天気記録のデータ同化による20世紀の大気場の復元

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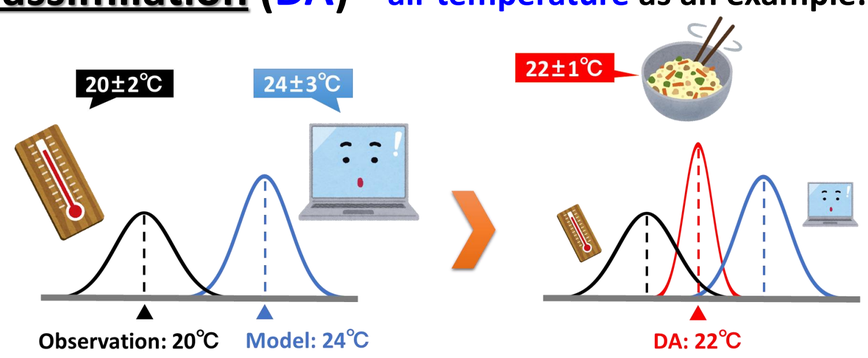
Key issue: How to get accurate weather data from descriptive information in ancient diaries?

- ✓ **Old diaries** record historical weather conditions.
- ✓ These records can be used to reconstruct weather **before instrumental measurements available**.
- ✓ **Data assimilation** is widely used because it can optimally combine observation with climate models.
- ✓ Cloud cover can be converted from the descriptive records but is difficult to assimilate because of its **non-Gaussian characteristic**.

- Method -

◆ Data assimilation (DA) – air temperature as an example:



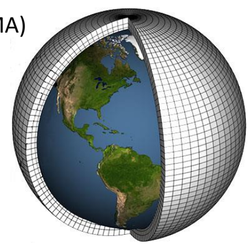
Local ensemble transform Kalman filter (LETKF)

$$x_a = x_b + \boxed{BH^T(R + HBH^T)^{-1}}(y - Hx_b)$$

- x_a: analysis state vector
- x_b: model background state vector
- H: observation operator
- R: observation error covariance matrix (total cloud cover)
- B: background error covariance matrix (U, V, T, Q, cloud, precipitation, surface pressure, solar radiation, etc.)
- y: observation vector
- $BH^T(R + HBH^T)^{-1}$: Kalman gain matrix

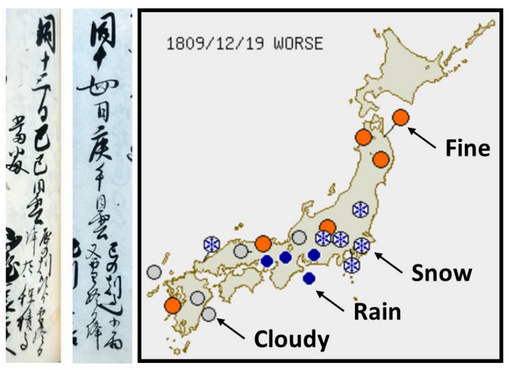
◆ Model – Global spectral model (GSM):

(Source: JMA)



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

◆ Observation – Historical weather database (HWDB)



(Source: Hirosaki office diary)
Accessible from: http://tk2-202-10627.vs.sakura.ne.jp

Descriptive weather information:
"Fine", "cloudy", "rain", "snow", etc.

