Review of ‘Arctic Rapid Sea Ice Loss Event in Regional Coupled Climate Scenario Experiments’ by R. Döscher and T. Koenigk

Synopsis:
The manuscript presents results from regional arctic climate model results (RCAO) on rapid sea ice loss events (RILEs). The topic of this study is of high science relevance as the Arctic sea ice is rapidly declining for the past decade or so. The dynamical downscaling approach is also sound, however it is not clear how much gain compared to the global ECHAM5MPI-OM model it provides given its relatively course resolution of ½-degree especially when applied in ocean and sea ice components.
The paper appears to be somewhat hastily written, with common typos, incomplete description of model setup, figures and captions, missing or incomplete references, etc. In addition, the text is not easy to read as the authors often draw conclusions without providing proper information (see #3) or analyses.
In summary, since this manuscript requires major revision I rate it between fair and good (2.5).

General Comments:

1. The model used has a number of limitations (e.g. lateral boundary conditions, surface salinity restoring/flux correction, representation of clouds, precip/snow, sea ice and ocean processes) which could affect its simulation of the relative importance of specific factors, forcings and feedbacks leading to RILE events. It would help to include a few figures such as mean seasonal SLP, SST and sea ice thickness maps to demonstrate the realism of model surface climate (see comments on L109-110) and modeled versus observed to-date RILEs.

2. Conclusions are made several times regarding inflow of warm air from lower latitudes based on plots of SLP and T2M anomalies. While this might sometimes be the case it is hard for a reader to follow such arguments without actual maps of SLP, T2M as well as sea ice concentration and thickness. A common argument made throughout the paper is that winter SLP anomalies bring warmer air from lower latitudes, which result in negative ice thickness anomalies, in winter. Such an argument, if it holds at all requires further evidence (see detailed comments below).

3. Sections 4.4 Composites and 4.5 Individual Cases can’t be properly evaluated as the figures discussed in those sections are not described with enough details (Fig.6) or are incomplete (Fig.7-9) in addition to the need for clarification on the text there.

4. Evidence exists (e.g. Screen et al., GRL, 2012) that largest warming in the Arctic atmosphere is near the surface and it is related to loss of sea ice and SST changes. Other

studies (e.g. Jackson et al., JGR, 2011) suggest that the Arctic Ocean has been warming as well, especially in the western Arctic where sea ice has retreated most recently and below the surface mixed layer. Ice-ocean interactions appear increasingly important (e.g. this summer 2012) and they should be considered in modeling studies as well, especially if model representation of such processes and feedbacks is limited and known (see #1). My recommendation is to include some discussion of ‘missing physics’ in the model and how this may affect the simulated RILEs and conclusions of this paper.

Detailed Comments

Abstract:
Has the preconditioning by sea ice thinning during season and years before the event also been related to atmospheric circulation or something else? If so what were the mechanisms?

1. Introduction
L71: change ‘Kwock’ to ‘Kwok’
L71-74: This is potentially a critical question: if the atmospheric circulation controls RILE events, what controls seasonally persistent atmospheric circulation patterns?
L95-96: How the proposed mechanisms hold relative to the 2012 RILE event?
L109-110: Explain where in Koenigk et al. 2011 a realistic level of sea ice extent in the Arctic Ocean is presented/discussed or provide a different reference where not only ice extent time series but also ice concentration/thickness maps are shown; change ‘Arctic ocean’ to ‘Arctic Ocean’ here and elsewhere.

2. Model data and experiments
L141-143: Explain if with the closed lateral boundary along the Aleutian Island chain there exists a net flow through Bering Strait. If so provide mean volume/heat/freshwater fluxes there. If not explain what is the ocean circulation in the Chukchi/Beaufort Sea in absence of a net northward flow through Bering Strait. Also, explain if the PHC monthly climatology is applied at the closed lateral boundary along the Aleutian Island chain. In not, explain/justify why not.
L143-144: delete new paragraph
L146-149: explain why there is an artificial salinity drift in a coupled atm-ocean model; Why there is not enough precip? Is river runoff prescribed? How do you justify your conclusions about RILE events if your salinity is restored or flux corrected?
L161-162: delete new paragraph
L164-165: Explain the basis of your assumption that the ocean fields are in advective balance after 20 years; what fields and down to what depth?
L169: provide a reference for IPCC Assessment Report
L180: explain/define/revise ‘the freezing height of lateral freezing’

