High-resolution modeling of Arctic cyclones

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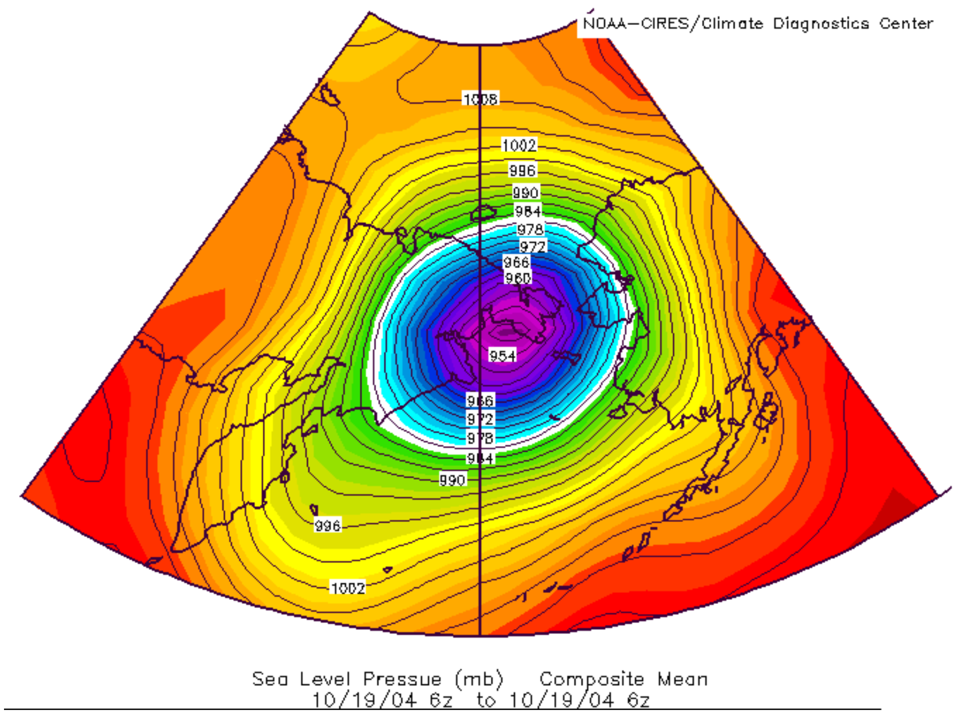
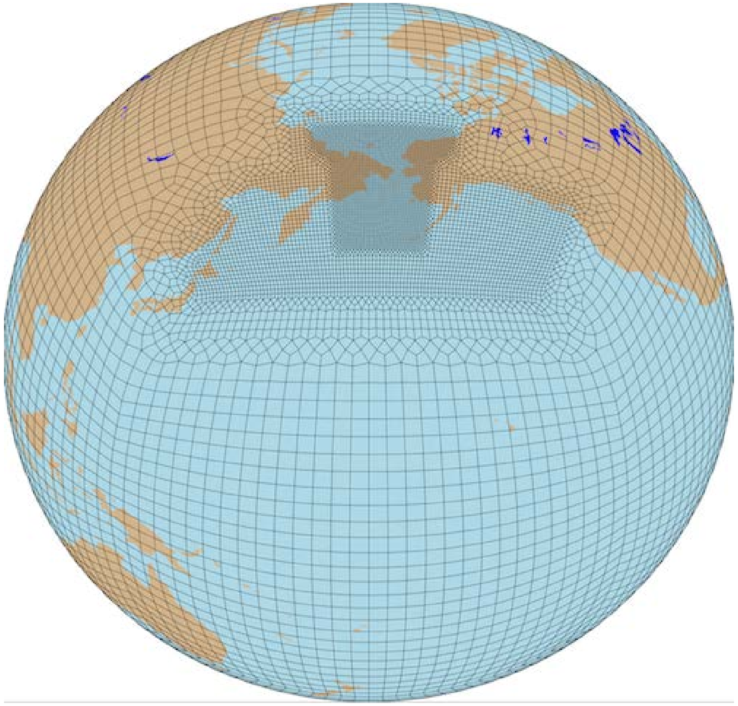
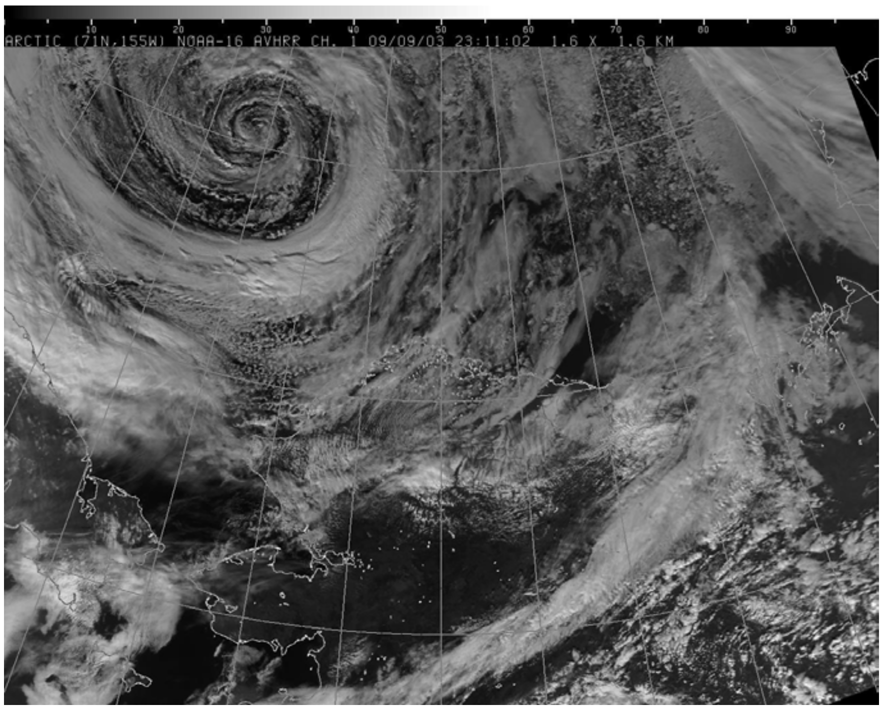