Weather **category**:
1-sunny, **2**-cloudy, **3**-rainy

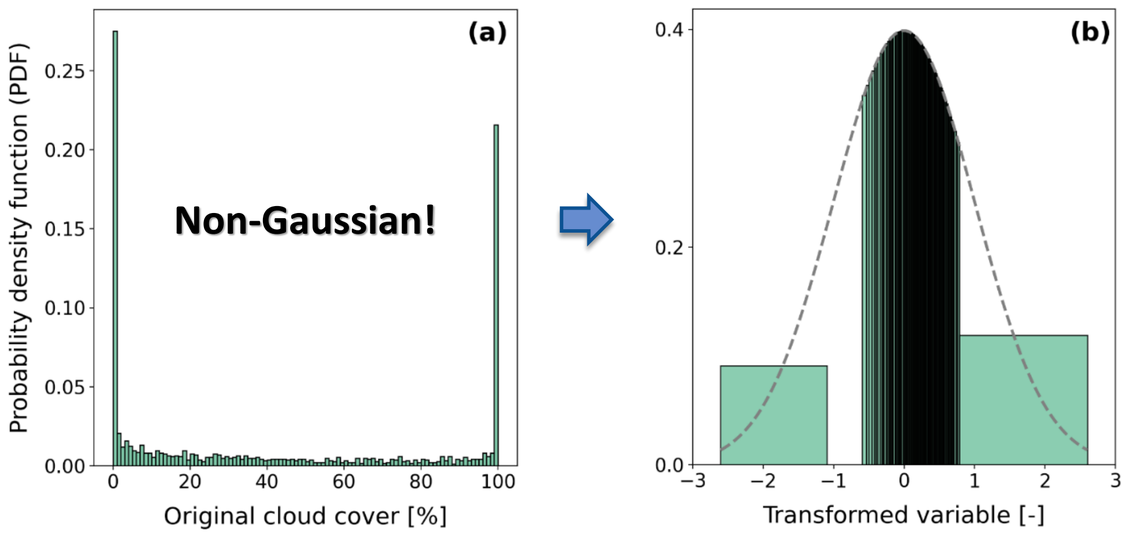
Total cloud cover: **0% - 100%**

* For **weather category**, please also refer to **Poster B-6**.

- **Descriptive diary-based records** are firstly grouped into **three weather categories**, and then converted into the number of **total cloud cover values**.

◆ Gaussian transformation (GT)

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



- **GT** process is based on the **equivalent relationship of cumulative distribution functions** (CDFs) between the original total cloud cover and the transformed variable.

