Ensemble Data Assimilation of MODIS Surface Temperature into Land Surface Model

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Summary for the 2015 RIKEN IPA program
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RIKEN AICS Data Assimilation Seminar
Mar. 2nd, 2016

Outline

- Introduction
- Observation data
- Data assimilation experiments
- Discussion
- Summary

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- **Introduction**
- Observation data
- Data assimilation experiments
- Discussion
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Land Surface Model (LSM)

$$x_{t+1} = f\left(x_t, parameter, forcing\right)$$

x: state variables

f: model

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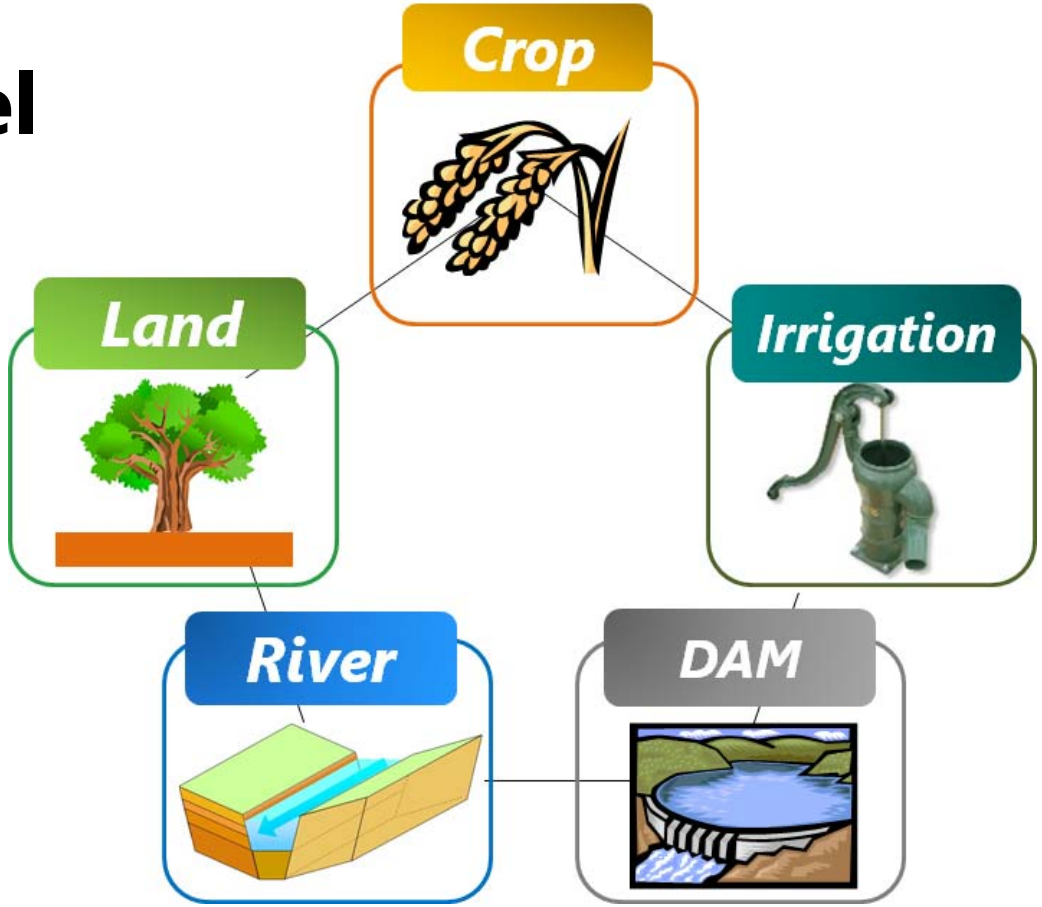
Land Surface Model

SiBUC

Simple Biosphere model
including Urban Canopy



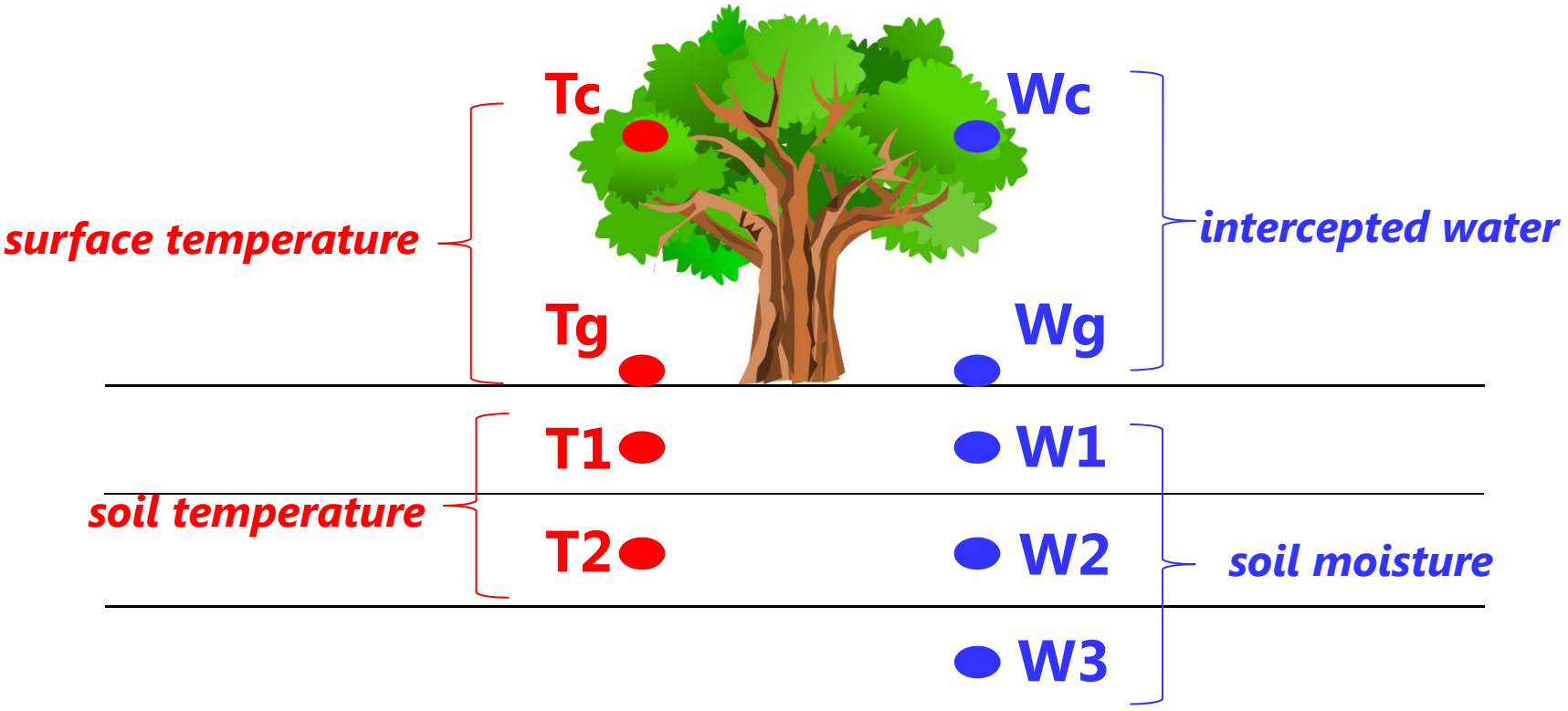
Tanaka (2004)
Kotsuki and Tanaka (2012)

