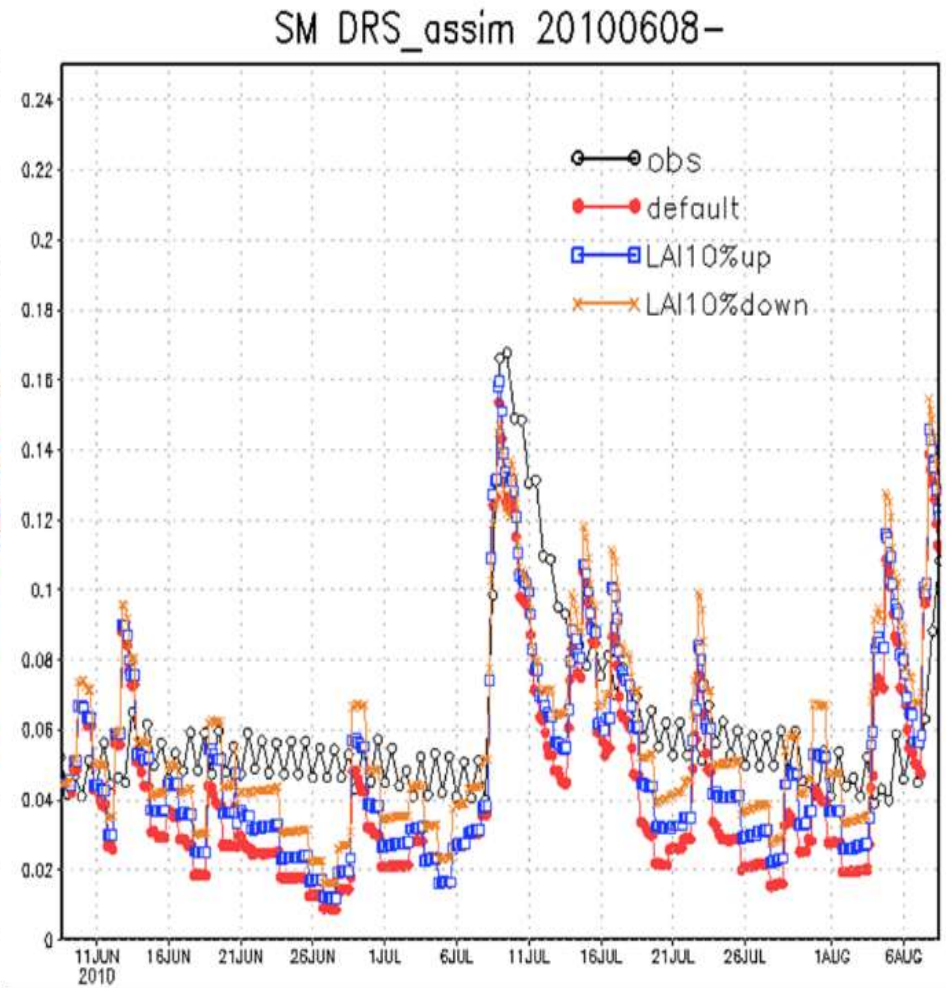
-Soil physics usually treats phenomena with a scale of several tens cms. Filling this scale gap will provide more usable information to agriculture.

Assimilation step

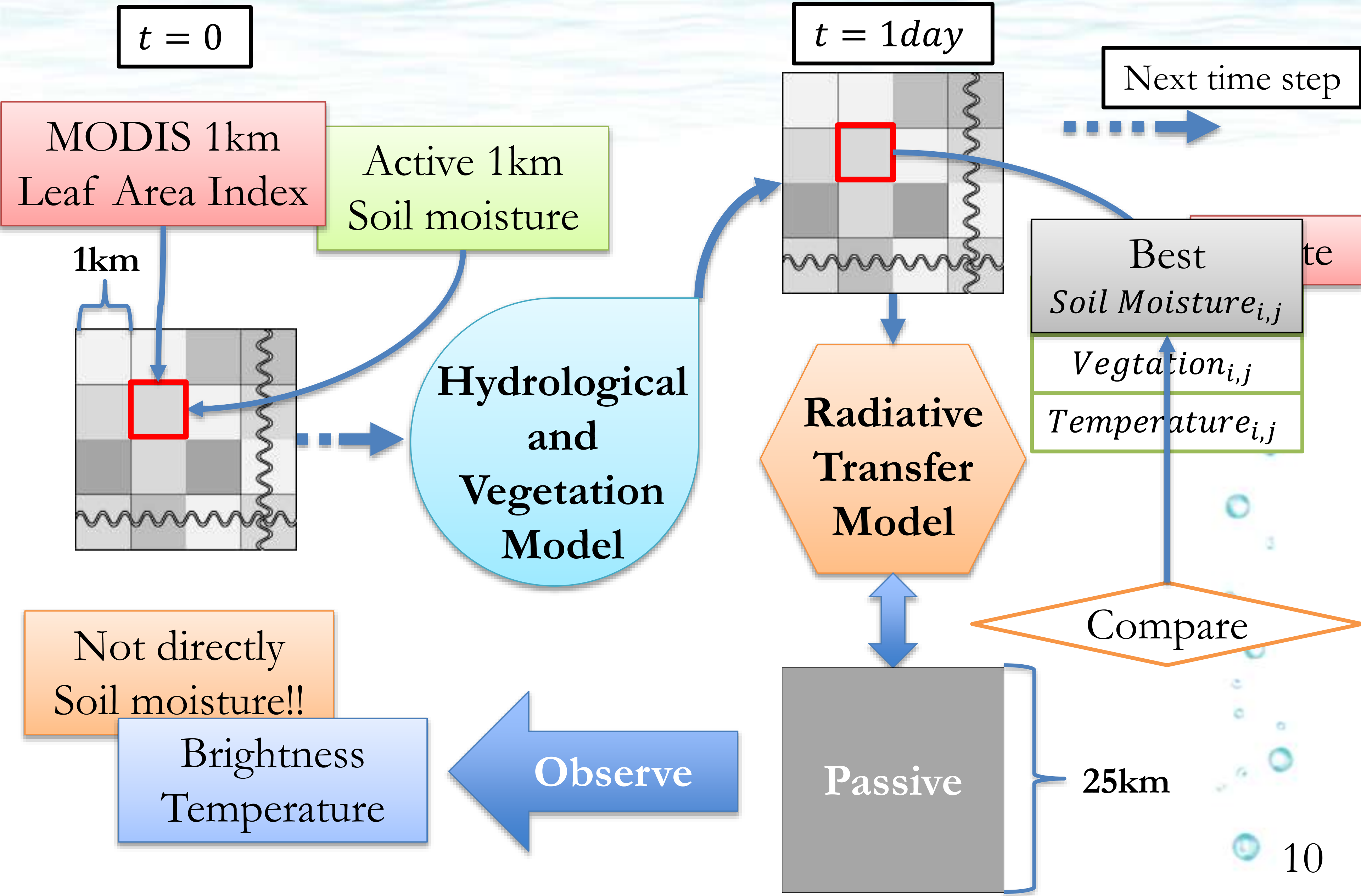
$$\mathrm{COST(i,j)} \;=\; \left(T_{b,est}^{6.9V\,\prime} - k^{6.9V} \times T_{b,est}^{6.9V}\right)^2 + \left(T_{b,est}^{18.7V\,\prime} - k^{18.7V} \times T_{b,est}^{18.7V}\right)^2$$

