# Impact of Gaussian transformation on cloud cover data assimilation for historical weather reconstruction

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## 1. Introduction

- ✓ **Old diaries** recorded historical weather conditions.
- ✓ These records are useful to reconstruct historical weather **before modern instrumental measurements**.
- ✓ **Data assimilation** is widely used to optimally combine various observations with climate models.
- ✓ Cloud cover can be converted from descriptive records but is difficult to be assimilated because of its **non-Gaussian characteristic**.

**Q: How to optimally assimilate cloud cover to achieve historical weather reconstruction?**

## 2. Methods

◆ **Model – Global spectral model (GSM):**

- **Resolution:**
  6-hour; 192[lon]*94[lat]*28[level]
- **Variables:**
  **3D**: wind speed, air temperature, humidity
  **2D**: cloud cover, solar radiation, surface pressure, precipitation

◆ **Data assimilation – Local Ensemble Transform Kalman Filter (LETKF):**

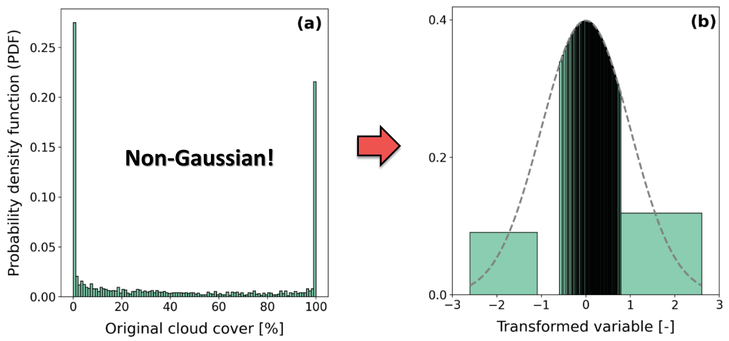
$$\boldsymbol{x}_a = \boldsymbol{x}_b + \boldsymbol{B}\boldsymbol{H}^T(\boldsymbol{R} + \boldsymbol{H}\boldsymbol{B}\boldsymbol{H}^T)^{-1}(\boldsymbol{y} - \boldsymbol{H}\boldsymbol{x}_b)$$

$\boldsymbol{x}_a$: analysis state vector; $\boldsymbol{x}_b$: model background state vector; $\boldsymbol{B}$: background error covariance matrix; $\boldsymbol{R}$: observation error covariance matrix; $\boldsymbol{H}$: observation operator; $\boldsymbol{y}$: observation vector

$\boldsymbol{B}$: {total cloud cover; U, V, T, Q, cloud, precipitation, surface pressure, solar radiation, etc.}

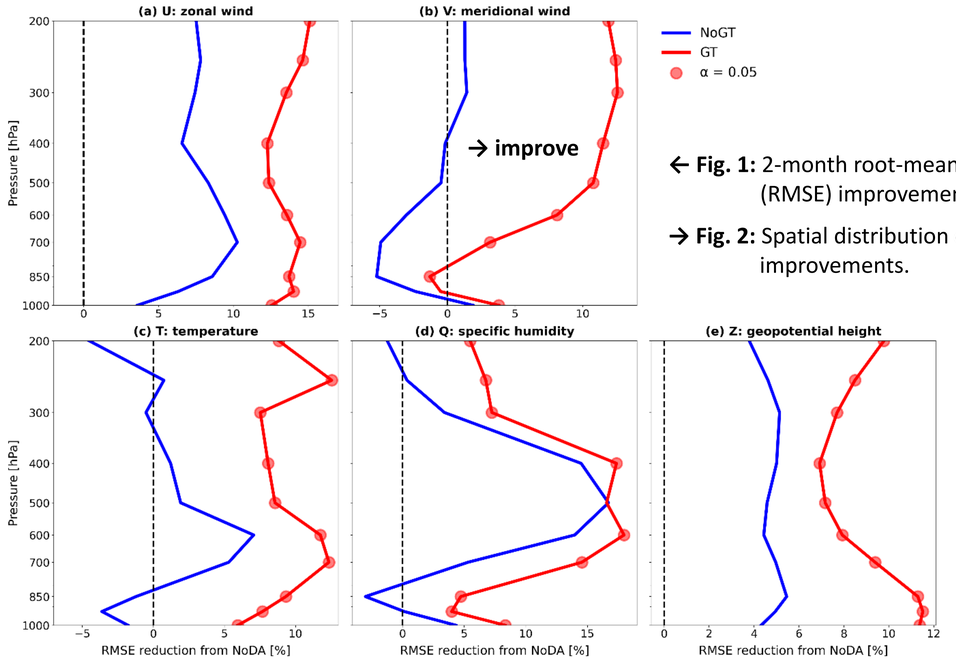
◆ **Gaussian transformation (GT):**

$$\text{cloud}_{\text{trans}} = \text{G}^{-1}[\text{CDF}_{\text{orig}}] = \sqrt{2}\,\text{erf}^{-1}(2*\text{CDF}_{\text{orig}}\text{-}1)$$




- **GT** of original cloud cover
  → **more Gaussian climatological distribution**
  → more Gaussian error distribution

## 3. Results




← **Fig. 1:** 2-month root-mean-square error (RMSE) improvement profiles.

→ **Fig. 2:** Spatial distribution of temperature improvements.

