SPECIAL PROJECT PROGRESS REPORT

Progress Reports should be 2 to 10 pages in length, depending on importance of the project. All the following mandatory information needs to be provided.

Reporting year	2018
Project Title:	Impact of land surface and ocean initial conditions on sub-seasonal to seasonal forecasts
Computer Project Account:	SPFRBATT
Principal Investigator(s):	Lauriane Batté
Affiliation:	CNRM (Météo-France)
Name of ECMWF scientist(s) collaborating to the project (if applicable)	……………………………………………………………… ………………………………………………………………
Start date of the project:	01/01/2016
Expected end date:	31/12/2018

Computer resources allocated/used for the current year and the previous one
(if applicable)
Please answer for all project resources

		Previous year		**Current year**	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	12,000,000	10,145,433	12,000,000	1,023,034
Data storage capacity	(Gbytes)	20,000	18,750	20,000	1,360

* Our user accounts are linked to frtodcli and output files are stored on this ECFS account

Summary of project objectives
(10 lines max)

The main objectives of this special project are to assess beyond conclusions from the FP7-SPECS project the impact of the initialization of land-surface and sea-ice components of the CNRM-CM model on sub-seasonal and seasonal predictability. Two main questions are addressed:
- What is the extent of initial condition information needed to properly initialize the sea ice and land-surface components of the model?
- Can improvement in model initialization impact the predictability of specific events?

The objective is to study these questions using land surface and sea ice initial conditions and climatologies built with the corresponding CNRM-CM components run in forced mode, and studying specific test cases with initial conditions representing extremes of the climatologies.

Summary of problems encountered (if any)
(20 lines max)

We originally intended to work with a more recent version of NEMO-GELATO but due to delays had to switch back to NEMO 3.2. As a consequence, the forced NEMO-GELATO runs initially planned were not run, and we resorted to using initial conditions for sea ice derived by Mercator-Ocean by nudging the NEMO-GELATO model towards the GLORYS2V4 reanalysis. This restricts the re-forecast period to 1993-2012 instead of 1979-2012.

The most recent version of the SURFEX interface enabling nudging of land surface towards reference data is not yet ported on the Cray. We therefore chose to work on land surface initial condition sensitivity using the ERA-Land reanalysis, and an offline SURFEX run.

Summary of results of the current year (from July of previous year to June of current year)
This section should comprise 1 to 8 pages and can be replaced by a short summary plus an existing scientific report on the project

a) Soil moisture conditions

The study from Hurk et al. (2012) derived from the GLACE-2 initiative (Koster et al. 2011) on the impact of soil moisture initialization for sub-seasonal forecasting over Europe paved the way to a relatively unexplored field of investigation.

Here, we extended a predictability case study focused on the heat wave that hit Western Europe during the first days of July 2015 (Ardilouze et al. 2017b).

