Satellite Infrared Retrievals of Sea-Surface Temperature at High Latitudes

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Contents

1 Background & Introduction

Background & Introduction

Arctic Amplification

Climate change is amplified in the Arctic region relative to elsewhere.

Surface Albedo Feedback

The phenomenon is often explained by retreating snow and ice leading to more solar surface warming.

Temperature Feedback

Pithan and Mauritsen (2014) found that the largest contribution to Arctic amplification comes from temperature feedbacks.

Satellite Remote Sensing

Satellite remote sensing offers the best way of deriving surface temperatures in the Arctic.

Collaborative research

NOPP project: Multisensor Improved SST – III MISST-III

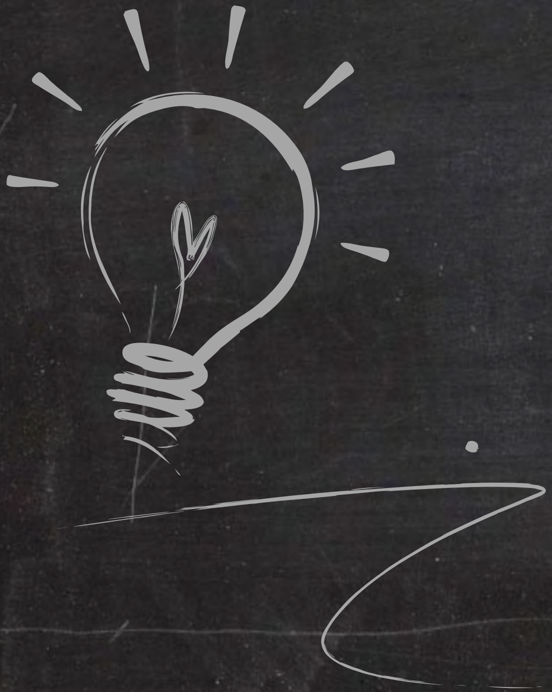
Objective: to improving satellite-derived SSTs in the Arctic

PI: Chelle L. Gentemann, Earth and Space Research
Co-I: Peter Minnett, Ocean Sciences, RSMAS, University of Miami
Co-I: Michael Steele, Polar Science Center, Applied Physics Laboratory, University of Washington

