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Data assimilation of GNSS Zenith Total Delays in KMA convective scale model

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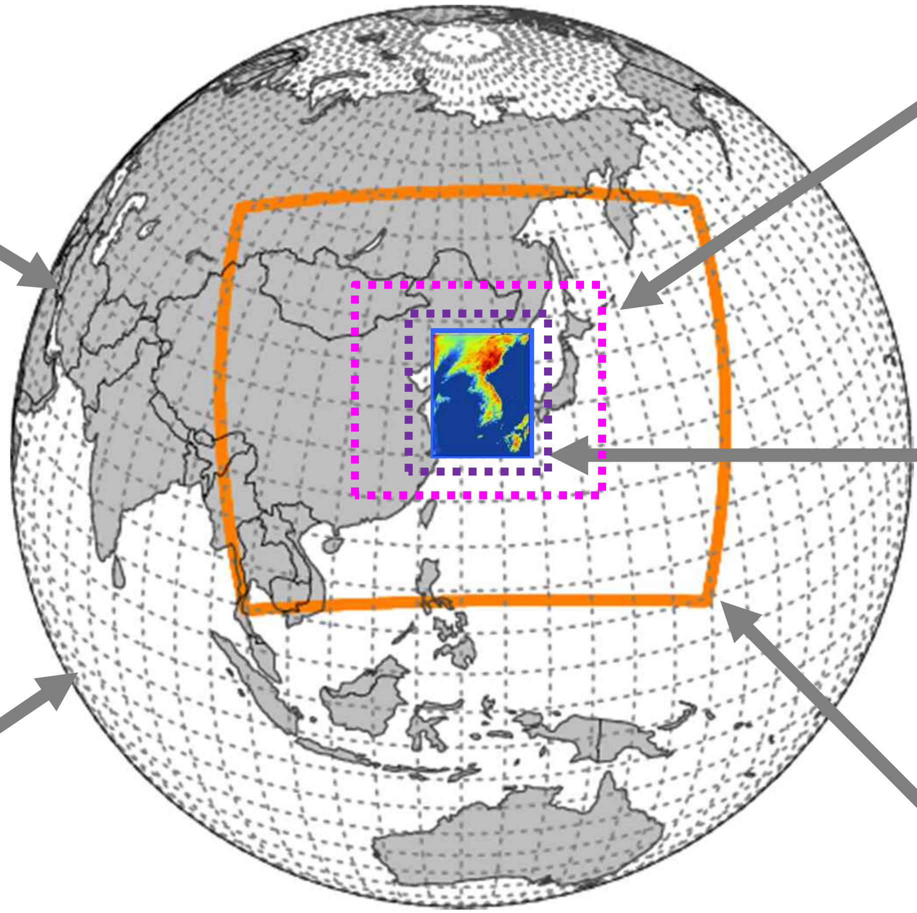
KMA Operational NWP system(Feb. 2018)

❖ KMA's operational models are based on Unified Model

Global(GDAPS)
- Resolution
  N768L70(UM)
  (~17km / top = 80km)
- Target Length
  288hrs (00/12UTC)
  87hrs (06/18UTC)
- Initialization: Hybrid Ensemble 4DVAR

Global EPS
- Resolution
  N400L70(UM)
  (~32km/ top = 80km)
- Target Length: 288hrs
- Members: 49



Local(LDAPS)
- Resolution
  1.5~4km L70(UM)
  (1188×1148 / top=39km)
- Target Length: 36hrs
- Initialization: 3DVAR

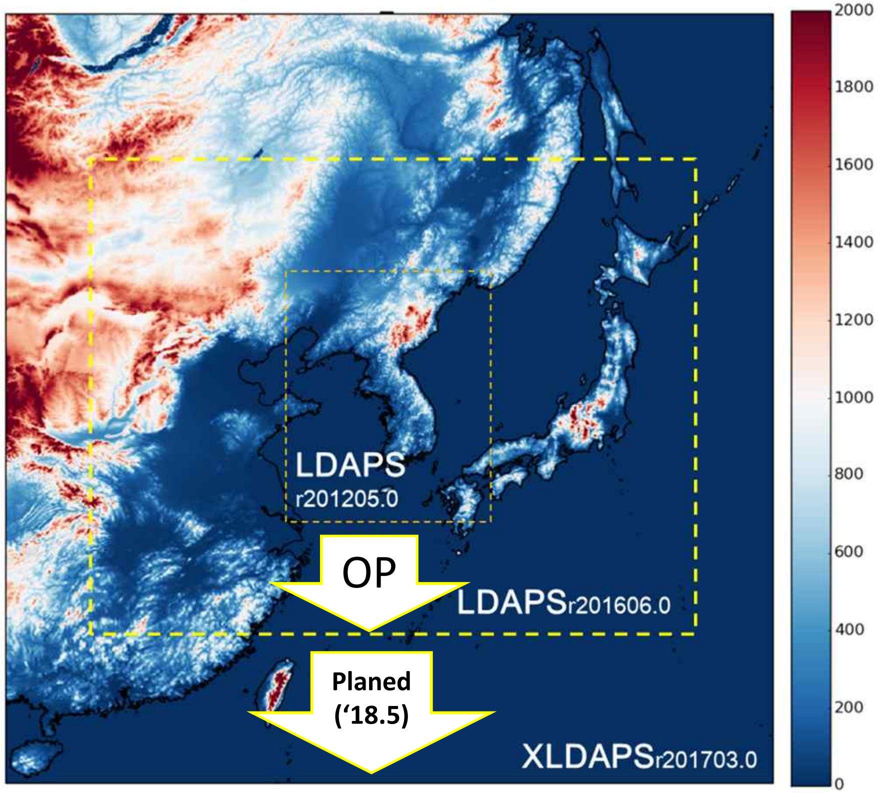
Local EPS
- Resolution
  3km L70(UM)
  (460×482 / top = 39km)
- Target Length: 72hrs
- Members: 13