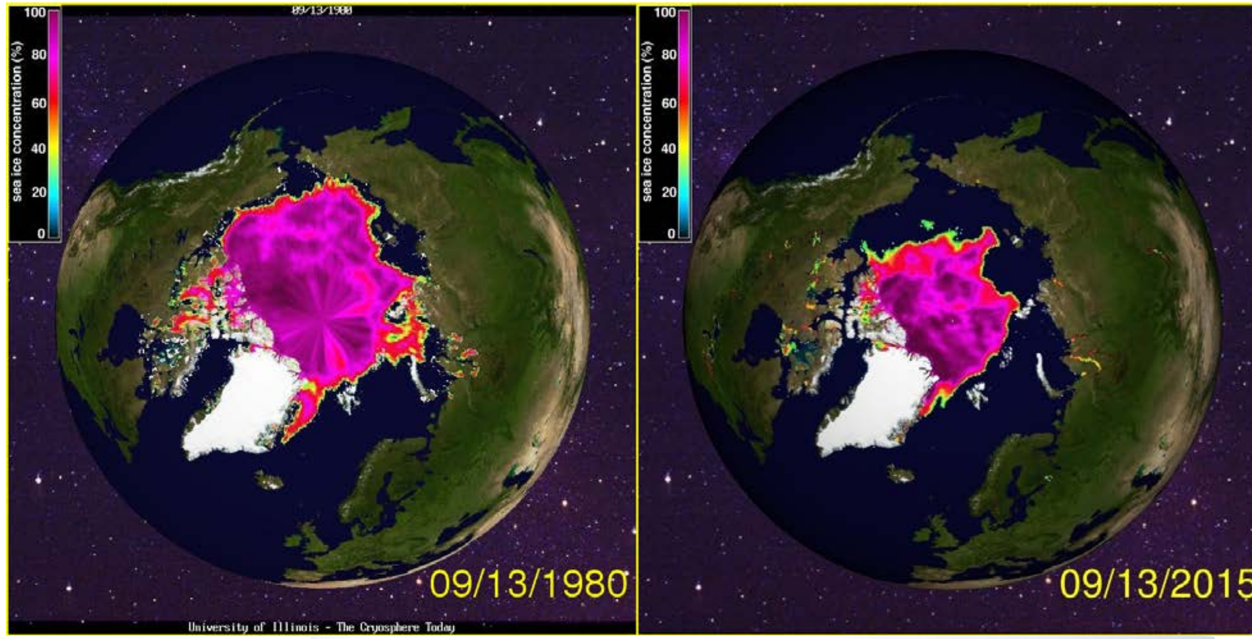
Arctic cyclone origins: Arctic Ocean (left) and subarctic/midlatitudes (right)



