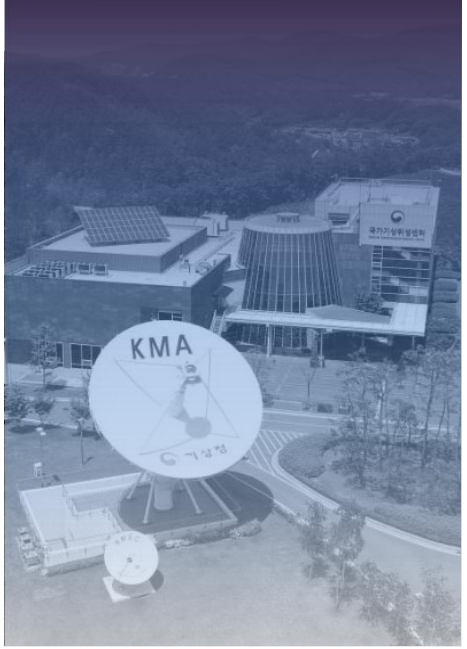
NWP Model Diagnosis based on Simulated GK2A Satellite Imagery

30 October 2025

Byung-il Lee, Hae-Min Kim, Inchul Shin,
Changbeom Cho, KiRyong Kang

NMSC, KMA

Korea Meteorological Administration (KMA)
National Meteorological Satellite Center (NMSC)



Contents

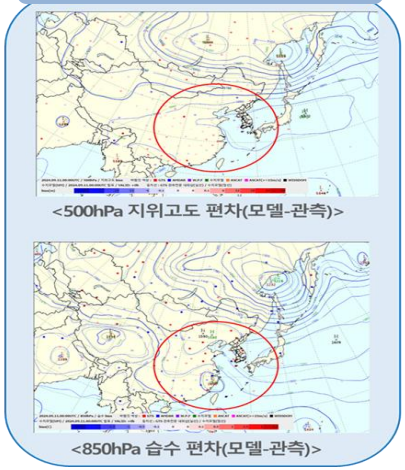
Backgrounds and Objectives

- **NWP model diagnosis is required for effective weather forecasting**

  - Forecaster need to understand the differences between the observation and the model predicted conditions.

AS-IS

Comparison with GTS



<500hPa 지위고도 편차(모델-관측)>

<850hPa 습수 편차(모델-관측)>

Limited spatial and temporal coverage
- GTS observations: available at 00, 06, 12, and 18 UTC

Expansion of observation-comparison is needed

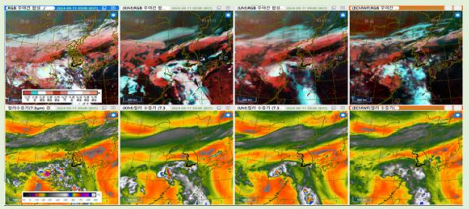
Diagnosis of NWP model

- Direct comparison between satellite observations and numerical model predictions.

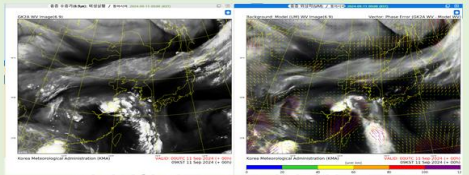
➔ **Provide wider spatial and temporal coverage than GTS observations**