Regional(RDAPS)
- Resolution
  12kmL70(UM)
  (0.11°x0.11° / top=80km)
- Target Length: 87hrs
  (6 hourly)
- Initialization: 4DVAR

KMA convective scale model

❖ KMA's operational models are based on Unified Model

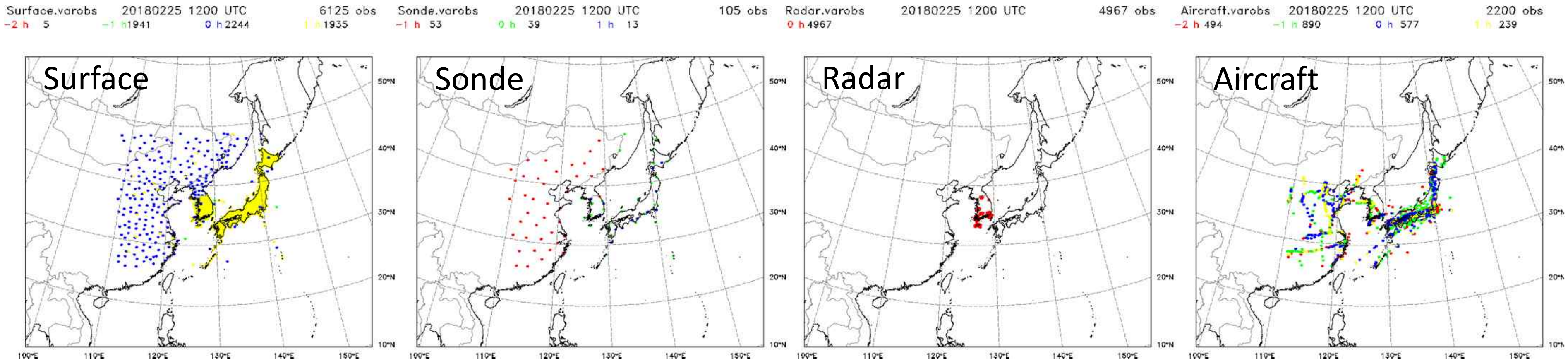
❖ **LDAPS(Local Data Assimilation and Prediction System)**

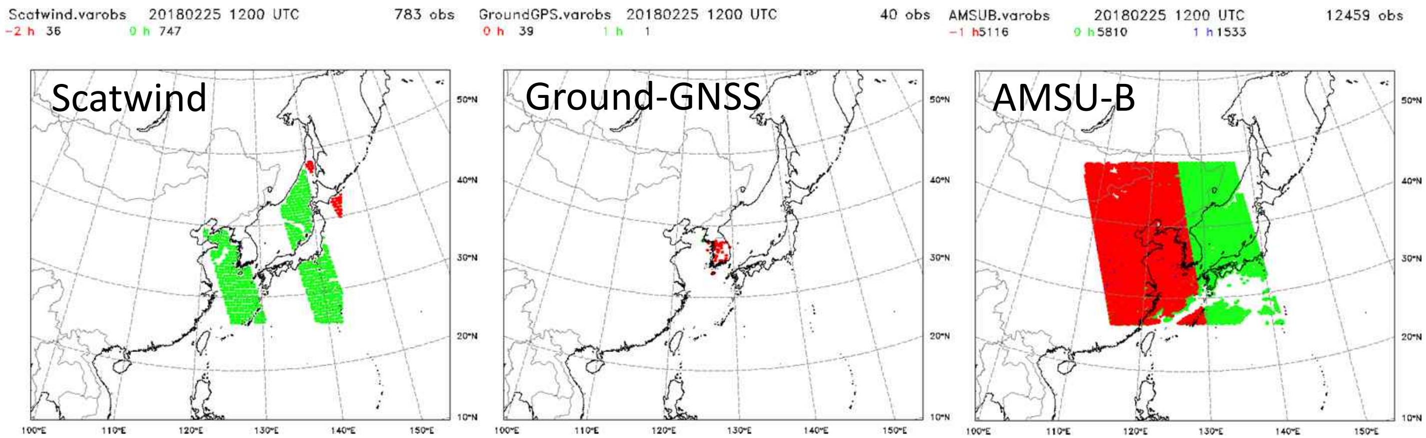


- **Model**
  - UM **vn10.1k** (ENDGame)
- **Area, resolution**
  - grid number: 1,598 (E-W) X 1,718 (S-N)
  - resolution: 1.5~4 km (Variable grid), DA 3 km, 70 levels
- **Forecast time (cycle)**
  - **36 hours** (3 hourly)
- **DA system:** 3DVAR(FGAT, IAU)
  - surface, sonde, radar, aircraft, Scatwind (± 90 min cutoff time)
  - **GNSS**, **AMSU-B, TC Bogus (added '18.1)**
- **Operation**: since July 2016

Observation usage in LDAPS

- **Surface**(synop, ship, buoy, metar), **Sonde**(temp, pilot, windprofiler), **Radar**(radial velocity), **Aircraft**(amdar), **Scatwind**(ASCAT) → **Ground-GNSS, AMSU-B**
- 3 hourly cycling 3D-Var: lack of available observation, need more satellite DA