Land Surface Model (LSM)

$$x_{t+1} = f\left(x_t, parameter, forcing\right)$$

x: state variables
f: model

State Variables x_t



Land Surface Model (LSM)

$$x_{t+1} = f\left(x_t, parameter, forcing\right)$$

x: state variables

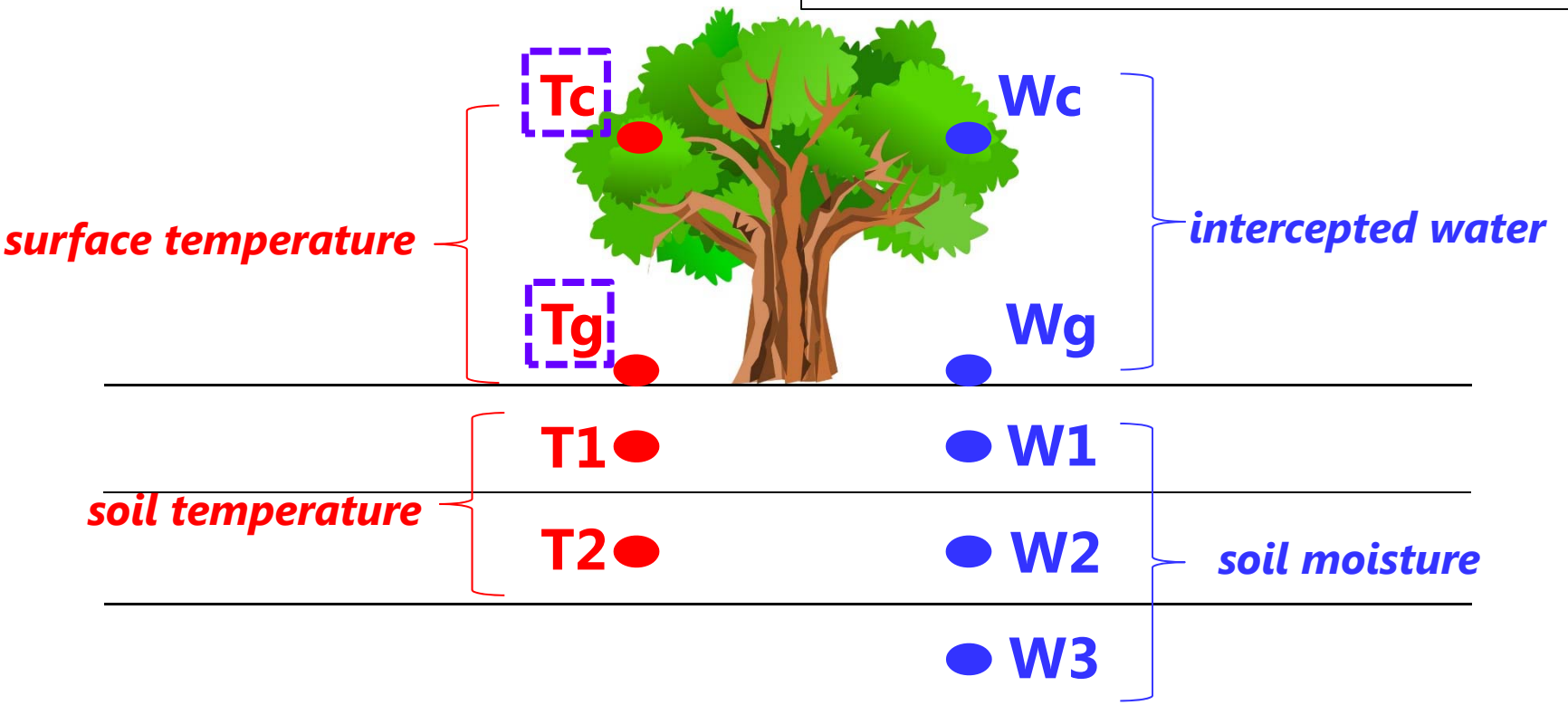
f: model

State Variables x_t

LST: Land Surface Temperature

$$LST = vc \cdot Tc + (1 - vc) \cdot Tg$$

vegetation coverage ratio



Land Surface Model (LSM)

$$x_{t+1} = f\left(x_t, parameter, forcing\right)$$

x: state variables
f: model

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forcing

PR	Precipitation
SW	Short wave radiation
LW	Long wave radiation
Tair	Air temperature
Qv	Specific humidity
Ps	Surface pressure
Wind	Wind speed

parameter

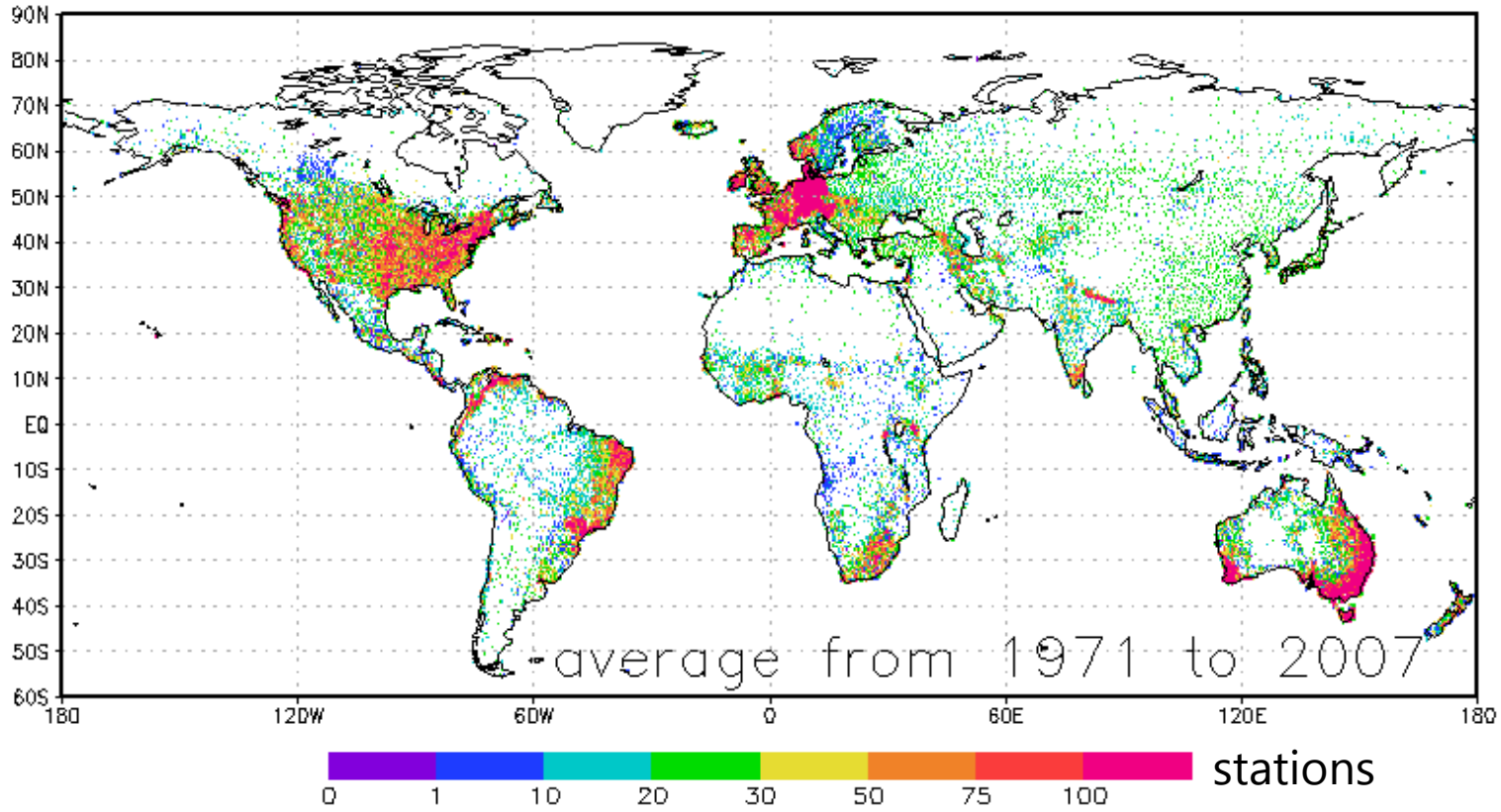
Vegetation parameter : LAI, vegetation coverage, …

