Global precipitation nowcasting with ConvLSTM and adversarial training

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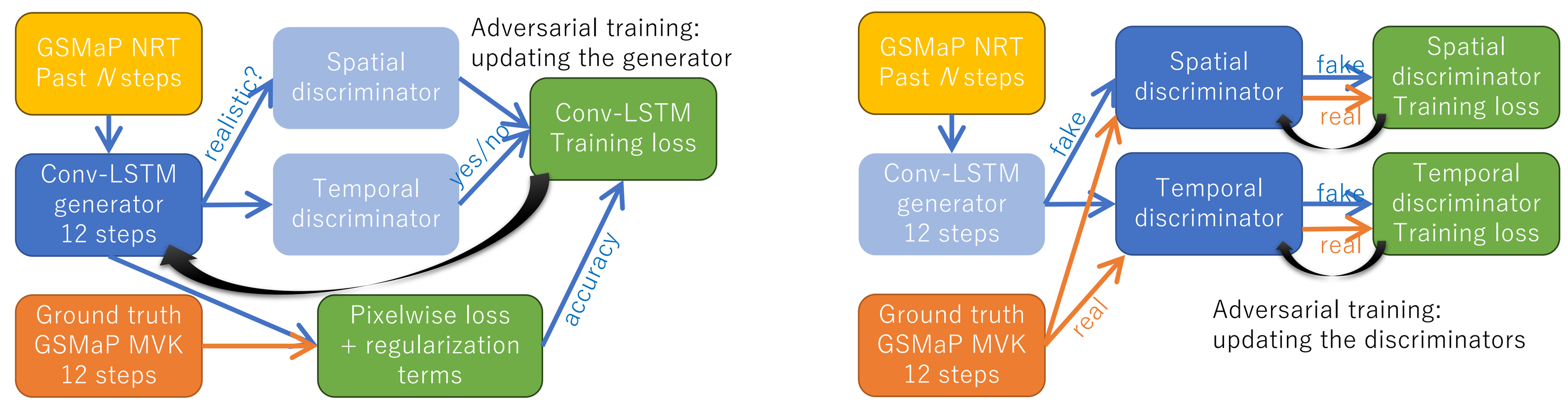
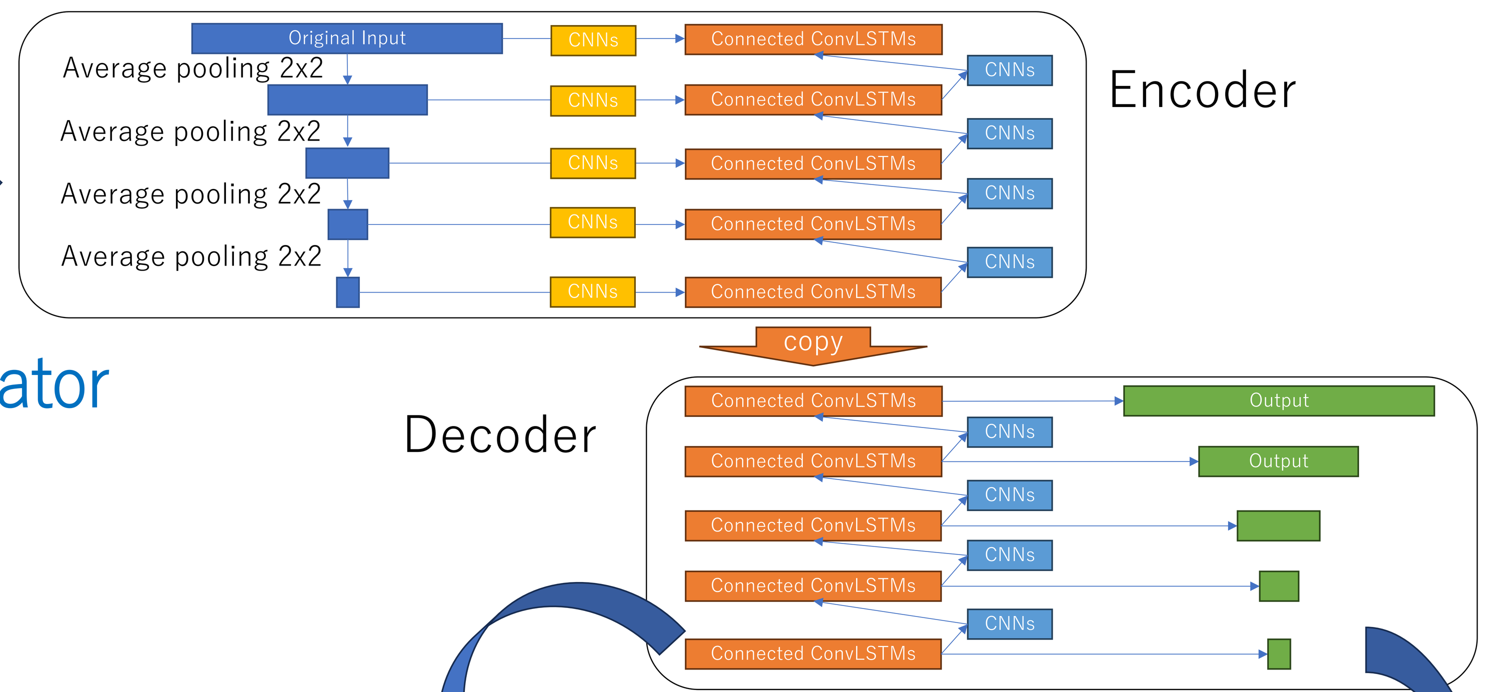
1. AI-based global precipitation nowcasting