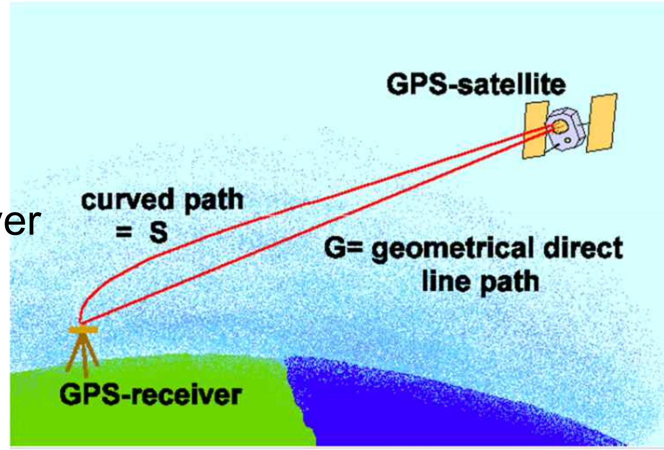




✓ Adding moisture information to lower and upper layers

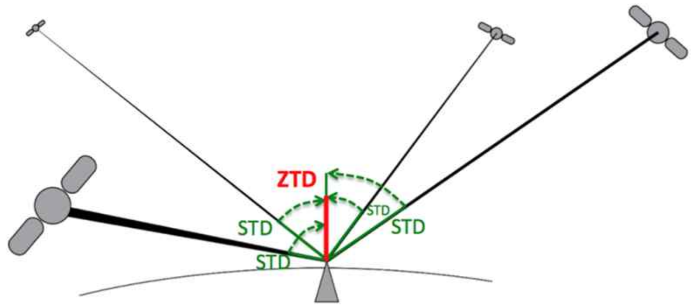
What is the GNSS?

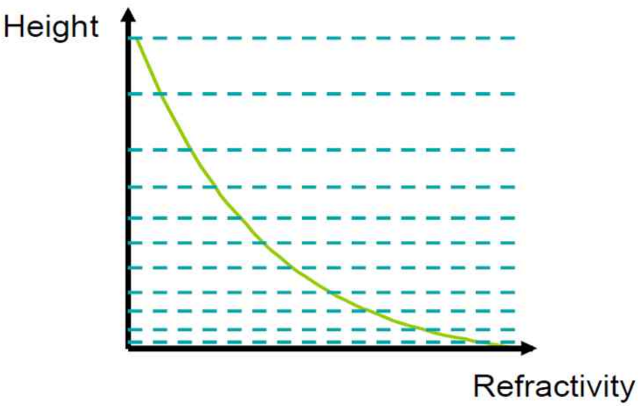
- Global Navigation Satellite System
  - GPS (United States), GLONASS (Russian Federation), Galileo (European Union), BeiDou (China)
  - The purpose is to calculate the position of the GPS receiver
  - The signal is delayed due to the amount of water vapor



- Zenith Total Delay
  - $ZTD = 10^{-6} \int_{z=0}^{z=\infty} N \, dz$

    $N(refractivity) = \frac{k_1 p_d}{T} + \frac{k_2 p_v}{T} + \frac{k_3 p_v}{T^2}$
  - Refractivity exponential decay with height





k: constant (Smith and Weintraub, 1953)

p_d: partial pressure of dry air

p_v: partial pressure of water vapor

T: absolute temperature

(Bevis et al., 1994)

Current GNSS Usage at the KMA

❑ Purpose

- Ground-based GNSS: **moisture** information in the **lower** level → improved **precipitation**
- GNSS-RO: atmospheric **upper** layer → improved **synoptic field**

❑ Status

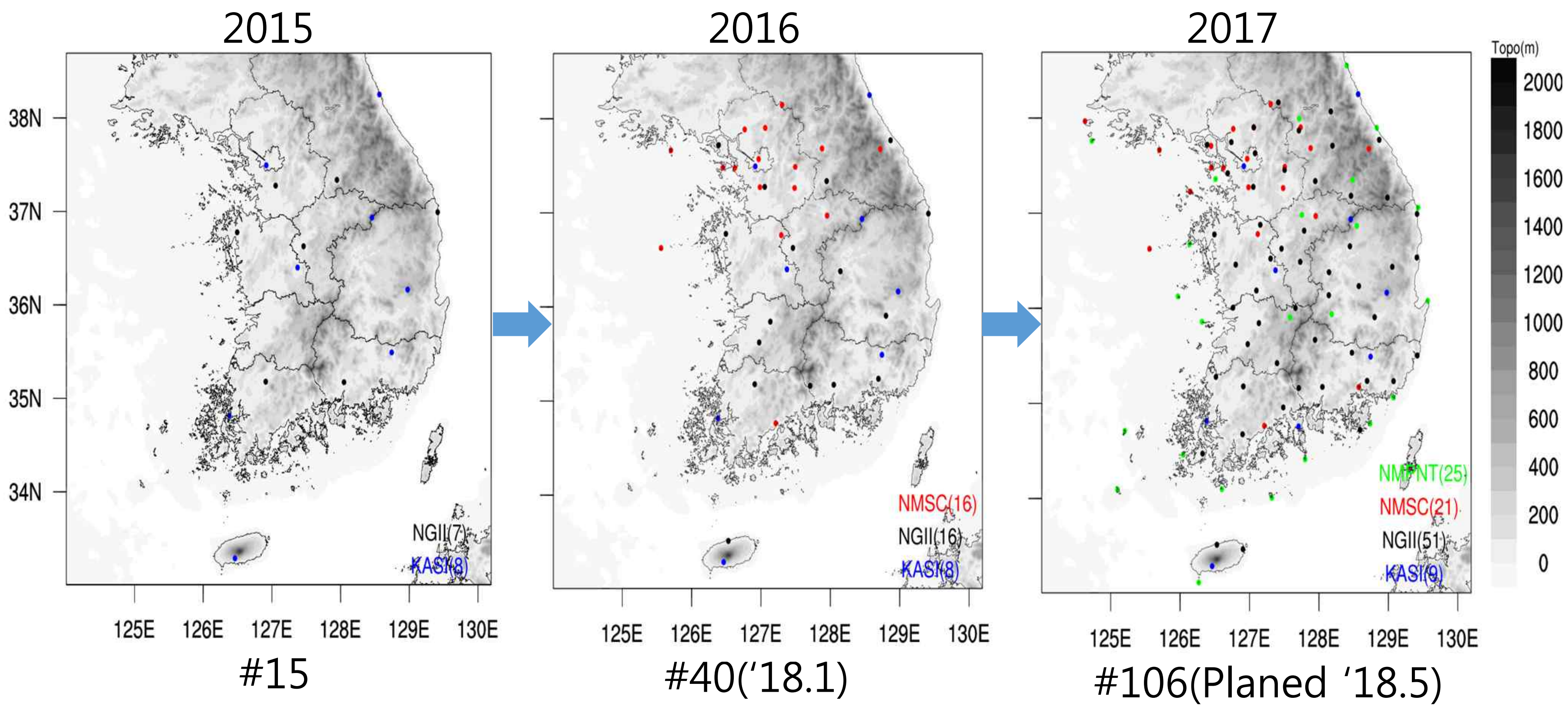
- Using ground-based GNSS data and planed GNSS-RO data in local model