TO-BE

Comparison with Satellite Images



<주야간 RGB(상단), 수증기컬러강조영상(하단)>



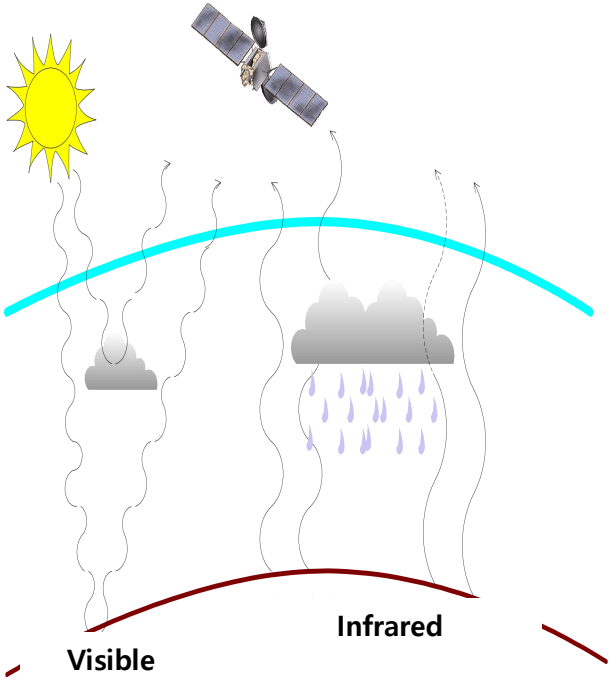
<위성실황(왼쪽), 수증기위상차(오른쪽)>

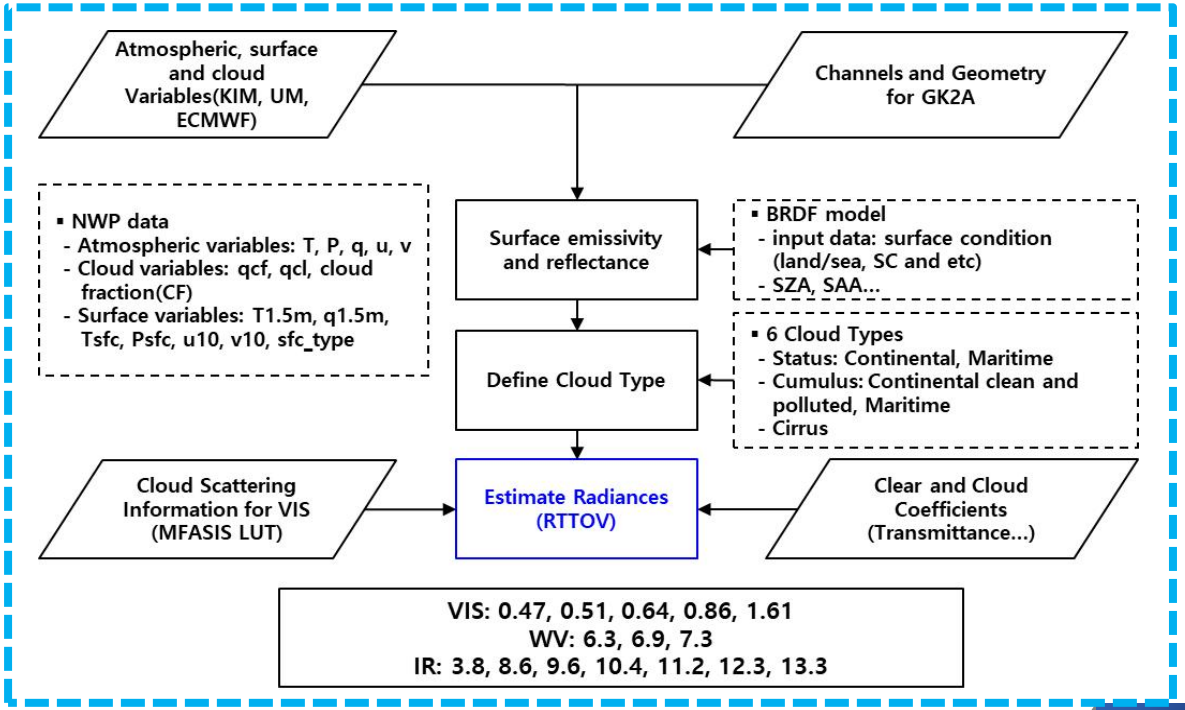
Simulated Imagery
- Satellite observations: every 10 minutes with 2km resolution

Methodology: Simulation of GK2A data

Radiative Transfer Model: Estimation of radiance with atmospheric information

$$R_\lambda = \varepsilon_\lambda^{sfc} B_\lambda(T_{sfc}) \tau_\lambda(p_{sfc \to top}) + \int_p^0 B_\lambda(T(p)) \left[\frac{d\tau_\lambda(p)}{dp}\right] dp$$





Methodology: Simulation of GK2A data

Input(Model variables) and Outputs(Simulated Cloud Images)

