Arctic Research Collaboration for Radiosonde Observing System Experiment (ARCROSE)

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1. Introduction

An improved weather forecasting capacity over the ice-free Arctic Ocean is vital for safe ship navigation in the Northern Sea Route and Northwest Passage because storms can generate strong winds, high waves, icing on the ship surface, and sea-ice advection. A precise prediction depends on not only a sophisticated model itself but also in situ observations. The expansion of the Arctic observing network would also help improve the weather forecast over the mid-latitude. We have started the Arctic Research Collaboration for Radiosonde Observeing System Experiment (ARCROSE) since 2013.

In this project, the impact of special sounding array on the local and remote atmospheric circulations will be investigated by expanding the observing network with the international collaboration.

2. Previous achievements

To date, the number of radiosondes launched over the Arctic Ocean has been very limited due to the difficulty of operational observations; however, the impact of Arctic radiosonde observations on reanalyses data, and weather and sea-ice forecasts has not been fully investigated.

Auto launch of a radiosonde from the R/V Mirai over the ice-free Arctic.

Using the special raidiosonde data observed by the Japanese research vessel Mirai and the data assimilation system developed by the Earth Simulator Center at JAMSTEC, Inoue et al. (2013) demonstrated that the high-temporal radiosonde data over a portion of the ice-free Arctic Ocean can help reduce uncertainty, not just at the local observation site and time but throughout the northern half of the Northern Hemisphere for weeks afterwards.

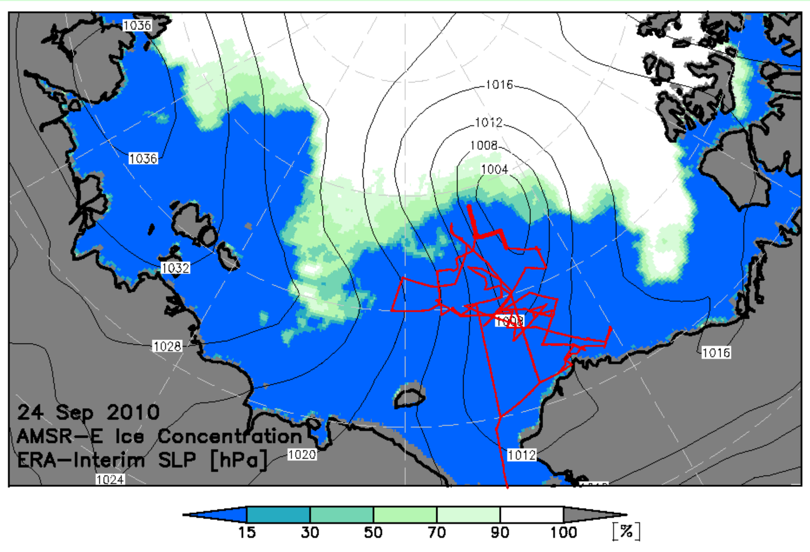


Fig. 1: SLP & SIC on September 24, 2010 with the track of R/V Mirai. Thick line shows the period when an Arctic cyclone was observed (Inoue et al. 2013).