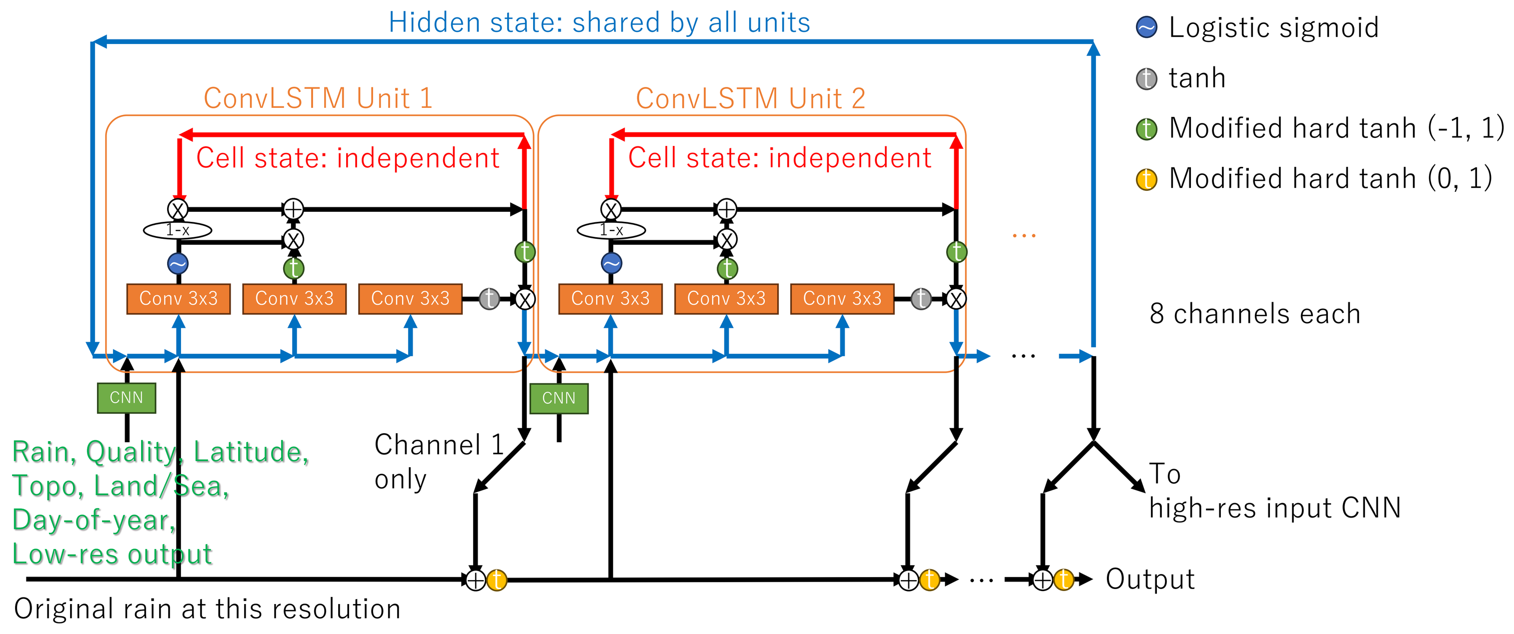
Adversarial training

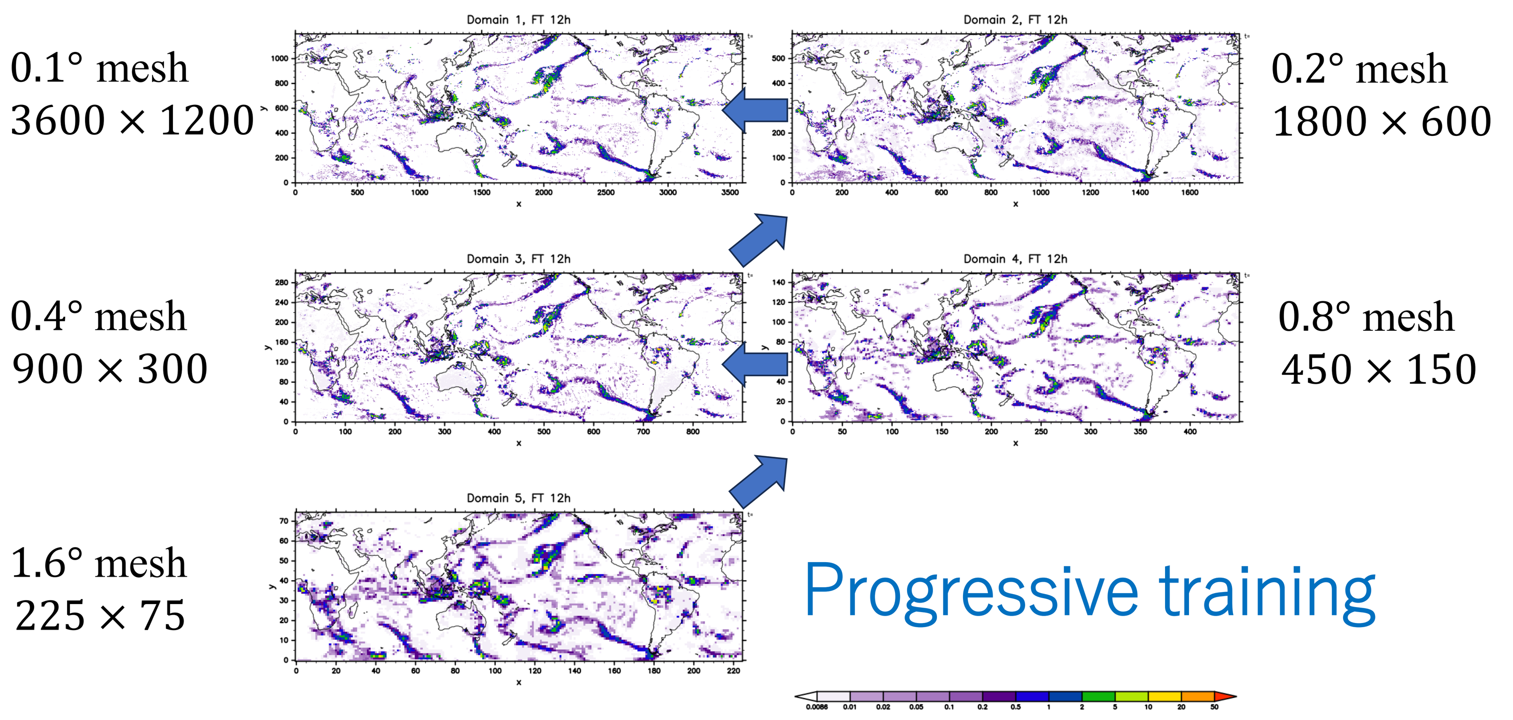


Generator



Connected ConvLSTMs (8 or 16 units are used)