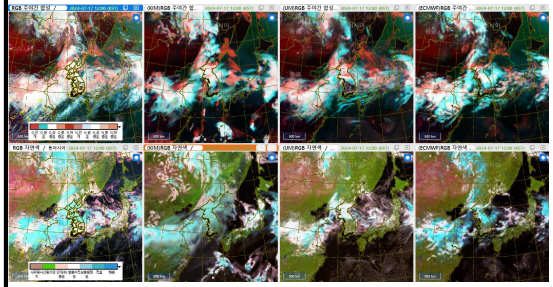
	KIM	UM	ECMWF
Atmospheric Variables	Pressure(P), Temperature(T), Specific Humidity(q)		
Cloud Physical Variables	Cloud fraction (CF), Cloud liquid water mixing ratio (CLW), Cloud ice water mixing ratio (CIW)		
Surface Variable	Surface temperature (ST), Surface pressure (SP), 1.5 meter temperature and humidity (1.5m T & q), U and V wind components (Uwind, Vwind), Land/sea surface information, Snow cover (SC)		
Horizontal Resolution/Vertical Layers	8km / 91L	10km / 70L	25km / 25L
Backgrounds	00, 12UTC	00, 12UTC	00, 12UTC
Forecast Time / Output Frequency	00 to +18h by 1-hour interval, +21h to +144h by 3-hour interval		
Domains	Korean Peninsula, East Asia, Typhoon region		
Output	• **Color Enhancement Images**: Infrareds(10.5), WVs (upper, middle, lower layers) • **RGB Images**: Day-night, True color, Natural color, Airmass, WV • **WV Products**: Phase Error and Brightness Temperature Difference, PVU Images		

Examples of Simulated Cloud Imagery of GK2A

Analysis of Clouds and dry zone

RGB Images (Day/Night, Nature Color and etc)

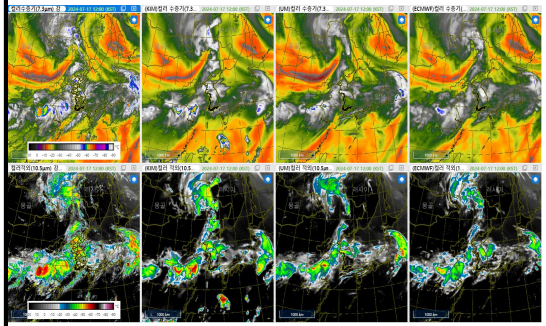
Observation KIM UM ECMWF



- **RGB Imagery**
  - Analyze the altitude, development, dissipation, and movement of cloud layers

Colored Water Vaper and Infrared images

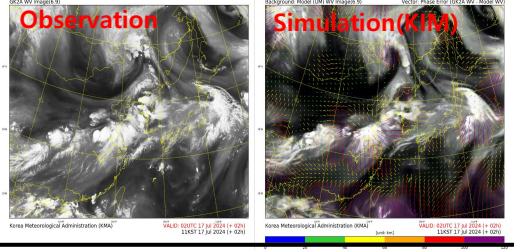
Observation KIM UM ECMWF



- **Dry Regions of WV**
  - Utilize for examining the location, intensity, and subsidence of dry air regions
  - To anlyze trough or ridge associated with frontal system

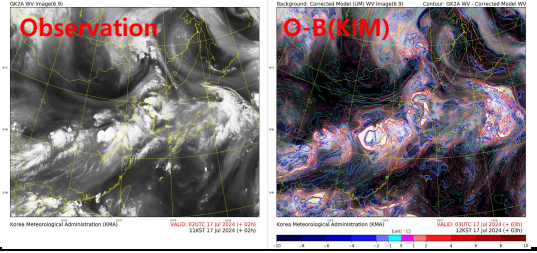
Synoptic-scale analysis

WV Phase Error(6.9μm)



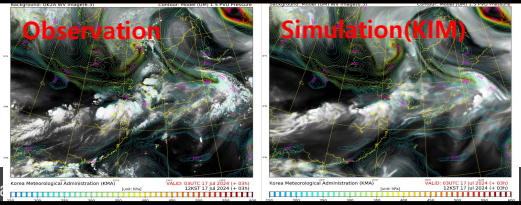
- **Phase analysis**
  - To analyze the location and movement speed of dry regions

BT difference(6.9μm)