Remember Chelle Gentemann's presentation on Monday

2 Data & Algorithm

Data



Satellite SSTs

MODIS on Aqua

https://podaac.jpl.nasa.gov/

In situ Buoy Data

Quality controlled drifter data

https://www.star.nesdis.noaa.gov/sod/sst/iquam/

Matchup Database

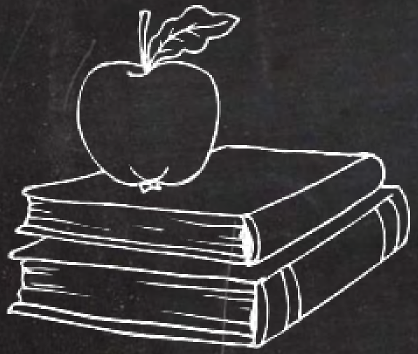
Within 30 minutes and 10 km

Time: 2013 – 2018. Latitude: > 60^{o}N

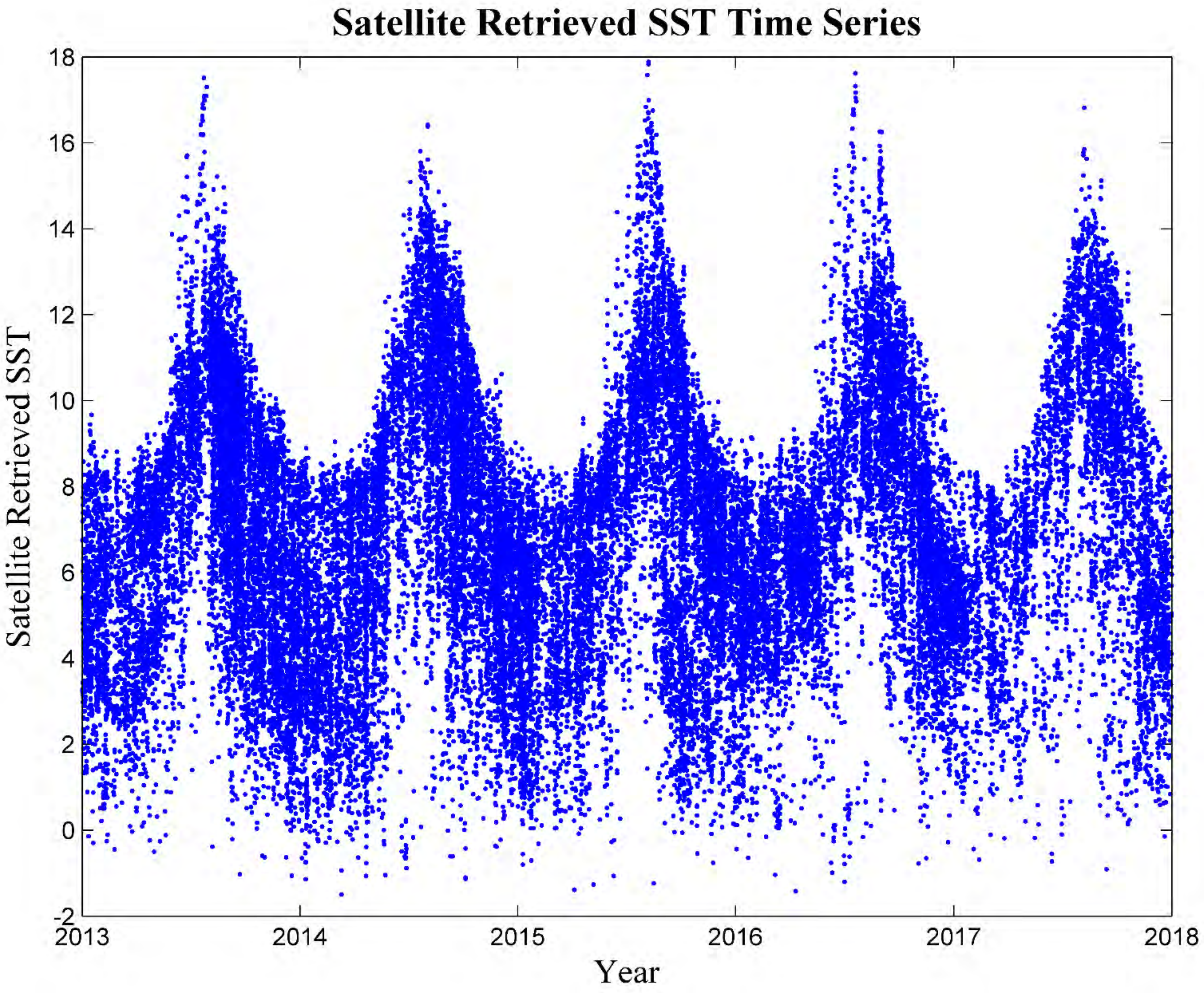
Confidently cloud clear

https://seabass.gsfc.nasa.gov/archive/SSTVAL

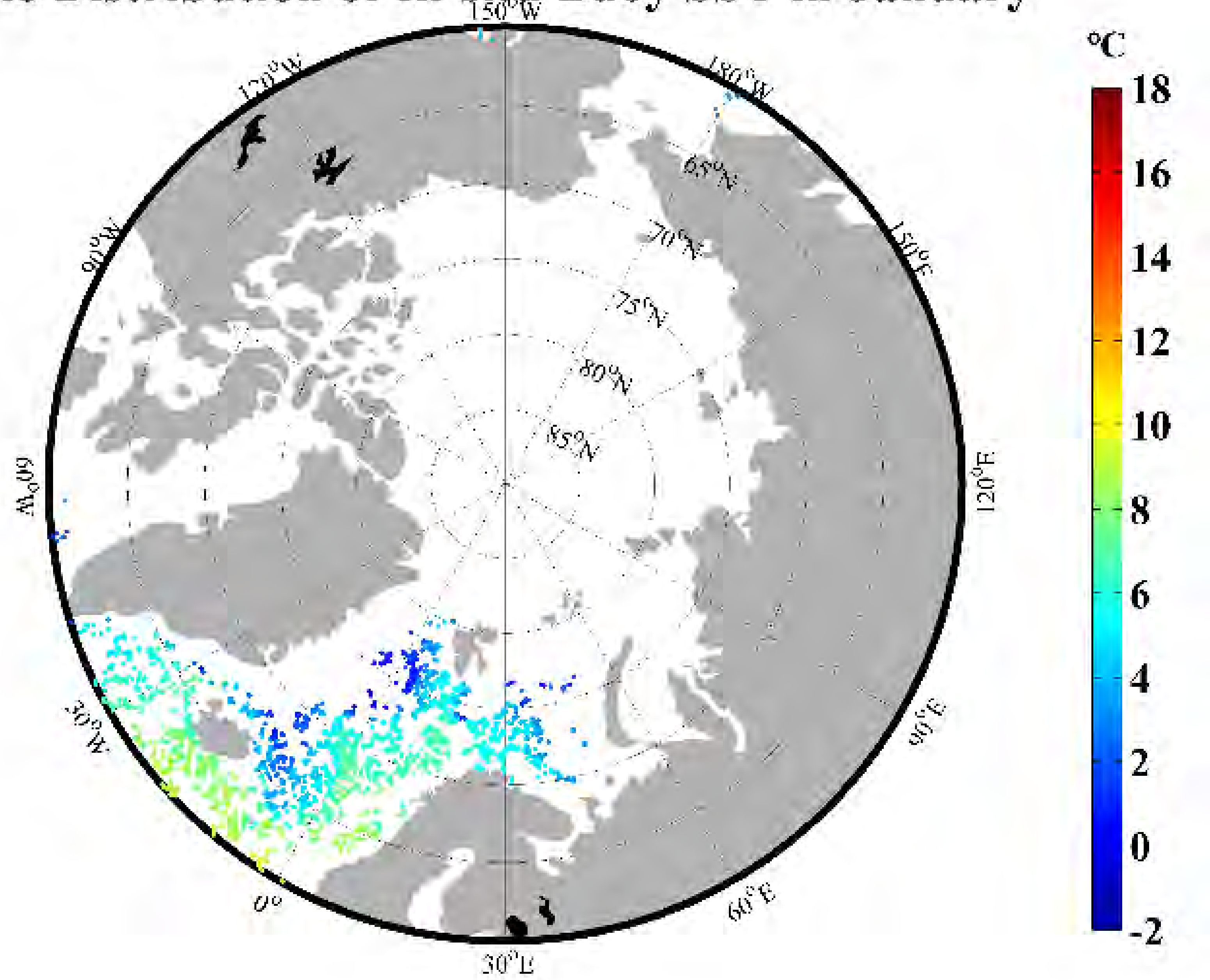
MODIS SST Algorithm



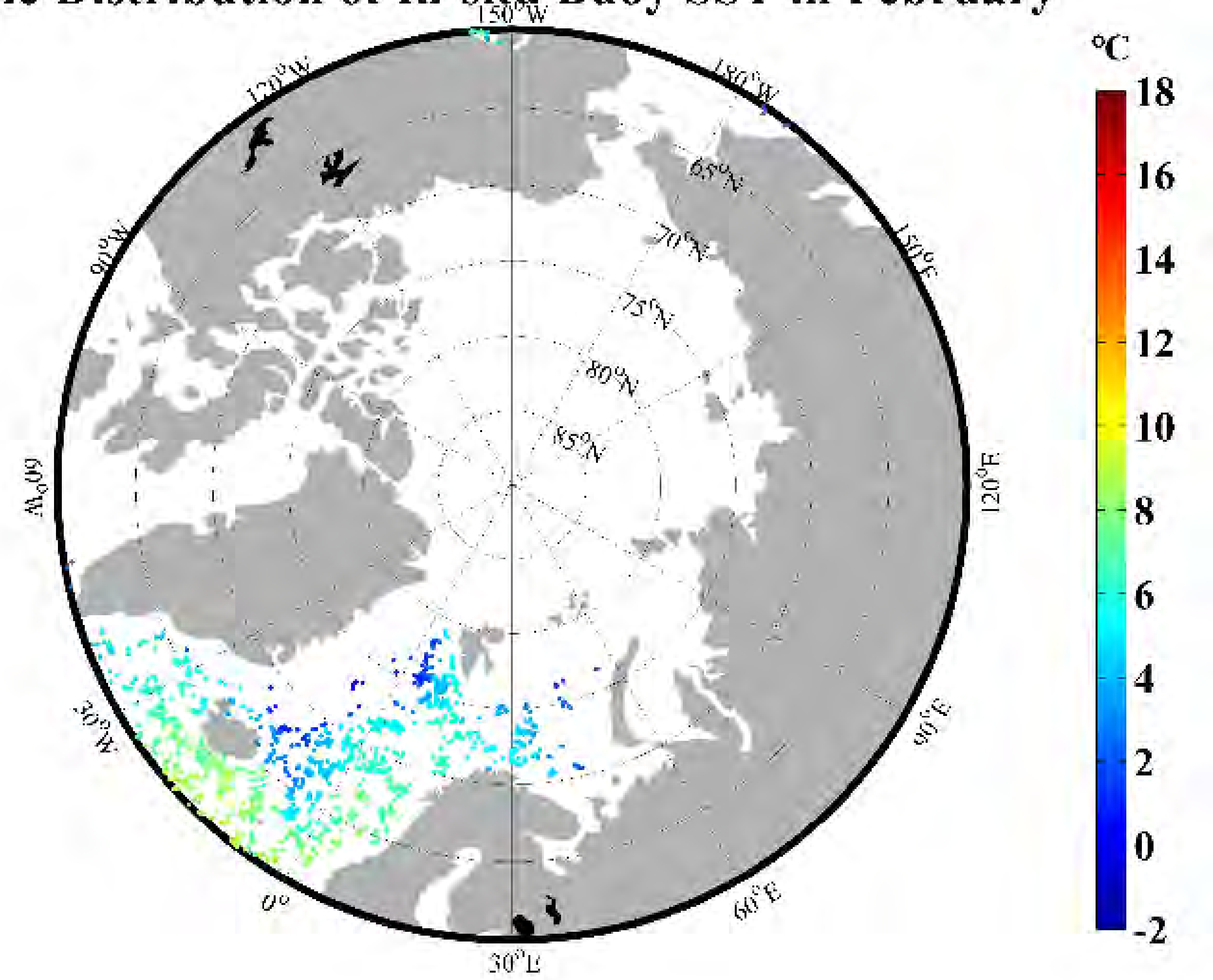
$$SST = a_0 + a_1 * T_{11} + a_2 * (T_{11} - T_{12}) * T_{sfc} + a_3 * (\sec\theta - 1) * (T_{11} - T_{12}) + a_4 * (mirror) + a_5 * (\theta) + a_6 * (\theta^2)$$


Satellite Retrieved SST Time Series
Satellite Retrieved SST
Year
18
16
14
12
10
8
6
4
2
0
-2
2013
2014
2015
2016
2017
2018

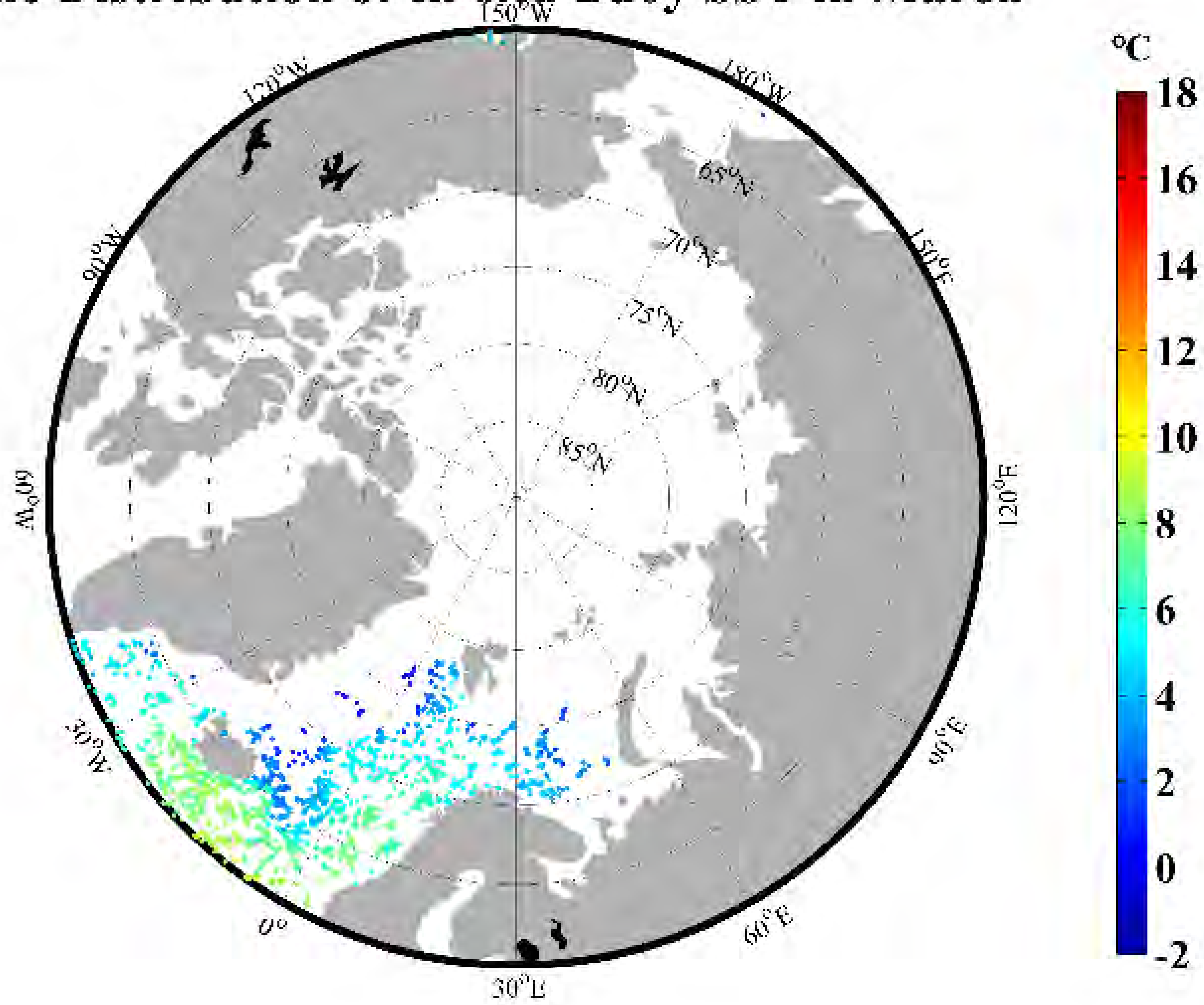
The Distribution of In-situ Buoy SST in January



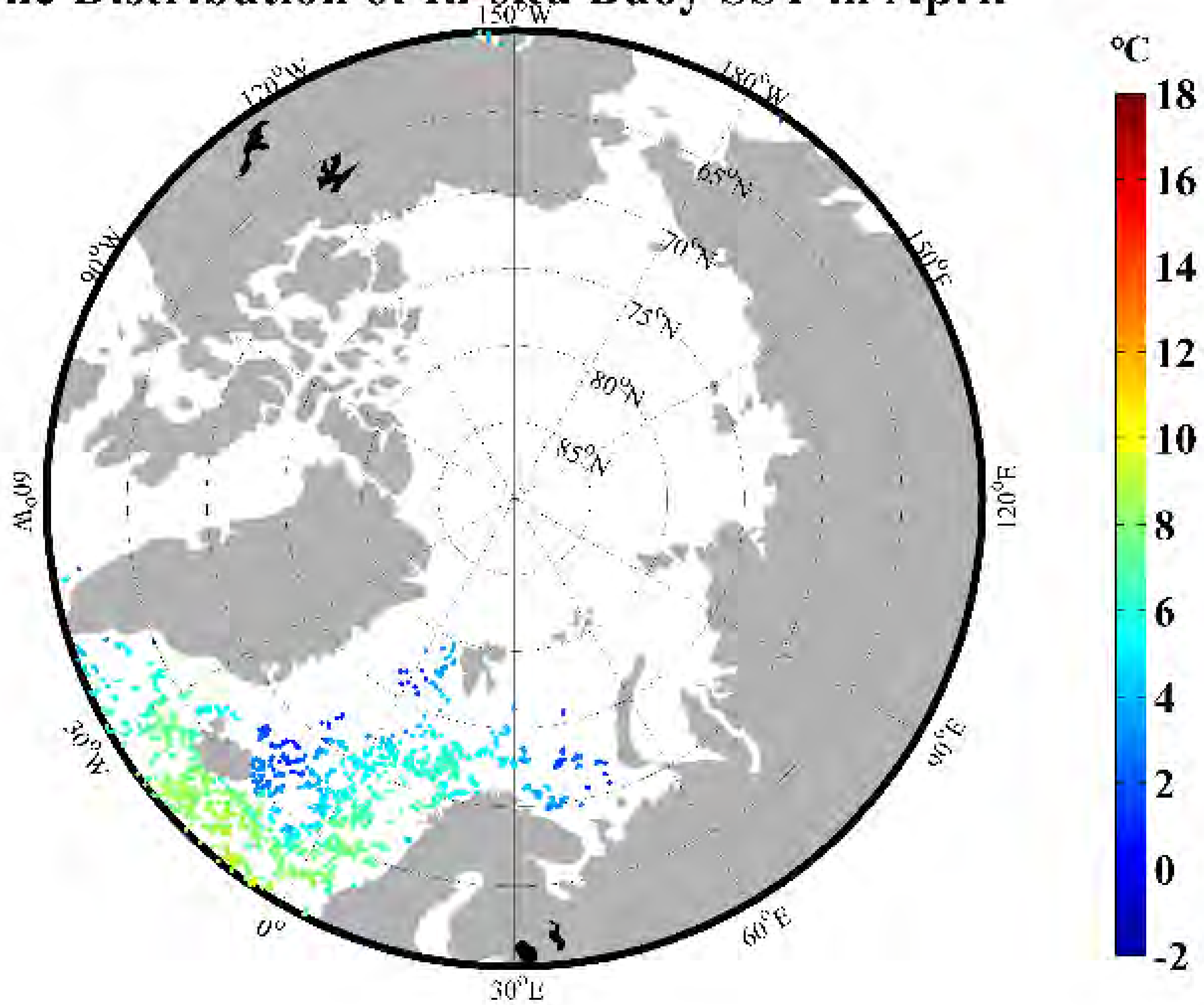
The Distribution of In-situ Buoy SST in February