Data spices		Global	Regional	Local	Very-short
Ground based GNSS (ZTD)	1 hourly	O	-	O **('18.1)**	-
	15 minutes	-	-	-	**Planed ('18.5)**
GNSS-RO (Bending angle)	COSMIC 1~6	O	O	**Planed ('18.5)**	-
	Metop-A/B	O	O		-
	TanDEM-X TerraSAR-X Grace-B	O **('17.10)**	-		-
	KOMPSAT-5	**Planed**	-		-

✓ Challenge : global observation speices which covers **local domain** assimilated

ground-based GNSS operation

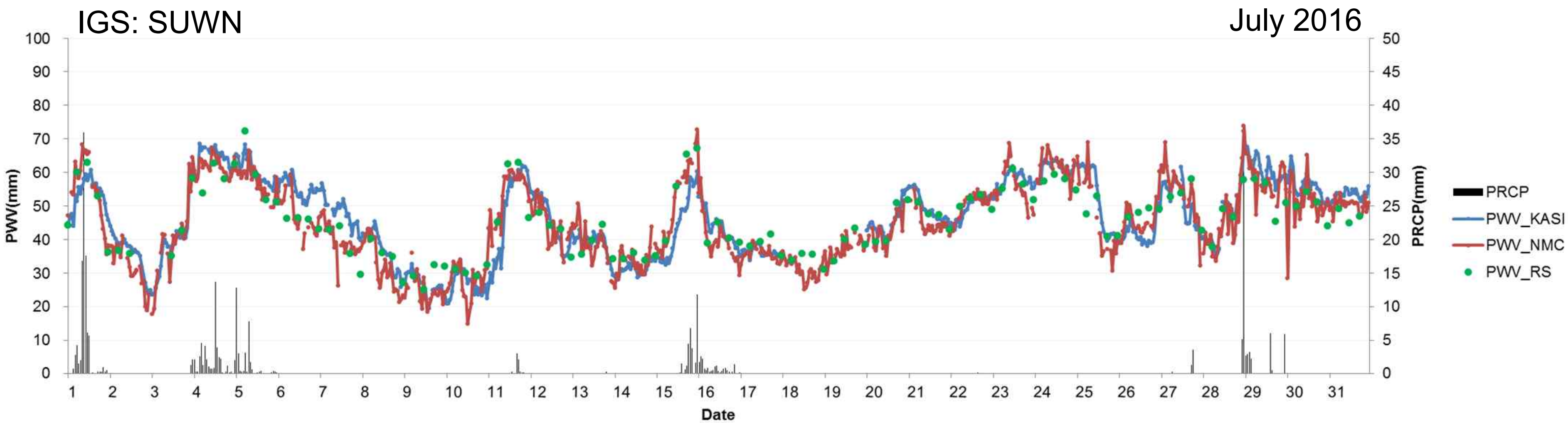
- ❖ NMSC/KMA receives raw signal data from several domestic GNSS networks of around 100 stations over the Korean Peninsular
- ❖ 40 sites operationally used in Jan. 2018 for local model
- ❖ **106 sites are testing for quality control and impact of observation error**



KASI : Korea Astronomy and Space Science Institute
NGII : National Geographic Information Institute
NMSC : National Meteorological Satellite Center
NMPT : National Maritime PNT Office

Quality Control

- ❖ **Comparison to PWV of ground-based GNSS and Sonde stations**
- ❖ Improvement of data quality by improving **fixed sites**(Courtesy of NMSC)
- ❖ ZTD calculation stability and improvement of O-B
- ❖ Static bias correction(1 month mean of O-B)



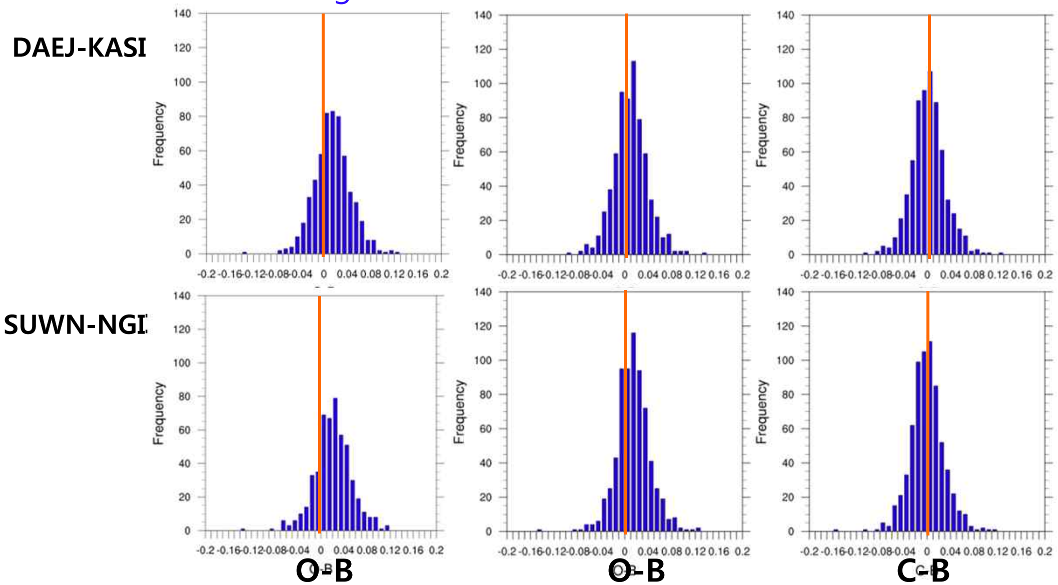
✓ Through comparison of the PWV with Sonde, the quality of GNSS data is reliable

