Arctic OSE studies by using the AFES-LETKF data assimilation system (ALEDAS2)

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Summary

- Ensemble-based data assimilation system for global atmospheric data has been developed and experimental reanalysis dataset generated by the system has been archived from 2008.
- Observing-system researches especially for Arctic radiosonde observations by using the data assimilation system are introduced here.
- We have been developing the data assimilation system to increase the ensemble members and to implement a diagnostic technique to estimate forecast sensitivity to observations.

1. Introduction

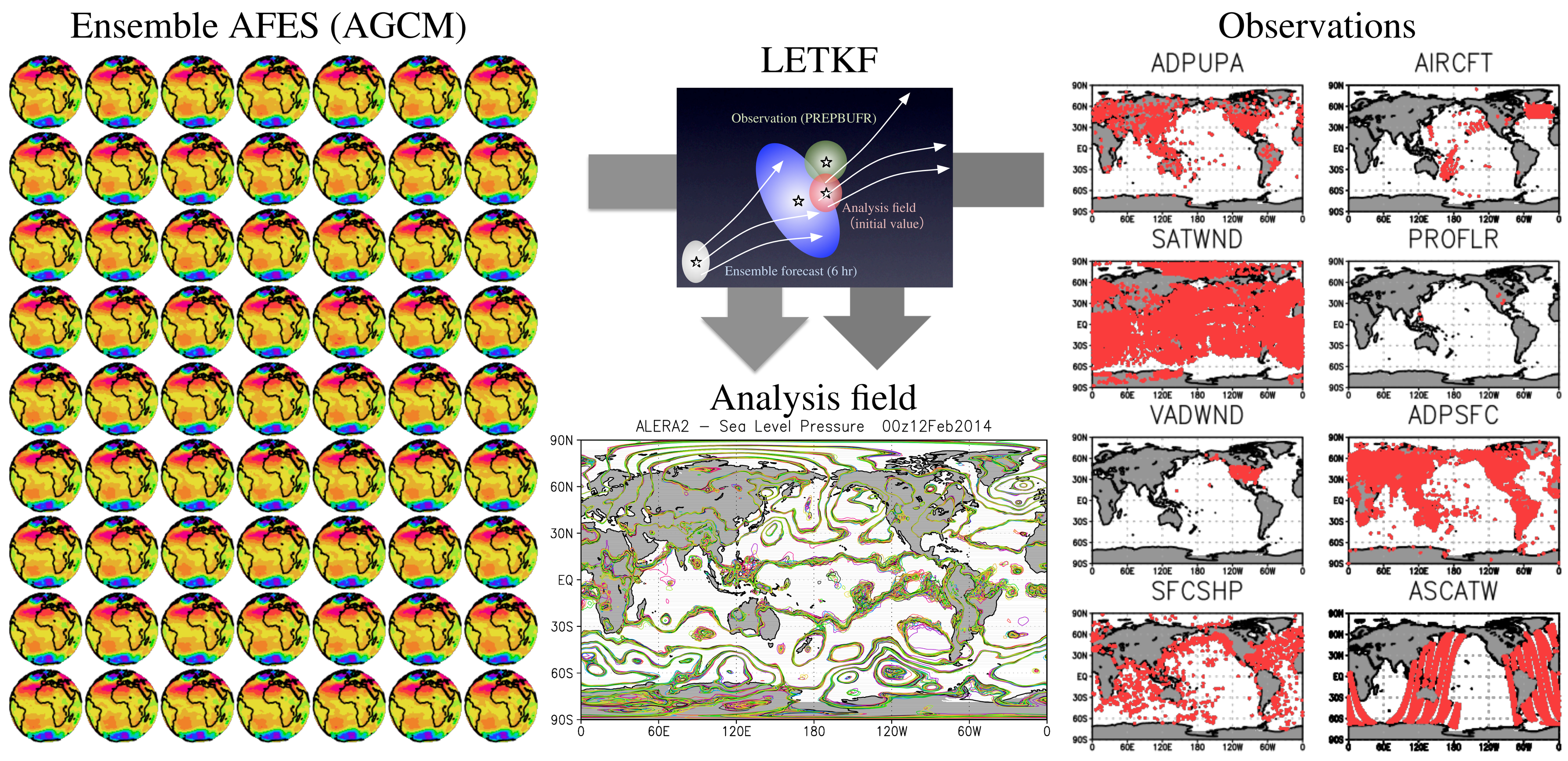

Fig 1: Schematics of ALEDAS2.

- An ensemble data assimilation system, ALEDAS2 is composed of the Atmospheric GCM for the Earth Simulator (AFES) and the local ensemble transform Kalman filter (LETKF) (Fig. 1; Enomoto et al. 2013).
- AFES-LETKF experimental ensemble reanalysis 2 (ALERA2) generated by ALEDAS2 has been archived from 2008 to early 2016 (Table 1).
- Currently, three streams have been conducted as ALERA2. Dataset of stream 2008 and 2010 can be available from http://www.jamstec.go.jp/esc/research/oreda/products/index.html.

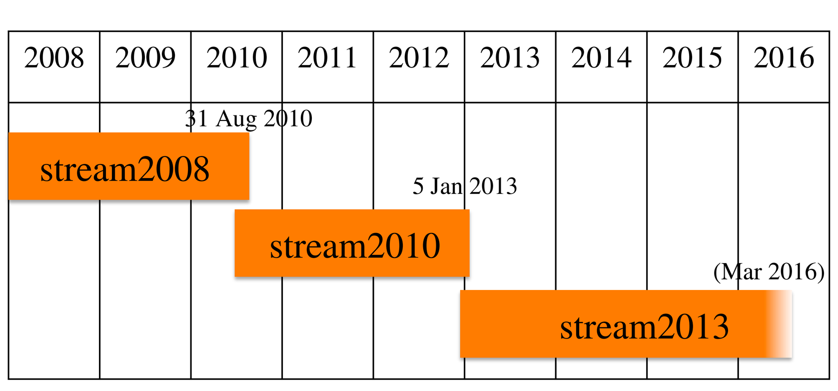

Fig 2: Streams in ALERA2.

Table 1: The configuration of ALERA2.

Resolution	T119L48 (~1°×1°, up to ~3 hPa)