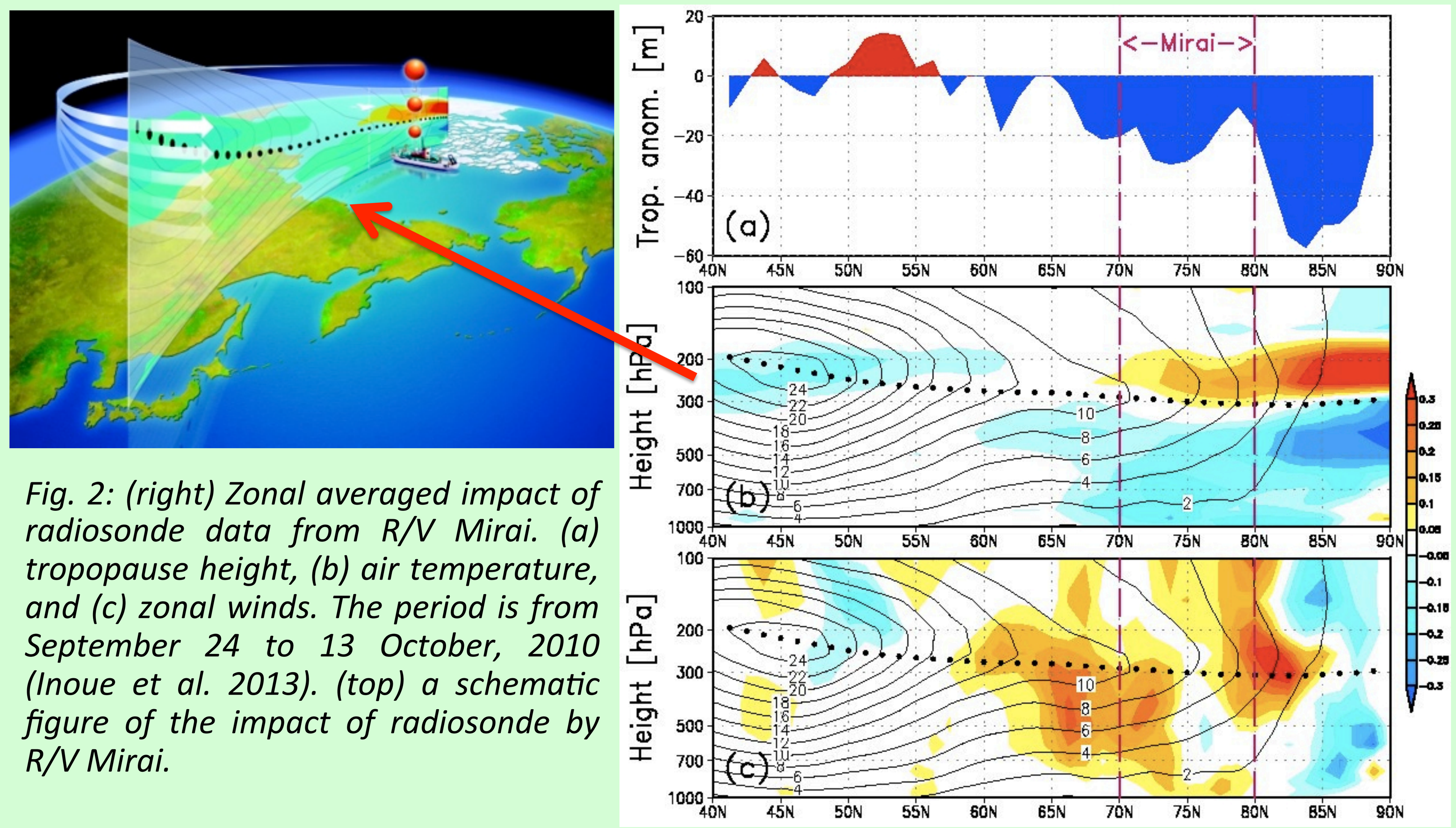


Fig. 2: (right) Zonal averaged impact of radiosonde data from R/V Mirai. (a) tropopause height, (b) air temperature, and (c) zonal winds. The period is from September 24 to 13 October, 2010 (Inoue et al. 2013). (top) a schematic figure of the impact of radiosonde by R/V Mirai.