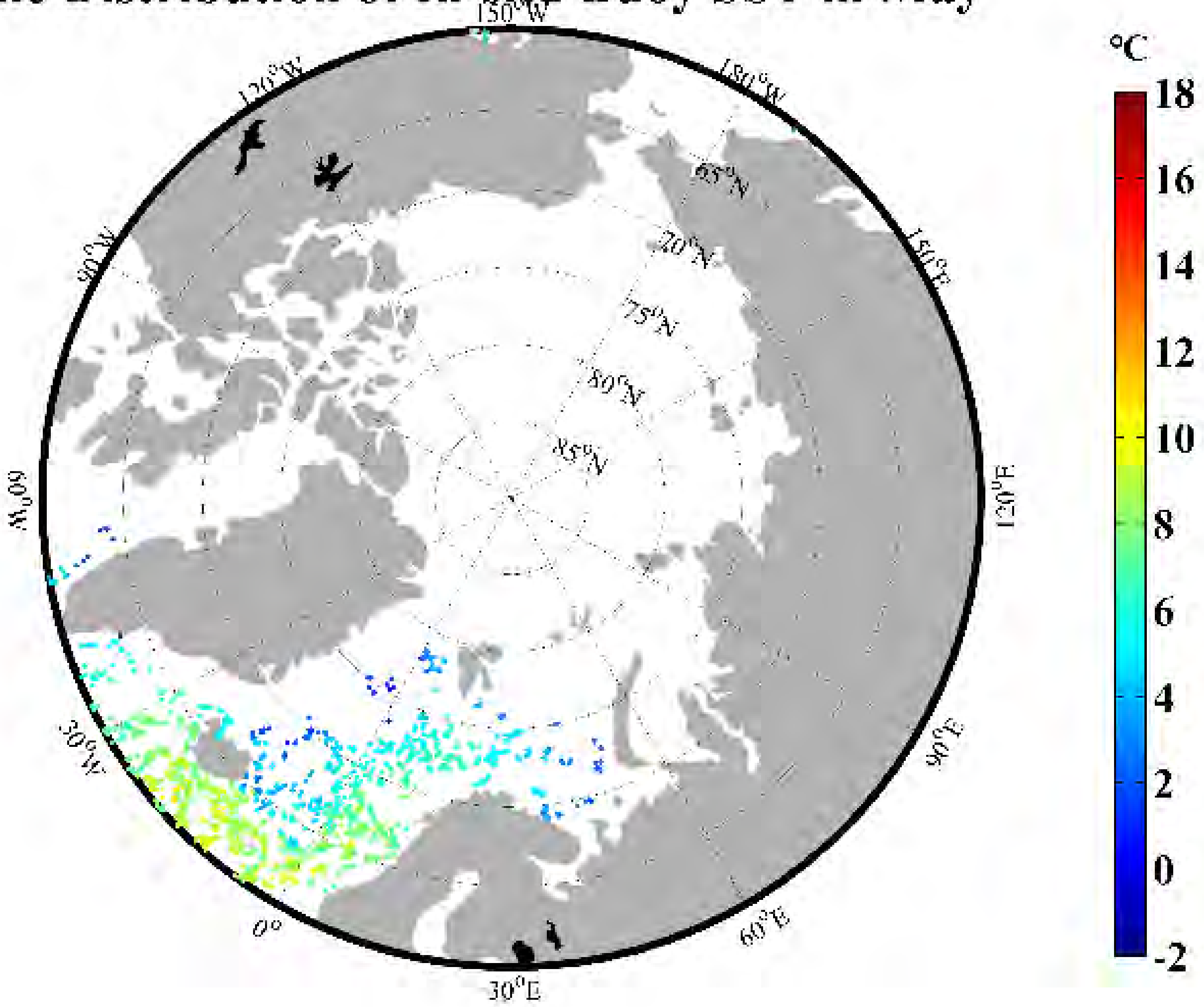
The Distribution of In-situ Buoy SST in March



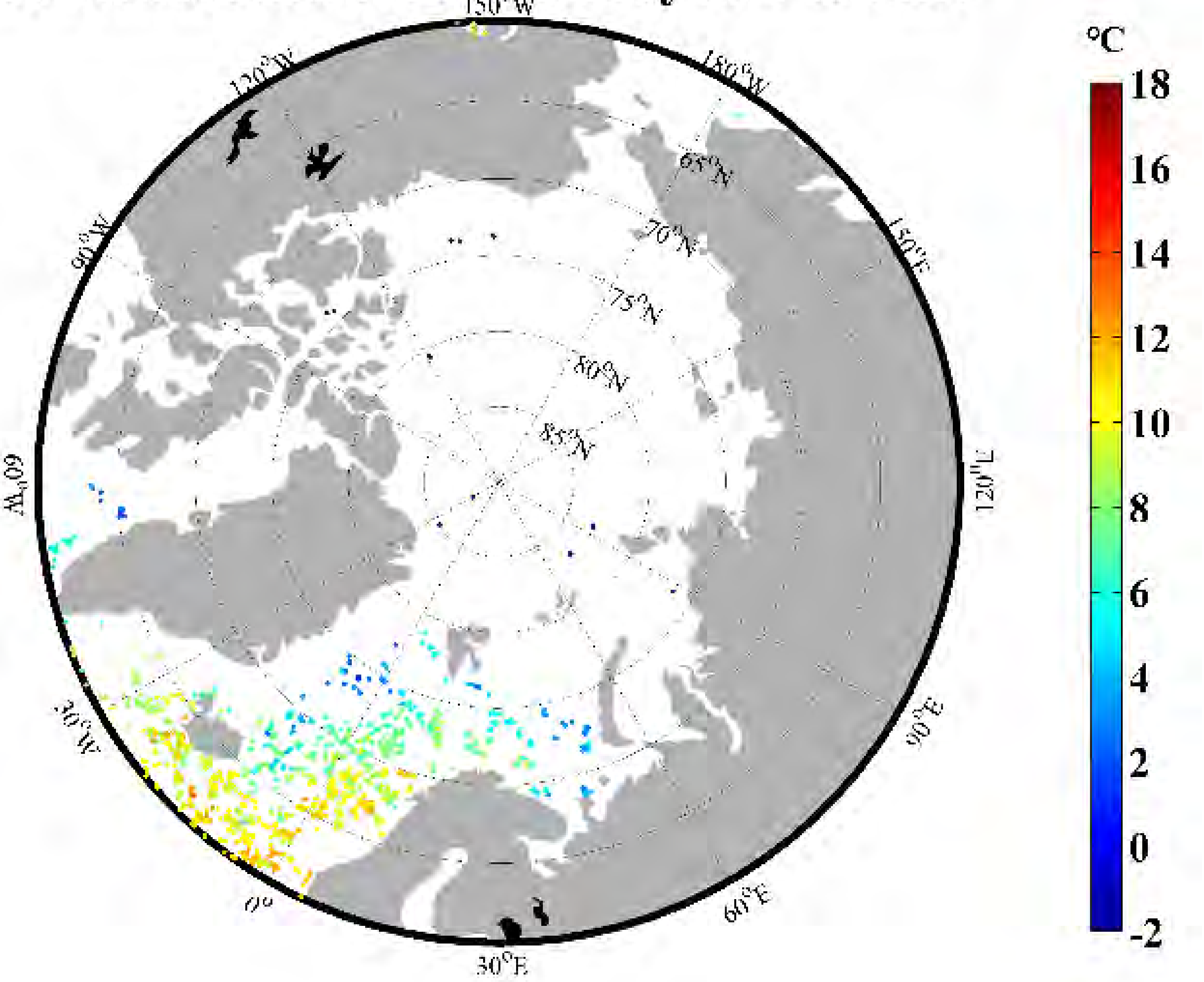
The Distribution of In-situ Buoy SST in April



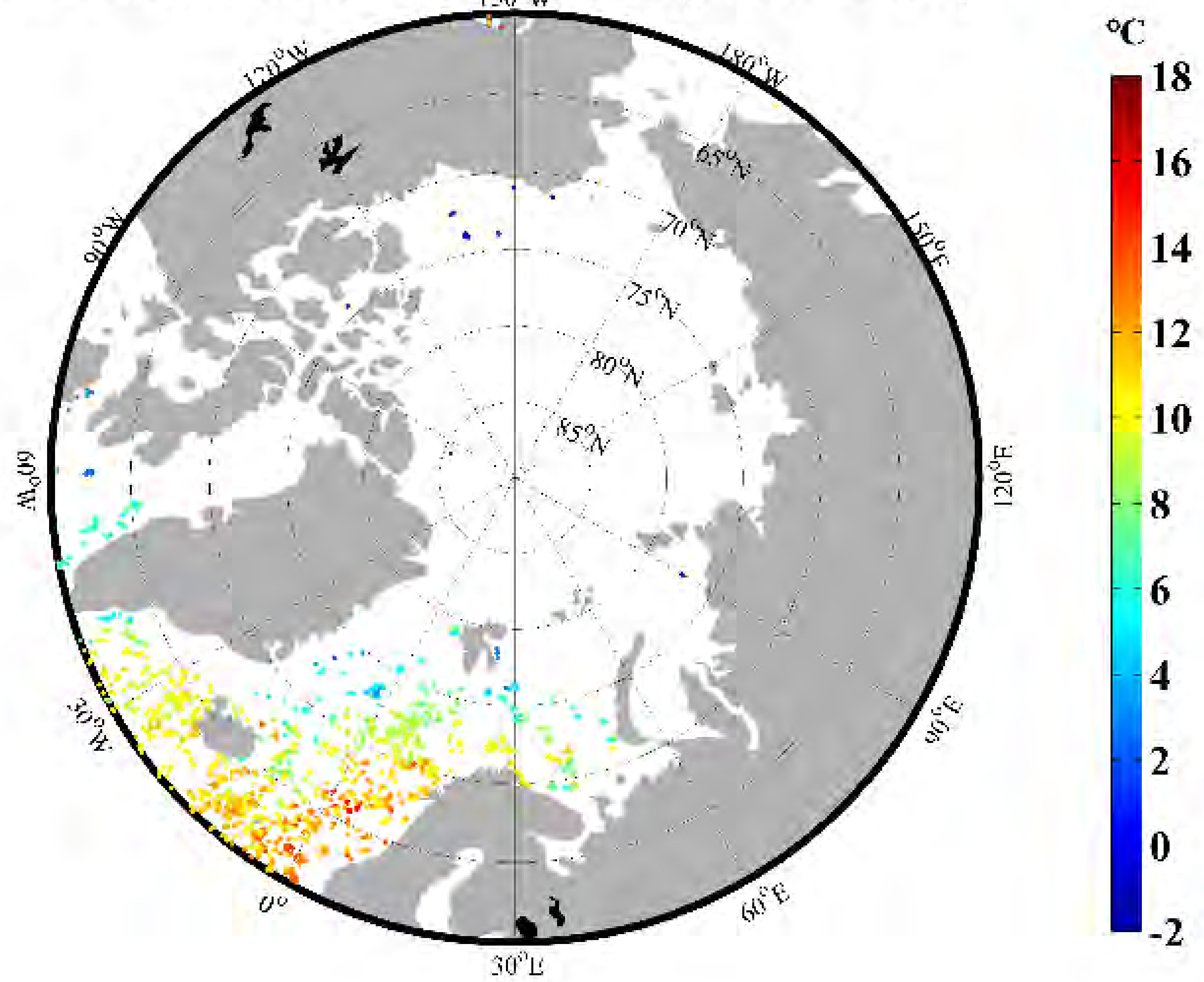
The Distribution of In-situ Buoy SST in May