Ensemble size	63+1
Covarianace localization	σ=400 km / 0.4 ln*p*
Spread inflation	10% (fixed)
Observations	NCEP PREPBUFR
Boundary conditions	OISST daily ¼°
DA window	6 h

- Since ALERA2 shows very similar global and synoptic fields with other reliable reanalyses, it can be treated as a reanalysis representative of the real atmosphere.
- We have been conducted some observing system experiment (OSE) studies by using ALEDAS2. In the study, we compare ALERA2 as the control reanalysis (CTL) with an OSE which is a reanalysis generated by a data assimilation system within which specific observations are added or excluded, and evaluate the impact of the observations.
- Targets of the OSE studies are from tropical to Arctic regions (e.g., Inoue et al. 2013; Hattori et al. 2016), but we here mainly introduce the studies for Arctic observations and atmospheric phenomena there.

2. Arctic OSE studies

1) Case of the 'great' Arctic cyclone in August 2012 (Yamazaki et al. 2015)

- The Arctic cyclone which occurred in early August 2012 (AC12) is given the adjective 'great' because its surface central pressure was the lowest of any Arctic cyclone during August since records began in 1979 (Simmonds and Rudeva 2012).
- The trough in the upper troposphere near the surface AC12 affects the development of AC12. => Importance of reproducibility of the upper tropospheric circulations.