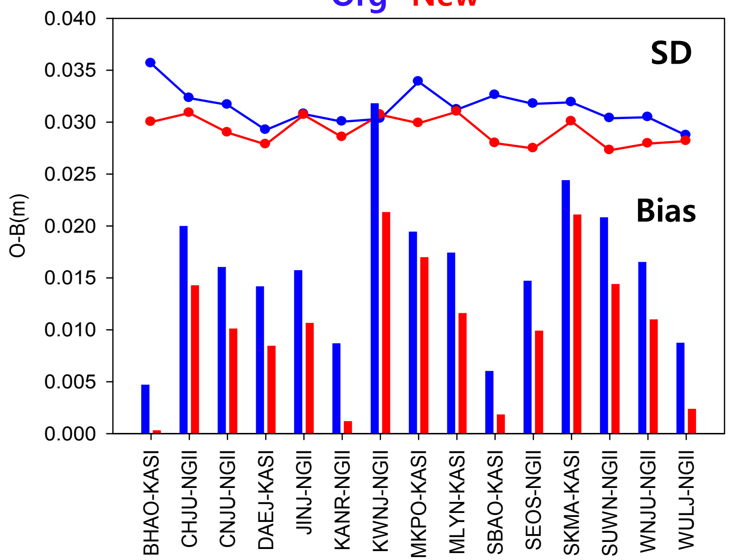
KASI vs. RS	NMC vs. RS
Bias= 0.5 RMSE= 5.8 Corr= 0.86	Bias= -0.5 RMSE= 5.0 Corr= 0.91

Quality Control

- ❖ Comparison to PWV of ground-based GNSS and Sonde stations
- ❖ Improvement of data quality by improving **fixed sites**(Courtesy of NMSC)
- ❖ ZTD calculation stability and improvement of O-B
- ❖ Static bias correction(1 month mean of O-B, remove outlier ±0.1)

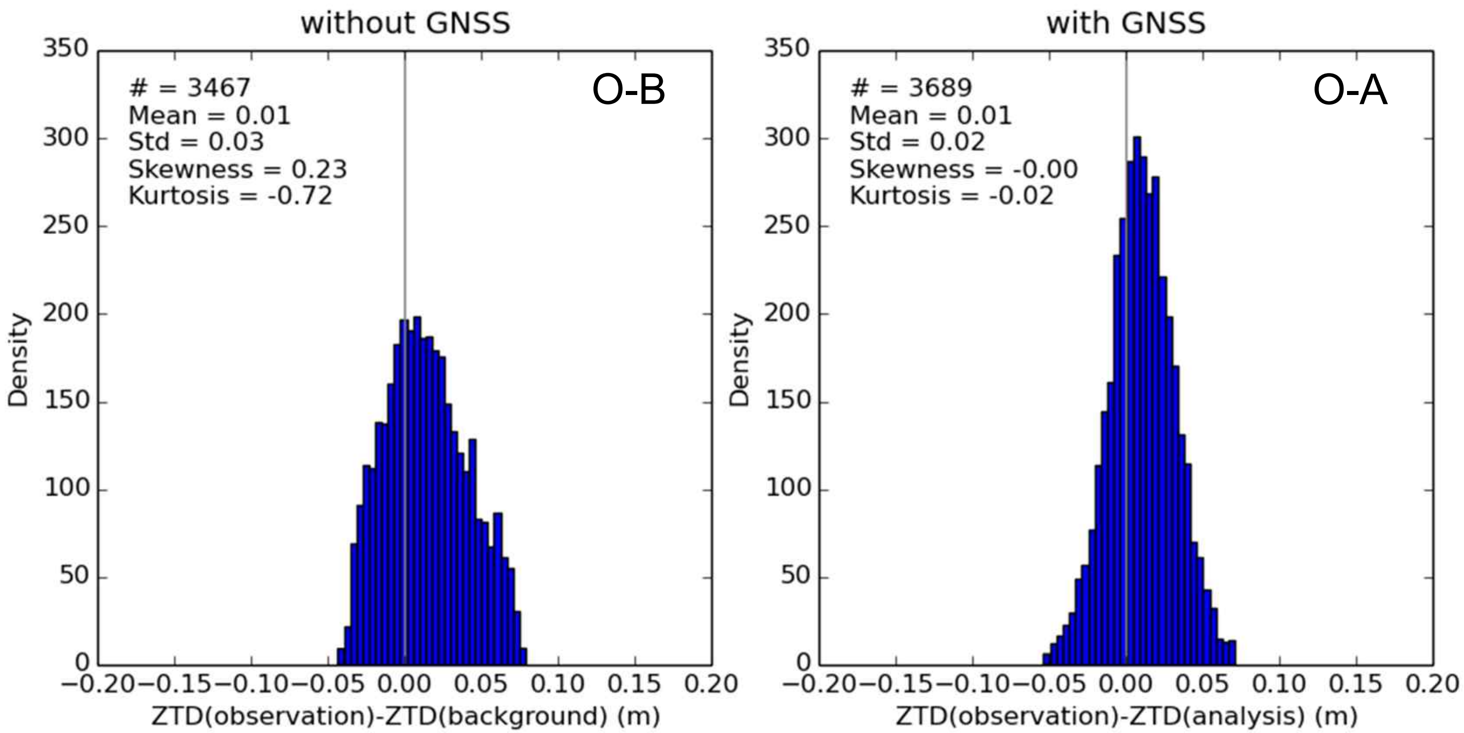
	Org	New
Fixed sites	DAEJ, SUWN, SHAO, LHAZ, IRKM, **AIRA, *CHAN, TSKB, USUD***	DAEJ, SUWN, SHAO, LHAZ, IRKM, ***XIAN, URUM***





