Ensemble Data Assimilation of GSMaP Precipitation into the Nonhydrostatic Global Atmospheric Model NICAM

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AICS

Data Assimilation Team

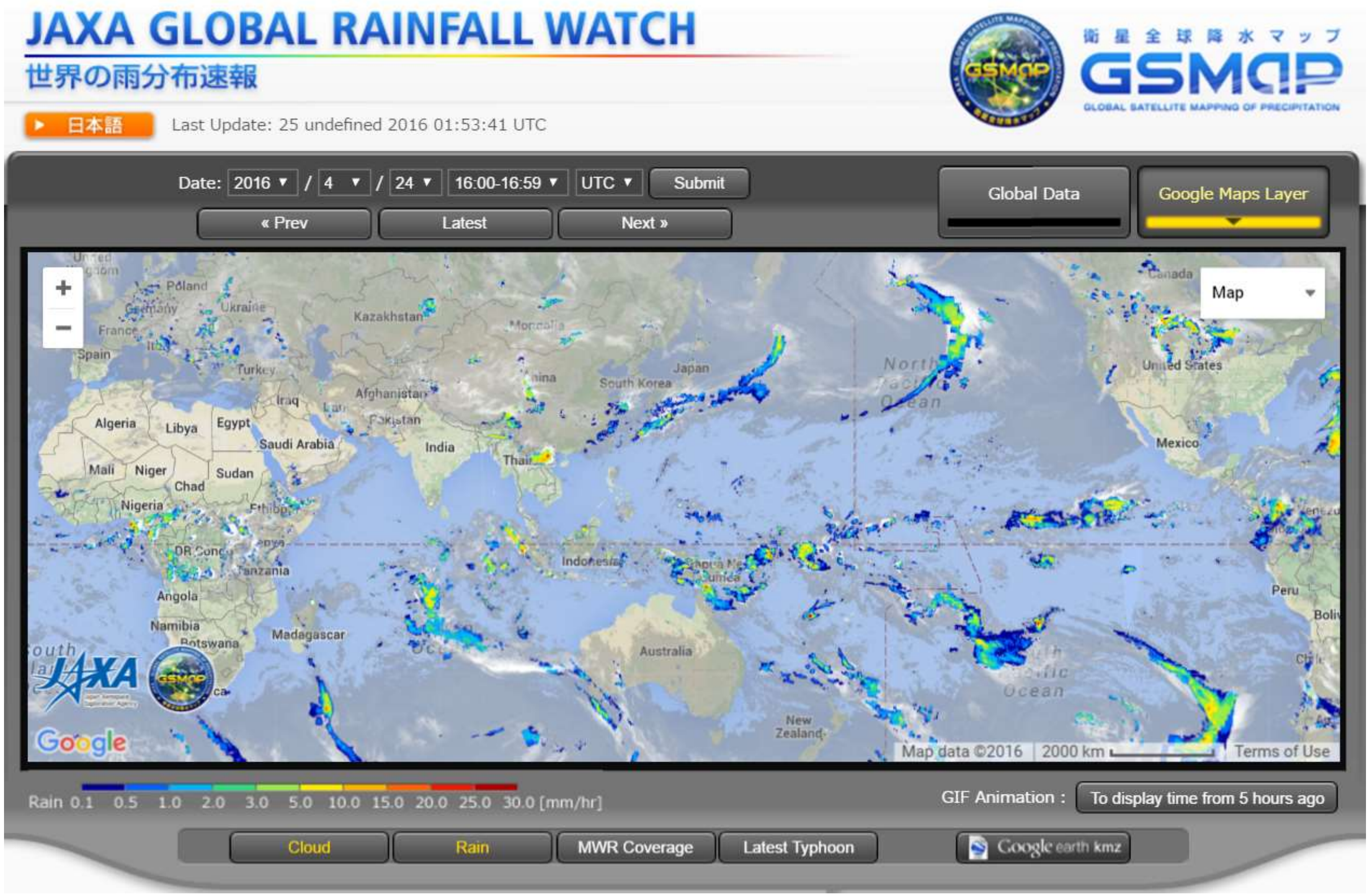
K computer

The 7th EnKF Data Assimilation WS, May 26, 2016 @ PA, USA

Outline

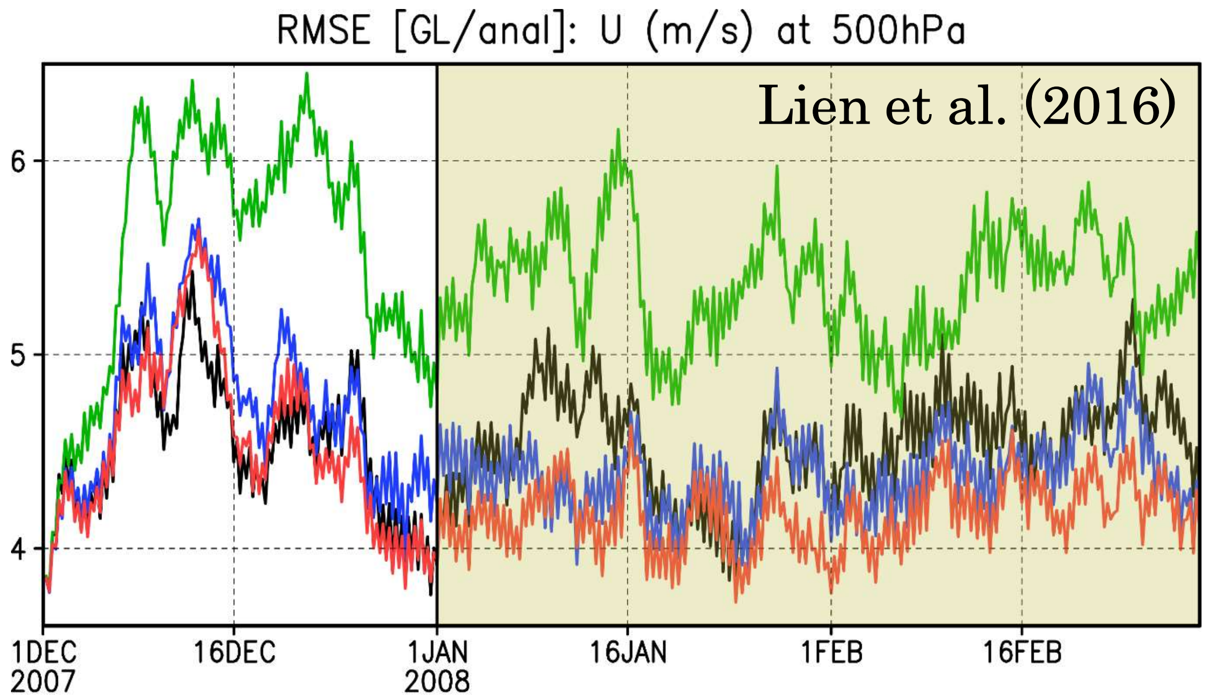
- **Introduction**
- **Gaussian Transformation**
- DA-cycle experiments
- Forecast experiments
- Parameter estimation
- Summary

GSMaP:
Global Satellite Mapping of Precipitation



Goals

- <u>To improve NWP</u> using satellite-derived precipitation data following ***Lien et al. (2013, 2016a, 2016b)***
- <u>To produce a new precipitation product</u> through data assimilation



Improvement achieved with GFS-LETKF
(U-wind @ 500 hPa)

Radiosondes ONLY

Radiosondes+Precip. (No-Transform)

Radiosondes+Precip. (Log-Transform)

Radiosondes+Precip. (Gaussian-Transform)

Experimental Setting

- **Numerical Model**
  - NICAM (Satoh and Tomita 2004, Satoh et al. 2008, 2014)
    - GL6 (approx. 110 km resolution)

- **Observations**
  - CTRL: PREPBUFR: only upper sounding data (ADPUPA)
  - TEST: + GSMaP_Gauge (Ushio et al. 2009)
    - **with Gaussian transformation**

- **Data assimilation**
  - LETKF (Hunt et al. 2007)
  - NICAM-LETKF (Terasaki et al. 2015) with 36 members
    - 3D-LETKF
    - Localization: 400 km for horizontal & 0.4 log(p) for vertical
    - Relaxation to prior perturbation (Zhang et al. 2004; α = 0.7)

Gaussian Transformation

$$F^G(\tilde{y}) = F(y) \quad \Leftrightarrow \quad \tilde{y} = F^{G^{-1}}\left[F(y)\right] \quad \Leftrightarrow \quad y = F^{-1}\left[F^G(\tilde{y})\right]$$

Forward transform (mm/6hr→sigma) Inverse transform (sigma→mm/6hr)

y : original variable (mm/6hr)

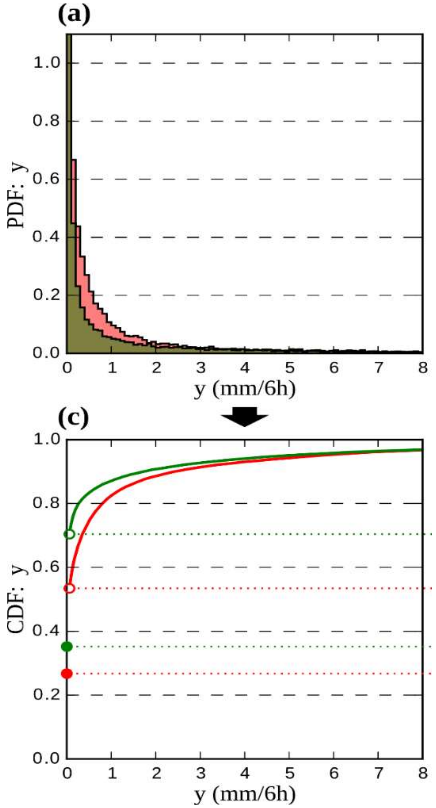
$\tilde{y}$: Transformed variable (sigma)

$F()$: CDF of original variable

$F^G()$: CDF of Gaussian distribution

PDF

CDF



Original variable

—: Model
—: Obs.

Step 0: Obtain PDF & CDF

Lien et al. (2013, 2016)

Gaussian Transformation

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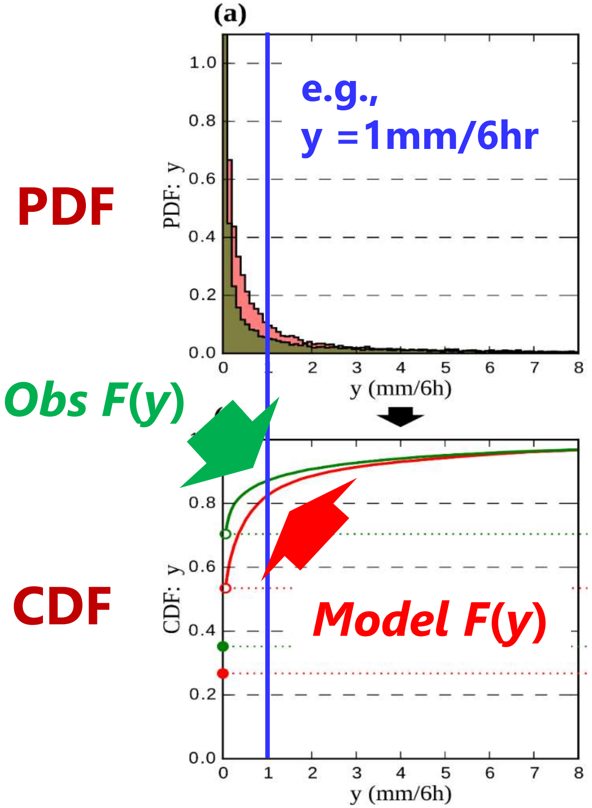

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—: **Model**

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Step 1: Compute $F(y)$

Lien et al. (2013, 2016)

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Forward transform (mm/6hr→sigma) — $\tilde{y} = F^{G^{-1}}\left[F(y)\right]$

Inverse transform (sigma→mm/6hr) — $y = F^{-1}\left[F^G(\tilde{y})\right]$

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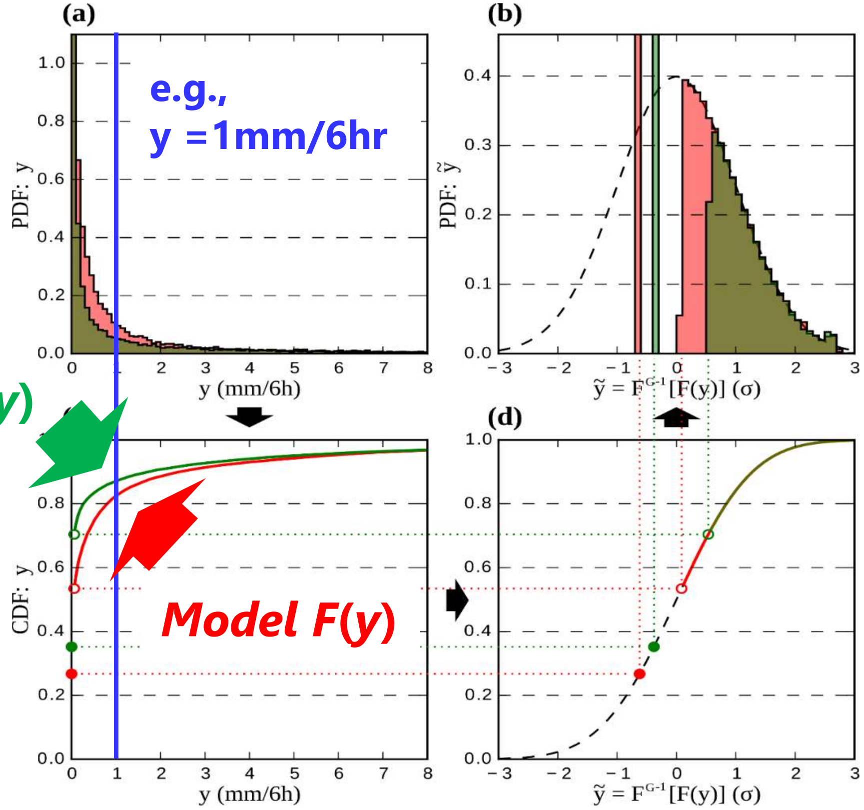
PDF

CDF

Obs F(y)



Original variable

Transformed variable

—: Model

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Lien et al. (2013, 2016)

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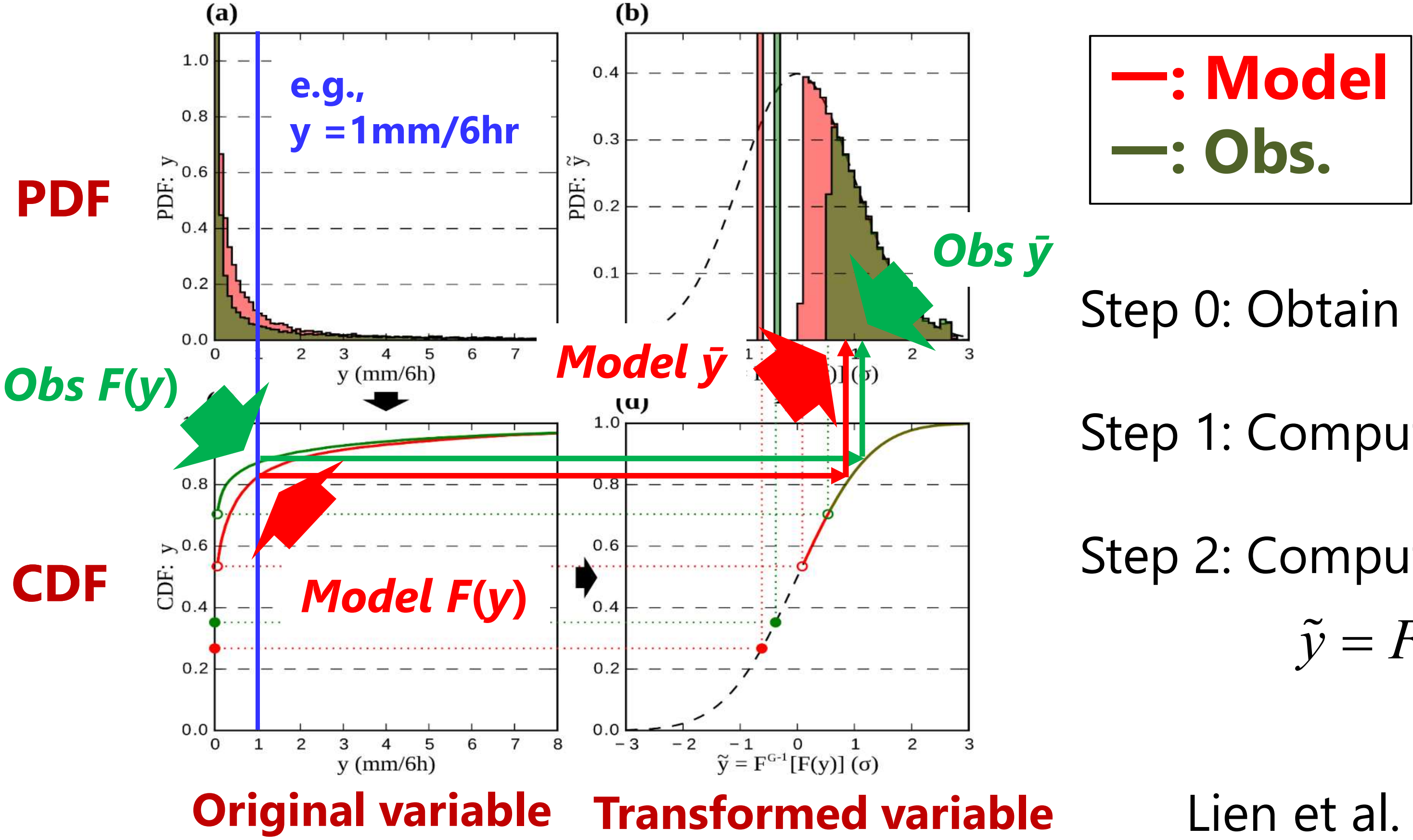


