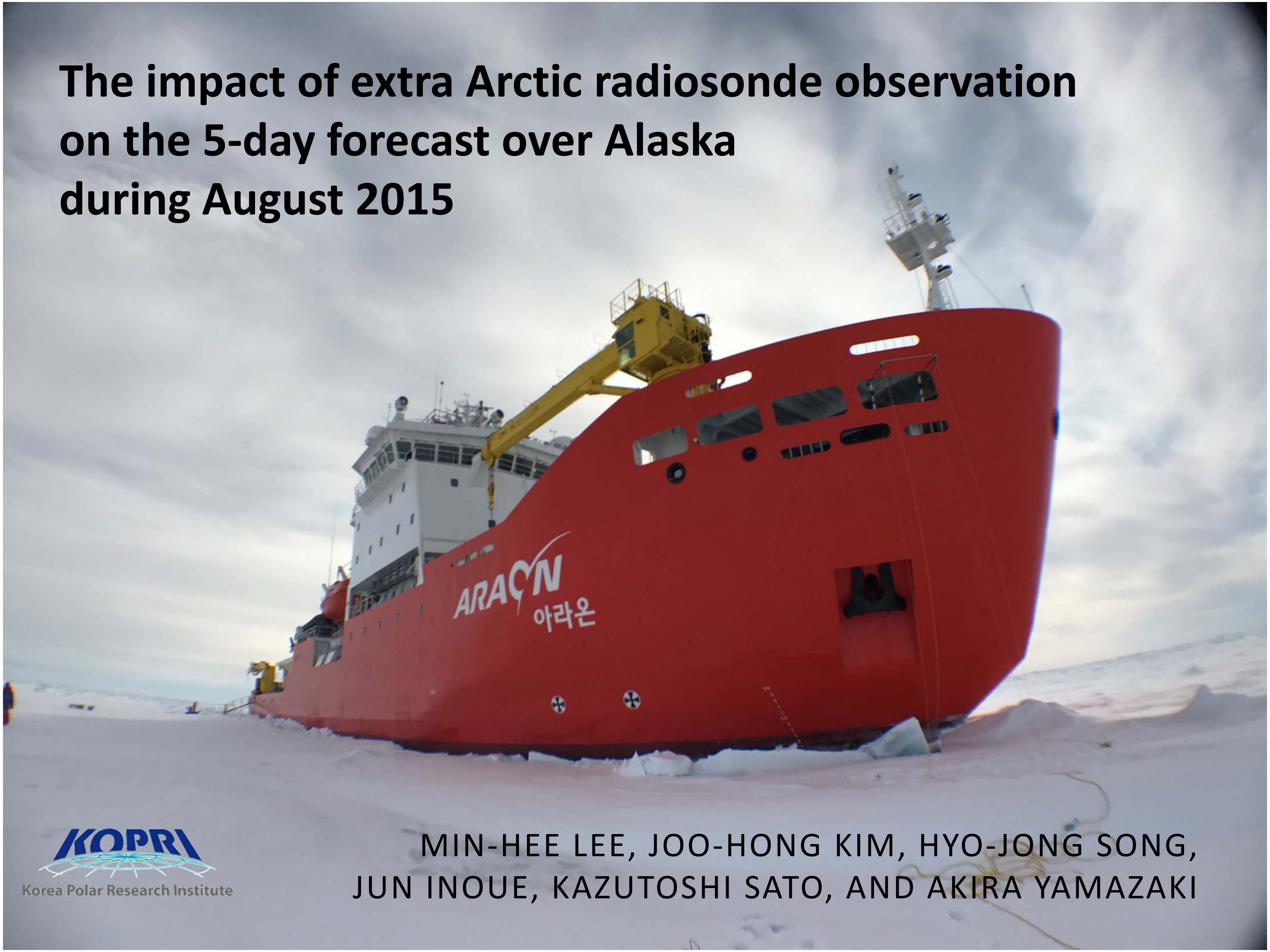

The impact of extra Arctic radiosonde observation on the 5-day forecast over Alaska during August 2015

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JUN INOUE, KAZUTOSHI SATO, AND AKIRA YAMAZAKI

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Background

- The Arctic receives considerable attention both the public and science community under recent rapid climate change.
- Beyond its passive role as an energy sink of the globe, the accelerating Arctic warming in recent decades made the Arctic more active in forming its nonlinear interaction with the adjacent regions
- Given the emerging role of the Arctic in NH weather and climate, a lack of a sustainable observing network in the Arctic is a big issue, which could be the substantial source of uncertainties in weather and climate forecasts, limiting predictability in the NH mid-latitudes.
- The ongoing international effort, such as the 'Year Of Polar Prediction (YOPP)' for the period 2017-19, would extensively evaluate the predictability source from the Arctic (Jung et al., 2016).
- Prior to the YOPP period, however, several studies have already shown the positive impact of extra Arctic observations on the wider range weather and sea ice predictability of numerical models.
- The extra Arctic observations with great interest were the radiosonde vertical atmospheric profiles over the data-sparse Arctic Ocean obtained by the research vessels (R/Vs), such as the Korean *Araon*, Japanese *Mirai*, German *Polarstern*, Norwegian *Lance*, etc.

Previous studies on the impact of extra observation

- **Improvement of forecast skill for Arctic cyclone in 5-7-day scale**

[Yamazaki et al., 2015]

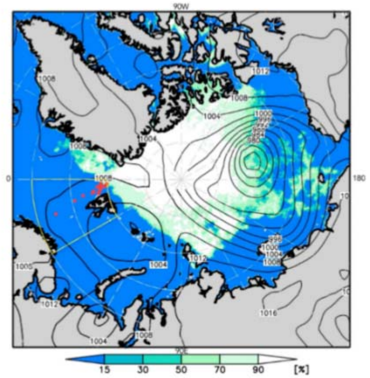


Figure 1. Locations of radiosonde observations performed by the *Polarstern* (red dots) during 13–29 July 2012, sea level pressure at 00:00 UTC on 6 August 2012, in ERA-Interim (ERAI), and sea ice concentration on 6 August 2012, in AMSR2. Area defined by yellow line near Svalbard indicates the averaging region used for Figure 11.