- **Intensity**
  - Enables comparative analysis of dry region intensity

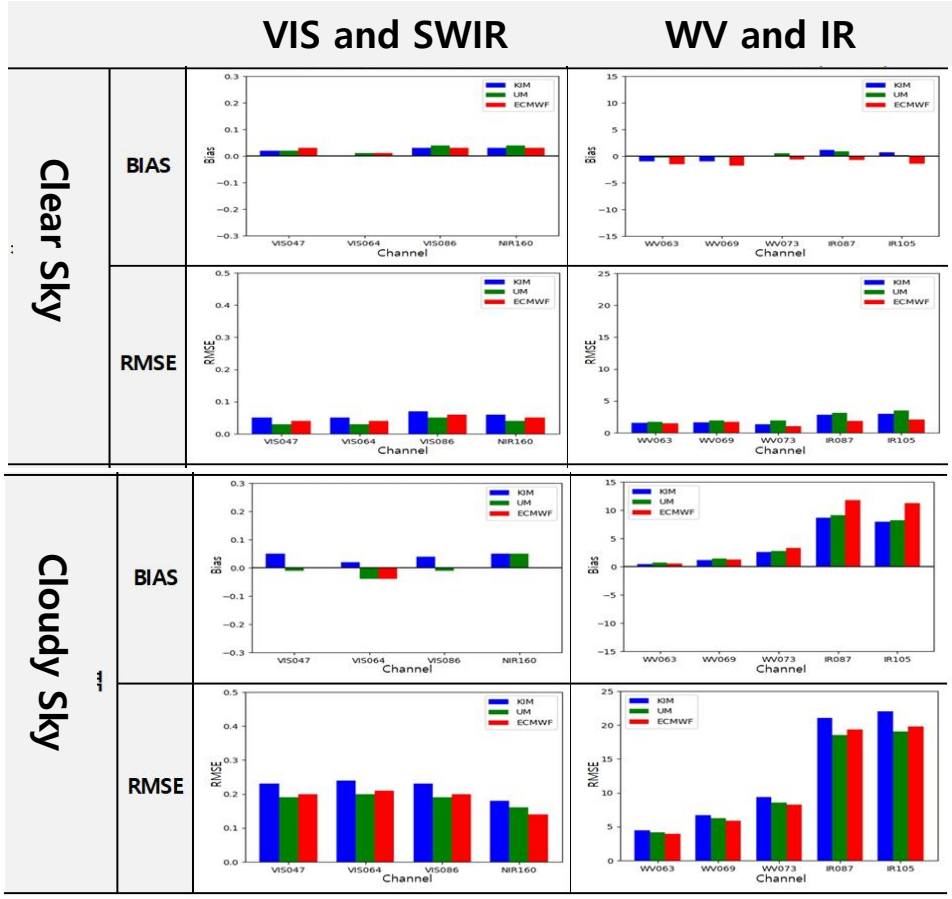
Potential Vorticity Unit(6.9μm)



- **PUV fields**
  - To analyze tropopause altitude and its spatial variation

Validation of Simulated Cloud Imagery

Validation statistics by channels (July 2023)



- **Validation Method**

$$BIAS = \frac{1}{N}\sum_{i=1}^{N}(S_i - O_i) \qquad RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(S_i - O_i)^2}$$

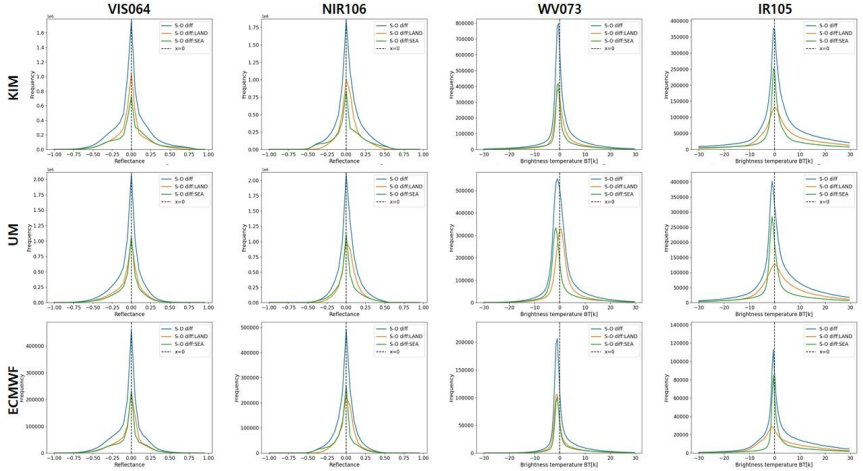
※ S: Simulation, O: Observation

- **Validation results**
  - Biases are similar in both, but RMSEs are much larger in cloud regions
    → Errors are increased due to uncertainties in the cloud microphysics parameters of the NWP model.
  - **VIS, SWIR and IR**: all three models show positive biases
    → higher RMSE than the WV channels
  - **WV**: lower BIAS and RMSE
    → KIM and EC models show negative biases