Step 0: Obtain PDF & CDF

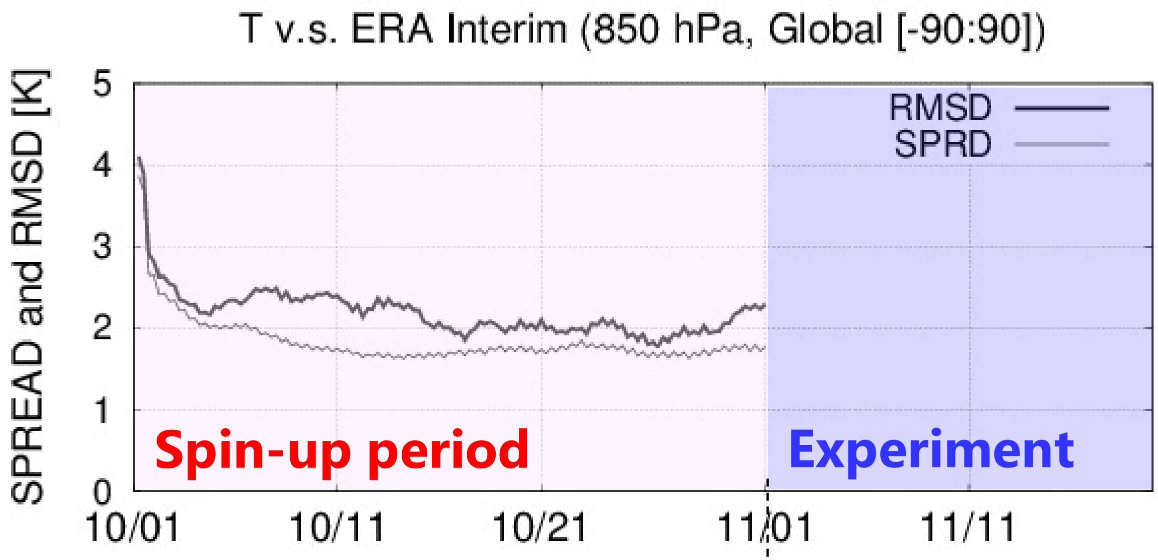
Step 1: Compute $F(y)$

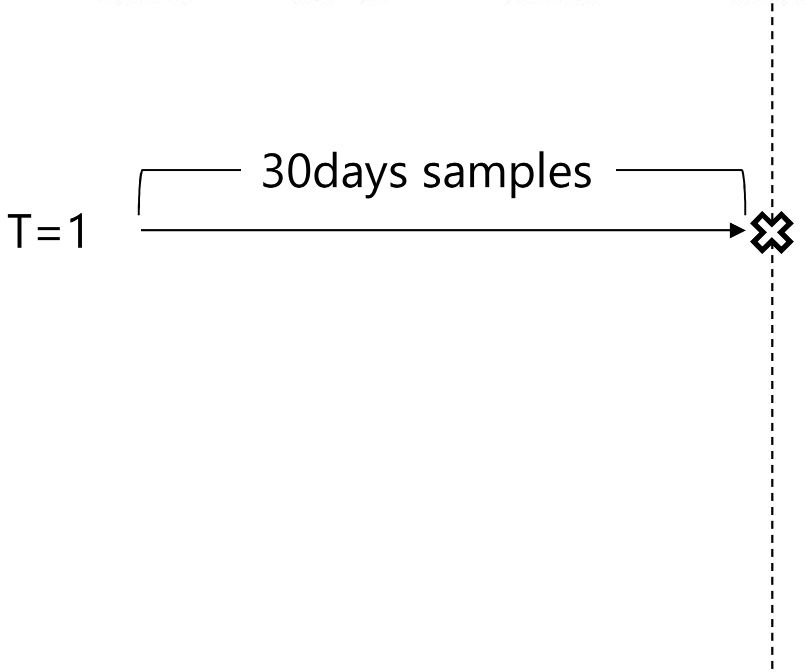
Step 2: Compute

$$\tilde{y} = F^{G^{-1}}\left[F(y)\right]$$

Lien et al. (2013, 2016)

PDF/CDF construction





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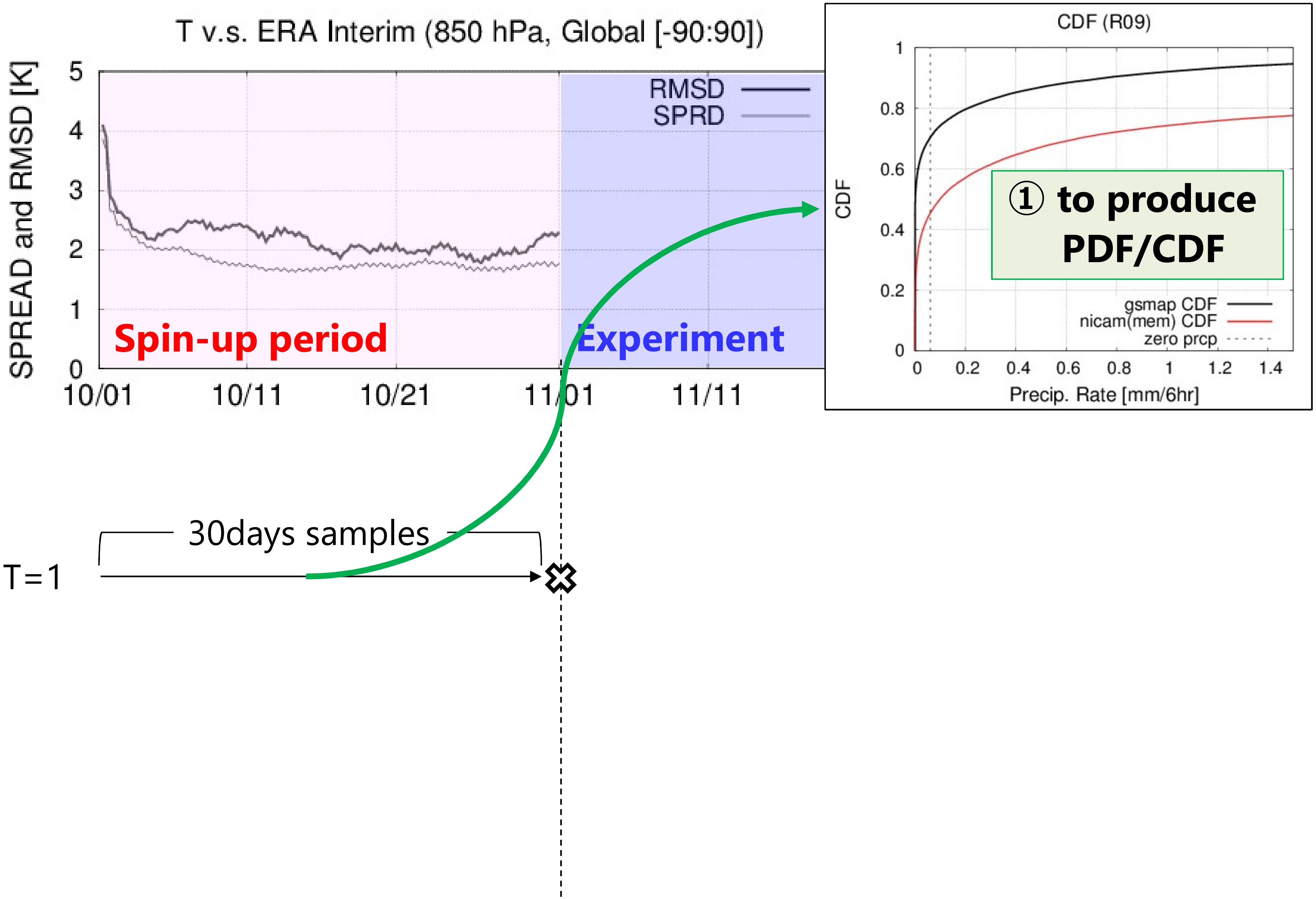

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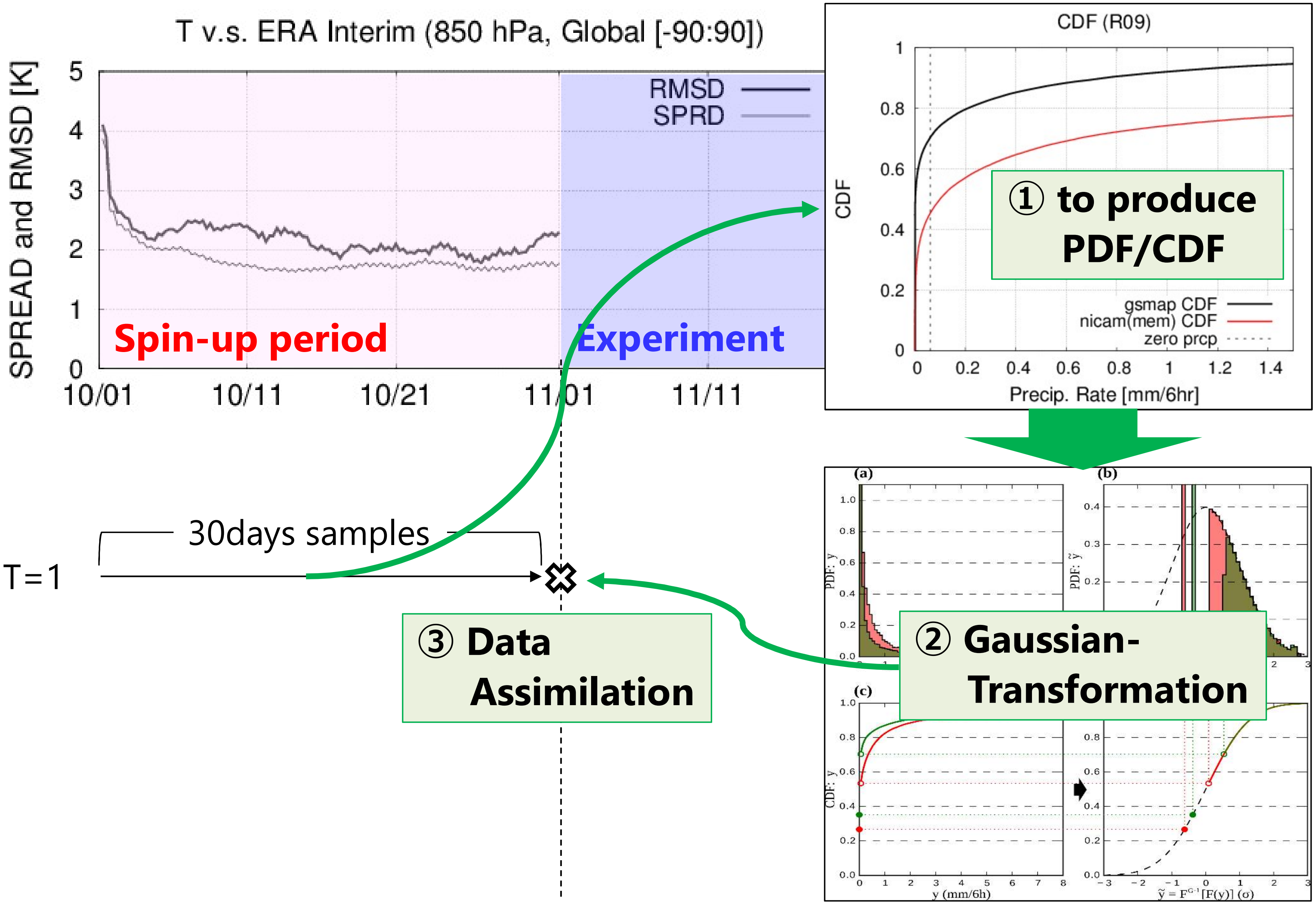

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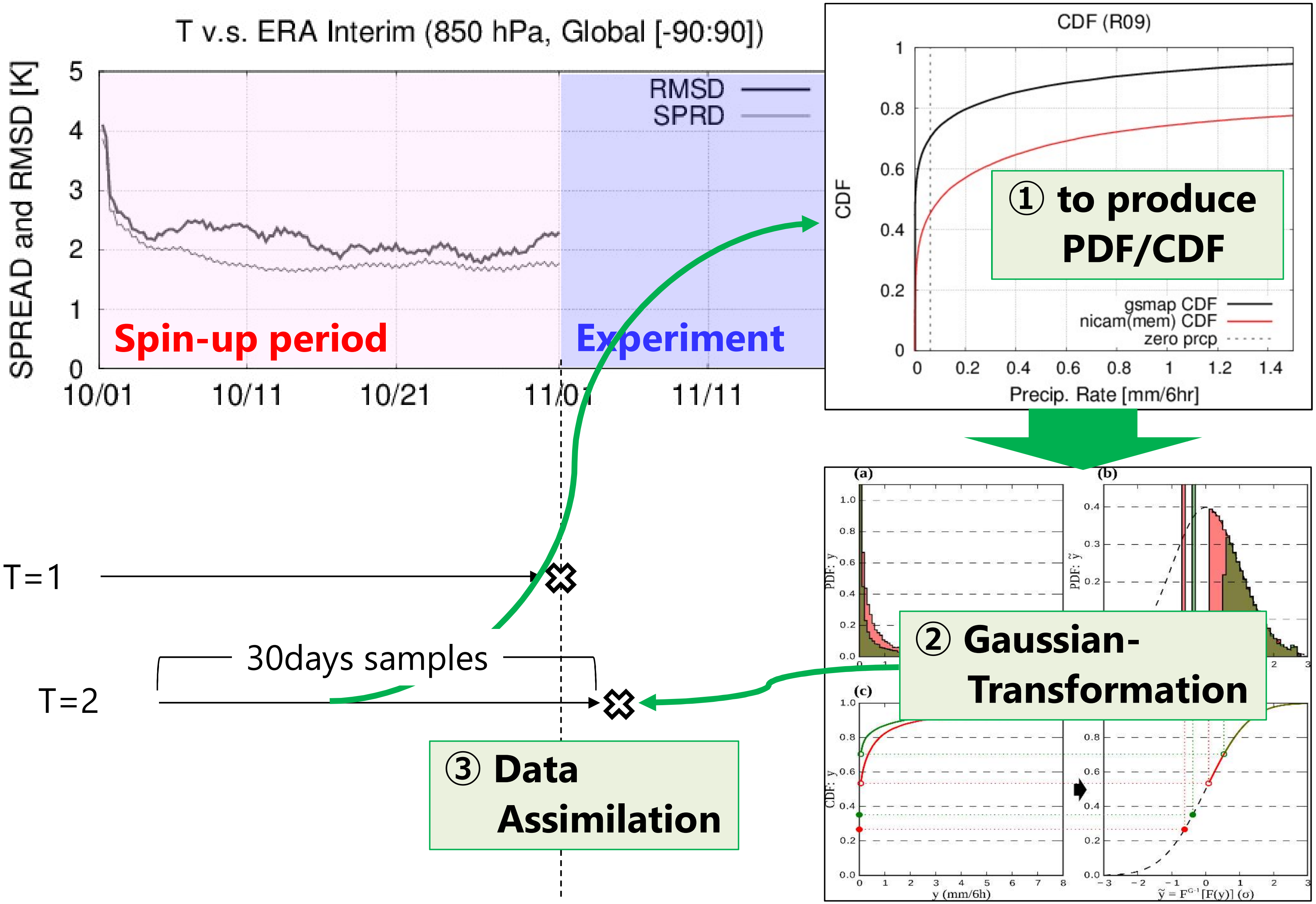