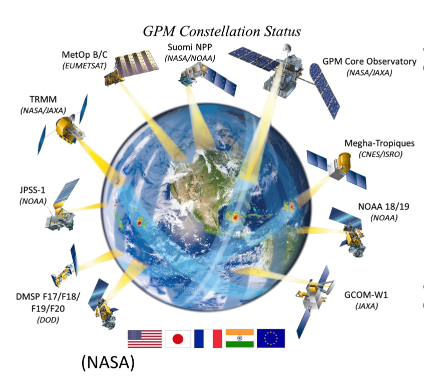


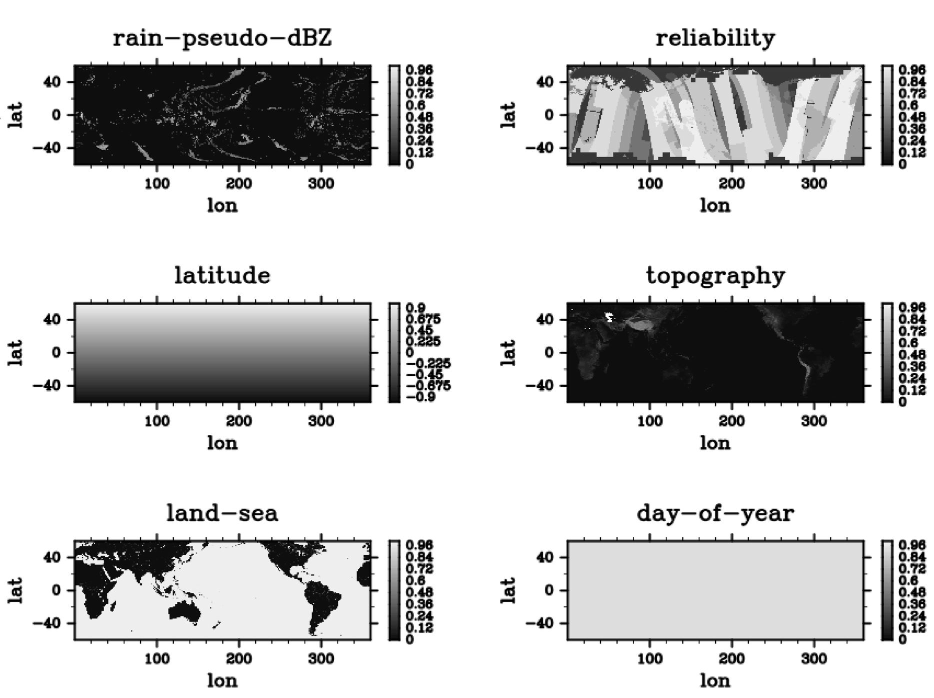
2. Training loss

- Loss_generator = Loss_pixelwise
  + Loss_non_local + α * Loss_adversarial
- Loss_pixelwise = Σ i(Huber(xi, yi) * wi)
- Loss_adversarial = BinaryCrossEntropy(D_spatial(x, 0.8))
  + BinaryCrossEntropy(D_temporal(x, 0.8))
- Loss_non_local:
  - parameters:
    - Mean and higher-order moments: For each time step, $(\overline{x^p})^{\frac{1}{p}}, p = 1,2,4,6,8,10$
    - Sharpness: For each time step, $\left(\overline{(\nabla^q x - \overline{\nabla^q x})^p}\right)^{\frac{1}{p}}, p = 2,4, q = 2,4,6,8$
    - To avoid unrealistic pattern: For time-averaged value, $\left(\overline{(\nabla^q x - \overline{\nabla^q x})^p}\right)^{\frac{1}{p}}, p = 2,4, q = 2,4,6,8$
    - To avoid unrealistic pattern: For each time step, $\left(\overline{(x\nabla^q x - \overline{x\nabla^q x})^p}\right)^{\frac{1}{p}}, p = 2,4, q = 2,4,6,8$
  - Loss for each resolution, each parameter X: $\left(\frac{X_{Prediction} - X_{Truth}}{X_{Time-averaged\ truth}}\right)^2$