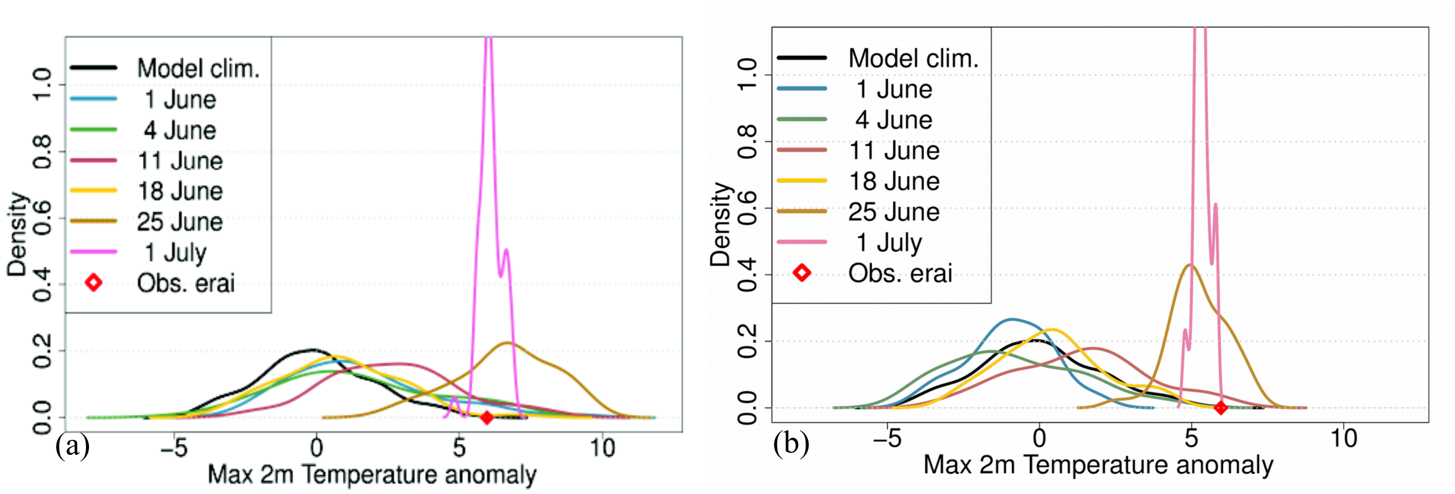

Figure 1: 6DS Tmax anomalies probability density functions of successive forecasts with 2015 (a) and 2016 (b) land surface initial conditions

This study assessed the capacity of successive forecasts issued from the Météo-France S2S forecast system to capture that event. Ardilouze et al. (2017b) defined a forecast target named 6DS, consisting in the daily maximum temperature averaged spatially over France and temporally over the 6-day period when the heat-wave peaked (from 1st July to 6th July 2015). They found that the Tmax ensemble distribution of 6 successive sub-seasonal forecasts initialized from June 1st to July 1st were all shifted towards higher temperatures than the model climatology (Fig. 1a). This climatology was computed using retrospective forecasts initialized in June over a 22-year period. They also found evidence that this shifting was not a mere consequence of the warming trend of recent years. In this study, the impact of drier than usual soils at initial time was only hinted but not confirmed.

To get further insight on this hypothesis, we re-ran the same 2015 successive forecasts but changing the land surface initial conditions. Fig. 2 (top row) shows the 2015 anomalies of the root-layer soil wetness index (SWI) in the IFS operational analyses used to initialize the land-surface component of the Météo-France S2S forecast system.