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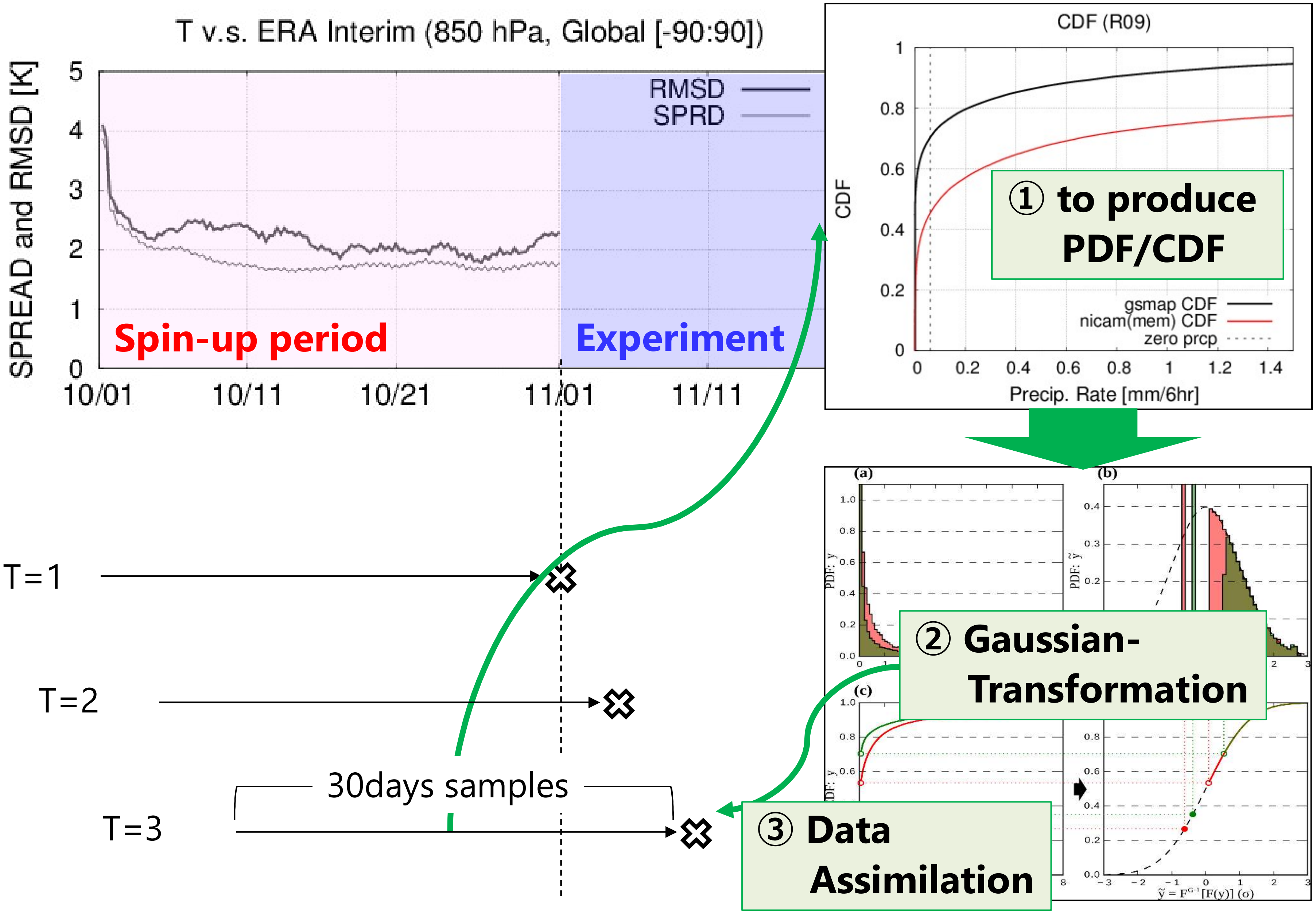
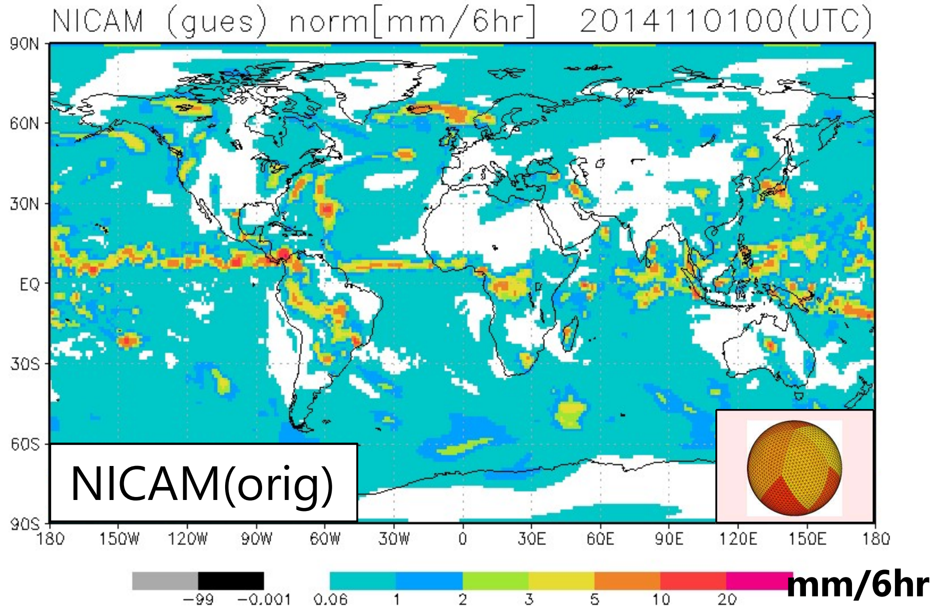
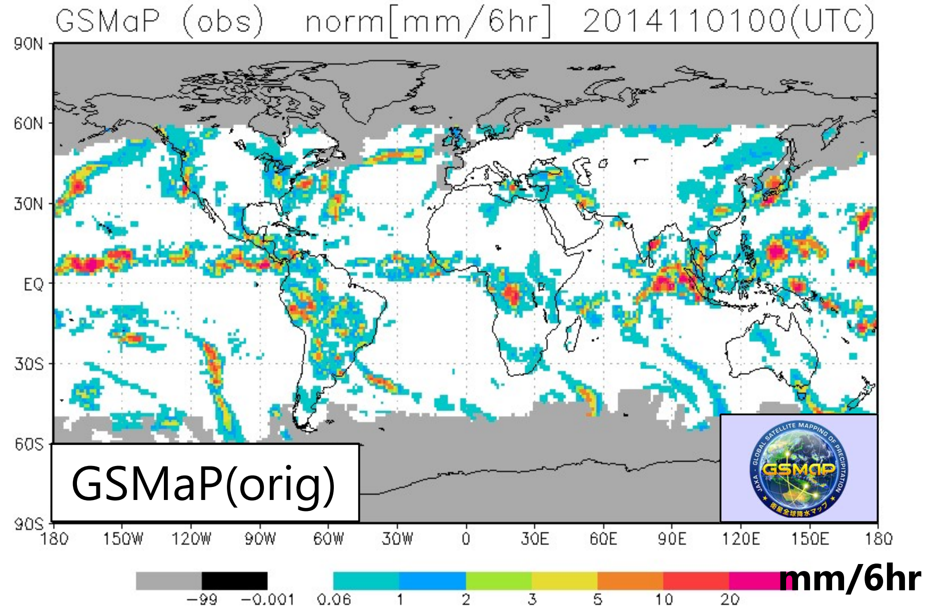


Gaussian Transformation





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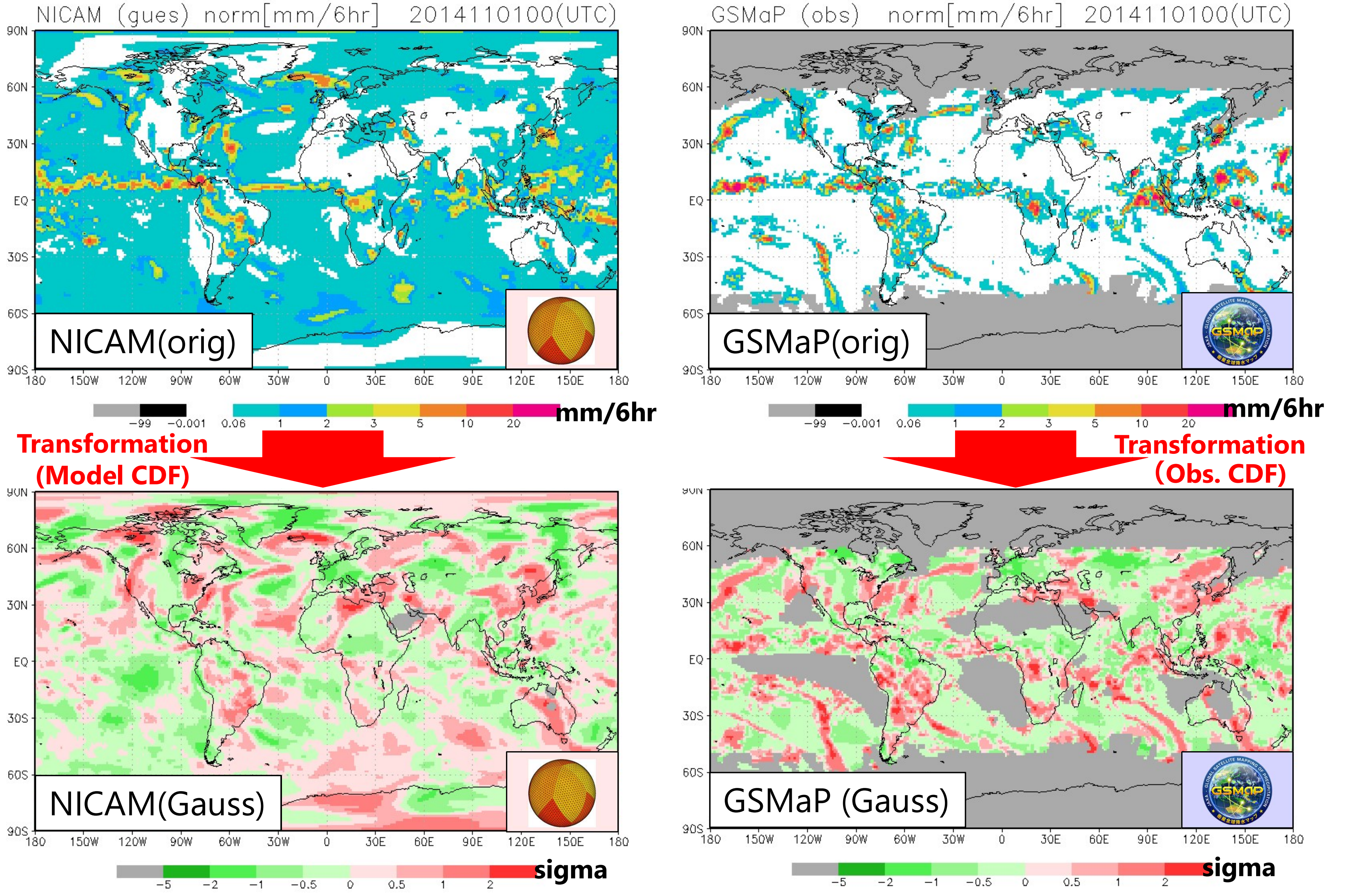
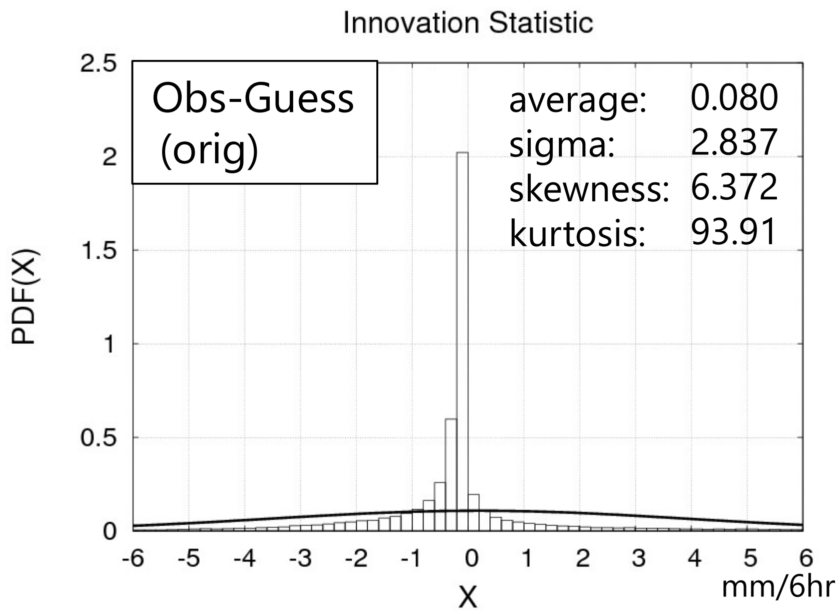
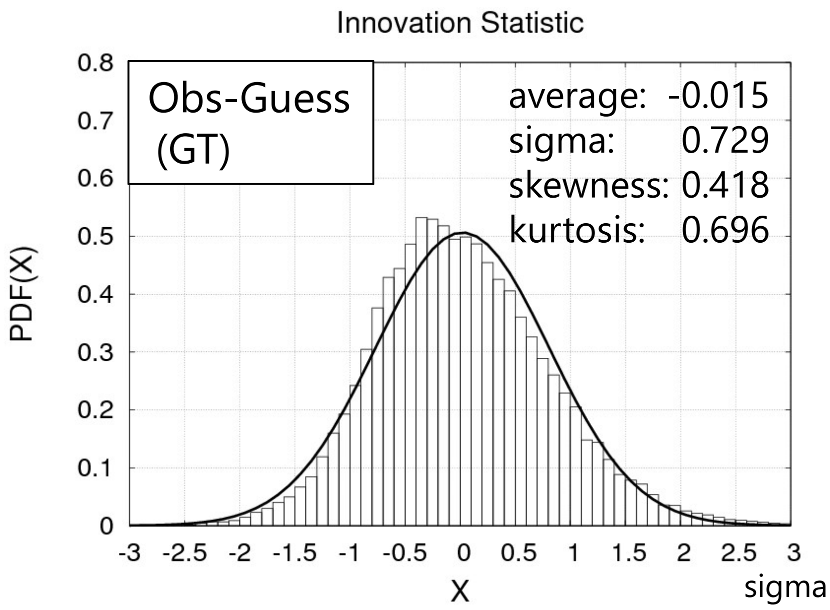


w/wo Gaussian Transformation

wo Gaussian-Transformation



w Gaussian-Transformation



More Gaussian

Sampling period : 2014110100 - 2014110118

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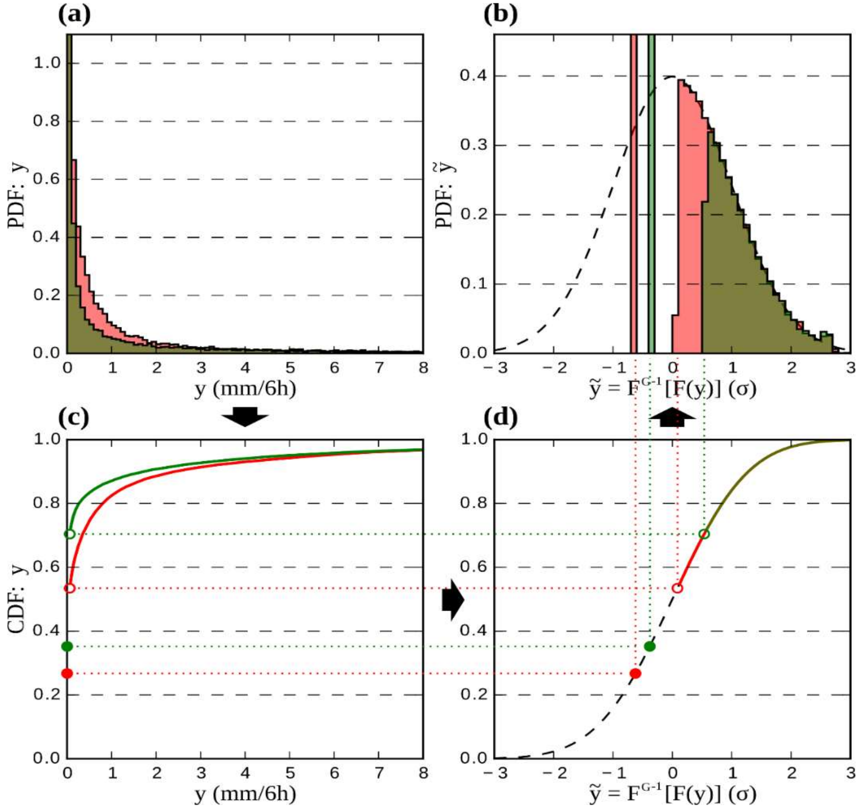
CDF



Original variable **Transformed variable**

—: Model

—: Obs.