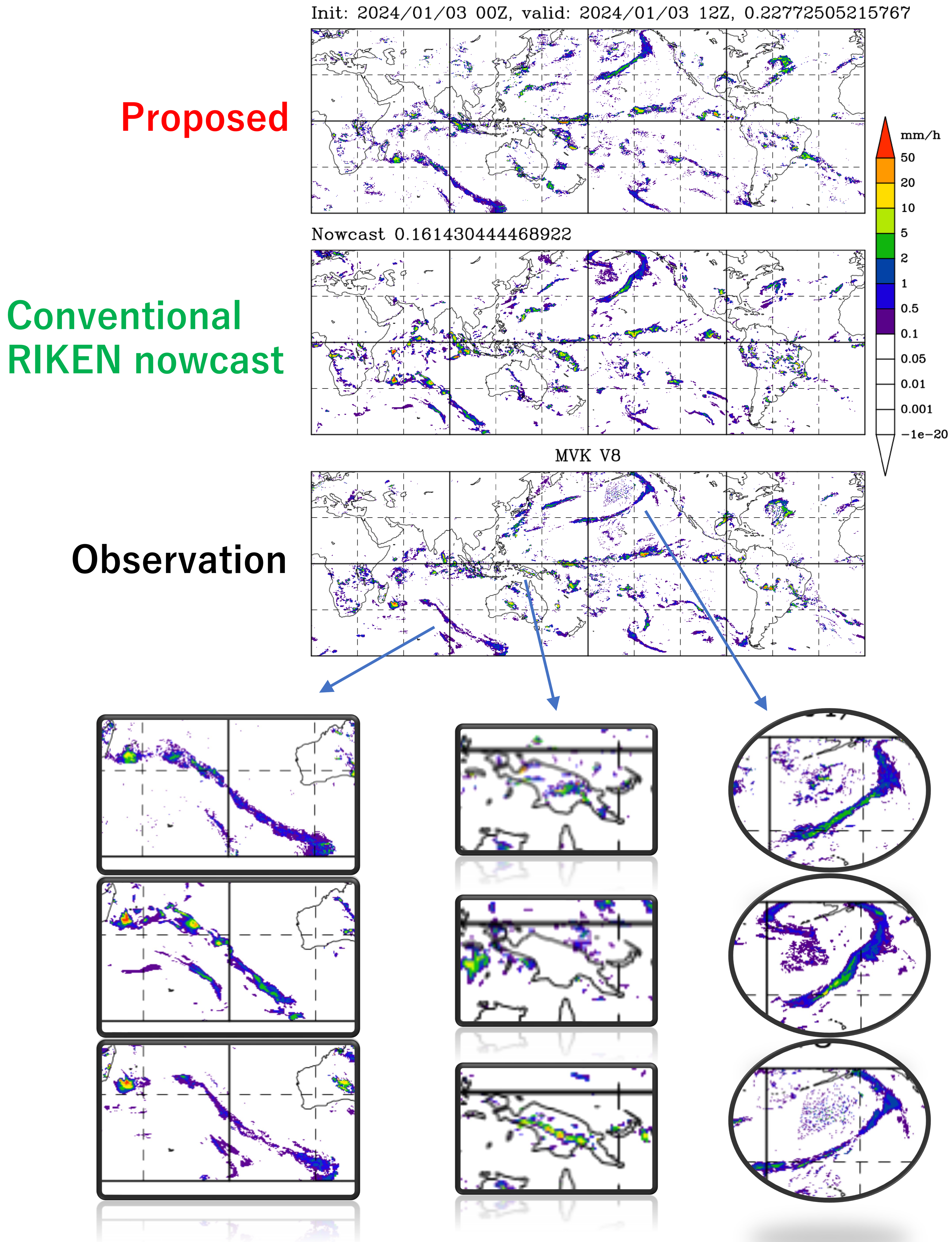
3. Data

- Input: hourly, past 24 h
  - GSMaP
    Near-Real-Time (NRT) v8
- Truth: hourly, 12-h lead
  - GSMaP Standard (MVK) v8
- Training:
  2022/01/01 - 2023/12/31
  - ~2 weeks on A100 x 2
- Validation:
  2021/12/06
- Test:
  2024/01/01 - 2024/01/31
  - ~5 seconds/12-h-prediction on A100 x 1
    - ~10 seconds for I/O