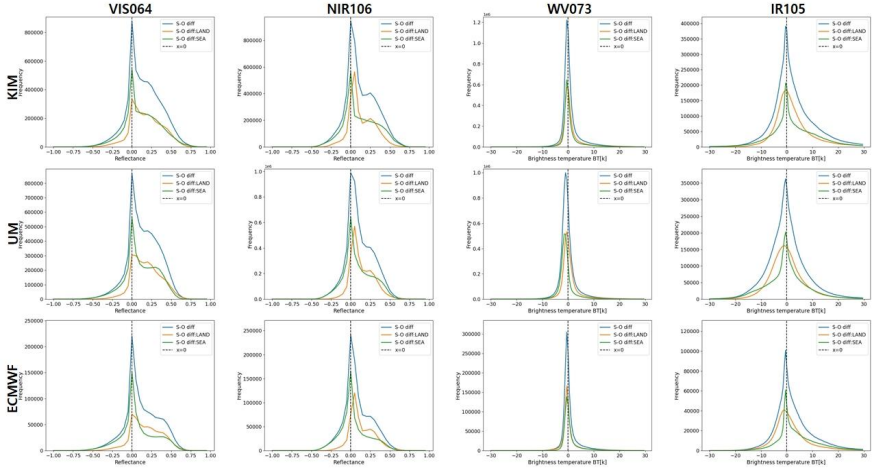
Validation of Simulated Cloud Imagery

Validation over land and ocean

Summer (July 2023)



Winter (January 2024)

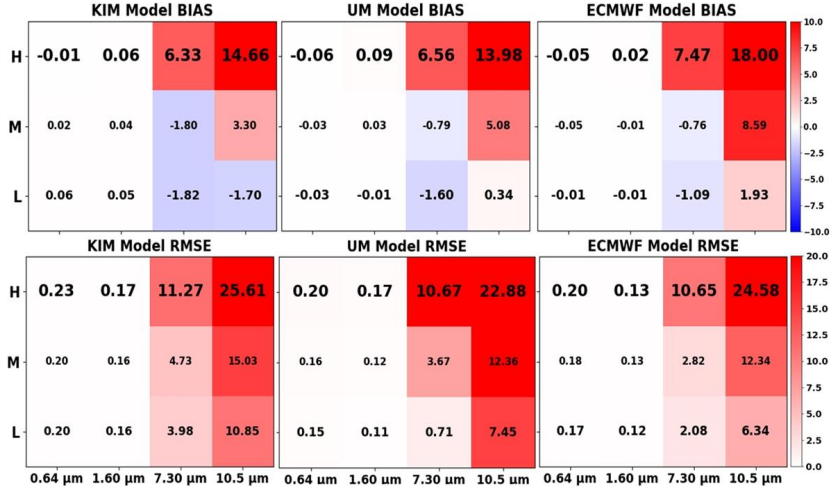


- **Reflectance channels (0.64 μm, 1.6 μm):** Larger difference in winter due to differences between land and ocean, as well as the influence of clouds and snow cover
- **Thermal infrared channels:** Land areas show larger differences in both seasons
- **Water vapor channel (7.3 μm):** Shows good agreement regardless of the season and land/sea

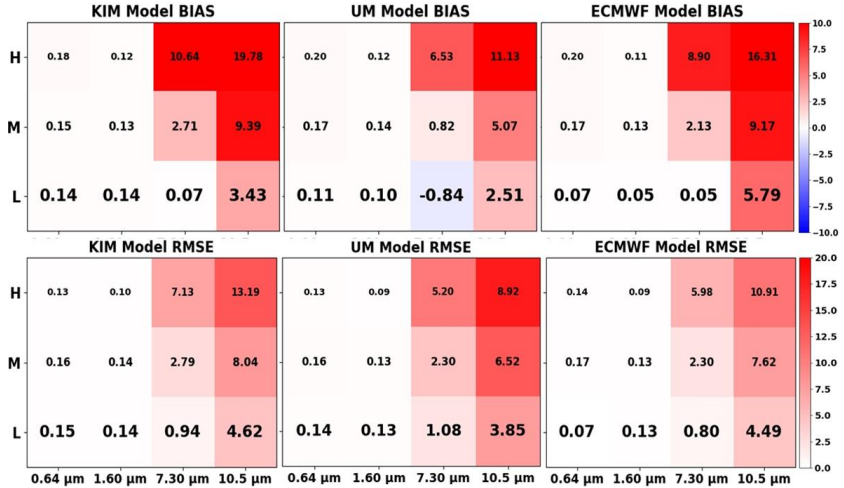
Validation of Simulated Cloud Imagery

Validation according cloud types

Summer (July 2023)