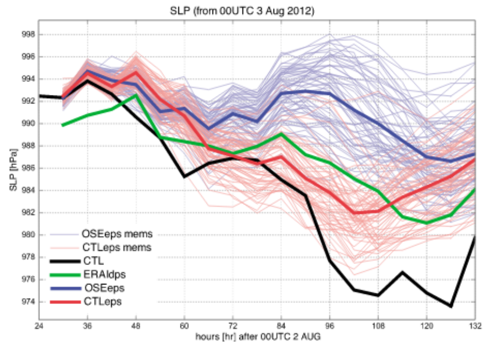
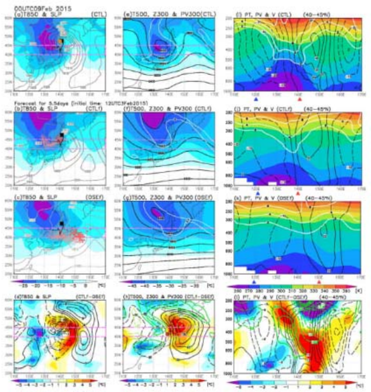


Figure 17. Same as Figure 9a but for the CTL Ensemble Prediction System (CTL_{EPS}) experiment (red) and the OSE_{EPS} (blue). Light and thin lines indicate temporal evolutions of all 63 ensemble members of CTP_{EPS} (red) and OSE_{EPS} (blue). The thick red and blue lines indicate the ensemble means of minimum SLP at AC12 centers of the ensemble members. Time evolutions in the CTL reanalysis (black) and ERAI Deterministic Prediction System experiment ($ERAI_{DPS}$, green) are also shown.

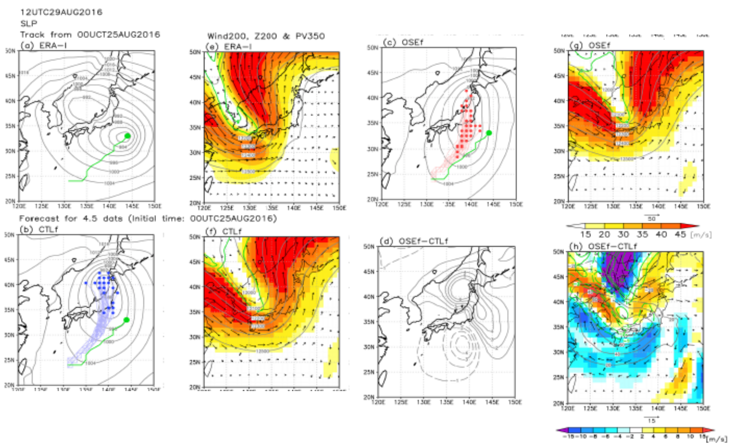
- **Impact on the mid-latitude extremes (i.e., typhoon, cold-surge)**

[Sato et al., 2017]

Winter extreme cold (w. N-ICE 2015 …)

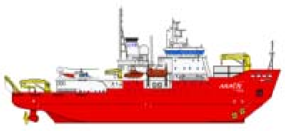


Summer tropical cyclone (w. Araon 2016)

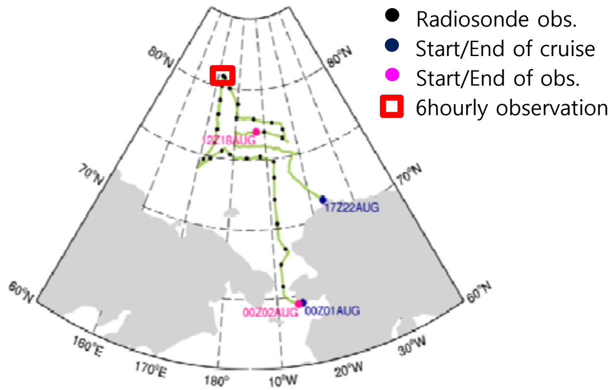


Objectives of this study

- The Korean ice-breaking R/V *Araon* has regularly cruised the Pacific Arctic sector during August and early September since 2010. Since 2015, the radiosonde atmospheric profiles have been obtained on the vessel over the data-sparse Arctic seas. In 2015, twice-daily observations were first conducted every 00:00 and 12:00 UTC from 4 August to 18 August, except four times a day from 12:00 UTC 11 August to 00:00 UTC 14 August.



R/V ARAON



We have investigated,

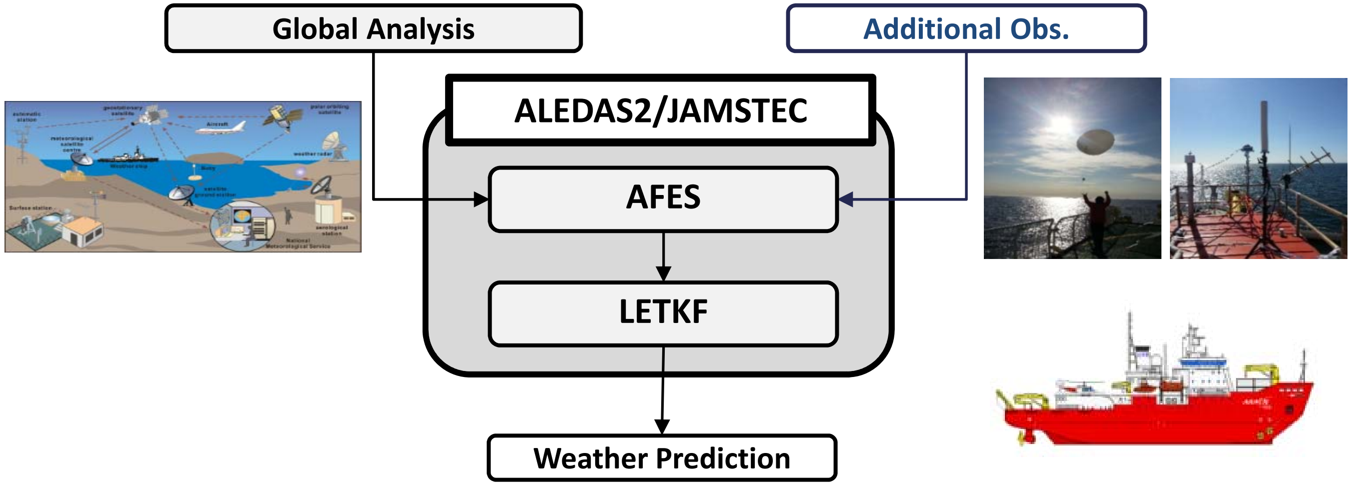
1) **Whether the one-point profile observation can affect the 5-day forecast. In particular, we have focused on the weather over Alaska, which is the human-lived area at the downstream region of ARAON.**

2) **the way how it impacts on the improvement of the forecast over there.**

* Why the 5-day forecast?