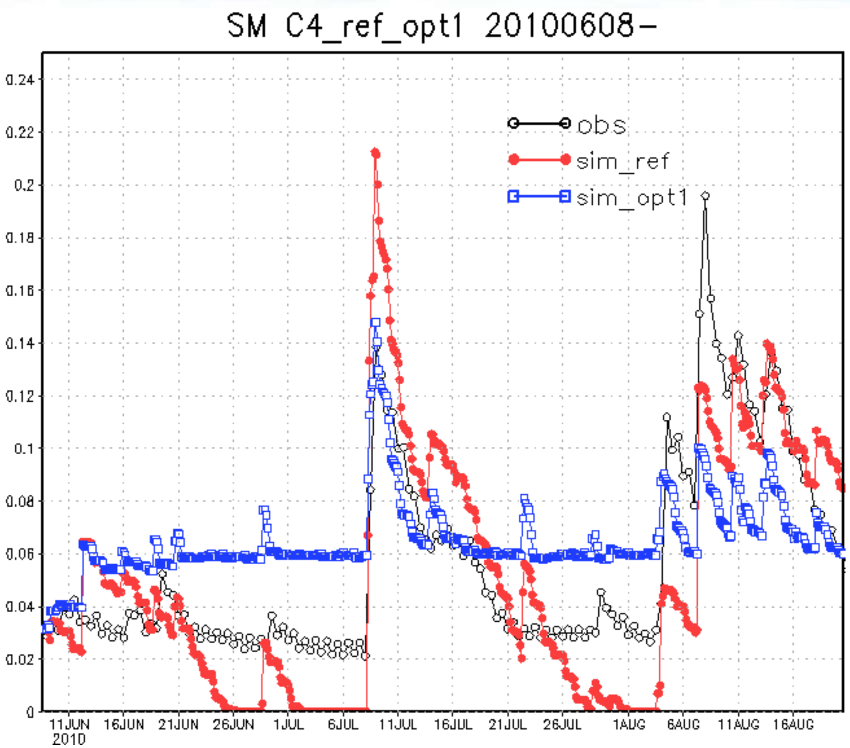
LAI analysis





System Structure -Assimilation Step-





SM C4_ref_opt1 20100608-
obs
sim_ref
sim_opt1
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
11JUN 2010
16JUN
21JUN
26JUN
1JUL
6JUL
11JUL
16JUL
21JUL
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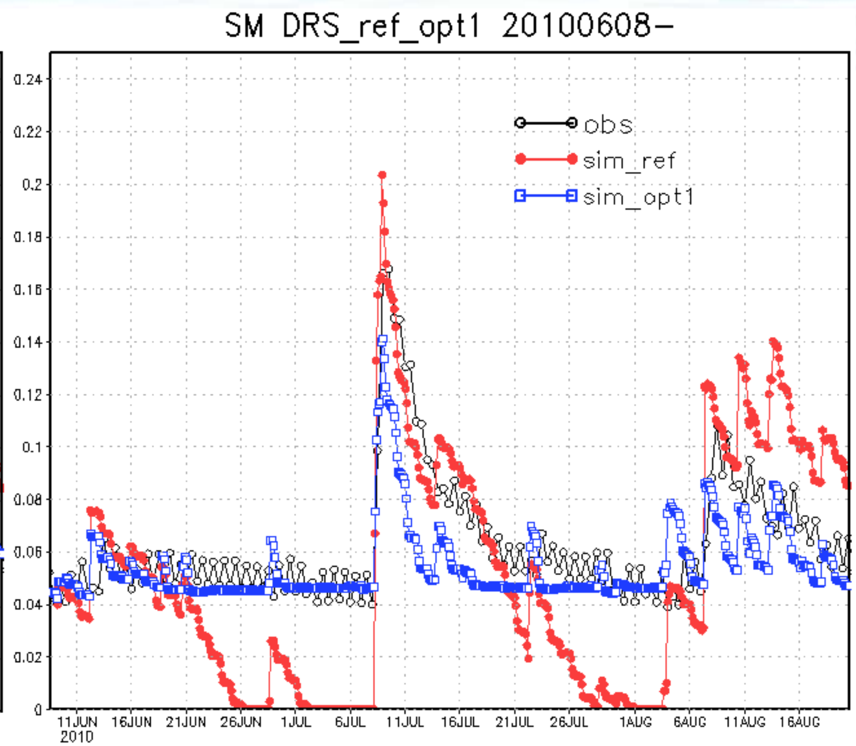
6AUG
11AUG
16AUG



