June 2019 Sea Ice Outlook Key Statements

Contributor	Type	Dynamic Model Type	Arctic Extent	Antarctic Extent	Alaska Extent	Hudson Bay Extent	Median	Range	Standard Deviation	EstimateSummary	Executive Summary	Method Summary	Sea Ice Concentration Data	Sea Ice Thickness Data
Sanwa Elementary School (Iihoshi et al.)	Heuristic		3.06								Monthly mean ice extent in September will be about 3.06 million square kilometers. We estimated the minimum ice area through discussion among 22 students based on the ice map from 2004 to 2018.	Monthly mean ice extent in September of 2004,2006,2008,2010,2012,2014,2016 and 2018 from the ice concentration map, by approximating the ice cover with a triangle or trapezoid. Based on this rough estimation, we discussed a yearly change of the ice area and calculated the ice area of this September.	SIC is not used.	Sit is not used.
Morison	Heuristic		3.8								email rec'd 11:00 pm (AKDT) on12 June: Hi Betsy, Well we just got back from the historic last C-130H mission from USCG Air Station Kodiak. The long serving Hs are being replaces by the C-130J model. Our Seasonal Ice Zone Reconnaissance Survey (SIZRS) flight was successful. We flew up 150°W making oceanographic stations with expendable probes every degree fro 72 to 76 and then flew back at higher altitude doing atmospheric dropsonde drops. Notable ice observations are that the ice edge has already retreated to 72°N and there was a lot of o[en water even up to 76°. The snow is already gone. I usually try to do a little more analysis of trends for the year around the Arctic Ocean and look at the AO, but no time for that; it's already midnight Pacific Daylight Time. To be any later and still be on the 12th, I'd have to be in Hawaii. So after exhausting if not exhaustive deliberation with my SIZRS colleges over pizza at the last eatery still open Kodiak, and considering the ice we saw today, my fresh from looking out the window is 3.8 million square km average Sept 2019 ice extent. Method would be politely called heuristic, and as ever the outlook recognizes that this summer's weather trumps everything else and is for the most part unknowable. Best regards, Jamie			
McGill Team	Statistical		3.99							RMSE: 0.50 million square kilometers. From comparison of hindcasts to the observed minimum September sea ice extent.	Our research focuses on seasonal predictability of sea ice in the Arctic Ocean, using observations-based approaches. We are interested in the winter preconditioning effect on the pack ice before the summer melt. Specifically, we investigate how dynamic processes affect preconditioning, in other words, we ask how anomalies in the general circulation of sea ice will influence later conditions of the Arctic Ocean pack ice under a typical melt season. We investigate the skill of different sea ice predictors, including atmospheric forcing parameters that physically connect to wintertime sea ice dynamics. The dovekSIE method builds on the correlation between winter Fram Strait sea ice export and the following September minimum sea ice extent, presented in Williams et al., 2016. A positive anomaly of the winter Fram Strait sea ice export is associated with enhanced circulation of ice through the Transpolar Drift Stream and positive anomalies of coastal divergence of sea ice along the Eurasian coastlines. Increased coastal divergence late in the winter causes anomalies of younger and thinner ice in the peripheral seas, which is more vulnerable to melting in the summer. The dovekSIE forecasts are generated using the sea level pressure difference between Greenland and Svalbard as a proxy for area of ice exported through Fram Strait. Sea ice tends to flow parallel to isobars and the pressure difference across Fram Strait correlates with sea ice export (r=0.44). Sea level pressure fields are available in near-real-time and therefore enable the continuous update of dovekSIE forecasts during winter via the web app.	The dovekSIE prediction for the minimum September ice extent is 3.99 million square kilometers. The dovekSIE prediction is computed as a sum of the linear trend (climatology) and departure from the trend (interannual variability). We take the long-term linear trend in a time series of the minimum September sea ice extent over the 1993-2018 period. A negative departure from the trend is projected for the 2019 September minimum sea ice extent. We use the integrated sea level pressure difference across Fram Strait from November 1 to May 31 in a linear least squares fit model as a predictor for the anomaly of monthly mean September sea ice extent over the same period. Using this method, the September mean sea ice extent predictions are only marginally different from the minimum sea ice extent predictions.	NOAA/NSIDC, Sea Ice Index, Version 3. https://doi.org/10.7265/N5K072F8	
NASA GISS / McGill University	Statistical		4						0.44 million sqr km	An error analysis of a hindcast using this method was done in Williams et al (2016)	It has been shown that the September sea-ice extent anomaly is significantly correlated with the mean Arctic Oscillation (AO) index during the previous winter. The mean AO provides a characterization of the mean atmospheric circulation pattern which in turn drives the sea-ice circulation during the winter. In other words, the wind patterns associated with the positive phase of the AO (mainly increased number and strength of cyclones penetrating deep into the Arctic region) lead to enhanced sea-ice export through Fram strait, and an anomalously younger / thinner ice cover in the Siberian shelf seas. These two processes provide a preconditioning effect which sets the stage for additional ice loss when compared to a typical melt season. We, therefore, use the winter mean AO index as a predictor for the September sea-ice extent anomaly. This anomaly forecast is then superimposed on the longer term trend of September sea-ice loss to form a seasonal forecast of the Pan-Arctic September sea-ice extent.	We perform a linear regression between the detrended September mean SIE and the winter mean (DJFMA) AO index during the period 1993-2018. This allows us to form a prediction for the 2019 September sea-ice extent anomaly using this past year's AO index, derived from SLP observations. For this year, the winter mean AO index was 0.481, which translates into a Sept SIE anomaly of -0.14 million km2. This anomaly forecast is then added to an extrapolation of the linear trend line from 1993-2018. The linear trend forecast for 2019 is 4.14 million km2. Summing it up, we get a par-Arctic forecast for the September mean SIE of 4.00 million km2.	NSIDC Sea Ice Index Version 3: https://nsidc.org/data/G02135/versions/3	