Impact of Ground-based GNSS

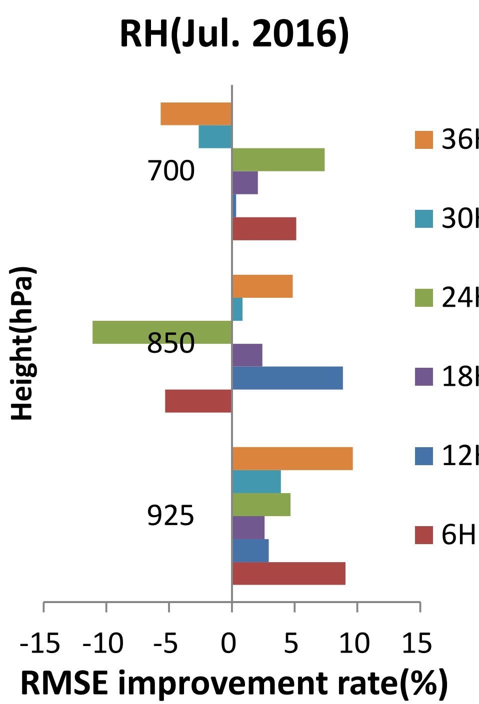
- ❖ By adding GNSS data, the **differences** ZTD of between observation and analysis are **reduced**
- ❖ The improvement of 850 hPa Temperature in July 2016
- ❖ Improved precipitation forecast performance using spatially dense GNSS data



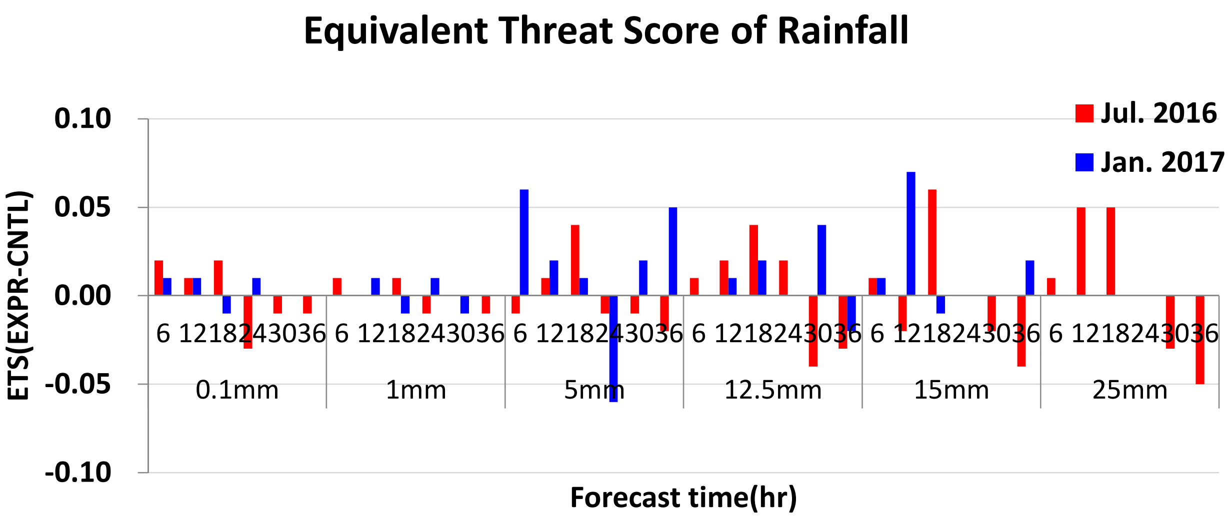
✓ The analyses of GNSS DA match the GNSS ZTD observations better than without GNSS cycle

Impact of Ground-based GNSS

- ❖ By adding GNSS data, the **differences** ZTD of between observation and analysis are **reduced**
- ❖ The significant improvement of lower tropospheric humidity field and rainfall
- ❖ Improved precipitation forecast performance using spatially dense GNSS data



