2021 June Sea Ice Outlooks
Executive Summary Reports
Organized Alphabetically

ANSO IAP-LASG, 4.23, Dynamic Model. The prediction for the sea ice outlook June 2021 was carried out on China's Tianhe-2 supercomputer, with a dynamic model prediction system CAS FGOALS-f2 S2S V1.3. The dynamic model prediction system, named FGOALS-f2 (ice-ocean-atmosphere-land model), provides a real-time predictions in the subseasonal-to-seasonal (S2S) timescales. FGOALS-f2 S2S system has been established in 2017 by R&D team of FGOALS-f2 from both LASG Institute of Atmospheric Physics Chinese Academy of Sciences and PAEKL Chengdu University of Information Technology. The FGOALS-f2 S2S prediction results are used in three major national operational prediction centers in China. Basing on the 4-month lead dynamic model prediction from June 9th, 2021 the outlook predictions of Sea Ice Extent are 4.23 million square kilometers for pan-Arctic in September 2021.

APPLICATE Benchmark, 4.5, Statistical. See attachment

ARCUS Team (Wiggins et al.), 4.17, Heuristic. Our team submission is the median of all the values contributed for the September mean sea ice extent by 10 ARCUS team members.

ASIC/NIPR, 4.27, Statistical. Monthly mean ice extent in September will be about 3.81 million square kilometers. Our estimate is based on a statistical way using data from satellite microwave sensor. We used the ice movement from December to April. Predicted ice concentration map from July 1 to September 20 is available in our website: https://www.nipr.ac.jp/sea_ice/e/forecast/2021-05-31-1/

AWI Consortium (Kauker et al.), 4.16, Dynamic Model. Forced sea ice - ocean model initialized in March and April with satellite products. Ensemble forecast is generated by using the forcing from ten previous years. Prediction potential comes from the initialization in March and April with satellite observations (sea ice thickness and sea ice concentration).

BDAL Group, 4.628, ML/Other. It is our goal to predict the 2021 September sea ice extent with a leading time of 4 months (at the end of May) using deep learning methods. The contributing factors are the monthly values of 10 atmospheric and ocean variables for the Pan-Arctic region. The monthly satellite retrieved sea ice data is taken from NSIDC GSFC NASA team, while atmospheric and oceanic variables data is taken from ERA5 global reanalysis product for 42 years, i.e., from January 1979 to May 2021. These atmospheric and ocean variables include surface pressure, 10-meter wind velocity, specific humidity, 2-meter air temperature, shortwave radiation, longwave radiation, rain rate, snowfall rate, sea surface temperature and sea ice extent.

Climate Prediction Center, 4.36, Dynamic Model. The forecast is based on an initialized fully coupled system. Contributing factors include initial oceanic, sea ice and atmospheric conditions, with initial sea ice thickness being the dominant factor.

CPOM, 4.2, Statistical. We predict the September ice extent 2021 to be 4.2 (3.7-4.7) million km2. This is just on the trend line of September ice extent over last 43 years. Air temperature, sea ice conditions and melt pond fraction in May 2021 are pretty average with respect to the last decade.

CPOM UCL (Gregory et al.), 4.5, Statistical. This statistical model computes a forecast of pan-Arctic September sea ice extent. Monthly averaged May sea ice concentration and sea surface temperature fields between 1979 and 2021 were used to create a climate network (based on the approach of Gregory et al 2020). This was then utilised in a Bayesian Linear Regression in order to forecast September extent. The model predicts a pan-Arctic extent of 4.5 million square kilometres. Sea ice concentration data were taken from NSIDC (Cavalieri et al., 1996; Maslanik and Stroeve,1999). Sea surface temperature data were from ERA5 reanalysis.

CNRM (Batté et al.), 4.04, Mixed. This contribution is based on Meteo-France System 7 operational forecasts initialized end of April / 1st of May, accounting for a lack of consistency between the re-forecast period and real time forecasts in the Arctic sea ice concentration and thickness. We therefore empirically corrected our outlook based strictly on the error from last year (only available forecast data for the same start dates).