Simmons	Statistical		4.026						0.5 million square kilometers	Standard Error of Linear Regression	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 variant of Rob Dekker's prediction. Dekker performs a linear regression on northern hemisphere snow area, sea ice area, and sea ice extent. Predictions of more or less similar quality can be obtained by substituting Extent with another series that tends to increase or decrease over time, including the year. We choose to use the CO2 concentration as measured at Mauna Loa as being a particularly provocative measure. Additionally, Dekker performs the regression on a subset of available data, we use all the available data.	We do not use SIC nor SIT. We use the following data sources: Average monthly northern hemisphere snow area: https://climate.rutgers.edu/snowcover/table_area.php?ui_set=1 Average monthly northern hemisphere sea ice area: ftp://sidads.colorado.edu/DATASETS/NOAA/G02135/seaice_analysis/Sea_Ice_Index_Monthly_Data_with_Statistics_G02135_v3.0.xlsx Average monthly CO2 concentration at Moana Loa: ftp://aftp.cmdl.noaa.gov/products/trends/co2/co2_mm_mlo.txt	
University of Washington/APL	Dynamic Model	Not Specified	4.07							uncertainty = ±0.4	Driven by the NCEP CFS forecast atmospheric forcing, PIOMAS is used to predict the total September 2019 Arctic sea ice extent as well as ice thickness field and ice edge location, starting on June 1. The predicted September ice extent is 4.07± 0.40 million square kilometers. The predicted ice thickness fields and ice edge locations for September 2019 are also presented.		Satellite sea ice concentration data (NASA team) for data assimilation in hindcast.	CryoSat2 sea ice thickness up to 4/2019 for data assimilation in hindcast.
University of East Anglia (Cawley)	Statistical		4.1452				4.1452	3.0324 - 5.2580 (Bayesian credible region)		Gaussian Process models provide the posterior predictive distribution. Doesn't includehyper-parameter uncertainty.	This is a purely statistical method (related to Krigging) to extrapolate the long term trend fromprevious observations of September Arctic sea ice extent. As this uses only Septemberobservations, the prediction is not altered by observations made during the Summer of 2019.	A Gaussian Process model, with a squared exponential covariance function, is used to model thehistorical NSIDC September Arctic sea ice extent data. The hyper-parameters are optimised bymaximising the marginal likelihood for the model (marginalising them would probably be betterto include the additional predictive uncertainty due to uncertainty in estimating thehyper-parameters). The model was implemented in MATLAB using the GPML toolbox(http://www.gaussianprocess.org/gpml/code/matlab/doc/). An images has hopefully beenuploaded showing how the predictive uncertainty increases as the model extrapolates into thefuture. For an animation showing how the model changes as the amount of calibration dataincreases, see https://twitter.com/Gavin_Cawley/status/1004987808367464448 .	Include source (e.g., which data center), name (algorithm), DOI and/or data set website, and date (e.g., "NSIDC NASA Team, https://nsidc.org/data/nsidc-0081, https://doi.org/10.5067/U8C09DWVX9LM.")	NSIDC September average Arctic sea ice extent data.
LASG-IAP	Dynamic Model	Coupled	4.15				3.71	2.207-4.572	0.46	The uncertainty was estimated by the ensemble member spread.	The prediction for the sea ice outlook June 2019 was carried out on China's Tianhe-2 supercomputer, with a dynamic model prediction system CAS FGOALS-f2 S2S V1.2 . 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 two major national climate operational prediction centers in China. Basing on the 6-month lead dynamic model prediction from June 1st, 2019 the outlook predictions of Sea Ice Extent are 4.15 million square kilometers for pan-Arctic in September 2019.	FGOALS-f2 S2S V1.2 is a global coupled dynamic prediction system. The initialization of this prediction system is based on a nudging scheme, which assimilates wind components (U and V), Temperature (T) in atmosphere and potential temperature in ocean from 1 Jan 1980 to 1 June 2019, and 40 ensemble members are generated by a time-lag method. The predictions are available here for 6 months. This real-time S2S prediction system is fully operated on China's Tianhe-2 supercomputer.	None	None

Meier NSIDC	Statistical		4.2	17.05					0.66 million square kilometers	The uncertainty is based on the standard deviation of projections using the decline rates from years 2007 through 2018.	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 2007-2018. The 2007-2018 average daily rates are used to estimate the official submitted estimate. The predicted September average extent for 2019 is 4.20 (±0.66) million square kilometers. The minimum daily extent is predicted to be 4.08 (±0.66) million square kilometers and occurs on 14 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 14 years, there is a 7% chance that 2019 will be lower than the current record low extent of 2012. Using the same method, the predicted Antarctic average extent for 2018 is 17.05 (±0.61) million square kilometers. The maximum daily extent is predicted to be 17.16 (±0.63) million square kilometers and occurs on 2 October.	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 2007 to 2018 are used, as well as averages over 1981-2010 and 2007-2018. The 2007-2018 average daily rates are used to estimate the official submitted estimate. The method essentially provides the range of September extents that can be expected based on how the ice has declined in past years, though it is possible that record fast or slow daily loss rates may yield a value outside the projected range. It also can provide a probability of a new record by comparing how many years of loss rates yield a record relative to all years. It has the benefit that it can easily and frequently (daily if desired) be updated to provide updated estimates and probabilities and as the minimum approaches the "window" of possible outcomes narrows.	Maslanik, J. and J. Stroeve. 1999, updated daily. Near-Real-Time DMSP SSMIS Daily Polar Gridded Sea Ice Concentrations, Version 1. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. doi: https://doi.org/10.5067/U8C09DWVX9LM. Fetterer, F., K. Knowles, W. Meier, M. Savoie, and A. K. Windnagel. 2017, updated daily. Sea Ice Index, Version 3. Boulder, Colorado USA. NSIDC: National Snow and Ice Data Center. doi: https://doi.org/10.7265/N5K072F8.	SIT is not used in this method
