Impact of the 2007 Arctic sea ice reduction in coupled ocean-atmosphere hindcasts

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Arctic sea-ice extent decrease

- Decreasing trend in Arctic sea-ice extent (~8% per decade), maximizing in late summer, superposed on a large inter-annual variability
- The summertime inter-annual variability is influenced by a variety of factors: oceanic (influx of Atlantic & Pacific warm waters), meteorological (Arctic circulation patterns), radiative (cloud feedbacks) and cryospheric (pre-conditioning by winter ice thinning)

Key issue : Atmospheric response to the summer decrease in Arctic sea-ice extent

→Does the reduced sea-ice extent at end of summer impact the weather and climate in following autumn and winter months ? Does this influence extend beyond boundaries of Arctic Ocean ?

- Here, we focus on autumn when accumulated heat in upper ocean due to lowered albedo is released to the atmosphere, and the year 2007 with record low summer extent
- Here, we use a high-resolution, global forecast model to resolve regional aspects of sea ice forcing.

Seasonal forecast model from ECMWF

- High horizontal resolution (T159;l62) coupled ocean-atmosphere model (IFS HOPE V3 – cy31r1)
- The operational ensemble prediction system contains no dynamic sea-ice module; rather, the sea ice albeit realistically initialised from ocean analyses is persisted for ~10 days, then relaxed to seasonal climatology.
- We have adapted the model to be forced by realistic, observed sea-ice throughout the simulation.
- Ensemble runs with prescribed sea-ice have been made for the autumn-early winter 2007, and additional ensembles with “erroneous” sea-ice from 6 previous years have been for sensitivity and potential predictability studies.

The 2007 Experiment

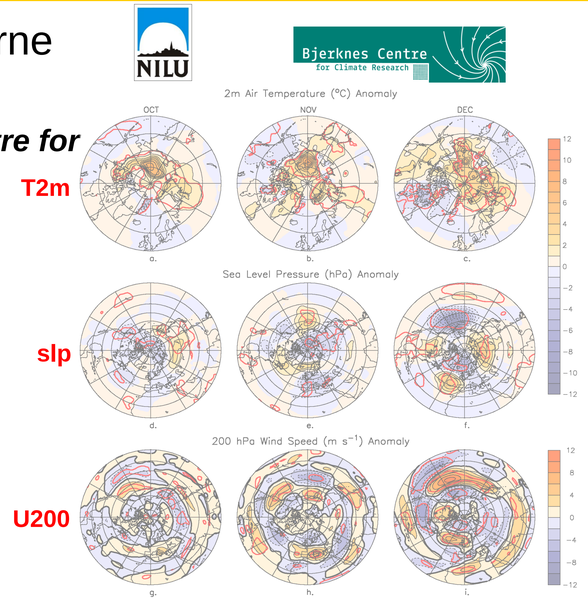
- 5-month hindcasts
- 5-member ensemble (perturbed SST)
- initialized on 2007-10-01 (atm, ocean, sea-ice)
- Prescribed (2007) sea ice throughout the period

Sensitivity Experiments

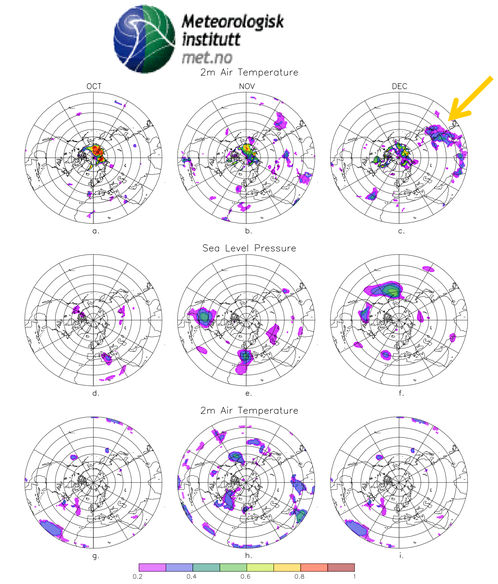
- (same 2007 ensemble hindcasts)
- But prescribed “erroneous” sea ice from 2002 to 2006

Grand ensemble of 30 hindcasts for OCT-FEB 2007, 5 of which had actual observed 2007 sea-ice.