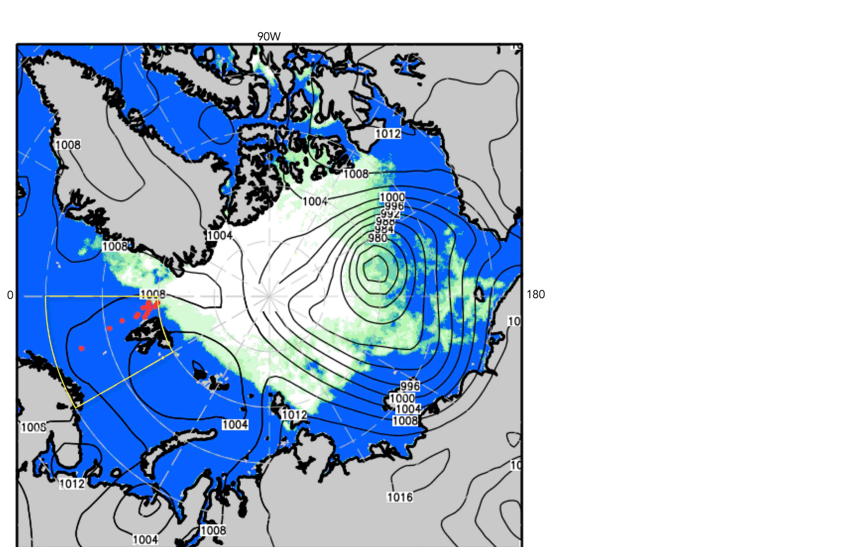

Fig 3: Locations of radiosonde observations performed by the *Polarstern* (red dots) during 13–29 July 2012 with SLP and sea ice concentration on 6 August 2012 (After Yamazaki et al. 2015).

- Just before and during the AC12's lifetime, the German R/V *Polarstern* took twice-daily radiosonde observations near Svalbard (Fig. 3).
- Inoue et al. (2013) found that radiosonde observations in the Arctic region improves reproducibility of the upper tropospheric circulations over there.

➢ The observation by *Polarstern* would contribute to forecasting AC12?

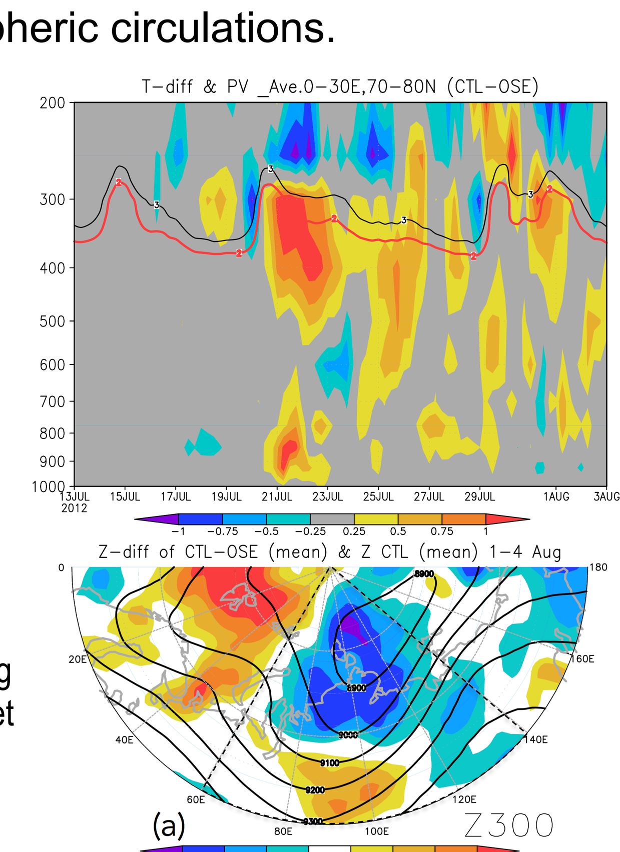

Fig 4: (Upper) Vertical distributions of temperature differences (shading, [°C]) between the CTL and OSE and dynamical tropopause [PVU] in the CTL, averaged over the *Polarstern* observation area (within the yellow box in Fig. 3). (Bottom) Average differences (shading) and fields in the CTL (contours) in Z300 (m) between CTL and OSE during 1–4 Aug. After Yamazaki et al. (2015)