Sept. 1980 Sept. 2015

Motivation:

Loss of Arctic sea ice increases coastal vulnerability to flooding, erosion



Driving questions:

- **What is the resolution-dependence of model simulations of Arctic cyclones?**
- **How do the storms impact sea ice?**
- **How do changes in sea ice impact Arctic storms?**
- **How will Arctic cyclone frequency and intensity change in the future?**

Synopsis of methods (1):

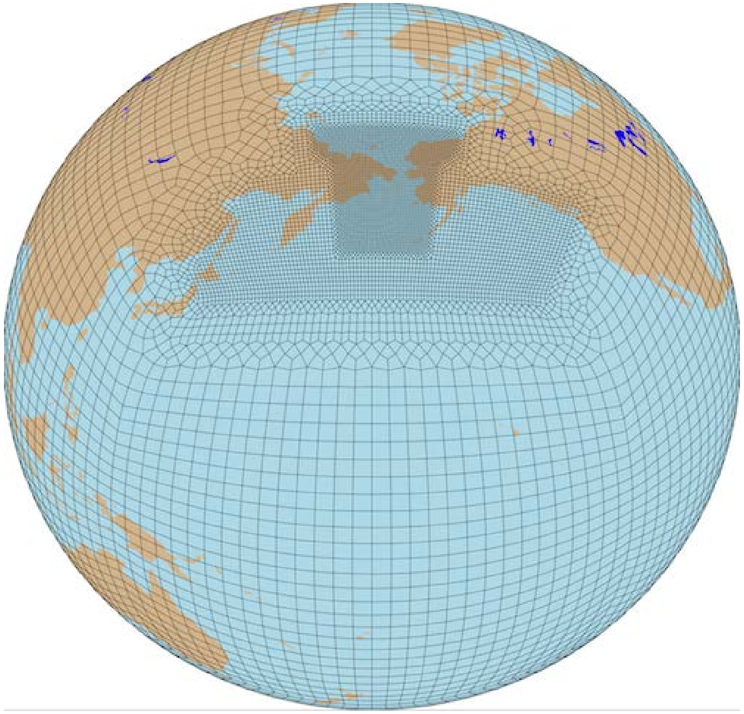
- **What is the resolution-dependence of model simulations of Arctic cyclones?**

  -- comparison of E3SM and WRF regional model at various resolutions

  -- case studies and climatology (seasonal)

  -- particular emphasis on polar lows

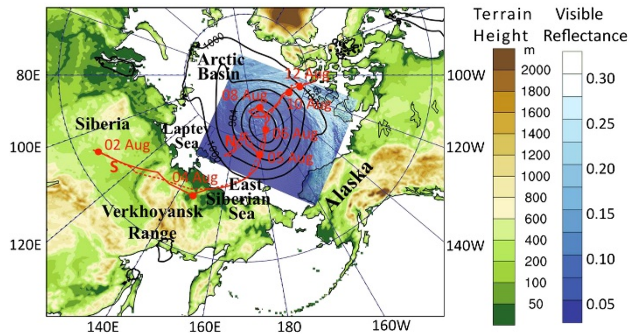
North Pacific Regionally Refined Grid used to study Arctic storms in E3SMv0.0 (11,747 atmospheric columns)



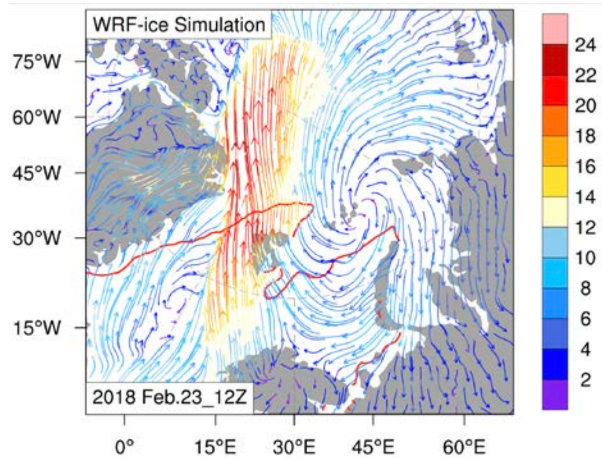
The low resolution is effectively 1-degree, which is refined to ¼-degree over the North Pacific, then further refined to ⅛-degree over the Bering Sea and coastal region of western Russia and Alaska.