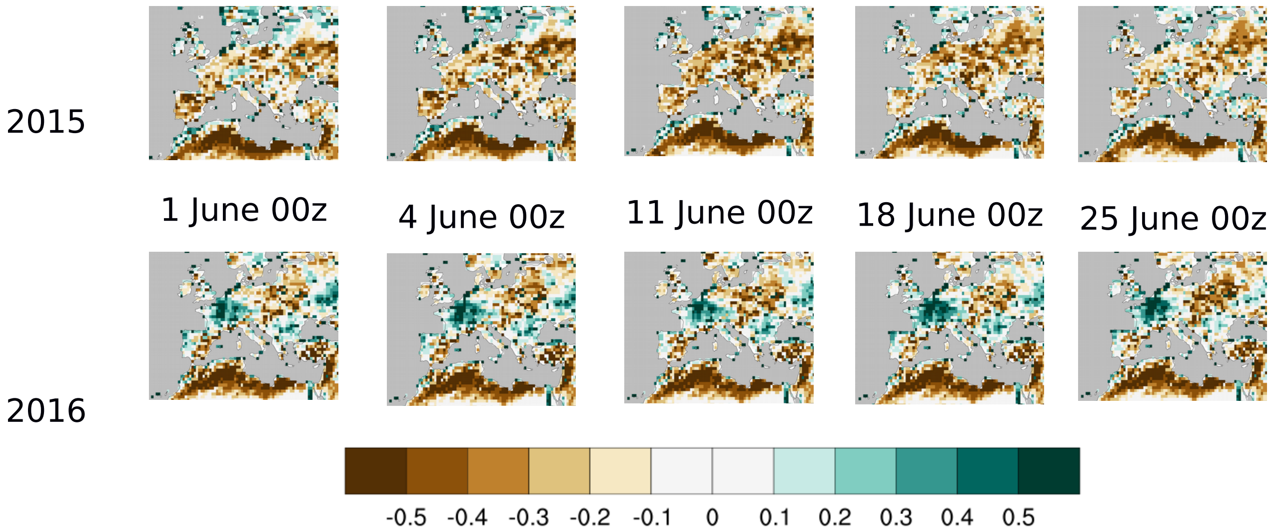

Figure 2: Soil wetness index anomalies in IFS operational analyses

A predominantly dry anomaly characterizes these 5 initial conditions over western Europe, although less pronounced towards the end of June. Fig. 2 (bottom row) shows the 2016 SWI anomalies computed on the IFS analyses of the same day. The very wet anomalies over France contrast with these of 2015. They resulted from unusually abundant rainfall leading to major overflows of many rivers in France, such as the Seine in Paris (Oldenborgh et al., 2016).
Here, we re-compute the 2015 successive forecasts using these 2016 land surface conditions but without any other change.
Fig. 1b shows the forecast distributions of 6DS Tmax anomalies. When comparing with Fig. 1a, the forecasts initialized in 1 June and 4 June are no longer shifted towards warm values. Moreover, the upper tails of all the forecast distributions no longer reach anomalies as extreme as 10 K. Interestingly, even the distribution of the forecast initialized on 1st July is slightly shifted towards cooler temperatures.

These results suggest that soil moisture initial conditions did contribute to the predictability of the July 2015 heat wave over France both at short and long range.

b) Sea ice conditions

In 2017 we ran and evaluated the IINI 30-member ensemble re-forecasts (with sea ice initialization from Mercator-Ocean) over the 1993-2012 period, for 1st November initialization dates.

Figure 3 shows correlation over the DJF 1993-2012 period with respect to ERA-Interim data for sea-surface temperature (Fig. 3a) and 500 hPa geopotential height (Fig. 3b). This version of CNRM-CM performs as expected for these two fields (as for other fields evaluated, not shown) when compared to the operational System 5 based on the same coupled model. For SST, as expected the skill is higher over the Tropical Pacific region, but is also significant over most areas of the globe for 2-4 months lead time seasonal averages. For Z500 over the Northern Hemisphere, areas of significant correlation are found over the North Atlantic sector, Western Europe and Eastern North America, as well as most of the Arctic. No correlation is found over most of the Pacific sector, save for regions influenced by the PNA mode.

We also evaluated the skill in representing the North Atlantic Oscillation and its variability. Figure 4 shows the re-forecast spread and correlation of the ensemble mean NAO index with ERA-Interim (for an NAO index computed as the projection of re-forecast and ERA-Interim anomalies onto the leading EOF of ERA-Interim Z500 DJF monthly means over the 1993-2012 period, in cross-validation mode). The correlation between the IINI ensemble mean index and ERA-Interim is 0.42, again comparable to similar model versions used at Météo-France (although uncertainty levels for such a short period of re-forecast and limited ensembles are high).