Step 0: Obtain PDF & CDF

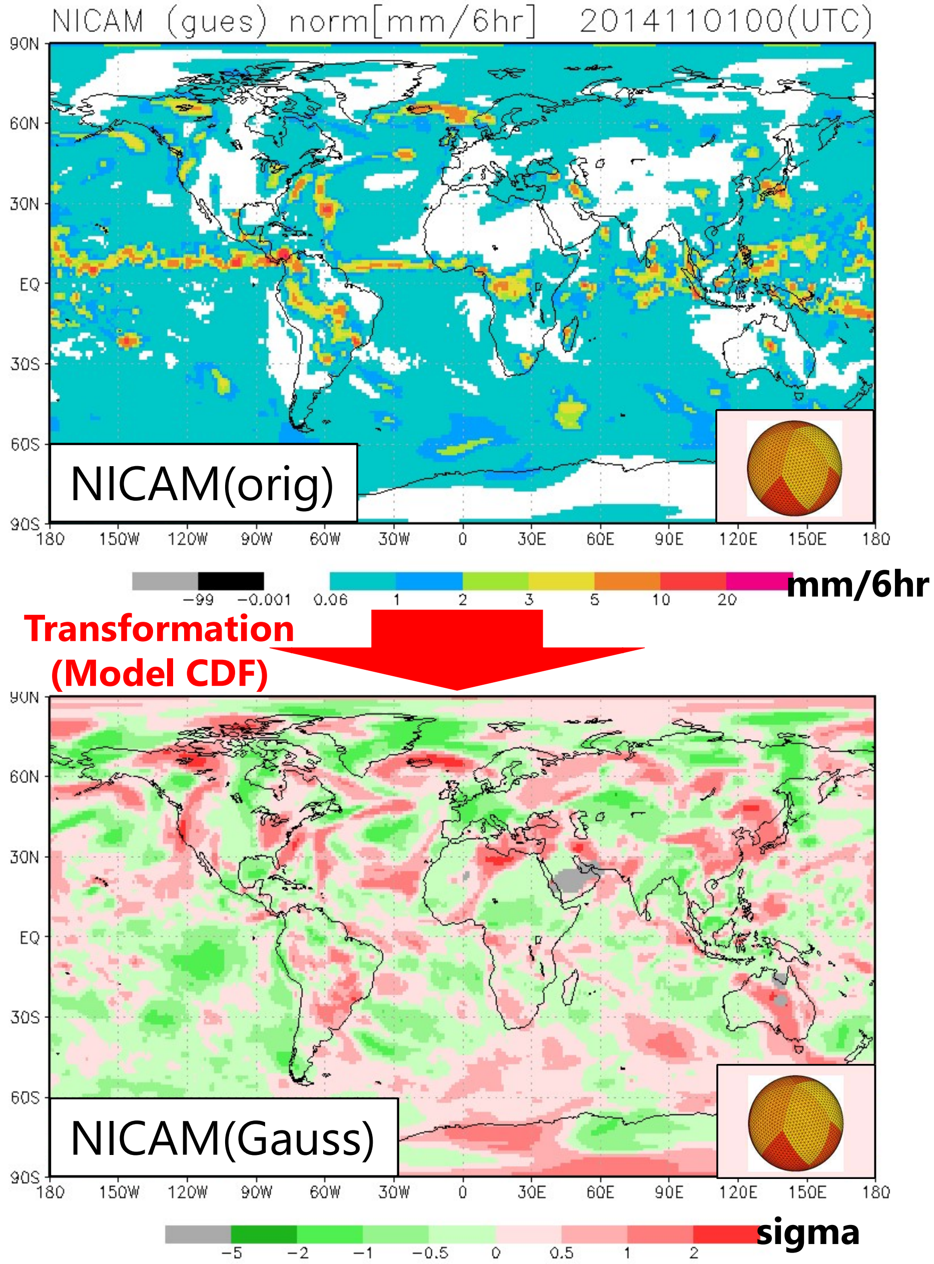
Step 1: Compute $F(y)$

Step 2: Compute

$$\tilde{y} = F^{G^{-1}}\left[F(y)\right]$$

Lien et al. (2013, 2016)

Forward/Inverse Transformations



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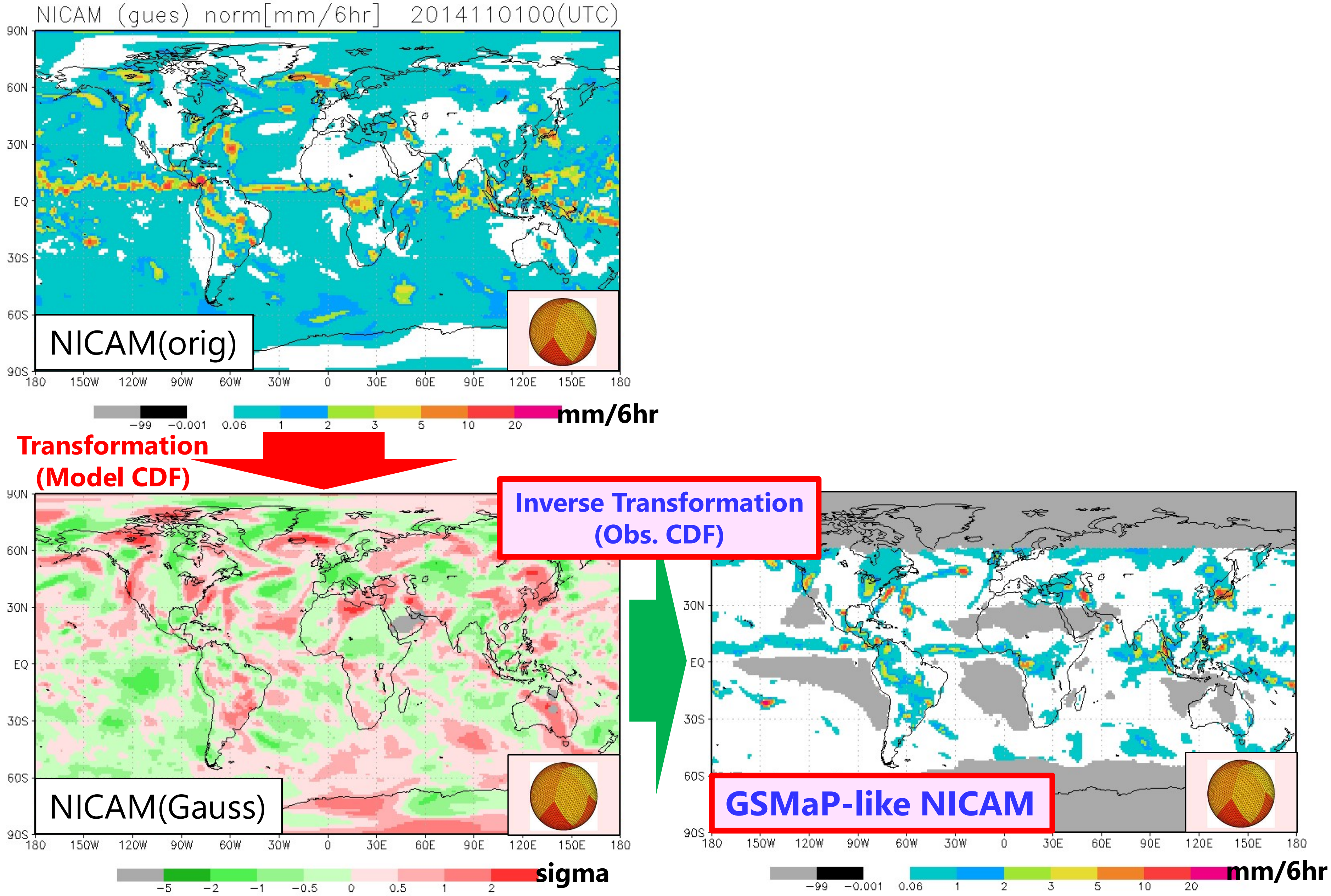

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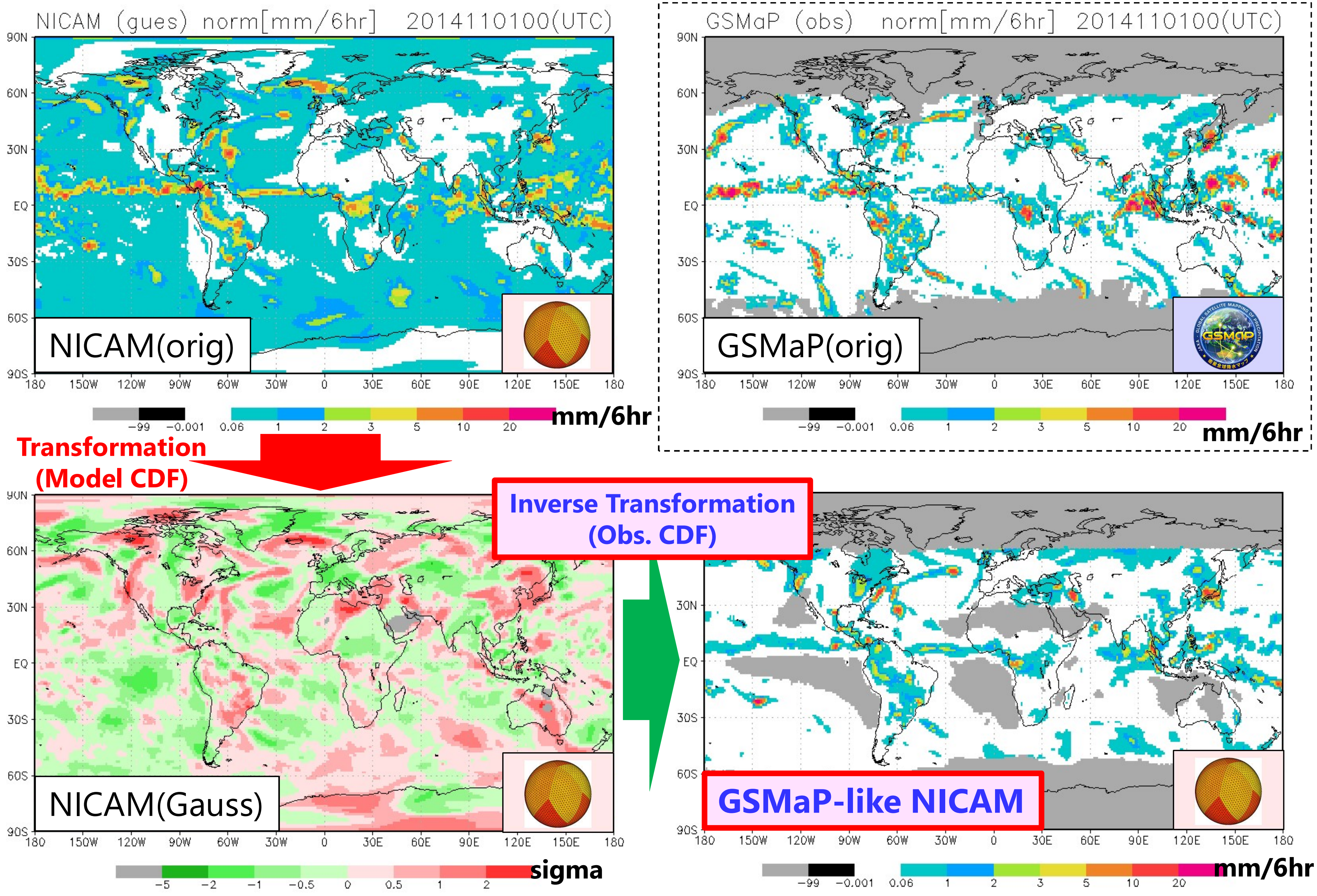

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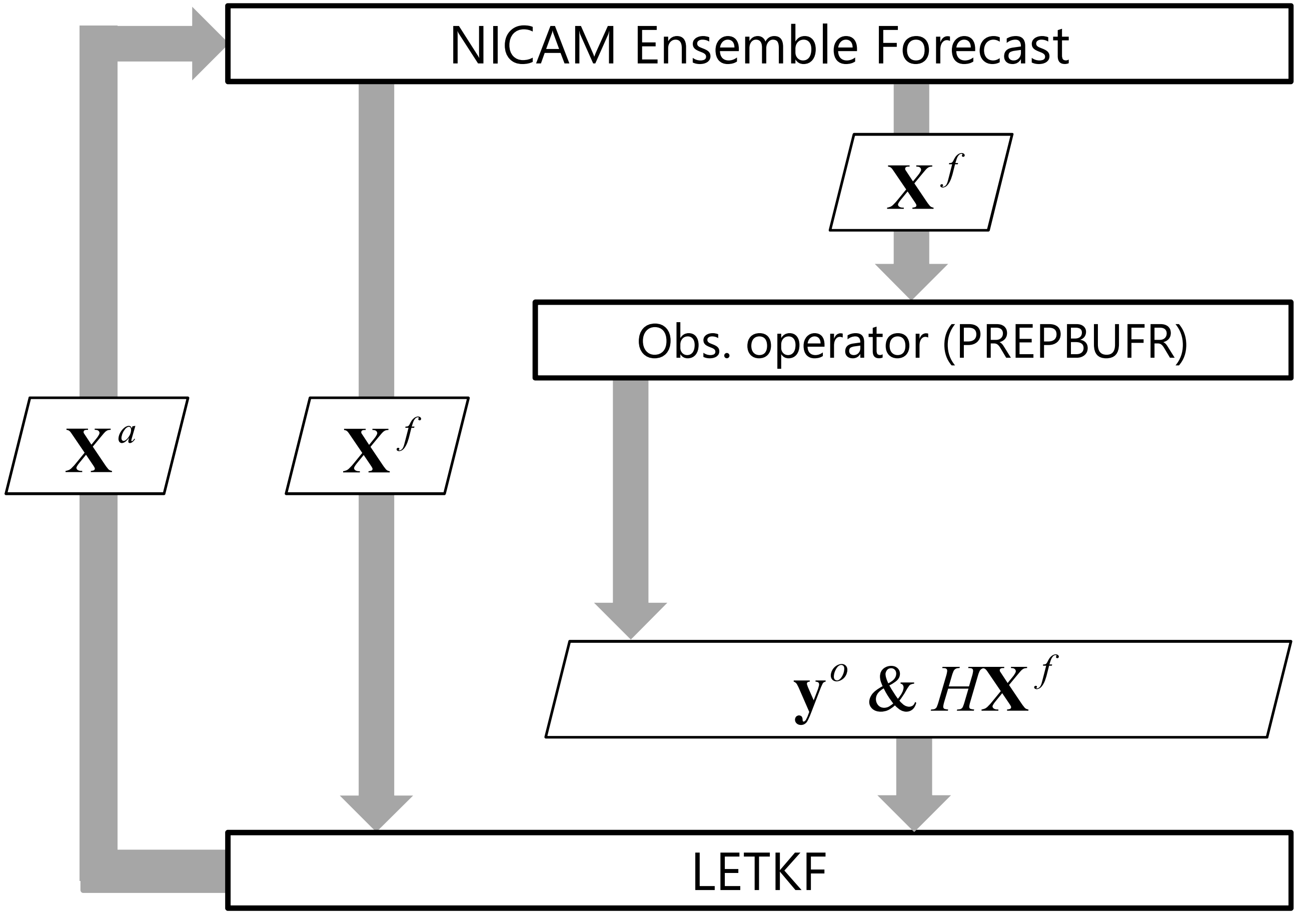
Assimilation of GSMaP by NICAM-LETKF