- An OSE reanalysis in which the *Polarstern* radiosonde data were excluded from ALEDAS2 was created and compared with ALERA2 (CTL).
- The observational impact, that is the difference between CTL and OSE was large in the upper troposphere (Fig. 4).
- The impact 'propagated' as a stationary Rossby wave from the observation points to the trough just located downstream through the upper troposphere and improved reproducibility of the trough, even though the difference was small relative to the amplitude of the trough.

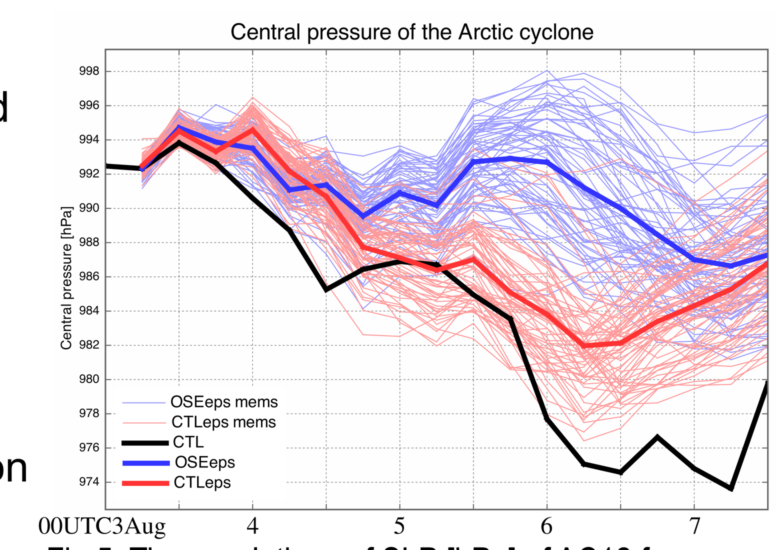

Fig 5: Time evolutions of SLP [hPa] of AC12 for predictions from CTL (red) and OSE (blue). Light and thin lines indicate temporal evolutions of all 63 ensemble members and the thick lines indicate the ensemble means of minimum SLP at AC12 centers of the ensemble members. Time evolutions in CTL reanalysis (black) are also shown. After Yamazaki et al. (2015).

- Ensemble predictions using AFES with the same configurations as ALEDAS2 were then conducted using the CTL and OSE reanalyses as initial values when AC12 started to develop (00 UTC 3 Aug).
- The CTL prediction reproduced the formation of AC12, but the OSE shows a significantly weaker one (Fig. 5), indicating that the improved reproduction of then upper tropospheric circulation due to the *Polarstern* radiosonde was indispensable for the prediction.
- Ono et al. (2016) used the prediction data for an ice-ocean coupled model and found that the improved prediction also has large impact on precisely forecasting sea-ice distribution along the Northern Sea Route during the period.

2) OSE for the strong wind event in Sep 2013 (Inoue et al. 2015)