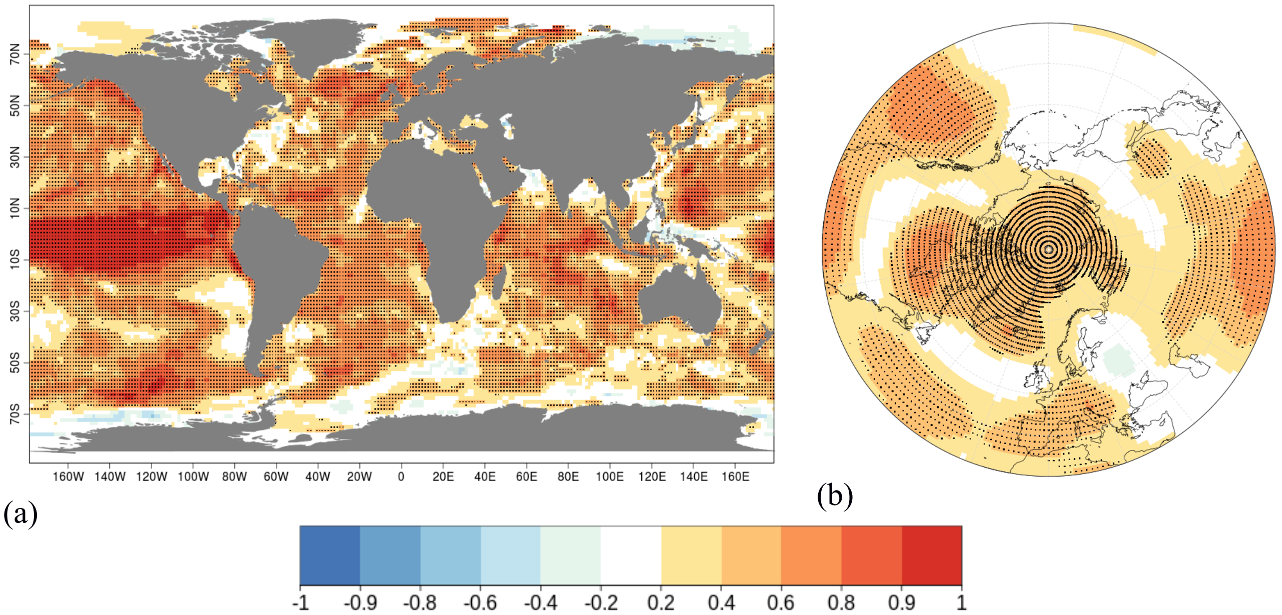

Figure 3: Gridpoint time correlation for DJF 1993-2012 IINI re-forecasts initialized in November with respect to ERA-Interim for (a) SST and (b) Z500. Dots indicate regions where correlation is significant at a 95% level based on a one-sided Student t-test.

