Development of AIRCRAFT data processing system and impact on a 3D-VAR system at KIAPS

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Introduction

The **K**orea **I**nstitute of **A**tmospheric **P**rediction **S**ystems (KIAPS) was founded in 2011 by the Korea Meteorological Administration (KMA) to develop Korea's own Global NWP model as nine years (2011-2019) project. Data Assimilation team at KIAPS has been developing the observation processing system (**K**IAPS **P**ackage for **O**bservation **P**rocessing: KPOP) to provide optimal observations to the data assimilation system for the KIAPS Global Model (KIAPS Integrated Model: KIM). Currently, the KPOP provides AMSU-A, IASI radiance and GPS-RO data for Local Ensemble Transform Kalman Filter (LETKF) and also provides AMSU-A radiance, SONDE, SURFACE, and AIRCRAFT data for Three-Dimensional Variational Assimilation (3DVAR).

Aircraft Meteorological DAta Relay (AMDAR) is the automated real-time reports of atmospheric conditions from an commercial aircraft platform at a lower cost relative to that derived from conventional radiosonde programs. Typically, AMDAR data include temperature and winds referenced to the location and altitude of the aircraft. Many studies have been demonstrated the positive impact of AMDAR data on numerical model performance. Preliminary results and details on each major processing step for the AIRCRAFT observation data are introduced in this presentation.
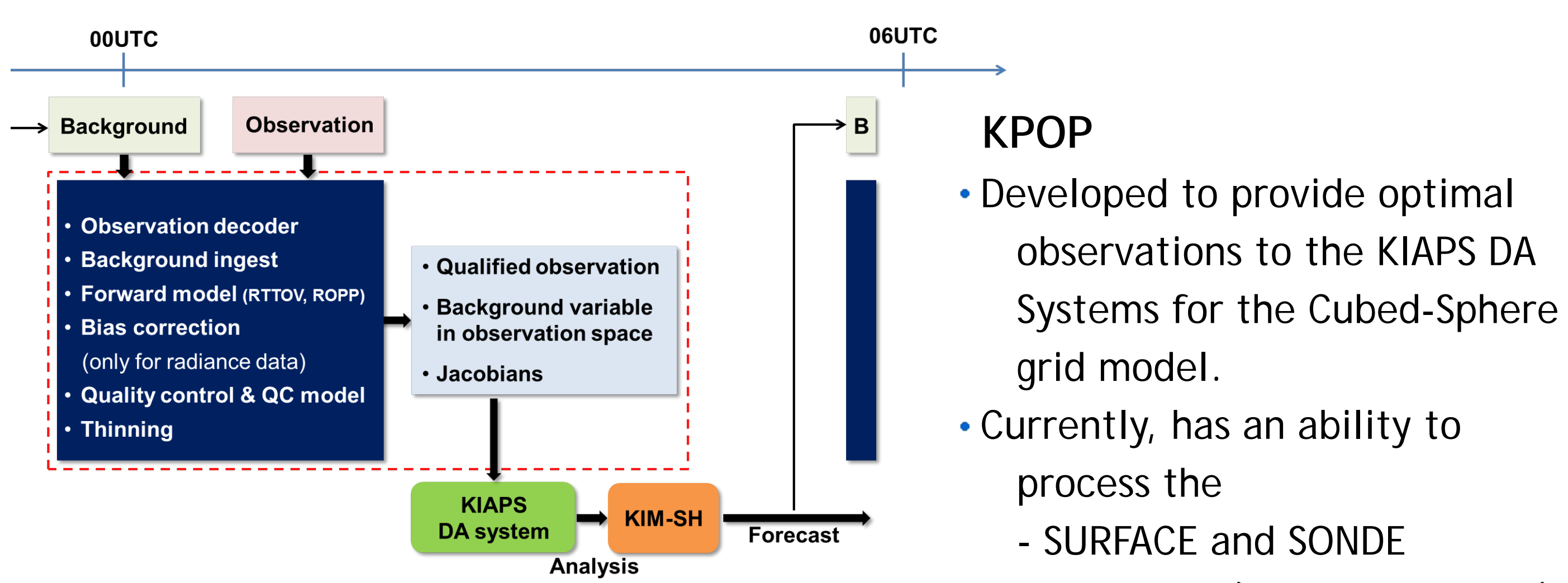
KPOP Design and progress