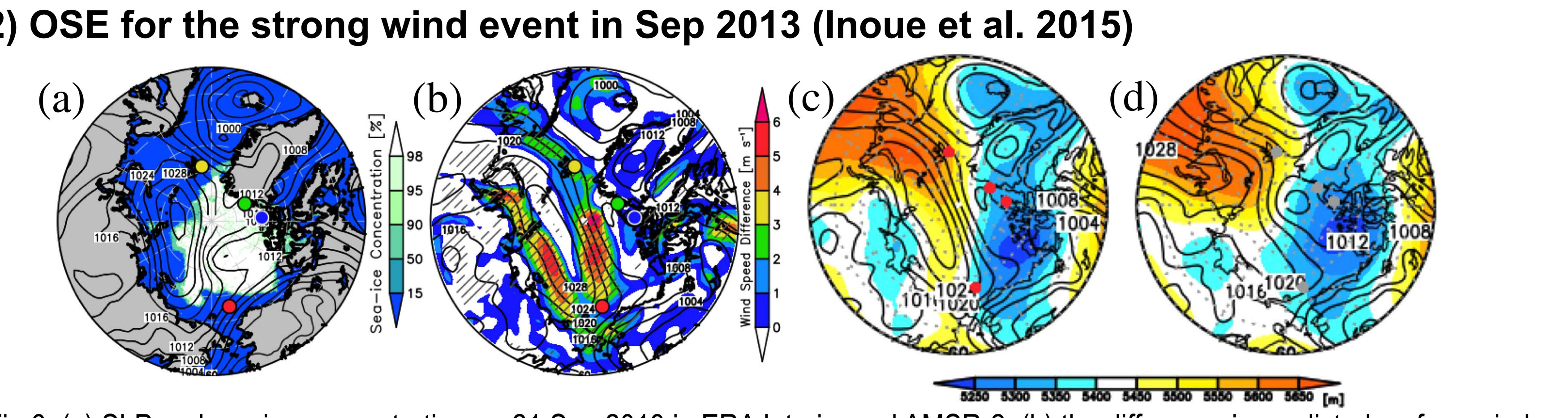

Fig 6: (a) SLP and sea ice concentration on 21 Sep 2013 in ERA Interim and AMSR-2, (b) the difference in predicted surface wind speeds (CTL-OSE), and predicted Z500 (shading) with SLP (contour) in (c) the CTL and (d) OSE at 21 Sep (5.5 forecast day). The ARCROSE stations are indicated by dots. After Inoue et al. (2015).

- The impact of the additional observations during Sep 2013 obtained by a special radiosonde observing network as part of the Arctic Research Collaboration for Radiosonde Observing System Experiment (ARCROSE) on the predictability of weather and sea-ice patterns was evaluated through an OSE study.
- Forecast experiments initialized by CTL and OSE fields were conducted and it was revealed that additional Arctic radiosonde observations improved reproduction of the upper tropospheric and surface anticyclones and were useful for predicting a persistent strong wind event (Fig. 6).

3. Recent development of ALEDAS2

Recently, we have developing and improving ALEDAS2 more useful for observing-system researches to contribute to constructing optimal observation networks and improving forecasts.

1) Increasing ensemble members in ALEDAS2

- A test is conducting to increase ensemble members in ALEDAS2 to 255 (M255) with the same configurations as the current ALEDAS2 (M63).
- Increasing the members improves reproduction of global fields (Fig. 7), and extends spread more larger than M63.