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obs
sim_ref
sim_opt1
0.24
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11JUN 2010
16JUN
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6AUG
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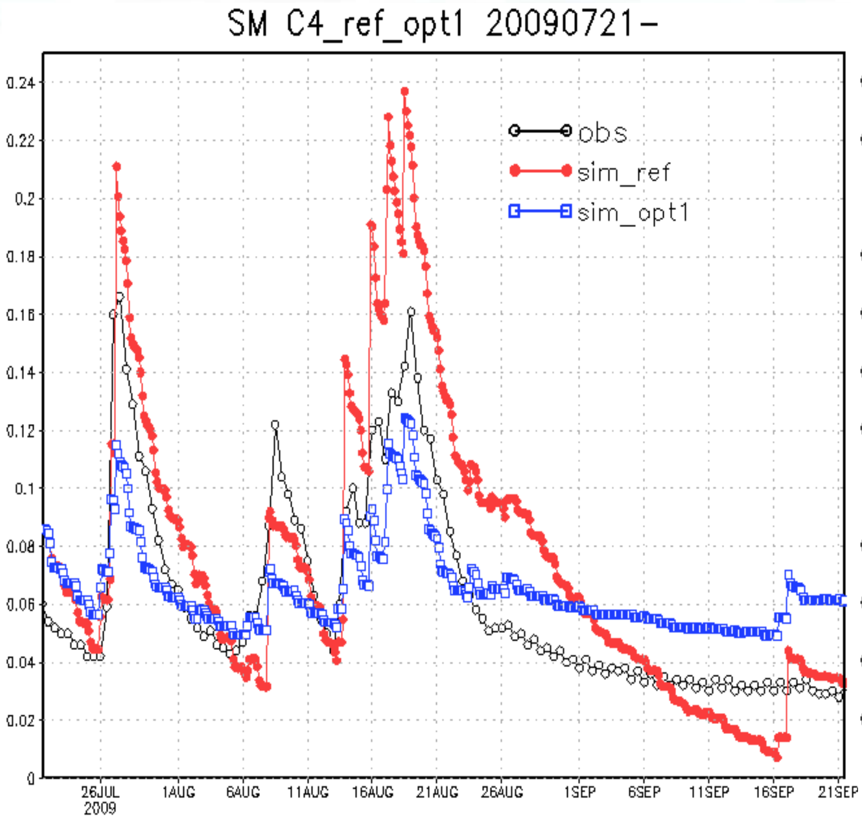