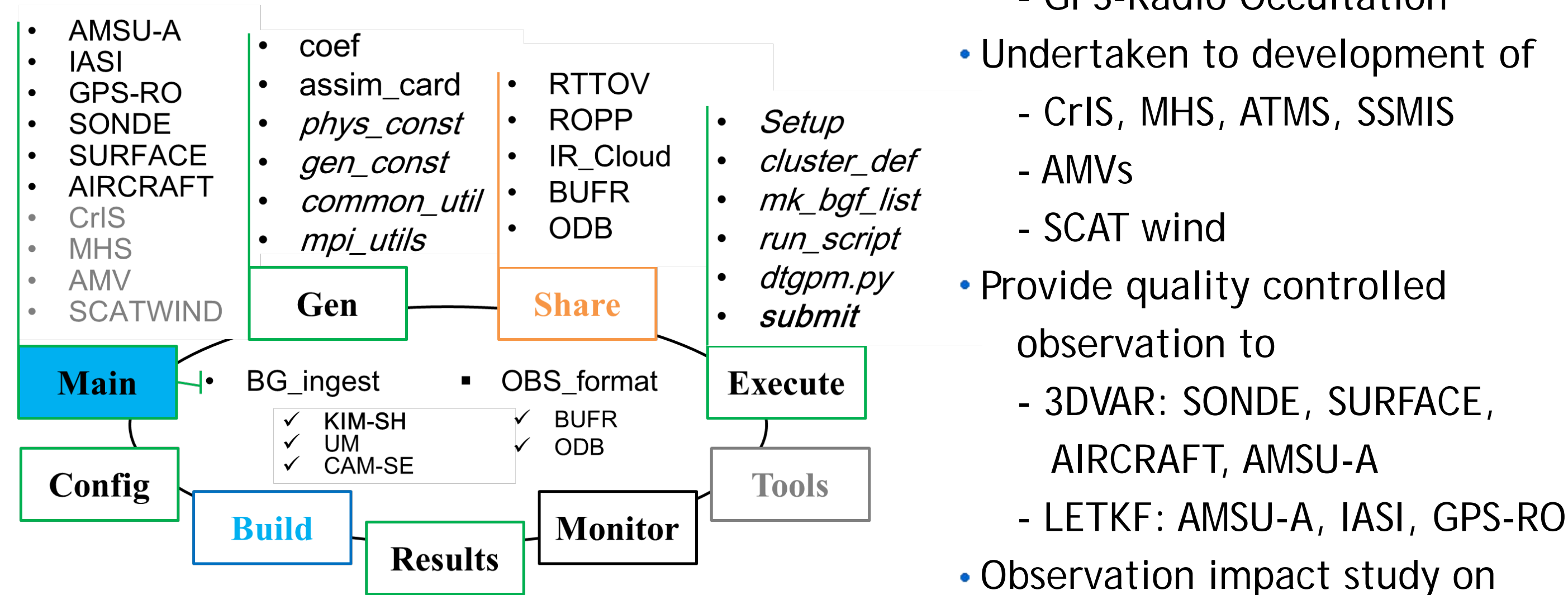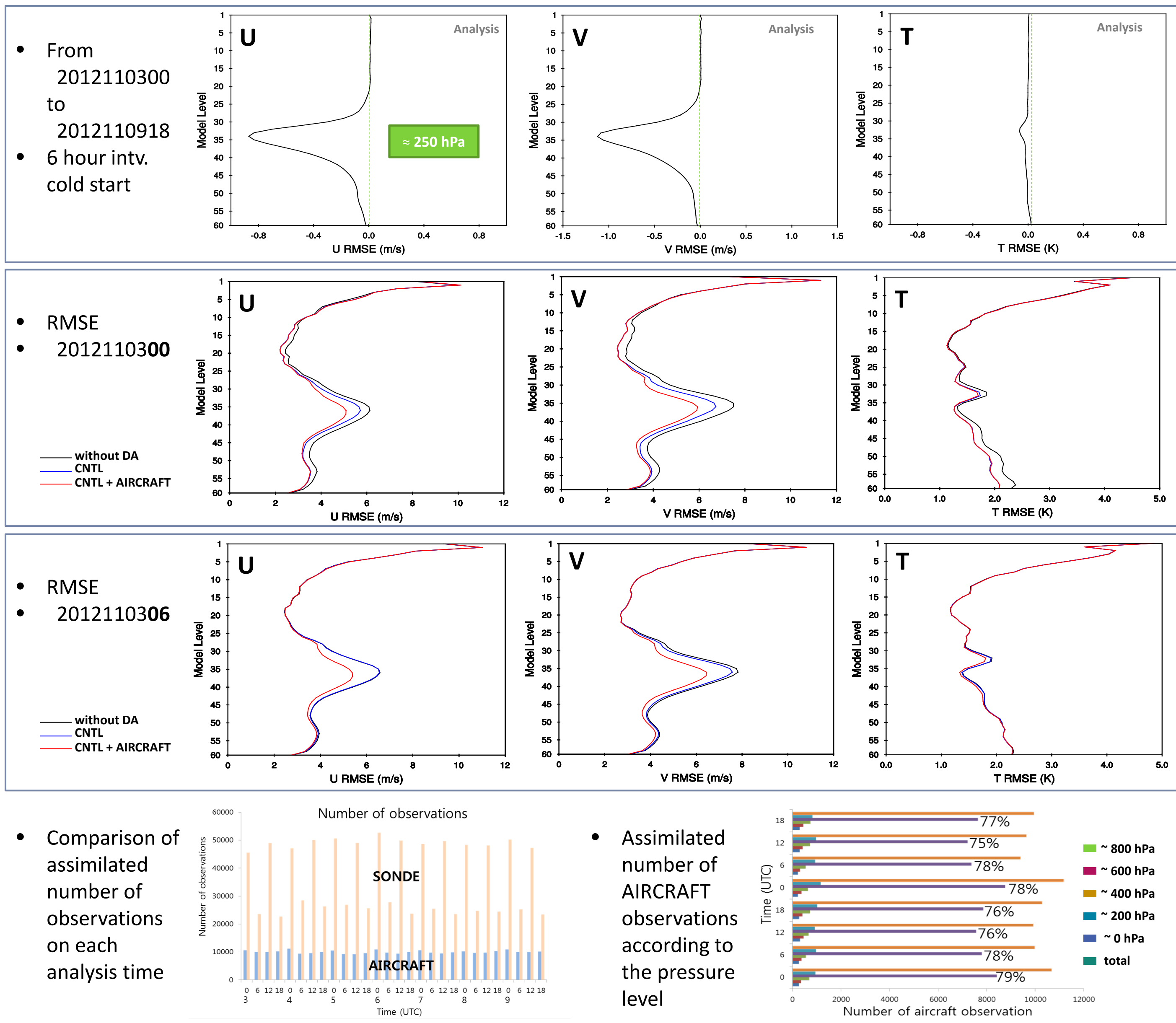Fig. 1. Design of KIM cycle run and brief description of KPOP elements.