Soil parameter : soil type, albedo, …

Surface parameter : plant type, elevation

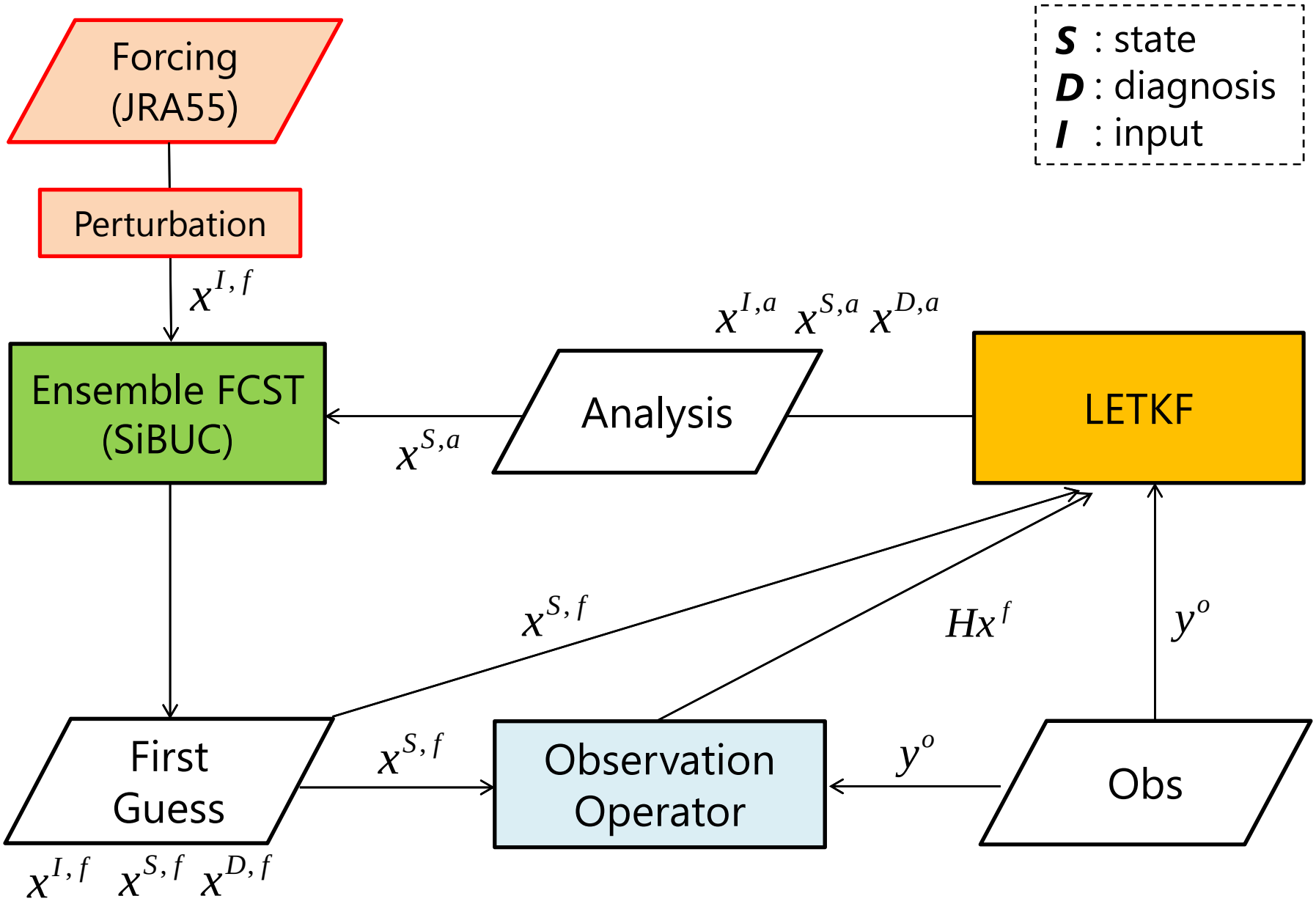
Limitation of surface observations

Gauging stations (global precipitation data sets by DWD)



Assimilation of satellite data would improve estimations in regions with sparse surface obs.

Land Data Assimilation (SiBUC-LETKF)



Perturbation for forcing data

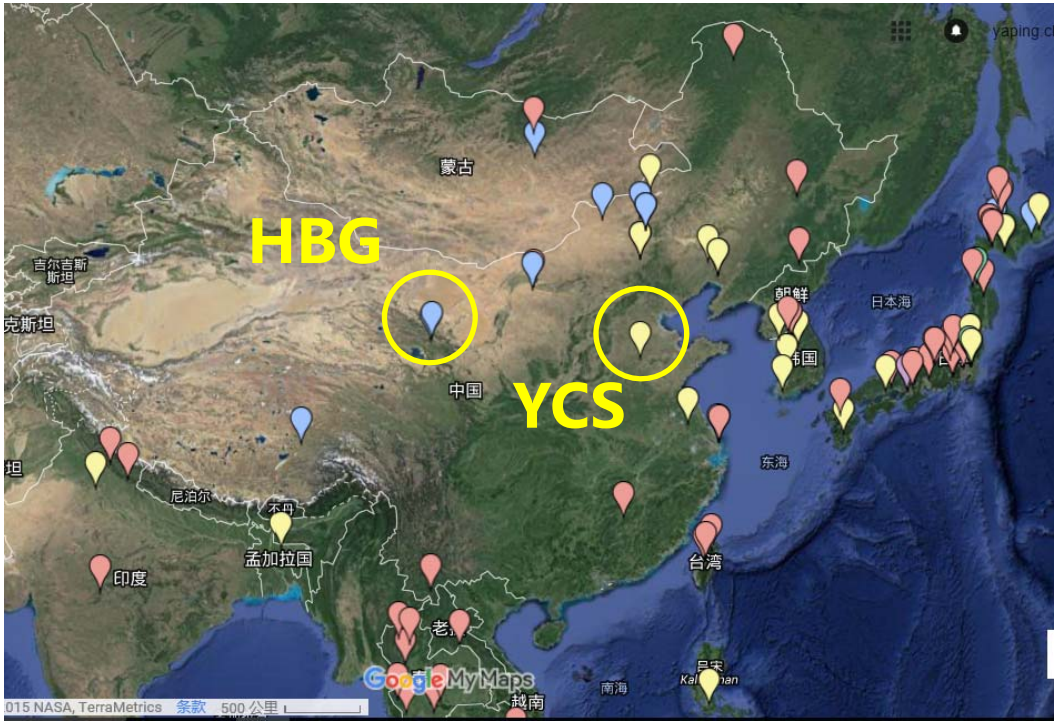
Forcing	Perturbation			Correlation			
	Type	SD	Unit	PR	SW	LW	Tair
PR	Multiplicative	0.5	-		-0.10	0.50	-0.10
SW	Multiplicative	0.5	-	-0.10		-0.30	0.30
LW	Additive	50.0	W/m^2	0.50	-0.30		0.60
Tair	Additive	1.0	K	-0.10	0.30	0.60	
Qv	-						
Ps	-						
Wind	-						

Multiplicative perturbation $F' = F \cdot SD \cdot N(0,1)$

Additive perturbation $F' = F + SD \cdot N(0,1)$

F : original forcing data (JRA55)
F' : perturbed forcing data

Experiment sites



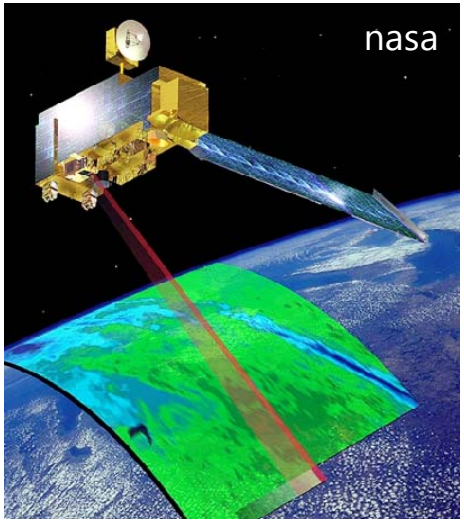
	HBG (Haibei Grassland Site)	YCS (Yucheng Site)
Longitude	101.32°	116.34°
Latitude	37.6°	36.5°
Land cover	Alpine meadow	Crops
Elevation(m)	3250	28
Climate	Highland continental climate	Semi-humid monsoon climate

Asia-Flux: http://asiaflux.net/

Tentative setting of SiBUC-LETKF

	This study	**Other publications**
Initial condition	1-yr spin-up w/ perturbed forcing	?
Ensemble size	10	12, 50
Covariance inflation	Perturbed forcing	Perturbed forcing or Perturbed observation
DA interval	1 hr	?
Observation (LST)	Median of 3 x 3 grids from MODIS	interpolation
Observation error	1 K	1-2 K

DA Experiments

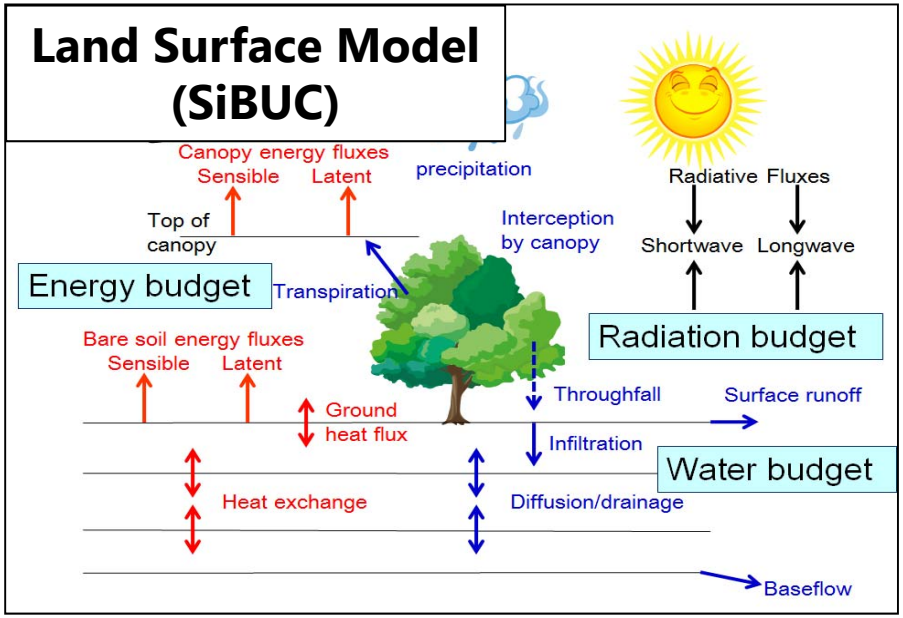


MODIS (TERRA/AQUA)

Surface Temp.

