Verification of polar low modeling results with satellite data

K. S. Khvorostovsky, K.I. Yarusov, E.V. Zabolotskikh
Russian State Hydrometeorological University, Satellite Oceanography Laboratory, St.Petersburg, Russia

Introduction

Polar lows (PL) are mesoscale cyclone vortices that form in high latitudes over ocean areas and characterized by significant wind speeds and intense precipitation. PLs are of great interest for the safety of navigation and oil and gas drilling activities in the Arctic region. However, relatively small sizes (up to 1000 km) and a short lifetimes (1-3 days) of PLs make them difficult to study and forecast using only regular in-situ observations and global climate models.
This work presents a verification of the Weather Research and Forecasting (WRF) model simulations of the surface wind speed (SWS) and track for eight PLs observed in the Nordic seas in 2009 and 2010 by comparison with the satellite data.

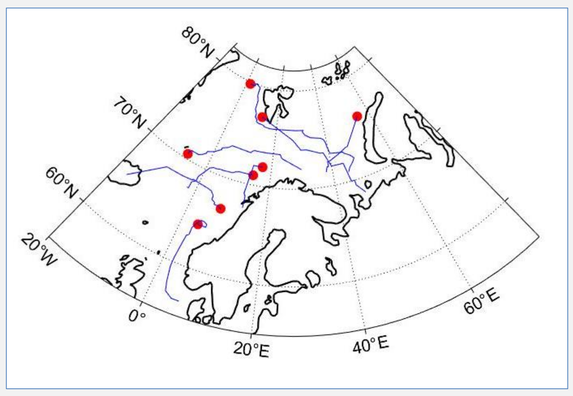
Model and data

- The WRF model is a three-dimensional nonhydrostatic model used for studies of mesoscale weather systems.

Initial and boundary conditions: NCEP reanalysis (1° by 1° grids every 6 hours).
Simulation periods: - 3 days with the second day corresponding to the mature stage of the PL
- 2 days starting from the second day of 3-days period
Spatial resolutions: 5 km and 10 km
Parameterization schemes:

- boundary layer: Mellor–Yamada–Janjic, Bougeault–Lacarrere, Yonsei University
- microphysics: Lin (MP2), WRF Single-Moment 3-class (MP2)
- cumulus: Kain–Fritsch (CU1), Betts–Miller–Janjic (CU2)
- surface layer: revised MM5 (SL1), Eta Similarity (SL2)
- longwave: the Rapid Radiative Transfer Model
- shortwave: Dudhia

- **Satellite data**
  - Advanced Scanning Microwave Radiometer (AMSR-E) and Advanced Scatterometer (ASCAT) data to retrieve SWS and track of the PLs
  - MODIS and AVHRR spectral radiometer images to detect size and track of the PLs



Date	Location of track
3 Apr 2009	Barents Sea from south of Svalbard
22 Dec 2009	From Norwegian to Greenland Sea
4 Jan 2010	East of Barents Sea
31 Jan 2010	South of Norwegian Sea
15 Feb 2010	North of Norwegian Sea westward
2 Mar 2010	Barents Sea from north of Svalbard
13 Mar 2010	North of Norwegian Sea southward
22 Mar 2010	From Greenland to Norwegian Sea