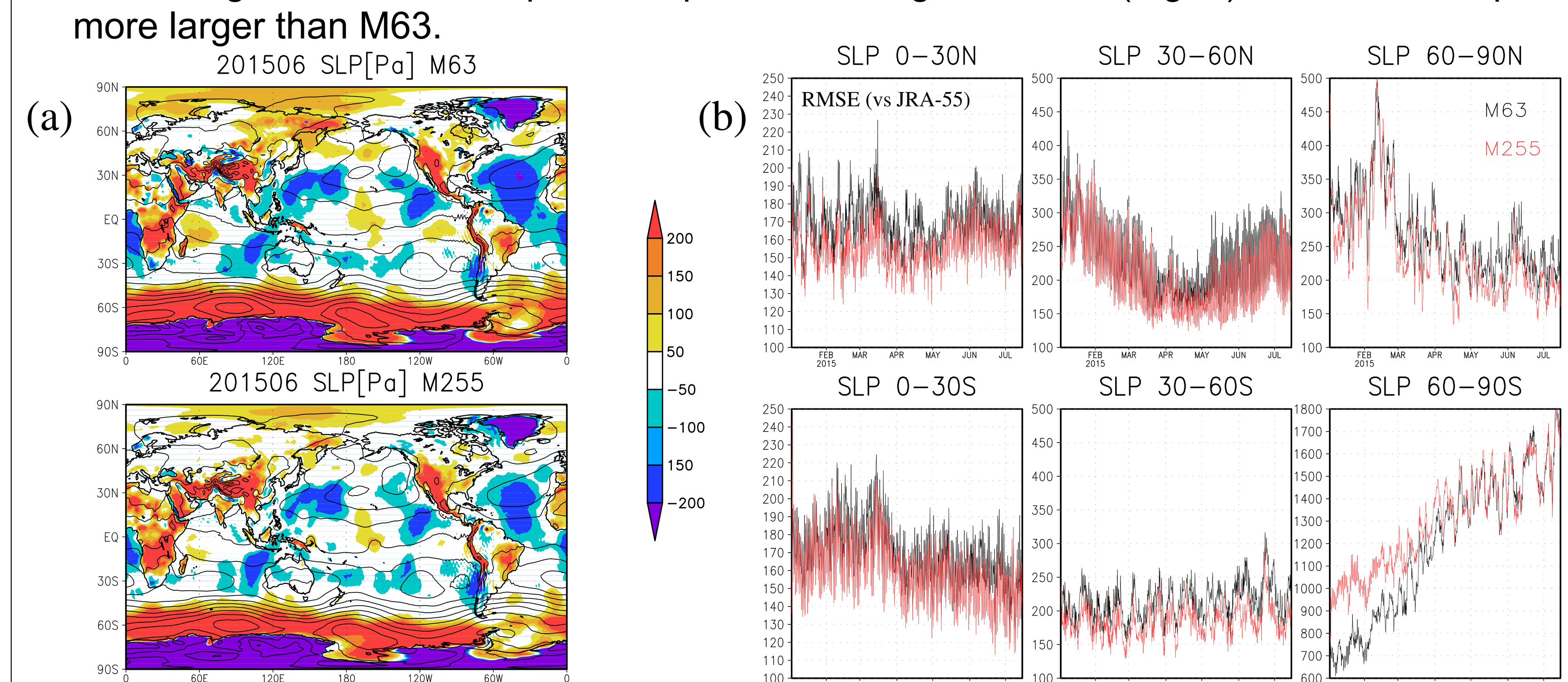

Fig 7: (a) Averaged difference against JRA-55 (Kobayashi et al. 2015) and fields in SLP [Pa] during Jun 2015 for (upper) M63 and (bottom) M255. (b) Time sequences of RMSE of M255 (red) and M63 (black) against JRA-55 in SLP [Pa] during Jan-Jul 2015 in (left) tropics, (middle) midlatitudes, and (right) polar latitudes. Note that forecast-analysis cycle in the M255 system started from 3 Jan 2015 by using arbitrary ALERA2 fields.

2) Ensemble Forecast Sensitivity to Observations (EFSO)

A novel diagnostic technique, EFSO (Ota et al. 2013; Hotta 2014), to quantify how much each observation has improved or degraded the forecast is implemented to the current ALEDAS2.

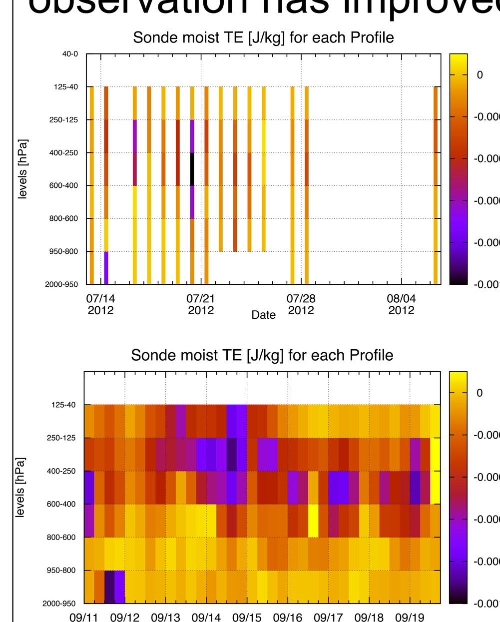

Fig 8: Time series of estimated error reduction [J/kg] by (upper) the *Polarstern* radiosondes (Section 2.1) and (bottom) the Arctic radiosonde observations (Section 2.2).