DA

Surface Temp.

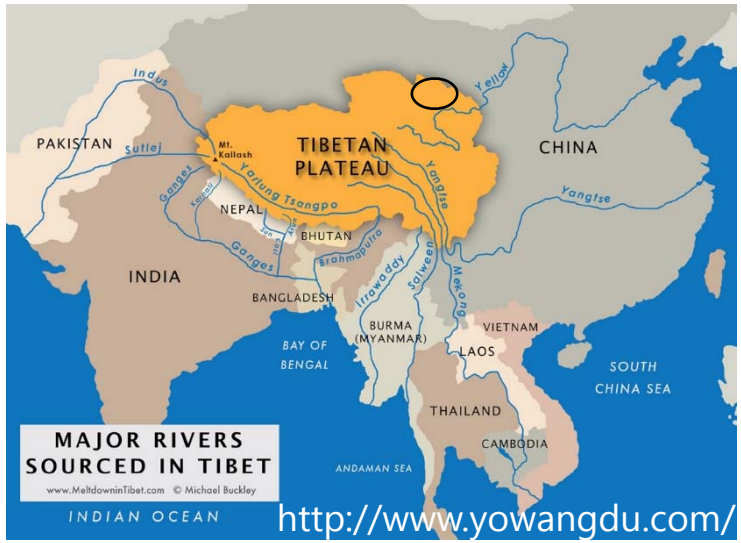


Validation

validation with independent flux obs.

Background

- Master thesis
  - Study area: Northeast of Tibetan Plateau
  - Estimation of evapotranspiration based-on satellite data
    - using Landsat, MODIS, HJ-1B



- Motivation
  - To learn simulation & data assimilation with LSMs

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- **Observation data**
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Observation data

- MODIS data for data assimilation

- Flux-observation for validation

MODIS LST

- Satellites
  - TERRA: 10:30 a.m./p.m. (day/night)
  - AQUA: 1:30 p.m./a.m. (day/night)

- MODIS Level2
  - 1-km resolution
  - Based on TIR-bands

- Software for processing data
  - ENVI/IDL & MODIS Conversion Toolkit

Data source:: https://ladsweb.nascom.nasa.gov/data/search.html

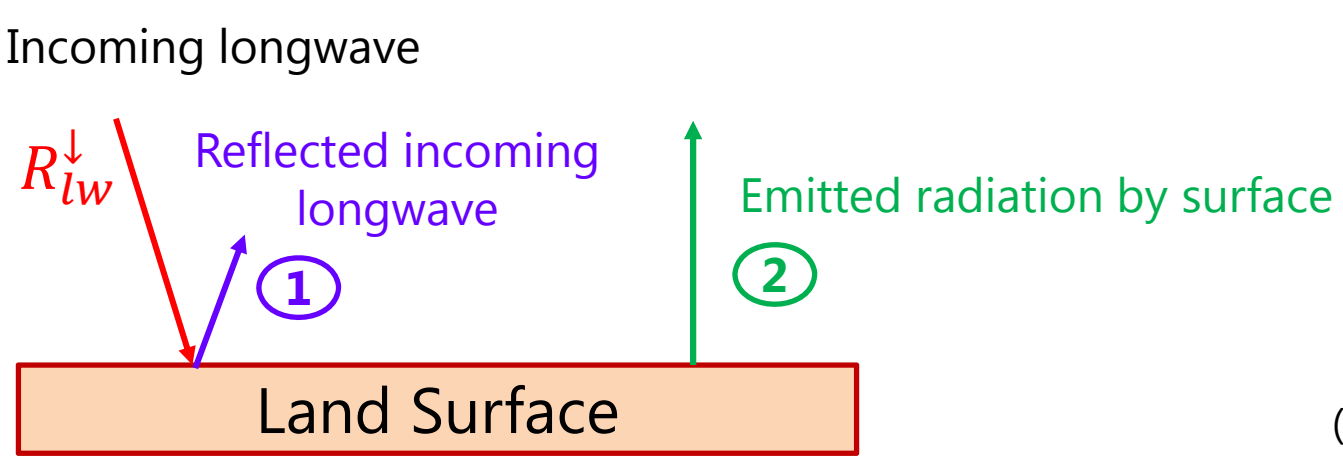
Estimation of LST from flux-observation

$$R_{lw}^{\uparrow} = \underbrace{(1-\varepsilon)R_{lw}^{\downarrow}}_{①} + \underbrace{\varepsilon\sigma T_s^4}_{②}$$

$$\Leftrightarrow \; T_s = \left[\frac{(R_{lw}^{\uparrow} - (1-\varepsilon)R_{lw}^{\downarrow})}{\varepsilon\sigma}\right]^{\frac{1}{4}}$$

$R_{lw}^{\uparrow}$: outgoing longwave radiation
$R_{lw}^{\downarrow}$: incoming longwave radiation
ε : land surface emissivity
σ : Stefan-Boltzmann constant
$= 5.67 \times 10^{-8} W m^{-2} K^{-4}$

$$\varepsilon = 0.96$$



(Yang K et al., 2008)

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Experimental setting

	Data Assimilation	
	State variables	Forcing
w/o DA		Fixed perturbation
EXP1	X	Fixed perturbation

Experimental setting

Forcing	Perturbation			Correlation			
	Type	SD	Unit	PR	SW	LW	Tair
PR	Multiplicative	0.5	-		-0.10	0.50	-0.10
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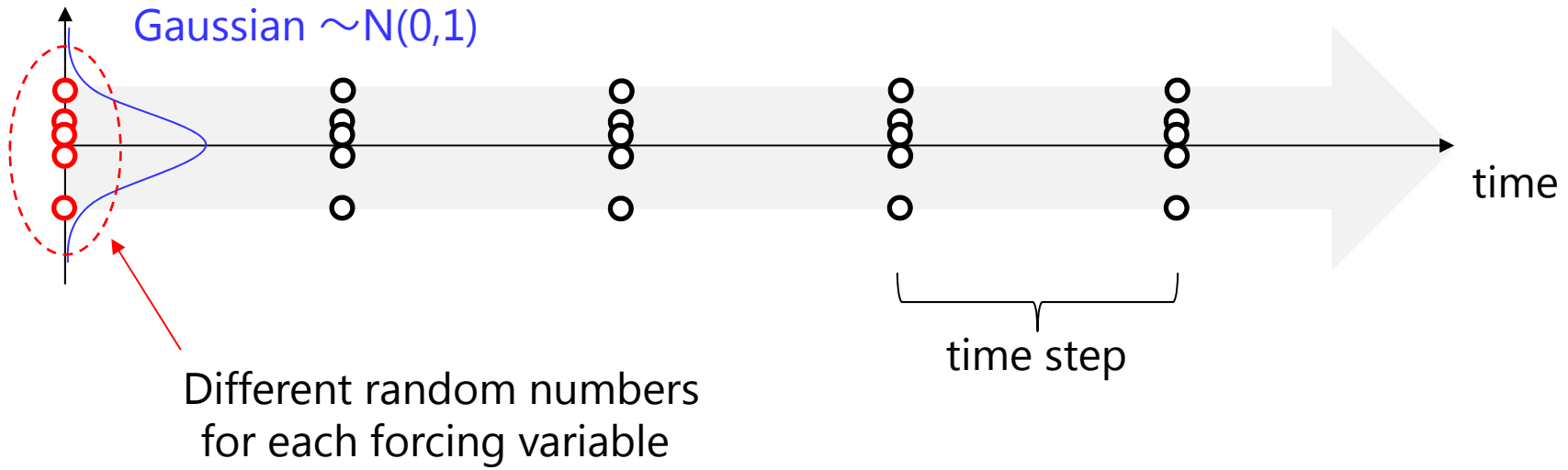
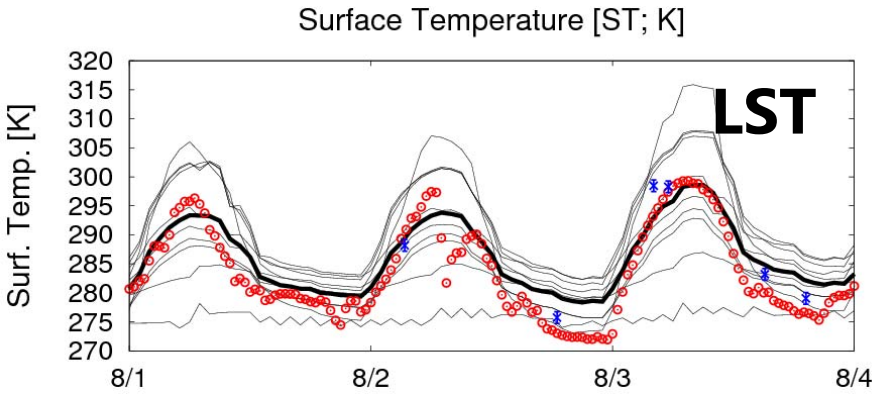
Experiments with perturbed forcing