WRF-ice modeling of storm events in the Arctic

Physically Optimized, Snow/Ice Enhanced WRF Model (WRF-ice) for the Arctic



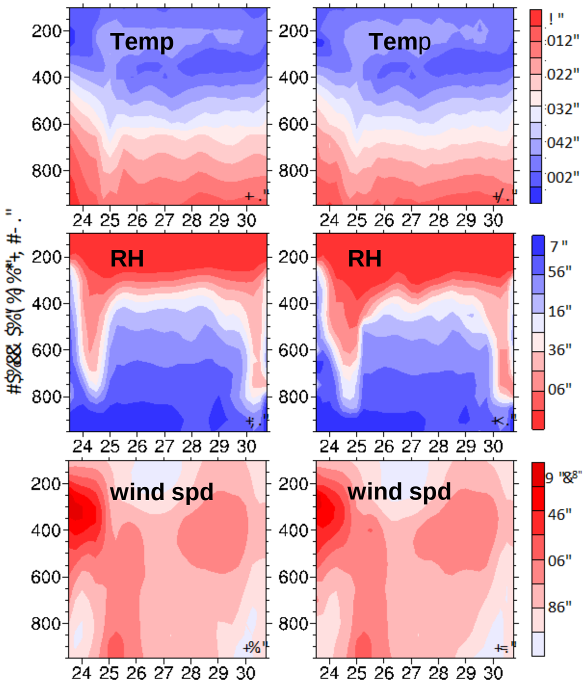
The simulated 2012 summer super storm. Black contours: the simulated SLP; solid red line: the simulated storm track; dashed red line: the storm track in ERA-Interim



The simulated extreme wind and polynya event associated with a intense storm and an anticyclone in February 2018. Streamlines: wind field; color: wind speed; red line: sea ice edge. (J. Zhang, X. Zhang, J. E. Walsh, and E. L. Roesler, 2020*)*.

