InMotion: Influx of Momentum into the Arctic Ocean – PIOMAS estimates of Arctic Ocean surface stress

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Dataset Overview:

In our NSF-funded project "InMotion: Influx of Momentum into the Arctic Ocean – Changes Associated with Sea Ice Reduction" we investigated how the observed thinning and retreat of the sea ice cover affects the amount of wind energy entering the Arctic Ocean. In the Arctic, wind is the dominant driver of sea ice and ocean motion. The momentum flux from the atmosphere into the ocean (a.k.a. ocean surface stress) generally depends the wind speed, the surface roughness, and sea ice conditions.

Here, we provide Arctic-wide (49˚-90˚N) daily fields of ocean surface stress based on a simulation with the Pan-arctic Ice-Ocean Modeling and Assimilation System (PIOMAS) for the period 1979-2012. The simulation is forced by atmospheric reanalysis fields and constrained by assimilating satellite-observed sea ice edge position. Our analysis yielded two main results: (i) Over the 34-year period annual mean basin-wide ocean surface stress is increasing, which we link to the significant sea ice thickness decrease and related ice strength loss over the same period. (ii) Momentum flux into the ocean is greatest at an optimal ice concentration of 80-90%. This is because the overall surface roughness increases with increasing ice coverage as sea ice adds roughness but only to a point, the optimal ice concentration, where "frictional" losses due to high ice compactness reduce the momentum transfer. As summer Arctic sea ice coverage has been shrinking over the past years, our data show decreasing ocean surfaces stress for the summer months (July to September). More details are given in *Martin et al.* (2014).

- Time period covered by the data
  Daily output from 1/1/1979 to 12/31/2012

- Physical location, including:
  - Latitude (49, 90)
  - Longitude (-180, 180)
  - Elevation/Depth: sea level
  - The spatial resolution ranges from 7 to 70 km with an Arctic Ocean mean of 30 km (the model grid converges toward Greenland)

- Data source
  Data are derived with a Pan-arctic Ice-Ocean Modeling and Assimilation System (PIOMAS) simulation covering the period 1979-2012 forced by atmospheric fields of the NCEP/NCAR reanalysis [Kalnay et al., 1996] and constrained by satellite-observed sea ice edge, which was provided by the NSIDC [Nolin et al., 1998].

- Background information
  This is a single realization with PIOMAS. Upon request from Drs. Martin and Zhang, other sea ice or ocean specific output from the same simulation may be available.

Data Format:

- Data file type is ***netCDF***

- File naming conventions is "**model_variable_temporal-resolution_year.nc"**, for example piomas_ostr_daily_1979.nc

- Data are provided in compressed netCDF files (.nc.gz). All information is provided in the global or variable specific attributes. Files are compressed using *gzip*. Use gunzip to uncompress. Size of compressed files is 88 MB per file (size when uncompressed is 197 MB). Each file contains the output from one model year.

- The main variable is ocean surface stress [in N/m^2], of which daily mean magnitude, x-, and y-components are provided in single precision (*float* or *real*4*). Additionally an ice mask is provided, which indicates the ice extent (15% ice concentration) as signed integer (*byte* or *int8*). Further fields are longitude, latitude, grid cell area [m^2], and a land mask.

- Example header information and content of provided files:

```
netcdf piomas_ostr_daily_1979 {
dimensions:
    x = 360 ;
    y = 120 ;
    t = 365 ;
variables:
    float lon(y, x) ;
          lon:name = "lon" ;
          lon:long_name = "geographic longitude" ;
          lon:units = "degrees north" ;
    float lat(y, x) ;
          lat:name = "lat" ;
          lat:long_name = "geographic latitude" ;
          lat:units = "degrees east" ;
    float time(t) ;
```

```
            time:name = "time" ;
            time:long_name = "seconds since 1979-01-01 00:00 counting 365 days per
    year" ;
            time:units = "seconds" ;
       float area(y, x) ;
            area:name = "area" ;
            area:long_name = "grid cell area" ;
            area:units = "m^2" ;
       byte mask(y, x) ;
            mask:name = "mask" ;
            mask:long_name = "land mask, 0=land, 1=ocean" ;
            mask:units = "[0 1]" ;
       float ostr(t, y, x) ;
            ostr:name = "ostr" ;
            ostr:long_name = "ocean surface stress magnitude" ;
            ostr:units = "N/m^2" ;
            ostr:missing_value = -1.e+30 ;
            ostr:comment = "derived from daily mean ice concentration output: 1 for
    ice concentration > 15%, 0 otherwise" ;
       float ostrx(t, y, x) ;
            ostrx:name = "ostrx" ;
            ostrx:long_name = "ocean surface stress, x-component" ;
            ostrx:units = "N/m^2" ;
            ostrx:missing_value = -1.e+30 ;
            ostrx:output_type = "time: mean" ;
            ostrx:output_freq = 86400. ;
       float ostry(t, y, x) ;
            ostry:name = "ostry" ;
            ostry:long_name = "ocean surface stress, y-component" ;
            ostry:units = "N/m^2" ;
            ostry:missing_value = -1.e+30 ;
            ostry:output_type = "time: mean" ;
            ostry:output_freq = 86400. ;
       byte icemask(t, y, x) ;
            icemask:name = "icemask" ;
            icemask:long_name = "ice extent mask" ;
            icemask:units = "[0 1]" ;
            icemask:missing_value = -128b ;

    // global attributes:
            :title = "Arctic Ocean surface stresses" ;
            :long_title = "InMotion - Modeled Arctic Ocean surface stress estimates
    from PIOMAS" ;
            :comments = "A product from the NSF project InMotion: Influx of Momentum
    into the Arctic Ocean - Changes associated with sea ice reduction (NSF ARC-
    1203240)" ;
            :institution = "Polar Science Center, Applied Physics Laboratory,
    University of Washinton, Seattle, WA, USA" ;
            :source = "Pan-arctic Ice-Ocean Modeling and Assimilation System
    (PIOMAS)" ;
            :CreationDate = "2014/11/17 13:06:35" ;
            :CreatedBy = "Torge Martin, torge.martin@gmail.com" ;
    }
```

- Derivation of main variable: Ocean surface stress is computed from the vector sum of air-ice stress (weighted by ice concentration *A*), air-water stress (weighted by open water area fraction *(1-A)*), and ice interaction force (divergence of internal ice stress). All quantities are computed by PIOMAS during run time.

References:

- **List references for materials cited in this dataset documentation**

Kalnay, E., M. Kanamitsu, R. Kistler, W. Collins, D. Deaven, L. Gandin, M. Iredell, S. Saha, G. White, and J. Woollen (1996), The NCEP/NCAR 40-year reanalysis project, *Bull. Amer. Meteor. Soc.*, *77*(3), 437–471.

Martin, T., M. Steele, and J. Zhang (2014), Seasonality and long-term trend of Arctic Ocean surface stress in a model, *J. Geophys. Res. Oceans*, *119*(3), 1723–1738, doi:10.1002/2013JC009425.

Nolin, A., R. L. Armstrong, and J. Maslanik (1998), Near-Real-Time SSM/I-SSMIS EASE-Grid Daily Global Ice Concentration and Snow Extent, Digital Media, Natl. Snow and Ice Data Cent., Boulder, Colo.

- **List publication references that make use of these data in scientific study**

Martin, T., M. Steele, and J. Zhang (2014), Seasonality and long-term trend of Arctic Ocean surface stress in a model, *J. Geophys. Res. Oceans*, *119*(3), 1723–1738, doi:10.1002/2013JC009425.