3% improvement



Jul.: F06~18hr 7.2%
Jan.: F06~18hr 3.8%

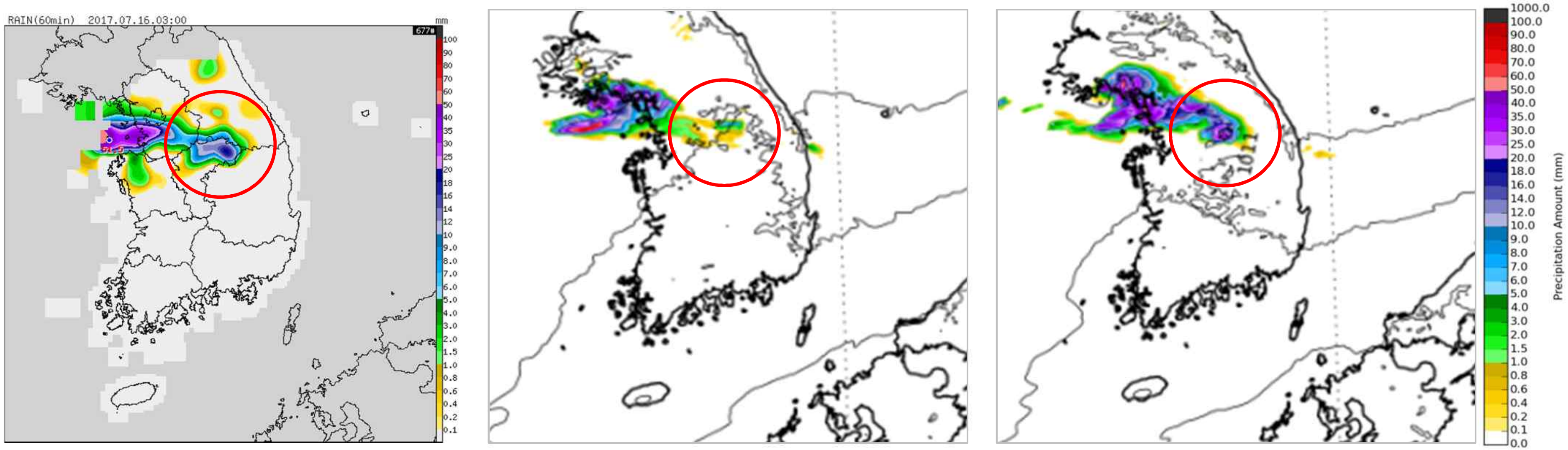
✓ Positive impact for heavy rainfall than weak rainfall

Impact of Ground-based GNSS

- ❖ By adding GNSS data, the **differences** ZTD of between observation and analysis are **reduced**
- ❖ The improvement of precipitation and 850 hPa Temperature in July 2016
- ❖ Improved precipitation forecast performance using spatially dense GNSS data

Observation	STN **#35** (+06h FCST)	STN **#80** (+06h FCST)

2017.07.15.18UTC



<1 hour accumulated precipitation>

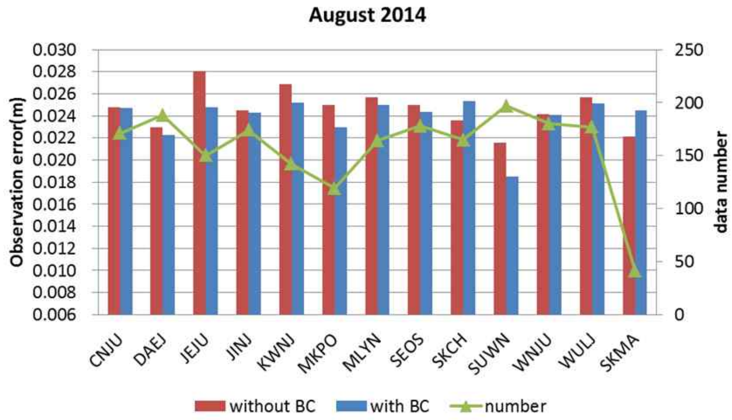
✓ STN #80 shows better agreement with observation than STN #35

Observation error

- Observation error calculation for 15 domestic sites (**previous LDAPS**)
- Observation error estimation and sensitivity experiment of GNSS

$$\mathbf{R} = E((y - H(x_a))(y - H(x_b))^T)$$

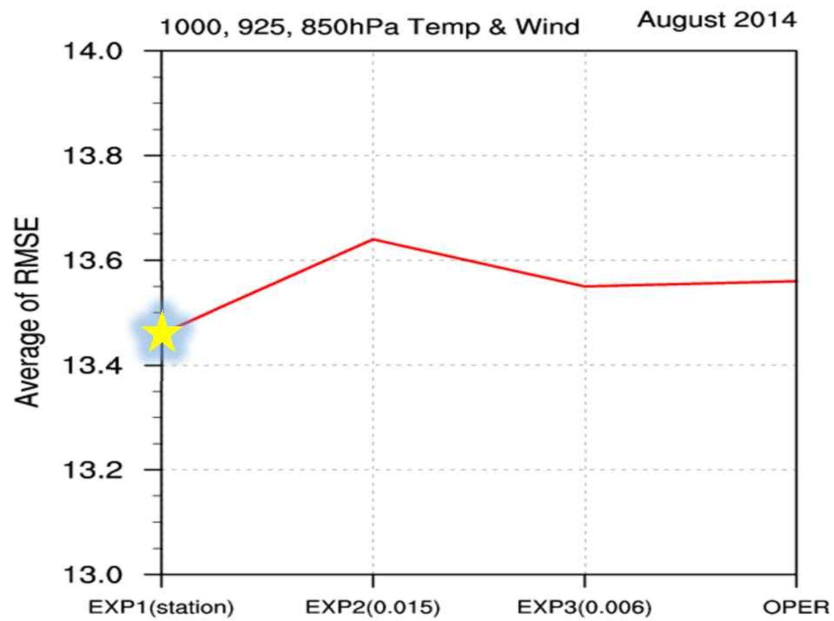
(Desroziers et al., 2005) ⇐ Observation error covariance estimation method using statistical values of innovation and analysis residual



<Observation error by station>

OPER	ZTD not assimilated
EXP1	ErrTZD= each station's R (at least 20mm)
EXP2	ErrTZD=15mm
EXP3	ErrTZD=6mm (Met Office)