Time-height sections

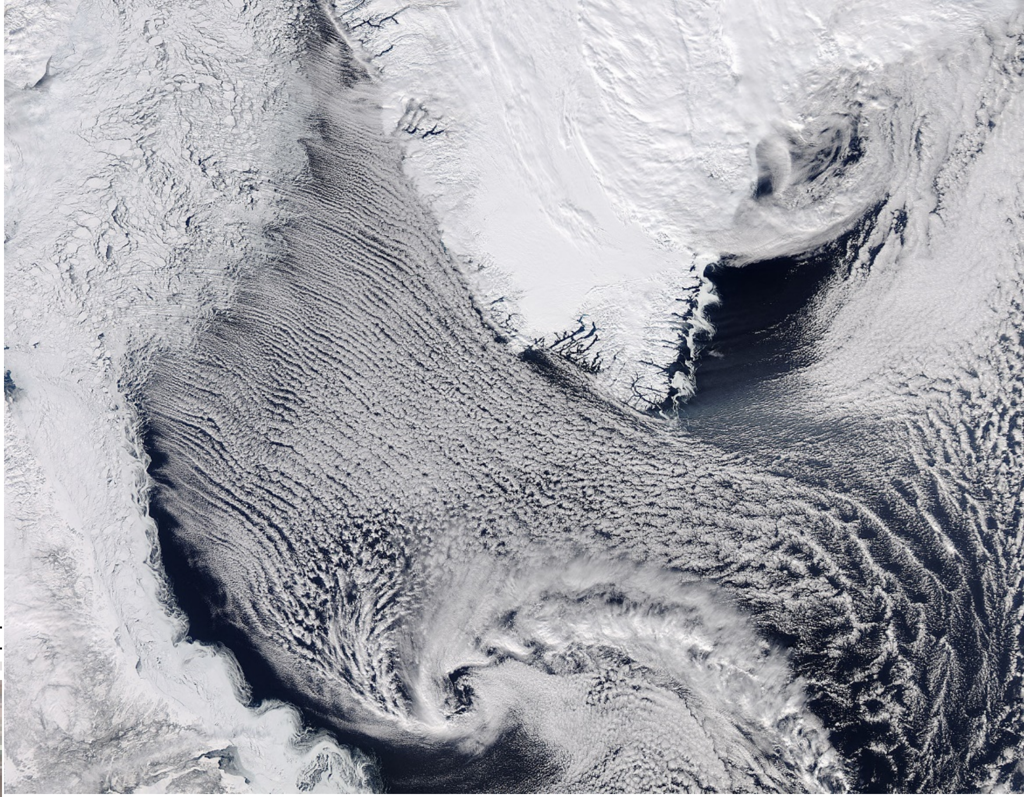
Simulated **in situ observed (Mirai)**



The simulated vertical structures of a 2010 autumn long-living storm in the Arctic. The in-situ observation was from GPS Radiosonde onboard R/V Mirai (W. Tao, J. Zhang, and X. Zhang, 2017*)*.

<u>Polar lows</u>:

Mesoscale (~100-300 km) cyclones forming in cold air outbreaks over subarctic seas



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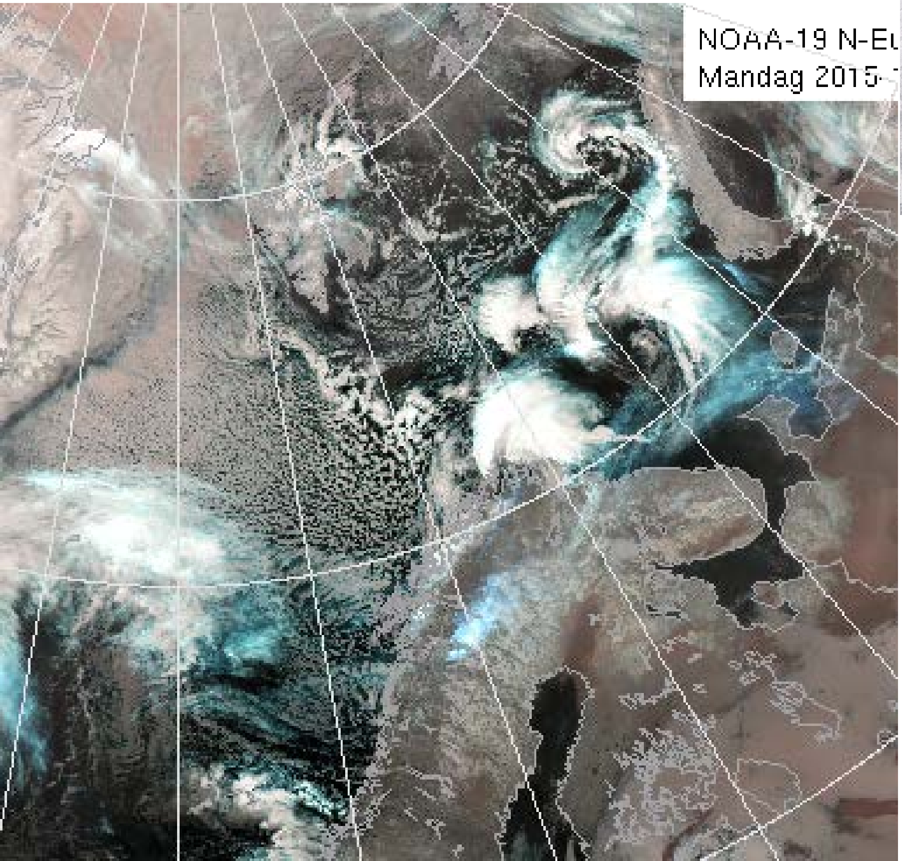
Labrador Sea



← Nordic Seas

Synopsis of methods (2):

- **How do the storms impact sea ice?**

  -- case studies, same events using E3SM and WRF

  -- dynamic vs. thermodynamic response of sea ice to storms

  -- surface energy budget analysis to determine whether primary impacts of storms are directly from atmosphere (top of sea ice) or from ocean via mixing (bottom surface)

Synopsis of methods (3, 4):