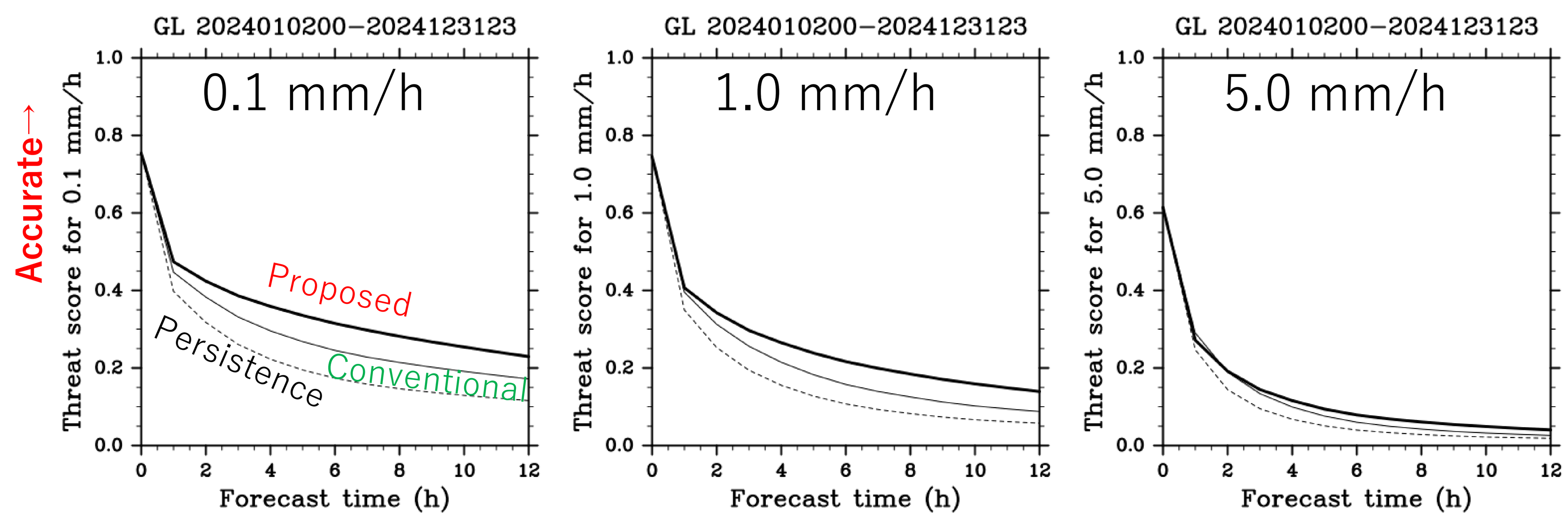




4. Comparison with conventional nowcasting



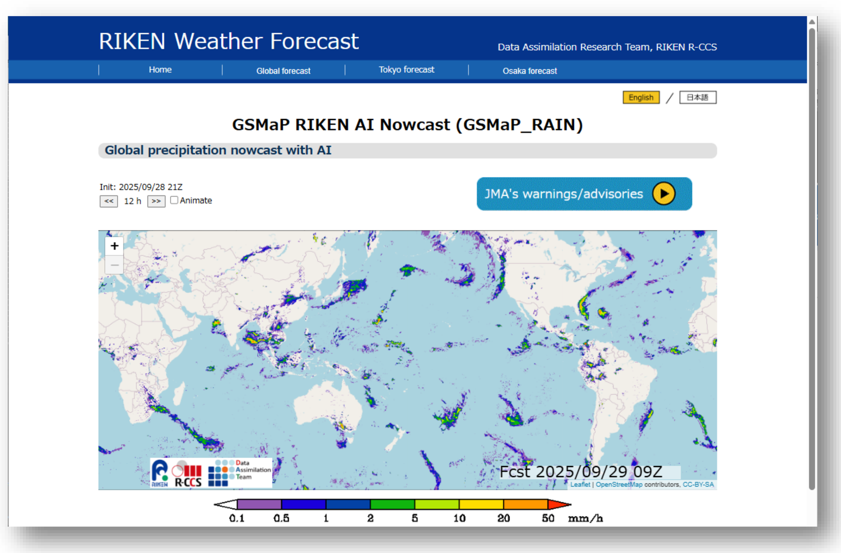
5. Verification scores for January-December 2024



Threat scores with respect to GSMaP MVKv8

6. Summary

- Deep learning-based global precipitation nowcasting outperforms conventional tracking-based nowcasting for most cases
- GAN-based training helped reproduce small-scale rain areas
- Further improvements are needed for the shortest-range forecasts
- Large-scale distributed training framework is needed in the future



GSMaP RIKEN AI Nowcast website
https://weather.riken.jp/en/gsmap_rain/gsmap_rain.html

World Meteorological Organization Intercomparison project
"AI for Nowcasting Pilot Project"
https://community.wmo.int/en/meetings/wmo-artificial-intelligence-nowcasting-pilot-project-ainpp-workshop