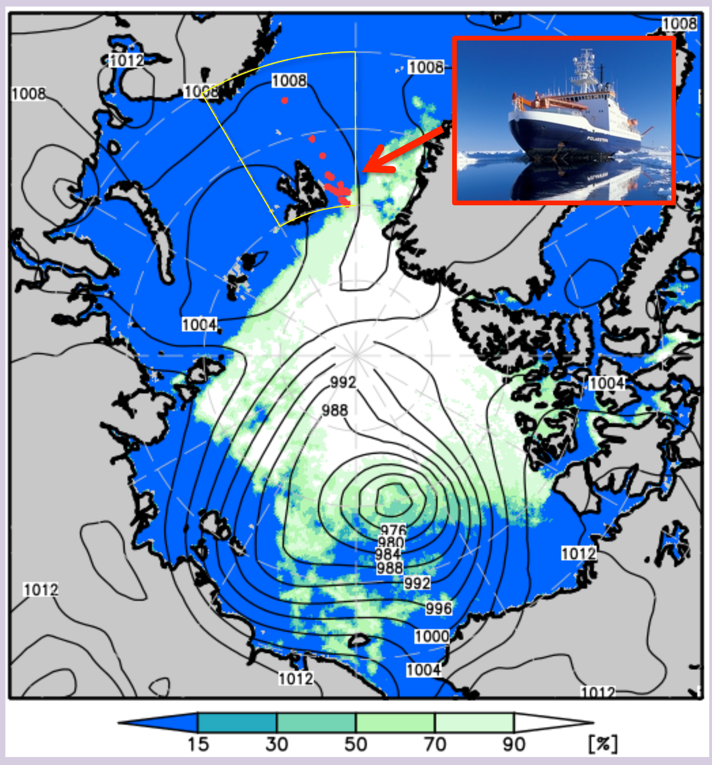


Fig. 3: Locations of radiosonde observations by R/V Polarstern (red) during July 13-29, 2012, and SLP and SIC on August 6, 2012 (Yamazaki et al. 2014).

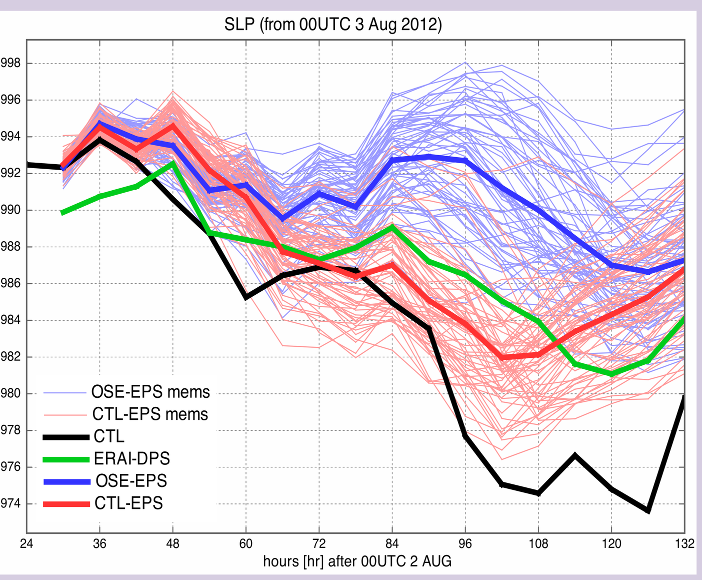
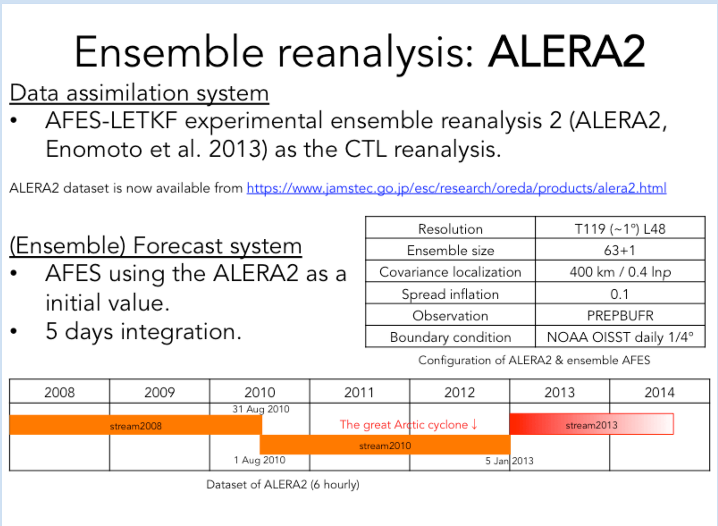
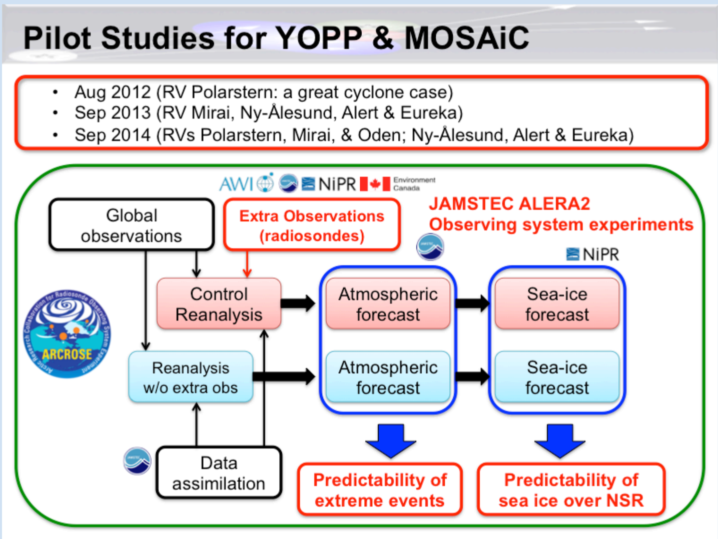