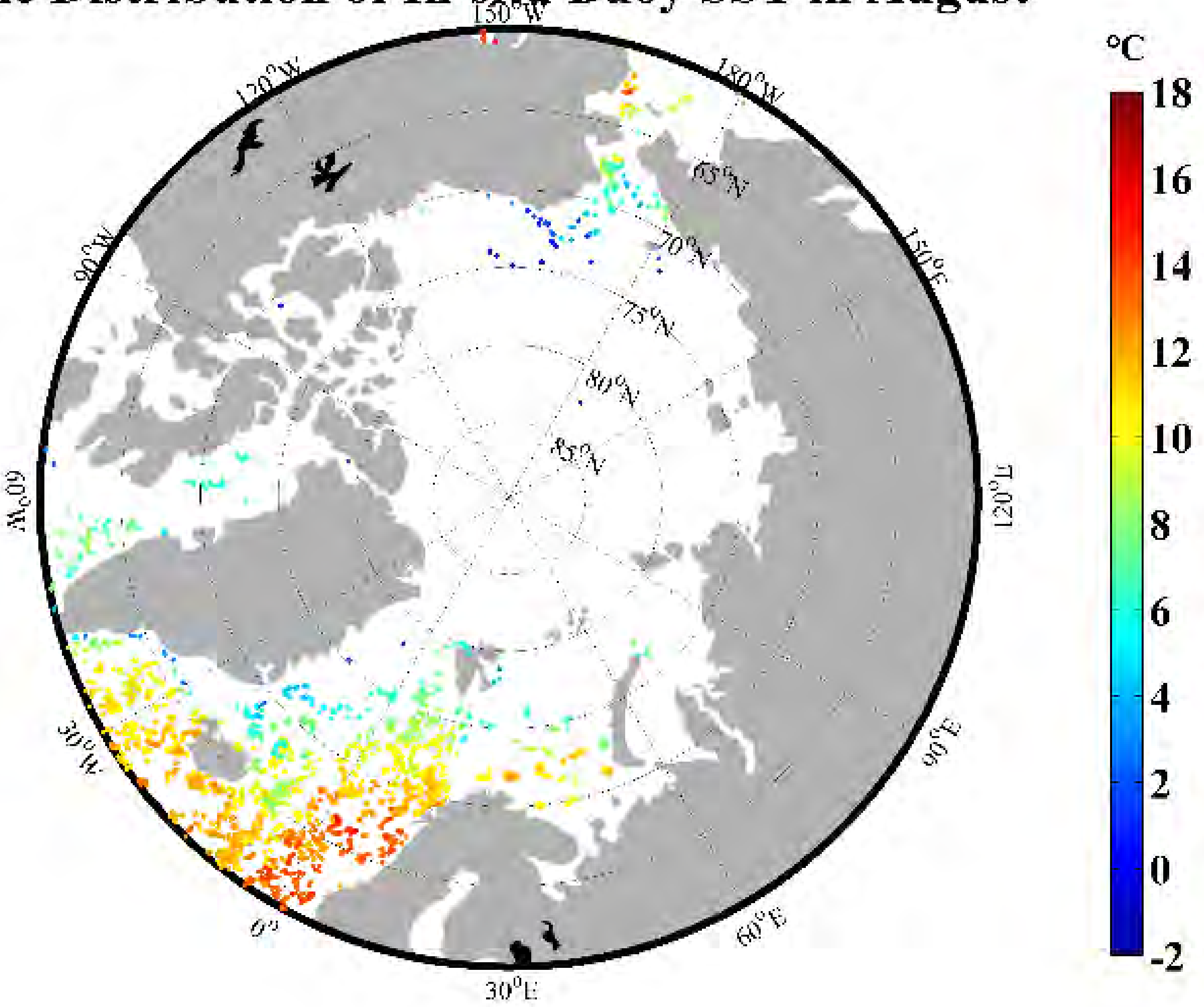
The Distribution of In-situ Buoy SST in June



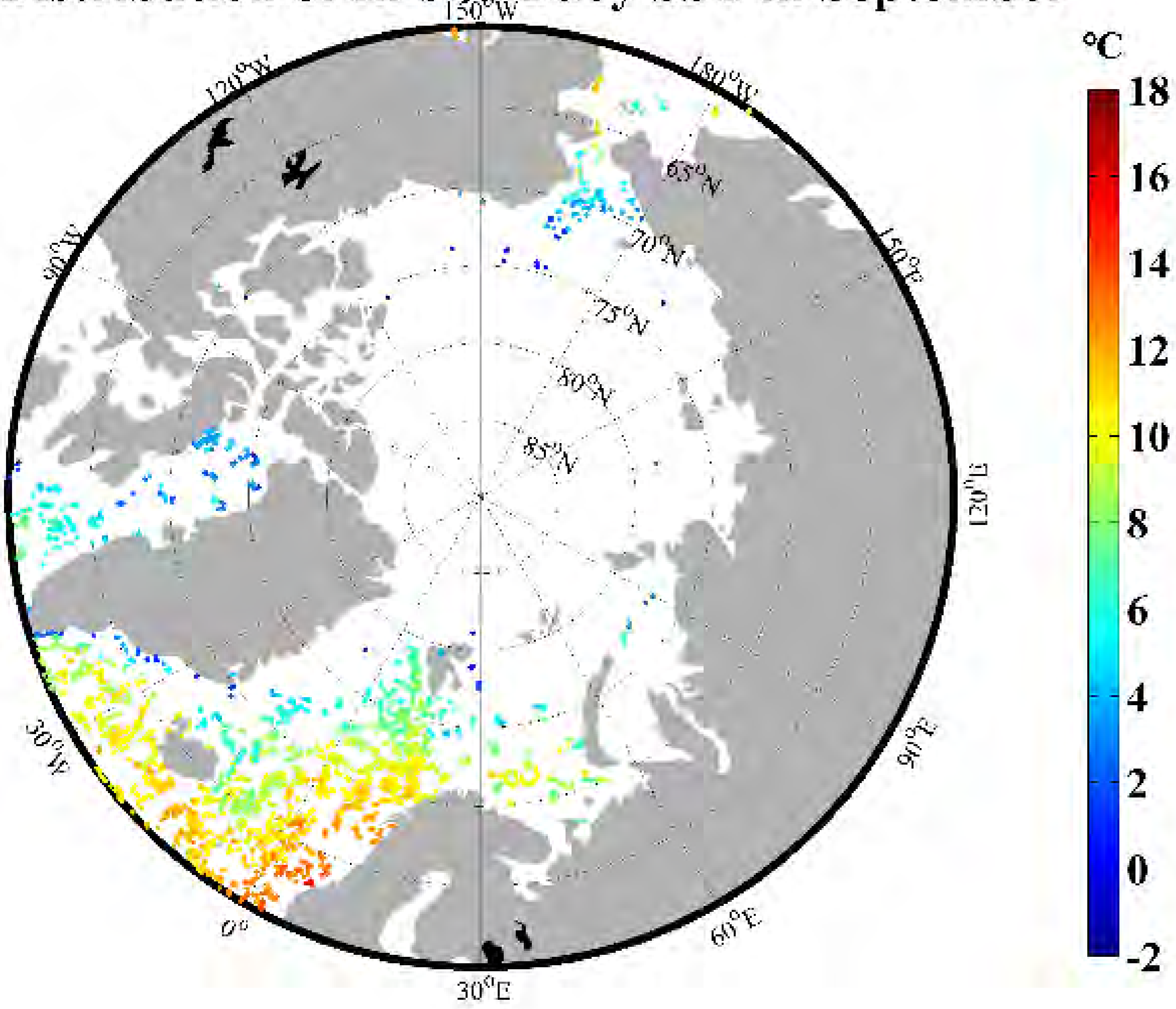
The Distribution of In-situ Buoy SST in July



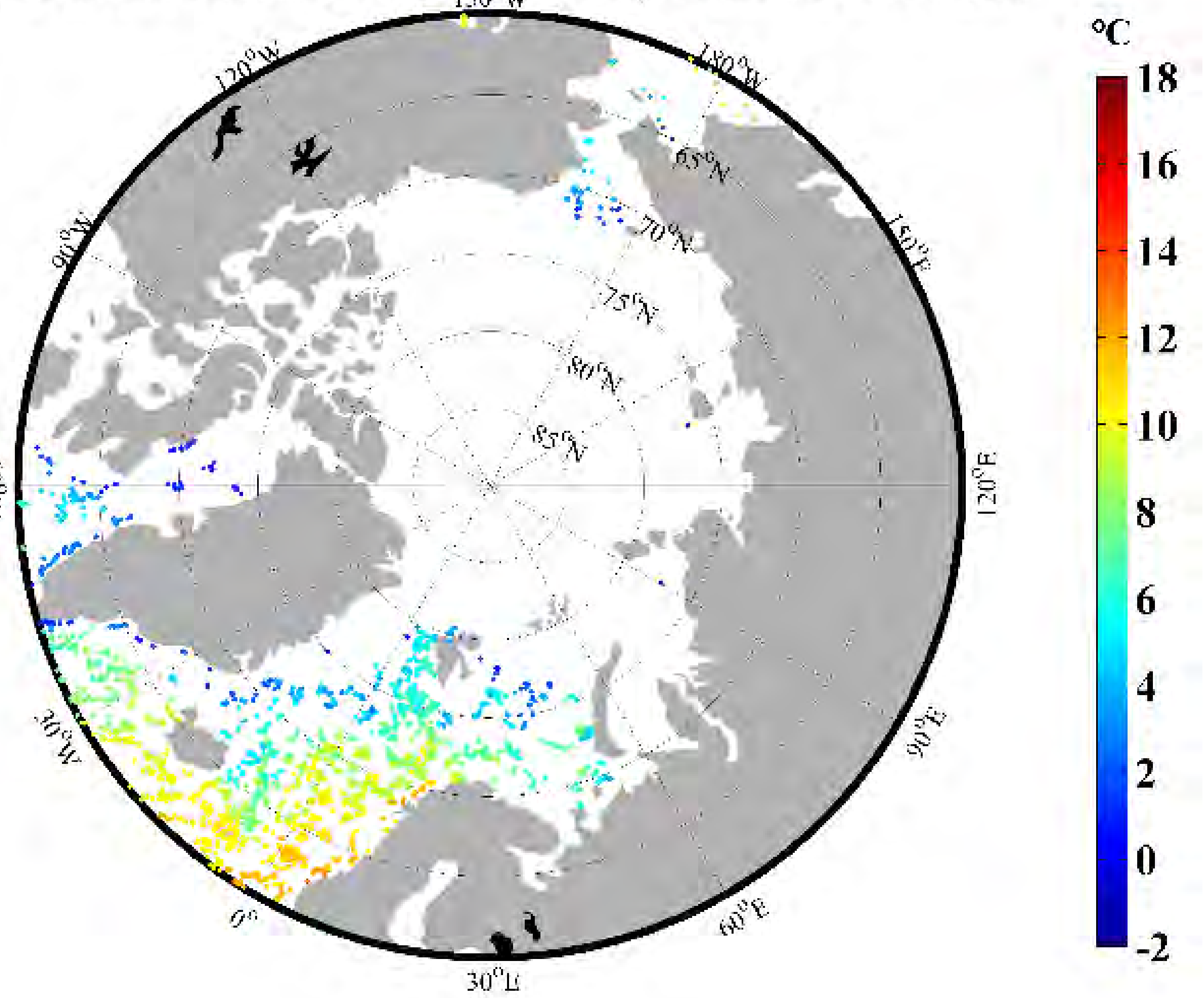
The Distribution of In-situ Buoy SST in August