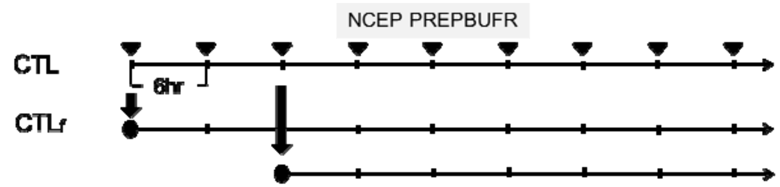
For the operational forecast application, the anomaly correlation should be higher than 0.8. The time scale of forecast model which satisfied this criteria is about 5 day on average in current NWP technique.

Forecast system : ALERA2/ALEDAS2

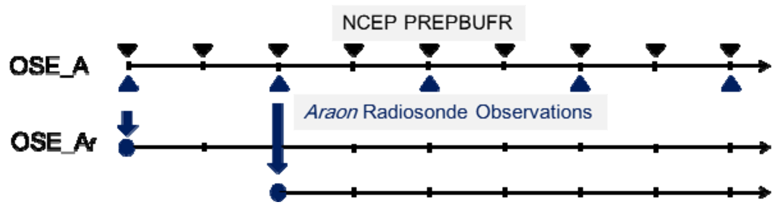


- **Experimental design**

1) Without ARAON observation (CTL)



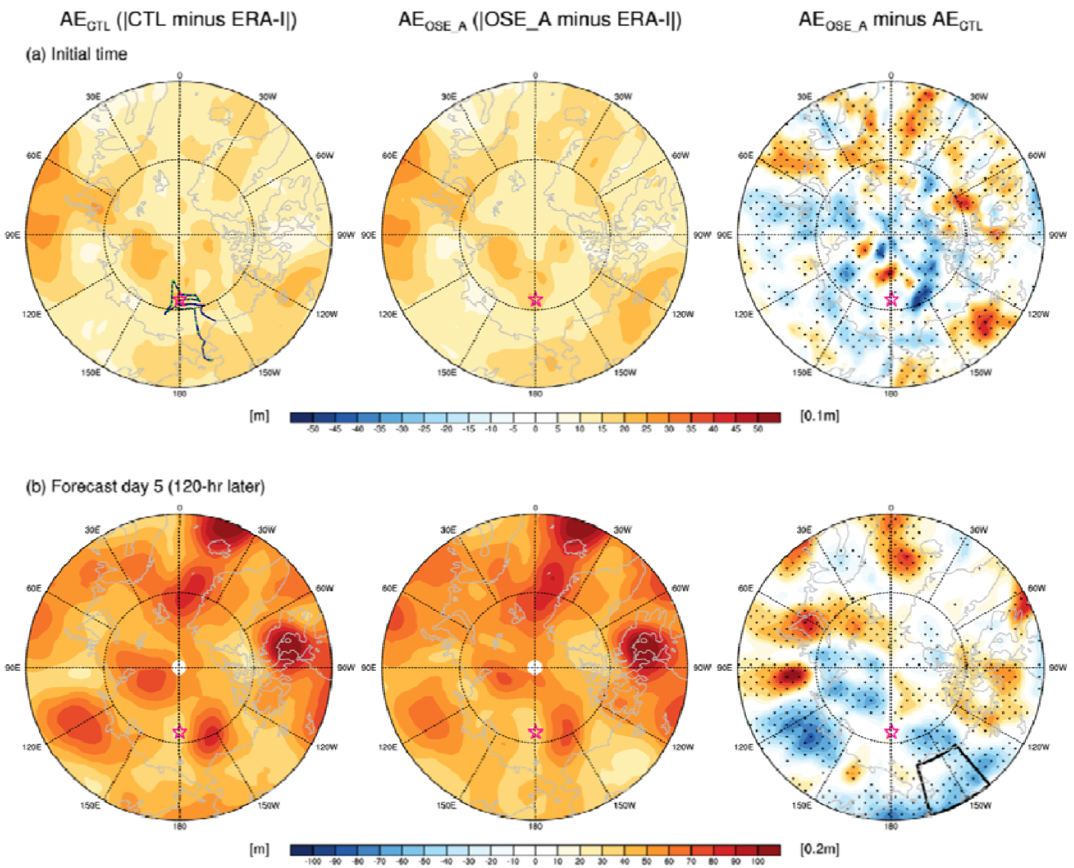
2) With ARAON observation (OSE_A)



ALEDAS2	
Atmospheric AGCM	AFES
Dynamic core	Spectral, Eulerian, and primitive equation
Horizontal resolution	T119 (~1˚X1˚)
Vertical levels	L48 (σ level, up to about 3hPa)
Boundary conditions	OISST daily 0.25˚
Initial conditions	ALERA2
Data assimilation method	LETKF
Ensemble size	63
Observations	NCEP PREBUFR/ARAON Radiosonde
Data assimilation window	6hour

Absolute errors: OSE_A and CTL compared to ERA-Interim

The average AEs of H500 for both CTL_f (left column, AE_{CTL}) and OSE_A_f (middle column, AE_{OSE_A}) (a) at the initial time and (b) 5-day (120-hr) later in comparison with the ERA-I, as well as their differences (right column; i.e., AE_{OSE_A} minus AE_{CTL}). Here the CTL and OSE_A reanalysis data are used at the initial time. The cruise track of the R/V *Araon* is overlaid in (a) and the average position is marked with a red star symbol. In the rightmost panels, the dots represent the statistically significant grid points ($p < 0.05$) based on bootstrap resampling and the box denotes the Alaska domain. The difference plots use the color bar with scaled units (multiplied by 0.2).