Fig. 4: Time evolutions of SLP of the cyclone center by the ensemble prediction system. Thick and thin lines indicate ensemble mean and ensemble members, respectively (Yamazaki et al. 2014).

3. ARCROSE Data Assimilation Framework

The additional radiosonde data are subject to data assimilation by the Earth Simulator (Observing System Experiment: OSE). The name of data assimilation system is called ALERA2 (Enomoto et al. 2013). Emphasis of the analyses will be on the Arctic Ocean region where Arctic cyclones frequently pass. The higher observation frequency is expected to improve both numerical weather prediction and reanalyses, allowing to determine predictability and identify key sources of forecast errors in polar regions.





4. A great cyclone case on August 6, 2012

Ensemble predictions for the great cyclone on August 6, 2012 were conducted using the two reanalyses; ALERA2 was used as CTL, and OSE applies the same reanalysis as the CTL except for the exclusion of radiosonde observations from the German icebreaker *Polarstern* (all sounding data were sent to the GTS), which cruised near Svalbard during mid-July to early August 2012. The CTL prediction reproduced the development of the Arctic cyclone, but the OSE did not. These results indicate that the improved reproduction of upper tropospheric circulation in the Arctic region due to additional radiosonde observations, is indispensable for the prediction of Arctic cyclones.

Radiosonde team on the R/V Mirai during ARCROSE2014

5. ARCROSE Observation Campaign in 2013 & 2014

ARCROSE is a cooperation of the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI), the Japanese National Institute of Polar Research (NIPR), the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), and the Environment Canada. In 2014, Stockholm University and NOAA would be involved in ARCROSE using R/V Oden.