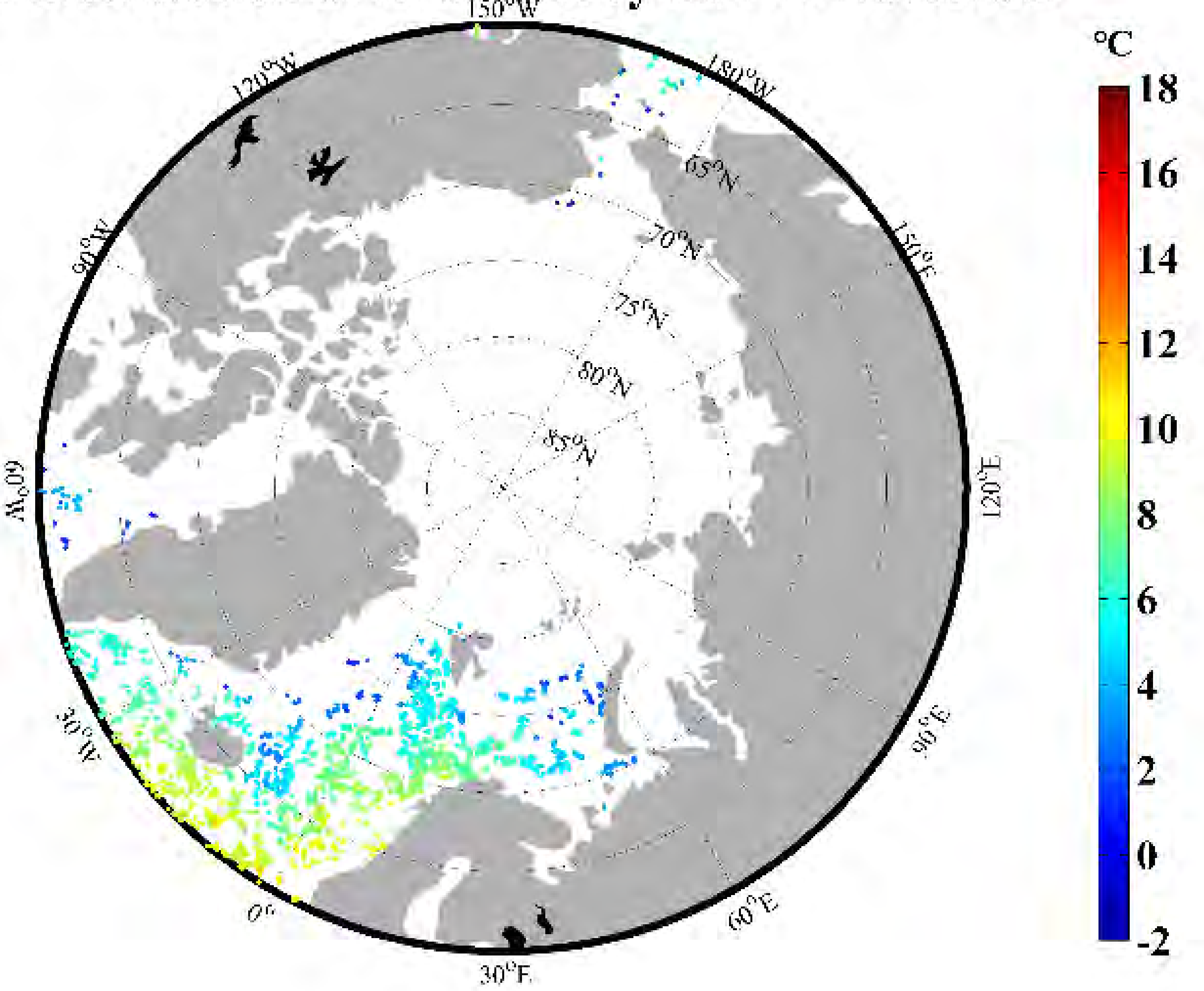
The Distribution of In-situ Buoy SST in September



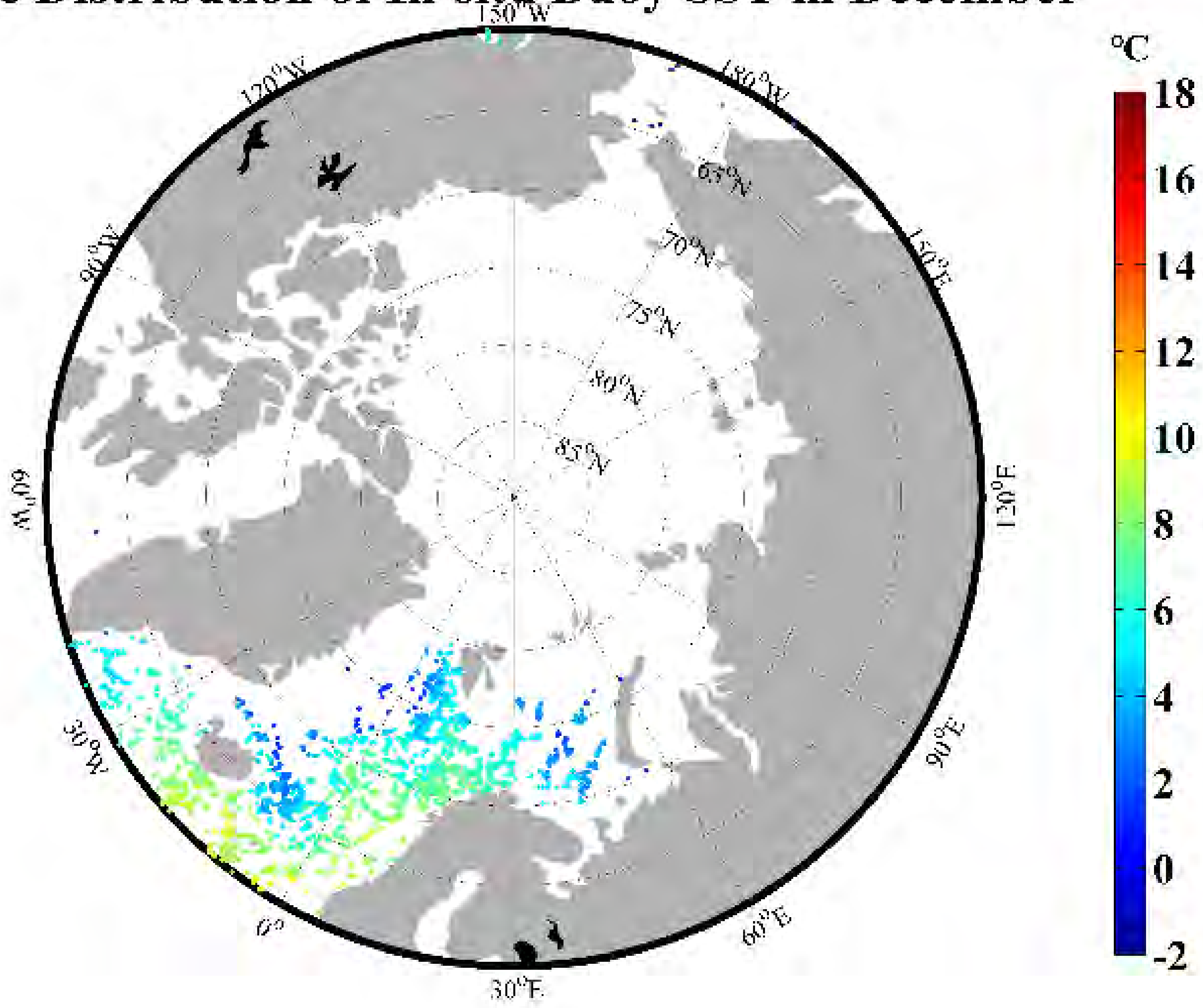
The Distribution of In-situ Buoy SST in October



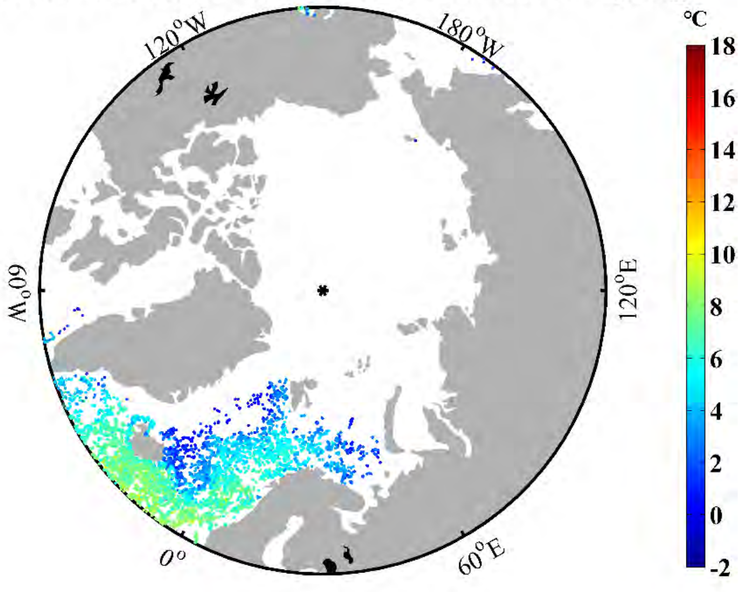
The Distribution of In-situ Buoy SST in November



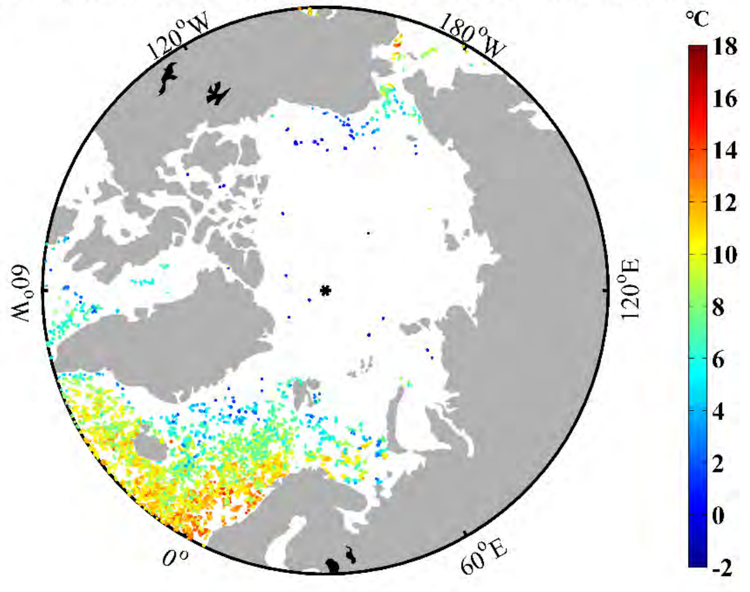
The Distribution of In-situ Buoy SST in December



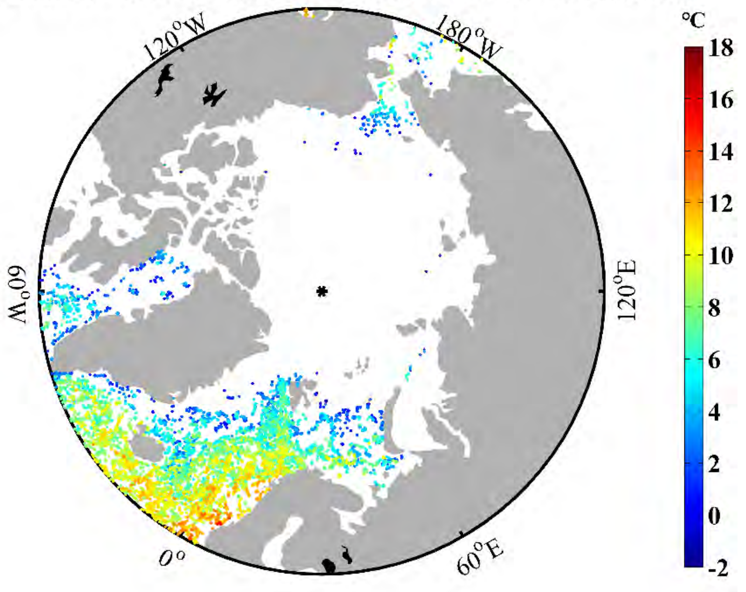
The Distribution of Satellite Retrieved SST in Spring