At the initial time

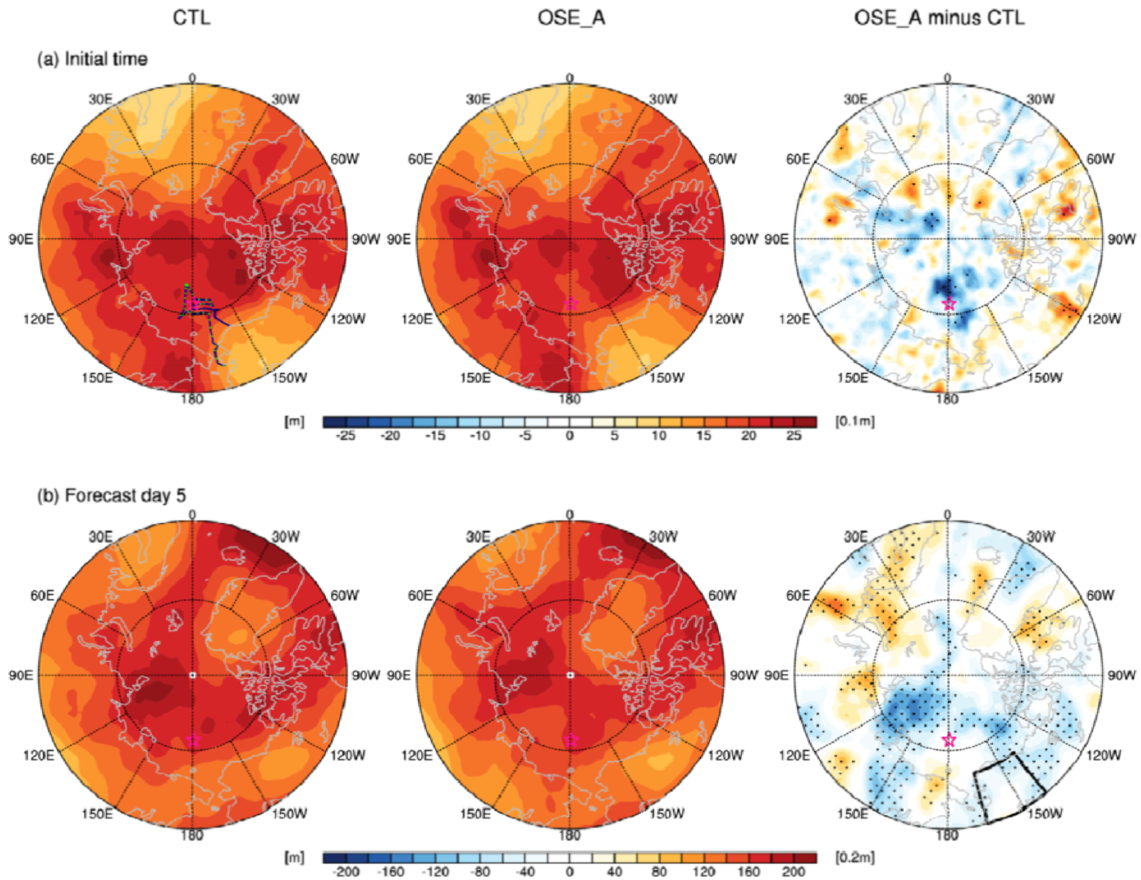
- reduced AEs in OSE_A are distributed in Arctic Ocean and the northern Russia-western Alaska
- In rest regions, larger AEs appear in OSE_A

The 5-day forecast

- also show coexistence of both reduced and increased errors in the field of difference.
- Compared with the initial time, the error pattern appears to rotate eastward

Averaged ensemble spreads

The average ensemble spreads of H500 for both CTL$_f$ and OSE_A$_f$ (a) at the initial time and (b) 5-day (120-hr) later in comparison with the ERA-I, as well as their differences



- The individual gross patterns of both AEs and ensemble spreads have a similarity between CTL$_f$ and OSE_A$_f$, because they are primarily determined by an inherent performance of the forecast system.
- However, the pattern of difference reflects the impact of different observational input to the forecast system.

At the initial time,

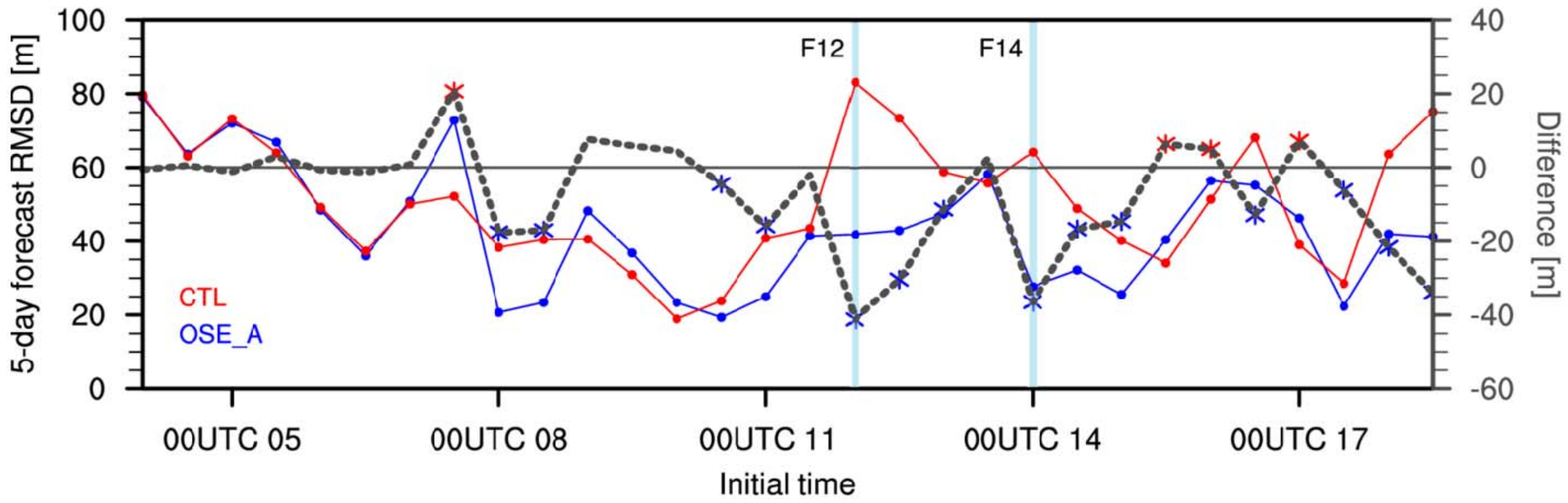
- the larger reduction in OSE_A is found around the observational locations

In the 5-day forecast,

- the reduced ensemble spread is more prevalent at the half circle toward the Pacific side

