Long-Term High-Resolution North Atlantic Atmospheric Hindcast for Multipurpose Applications

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Introduction

It is a well accepted expectation that increasing of model resolution will significantly improve the output quality due to the opportunity to explicitly resolve subsynoptic and mesoscale processes. There are evidences of the paramount impact of mesoscale dynamics in forming cold-air outbreaks (Kim et al. 2016, among others) and generating polar lows (Kolstad et al. 2016, among others); also mesoscale-resolving models provide more realistic clouds which in turn leads to more accurate radiation balance (Schneider et al. 2019, among others).

All of these phenomena cannot always be adequately captured by the coarse grid of global reanalyses. There is an urgent demand from different communities for long-term high-resolution atmospheric hindcasts performed with high-resolution model configurations for the North Atlantic where subsynoptic and mesoscale processes are of high relevance. Facing this challenge, the P.P. Shirshov Institute of Oceanology of the Russian Academy of Sciences (IORAS) in cooperation with the Institut des Géosciences de l'Environnement (IGE) developed a high-resolution (14 km) atmospheric downscaling experiment for the North Atlantic Ocean (North Atlantic Atmospheric Downscaling, NAAD).

Model description

In NAAD we used the nonhydrostatic WRF Model, version 3.8.1 (Skamarock et al. 2008). The domain (Fig. 1, A) covers the North Atlantic from 10 to 80N and from 90W to 5E, with the center at 45N, 45W. The initial and lateral boundary conditions (including sea surface temperature (SST)) were provided by the ERA-Interim reanalysis (Dee et al. 2011). The spatial resolution in the basic NAAD high-resolution experiment (HiRes) was 14km and 50 terrain-following, dry hydrostatic pressure levels, starting from around 10–12m above the ocean surface to 50 hPa with 15 levels in the boundary layer. Besides the HiRes experiment, we also conducted a moderately low resolution experiment (LoRes) with the hydrostatic setting of the WRF Model at 77-km resolution with 50 vertical levels (as in HiRes). The LoRes experiment (with resolution comparable to ERA-Interim) will be used to quantify the added value of the HiRes experiment, which cannot be directly compared with ERA-Interim (due to the fact that different models were used). All experiments were run for the 40-yr period from January 1979 to December 2018.

We conducted more than 32 sensitivity tests to determine the most suitable model configuration for the North Atlantic region. The configuration turned out to be very similar to the one used in Polar WRF of ARSv2 (Bromwich et al. 2018). Details of the model settings for the HiRes and LoRes experiments could be found in Gavrikov et al. (2020).

In order to constrain (nudge) the interior of both LoRes and HiRes experiments toward the larger-scale driving field, we applied throughout the 40-yr period the procedure of spectral interior nudging (Jeuken et al. 1996). Configuration of nudging was set according to the sensitivity study of Markina and Gavrikov (2016), which implied the optimal wavelength cutoff being 1100 km, applied only above the PBL. For determining the optimal nudging strength, we performed 18 sensitivity experiments with the nudging strength coefficients increasing from 3x10-5 to 3x10-3 s-1. These experiments implied an optimal value of the nudging strength coefficient of 3x10-4 s-1 (equivalent to a damping scale of about 1 h). This value is also consistent with other studies (Otte et al. 2012; Tang et al. 2017, among others).

Results

As an example, we provide the diagnosis of intense polar mesocyclone on March 2, 2008 near the southern tip of Greenland (Fig. 1). The wind field in NAAD HiRes (B) reveals polar low in more details comparing with ERA-Interim (C) atmospheric reanalysis. Notably HiRes results are very similar to ARSv2 (D) reanalysis due to similar models and resolution. NAAD HiRes detects well the location of the pressure minimum identifying a 978-hPa central pressure, which is deeper than that in ERA-Interim (986 hPa) and even in ERA5 (not shown). Also, NAAD HiRes demonstrates the well-detectable comma-type structure not present in ERA-Interim and ERA5 (not shown) and less evident in ASRv2.

The NAAD dataset includes prognostic and di-

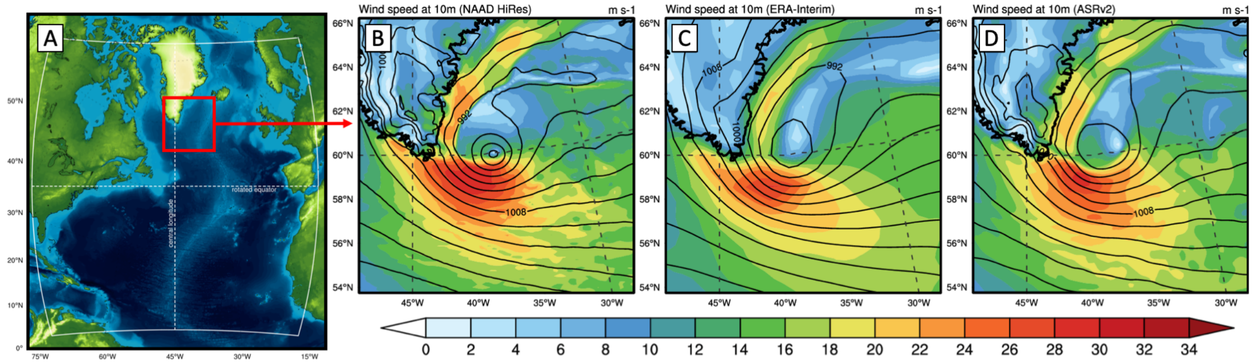

Figure 1: NAAD domain (A), diagnostics of the polar low on 2 Mar 2008. Shown is the surface 10-m wind speed (colors) and mean sea level pressure (MSLP; contours) as revealed by (B) NAAD HiRes, (C) ERA-Interim and (D) ASRv2.

agnostic variables at the surface and in the atmosphere at resolutions 14 km and 77 km for the period of 1979 to 2018. Coarse resolution was used to quantify the added value of the high-resolution experiment. All variables are provided at the native grids both for LoRes and HiRes experiment. The entire archive of the NAAD data amounts to 150 terrabytes (TB) with individual annual files ranging from approximately 140 MB in LoRes to 3.3 GB in HiRes for surface variables on to 165 GB for HiRes 3D fields. The whole NAAD data output is organized as annual NetCDF files by variable and is available online for download using Open-source Project for a Network Data Access Protocol (OPeNDAP) accesses at http://www.naad.ocean.ru.

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