Winter (January 2024)

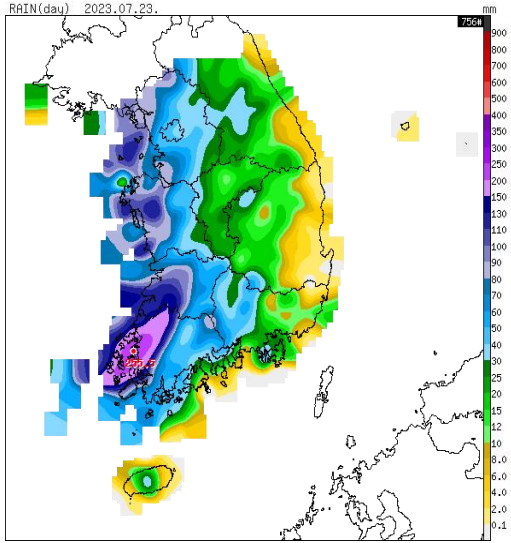


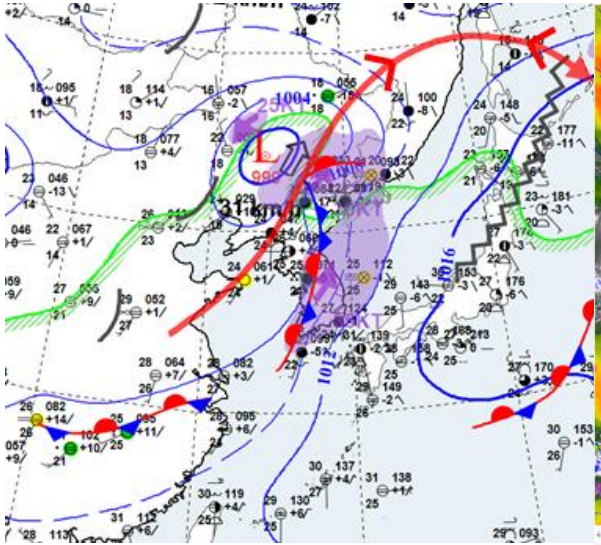
- Cloud height: Classified using the cloud-type information from GK2A
  - All three models simulate clouds with **higher brightness temperatures and drier conditions** than those of satellite observation
  - The models **tend to underestimate cloud amount compared to satellite observations**

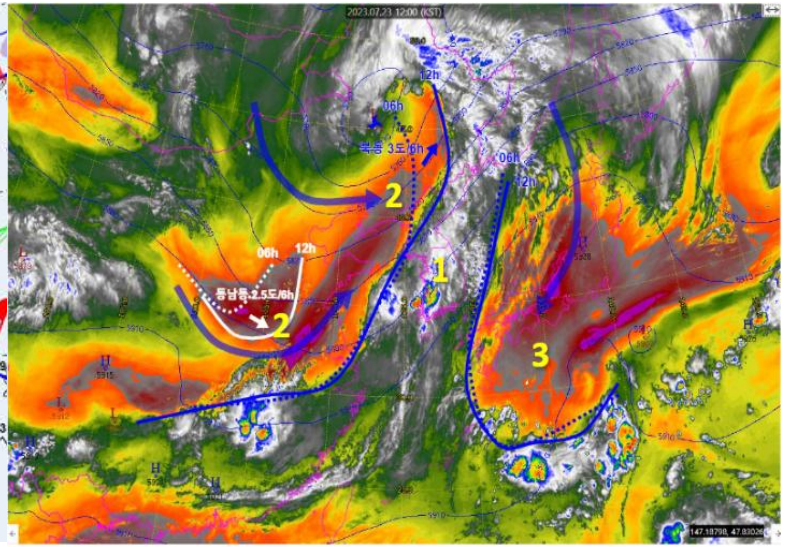
Application for Forecast Support

Heavy precipitation (23 July 2023, 244mm/24hour)

• Precipitation occurred in the southwestern part of the Korean Peninsula due to Stationary Front