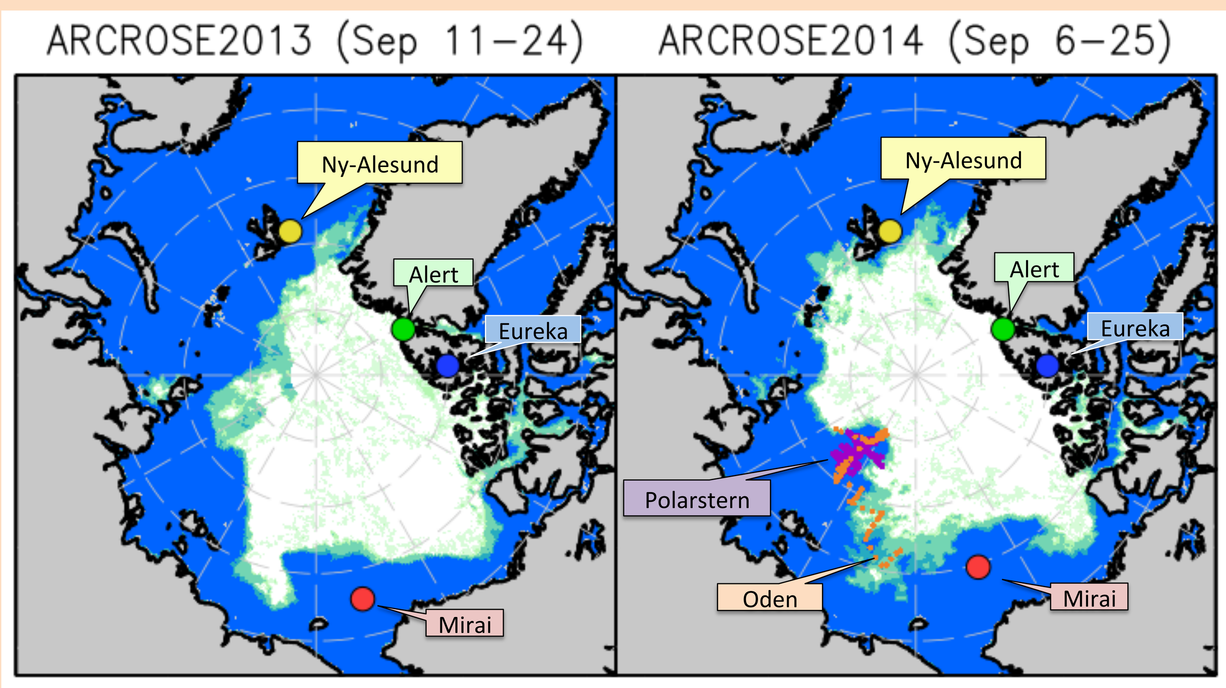


Fig. 5: ARCROSE stations during September 2013 (left), and 2014 (right).

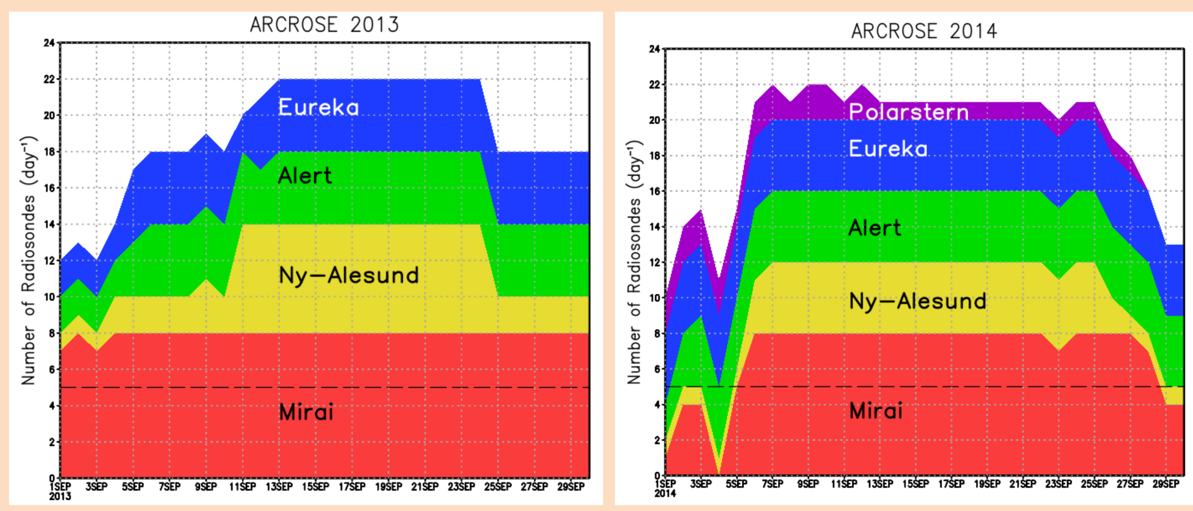


Fig. 6: The number of daily soundings from ARCROSE stations found in NCEP PREPBUFR data during September 2013 (left) and 2014 (right).