5-day forecast RMSD over Alaska

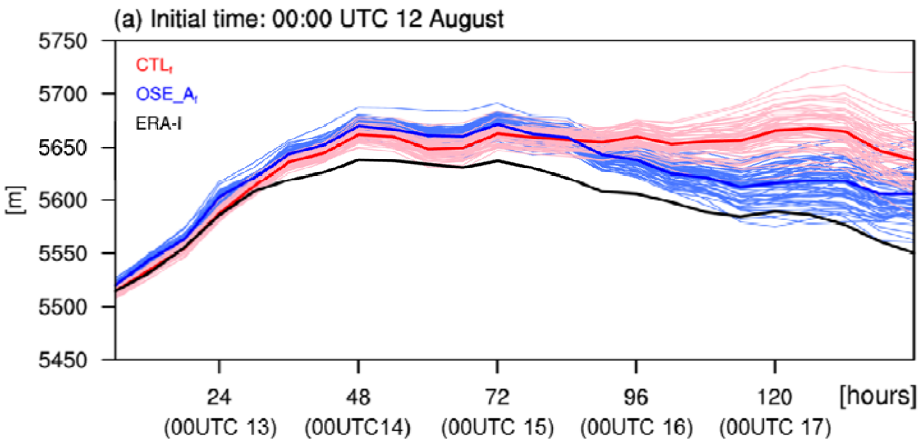
The root mean square distances (RMSDs) of CTL_f (red line) and OSE_A_f (blue line) from ERA-I for H500, at forecast day 5, averaged over the Alaska domain, with the difference of the RMSDs (dotted line; OSE_A_f minus CTL_f). The asterisks denote the statistically significant differences ($p < 0.05$) based on bootstrap resampling. F12 and F14 refer to the forecast experiments with initial conditions of 00:00 UTC 12 August and 00:00 UTC 14 August, respectively, which show the largest improvement in OSE_A_f.

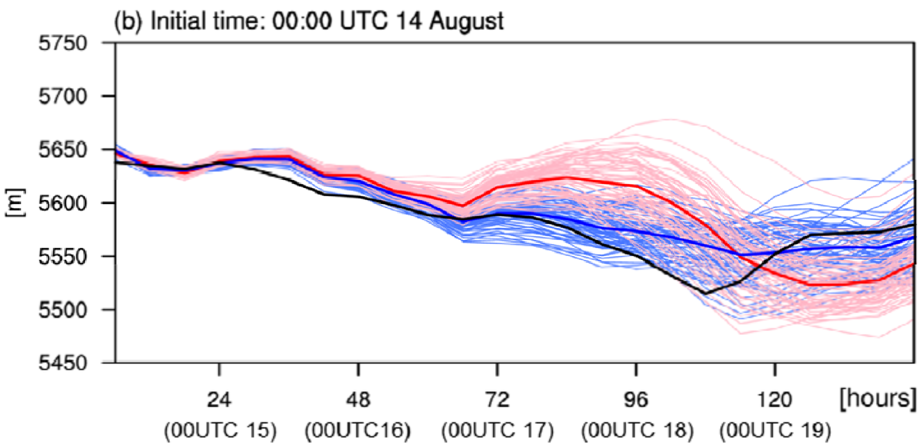


- In the forecasts with the earlier initial conditions (4–7 August), the performance is not much distinguishable.
- There exists an overall tendency towards the better performance of OSE_A_f after 8 August potentially due to the accumulating impact of the extra sounding data assimilation.
- The reduction of the 5-day forecast errors is found for 15 OSE_A_f forecast experiments among the total of 23. Among them, 14 OSE_A_f forecasts show statistically significant improvement by bootstrap resampling.
- In particular, two forecast experiments with initial conditions of 00:00 UTC 12 August (F12) and 00:00 UTC 14 August (F14) show the largest improvement in OSE_A_f.

Timeseries of Z500 over Alaska for each case

The forecast time evolutions of area-mean H500 over Alaska for (a) F12 and (b) F14: individual ensemble members (thin line) and ensemble-mean (thick line) of CTL_f (red) and OSE_A_f (blue). The ERA-I (black thick line) reanalysis is presented as a reference value.





- Case 1: 00 UTC 12 AUG

- The better performance in OSE_A_f begins to appear after 3.5 days (i.e., 12:00 UTC 15 August)

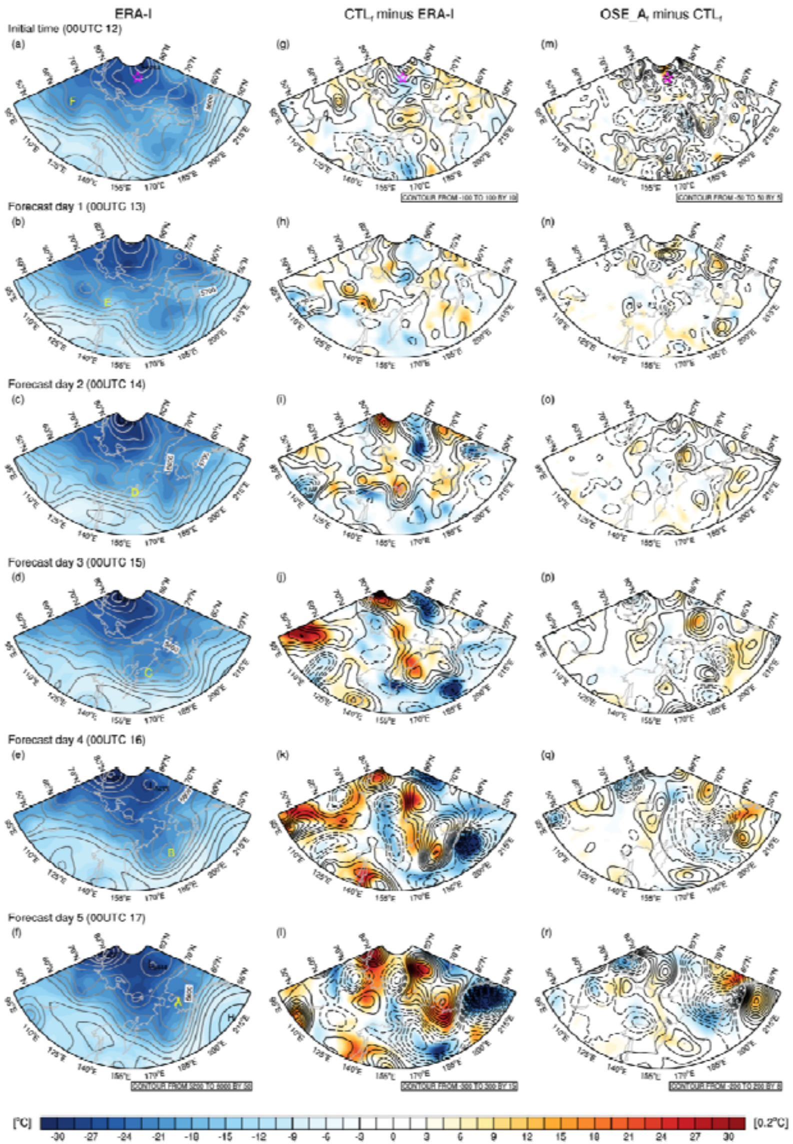
- Case 2: 00 UTC 14 AUG

- The better performance in OSE_A_f begins to appear after 2.5 days (i.e., 12:00 UTC 16 August)