NASA GMAO	Dynamic Model	Coupled	4.27		0.41	0.00294	Pan-Arctic: 4.28; Alaska region: 0.42; Hudson Bay: 0.00299	Pan-Arctic: 3.64 to 4.99; Alaska region: 0.07 to 0.81; Hudson Bay: 0.00000 to 0.00599	Pan-Arctic: 0.38; Alaska region: 0.23; Hudson Bay: 0.00225	The given uncertainty is the standard deviation of the 10 member ensemble.	An experiment of the GMAO seasonal forecasting system using CryoSat-2 derived ice thickness predicts a September average Arctic ice extent of 4.27 ± 0.38 million km2. The experiment tests the application of ice thickness data in a near-real time setting for the seasonal forecast system. The forecast suggests a reduced ice cover for 2019 as compared to the previous year.	The forecast uses a prototype the GEOS_S2S version 3 coupled system that was modified for this forecast. The model has an approximate grid spacing of ½° in both the atmosphere and the ocean. The ocean data assimilation system is driven by a near real-time atmospheric analysis that is similar to MERRA-2, and uses the Local Ensemble Transform Kalman Filter (LETKF) for assimilation of available observations and along-track ocean altimetry. A branch of the ODAS system was integrated from 1-December 2018 to 26-Apr 2019 that included nudging to CryoSat-2 sea ice thickness fields over the available time period until 12-Apr. The ensemble used a staggered initialization of 11-Apr, 16-Apr, 21-Apr, and seven additional ensemble members on 26-Apr based on initial condition perturbations of the atmosphere and ocean states.	The sea ice concentration was taken from MERRA-2 (doi:10.5067/Y67YQ1L3ZZ4R), which may be retrieved from the Goddard Earth Sciences Data and Information Services Center (GES DISC). The MERRA-2 sea ice concentration is derived from the Operational Sea Surface Temperature and Sea Ice Analysis system (OSTIA; Donlon et al. doi:10.1016/j.rse.2010.10.017), which in turn obtains sea ice from the EUMETSAT Satellite Application Facility on Ocean and Sea Ice (OSI SAF).	CryoSat-2 Level-4 Sea Ice Elevation, Freeboard, and Thickness, Version 1, https://nsidc.org/data/RDEFT4/, doi:10.5067/96JO0KIFDAS8. The data were incorporated into the ODAS over a four month period. The ODAS integrated for an additional 14 days after the end of the CryoSat-2 data period.
CPOM (David Schroeder)	Statistical		4.3					3.8-4.8	0.5	The given uncertainty is the mean forecast error based on forecasts for the years 1984 to 2013.	We predict the September 2019 ice extent will be 4.3 +/- 0.5 million km2. This means there is a 68% likehood it will be among the lowest 3, 50% among the lowest 2, and 6% it will be a new mininum record. May 2019 has been the warmest and sunniest May in the Arctic since 2012 leading to melt pond fraction above average.	This is a statistical prediction based on the correlation between the ice area covered by melt-ponds in May and ice extent in September. The melt pond area is derived from a simulation with the sea ice model CICE in which we incorporated a physically based melt-pond model1. See our publication in Nature Climate Change http://www.nature.com/nclimate/journal/v4/n5/full/nclimate2203.html for details2. References: 1. Flocco, D., Schröder, D., Feltham, D. L. & Hunke, E. C., 2012: Impact of melt ponds on Arctic sea ice simulations from 1990 to 2007. J. Geophys. Res. 117, C09032. 2. Schröder D., D. L. Feltham, D. Flocco, M. Tsamados, 2014: September Arctic sea-ice minimum predicted by spring melt-pond fraction. Nature Clim. Change 4, 353-357, DOI: 10.1038/NCLIMATE2203.		
GFDL/NOAA (Bushuk et al.)	Dynamic Model	Not Specified	4.31		0.13	0	4.26	3.81-5.01	0.36	These statistics are computed using our 12 member prediction ensemble.	Our June 1 prediction for the September-averaged Arctic sea-ice extent is 4.31 million km^2, with an uncertainty range of 3.81-5.01 million km^2. Our prediction is based on the GFDL-FLOR ensemble forecast system, which is a fully-coupled atmosphere-land-ocean-sea ice model initialized using a coupled data assimilation system. Our prediction is the bias-corrected ensemble mean, and the uncertainty range reflects the lowest and highest sea ice extents in the 12-member ensemble.	Our forecast is based on the GFDL Forecast-oriented Low Ocean Resolution (FLOR) model (Vecchi et al., 2014), which is a coupled atmosphere-land-ocean- sea ice model. The model is initialized from an Ensemble Kalman Filter coupled data assimilation system (ECDA; Zhang et al., 2007), which assimilates observational surface and subsurface ocean data and atmospheric reanalysis data. The system does not assimilate any sea ice concentration or thickness data. The FLOR atmospheric initial conditions are produced from an AMIP run forced by observed SST and sea ice. Historical radiative forcing is used prior to 2005 and the RCP4.5 scenario is used for predictions after 2005. For the predictions initialized after 2004, the aerosols are fixed at the RCP4.5 sce- nario year of 2004. The performance of this model in seasonal prediction of Arctic sea ice extent has been documented in Msadek et al. (2014), Bushuk et al. (2017), and Bushuk et al. (2018). For an evaluation of the model's September sea ice extent prediction skill from a June 1 initialization, see attached pdf.	No SIC is assimilated, but the sea ice state is constrained by ocean and atmosphere assimilation.	No SIT is assimilated, but the sea ice state is constrained by ocean and atmosphere assimilation.