<Configure of sensitivity experiment>

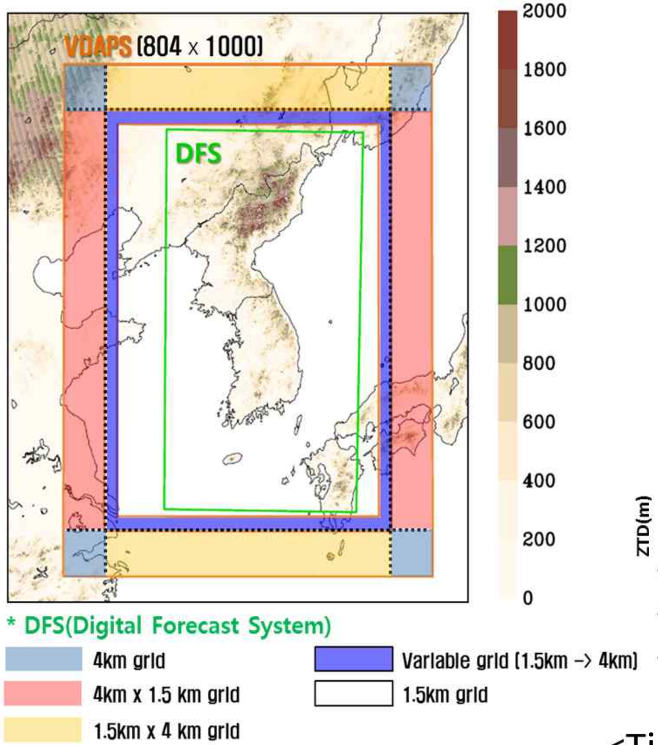


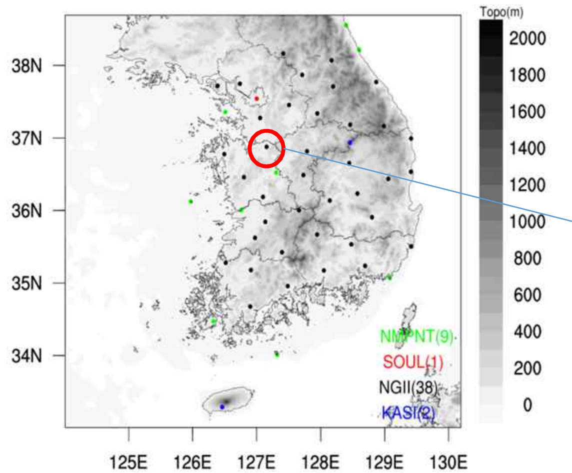
<Averaged RMSE by experiment>

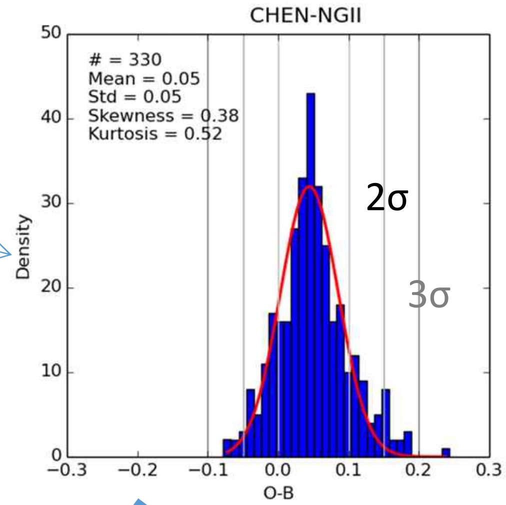
QC for Very-short range forecast model

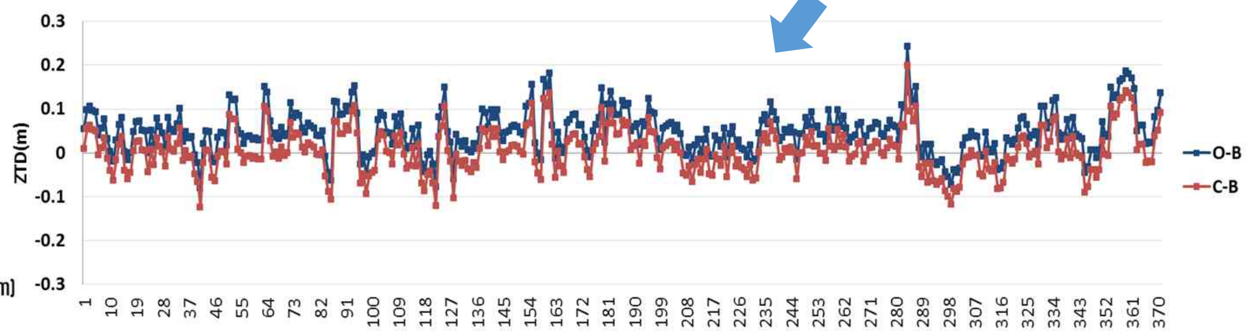
- ❖ Diagnosis of data quality at 50 stations every 15 minutes(**± 30 min cutoff time**)
- ❖ Static bias correction(1 month mean of O-B, **remove outlier ±2σ** each station)
- ❖ Seasonal experiments are in progress

VDAPS(Very-short range Data Assimilation and Prediction System)









<Time series of observation innovation before and after bias correction>

Ongoing activities for CS model

- Estimation of observation error covariance

  - Diagnosis approach (Desrozier et al., 2005, Hollingsworth and Lönnberg, 1986)

- Bias Correction

  - Ground-GNSS(Sánchez arriola et al., 2016), Aircraft, Radiance(IASI)

  Poster(1.5): Hee-Jung Kang

- Add available data

  - **15 minutes** ZTD → very-short range forecast model(VDAPS)

  - polar-orbiting **satellite**(IASI, ATMS, GNSS-RO, etc)

  - **Intensive observation** data for PyeongChang2018(Sonde, dropsonde, radar, etc)

Summary and Plan

Summary

- KMA has been dedicating to assimilate satellite data to fill gap at sparse area.
- The **quality** of ground-based GNSS station over the Korean Peninsular was evaluated and it looks **good** to assimilate for local and very-short range forecast model.
- Ground-based GNSS data gives **positive impacts** on the **lower tropospheric humidity** field and improved the skill score of **precipitation forecast**.

Future Plan

- To optimize use of the ground-based GNSS data, **estimation of observation error** and **new bias correction** have been investigated and initial trials show positive results.
- We plan to use the ground-based GNSS data in **NEW convective scale model** based on **KIM**(KIAPS Integrated Model system).

Thank you for your attention!

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