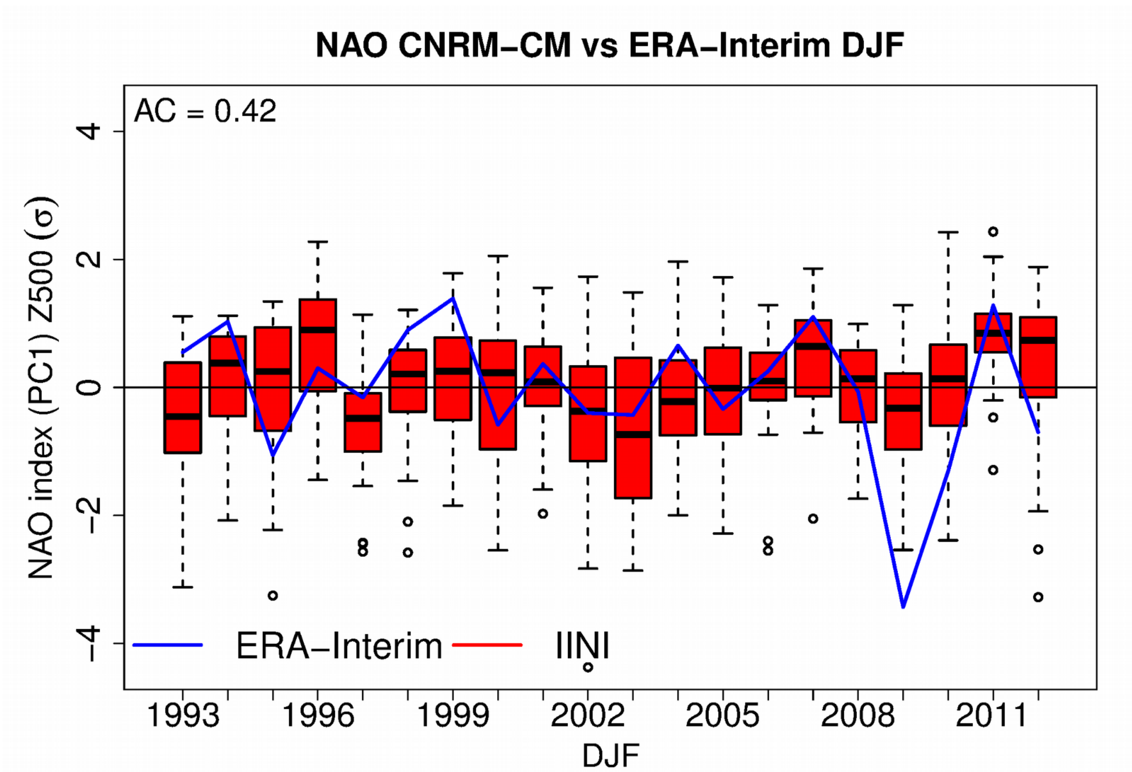

Figure 4: Box and whisker plot of the NAO index computed for the IINI ensemble re-forecasts for DJF 1993-2012 (see text for details). Red boxes show the interquartile range of ensemble members, the black line the median index, and whiskers show the range of values up to 1.5σ. Outliers are shown with black circles. The blue line shows the corresponding ERA-Interim NAO index. Anomaly correlation between ERA-Interim and the IINI ensemble mean index is shown in the top left corner.

Beyond this re-forecast, we also ran two case study re-forecasts for NDJF 2009 (corresponding to the extreme winter NAO) but replacing sea ice initial conditions with those of 2005 (IMAX) and

2011 (IMIN). The choice of these initial conditions was based on an analysis of the sea ice conditions in the Mercator-Ocean runs presented in the 2017 progress report. 2005 was chosen as a local maximum of sea ice extent in the more recent period (higher sea ice extent is found earlier in the period), for which positive anomalies were found both in total sea ice extent but also over the North Atlantic and Barents seas sector.