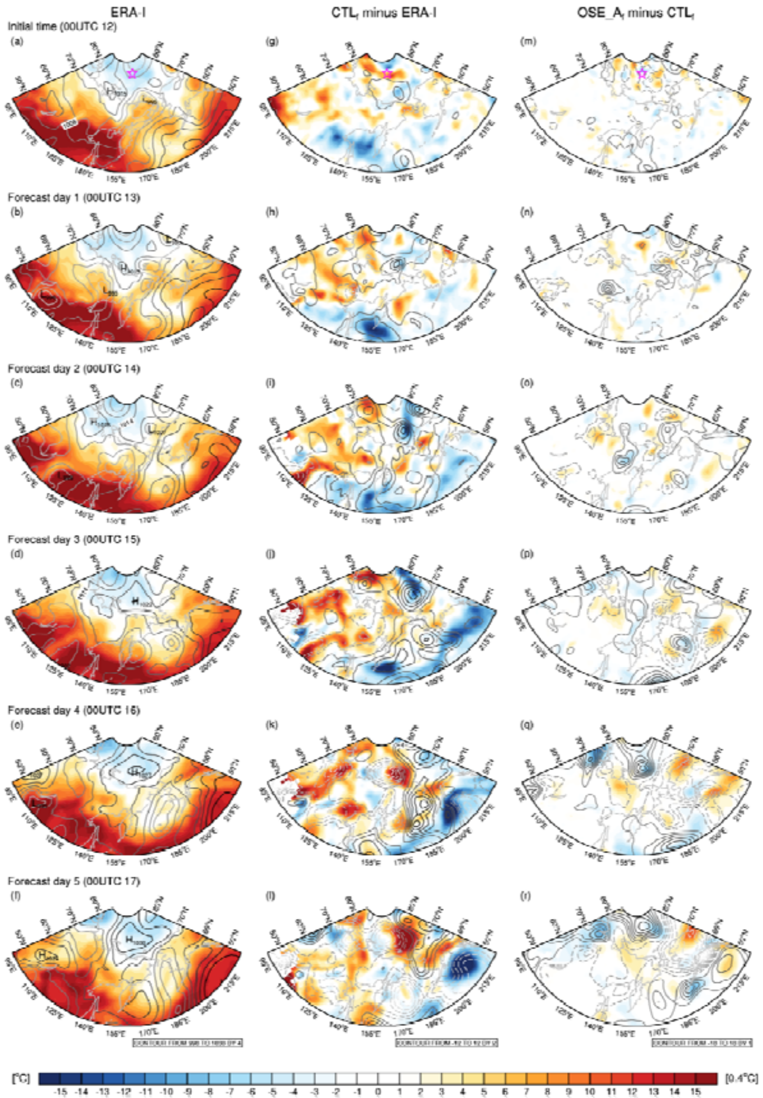
- The two forecast cases show the similar timing of bifurcation of the forecast performance (i.e., on 16 August), indicating that the improvement in OSE_A_f is related to the better simulation of the same synoptic weather phenomenon.

Case 1: 00 UTC 12 AUG Initial condition

T500(shading), Z300(contour)

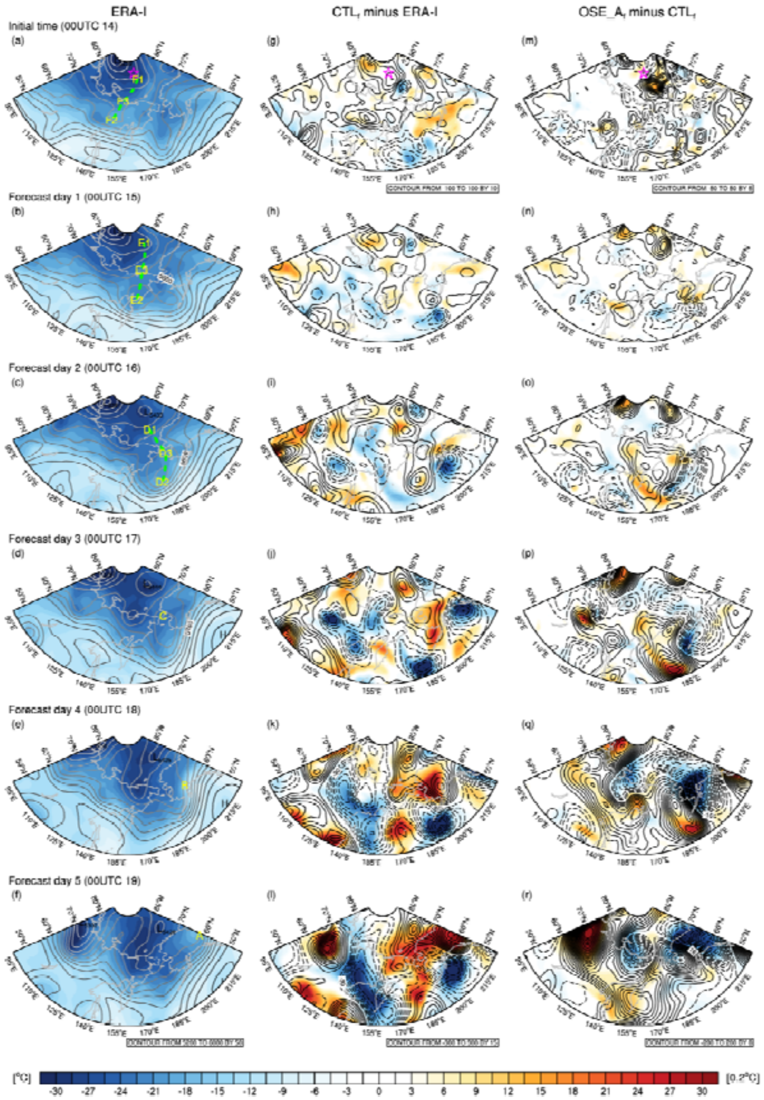


T850(shading), SLP(contour)