6. Preliminary results from ARCROSE2013

We prepared five reanalyses data (see table 1), and conduct ensemble forecasting experiments. The atmospheric fields at 12:00 UTC on September 15, 2013 were used as the initial values for the forecasting experiments. The target event is a strong wind case along Russian coast. During the period from 19 to 21 September, the Northern Sea Route was partly closed by sea-ice advection and/or sea-ice formation (Fig. 7). The impact of ARCROSE2013 data on the skill of wind prediction can be investigated using above experiments.

Table 1: The number of sounding data used in experiments.

	Mirai	Eureka		Alert		Ny-Alesund	
	IOP	IOP	operational	IOP	operational	IOP	operational
CTL	8	2	2	2	2	5	1
OSE_{MEAN}	0	0	2	0	2	0	1
OSE_M	0	2	2	2	2	5	1
OSE_{EA}	8	0	2	0	2	5	1
OSE_N	8	2	2	2	2	0	1

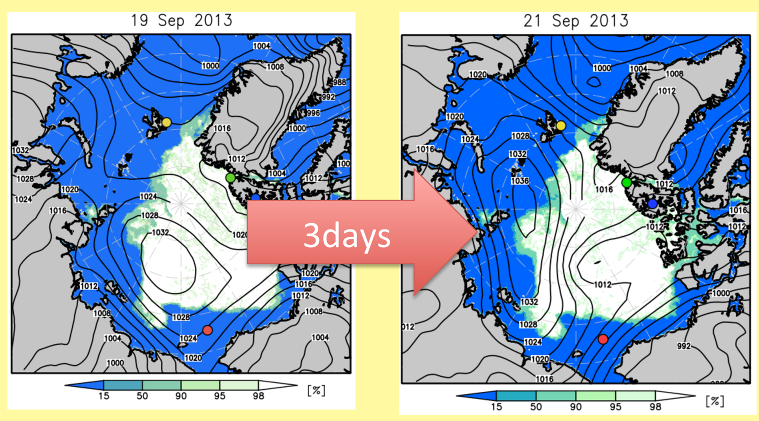


Fig. 7: SIC (AMSR2) and SLP (ERA-I) on Sep. 19 & 21.

Time series of SLP anomaly correlation coefficient (ACC) in the Eastern Hemisphere north of 70ºN shows that OSE_{MEAN} (i.e. without all ARCROSE2013 data) has the lowest ACC on Sep. 20 comparing with CTL; the second lowest are OSE_M & OSE_N (Fig. 8). These results suggest that the data from R/V Mirai and Ny-Alesund are likely effective for predicting the high pressure system along the ice edge in the eastern Arctic.

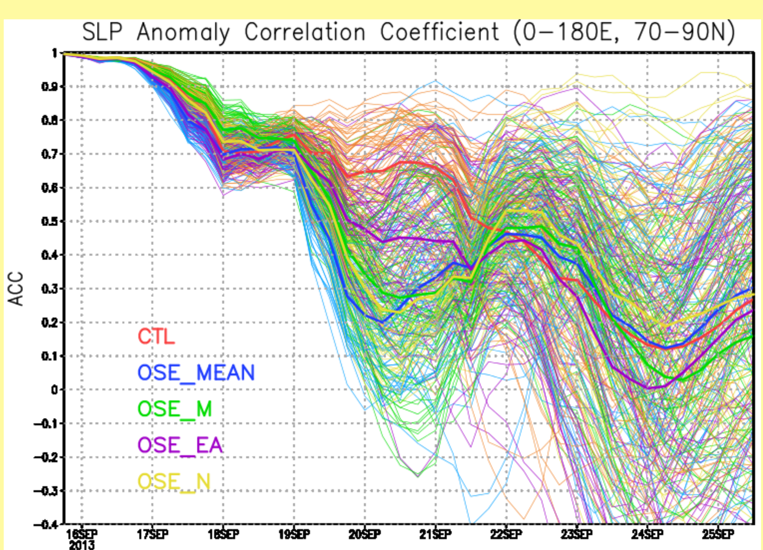


Fig. 8: Anomaly correlation coefficients (ACC) for SLP in the Eastern Hemisphere north of 70ºN in each experiment. Ensemble mean (thick line) and each member (thin line).