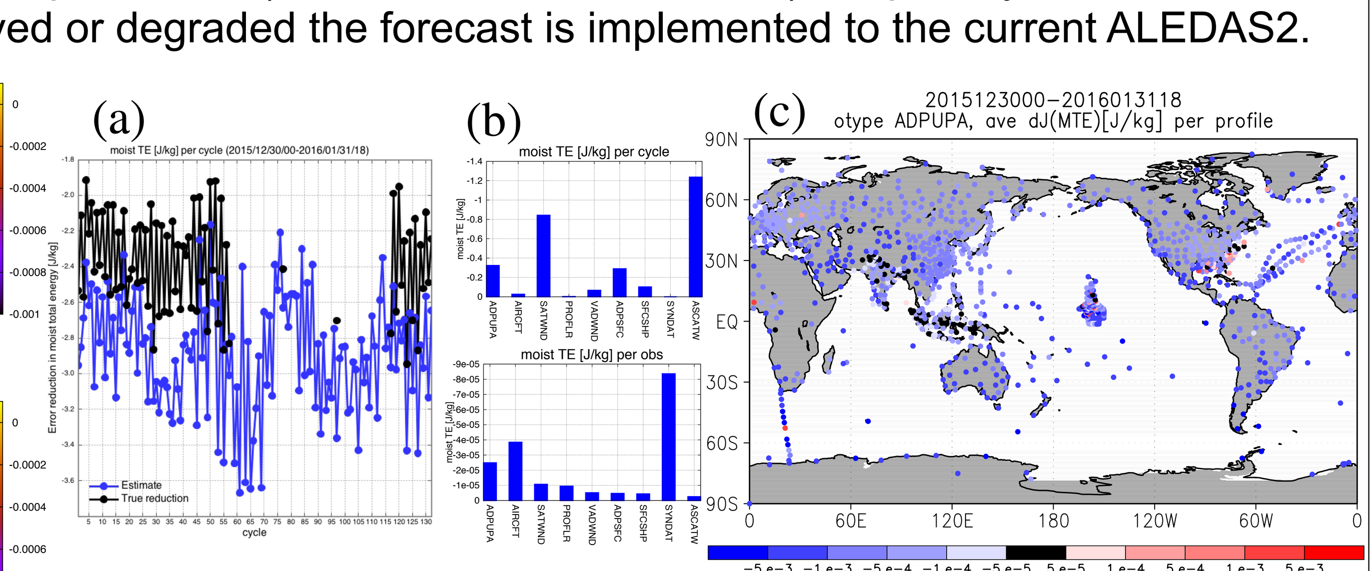

Fig 9: (a) Time series of the estimated total 6-hour forecast error reduction (blue, [J/kg]). Black line shows the actual forecast error reduction verified against the own analysis. (b) Estimated average 6-hour forecast error reduction [J/kg] contributed from each observation types. (b, upper) for the total error reduction and (b, bottom) for error reduction per observation. (d) Estimated average error reduction [J/kg] of a single radiosonde profile. Reductions in (b) and (c) are averaged during 30 Dec 2015 to 31 Jan 2016.

- Estimated error reductions for the cases in Section 2 show consistent vertical distributions in their time series with results of the OSE studies (Fig. 8).
- Estimated error reduction has close to the value of the actual error reduction (Fig. 9).
- Impact of each observation types, variables, and locations can be estimated separately.

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