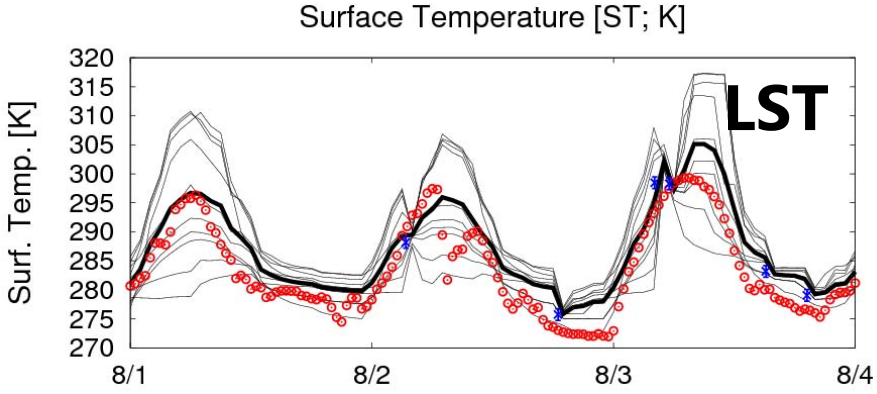


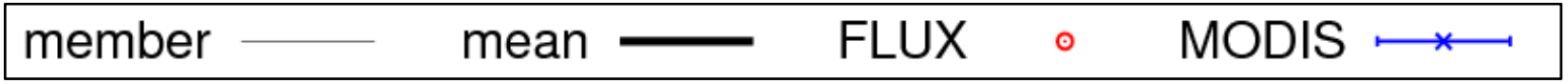
DA impact (summer)

w/o DA



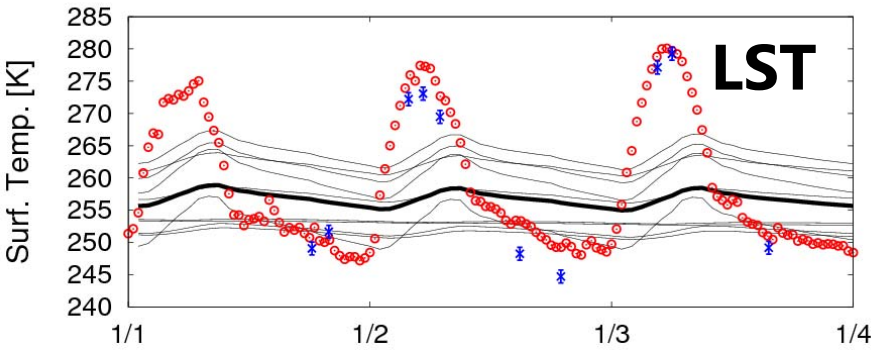
w/ DA (analysis)

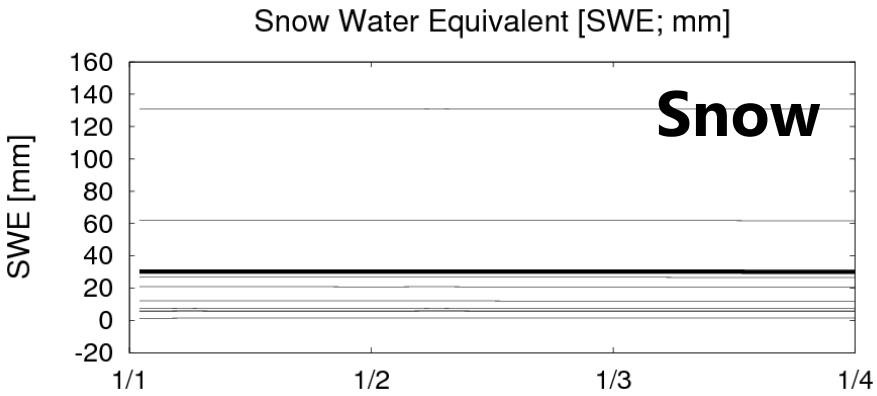




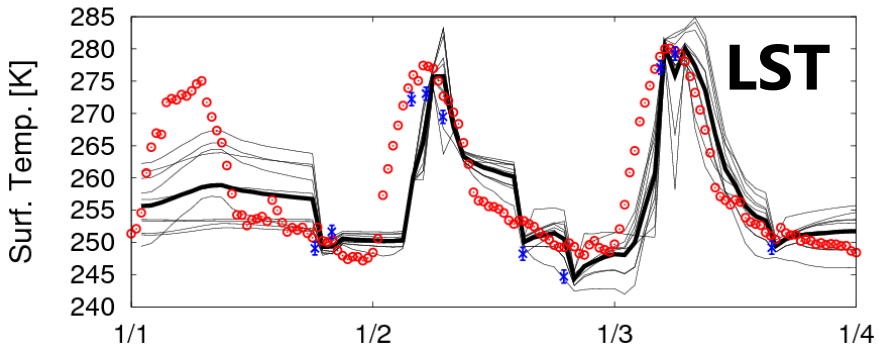
DA impact (winter)