UC Louvain (Massonnet et al.)	Dynamic Model	Ocean-sea ice	4.32	20.9	0.5	0.81	4.31	Arctic: 2.86-5.02 (min-max); Antarctic: 20.14-21.82 (min-max)	Arctic: 0.62; Antarctic: 0.50	The projection uncertainty is given as the range between minimum and maximum extents in the ensemble. Although relatively wide,	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 Jan 1, 2019, then forced with the JRA-55 atmospheric reanalysis from one year between 2009 and 2018. Our final estimate is the ensemble median, and the given range corresponds to the lowest and highest extents in the ensemble.	Our estimate is based on results from ensemble runs with the global ocean-sea ice coupled model NEMO3.6-LIM3. The ensemble members are expected to sample the atmospheric variability that may prevail this summer. In practice, the model is forced with JRA-55 atmospheric reanalysis data from 1948 to Dec 31, 2018. No data are assimilated during this simulation. Ten ensemble members are then started from the obtained model state, each using atmospheric forcing from one year between 2009 and 2018. This choice is a compromise between a sufficiently large ensemble and the rapidly changing Arctic atmospheric conditions in recent decades. The estimate given above corresponds to the ensemble median monthly September extent. No bias-correction is applied.	Initial sea ice concentrations come from a model free run on Jan 1, 2019	Initial sea ice thicknesses come from a model free run on Jan 1, 2019
NCAR/CU (Kay, Bailey, and Holland)	Heuristic		4.38				4.44	3.14 (min) to 5.03 (max)	0.40	The uncertainty estimate is based on the scatter in entries in our informal pool.	An informal pool of 29 climate scientists in early June 2019 estimates that the September 2019 ice extent will be 4.38 million sq. km. (stddev. 0.40, min. 3.14, max. 5.03). 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.	An informal pool of 29 climate scientists in early June 2019 estimates that the September 2019 ice extent will be 4.38 million sq. km. (stddev. 0.40, min. 3.14, max. 5.03). Guesses were collected by sending an e-mail out to the scientists and tempting them with local bragging rights and with local ice cream.		
Sun	Statistical		4.4		0.329	0	4.40	3.73-4.88		The uncertainty is based on the 2007-2018 remaining melt condition variations.	The forecast model is based on ice persistence. It uses incoming solar radiation and sea ice albedo derived from a predicted Sea Ice Concentration (SIC) value to calculate daily thickness losses for every NSIDC 25km grid cell. The initial thickness is calculated from AMSR2 sea ice volume and NSIDC SIC data. The mean forecast uses the 2007-2018 mean SIC (1/3 weight) and mean SIC change per day (2/3 weight) to predict future SIC. The low forecast reduces the predicted SIC by 0.38Stdv for previously observed SIC for this day and a 10% higher bottom melt. The high forecast increases the predicted SIC by 0.22Stdv and a 12% decreased bottom melt.	Each grid-cell is initialized with a thickness derived from the AMSR2 Sea Ice Volume model (v1.5 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) For 2019 the model was upgraded with a bottom-melt model and a radiation of thermal energy back to space. This allowed the model to forecast the intitial refreezing period during late September.	NSIDC NASA Team, https://nsidc.org/data/nsidc-0081, https://doi.org/10.5067/U8C09DWVX9LM. Initial SIC 1st June 2019. The model used observed SIC until 11th June 2019 to calculate melt.	AMSR2 Sea Ice Volume model (v1.5), 31st May 2019, developed by Nico Sun https://cryospherecomputing.tk/SIT
NSIDC (Group)	Heuristic		4.4						0.33 million square kilometers	The uncertainty is the standard deviation of the 10 individual estimates.	This estimate is based on polling NSIDC employees for their estimates of the September extent. The submitted group estimate is the average of 10 individual contributions.	The method is to simply average 10 individual heuristic estimates.	No specific dataset was used for initialization, but contributors were provided NSIDC Sea Ice Index extent values to inform their estimates.	SIT was not used in this method.