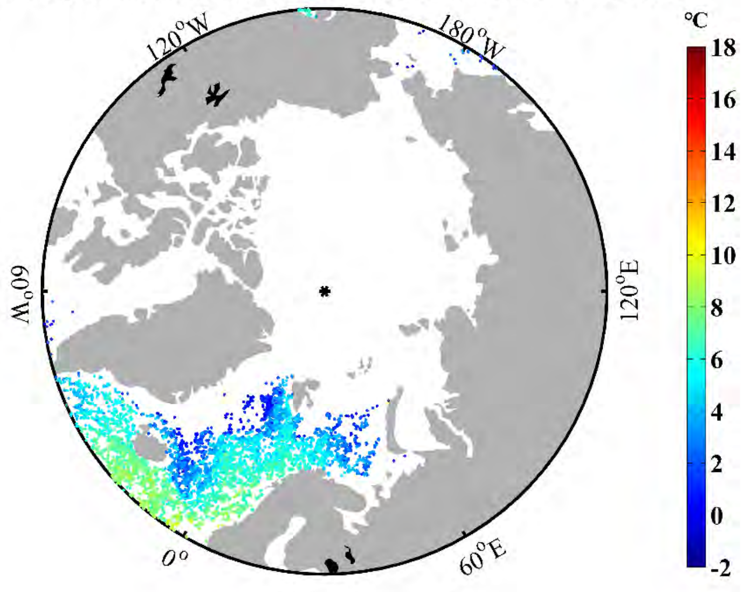
The Distribution of Satellite Retrieved SST in Summer



The Distribution of Satellite Retrieved SST in Autumn

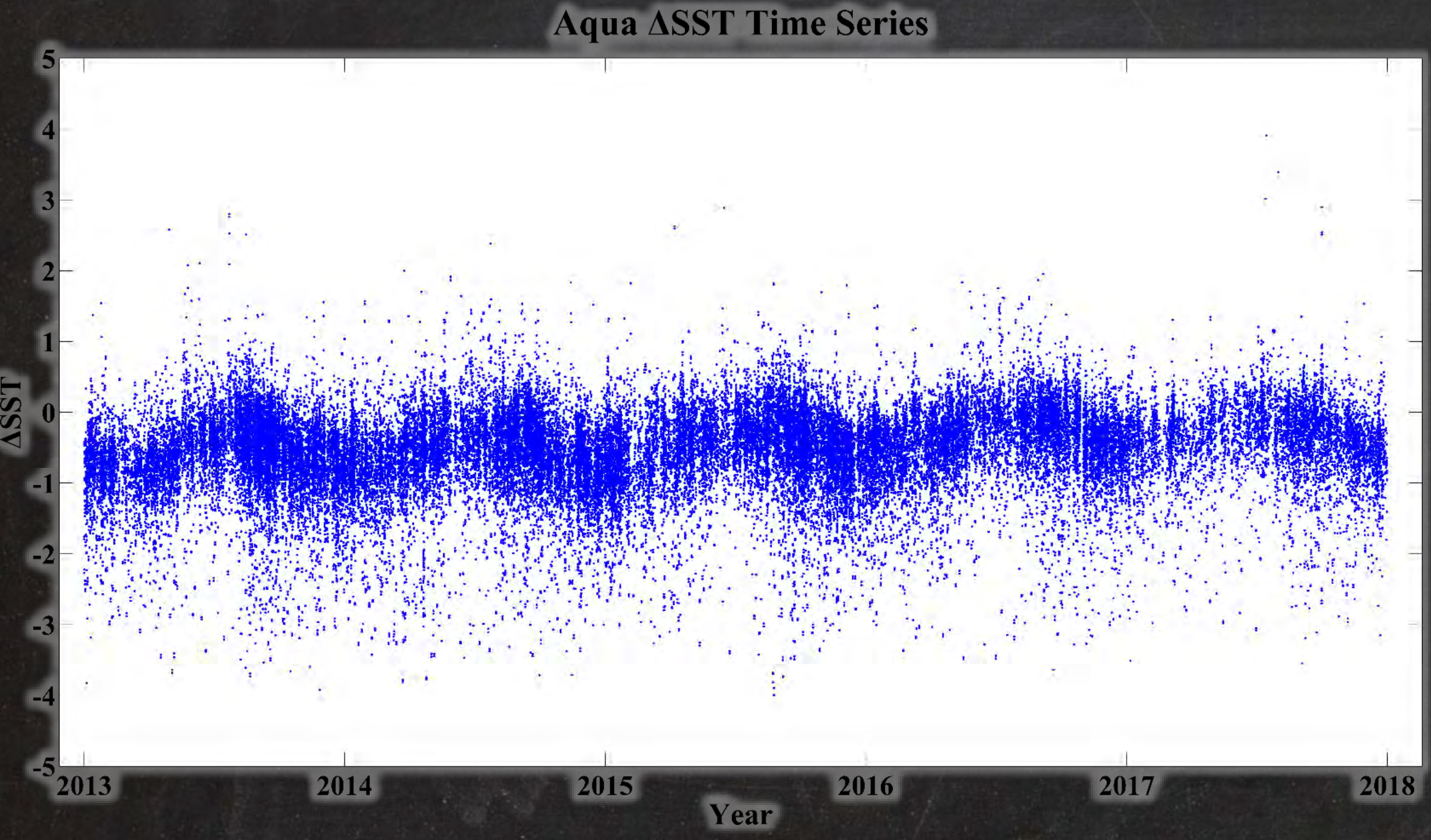


The Distribution of Satellite Retrieved SST in Winter



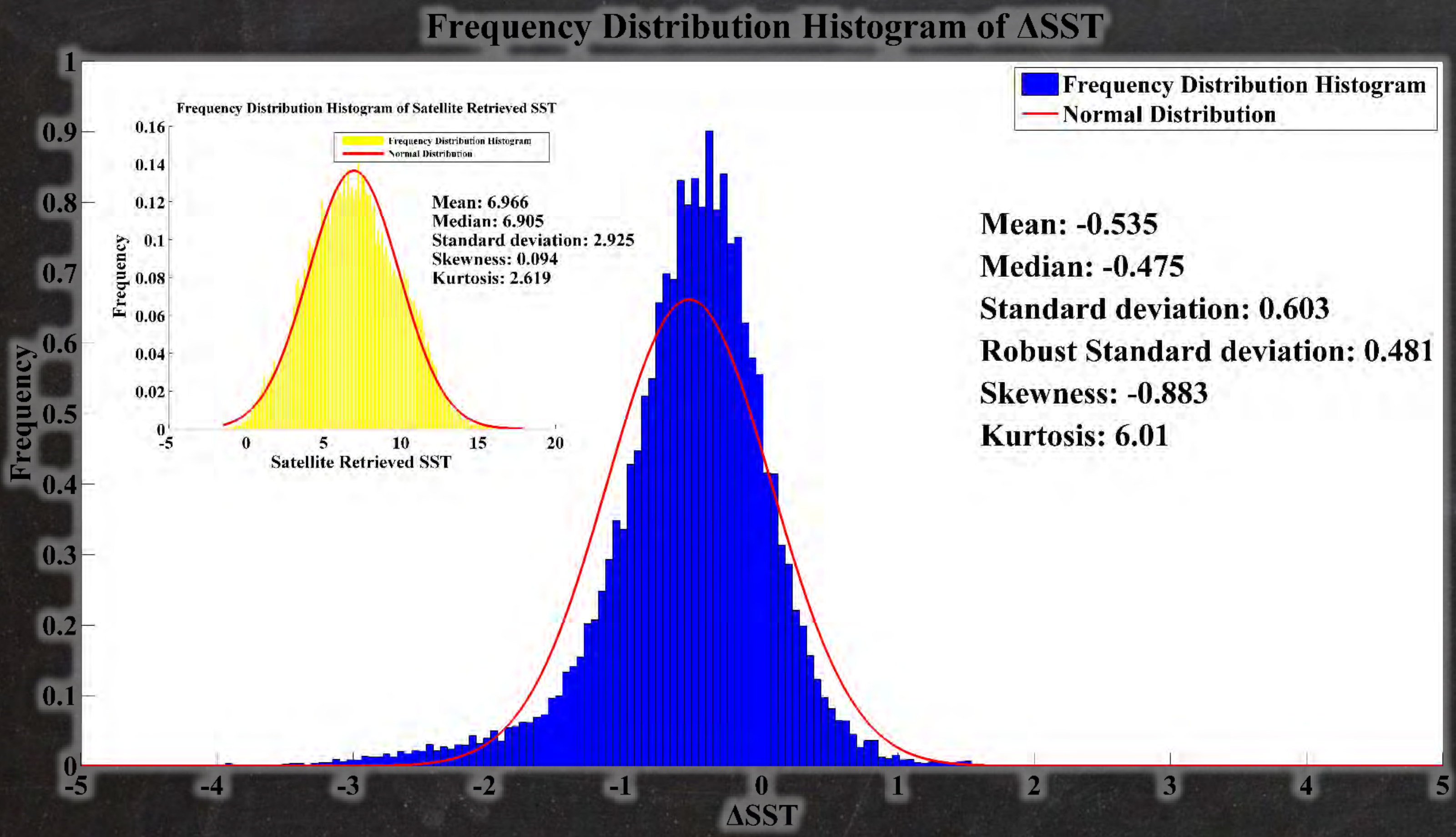
3 Analysis

Define ΔSST as the satellite retrieved SST minus its matchup in situ buoy temperature measurement