The difference in wind speeds at 10-m level between CTL and OSE_{MEAN} on Sep. 21 exceeds 4 m/s (Fig. 9) due to the failure of predicting the high pressure system in OSE_{MEAN}. Although the barotropic structure of the high pressure system is the same feature both in CTL and OSE_{MEAN}, the spatial distribution in the CTL extends from the Barents Sea to the Chukchi Sea (Fig. 10). The maximum difference in SLP and Z500 is also significant amount (more than 9 hPa and 100 m, respectively; Fig. 10), suggesting that the source of uncertainty would exist at higher levels. The trajectories of ensemble spread difference in Z100 clearly are clearly seen along the polar vortex. The uncertainty originated from Ny-Alesund and R/V Mirai would result in the failure of surface wind speeds over the NSR.

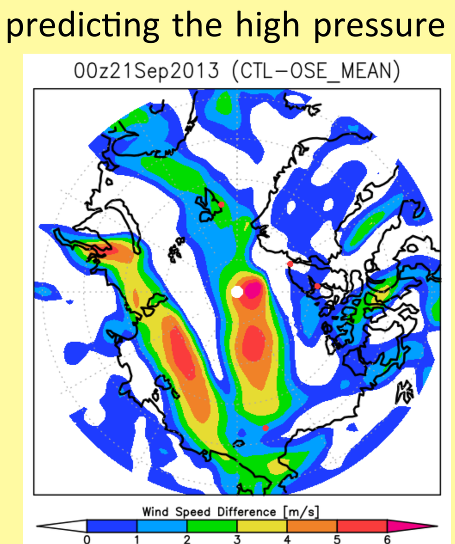


Fig. 9: Difference in predicted surface wind speeds (CTL-OSE_{MEAN}) on September 21.

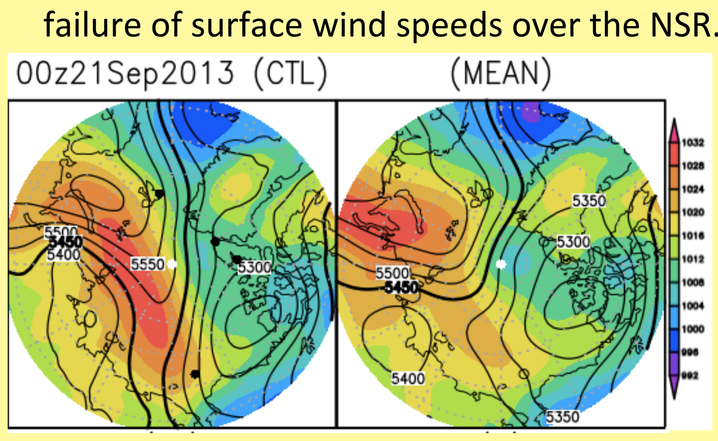


Fig. 10: Predicted SLP (shading) & Z500 for CTL & OSE_{MEAN} on Sep. 21.

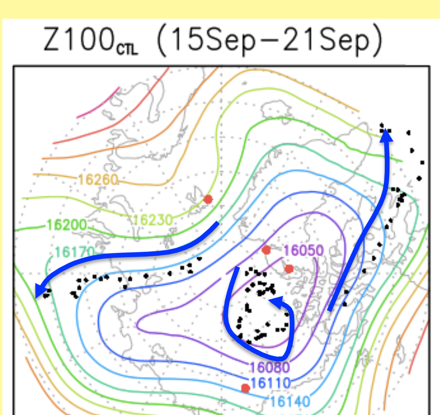
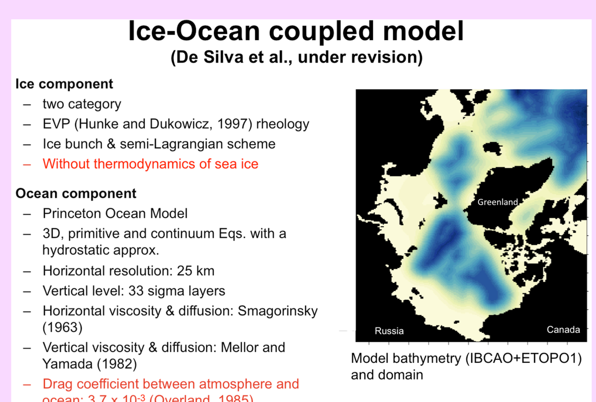


Fig. 11: Trajectories of the center of ensemble spread difference in Z100 between CTL and OSE_{MEAN}. Contours show the Z100 field in CTL. Red dots show ARCROSE stations.