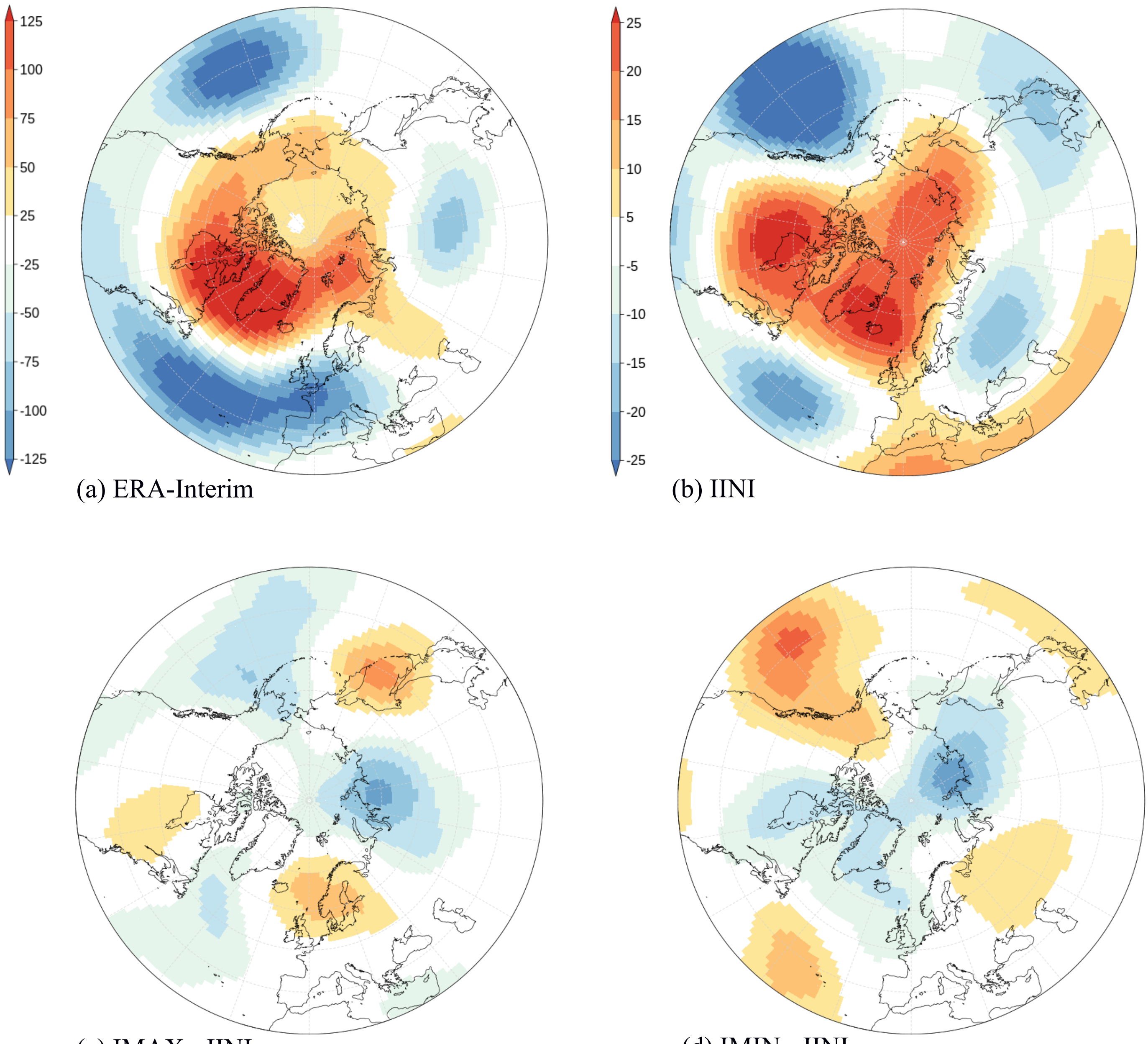

Figure 5: (a-b) Anomalies for DJF 2009/10 Z500 (in meters) with respect to 1993-2012 (in cross-validation mode) in ERA-Interim (a) and IINI (b). Note that the color scales differ between both figures. (c-d) Differences in ensemble mean Z500 for DJF 2009/10 in the IMAX (1st November 2005 sea ice initial condition; (c)) and IMIN (1st November 2011 sea ice initial condition; (d)) experiments with respect to IINI. The color scale is the same as in Fig. 5 (b).

Figure 5 shows the seasonal mean Z500 anomaly in ERA-Interim and in IINI with respect to the rest of the reference period (a-b), as well as the difference between the two case studies and the reference (IINI) experiment for DJF 2009/10 (c-d). The change in sea ice initial condition seems to have a lasting impact on the Z500 pattern over both the Arctic and mid-latitudes (both over the North Atlantic and North Pacific sectors). In particular, in Fig. 5d) the pattern partly projects onto the NAO pattern, suggesting (in average) a shift towards a less negative NAO index in IMIN. As shown in Fig. 5b) and in the NAO index in Fig. 4, the IINI ensemble favoured a negative ensemble mean NAO index for DJF 2009/10.

Figure 6 goes into further detail by showing the distribution of ensemble member NAO indices for DJF 2009/10 in IINI, IMIN and IMAX. Interestingly, although the mean NAO index for IMIN is indeed slightly less negative, the distribution tail does not encompass the ERA-Interim reference index, which isn't the case for IMAX. The IMIN distribution seems bi-modal with a larger peak in negative NAO index values than in positive values, while the peak of the IMAX distribution is close to 0. This shows that ensemble averaging can in fact mask a different distribution of the ensemble member values, and that overall the differences found in terms of ensemble means are very small.
It should be mentioned that these results were computed with 30 members, and taking into account the very large noise at these latitudes and high uncertainty, the ensemble size should be extended to strengthen any conclusion on this case study.