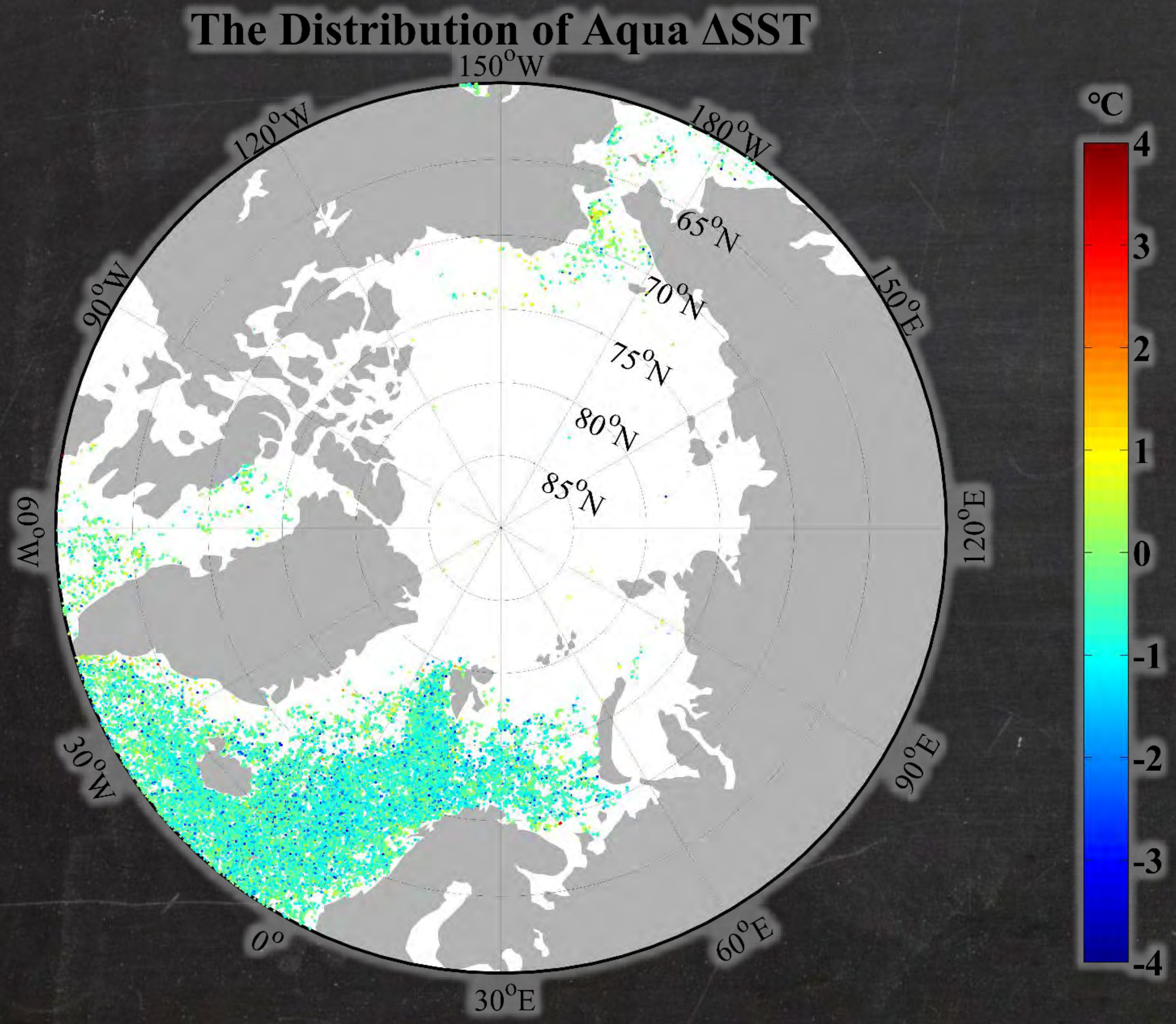


There is a significant annual cycle, and much more extreme positive outliers appear during summer

MODIS measures IR radiation originating from a layer less than 1 mm thick at the ocean surface, while buoy measures sub-surface temperature.



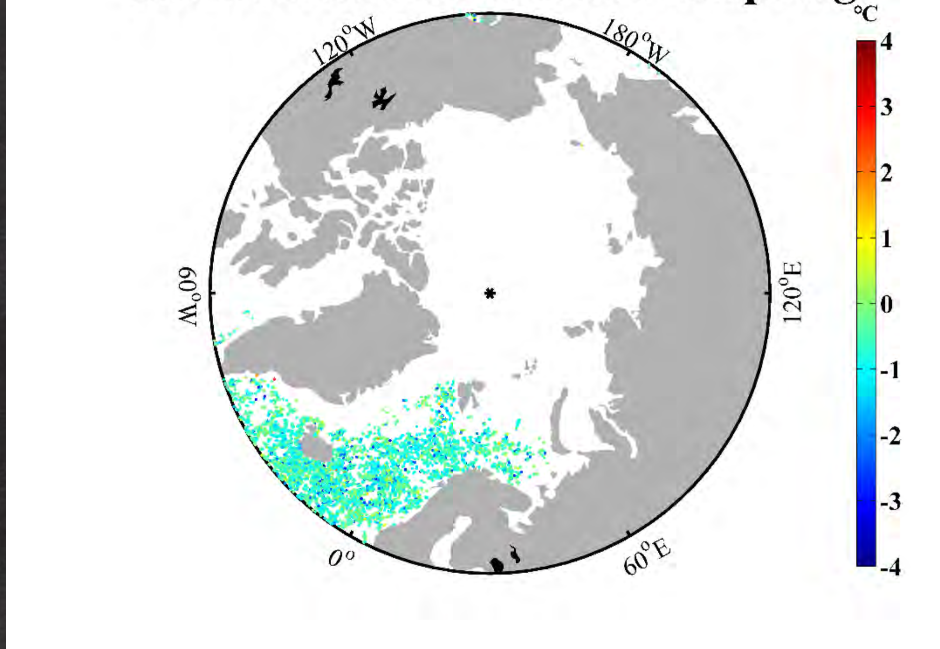
The presence of cold tail in the distribution of SST residuals, is a result of outliers tied to unidentified cloud contamination or anomalous atmospheres (Szczodrak, et al., 2014)



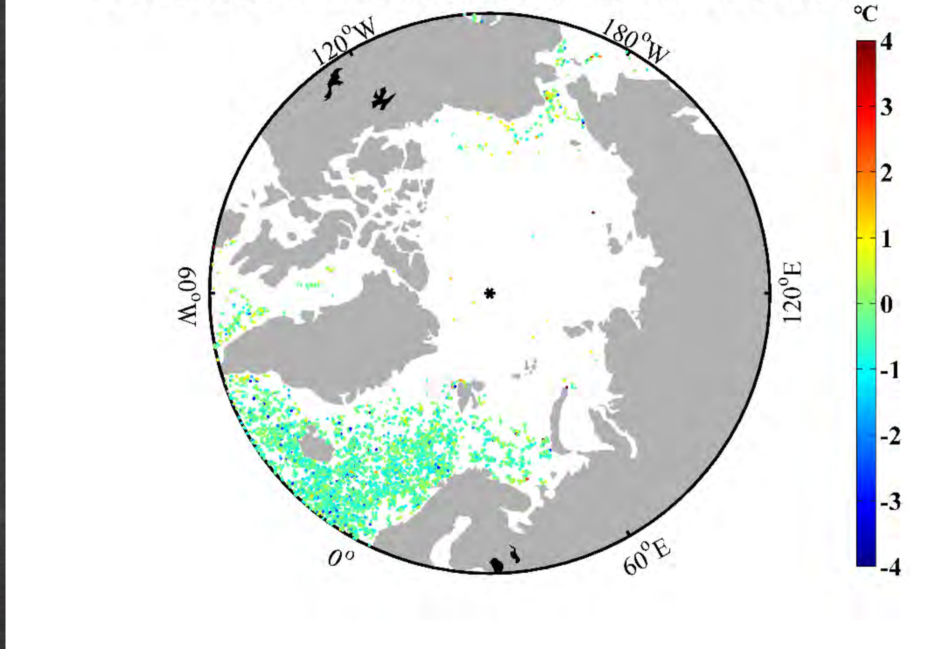
The spatial distribution is uneven. Most of the data are distributed in the Greenland Sea, Norwegian Sea, Baffin Bay, Davis Strait and Chukchi Sea, while over 80°N, i.e. in the Arctic Ocean, there are very few data points.

However, no obvious spatial characteristics of large differences.

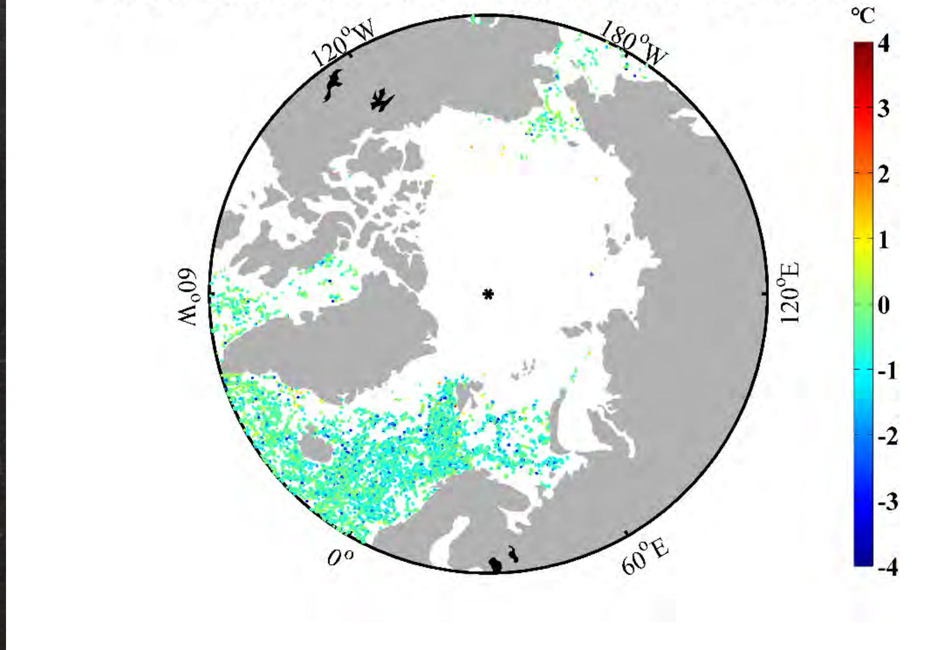
The Distribution of ΔSST in Spring



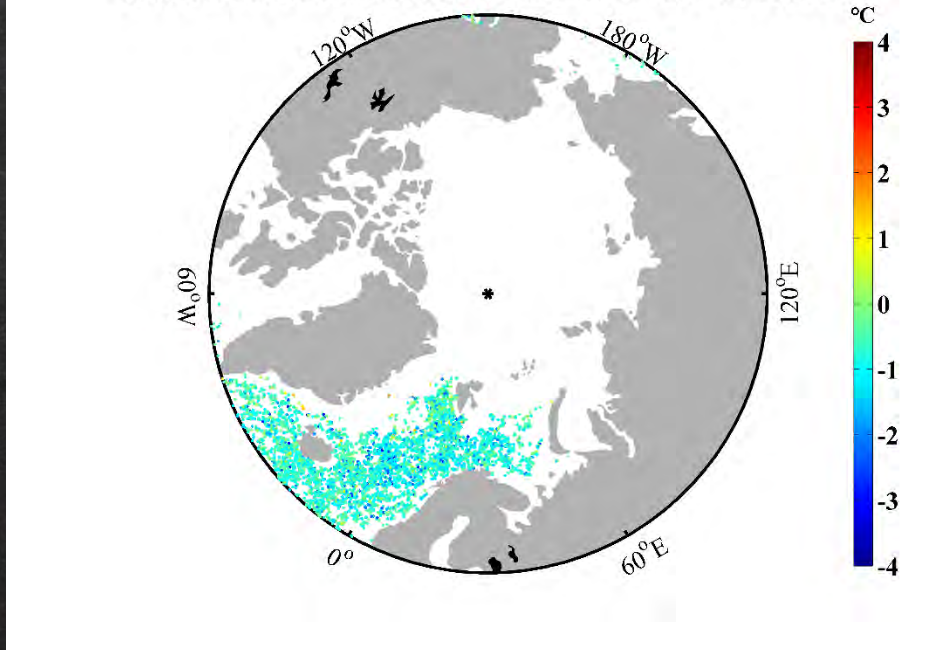
The Distribution of ΔSST in Summer



The Distribution of ΔSST in Autumn



The Distribution of ΔSST in Winter



Error Sources

1. Cloud screening and atmospheric correction algorithm imperfections
2. In situ measurements errors and uncertainties
3. MODIS instrumental artifacts
4. The observation time and space collocation window between the satellite and in situ observations in the MUDB