More details ↓

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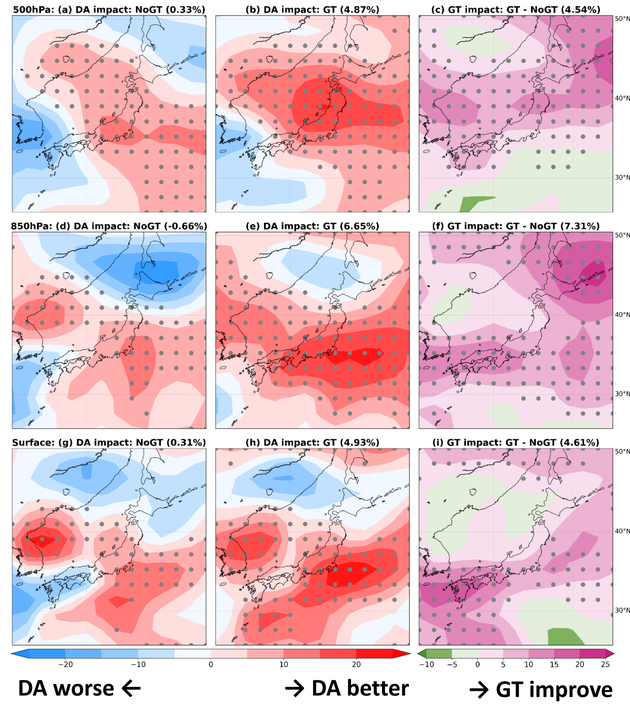
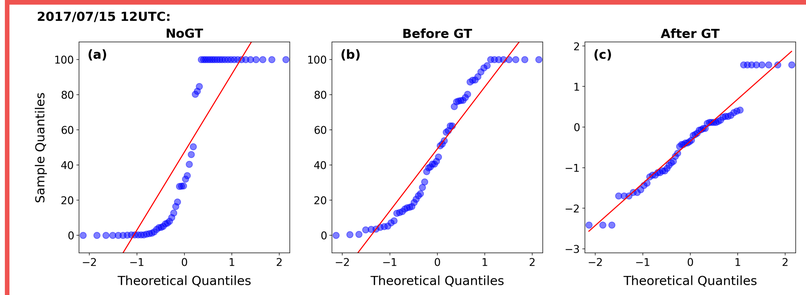
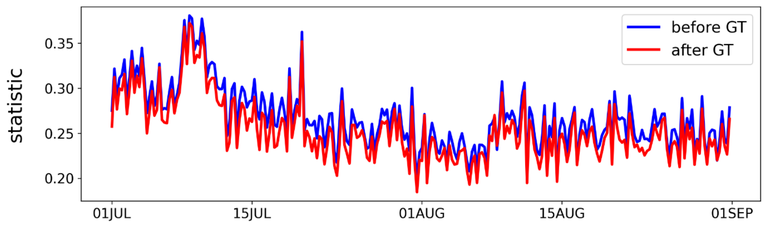
- **Temperature**



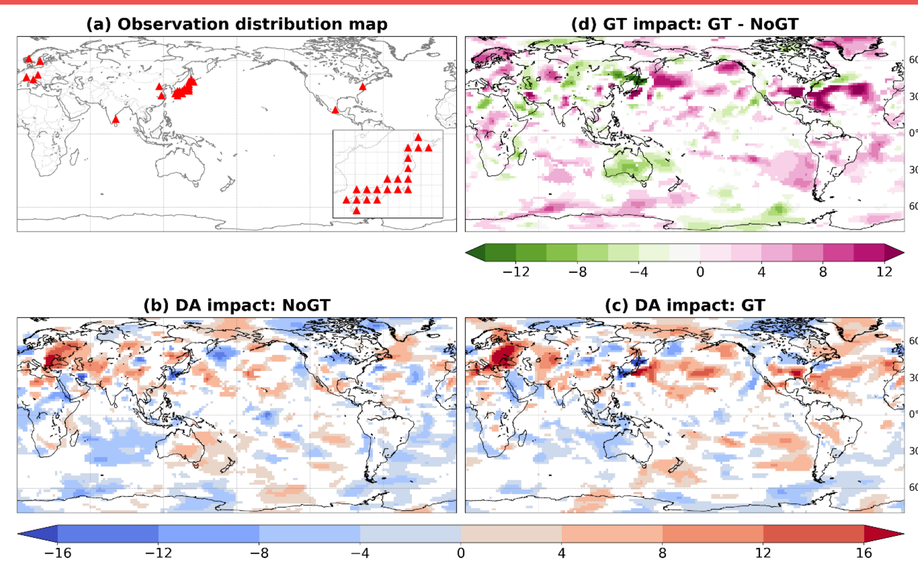

## 4. Discussion




↑ **Fig. 3:** QQ-plot of cloud cover ensembles in the first guess.




↑ **Fig. 4:** Time series of regionally averaged statistic by KS test from cloud cover ensembles in the first guess background field before GT (blue line) and after GT (red line).




↑ **Fig. 5:** Horizontal distributions of DA impact and GT impact on 850 hPa temperature estimation. All colored grid points show statistical significance at the 1% level.

## 5. Conclusion

✓ **Gaussian transformation (GT) transforms the original cloud cover into a normal distribution shape, improving cloud cover assimilation accuracy. Results demonstrate the potential of GT in high-resolution historical weather reconstruction using old descriptive diaries.**