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obs
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sim_opt1
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0.22
0.2
0.18
0.16
0.14
0.12
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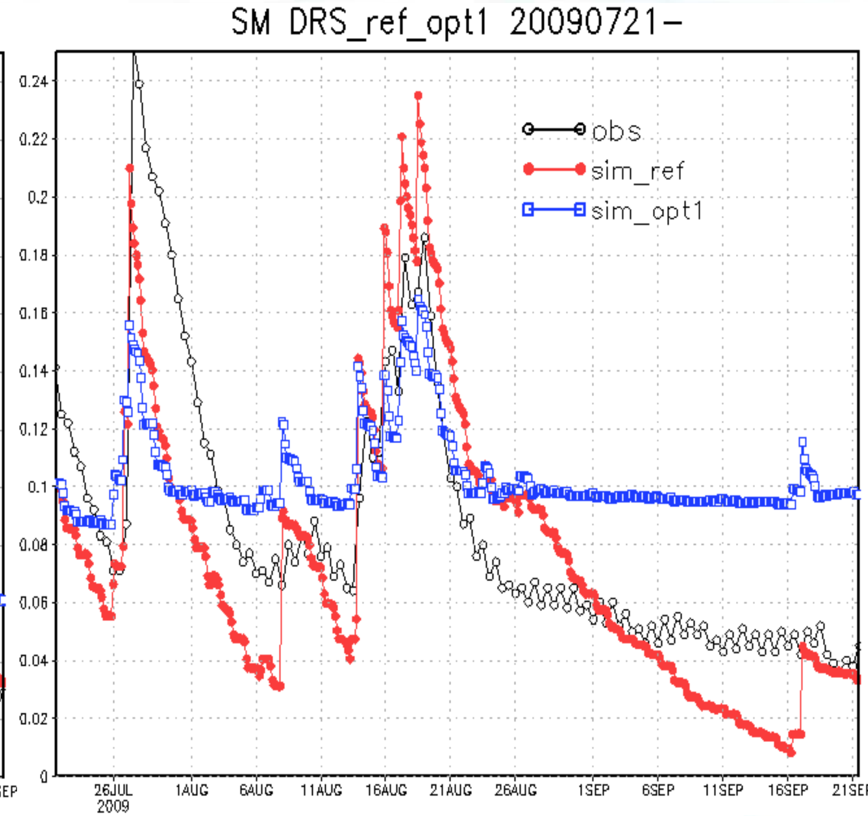
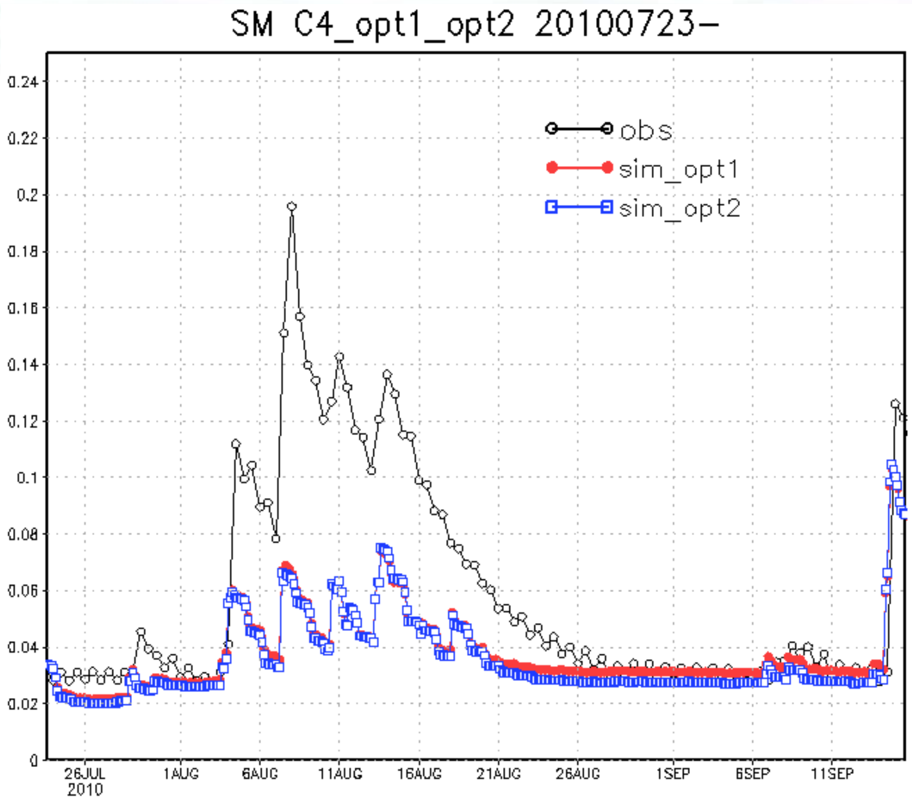
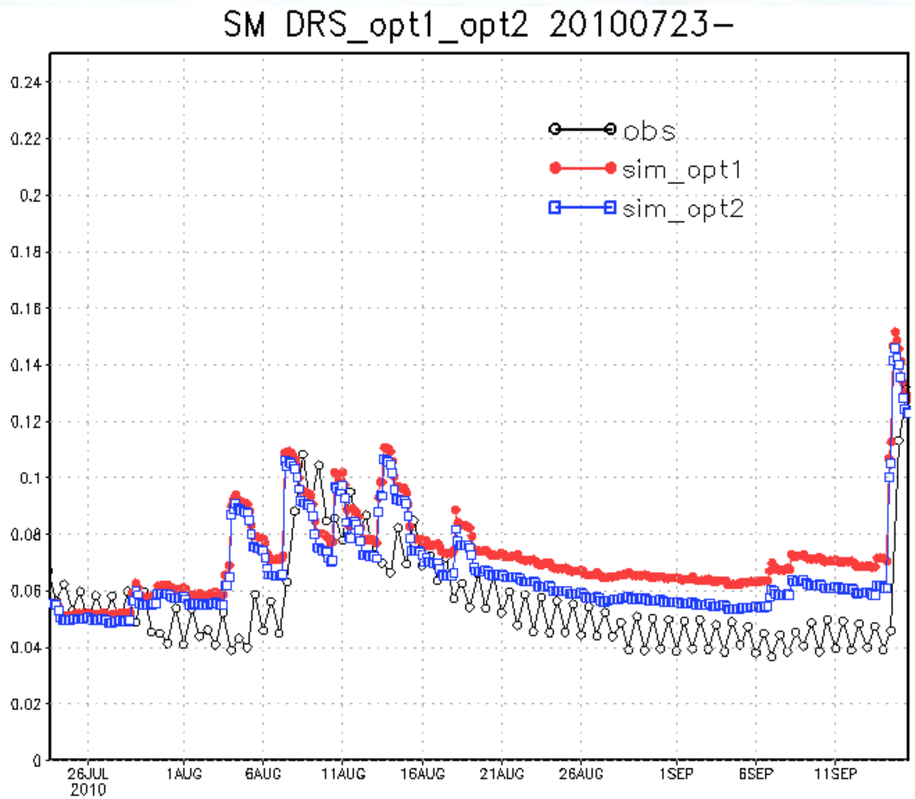
0.04
0.02
0
26JUL 2009
1AUG
6AUG
11AUG
16AUG
21AUG
26AUG
1SEP
6SEP
11SEP
16SEP
21SEP