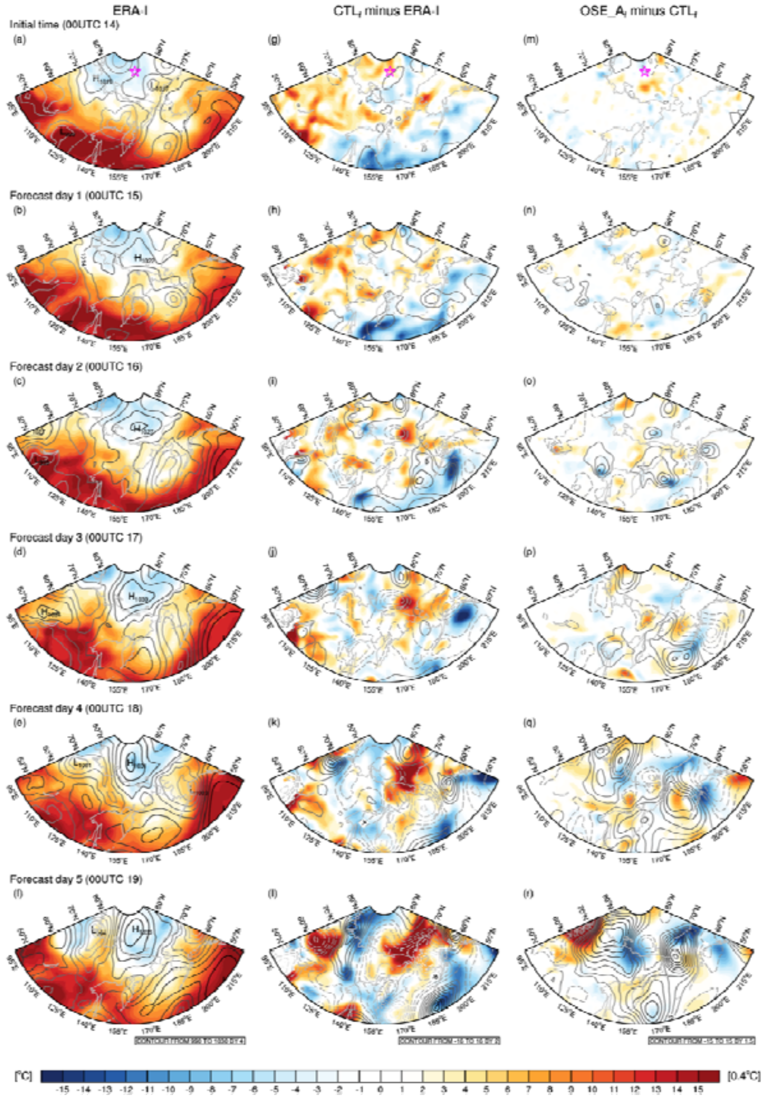


Case 2: 00 UTC 14 AUG Initial condition

T500(shading), Z300(contour)

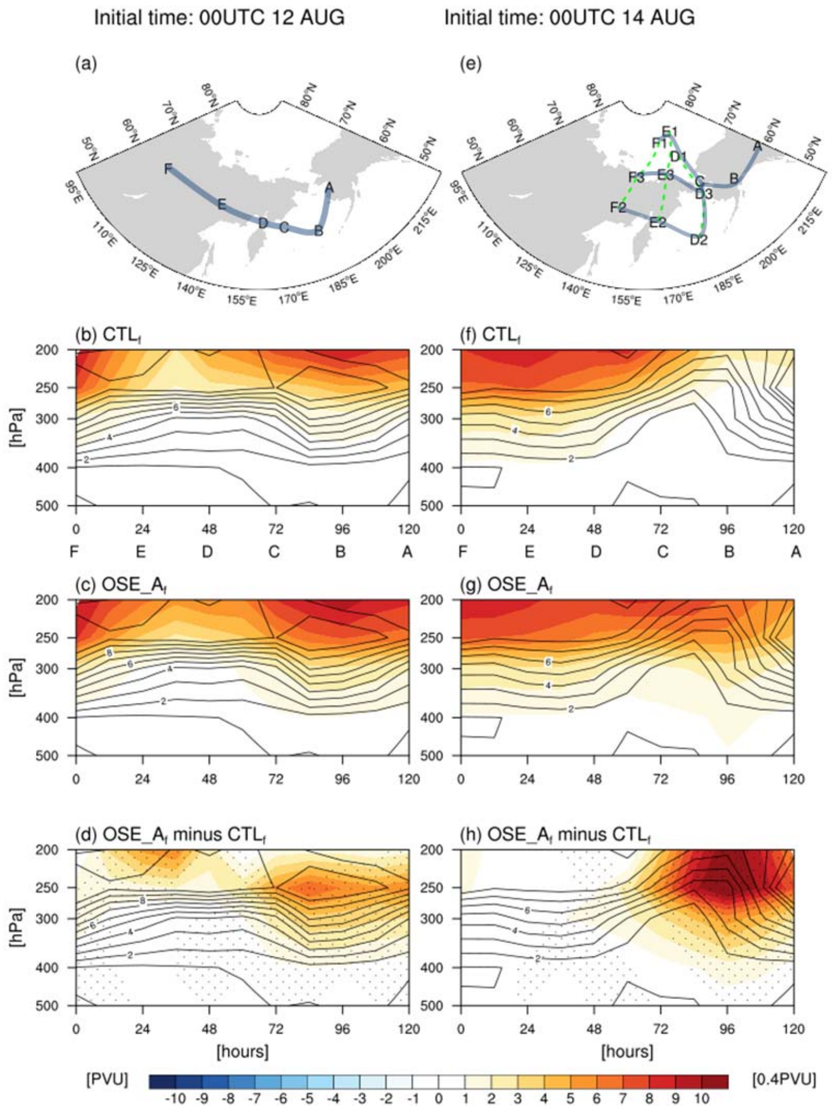


T850(shading), SLP(contour)



Vertical cross section of PV at the maximum difference regions

The propagation routes of the errors manually tracked backward from North America at forecast day 5 (mark 'A') for (a) the F12 case and (e) the F14 case, where the daily centers are marked with alphabets as in Figures 6 and 8. For the F14 case, three routes are detected contributing to the positive height error over the western coast of Alaska at forecast day 3 (mark 'C'). For the F12 case, the vertical cross sections of upper-level total PV along the routes of error evolution are displayed in (b) for CTL_f and in (c) for OSE_A_f. Their difference field (i.e., OSE_A_f minus CTL_f) is placed in (d). Corresponding plots for the F14 case are shown in (f) for CTL_f, in (g) for OSE_A_f and in (h) for OSE_A_f minus CTL_f, where the average PV fields over the three routes are used. For a comparison, the corresponding PV fields from the ERA-I (contour) are overlaid in all vertical cross section plots. In (d) and (h), the dots represent the points where the difference is statistically significant ($p < 0.05$) based on bootstrap resampling.