Fig. 2. Block diagram for the KPOP structure.

KPOP
- Developed to provide optimal observations to the KIAPS DA Systems for the Cubed-Sphere grid model.
- Currently, has an ability to process the
  - SURFACE and SONDE
  - AIRCRAFT (AMDAR, AIREP, ...)
  - Radiance (AMSUA, IASI)
  - GPS-Radio Occultation
- Undertaken to development of
  - CrIS, MHS, ATMS, SSMIS
  - AMVs
  - SCAT wind
- Provide quality controlled observation to
  - 3DVAR: SONDE, SURFACE, AIRCRAFT, AMSU-A
  - LETKF: AMSU-A, IASI, GPS-RO
- Observation impact study on 3DVAR in progress

Table 1. Progresses and plans for development of KPOP.
(blue arrow denote duration on prototype processing module development and yellow arrow denote improvement schedule on each prototype modules)
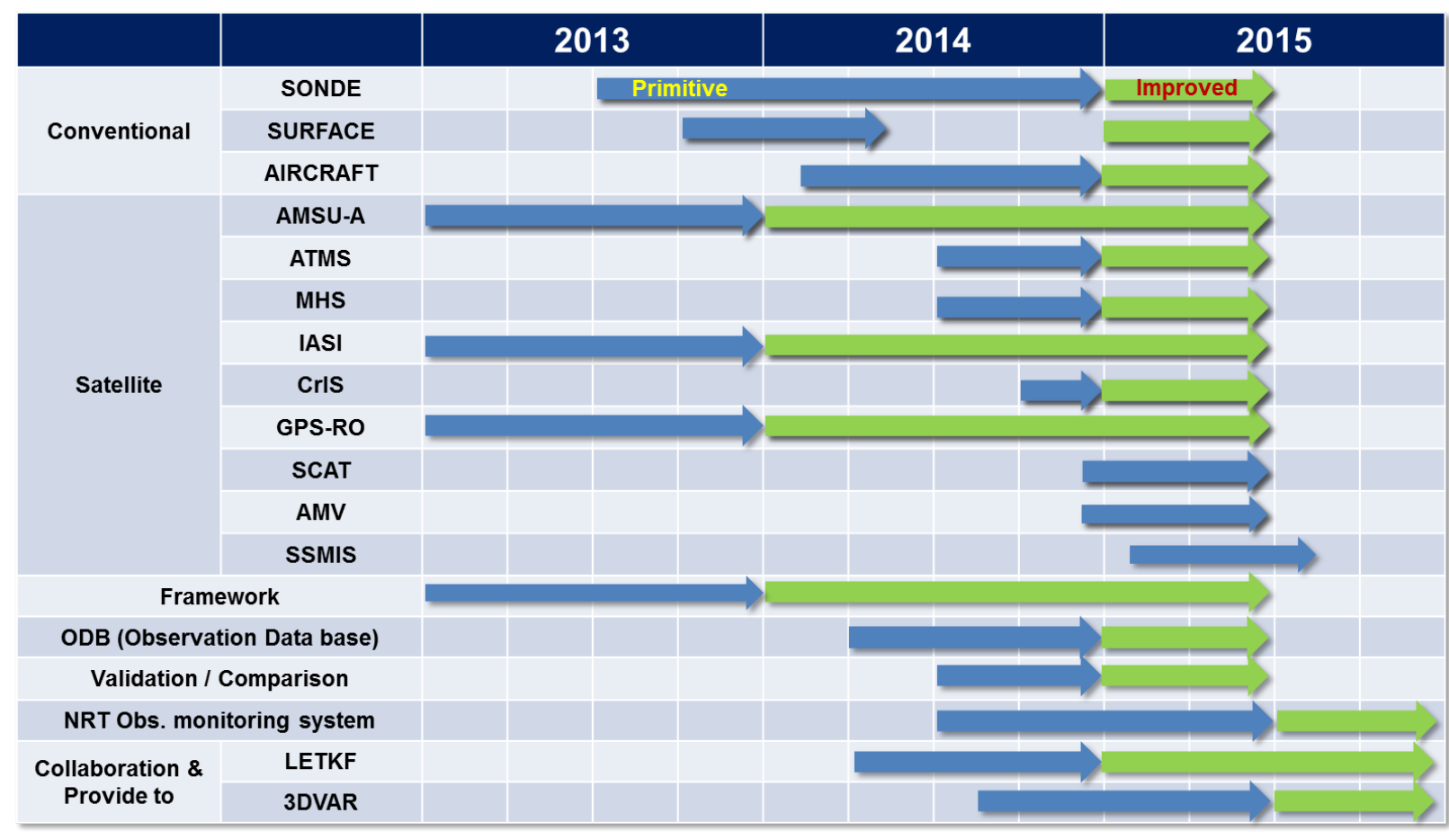
AIRCRAFT data assimilation impacts on 3DVAR