- Results -

◆ Performance evaluation in the idealized case

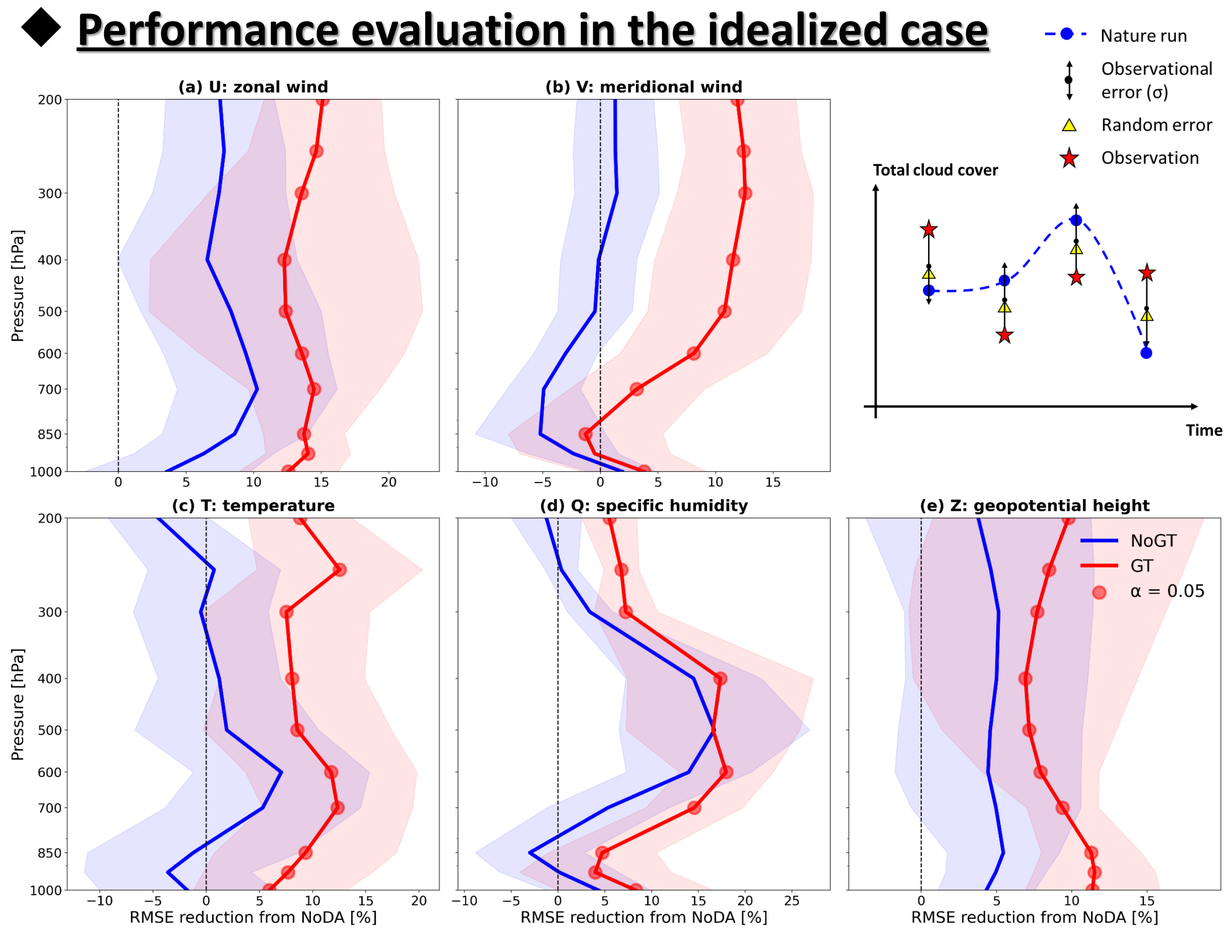


Figure1: 2-month root-mean-square error (RMSE) improvement profiles.

- Assimilating the Gaussian transformed cloud cover **improves RMSEs of both two- and three-dimensional variables**, showing the potential of GT to improve cloud cover assimilation.

◆ Practical reconstruction in 1995 winter

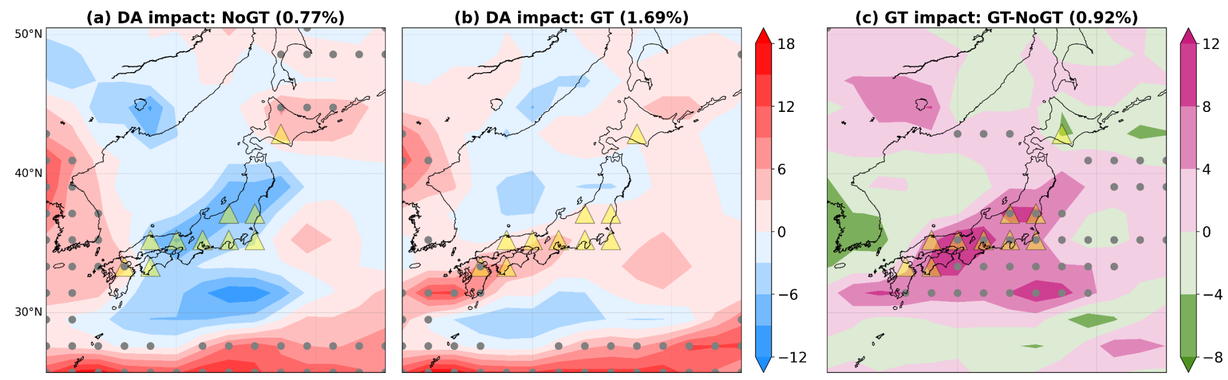


Figure 2: Precipitation improvements by NoGT/GT compared to NoDA.

day-by-day reconstruction of sea level pressure

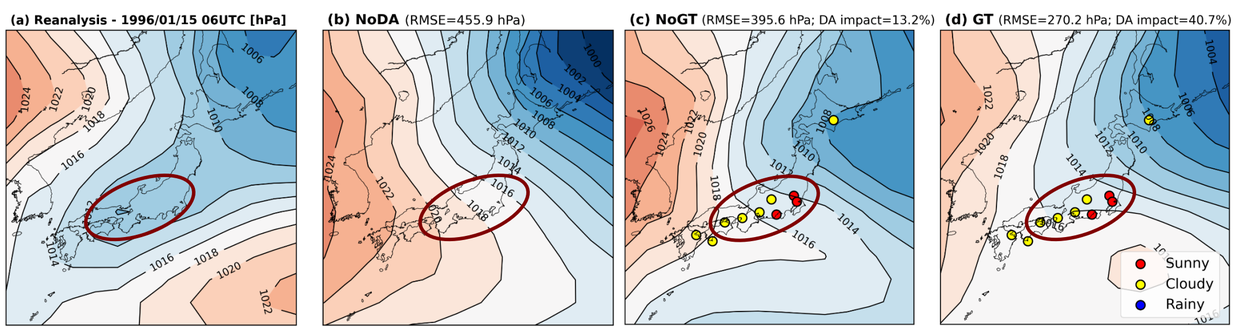


Figure 3: Maps of sea level pressure on **January 15, 1996**.

- This experiment assimilates visually observed weather conditions recorded by Japan Meteorological Agency (JMA) in the **winter of 1995**. The results are validated by **reanalysis data** and indicate that GT also improves the practical assimilation.

◆ Conclusion

- **GT** converts the descriptive information into **numerical values used in DA**.
- Assimilating weather records shows capability to reproduce **daily weather conditions before the 20th century**, and provides potential to generate a **long-term daily weather database** in the historical period.