4. Results

L207: explain what the anomalies in Fig.1b and 1c are relative to

L212-213: explain why summer T2M are increasing due to enlarged areas of leads and open water or revise this sentence to make the latter refer only to SST and discuss other reason(s) for increased summer T2M

L215-218: Fig1e is for summer melt rates so there is no ‘freezing rates’ shown there; revise this paragraph as the following two sentences are also not clear; ‘A weaker increase’ compared to what? Why summer surface melting is decreasing? The last sentence is even less clear.

L226-236: define ‘clustering’ and provide quantitative measure(s) of intra-ensemble coherence; then revise this paragraph accordingly.

L240: insert ‘RILE’ before ‘event’; also a figure of ice thickness and respective SLP distribution from the 6 ensemble members in 2035 would help to understand the effects of SLP change shown in Fig2.

L246: change ‘Pacific ocean’ to ‘Pacific Ocean’ (here and elsewhere); explain the intended meaning of ‘a broad inflow of air from the Pacific Ocean….connected to sea ice drift: do you mean ‘air inflow’ forces ‘ice drift’ or the other way around?

L253-254: The SLP anomalies shown in Fig2 can help explain some of the anomalies in sea ice thickness but given the coupled model it would help to quantify the direct dynamic contributions of winds versus the thermodynamic impacts by warmer oceanic currents and air as well as ocean-atmosphere feedbacks as the sea ice retreats. It is premature to conclude that SLP explain all the sea ice thickness anomalies without a proper analysis.

L260: provide a year for the Gerdes and Köberle reference

L286-293: Explain how change in winter T2M by 2K can reduce sea ice thickness by 35cm, especially without changing sea ice concentration (SIC); are you implying surface melt in winter? What is the role of ocean in this event? Without further analyses the argument that a less cold atmosphere can reduce ice thickness is not convincing or not supported at all. What is causing SIC anomalies in the eastern Arctic in winter?

L298-305: Explain how ice thinning by 20-30 cm in winter can increase T2M by 1K in spring? What is causing SIC decrease along the eastern Chukchi and southern Beaufort seas? what do you mean by SST anomalies following SIC changes? Are they getting above freezing temperature and due to warmer air or possibly due to oceanic advection of warm water from the south? Is it possible that the ocean plays a more important and dynamic role there instead of statically responding to atmosphere/ice via SST?

L307-310: Even with the multi-ensemble averaging it is hard to explain why the SIC is reduced most in the center of the ice pack and very little around the perimeter over the shelves. Please provide further discussion.

L311-313: Explain/discuss what processes might be involved in decreasing SIC and increasing SST in the central Arctic.

L318-325: Explain the evidence for an anomalous inflow of warm air from the Nordic seas into the Arctic Ocean based on Fig3a-summer SLP/T2M anomalies; if anything I can see a strong connection of summer T2M anomalies to spring SIC anomalies, which would suggest effect of warmer water in areas of sea ice retreat – please revise accordingly.

L335-337: Even with the discussion in the previous paragraph it is hard to follow the argument that the strongest melt rates are not coincident with largest ice thickness reduction; shouldn't the largest bottom melt rates be in the East Siberian Sea where up to 45 cm of ice melted? Explain and/or revise your arguments.

L339-346: Note that the warmer T2M in the Fall is similar to SIC anomaly distribution in Summer, which suggest a dominant role of delayed freezup, i.e. T2M resulting from a new sea ice/ocean state and not the other way around. As stated earlier, it would be useful for this paper to quantify such statements as 'Anomalous atmospheric circulation can only support a part of that warming of the central Arctic by advection from the Nordic Seas' instead of 'visual analysis'; also discuss why SLP are higher in the North Atlantic and over northern Europe in summer and fall than 10-year period before.

L363: delete extra 'period' after 'long-term trend.'

L364-365: I do not see 'a recovered sea ice extent' compared to the summary before in Fig3b-JAS. Please explain and/or justify. Perhaps you mean 'a recovered SIC'?

L392-393: please state explicitly that EOFs are based on RCA model output so when referring to an alternative of the DA by Overland and Wang (2010) based on actual SLP data.