- **Data Assimilation impact of temperature (T) and wind (u, v)**
  - ✓ RMSE difference: (CNTL + AIRCRAFT) − CNTL → negative values denote improvement of analysis field
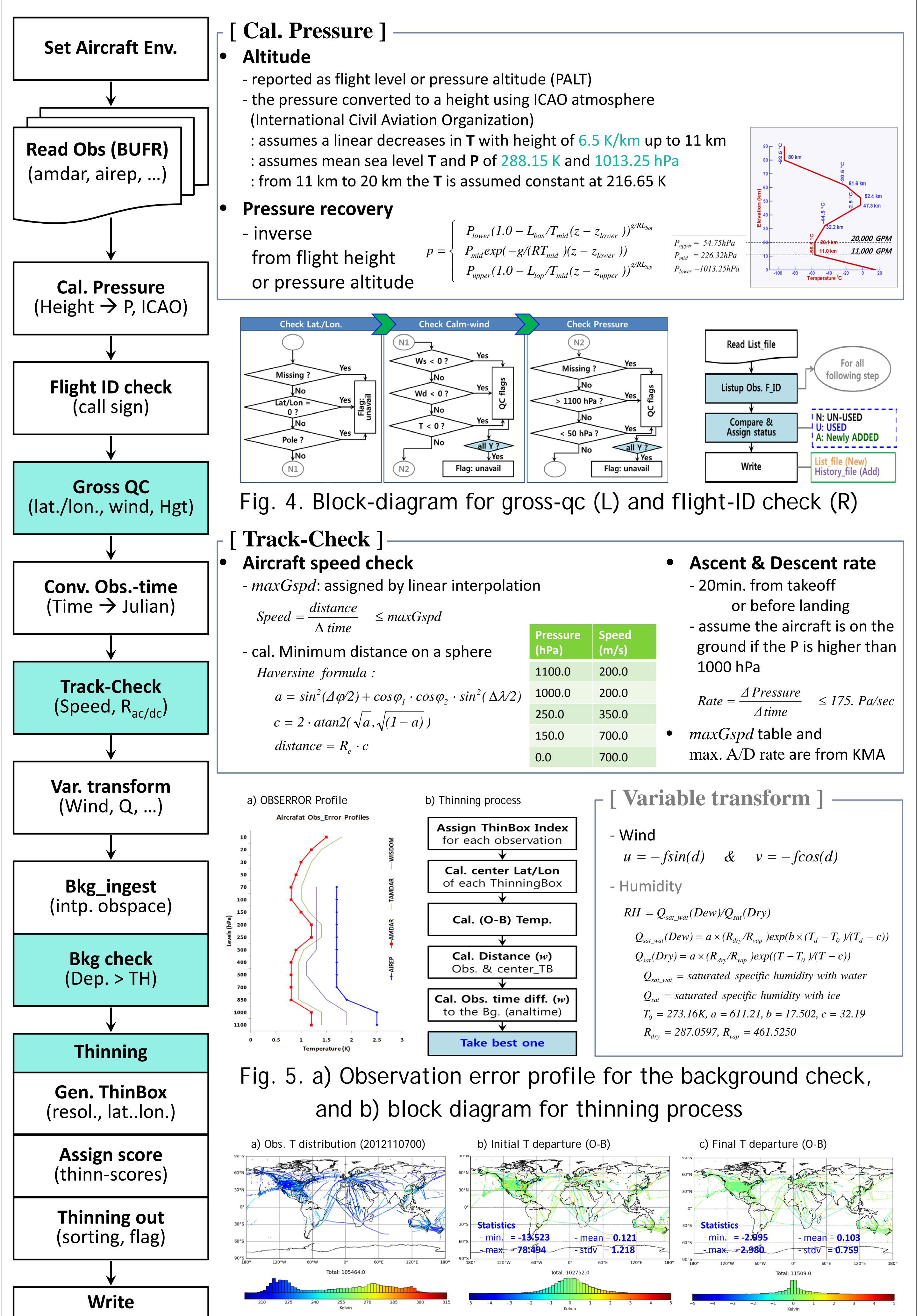 - CNTL: SONDE and SURFACE data are assimilated