Wu, Tallapragada, and Grumbine	Dynamic Model	Coupled	4.41	19.72							The projected Arctic minimum sea ice extent from the NCEP CFSv2 model with revised CFSv2 May initial conditions (ICs) using 31-member ensemble forecast is 4.41 million square kilometers with a standard deviation of 0.54 million square kilometers. The corresponding number for the Antarctic (maximum) is 19.72 million square kilometers with a standard deviation of 0.43 million square kilometers.	We ran the NCEP CFSv2 model with 31-case of May 2019 revised initial conditions (ICs). The IC was modified from real time CFSv2 of each day at 00Z by thinning the Arctic ice pack (based on test from previous years' sea ice outlook). If this thinning would have eliminated ice from areas observed to have sea ice, a minimum thickness of 10 cm was left in place for the ice ICs. Bias correction was applied to the Antarctic sea ice extent.	NCEP Sea Ice Concentration Analysis for the CFSv2 (May 1-May 31, 2019)	NCEP CFSv2 model guess with bias correction for the Arctic (May 1-May 31, 2019)
IARC (Brettschneider et al.)	Statistical		4.441				4.441	Upper: 4.965 million sq. km; Lower: 3.876 million sq. km.		The range assessments represent 95th and 5th percentile confidence intervals.	The International Arctic Research Center has developed a prototype model to estimate Arctic sea ice extent using an analogs approach. The analogs approach looks at prior years and finds the best matches that most closely represent the current state of the atmosphere in 2018. The model run in early June 2019 indicates September sea ice will be nearly identical the extrapolated linear trend of the previous four decades. We estimate a monthly extent of 4.441 million square kilometers.	Our statistical model uses the NCEP/NCAP (R1) Reanalysis data sets to develop analog matches of atmospheric variables that correlate with sea ice extent. The R1 data covers the time period of 1948-present. The model generates an estimated deviation from the 1979-2018 September sea ice linear trend line by identifying the top match years for a number of oceanic and atmospheric variables using the June through July time periods of each year, and then follows the seasonal decline in sea ice through the following September. The variables used are: 1) sea level pressure, 2) 500 mb heights, 3) 2-meter temperatures, 4) 925 mb temperatures, and 5) sea surface temperatures. A composite forecast is developed from a regression-weighted model.	Our model assumes no a priori knowledge of the current extent of Arctic sea ice. It does, however, rely on the NSIDC published monthly September sea ice extents to estimate the long-term trend line. We use the same linear trend that NSIDC adds to their published monthly extent graphics. Data source: Chapman, W. L. and J. E. Walsh. 1991, updated 1996. Arctic and Southern Ocean Sea Ice Concentrations, Version 1. [Indicate subset used]. Boulder, Colorado USA. NSIDC: National Snow and Ice Data Center	Our model does not utilize sea ice thickness.

UCLA (Kondrashov)	Statistical		4.48		0.49						This statistical model forecast is based on inverse modeling techniques applied to the regional Arctic Sea Ice Extent (SIE).	Nonlinear inverse modeling techniques have been applied to the regional Arctic Sea Ice Extent (SIE) from Sea Ice Index Version 3 dataset. The daily SIE data were aggregated to provide weekly-sampled dataset. The predictive model has been derived from SIE anomalies with annual cycle removed, and is initialized from latest SIE conditions by ensemble of stochastic noise realizations to provide probabilistic regional Arctic forecasts in September, as well as pan-Arctic ones. References: 1. Kondrashov, D., M. D. Chekroun, and M. Ghil, 2018: Data-adaptive harmonic decomposition and prediction of Arctic sea ice extent, Dynamics and Statistics of the Climate System, 3(1), doi:10.1093/climsys/dzy001. 2. Kondrashov, D., M.D. Chekroun, and M. Ghil, 2015: Data-driven non-Markovian closure models, Physica D, 297, 33-55, doi:10.1016/j.physd.2014.12.005.	Sea Ice Index Version 3 dataset	
Modified CanSIPS	Dynamic Model	Coupled	4.51				4.57	min=3.86, max=5.50	1 standard deviation = 0.39, uncertainty = ±0.77 (95% CI)	The uncertainty values were calculated from the ensemble of 20 fcst bias-corrected SIE anomalies (see section 5).	Our Outlook of forecast total bias-corrected Arctic sea ice extent (SIE), bias-corrected Ice-Free-Date (IFD) and Freeze-up-Date (FUD), and calibrated sea ice probability (SIP) was produced using the Canadian Seasonal to Interannual Prediction System (CanSIPS), but (as in 2017 and 2018) in a modified experimental configuration intended to test updates to the sea ice forecast methodology. These updates include changes to the data used to initialize both sea ice concentration (SIC) and sea ice thickness (SIT).	CanSIPS combines forecasts from 2 models, CanCM3 and CanCM4, with a total of 20 ensemble members (10 from CanCM3, 10 from CanCM4). First, the Arctic SIE anomaly was calculated for each individual ensemble member relative to a piecewise linear trend fitted to the respective model's ensemble-mean SIE time series over 1979-2018. These anomalies were added to the NSIDC SIE time series also fit to a piecewise linear trend, and averaged over all 20 ensemble members to yield a total SIE of 4.51 mil. km2. The piecewise fit, including breakpoint year, was found using non-linear least squares. This bias correction method differs from that used in 2017 and 2018 in an effort to account for trend dependence on forecast SIE bias. The IFD/FUD is defined as the first date in the retreat season (April 1 to September 30) or advance season (October 1 to March 31) at which the grid box sea-ice concentration drops below/exceeds 50% and stays below/above that threshold for at least 10 days (more details in Sigmond et al GRL, 2016). The dates are bias corrected based on 1981-2010 hindcasts. For the SIP field, we interpolated the raw SIC fields from the model grid onto a 1deg by 1deg regular grid, fit each grid point and each model SIC ensemble to the zero and one inflated beta distribution the parametric distribution. We calibrated each distribution using `trend-adjusted quantile mapping' (see Dirkson et al. 2019; https://doi.org/10.1175/JCLI-D-18-0224.1), and calculated the probability that local SIC will exceed 15% (or equivalently SIP) directly from the calibrated predictive probability distribution. Lastly, the average SIP value was taken across CanCM3 and CanCM4 to produce the final SIP field.	SIC is initialized by nudging model SIC to the Meteorological Service of Canada analysis (MSC) with a 3 day time constant. Initial conditions for the June submission are from May 31 nudged SIC.	SIT was estimated using the statistical model 'SMv3' described in Dirkson et al., 2017 (doi:10.1175/JCLI-D-16-0437.1). The parameters in SMv3 were fit using a blended SIC product (Had2CIS=HadISST2&Ice Charts) and PIOMAS SIT data over the period 2003-2018. The daily MSC SIC described above for May 31st was then used as the real-time predictor field in SMv3 to estimate real-time SIT.