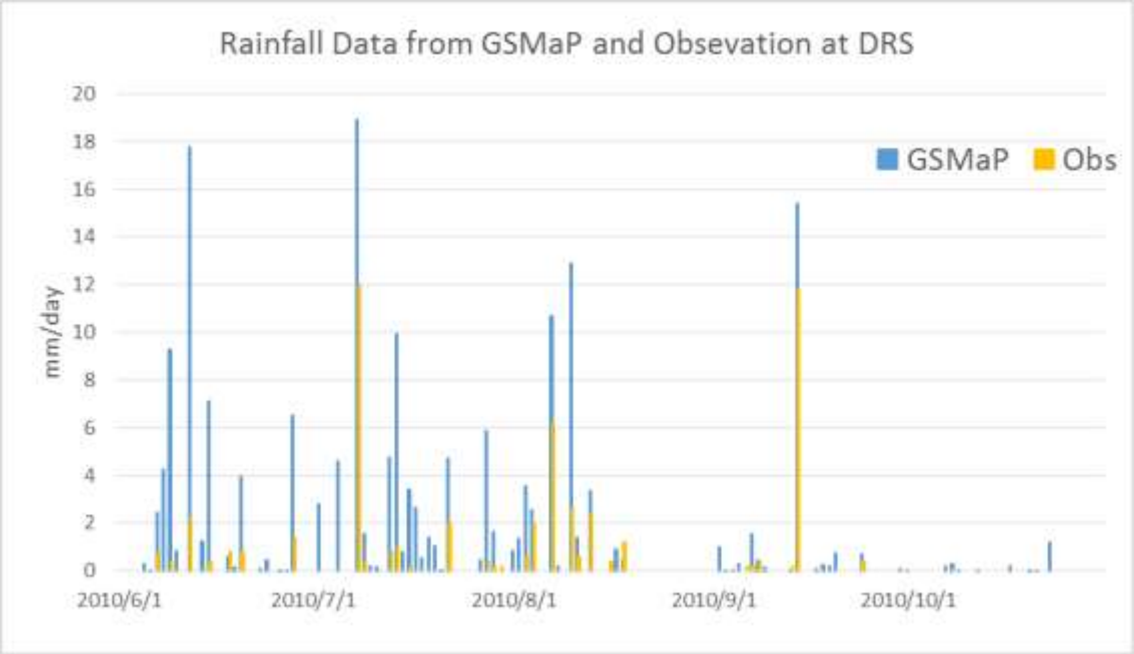


SM DRS_ref_opt1 20090721-
obs
sim_ref
sim_opt1
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
26JUL 2009
1AUG
6AUG
11AUG
16AUG
21AUG
26AUG
1SEP
6SEP
11SEP
16SEP
21SEP

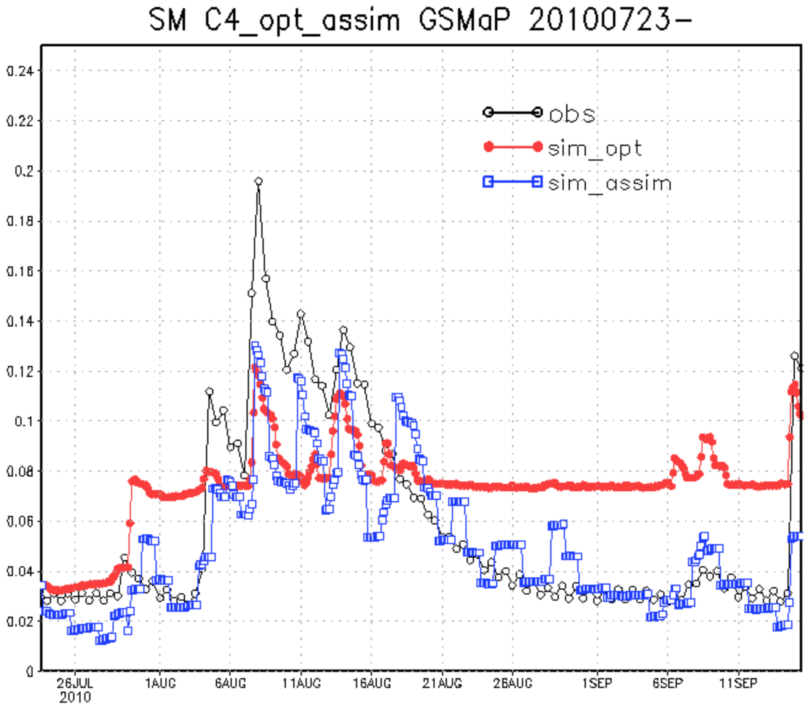

SM C4_opt1_opt2 20100723-
obs
sim_opt1
sim_opt2
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.22
0.24
26JUL
2010
1AUG
6AUG
11AUG
16AUG
21AUG
26AUG
1SEP
6SEP
11SEP


SM DRS_opt1_opt2 20100723-
obs
sim_opt1
sim_opt2
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.22
0.24
26JUL
2010
1AUG
6AUG
11AUG
16AUG
21AUG
26AUG
1SEP
6SEP
11SEP

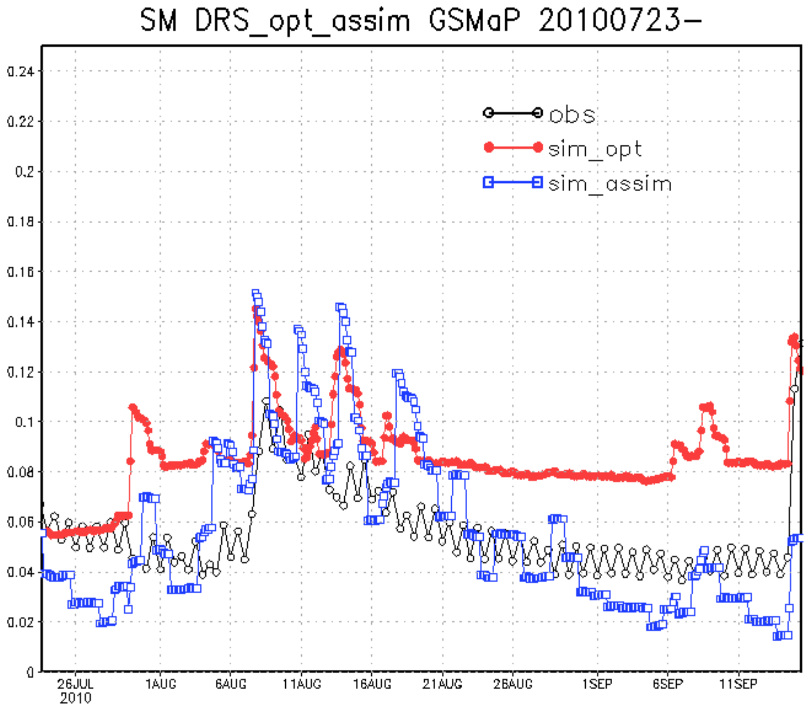
GSMaP



Rainfall Data from GSMaP and Obsevation at DRS
mm/day
GSMaP
Obs
0
2
4
6
8
10
12
14
16
18
20
2010/6/1
2010/7/1
2010/8/1
2010/9/1
2010/10/1