7. Impact of ARCROSE2013 data on sea-ice forecast

To assess the impact of ARCROSE2013 data on the sea-ice forecast over the Northern Sea Route, we run the POM-based ice-ocean coupled model forced by the ERA-Interim reanalysis and forecast data from CTL and OSE_{MEAN} without sea-ice thermodynamics. The initial time is 12:00 UTC September 15, 2013. The SIC is well reproduced in the case forced by ERA-I (Fig. 12). The difference in the ice-edge between CTL and OSE_{MEAN} runs is clearly found at the western part of East Siberian Sea (Fig. 13), suggesting that the difference in wind fields originating from additional radiosonde data is very important for predicting SIC over the NSR.



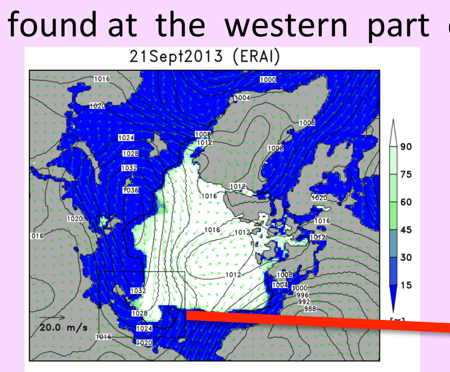


Fig. 12: Modeled sea-ice fields on Sep 21 forced by ERA-I. SLP and observed sea-ice edge is indicated by thin and thick contours.

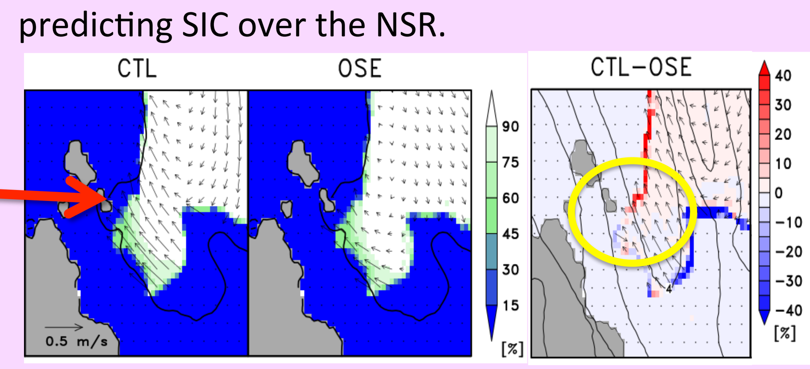


Fig. 13: As in Fig. 12 but forced by CTL and OSE_{MEAN} forecasts. Their difference is shown in the right.

8. Towards YOPP/MOSAiC

- Understanding the seasonality
- Coordination of land stations
- Model intercomparison
- Collaboration with operational agencies

References

- Enomoto et al. (2013), Observing-system research and ensemble data assimilation at JAMSTEC, *Data Assimilation for Atmospheric, Oceanic and Hydrological Applications* (Vol. II), S. K. Park and L. Xu, Eds., Springer, Vol. II, Chap. 21, 509-526.
- Inoue, Enomoto & Hori (2013), The impact of radiosonde data over the ice-free Arctic Ocean on the atmospheric circulation in the Northern Hemisphere, *GRL*, 40, 864-869.
- Yamazaki, Inoue, Dethloff, Maturilli, & Konig-Langlo (2014), Impact of radiosonde observations on forecasting summertime Arctic cyclone formation, *JGR-A* (submitted).