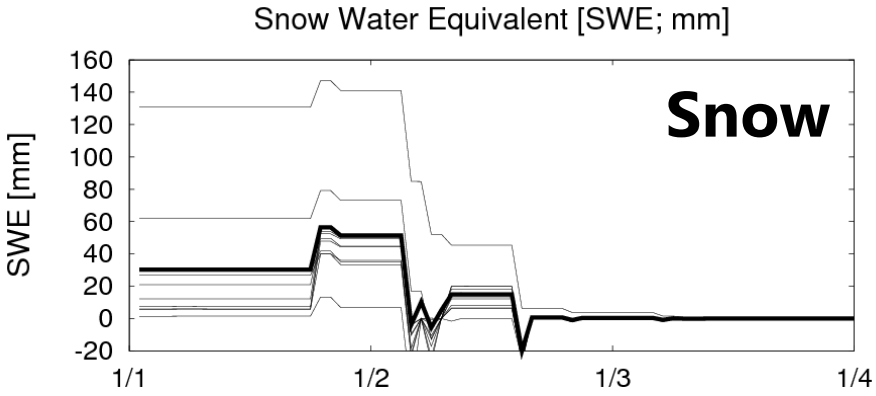
w/o DA





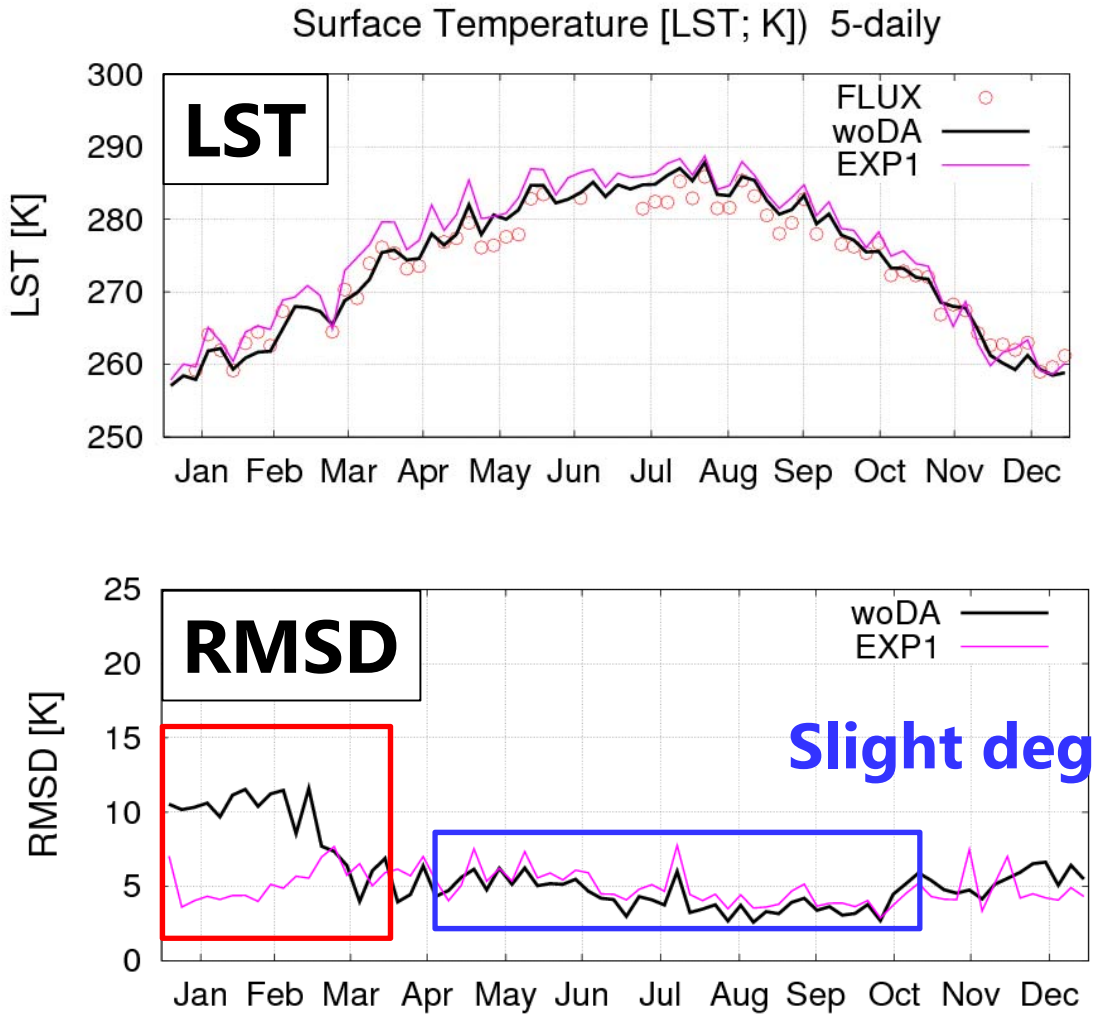
w/ DA (analysis)





member — mean — FLUX ⊙ MODIS —×—

validation



Slight degradation

Large improvement

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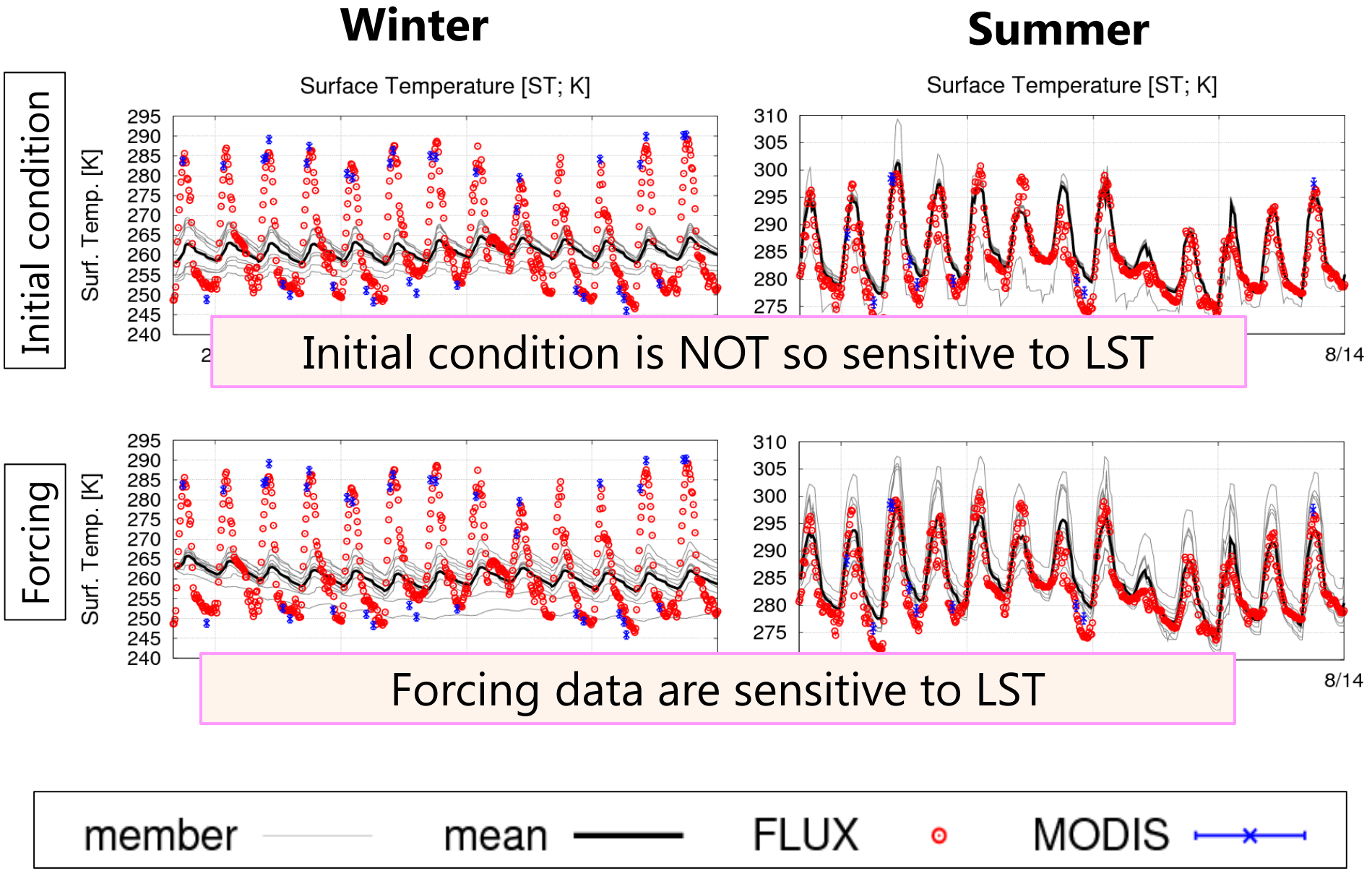
Sensitivity experiments

$$x_{t+1} = f\left(x_t, parameter, forcing\right)$$

x: state variables
f: model

- Sensitivity to the initial condition
- Sensitivity to forcing data

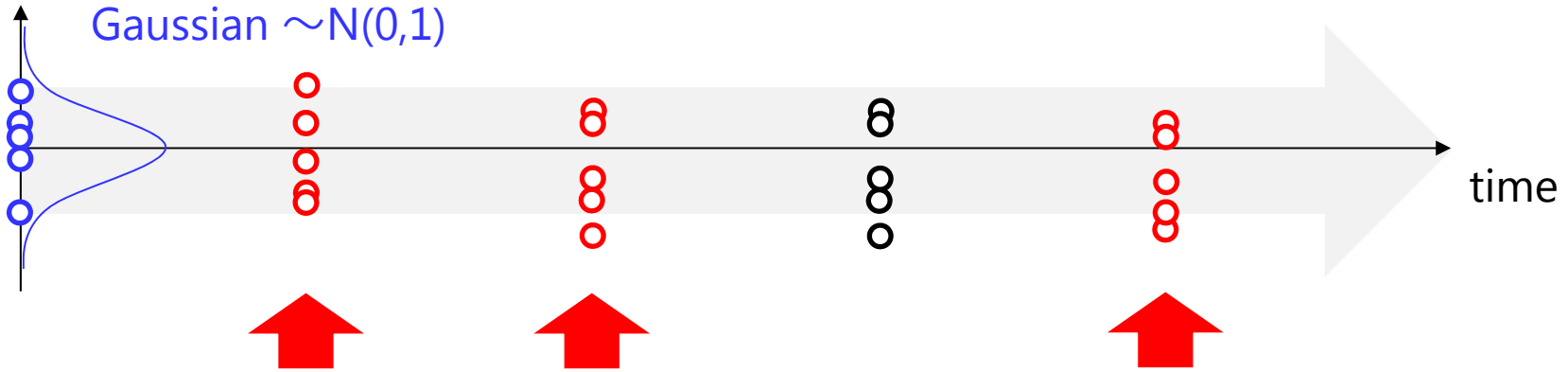
Sensitivity to the initial condition/forcing data