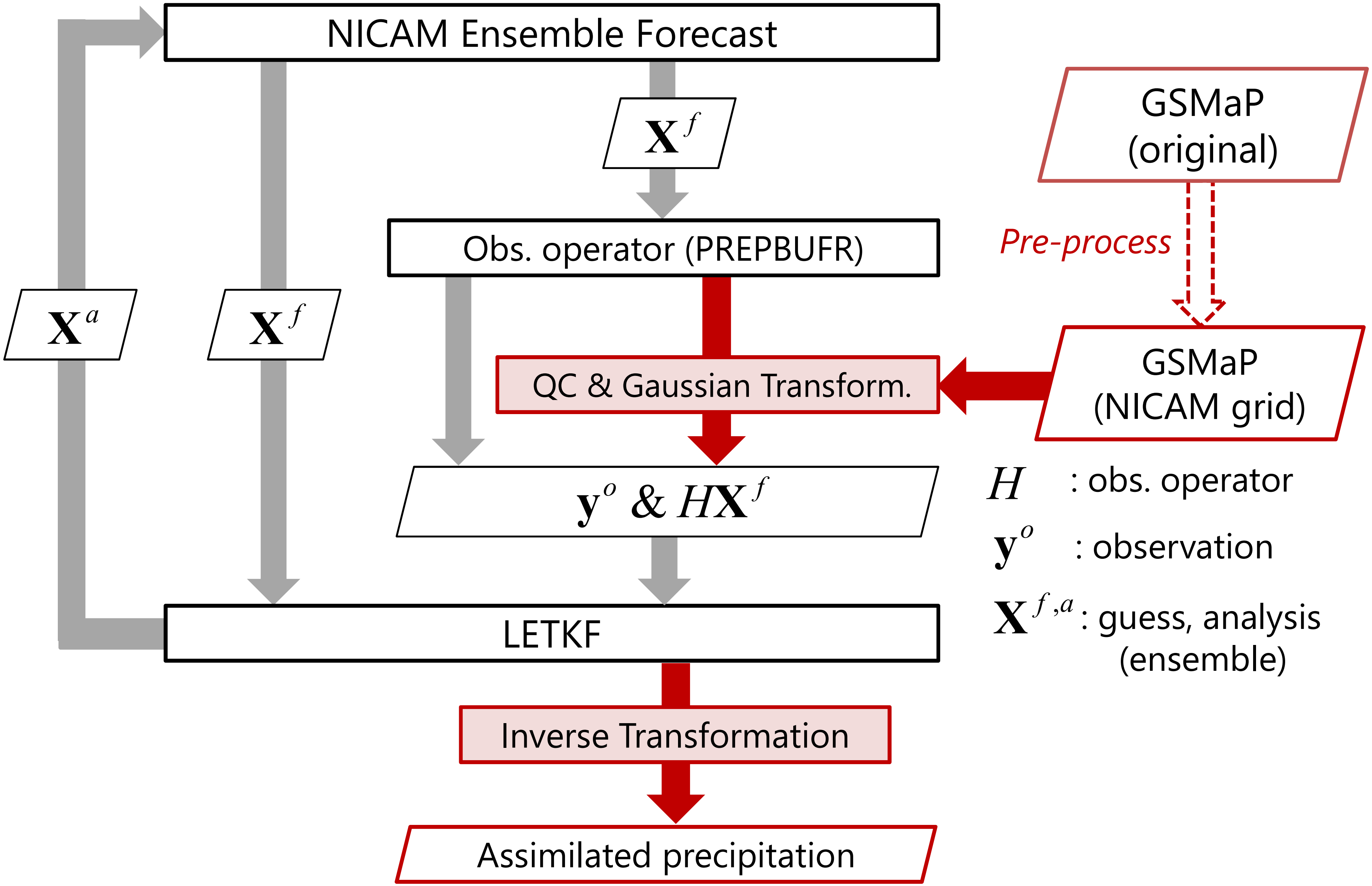


H : obs. operator

$\mathbf{y}^o$: observation

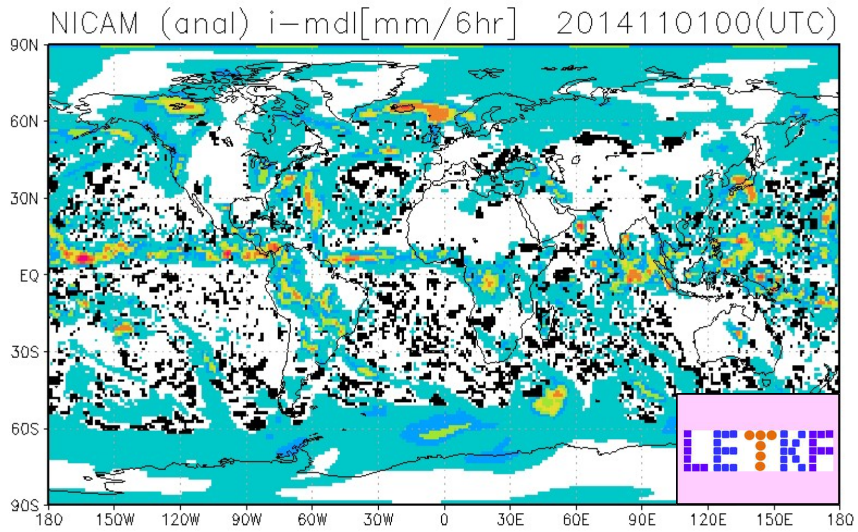
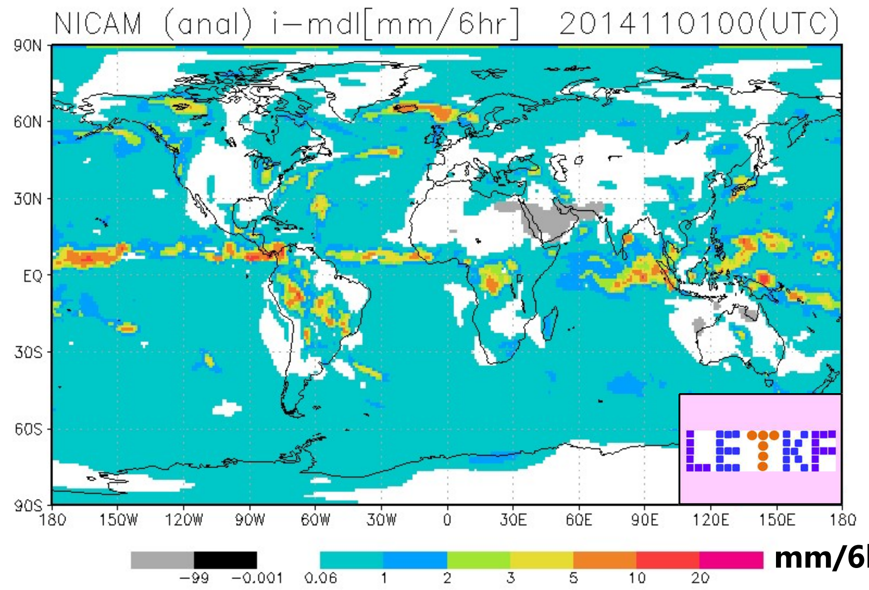
$\mathbf{X}^{f,a}$: guess, analysis (ensemble)

Assimilation of GSMaP by NICAM-LETKF



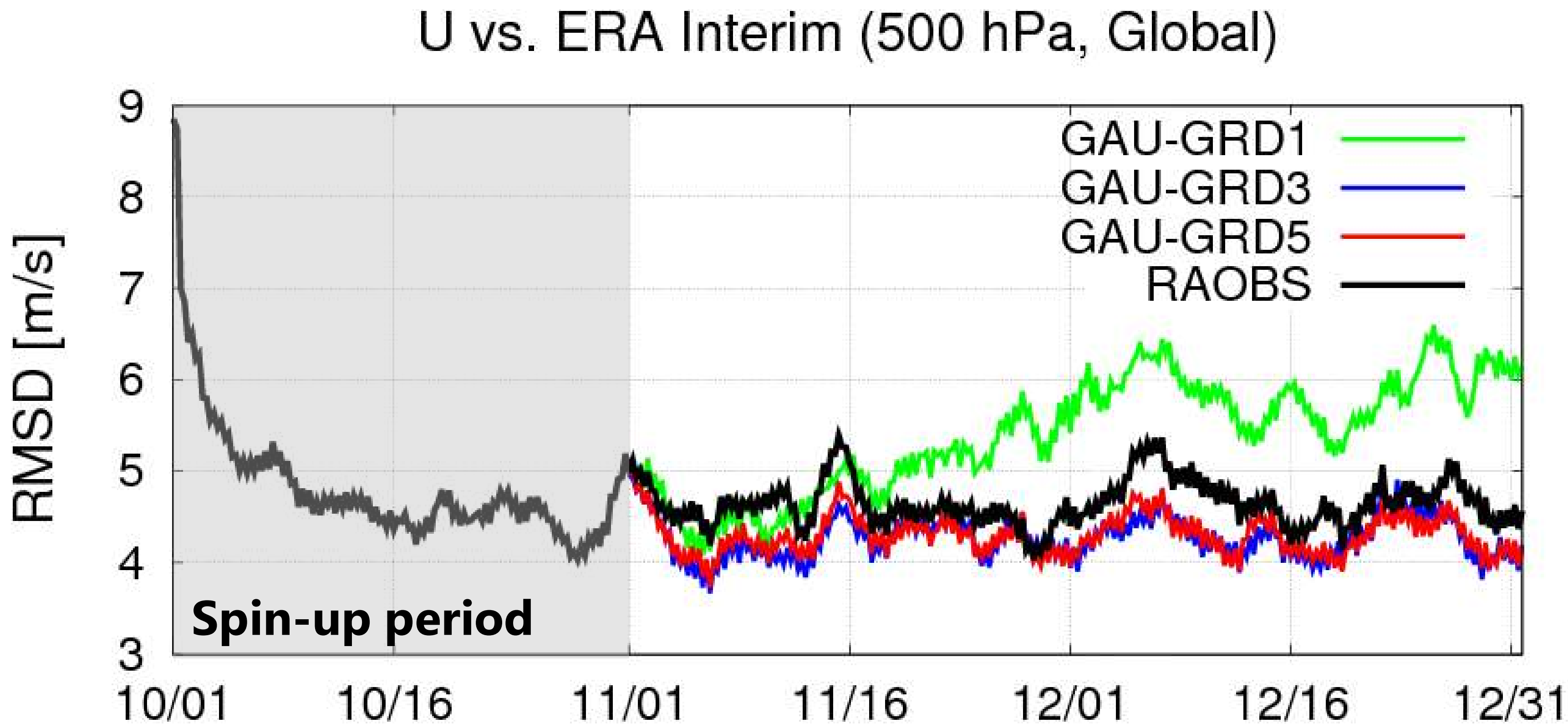
Precipitation after the first analysis

Noisy field w/ negative values

No-Transform (NT)	
Gaussian-Transform (GT)	

mm/6hr

RMSDs relative to ERA Interim (in 2014)



—: Raobs: Radiosondes ONLY

—: GRD1: Radiosondes + GSMaP/Gauge (ALL)

—: GRD3: Radiosondes + GSMaP/Gauge (every 3x3 grids)

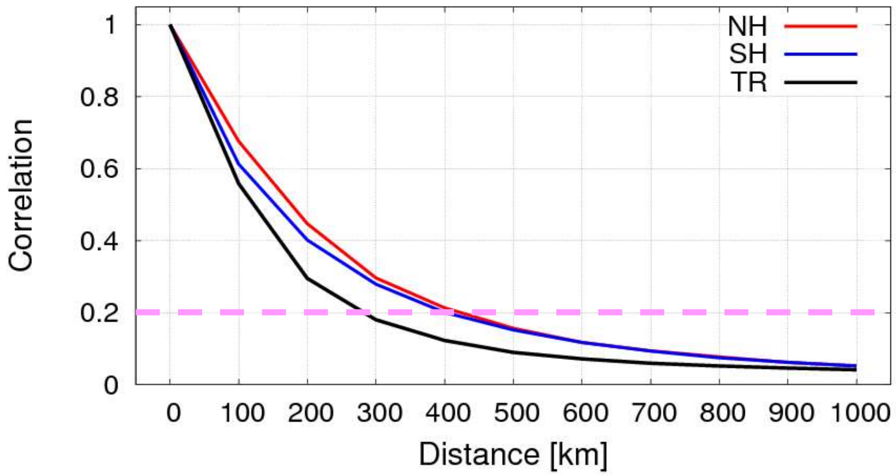
—: GRD5: Radiosondes + GSMaP/Gauge (every 5x5 grids)

Desrozier's diagnostics (for precip. obs)

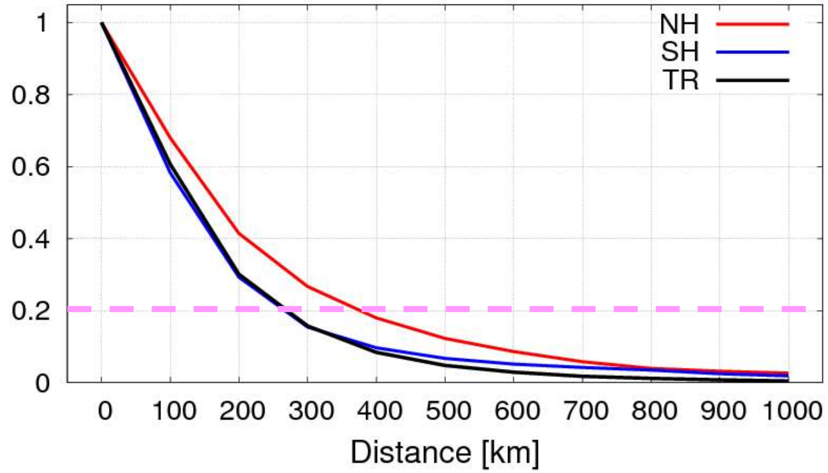
$$\mathbf{R} = \left\langle \mathbf{d}^a \left(\mathbf{d}^b\right)^{\mathbf{T}} \right\rangle \qquad \mathbf{d}^{a(b)} = \mathbf{y}^o - H\mathbf{x}^{a(b)}$$

Desroziers et al. (2005)

Horizontal correlations (ocean)



Horizontal correlations (land)



NOTE: Diagnosed with suboptimal experiment GRD1
2014/12/01 – 2014/12/31

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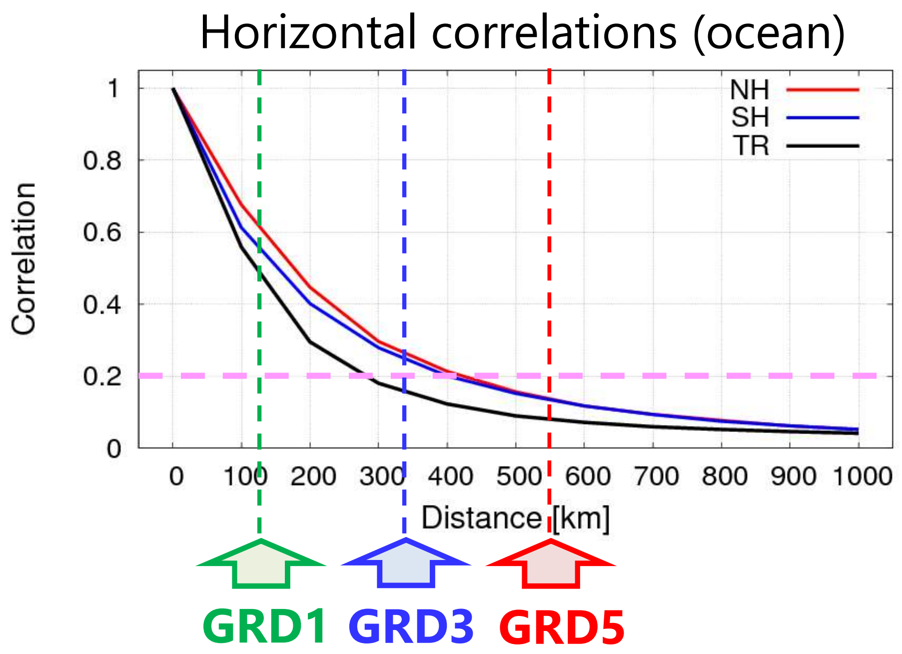
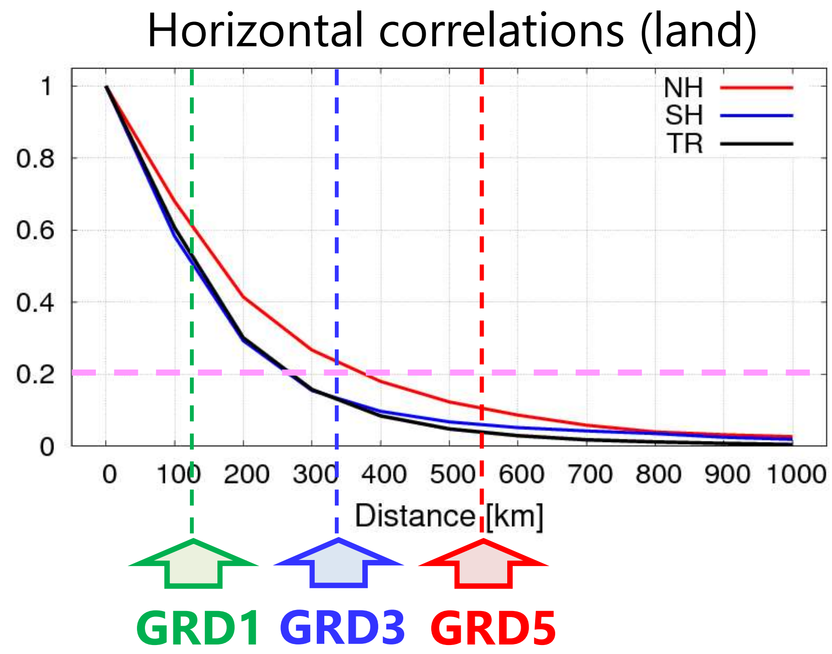