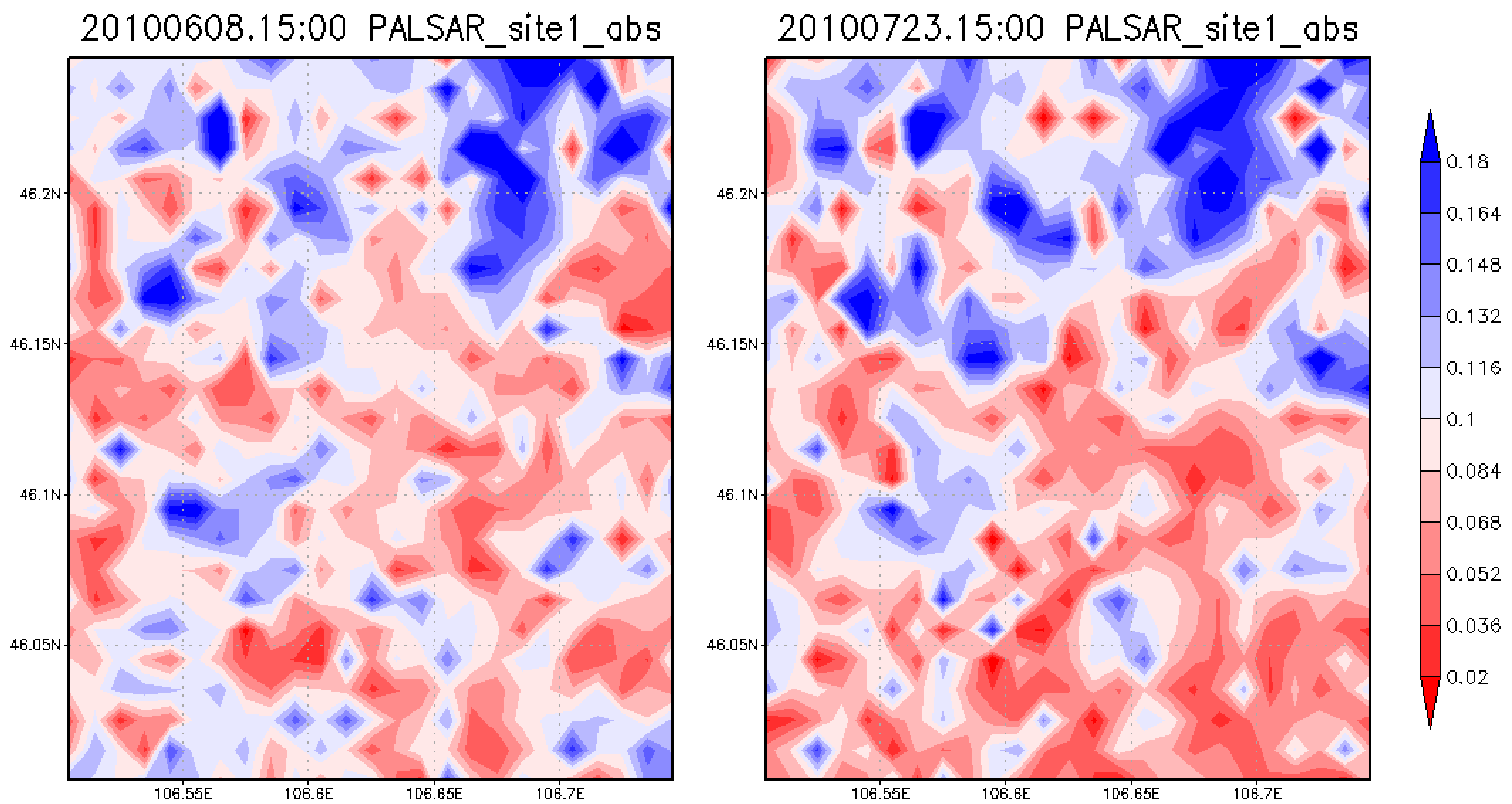


SM C4_opt_assim GSMaP 20100723-
obs
sim_opt
sim_assim
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.22
0.24
26JUL
2010
1AUG
6AUG
11AUG
16AUG
21AUG
26AUG
1SEP
6SEP
11SEP



SM DRS_opt_assim GSMaP 20100723-
obs
sim_opt
sim_assim
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.22
0.24
26JUL
2010
1AUG
6AUG
11AUG
16AUG
21AUG
26AUG
1SEP
6SEP
11SEP