Experimental setting

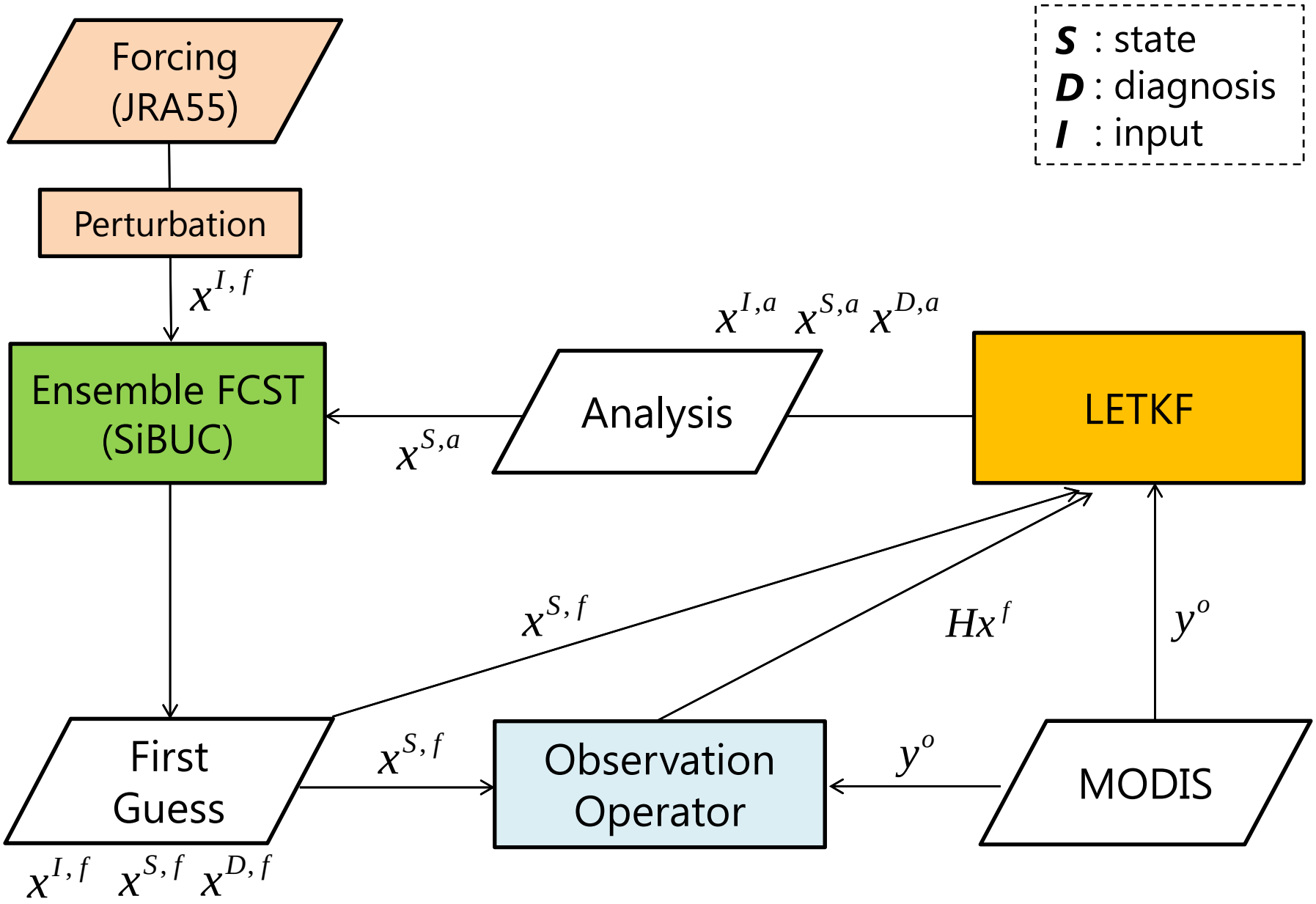
	Data Assimilation	
	State variables	Forcing
w/o DA		Fixed perturbation
EXP1	X	Fixed perturbation
EXP2	**X**	**X (w/ RTPS=1.0)**

Experiments with update of forcing

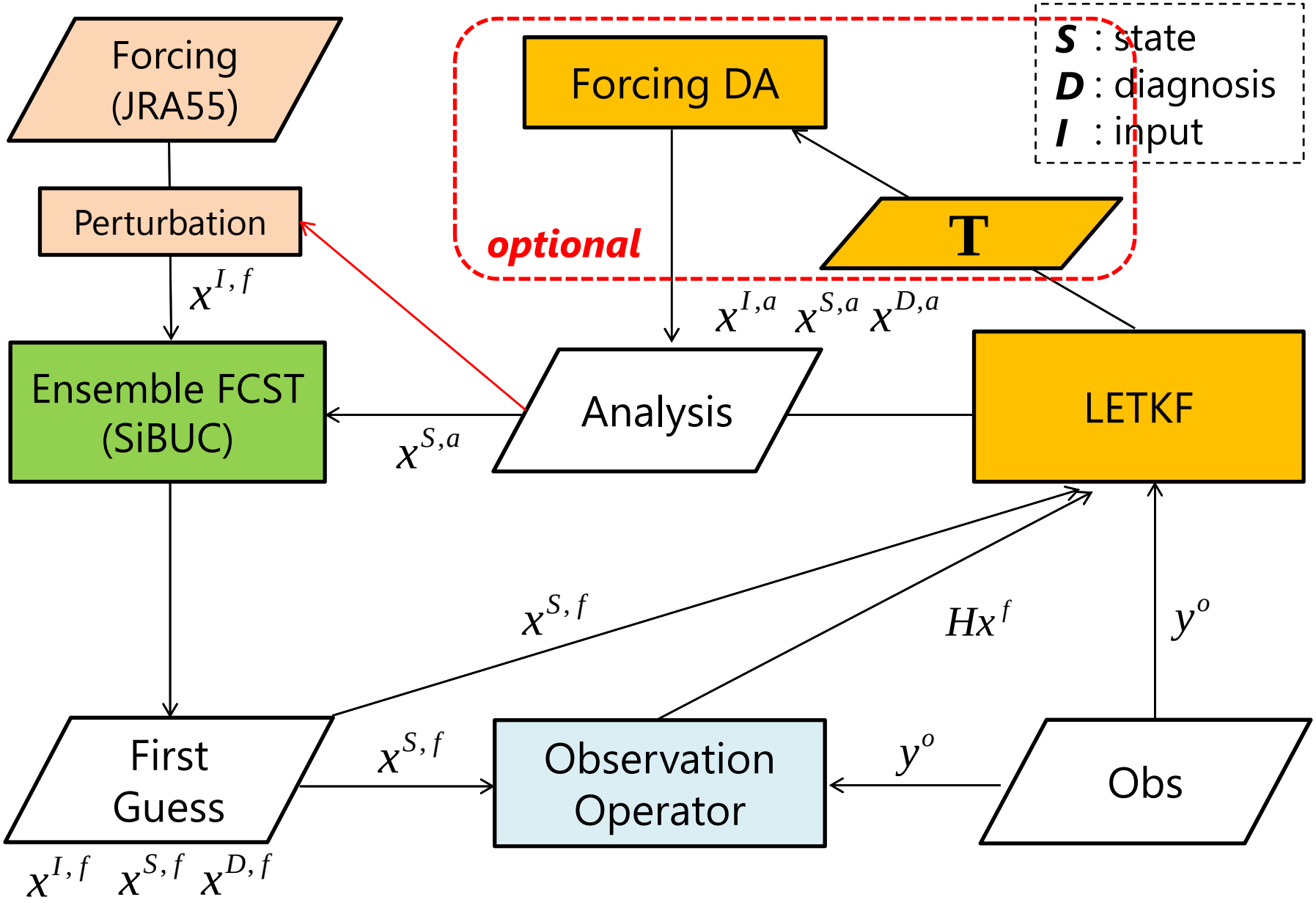


Update forcing parameters when observations are assimilated.