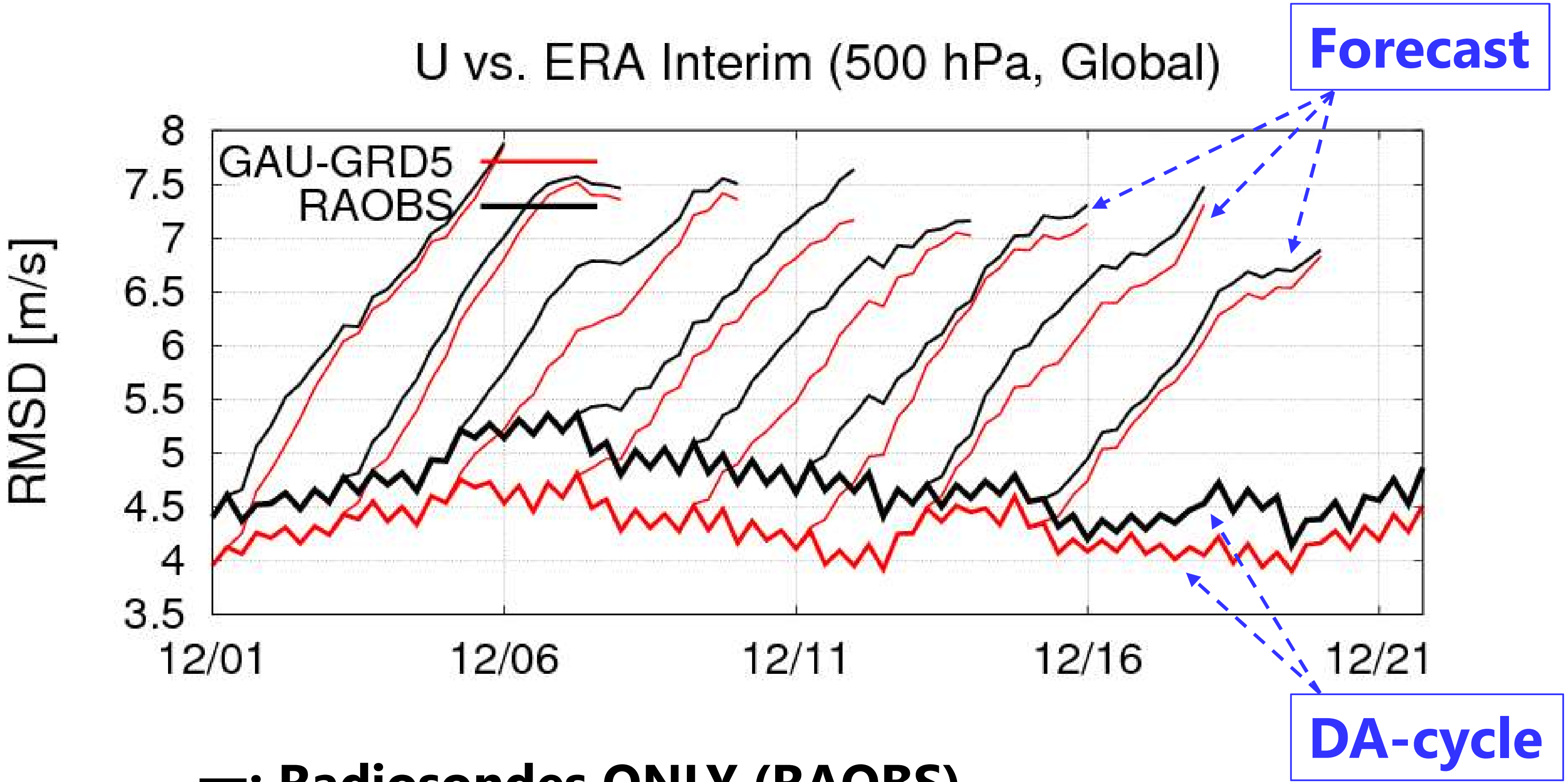


Strong horizontal correlation !!!

NOTE: Diagnosed with suboptimal experiment GRD1

2014/12/01 – 2014/12/31

RMSDs: 120h Forecasts vs. ERA Interim



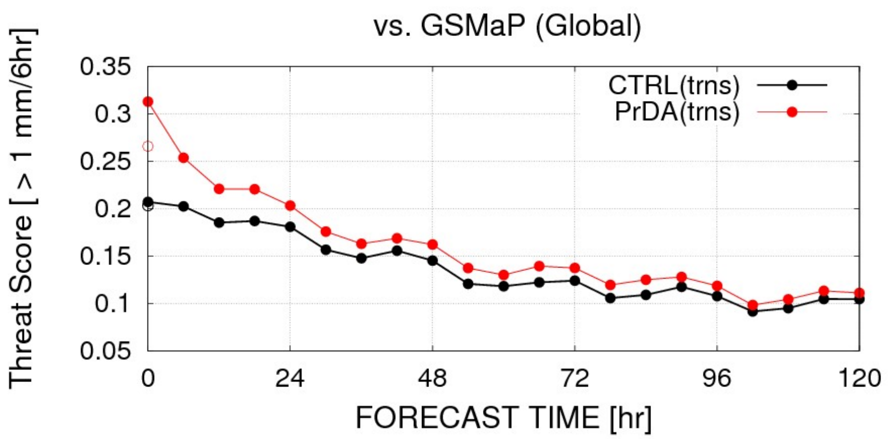
—: Radiosondes ONLY (RAOBS)

—: Radiosondes + GSMaP/Gauge (GRD5)

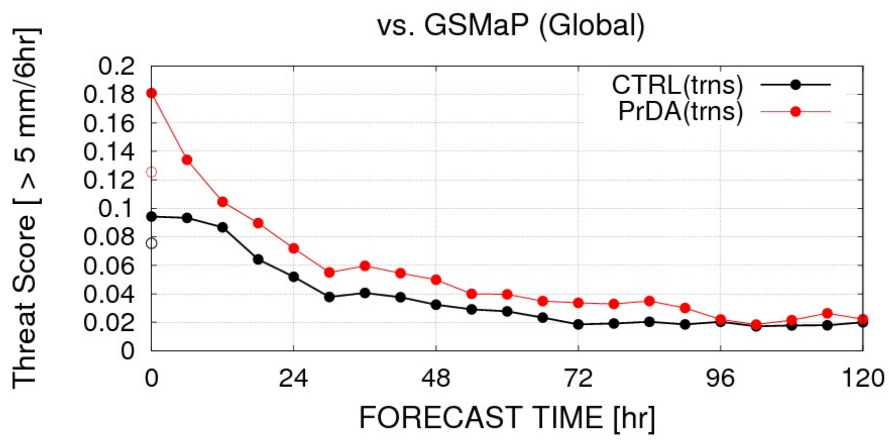
Validation with mean of ensemble forecasts from different initial dates

RMSDs: 120 hr Forecasts vs. GSMaP/Gauge

Threat Score (≥ 1 mm/6hr)



Threat Score (≥ 5 mm/6hr)



—: Radiosondes ONLY (RAOBS)

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Precipitation forecasts are improved !!!

Average over 8 ensemble forecasts from different initial dates

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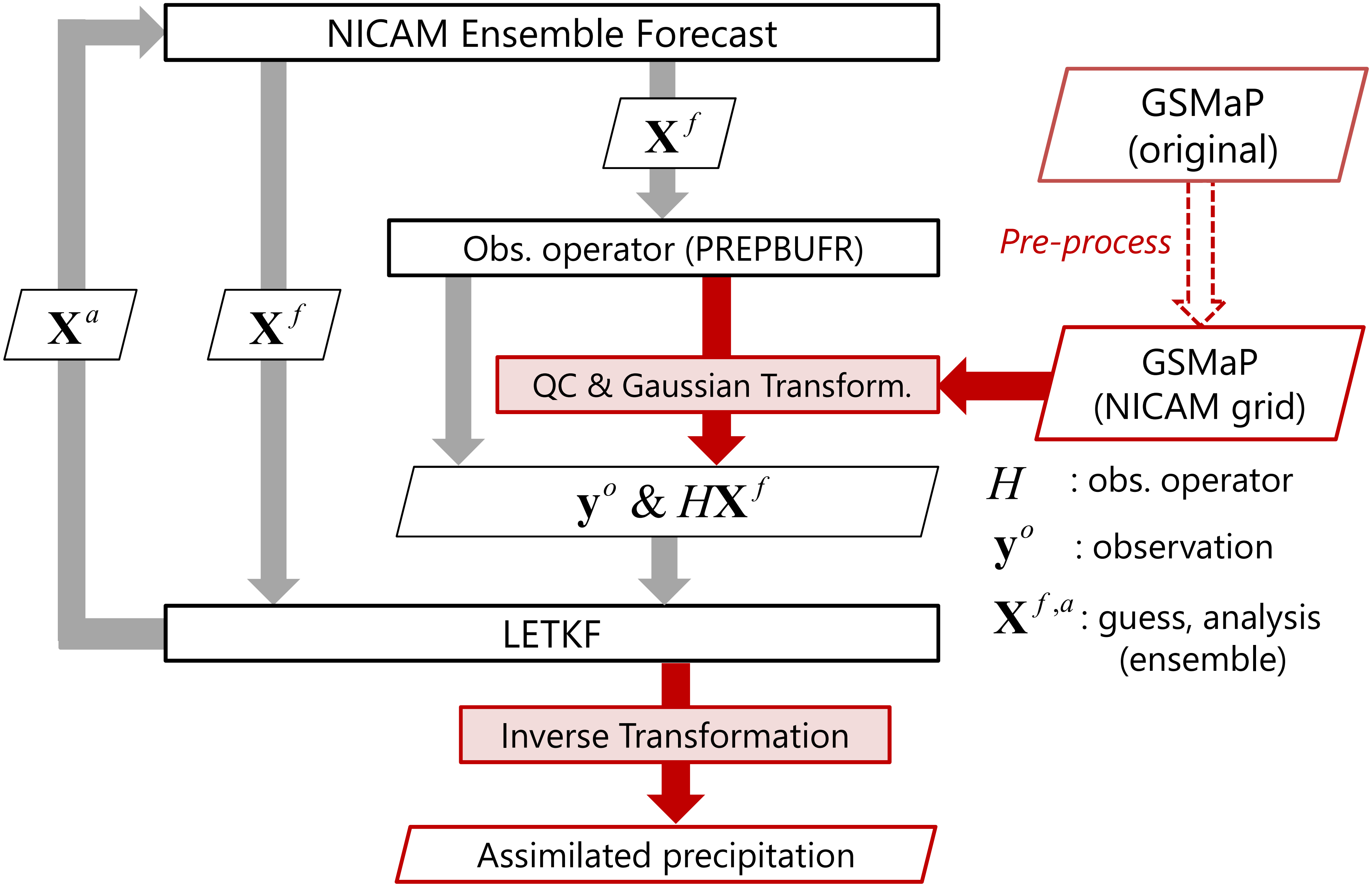
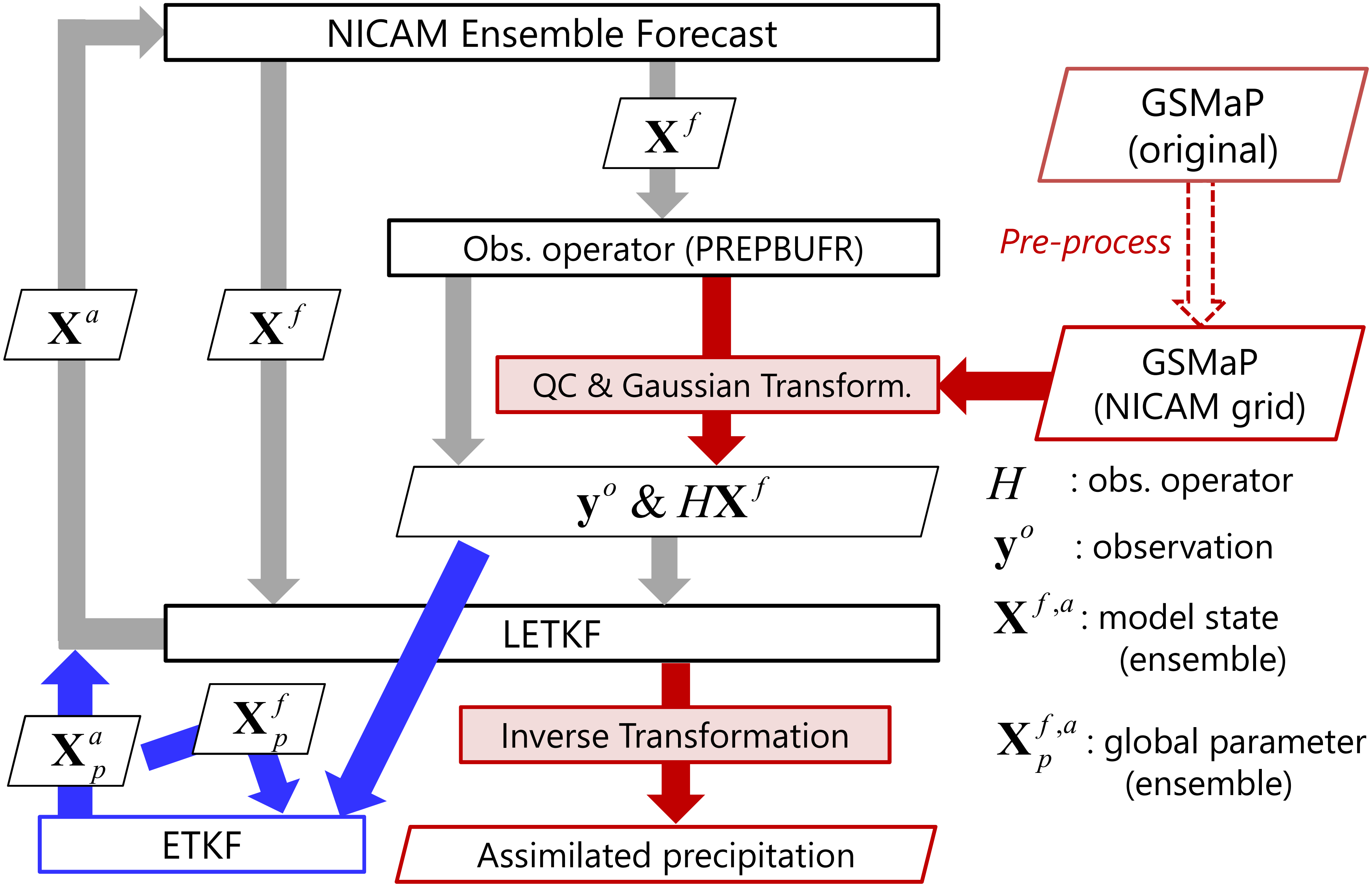