- **How do changes in sea ice impact Arctic storms?**

  -- multiyear simulations using E3SM and WRF

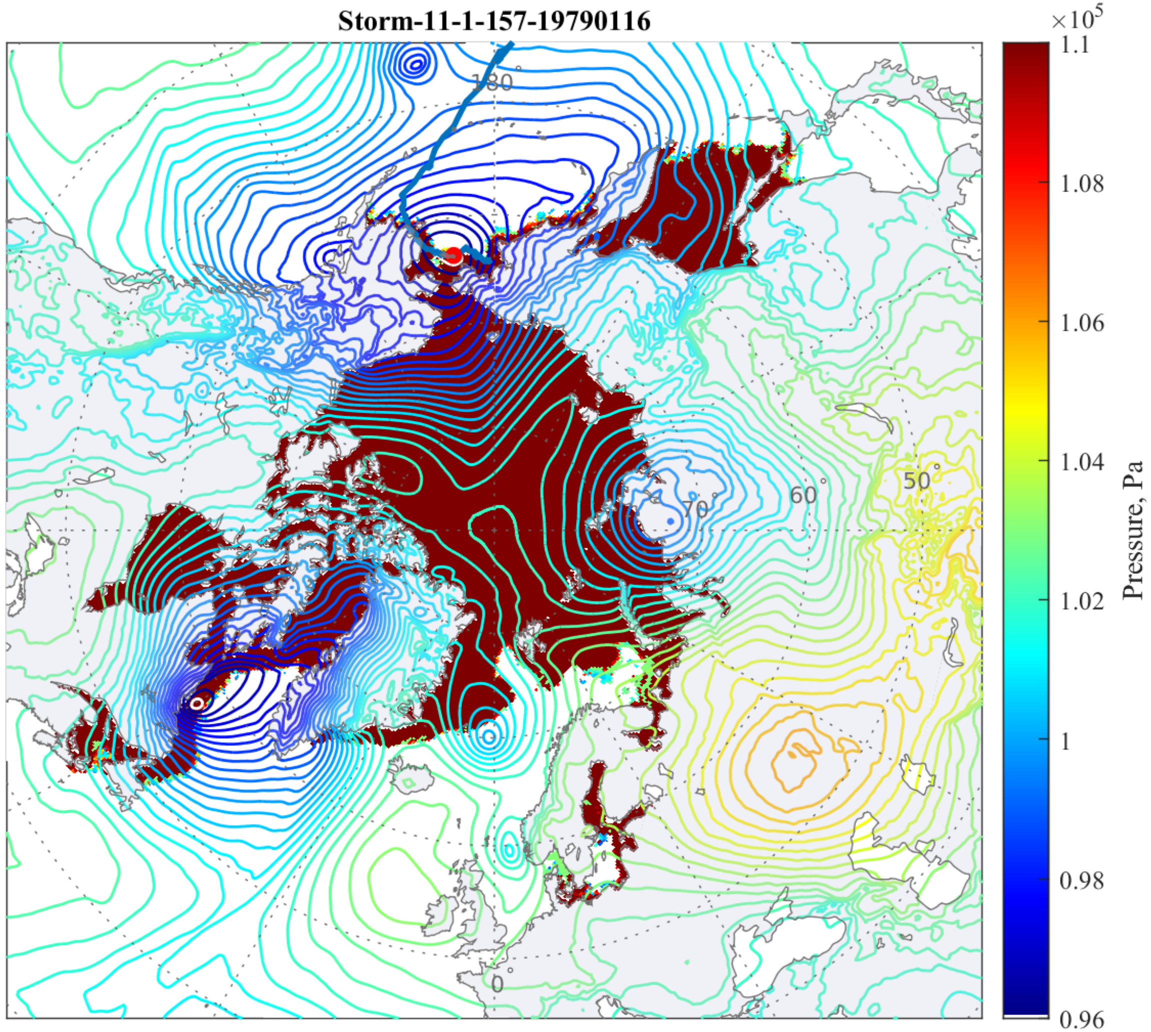
  -- prescribed sea ice extent, late-20th-century and late-21st-century (SSTs unchanged)

- **How will Arctic cyclone frequency and intensity change in the future?**

  -- As in (3), but with coupled simulations and external forcing of late 20th and 21st centuries

Cyclone tracking algorithm implemented

Example: 16 Jan 1979 01 UTC, ERA5 reanalysis (30 km resolution)



Number of storms over open water

1979 1980 2017 2018