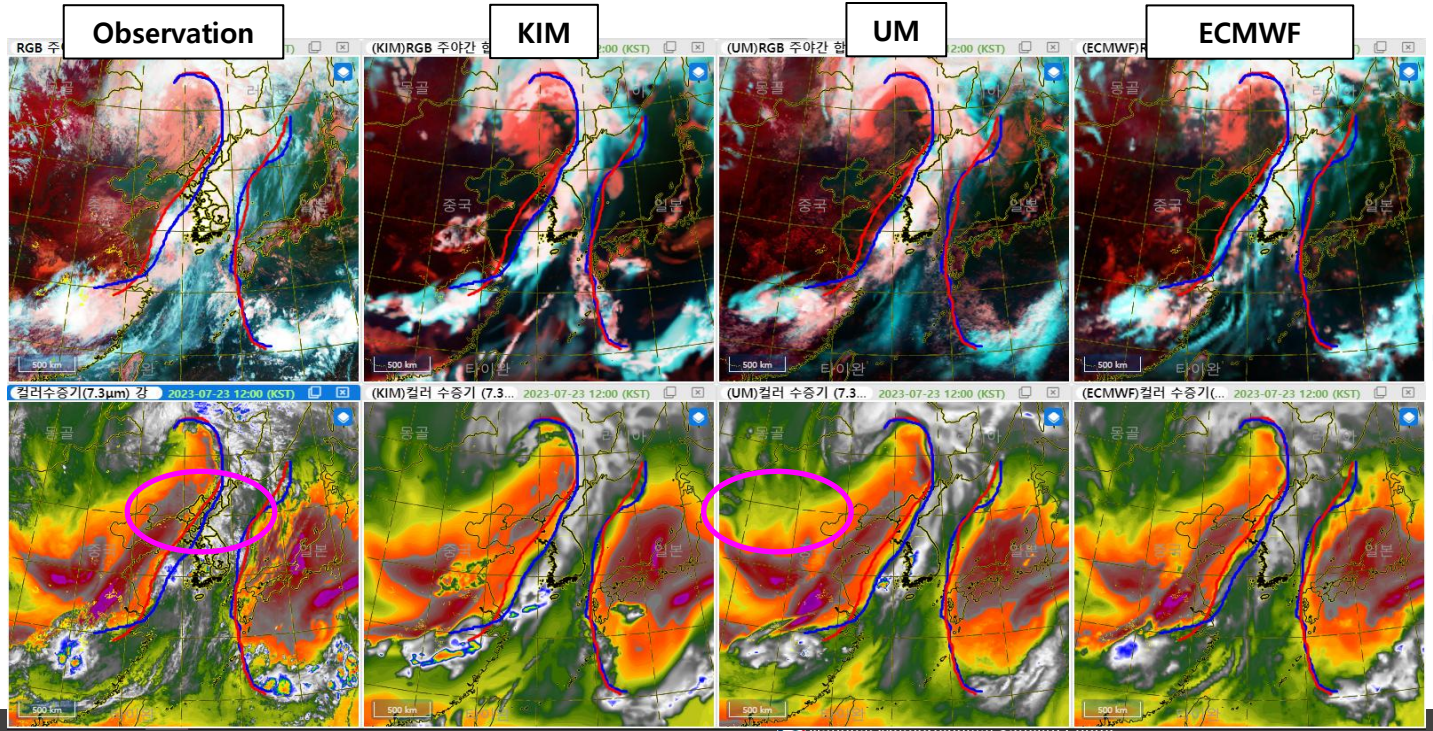


- The clouds system moved southeastward with an estimated speed of around 50 km/h, it was bringi ng strong rain and lightning over the south-western part of the Korean Peninsula
- The water vapor was transported between the two dry zones

Application for Forecast Support

Comparison between observation and Simulated GK2A WV images

- NWP models show a narrower moisture transport pathway than observed one
- And the western boundary of dry zone is located roughly 100 km farther west



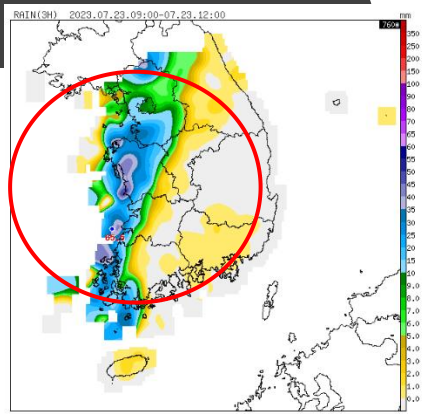
The UM model is most consistent with observations.