Parameter estimation by NICAM-LETKF

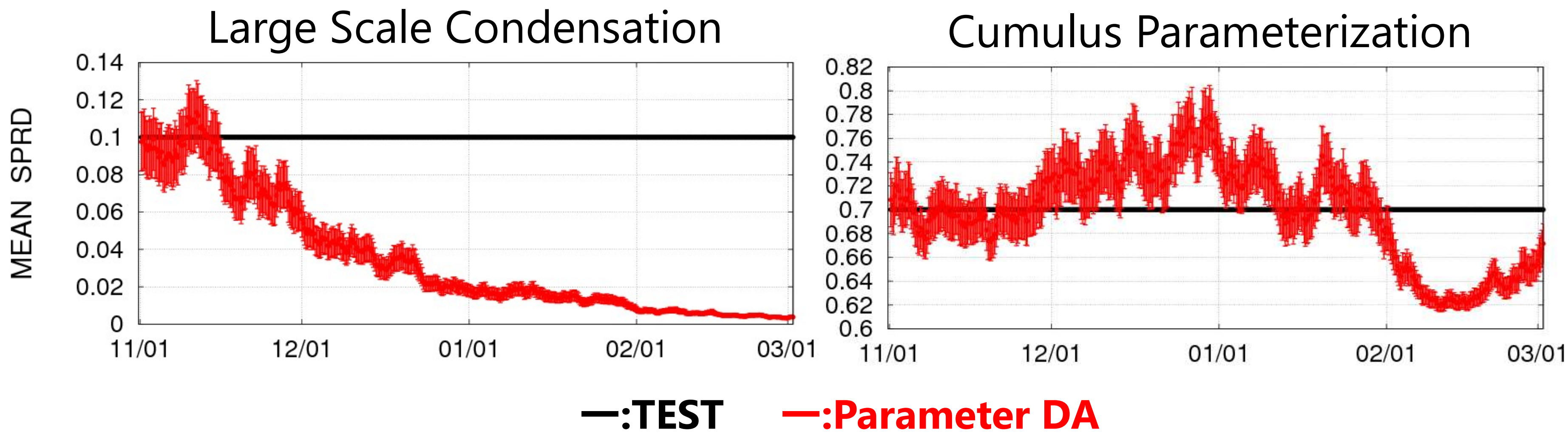


Parameter Estimation with ETKF

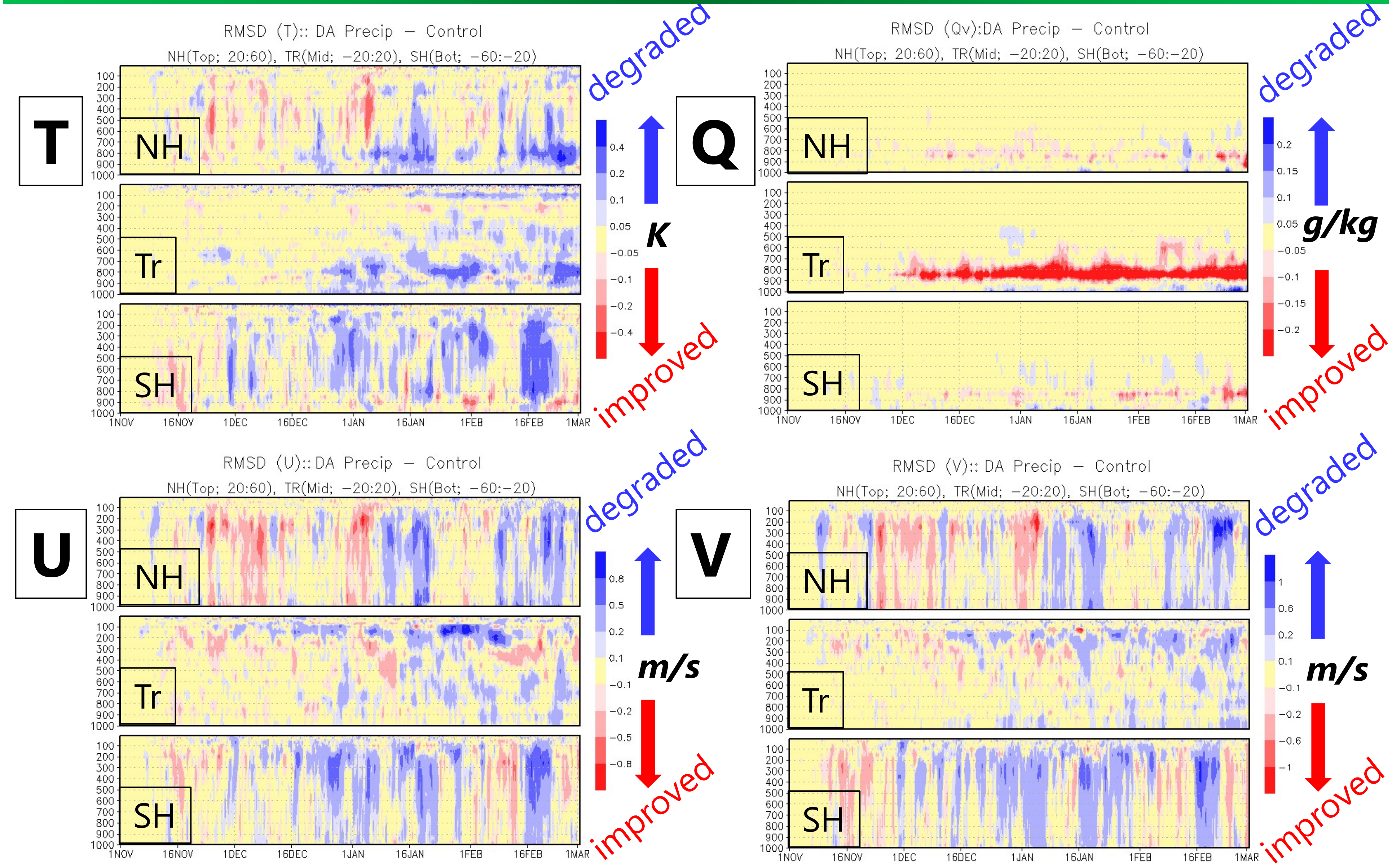
Experimental setting

Experiment	Parameters	
	Large Scale Condensation	Cumulus Parameterization
TEST	0.10	0.70
Parameter DA	**Estimated**	**Estimated**

Time series of estimated parameter (mean and spread)



Change in RMSD relative to TEST experiment



RMSD (Parameter DA) — RMSD (TEST)

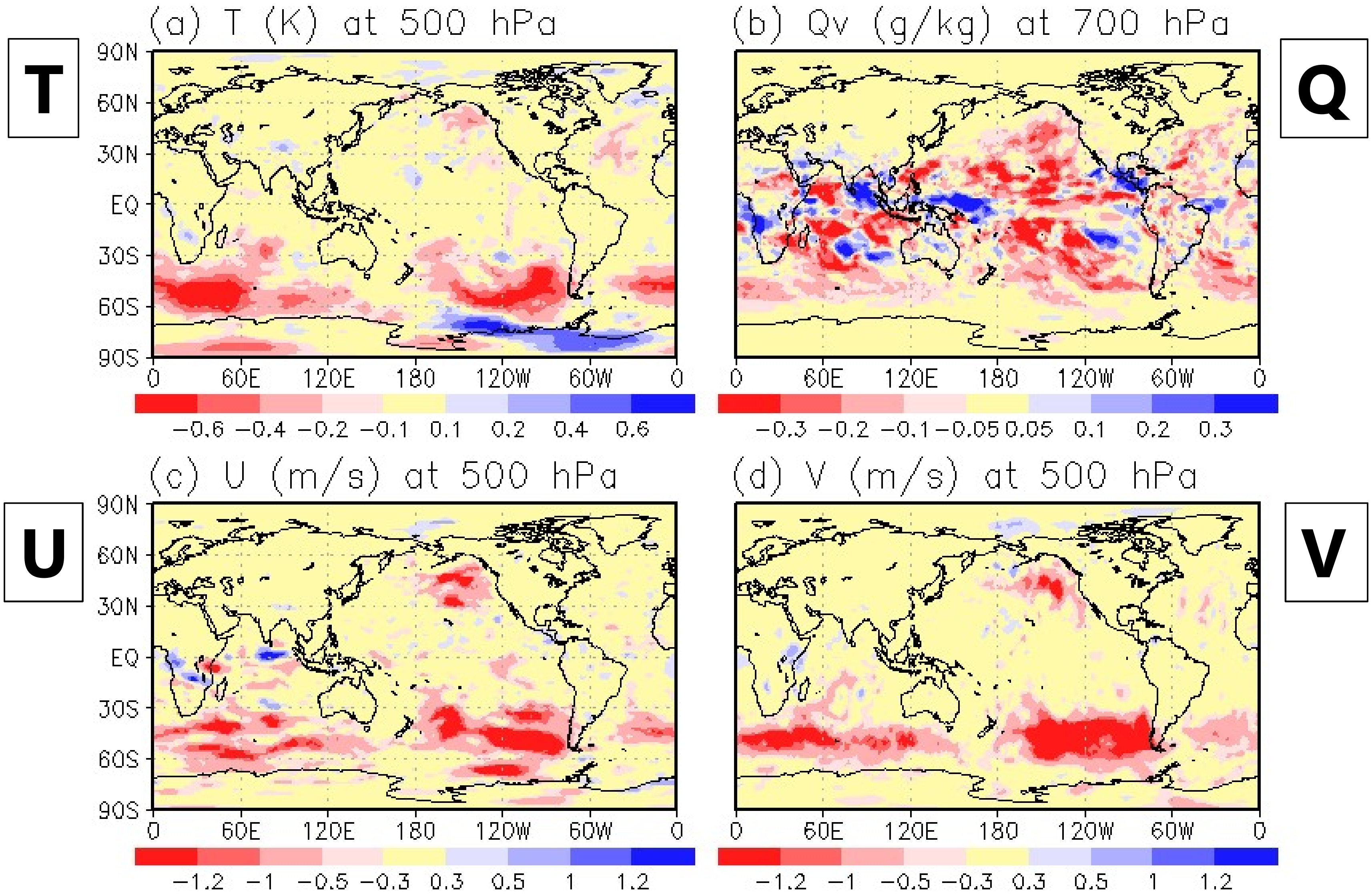
Summary

- Assimilating GSMaP precipitation with NICAM-LETKF
  - Lien et al. (2016a, 2016b) approach works well
  - New methods
    - Construction of flow-dependent PDF/CDF
    - Inverse GT to produce realistic precip. field from forecasts
  - Observation data thinning was essential
    - Horizontal obs. error correlation of precipitation
  - Parameter estimation
    - Estimate as globally-distributed parameters
    - Forecast experiments

APENDIX

Best experiments (MAE changes)

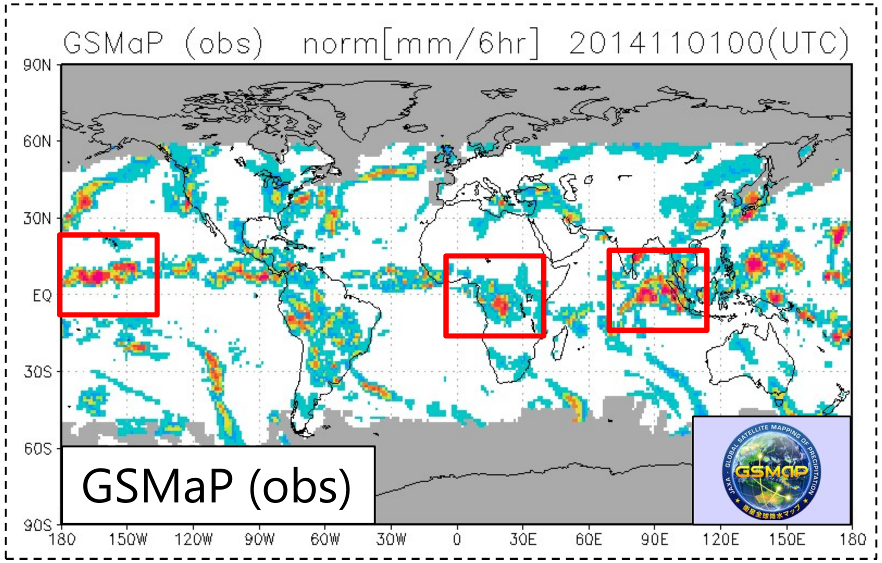
45-days average (2014/11/17-2014/12/31)

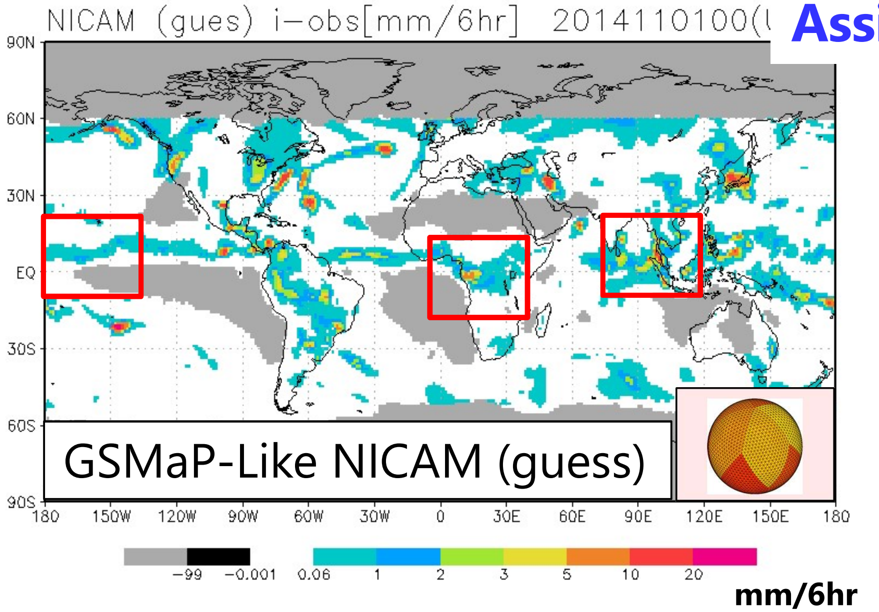


improved ← **MAE (GRD5) — MAE (Raobs)** → *degraded*

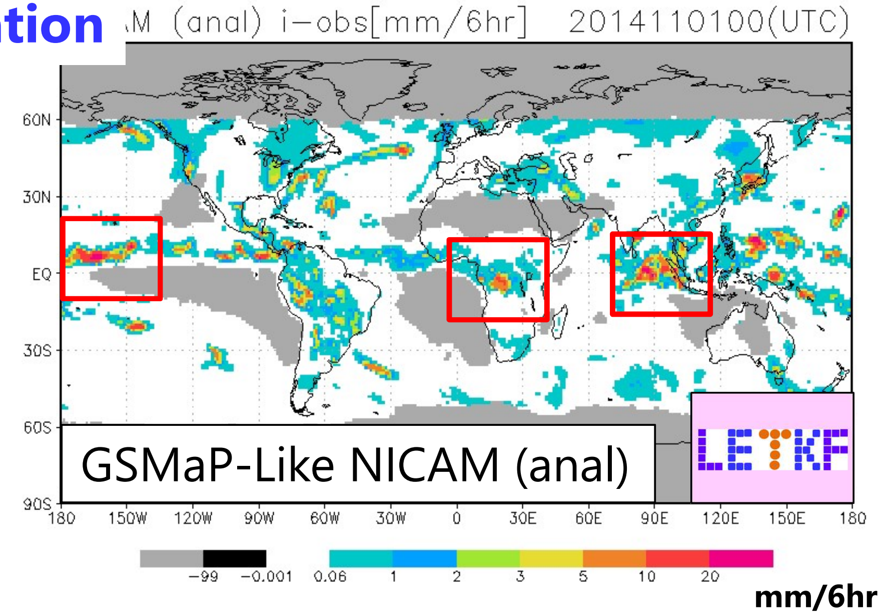
Precipitation after the first analysis

Improvement in precipitation field

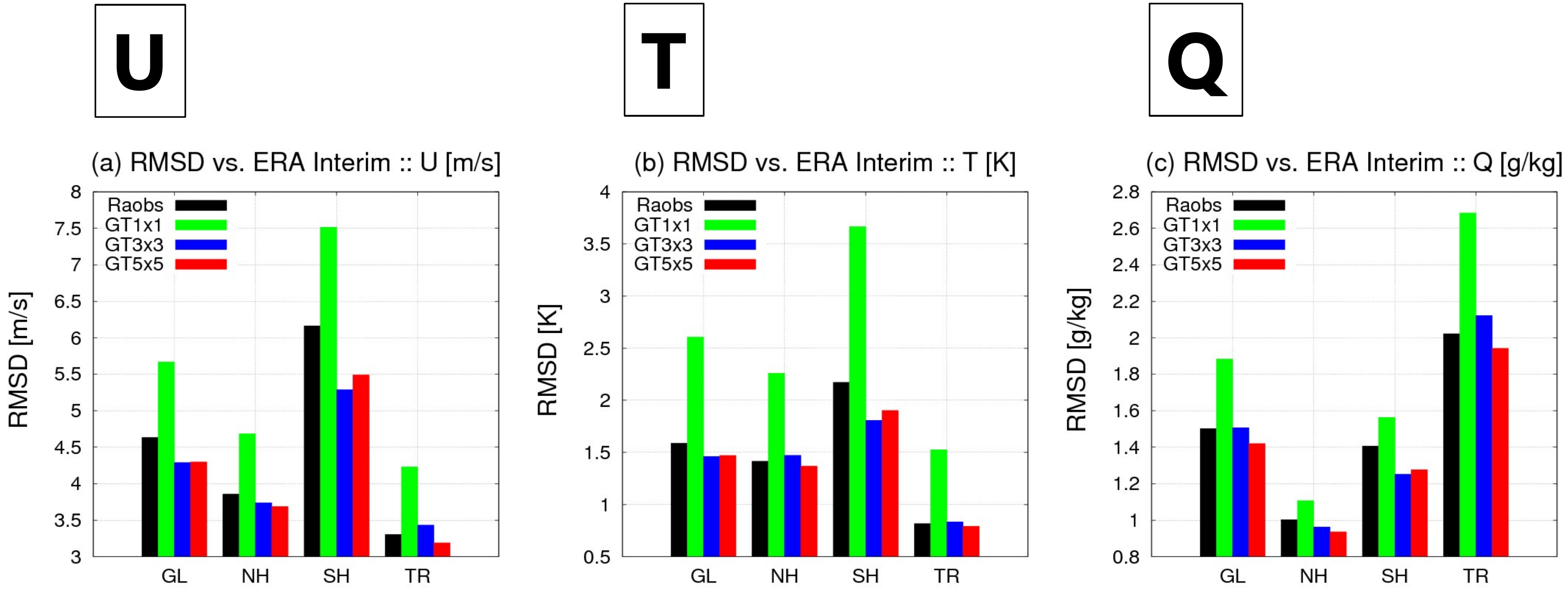




Assimilation



Sensitivity to thinning



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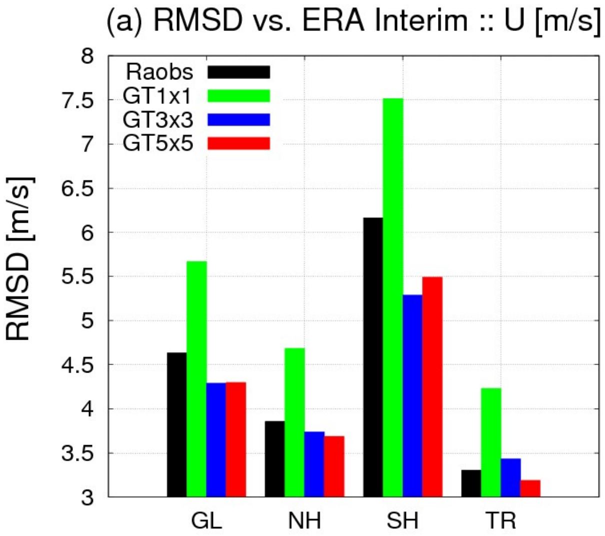
Sensitivity to thinning