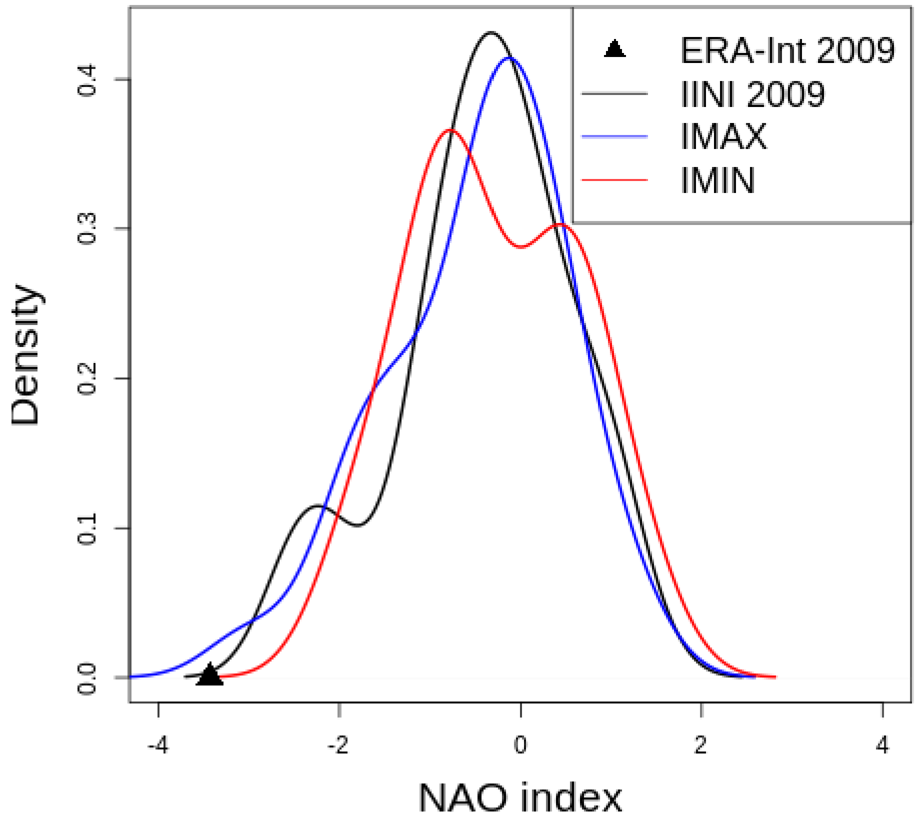

Figure 6: Distribution of the DJF 2009/10 NAO indices (computed as in Fig. 4) of each ensemble member for IINI (black), IMAX (blue) and IMIN (red) re-forecasts. The ERA-Interim index is plotted as the black triangle. Anomalies used to compute the indices for IMAX and IMIN are with respect to IINI over the other years of the re-forecast.

List of publications/reports from the project with complete references

Ardilouze, C., Batté, L., Bunzel, F., Decremer, D., Déqué, M., Doblas-Reyes, F. J., Douville, H., Fereday, D., Guemas, V., MacLachlan, C., Müller, W., and Prodhomme, C. (2017a): Multi-model assessment of the impact of soil moisture initialization on mid-latitude summer predictability. *Climate Dynamics, 49,* 3959–3974, doi:10.1007/s00382-017-3555-7.

Ardilouze, C., Batté, L., & Déqué, M. (2017b): Subseasonal-to-seasonal (S2S) forecasts with CNRM-CM: a case study on the July 2015 West-European heat wave. *Advances in Science and Research*, *14*, 115.

Summary of plans for the continuation of the project

(10 lines max)

This special project ends at the end of 2018. The allocated resources left for this year will be used to ensure the robustness of results found with the sea ice initial conditions.
Depending on resources, we could also complement the case study with other years of the re-forecast period.

Another aspect we wish to explore (depending on leftover resources) in the framework of this special project is the relative role of soil moisture and North Atlantic SSTs in the development of the July 2015 heatwave over Western Europe (Duchez et al. 2016).