ECCC-CanSIPSv2, 4.51, Dynamic Model. Our outlook includes an estimate of pan-Arctic sea ice extent (SIE) and anomaly extent, as
well as spatial forecast fields of sea ice probability (SIP), and ice-free dates (IFDs). The outlook was produced using the Canadian Seasonal to Interannual Prediction System (CanSIPv2; Lin et al., 2020: https://doi.org/10.1175/WAF-D-19-0259.1), which combines ensemble forecasts from two models, CanCM4i and GEM-NEMO, with a total of 20 ensemble members (10 from each model).

FIO-ESM (Shu et al.), 4.38, Dynamic Model. Our prediction is based on FIO-ESM (the First Institute of Oceanography-Earth System Model) with data assimilation. The prediction of September pan-Arctic extent in 2021 is 4.38 (+/-0.46) million square kilometers. 4.38 and 0.46 million square kilometers is the average and one standard deviation of 10 ensemble members, respectively.

GP Regression (Cawley), 3.960695, Statistical. Prediction based on statistical extrapolation of previous September Arctic sea ice extent observations.

Kondrashv, Dmitri (UCLA), 4.63, ML/Other. This model forecast is based on statistical/ML stochastic modeling techniques applied to the regional Arctic Sea Ice Extent (SIE) dataset.

KOPRI (Chi et al.), 4.04, ML/Other. Korea Polar Research Institute (KOPRI) initiated a project to develop AI-based Arctic sea ice prediction in 2020. The prediction model is currently in development using a combination of different types of neural networks. This is the first submission to the Sea Ice Outlook. KOPRI model was trained to predict the future 6 months of Arctic sea ice concentration (SIC) based on the past 12 months of sea ice properties. The predicted September extent for 2021 is 4.04 million square kilometers using monthly SIC from June 2020 to May 2021.

Lamont (Yuan and Li), 4.74, Statistical. A linear Markov model is used to predict monthly Arctic sea ice concentration (SIC) at all grid points in the pan-Arctic region (Yuan et al., 2016). The model is capable of capturing the co-variability in the ocean-sea ice-atmosphere system. The September pan-Arctic sea ice extent (SIE) is calculated from predicted SIC. The model predicts negative SIC anomalies throughout the pan-Arctic region. These anomalies are relative to the 1979-2012 climatology. The September mean pan-Arctic SIE is predicted to be 4.74 million square kilometers (mskm) with an RMSE of 0.40 mskm, at the four-month lead. The RMSE is estimated based on our model forward forecasts from 2013-2020. The Alaskan regional SIE is predicted to be 0.69 mskm. A Similar statistical model was also developed to predict the SIE in the Antarctic (Chen and Yuan, 2004). The September mean pan Antarctic SIE is predicted to be 18.32 mskm, lower than September 2019 (18.77), with an RMSE of 0.57 mskm based on model cross-validation experiments.

Met Office (Blockley et al.), 3.9, Dynamic Model. A dynamic model forecast made using the Met Office's seasonal forecasting system (GloSea). GloSea is a fully coupled Atmosphere-Ocean-sea Ice-Land (AOIL) model that produces a small 2-member ensemble of 210-day forecasts each day. Forecasts initialised over a 21-day period are used together to create a 42-member lagged ensemble or forecasts of September sea ice cover.

METNO-SPARSE-ST (Wang et al.), 4.4, Statistical. It's an AR model, based on the sea ice extend data of NSIDC.

Mihara Primary School (Iihoshi, et al.), 5.17, Heuristic. Monthly mean ice extent in September will be about 5.17 million square kilometers.

We estimated the minimum ice area through discussion students based on the ice map from 2004 to 2020.

NCAR/CU-Boulder, 4.14, Heuristic. An informal pool of 35 climate scientists in early June 2021 estimates that the September 2021 ice extent will be 4.14 million sq. km. (stdev. 0.33, min. 3.14, max. 4.91). Since its inception in 2008, the NCAR/CU sea ice pool has easily rivaled much more sophisticated efforts based on statistical methods and physical models to predict the September monthly mean Arctic sea ice extent (e.g., see appendix of Stroeve et al. 2014 in GRL doi:10.1002/2014GL059388; Witness the Arctic article by Hamilton et al. 2014 http://www.arcus.org/witness-the-arctic/2014/2/article/21066). We think our informal pool provides a useful benchmark and reality check for Sea Ice Prediction efforts based on more sophisticated physical models and statistical techniques.

NMEFC of China (Li and Li), 4.48, Statistical. We predict the September monthly average sea ice extent of Arctic by statistic method and based on monthly sea ice concentration and extent from National Snow and Ice Data Center.The predicted monthly average ice extent of September 2021 is 4.48 million square kilometers.