- From 2012110300 to 2012110918 6 hour intv. cold start

- RMSE 2012110**300**

- RMSE 2012110**306**

- Comparison of assimilated number of observations on each analysis time

- Assimilated number of AIRCRAFT observations according to the pressure level

KPOP-AIRCRAFT

Fig. 3. Block diagram for the KPOP-AIRCRAFT

[Cal. Pressure]
- **Altitude**
  - reported as flight level or pressure altitude (PALT)
  - the pressure converted to a height using ICAO atmosphere (International Civil Aviation Organization)
    : assumes a linear decreases in T with height of 6.5 K/km up to 11 km
    : assumes mean sea level **T** and **P** of 288.15 K and 1013.25 hPa
    : from 11 km to 20 km the T is assumed constant at 216.65 K
- **Pressure recovery**
  - inverse from flight height or pressure altitude

$$p = \begin{cases} P_{lower}(1.0 - L_{l017}/T_{mid}(z - z_{lower}))^{g/RT_{mid}} & P_{lower} = 54.75hPa \\ P_{mid}exp(-g/(RT_{mid})(z - z_{mid})) & P_{mid} = 226.32hPa \\ P_{upper}(1.0 - L_{top}/T_{mid}(z - z_{upper}))^{g/RT_{top}} & P_{upper} = 1013.25hPa \end{cases}$$

$$z = \begin{cases} 20,000 \ GPM \\ 11,000 \ GPM \end{cases}$$

Fig. 4. Block-diagram for gross-qc (L) and flight-ID check (R)

[Track-Check]
- **Aircraft speed check**
  - maxGspd: assigned by linear interpolation
    $$Speed = \frac{distance}{\Delta time} \leq maxGspd$$
  - cal. Minimum distance on a sphere
    Haversine formula :
    $$a = \sin^2(\Delta\varphi/2) + \cos\varphi_1 \cdot \cos\varphi_2 \cdot \sin^2(\Delta\lambda/2)$$
    $$c = 2 \cdot atan2(\sqrt{a}, \sqrt{(1-a)})$$
    $$distance = R_e \cdot c$$

- **Ascent & Descent rate**
  - 20min. from takeoff or before landing
  - assume the aircraft is on the ground if the P is higher than 1000 hPa
    $$Rate = \frac{\Delta Pressure}{\Delta time} \leq 175. \ Pa/sec$$
  - maxGspd table and max. A/D rate are from KMA

Pressure (hPa)	Speed (m/s)
1100.0	200.0
1000.0	200.0
250.0	350.0
150.0	700.0
0.0	700.0

[Variable transform]
- Wind
  $$u = -f\sin(d) \quad \& \quad v = -f\cos(d)$$
- Humidity
  $$RH = Q_{sat\_wat}(Dew)/Q_{sat}(Dry)$$
  $$Q_{sat\_wat}(Dew) = a \times (R_{dry}/R_{vap})exp(b \times (T_d - T_0)/(T_d - c))$$
  $$Q_{sat}(Dry) = a \times (R_{dry}/R_{vap})exp((T - T_0)/(T - c))$$
  $Q_{sat_wat} = $ saturated specific humidity with water
  $Q_{sat} = $ saturated specific humidity with ice
  $T_0 = 273.16K, a = 611.21, b = 17.502, c = 32.19$
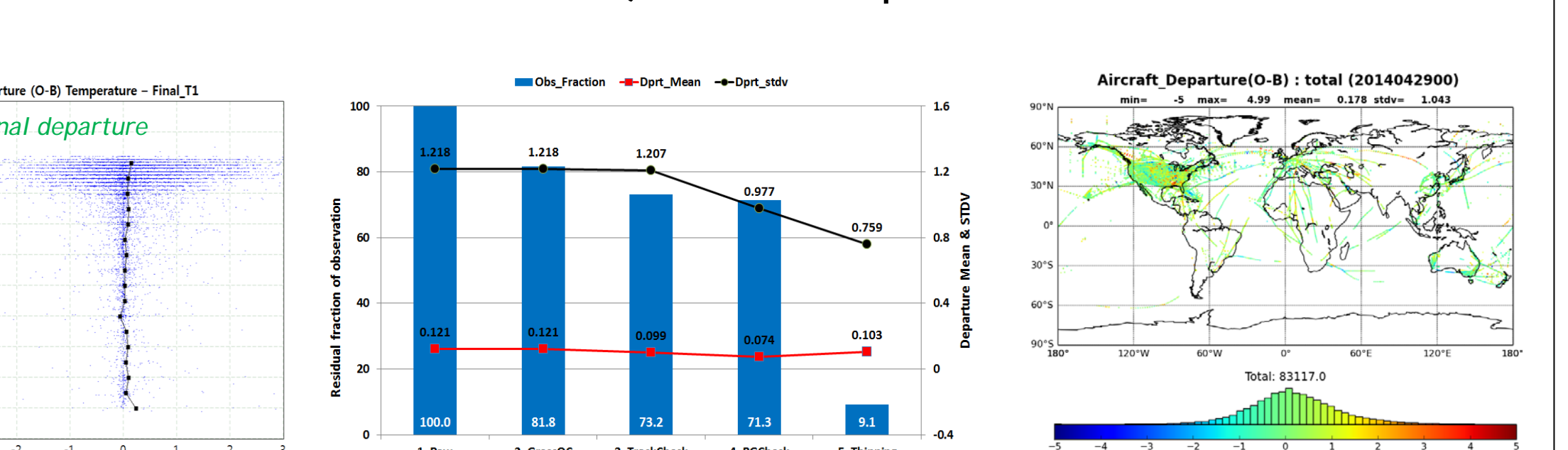 $R_{dry} = 287.0597, R_{vap} = 461.5250$