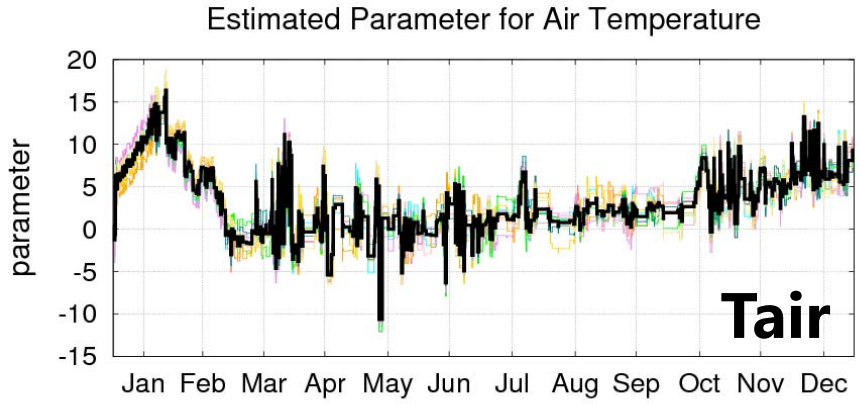
Land Data Assimilation (SiBUC-LETKF)

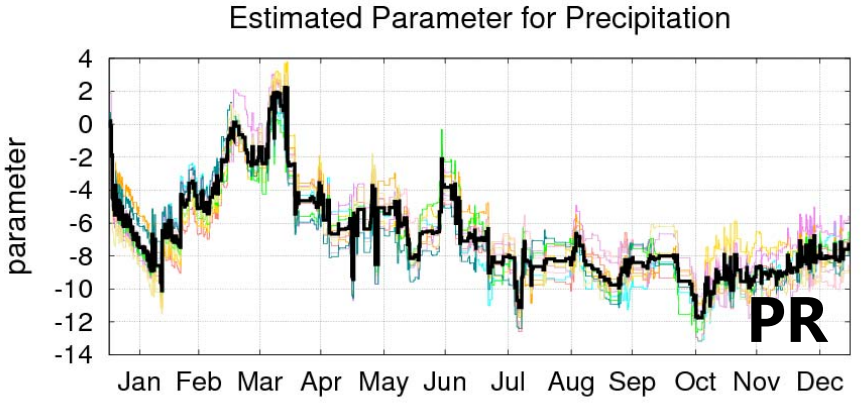


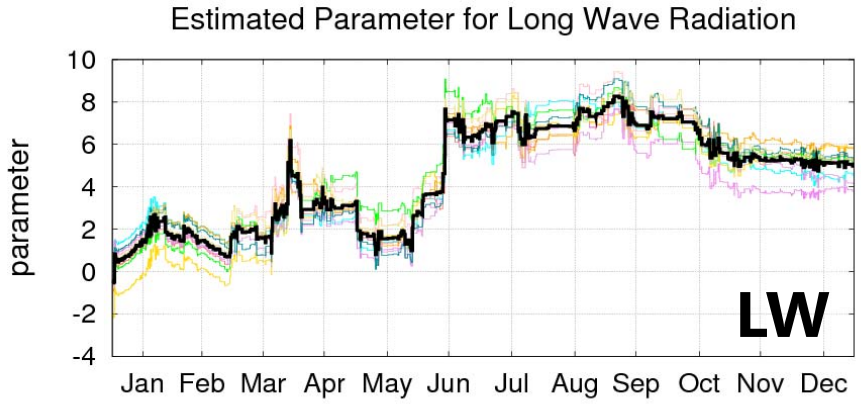
Land Data Assimilation (SiBUC-LETKF)

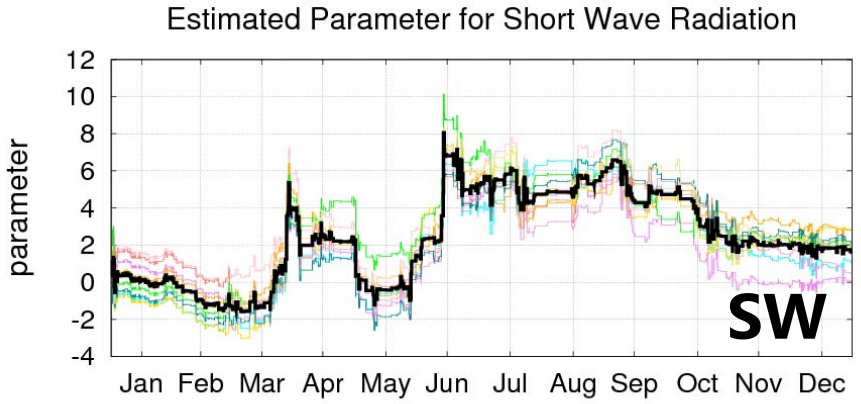


Estimated parameters

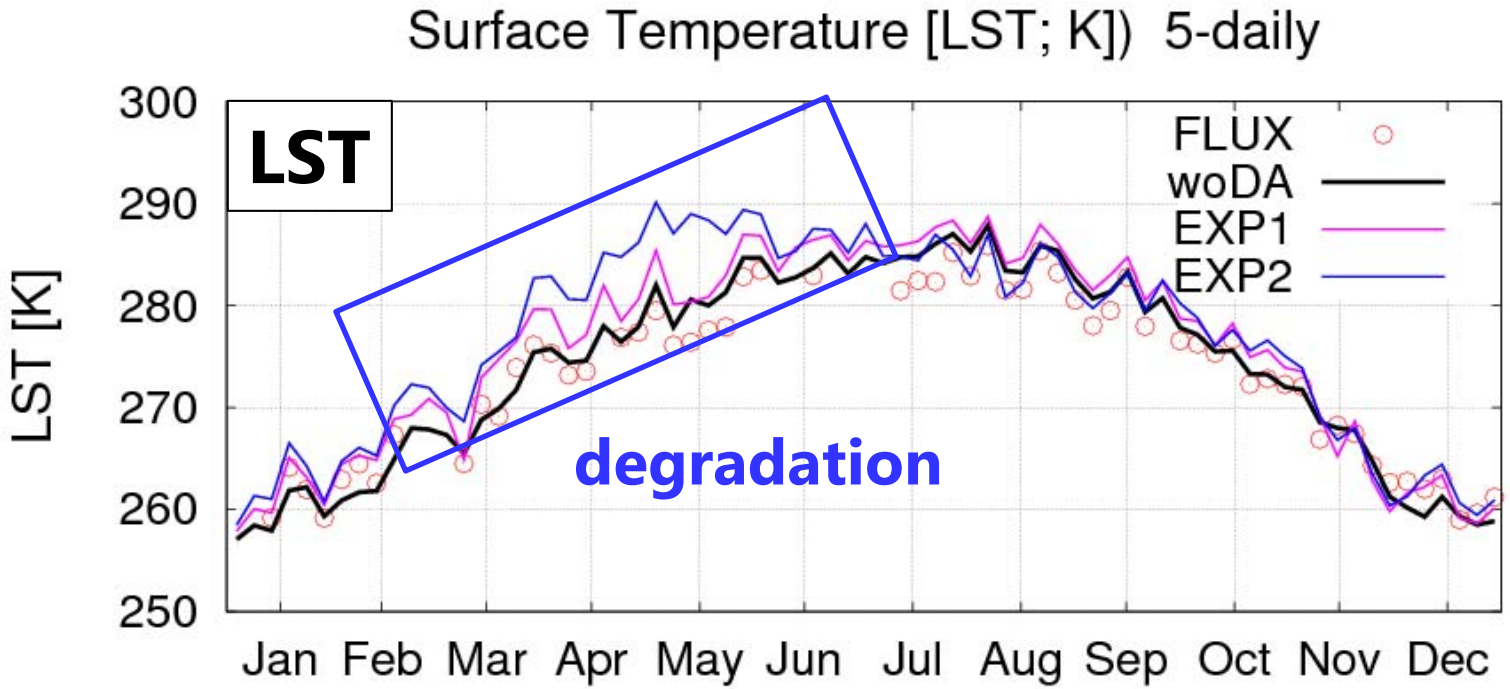








validation


Surface Temperature [LST; K]) 5-daily
LST
degradation
FLUX
woDA
EXP1
EXP2
LST [K]
300
290
280
270
260
250
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Summary

$$x_{t+1} = f\left(x_t, parameter, forcing\right)$$

x: state variables
f: model

- Land data assimilation experiments
  - LST in winter is improved
  - LST in summer is slightly degraded

  - Estimation of forcing data is needed
    - Tested but not successful yet…

Summary of IPA

- Encourage myself to study hard
- Learned how to use UNIX and some program skills
- Improve my English speaking