Lamont (Yuan and Li)	Statistical		4.51	18.64	0.24					The uncertainty is accessed by RMSE derived from cross-validation exeriments. See details in the report.	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 4.51 million square kilometers (mskm) with an RMSE of 0.48 mskm, at the four-month lead. It is 0.2 mskm below September SIE in 2018. Similar statistical models were also developed to predict the SIE in the Alaskan region (Li et al., in revision) and the Antarctic (Chen and Yuan, 2004). The Alaskan regional SIE is predicted to be 0.24 mskm with an RMSE of 0.22 mskm, which is only about 50% of the last year Alaska SIE. The September mean pan Antarctic SIE is predicted to be 18.64, at the same level of September 2018, with an RMSE of 0.57 mskm.	The linear Markov model has been developed to predict sea ice concentrations in the pan Arctic region at the seasonal time scale. The model employs 6 variables: NASA Team sea ice concentration, sea surface temperature (ERSST), surface air temperature, GH300, vector winds at GH300 (NCEP/NCAR reanalysis) for the period of 1979 to 2012. It is built in multi-variate EOF space. The model utilizes first 11 mEOF modes and uses a Markov process to predict these principal components forward one month at a time. The pan Arctic sea ice extent forecast is calculated by summarizing all cell areas where predicted sea ice concentration exceeds 15%. Bias corrections have been applied to ice concentration predictions at grid points as well as the total sea ice extent prediction. The predictive skill of the model was evaluated by anomaly correlation between predictions and observations, and root-mean-square errors (RMSE) in a (take one-year out) cross-validated fashion. On average, the model is superior to the predictions by anomaly persistence, damped anomaly persistence, and climatology (Yuan et al, 2016). For the four-month lead prediction of September sea ice concentrations, the model has the higher skill (anomaly correlation) and lower RMSE in the Chukchi Sea and Beaufort Sea than in other regions (figure 4). The skill of the four-month lead prediction of the pan Arctic sea ice extent in September is 0.87 with an RMSE of 0.48 million square kilometers. The Alaskan regional SIE prediction is produced by a regional linear Markov model developed by using SIC, SST, SAT, and in a rotated-EOF space (Li et al., in revision). Following the NSIDC regional mask, the Alaska SIE forecast is calculated from predicted SIC. The skill of the regional SIE is 0.90 (correlation using cross-validated experiments) with RMSE of 0.22 million square kilometers. A similar model is used for Antarctic SIE forecast (Chen and Yuan 2004).	NSIDC NASA Team, https://nsidc.org/data/nsidc-0081, https://doi.org/10.5067/U8C09DWVX9LM. NOAA NCEP/NCAR Reanalysis-1 atmospheric variables, http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP-NCAR/.CDAS-1/ NOAA NCDC ERSST version3b sst: Extended reconstructed sea surface temperature data, http://iridl.ldeo.columbia.edu/expert/SOURCES/.NOAA/.NCDC/.ERSST/.version3b/.sst/Include source (e.g., which data center), name (algorithm), DOI and/or data set website, and date (e.g., "NSIDC NASA Team, https://nsidc.org/data/nsidc-0081, https://doi.org/10.5067/U8C09DWVX9LM.")	
NCEP CPC	Dynamic Model	Not Specified	4.62		0.53		0.26		0.26	The standard deviation is calculated from the 20-member ensemble.	This contribution is from a 20-member ensemble forecast from the Climate Prediction Center Experimental sea ice forecast system (CFSm5). Model bias that is removed is calculated based on 2006-2018 retrospective forecasts and corresponding observations.	The outlook is produced from the Climate Prediction Center Experimental sea ice forecast system (CFSm5). The forecast is initialized from the Climate Forecast System Reanalysis (CFSR) for the ocean, land, and atmosphere and from the CPC sea ice initialization system (CSIS) for sea ice. Twenty forecast members are produced. Model bias that is removed is calculated based on 2006-2018 retrospective forecasts and corresponding observations.	Both sea ice concentration and sea ice thickness are initialized from the CPC sea ice initialization system (CSIS). The CSIS analysis is produced with GFDL MOM5 which uses surface fields from CFSR and assimilates satellite sea ice concentration retrieval from NSIDC NASA Team.	Both sea ice concentration and sea ice thickness are initialized from the CPC sea ice initialization system (CSIS). The CSIS analysis is produced with GFDL MOM5 which uses surface fields from CFSR and assimilates satellite sea ice concentration retrieval from NSIDC NASA Team.
FIO-ESM (Shu et al.)	Dynamic Model	Coupled	4.63						uncertainty = ±0.32		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 2019 is 4.63 (+/-0.32) million square kilometers. 4.63 and 0.32 million square kilometers is the average and one standard deviation of 10 ensemble members, respectively.	This is a model contribution. The initialization is also from the same model (FIO-ESM) but with data assimilation. The data assimilation method is Ensemble Adjustment Kalman Filter (EAKF). The data of SST (sea surface temperature) and SLA (sea level anomaly) from 1 January 1992 to 1 Jun 2019 are assimilated into FIO-ESM model to get the initial condition for the prediction of the Arctic Sea Ice. There is no sea ice data assimilation.	No dataset are used for initial sea ice concentration.	No dataset are used for initial sea ice thickness.