L403-412: explain how warmer Pacific-Arctic inflow in winter (i.e. still well below freezing temperatures) can reduce sea ice in summer – where is the memory over time scale of several months? What is the cause of positive DA anomalies in winter before? Change 'mid panel' to 'bottom panel' in L405; explain/revise the reference to 'Fig. COMP3c' – is it Fig.6

L419: either label panels in Fig.4 (a-f) or revise the reference to Fig.4e

L420-421: Expand/justify the conclusion about 'low phases DA preventing strong extreme events'

L425-506: The whole section 4.4 Composites is hard to follow because it is not clear what criteria were used to select (6 out of 30) events for each composite. It needs to be revised, including presentation of actual fields and not or in addition to anomalies in Fig.6, to support arguments about advective forcing of some of the events.

L433: spell out 'resp.'

L437-439: You need to show the actual SLP and T2M patterns and not their anomalies to argue about advection of warm air into the Arctic. Regardless, air temperature differences of 3K in winter are not going to melt ice during that time so what is the connection between winter SLP changes and summer ice concentration?

L439-441: the sentence on composite 2 is not clear, revise; what is 'an isolated low pressure' and how does it reduce ice concentration?

L441: the phrase 'moderate rapid change' sounds awkward, revise

L526-559: Fig7 (as well as 8&9) are missing color scale/legend, which makes the interpretation of discussed results difficult, e.g. how anomalous are T2M or ice thickness in preceding winters? In addition, there are many statements that need further clarification (e.g. 'This' in L530 versus 'This' in L531). Also, see comments below. Revision of this whole section is recommended.
L528-532: As before, in order to imply arguments about atmospheric transport of warm surface temperatures actual fields need to be presented and some additional diagnostics (e.g. heat flux convergence) provided. It is hard to imagine that an increase of winter temperatures by a few degrees in the eastern Arctic two winters before (Fig7) can result in reduced ice thickness by say 50cm in the southern Chukchi and East Siberian seas. However, it might be possible that reduced ice cover in the western Arctic two falls before the event (which is not shown) increases T2M by delayed cooling and freezing of the ocean into the following winter.
L541-546: This paragraph suggests just the above, so I'm not sure which arguments the authors are proposing here, warming of the atmosphere and subsequent effect on SLP due to delayed cooling/freezup or transport of warmer air from lower latitudes reducing ice thickness.
L550: if the atmospheric inflow from the Nordic Seas reduces ice concentration north of the Laptev Sea, why ice is not/less affected north of Barents/Kara seas?
L555-559: add 'exists' after 'thin ice'; see comments above regarding alternative conclusions

L561-597: similar comments as above, including lack of color scales in Fig.8, inclusion of actual fields (to help with discussion of the role of atmospheric flow) and the need for revision of the text for more clarity.
L594-597: This paragraph needs extra clarification: what season is discussed here? How about other seasons? What happens with radiative heat after ice retreats? What is the thickness of the ocean surface mixed layer in summer and how it may affect the heat storage? The fact that oceanic heat does not appear to be a factor contributing to sea ice retreat in this model does not mean it is not; given the fact that observations suggest that heat content in the upper western Arctic Ocean has been increasing during the recent retreat of sea ice and insufficient ocean model spatial resolution to represent potentially involved processes (e.g. eddies, upwelling, etc.).

L599-634: as in the two previous cases: add color scale in Fig.9, include maps of actual fields; revise the text, including the cause of original of sea ice thinning two winters before the event; one of the important questions to address in this case is what was the initial thickness distribution north of the Canadian Archipelago and Greenland and how is it possible to move/thin ice there without reducing it much on the Siberian side? The main issue here is that if the model over-represents sea ice response to winds (i.e. thick ice moves too fast) the resulting feedbacks and interactions would be much less physical and more numerical model artifacts.

L637-639: The results and discussion in this section are not sufficient to make such a conclusion – see earlier comments; more results and better discussion is needed to resolve the initial cause of sea ice thinning seasons/years before each event.

Figures

1a: units of ice extent should be km^2 not km^3: correct on the figure y-axis and in the caption

3c: provide units of ice melt rates

6: explain in the caption what are the numbers on the right (comp#1-6) and why there is no #2?
7-9: include color legends/scales