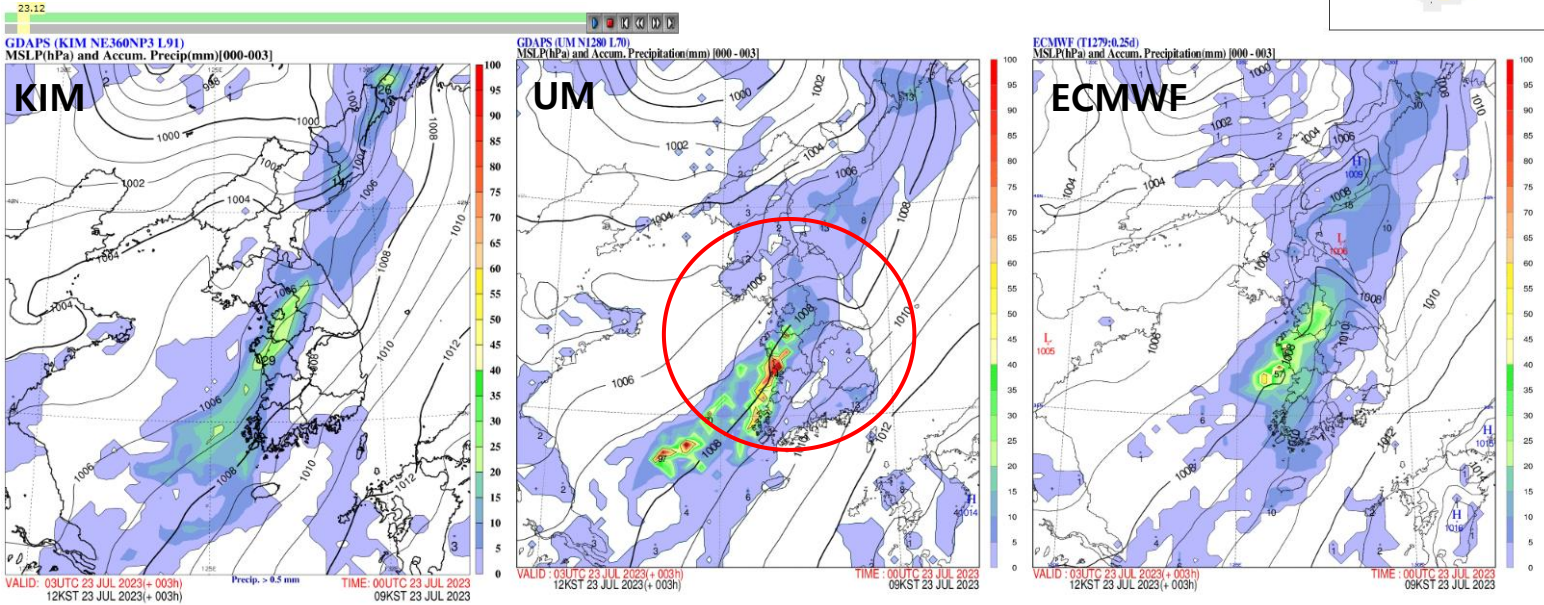
Red: Observation
Blue: Simulated Cloud image

Application for Forecast Support

Verification of Precipitation in Numerical Models

- The UM: Chungnam and Jeolla Province
- The KIM: Slightly farther north, mainly over southern Gyeonggi Province
- The ECMWF: Pattern similar to the UM but weaker intensity





Conclusion

- **Limitation of Conventional diagnosis of NWP model**
  - GTS-based verification only available at limited points and fixed times (00, 06, 12 and 18 UTC)
  - Insufficient to capture spatial and temporal variability of cloud and moisture patterns

- **Development New Diagnostic Framework using simulated satellite data**
  - Established a system to compare satellite observations with model-simulated cloud imagery
  - Enable analysis of dry regions, cloud structures, and synoptic-scale patterns
  - Support real-time decision-making for forecasters

- **Enhancing Reliability for the New Method**
  - Try to Development Objective Analysis Techniques

Thank you

Korea Meteorological Administration (KMA)
National Meteorological Satellite Center (NMSC)