UTokyo (Kimura et al.)	Statistical		4.87								Monthly mean ice extent in September will be about 4.87 million square kilometers. Our estimate is based on a statistical way using data from satellite microwave sensor. We used the ice thickness in December and ice movement from December to April. Predicted ice concentration map from July to September is available in our website: http://ccsr.aori.u-tokyo.ac.jp/~kimura_n/arctic/2019e.html Ice retreat in the Beaufort Sea will be faster than a normal year. Though ice cover in the East Siberian Sea will retreat with nearly same speed as a normal year, ice retreat around the New Siberian Islands will be faster than a normal year. On the other hand, the retreat speed in the Kara Sea and Severnaya Zemlya will be slower than a normal year.	We predicted the Arctic sea-ice cover from coming July 1 to November 1, using the daily ice velocity data from satellite microwave sensors, AMSR-E (2002/03-2010/11) and AMSR2 (2012/13-2018/19). The analysis method is based on our recent research (Kimura et al., 2013). First, we expect the ice thickness distribution in April 30 from redistribution (divergence/convergence) of sea ice during December and April, based on the ice velocity. Then, we predict the summer ice area depending on the assumption that thick ice remains later and thin ice melts sooner than the average.		
RASM	Dynamic Model	Coupled	4.91		0.324	0.0000168	4.95	4.17 – 5.38	0.305	The uncertainty of pan-Arctic sea ice extent was estimated from the 30 ensemble members.	We used RASM2_1_00, which is a recent version of the limited-area, fully coupled climate model consisting of the Weather Research and Forecasting (WRF), Los Alamos National Laboratory (LANL) Parallel Ocean Program (POP) and Sea Ice Model (CICE), Variable Infiltration Capacity (VIC) land hydrology and routing scheme (RVIC) model components (Maslowski et al. 2012; Roberts et al. or 2015; DuVivier et al. 2015; Hamman et al. 2016; Hamman et al. 2017; Cassano et al. 2017). The model uses CFSR/CFSv2 reanalysis output for RASM-WRF lateral boundary conditions and for nudging winds and temperature starting above 500 mbar. This model initial condition for ensemble forecast was derived from a hindcast, forced with CFSR/CFSv2 reanalysis for September 1979 through May 2019. The ocean and sea ice initial conditions at the beginning of the hindcast were derived from the 32-year spin-up of the ocean-sea ice model only (RASM G-case) forced with CORE2 reanalysis for 1948-1979.	As explained in the "Executive summary", RASM is used for dynamic downscaling of the global NOAA/NCEP CFSv2 7-month forecasts. The initial conditions for the June Sea Ice Outlook were derived from the RASM 1979-2018 hindcast and are physically and internally consistent across all the model components. Neither data assimilation nor bias correction was used. Each of the 30 ensemble members ran forward for 6 months using outputs from CFSv2 reanalysis. The CFSV2 forcing streams used for the ensemble members were initialized every day (at 00:00) between May 1st and May 31st (except 18th of May because of no input data available) and used for RASM forcing at 00:00 on June 1st, 2019.	Self-generated from a 39-year hindcast run.	Self-generated from a 39-year hindcast run.
NMEFC of China (Li and Li)	Statistical		4.94								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 2019 is 4.94 million square kilometers .	A simple statistical model is used to predict September average Arctic sea ice extent. The sea ice extent of September is well related with the sea ice extent of January to March in the same year.Combined the regression method and optimal climate normal method, the predicted September sea ice extent in 2019 is 4.94 million square kilometers.	Sea Ice Index - Daily sea ice concentration(NASA Team) and monthly sea ice extent from National Snow and Ice Data Center.	

AWI Consortium (Kauker et al.)	Dynamic Model	Ocean-sea ice	5.18						0.22 mill. km2	Ensemble spread		For the present outlook the coupled sea ice-ocean model NAOSIM has been forced with atmospheric surface data from January 1948 to June 6th 2019 (combination of NCEP/NCAR and NCEP-CFSR and NCEPCFSv2). All ensemble model experiments have been started from the same initial conditions on June 6th 2018. The model setup has not changed with respect to the SIO in 2015. We used atmospheric forcing data from each of the years 2009 to 2018 for the ensemble prediction and thus obtain 10 different realizations of potential sea ice evolution for the summer of 2018. The use of an ensemble allows to estimate probabilities of sea-ice extent predictions for September 2019. A variational assimilation system around NAOSIM has been used to initialize the model using the Alfred Wegener Institute's CryoSat-2 ice thickness product, the University of Bremen's snow depth product, and the OSI SAF ice concentration and sea-surface temperature products. Observations from March and April were used. A bias correction scheme for the CryoSat-2 ice thickness which employs a spatially variable scaling factor could enhance the skill considerably (Kauker et al, 2015, http://www.the-cryosphere-discuss.net/tc-2015-171/).	OSI SAF EUMETSAT OSI-401b March and April 2019 (http://osisaf.met.no/docs/osisaf_cdop3_ss2_pum_ice conc_v1p6.pdf.)	CryoSat-2 from Alfred Wegener Institute of March and April 2019 (Hendricks, S. and Ricker, R. (2019): Product User Guide & Algorithm Specification: AWI CryoSat-2 Sea Ice Thickness (version 2.1), Technical Report, hdl:10013/epic.7dacf2fe-bead-4a1b-a266-c4fdd022877f, https://epic.awi.de/id/eprint/49542/).