PL tracks and formation dates

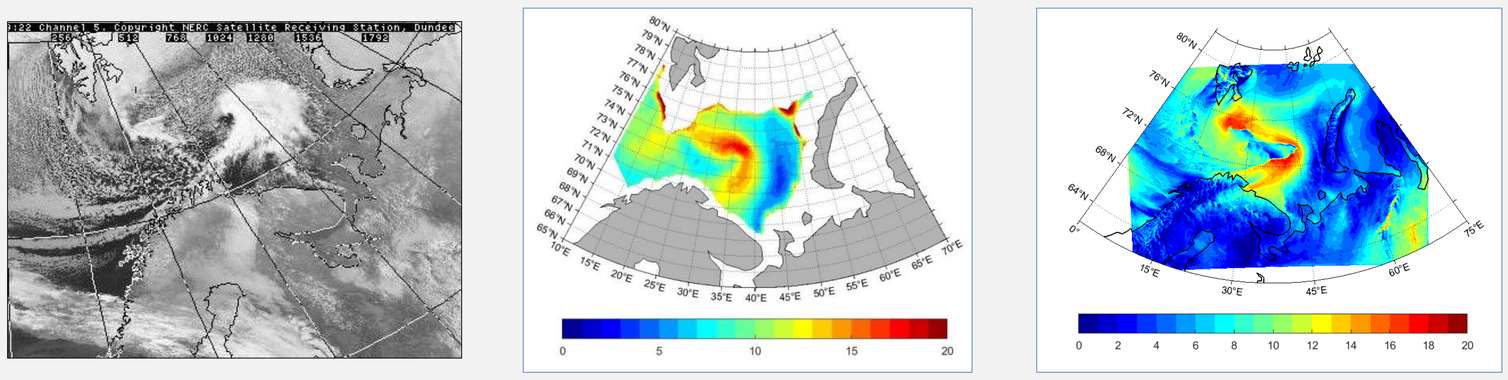
Method of comparison

- Detection of the PL centers
  - WRF: from the minimum value of the atmospheric pressure
  - ASCAT and AMSR-E: visually from the spatial distribution of SWS and using MODIS and AVHRR images
- Evaluation of the PL radius in stage of mature development: from MODIS and AVHRR images;
  estimation of the PL radius limited by available satellite measurements to ensure that satellite data and modeled results are compared over the area of equal size
- Estimation of the mean and maximum SWS, wind radius and SWS density distribution within both radii relative to the center of the PLs for model and satellite data

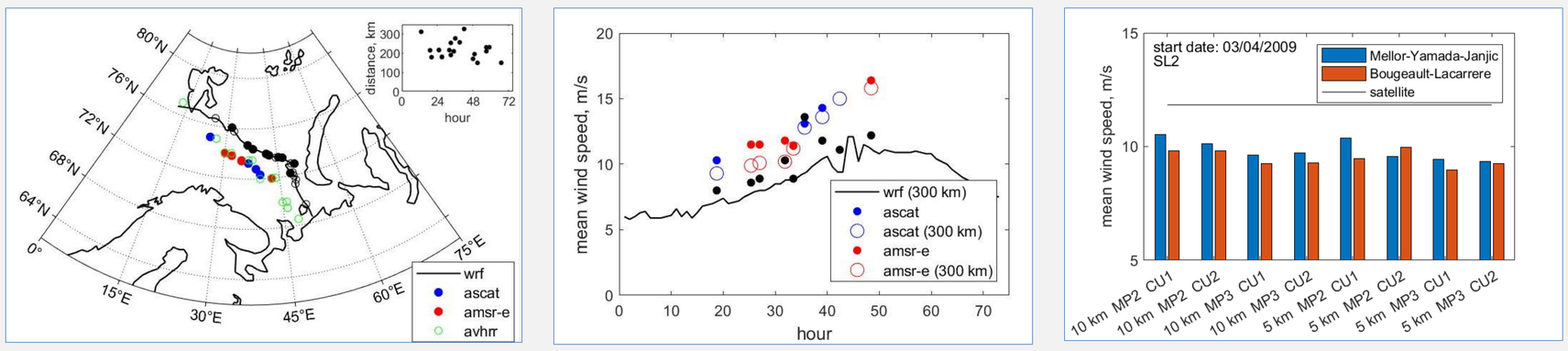
Results

- Mean SWS is underestimated by the most of model simulations especially for the PLs observed in the Norwegian Sea
- The simulated PL tracks often deviate from those observed by the satellites due to different direction and/or speed of PL propagation
- Effect of parameterization schemes on simulated SWS of the PLs:
  - boundary layer: Mellor-Yamada-Janjic scheme better reproduces the SWS for the PLs observed in the Barents Sea, while Bougeault–Lacarrere and Yonsei University schemes are more suitable for modeling of the PLs in the Norwegian Sea
  - microphysics and cumulus: Lin and the Kain–Fritsch schemes result in better consistency between the modeled and satellite SWS data for the majority of the considered PLs.
- Higher spatial resolution (5 km vs. 10 km) has limited impact on modeled results: simulation of the mean SWS improved only for one of the considered PLs observed in the south part of Norwegian Sea
- Start of the simulation from the day when the PL is in mature stage results in remarkably better agreement with the satellite observations for the most of PL cases

Results for the PL case in the Barents sea on 4 April 2009



AVHRR image of the PL on 4 April 2009, 9:22 UTC (left), and wind speed fields (in m/s) on 4 April at 9:29 UTC derived from AMSR-E (middle), and at 9:00 UTC simulated using WRF (right).



PL track (left) and mean SWS (middle) derived from satellite and modeled data. Unfilled circles and line (middle) correspond to a fixed radius of 300 km, while dots correspond to the radius limited by width of satellite swath.

Modeled mean SWS averaged over the PL lifetime as derived using different schemes for boundary layer parameterization with varying set of parameterization schemes and resolutions (right).

Conclusions

The model reproduces well the PL occurrences but typically underestimates the mean SWS by several meter per second, and the simulated PL tracks often deviate from those observed from the satellites by up to several hundreds of kilometers. Regional effect from using different boundary layer parameterization schemes and effect of the dates of the simulation start are revealed.