NSIDC Hivemind, 4.4, Heuristic. This method is based on individual NSIDC employees submitting their guess.

NSIDC (Horvath et al.), 4.44, Statistical. This statistical model computes the probability that sea ice will be present (concentration above 15%) for each grid cell in NSIDC's polar stereographic projection. Yearly data from 1980 through the present are used in a Bayesian logistic regression. Predictors include local surface air temperature, downwelling longwave radiation, and sea ice concentration, as well as the first principal component of geopotential height at 500mbars, and Pacific and Atlantic sea surface temperatures. Sea ice concentration data was obtained from NSIDC's Sea Ice Index V3 (Data Set ID:G02135), all other variables are from NASA's MERRA2 dataset.

NSIDC (Meier), 4.65, Statistical. This method applies daily ice loss rates to extrapolate from the start date (June 1) through the end of September. Projected September daily extents are averaged to calculate the projected September average extent. Individual years from 2005 to 2017 are used, as well as averages over 1981-2010 and 2007-2020. The 2007-2020 average daily rates are used to estimate the official submitted estimate. The predicted September average extent for 2020 is 4.65 (±0.66) million square kilometers. The minimum daily extent is predicted to be 4.53 (±0.66) million square kilometers and occurs on 16 September. The large range of estimates reflects the large variability in ice loss rates over the final 3+ months of the melt season. Based on the last 16 years, there is a 6% chance that 2020 will be lower than the current record low September extent of 3.57 million sq km in 2012. Using the same method, the predicted Antarctic average extent for September 2020 is 18.57 (±0.59) million square kilometers. The maximum daily extent is predicted to be 18.68 (±0.62) million square kilometers and occurs on 30 September.

OSEIBOLA, 5.231405, Statistical. It is based on a model which considers the anomaly persistence of May compared to September through all the years. It has been corrected thanks to a linear regression.

PolArctic, 3.83, ML/Other. This is PolArctic's third year submitting to the Sea Ice Outlook. Our September extent prediction is 3.83 million square kilometers. Our efforts are to investigate the usefulness of Artificial Intelligence and Machine Learning (AI/ML) as a predictive tool for Arctic sea ice extent. Hidden and non-linear relationships can be exposed through the use of AI/ML when high quality data is available. NSIDC's daily record of sea ice extent creates the perfect test bed to leverage and assess the power of AI/ML.

RASM@NPS (Maslowski et al.), 4.762, Dynamic Model. The Arctic sea ice extent September 2021 minimum is predicted to roughly continue the September declining trend (of 0.541x10^6 km^2/decade) based on 2000-2020 output from the Regional Arctic System Model (RASM) hindcast simulation. The difference between the 31-member ensemble mean September sea ice extent prediction and the extrapolation 2000-2020 linear trend into 2021 is 0.174x10^6 km^2. Compared to the RASM September 2020 sea ice extent minimum from the hindcast, the ensemble mean forecast for 2021 minimum is higher by 0.631x10^6 km^2, suggesting a temporary rebound similarly as it occurred following the 2007 and 2012 minima. According to the RASM ensemble mean predicted September sea ice thickness distribution, the majority of surviving ice thickness ranges between 1.0 m and 1.5 m, with the thickest sea ice north of the Canadian Archipelago and Greenland within the range of 1.5 m-2.5 m, and almost no sea ice thicker than 3.0 m. The RASM September outlook has been commonly biased high in recent years (bias of 0.086x10^6 km^2 and standard deviation of 0.419x10^6 km^2) compared to the NSIDC observation (2000-2020), especially in the northern Barents/Kara and East Siberian seas.

Simmons, Charles, 3.92, Statistical. We loosely model the contributions of ocean heat and insolation to sea ice melting. To model insolation, we use measurements of northern hemisphere snow area and sea ice area. To model ocean heat, we use measurements of CO2 concentrations. This is a minor variant of a model proposed by Rob Dekker.

Sun, Nico, 4.33, Statistical. Each grid-cell is initialized with a thickness derived from the AMSR2 Sea Ice Volume model (https://cryospherecomputing.tk/SIT). For each day the model calculates average thickness loss per grid cell using the exact solar radiation energy and the predicted sea ice concentration as an albedo value.
Ice-loss(m) = Energy(solar in MJ)*(1-SIC) / icemeltenergy

SIC = sea ice concentration
icemeltenergy = Meltenergy per m3, (333.55 KJ/kg*1000(m3/dm)*0.92(density)/1000(MJ/KJ)

In 2020 the model was updated a bias correction layer to approximate sea ice drift.