Met Office (Blockley et al.)	Dynamic Model	Coupled	5.2	17.7				Arctic: +/- 0.6 million sq km; Antarctic: +/- 0.8 million sq km	Arctic: 0.3 million sq km; Antarctic: 0.4 million sq km	Uncertainty range is provided as +/- 2 two standard deviations of the (42 member) ensemble spread around the ensemble mean.	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.	Ensemble coupled model seasonal forecast from the GloSea5 seasonal prediction system [MacLachlan et al., 2015], using the Global Coupled 2 (GC2) version [Williams et al., 2015] of the HadGEM3 coupled model [Hewitt et al., 2011]. Forecast compiled together from forecasts initialized between 15 May and 4 June (2 per day) from an ocean and sea ice analysis (FOAM/NEMOVAR) [Blockley et al., 2014, Peterson et al., 2015] and an atmospheric analysis (MO-NWP/4DVar) [Rawlins et al., 2007] using observations from the previous day. Special Sensor Microwave Imager Sensor (SSMIS) ice concentration observations from EUMETSAF OSI-SAF [OSI-SAF] were assimilated in the ocean and sea ice analysis, along with satellite and in-situ SST, sub surface temperature and salinity profiles, and sea level anomalies from altimeter data. No assimilation of ice thickness was performed.	Sea ice concentration (as for all ocean/ice variables) is initialised using the operational FOAM ocean-sea ice analysis. SSMIS sea ice concentration is assimilated using the EUMETSAT OSI-SAF (OSI-401b; See http://osisaf.met.no/docs/osisaf_cdop3_ss2_pum_ice-conc_v1p6.pdf)	Sea ice thickness (as for all ocean/ice variables) is initialised using the operational FOAM ocean-sea ice analysis. Sea ice thickness is not assimilated in FOAM.
NSIDC, CU Boulder (Horvath et al.)	Statistical		5.59				5.59	3.66-7.97 (95% Credible Interval)			This statistical model computes the probability that sea ice will be present (concentration above15%) 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. This model predicts a minimum September sea ice extent of 5.59 million square km. Sea ice concentration data was obtained from NSIDC's Sea IceIndex V3 (Data Set ID: G02135), all other variables are from NASA's MERRA2 dataset.	Yearly data from 1980 through the present are used in a bayesian logistic regression to predict the probability that sea ice concentration will be above 15%. To estimate total sea ice extent, grid cells with a percentage above a certain threshold (chosen from a drop-one cross-validation test) are multiplied by the pixel area grid dataset provided by NSIDC's polar stereographic toolset and then summed. This model predicts a minimum September sea ice extent of 5.59 million km2. Sea iceconcentration data was obtained from NSIDC's Sea Ice Index V3 (Data Set ID: G02135), all other variables are from NASA's MERRA2 dataset.	NSIDC's Sea Ice Index V3 (Data Set ID: G02135) NASA's MERRA2 dataset	
Navy ESPC (Metzger et al.)	Dynamic Model	Coupled	5.7	20.5	0.72	0		5.2 - 6.3 million km^2		The uncertainty estimate is the range of the 10 member ensemble, and does not represent a full measure of uncertainty.	The projected Arctic 2019 September mean sea ice extent from the Navy Earth System Prediction Capability (ESPC) is 5.7 million km2. This projection is the average of a 10 member time-lagged ensemble using initial conditions from 1 May to 10 May 2019. The range of the ensemble is 5.2 to 6.3 million km2. The projected Antarctic 2019 September mean sea ice extent is 20.5 million km2 with an ensemble range from 19.5 to 21.7 million km2. Note that our ensemble range does not represent a full measure of uncertainty.	We performed ensemble forecasts with the Navy ESPC using initial conditions on 2019-05-01 12Z through 2019-05-10 12Z. The atmospheric initial conditions are from NAVDAS-AR (Xu et al. 2005), which is part of the NAVGEM (Hogan et al. 2014) operational suite. The ocean/sea ice initial conditions are from the Navy's 3Dvar NCODA data assimilation system (Cummings 2005), which is a component of GOFS 3.1 using HYCOM and CICE (Metzger et al. 2014). SSMIS and AMSR2 ice concentrations are assimilated with NCODA (Posey et al., 2015). There was no bias correction performed on the results.	Sea ice concentration in the Navy ESPC forecasts was initialized from GOFS 3.1 (https://www7320.nrlssc.navy.mil/GLBhycomcice1-12).	Sea ice thickness in the Navy ESPC forecasts was initialized from GOFS 3.1 (https://www7320.nrlssc.navy.mil/GLBhycomcice1-12).
METNO SPARSE (Wang et al.)	Dynamic Model	Ocean-sea ice	5.896								This contribution is part of the Norwegian Research Coucil's project SPARSE (Developing and advancing Seasonal Predictability of Arctic Sea ice). Here we use the regional coupled ocean-sea ice model to make the prediction. We initialize the model with remote sensing sea ice concentration and thickness, and with reanalysis ocean data from the EU Copernicus Marine Service. The seasonal forecast atmospheric fields of ECMWF (SEA5) is used to drive the model. The model started prediction from 15 May 2019, and run until 1 October 2019. We have saved the daily mean and monthly mean sea ice extent for this period. The September sea ice extent is calculated from the monthly mean sea ice extent.	The Outlook is a straightforward result of the dynamic model prediction.	University of Bremen, AMSR2 sea ice concentration, https://seaice.uni-bremen.de/data/amsr2/	UCL Centre for Polar Observation and Modeling, Latest 5km Grid of 28-day thickness, http://www.cpom.ucl.ac.uk/csopr/seaice.html