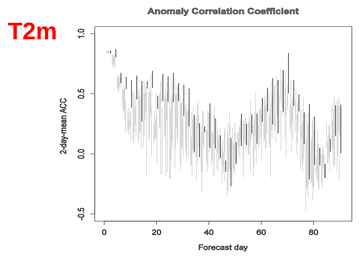
We call ”2007 anomalies” the departures of the ensemble-mean “2007 Experiment” from the grand ensemble mean



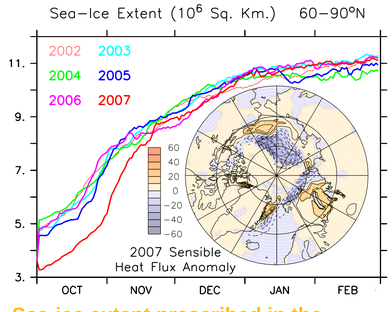
2007 anomaly maps: maps of monthly-mean 2007 forecast anomalies in T2m (a-c), SLP (d-f), and 200 hPa wind speed (g-i). Note in DEC: anomalous Highs over continents, Low and jet stream over the Pacific.



Potential predictability maps: the ratio of external to total (internal+external) variance indicates that sea-ice strongly influences Arctic surface temperatures in OCT and NOV. There is a remarkable enhancement along the Asian Pacific coast from Japan to southeast Asia in DEC. Top row is T2m, and mid row for SLP. Last row is potential predictability wrt SST rather than sea ice.

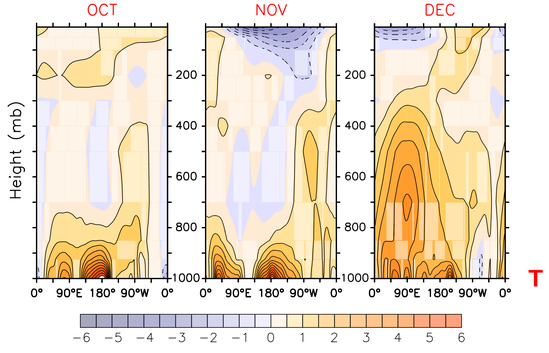


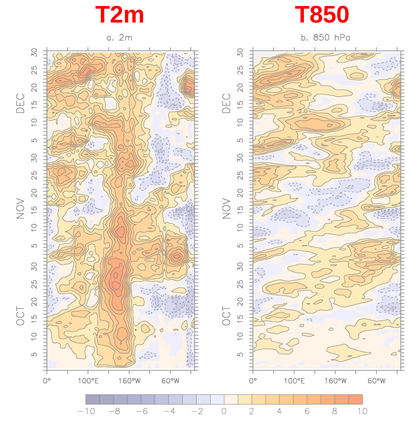
Forecasted surface temperature at high latitudes: anomaly correlation coefficients between hindcasts and observations (ERAINT) reveal that the hindcast based on the 2007 sea-ice (black) have consistently higher ACCs than those based on sea-ice from other years (grey), indicating a positive impact of realistic sea-ice conditions over the Arctic surface temperatures



Sea-ice extent prescribed in the different experiments:

- 2007 stands out with negative anomaly lasting until late NOV
- Inset: Sensible heat flux anomaly in OCT 2007: ocean is losing heat (blue) in regions where sea ice decreased (Pacific & Siberian sectors)





2007 Temperature anomalies at 80N:

- Warming of lower atmosphere over Pacific and Siberian sectors in OCT-NOV
- Magnitude (~10K) of surface maximum in agreement with recent observational studies (e.g. Overland and Wang, 2010)
- a regime change in DEC: warmth spread Pan-Arctic, anomaly dipole over both continents of Eurasia and North America, deeper T structure

Conclusions

Ensemble of hindcasts for autumn and early winter 2007 with coupled ocean-atmosphere ECMWF seasonal forecast model at high horizontal resolution reveal:

- Warm anomalies (10K), max. at surface in OCT and NOV consistent with other observational studies
- In DEC, a regime change indicative of an indirect response, with weaker but deeper T anomalies through the troposphere, a deeper Aleutian Low (Overland and Wang,2010),and an extended upper-level jet, esp. across the Pacific ocean, intensified Highs over continents over Asia and North America leading to cold (warm) air advection on their eastern (western) sides, and southward-shifted jet streams and T_{2m} dipole anomalies
- Improved correlation of T_{2m} wrt re-analyses over high latitudes through OCT from sea-ice being realistically prescribed
- Potential predictability analysis reveals a strong influence of sea ice on T_{2m} over the Arctic Ocean in OCT-NOV, and over Pacific coast of Asia in DEC (strongest signal beyond Arctic Ocean) : cooler temperatures due to cold air advection

References

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