SYSU/SML-KNN, 4.8, ML/Other. A machine learning KNN model is used to predict the daily sea ice concentration (SIC) and the sea ice extent (SIE) of September 2021 in pan-Arctic. Daily averaged sea ice concentration ("NSIDC NASA Team, https://nsidc.org/data/nsidc-0081)and sea surface temperature("NOAA National Centers for Environmental Information", "https://www.ncdc.noaa.gov/oisst") fields between 1978 and 2020 were used to predict. The model predicts a pan-Arctic sea ice extent of 4.80(±0.31) million square kilometers and has a positive anomaly of 0.32.

SYSU/SML-MLM, 4.63, Statistical. A multivariate linear Markov model is used to predict monthly sea ice concentration (SIC), from which sea ice extent prediction of monthly September 2021 in Artic is calculated to be 4.63±0.51 million square kilometers, and the Alaskan regional SIE is predicted to be 0.71±0.25 million square kilometers.

UCLouvain, 3.91, Dynamic Model. Our estimate is based on results from ensemble runs with the global ocean-sea ice coupled model NEMO3.6-LIM3. Each member is initialized from a reference run on May 1, 2021, then forced with the JRA-55 atmospheric reanalysis from one year between 2011 and 2020. Our final estimate is the ensemble median, and the given range corresponds to the lowest and highest extents in the ensemble.

UPenn Group 1 (FERL), 3.77, Statistical. The UPenn group is composed of economists and statisticians interested in predictive modeling of many aspects of climate in its relation to economic activity. The Arctic -- and Arctic sea ice in particular -- is of particular interest to us. As is well known, the Arctic is warming about twice as fast as the global average, and the Arctic amplification in surface air temperature is of course closely connected to the dramatic multi-decade reduction in Northern sea ice.

This loss of sea ice is one of the most conspicuous warning signs of \textit{current} climate change, and it also plays an integral role in the timing and intensity of \textit{future} global climate change. Not surprisingly then, we are keenly interested in predictive modeling of Arctic sea ice, particularly summer ice.

UPenn (VARCTIC), 4.25, Statistical. When it comes to forecasting sea ice, there is tension between opting for statistical methods vs forecasts based on climate models. While the former are explicitly designed for the prediction task, they usually lack interpretative potential. That is, we may get a good forecast, but it is hard to know why. Institutions in charge of macroeconomic policy have been facing such dilemmas for years. One model, Vector Autoregressions, have been an increasingly popular tool to forecast economic aggregates as they are a compromise between theory-based methods and statistical ones. As a result, it is possible to obtain an explainable forecast which are the results of dynamic interactions between key Arctic variables. Hence, our forecast implicitly uses physical transmission mechanisms in the data, without specifying them explicitly.

University of Washington/APL, 3.73, Dynamic Model. Driven by the NCEP CFS forecast atmospheric forcing, PIOMAS is used to predict the total September 2021 Arctic sea ice extent as well as ice thickness field and ice edge location, starting on June 1. The predicted September ice extent is 3.73± 0.40 million square kilometers. The predicted ice thickness fields and ice edge locations for September 2021 are also available.

UTokyo (Kimura et al.), 4.61, Statistical. Monthly mean ice extent in September will be about 4.61 million square kilometers. Our estimate is based on a statistical way using data from satellite microwave sensor. We used the accumulated sea ice convergence based on the 182 days backward tracking of the ice from May 31 to December 1.

Vandevoorde, Pirlet, and Audoor, 4.594692, Statistical. The probability of the sea ice extent being less than previous year is 36% according to our forecast.

Wu, Tallapragada, and Grumbine, 3.87, Dynamic Model. The projected Arctic minimum sea ice extent from the NCEP CFSv2 model May initial conditions (ICs) using 124-member ensemble forecast (4 cycles each day May 1-31) is 3.87 million square kilometers with a standard deviation of 0.31 million square kilometers. The corresponding number for the Antarctic (maximum) is 18.53 million square kilometers with a standard deviation of 0.56 million square kilometers.