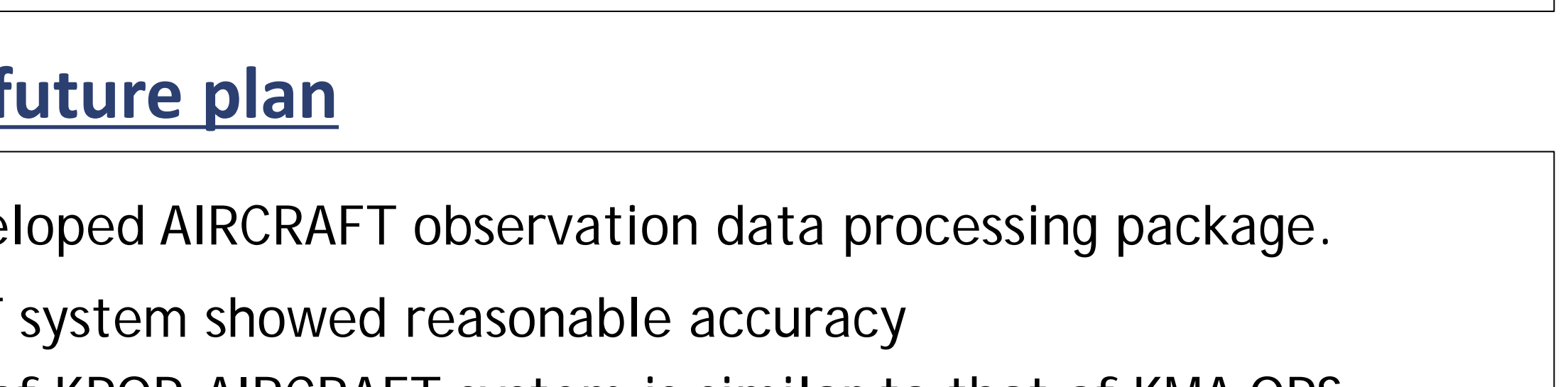Fig. 5. a) Observation error profile for the background check, and b) block diagram for thinning process

Fig. 6. Spatial distribution of a) observed temp., b) T departure of raw obs., and c) final T departure with statistics.

Fig. 7. Distribution of T-depart. with vertical levels

Fig. 8. Statistics on each processing step

Fig. 9. Status of KMA oper. OPS

Summary and future plan

- Have been developed AIRCRAFT observation data processing package.
- KPOP-AIRCRAFT system showed reasonable accuracy
  - the statistics of KPOP-AIRCRAFT system is similar to that of KMA OPS
- Wind components (u/v) of AIRCRAFT are shows significant impact relative to that of Temperature on 3DVAR and most AIRCRAFT impacts are concentrated around 250 hPa height.
- Planning to provide profile temperature and wind components