U



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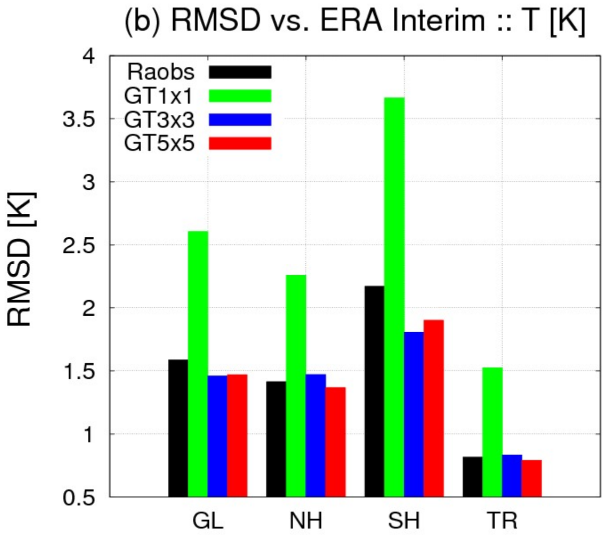

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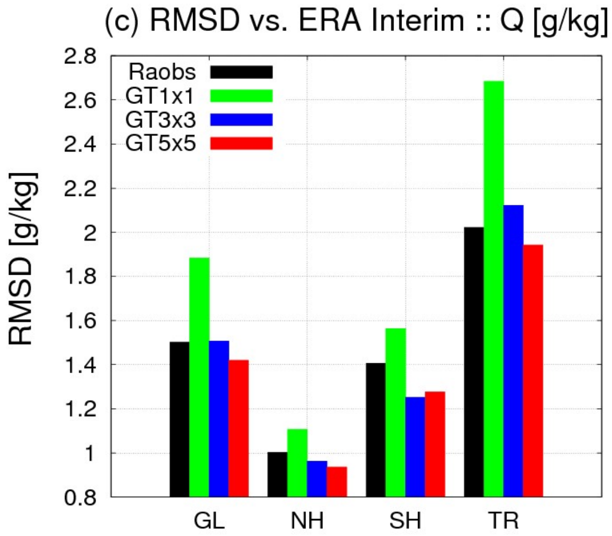

GRD5 always shows improvements !

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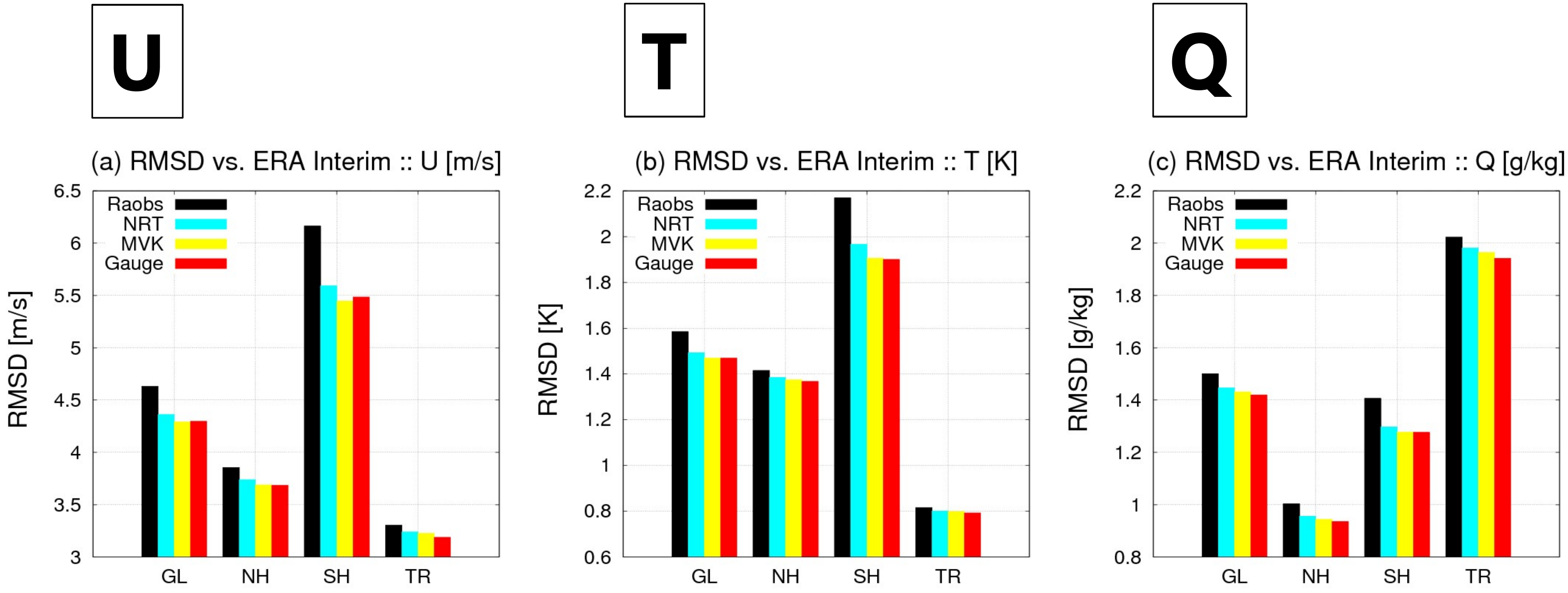
Sensitivity to GSMaP products (w/ 5x5 thinning)



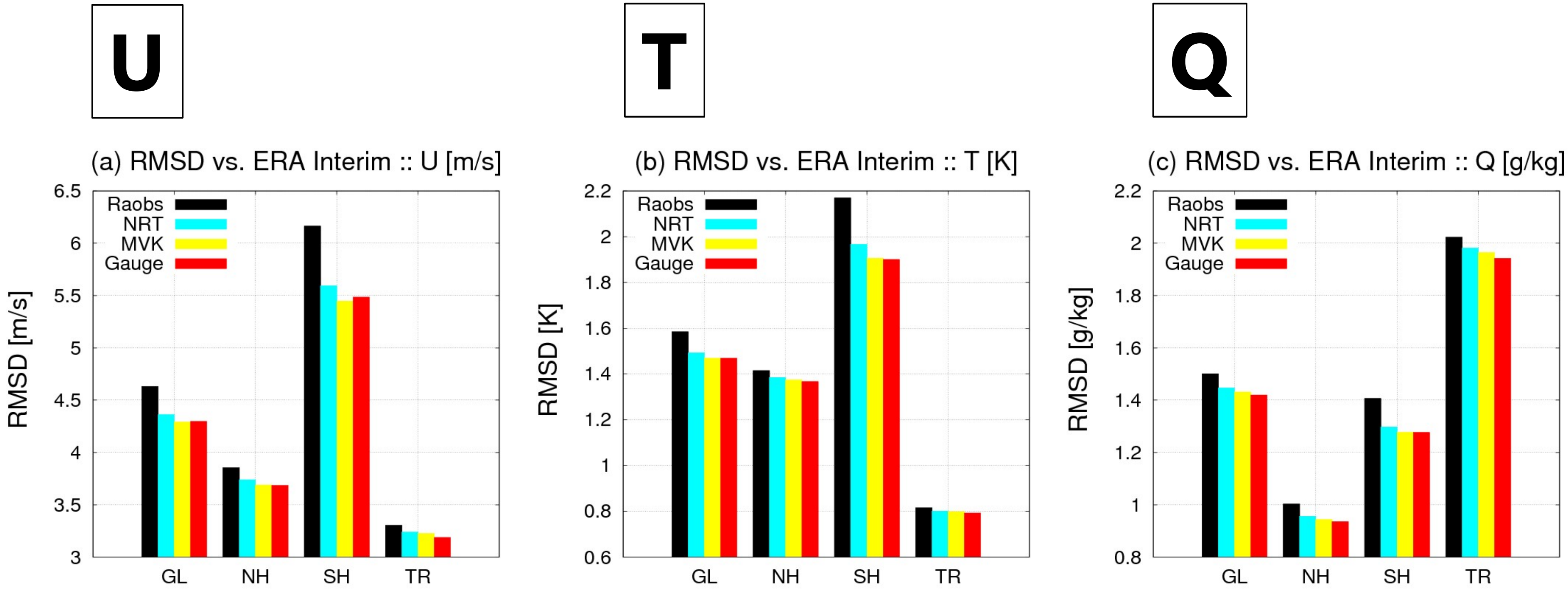
—: **Raobs:** **Radiosondes ONLY**

—: **NRT:** **Radiosondes + GSMaP/ Near Real Time**

—: **MVK:** **Radiosondes + GSMaP/ Standard**

—: **Gauge:** **Radiosondes + GSMaP/ Gauge-calibration**

Sensitivity to GSMaP products (w/ 5x5 thinning)



Near Real Time product shows improvements !

—: **Raobs:** **Radiosondes ONLY**

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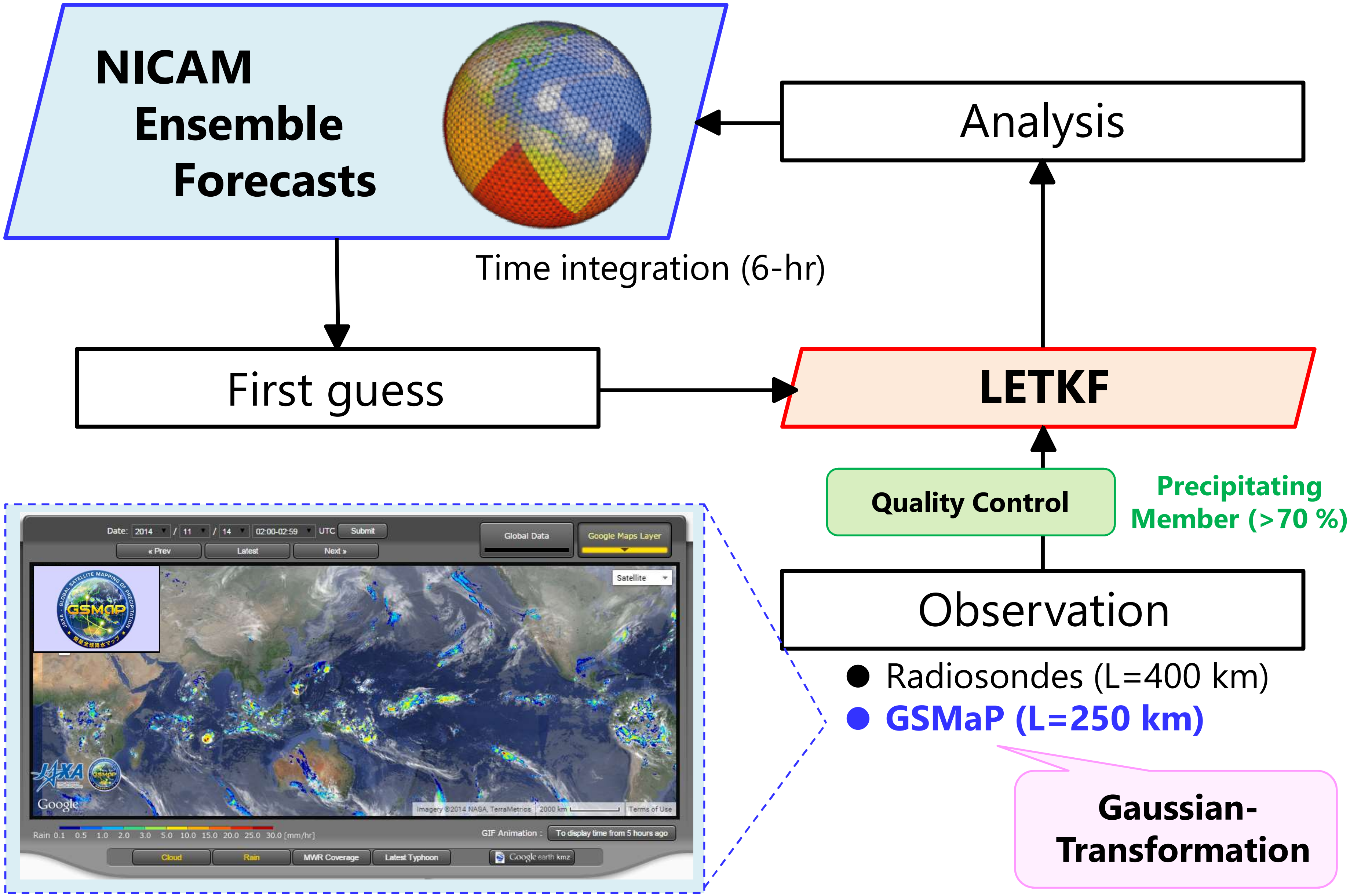
- DA-cycle experiments
- Forecast experiments
- Parameter estimation
- Summary

Assimilating GSMaP with NICAM-LETKF



Gaussian Transformation

$$F^G(\tilde{y}) = F(y) \quad \Leftrightarrow \quad \tilde{y} = F^{G^{-1}}\left[F(y)\right] \quad \Leftrightarrow \quad y = F^{-1}\left[F^G(\tilde{y})\right]$$

Forward transform (mm/6hr→sigma) — Inverse transform (sigma→mm/6hr)

y : original variable (mm/6hr)

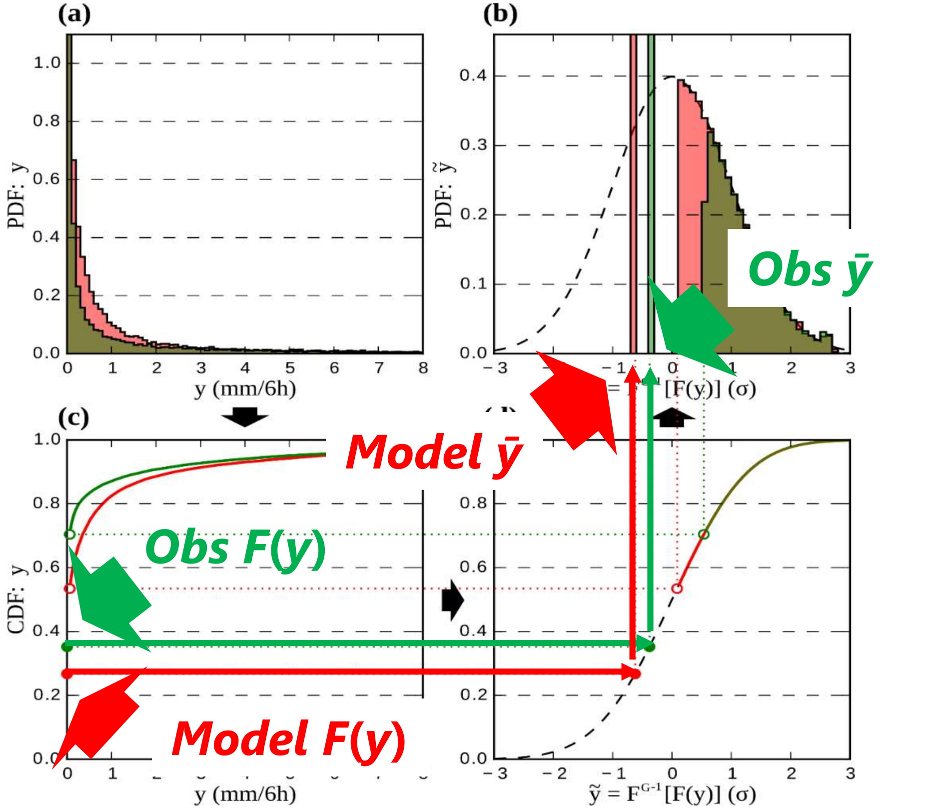
$\tilde{y}$: Transformed variable (sigma)

$F()$: CDF of original variable

$F^G()$: CDF of Gaussian distribution

PDF

CDF



Original variable **Transformed variable**

—: **Model**
—: **Obs.**

Step 0: Obtain PDF & CDF

Step 1: Compute $F(y)$

Step 2: Compute

$$\tilde{y} = F^{G^{-1}}\left[F(y)\right]$$

Lien et al. (2013, 2016)