PALSAR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20100723.15:00 PALSAR_site1_abs
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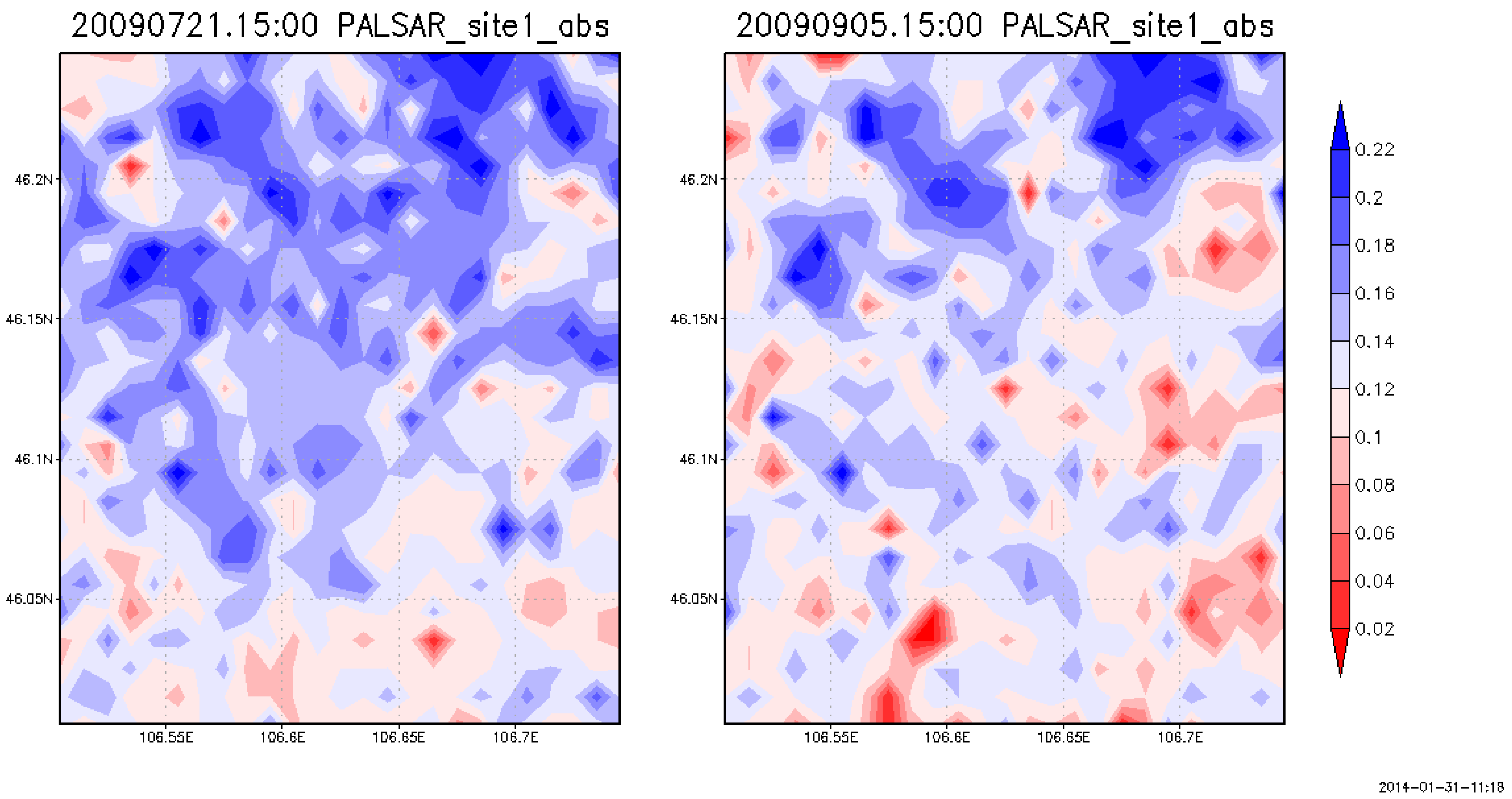
46.15N
46.1N
46.05N
106.55E
106.6E
106.65E
106.7E
0.18
0.164
0.148
0.132
0.116
0.1
0.084
0.068
0.052
0.036
0.02

PALSAR



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20090905.15:00 PALSAR_site1_abs
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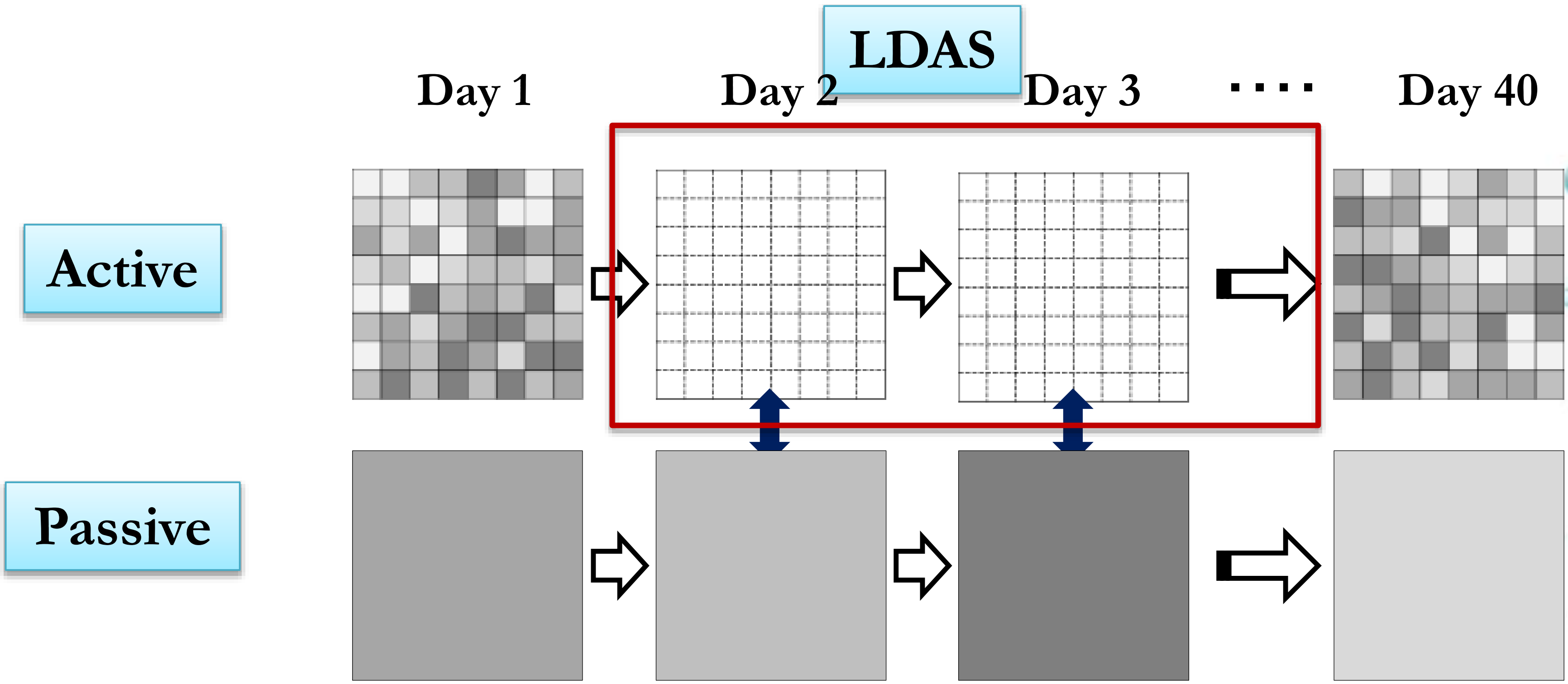
46.15N
46.1N
46.05N
106.55E
106.6E
106.65E
106.7E
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
2014-01-31-11:18