Summary

- **Using the radiosonde observation data in 2015 ARAON cruise, we have investigated**

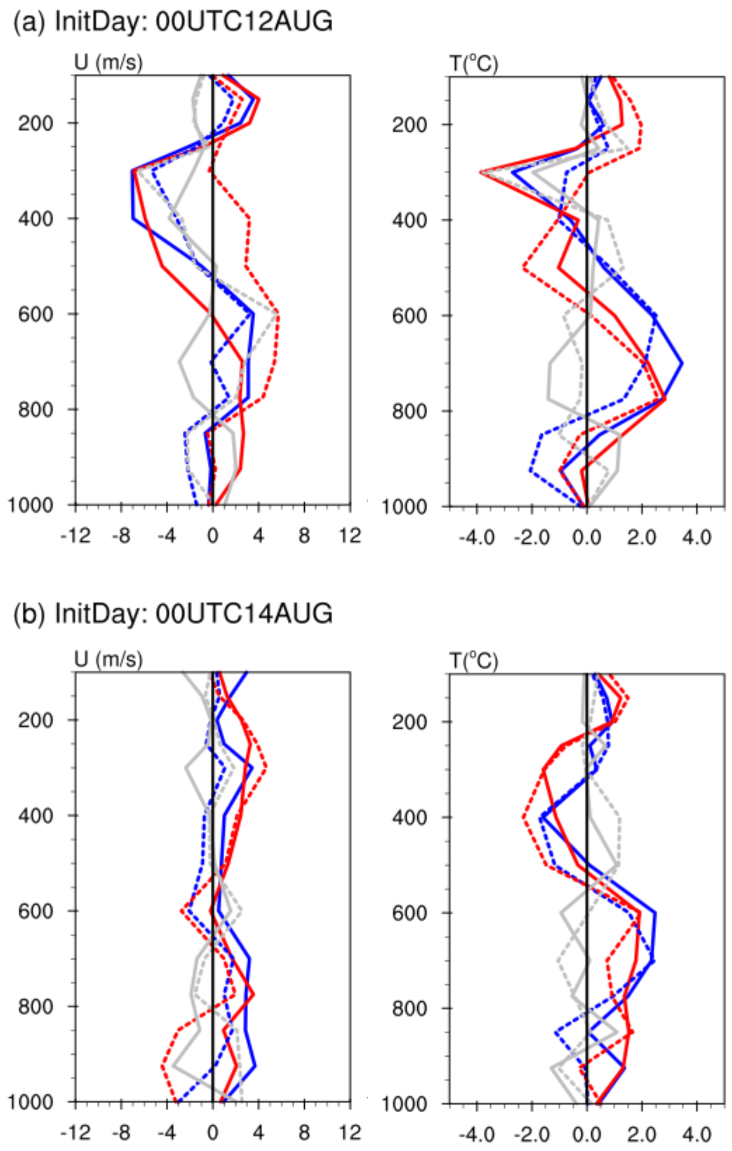
1) whether the one-point profile observation can affect the short-range forecast over Alaska

2) the way how it impacts on the improvement of the forecast over there

- During 2–18 August 2015, ship-borne radiosonde sounding observations were performed every 12 hour (except 6-hourly from 12:00 UTC 11 August to 00:00 UTC 14 August) around the Chukchi Sea.
- To assess the impact of those extra radiosonde observations, two sets of ensemble forecast experiments (CTL_f and OSE_A_f) were produced, which were respectively initialized by atmospheric reanalysis data without (CTL) and with (OSE_A) additional assimilation of those data.
- The tropospheric circulation fields are compared to verify their differences in forecast performance. While two forecasts have similar performance in the earlier spin-up period of the analysis-forecast cycle (from 4 to 7 August), their performance tends to diverge in the later period (from 11 to 18 August) due to the accumulated influence on the error reduction in OSE_A_f.
- Among the improved forecasts in OSE_A_f, two most outperformed forecasts, each initialized on 00:00 UTC 12 and 00:00 UTC 14, show a notable improvement in predicting the developing trough over Alaska on 16–17 August by suppressing the development of erroneous high anomalies in CTL_f.
- Though the positive impact of single-point observations is limited in a space, our results suggest that enhanced radiosonde profile observations in the data-sparse polar ocean could be beneficial for the forecasts beyond the observational area.

THANK YOU
FOR
YOUR ATTENTION !

Background and analysis error



Background error (solid line) and analysis error (dashed line) of zonal wind and temperature for CTL (red) and OSE_A (blue). The differences between the absolute error of analysis and the absolute error of background, which shows that how much errors of background are reduced by the assimilation of ARAON sonde, are indicated for OSE_A (gray solid) and CTL (gray dashed), respectively.

- While the temperature improvement by adopting the additional information of ARAON sonde does not show a vertically-consistent positive impact, the quality of zonal wind analysis is enhanced at almost every level (gray lines).

- This one-point profile result, as well as the investigation along the horizontal maps including the Alaska domain, implies that the ARAON sonde additionally introduced to the cycled data assimilation is anticipated to help better simulate the advection or the wave-propagation of a weather system, rather than its thermodynamic energy structure that associates the strength.

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Impact of Additional Arctic Radiosonde Observations on 5-day Weather Forecasts Over Alaska During August 2015

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This study has investigated the impact of extra radiosonde observations from the 2015 *Araon* summer Arctic cruise over the Chukchi and East Siberian seas on 5-day forecasts over Alaska. The radiosonde sounding data produced every 12 hour from 00UTC 04 AUG to 12UTC 18 AUG are additionally assimilated to the conventional ALERA2 reanalysis. With the two reanalysis data sets as the initial conditions, two sets of 10-day ensemble forecasts are produced and compared (CTL without *Araon* vs. OSE_A with *Araon*). To verify the forecast performance, we compare the Z500 fields between CTL and OSE_A. Two forecasts are not quite different for the earlier period of the analysis-forecast cycle (from 04 AUG to 08 AUG), but the accumulated impact on the error reduction of OSE_A is shown for the later period from 12 AUG to 18 AUG. More detailed analyses are made for the two selected forecasts begun at 00UTC 12 AUG and 00UTC 14 AUG, in which the

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