Goal

Achieve high spatial and temporal resolution soil moisture

How

-Combining Active and Passive microwave data
by Land Data Assimilation System (LDAS)



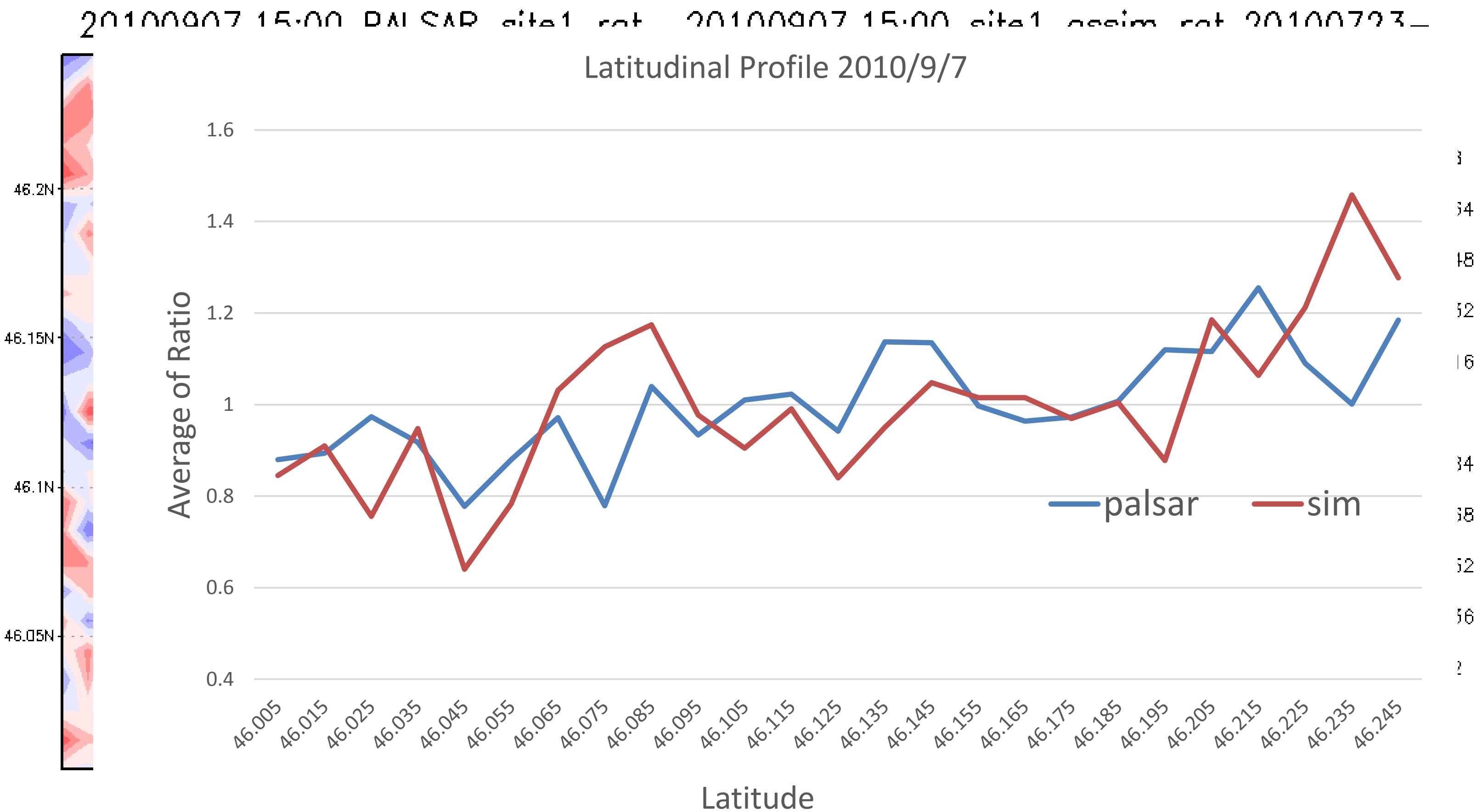
Research Outline

1. Development of downscaling system

2. Introduction of spatial heterogeneity of rainfall by GSMaP

3. Sensitivity analysis

4. Experiment of brightness temperature interpolation method



Latitudinal Profile 2010/9/7
Average of Ratio
1.6
1.4
1.2
1
0.8
0.6
0.4
46.005
46.015
46.025
46.035
46.045
46.055
46.065
46.075
46.085
46.095
46.105
46.115
46.125
46.135
46.145
46.155
46.165
46.175
46.185
46.195
46.205
46.215
46.225
46.235
46.245
Latitude
palsar
sim
46.2N
46.15N
46.1N
46.05N