Cloud screening

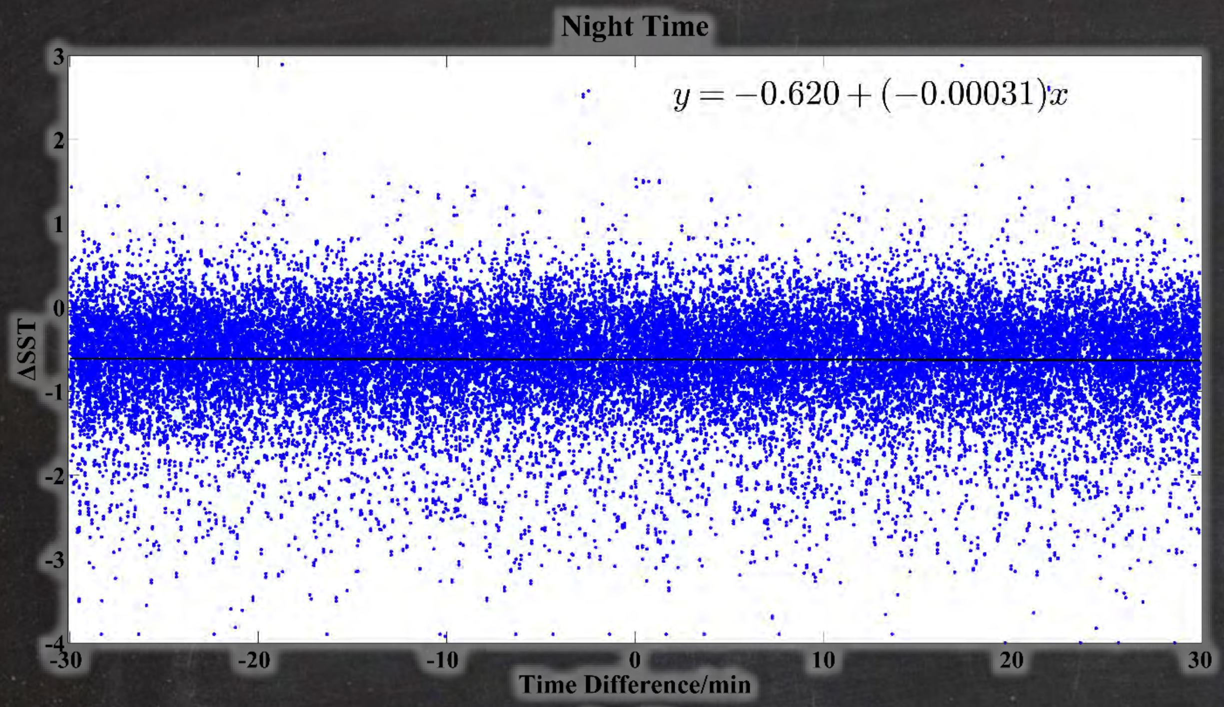
Cloud screening using a decision tree approach[1] has been shown to have particular problems at high latitudes and likely contribute to errors and uncertainty.

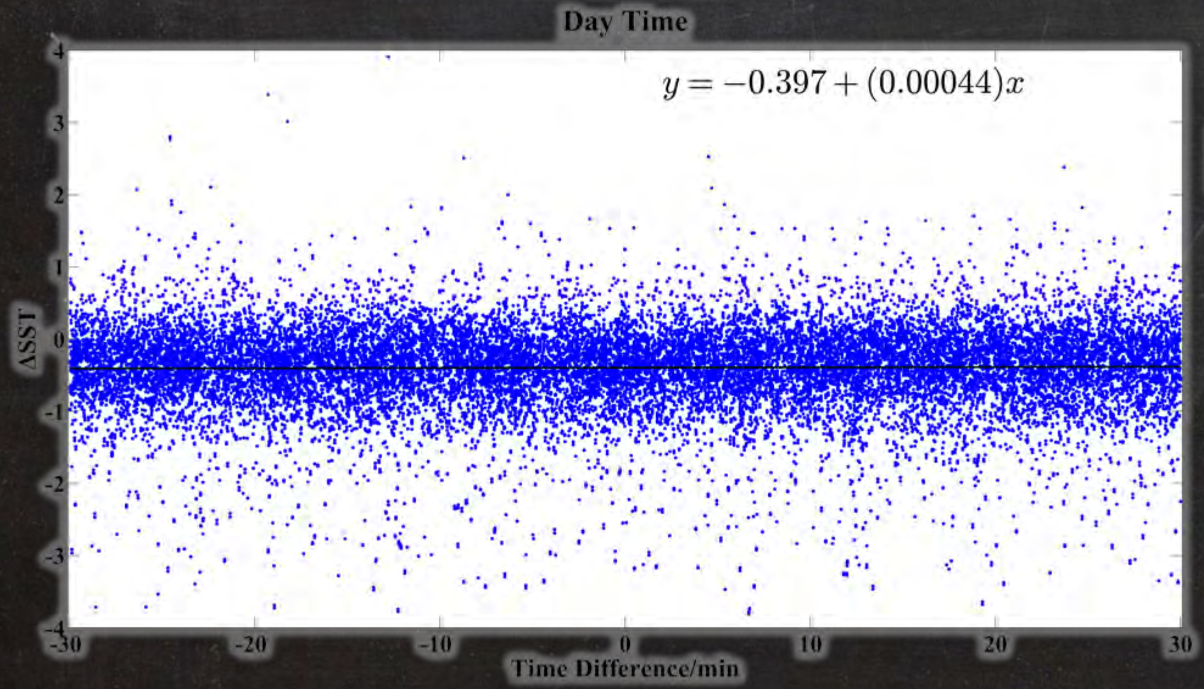
A new AI based cloud screening algorithm has been developed for MODIS and VIIRS[2] and will be used in the next reprocessing of MODIS data.

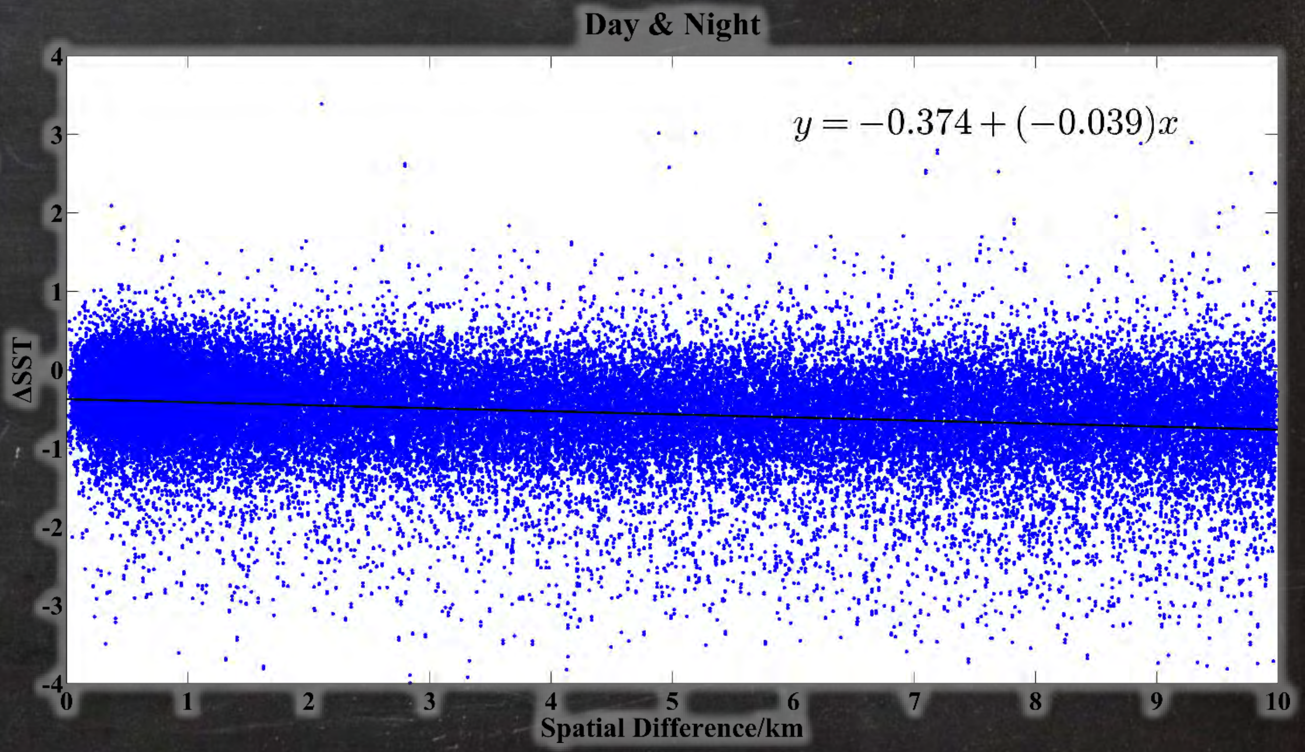
[1]Kilpatrick, K.A., Podestá, G., Walsh, S., Williams, E., Halliwell, V., Szczodrak, M., Brown, O.B., Minnett, P.J., & Evans, R. (2015). A decade of sea surface temperature from MODIS. *Remote Sensing of Environment* 165, 27-41. http://dx.doi.org/10.1016/j.rse.2015.04.023

[2]Kilpatrick, K. A., Podestá, G., Williams, E., Walsh, S., & Minnett, P. J. (2019). Alternating Decision Trees for Cloud Masking in MODIS and VIIRS NASA Sea Surface Temperature Products. *Journal of Atmospheric and Oceanic Technology* 36, 387-407. 10.1175/jtech-d-18-0103.1

Matchup temporal & spatial intervals

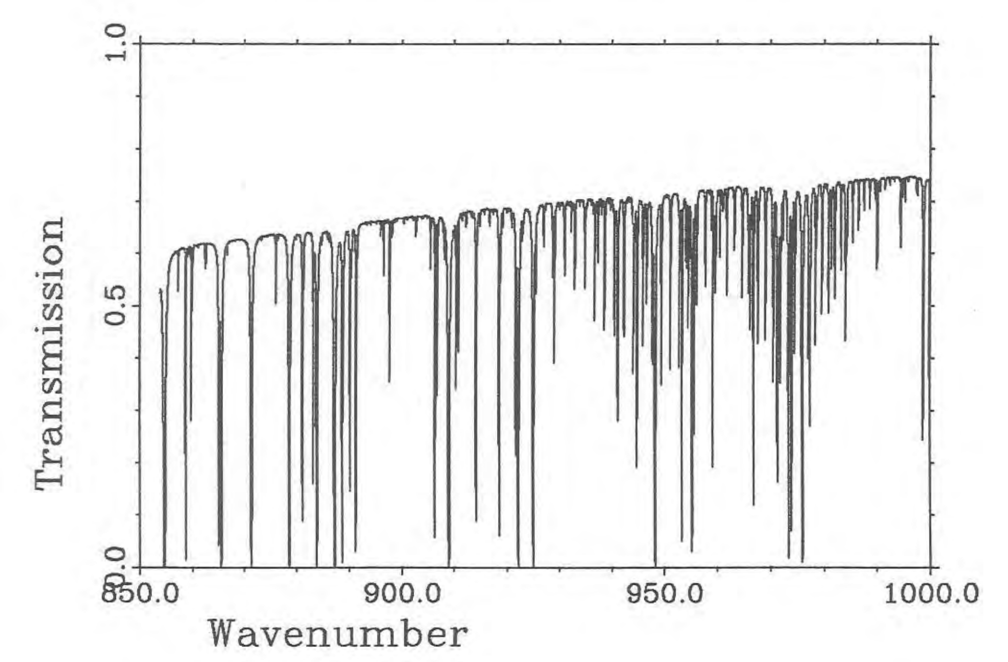




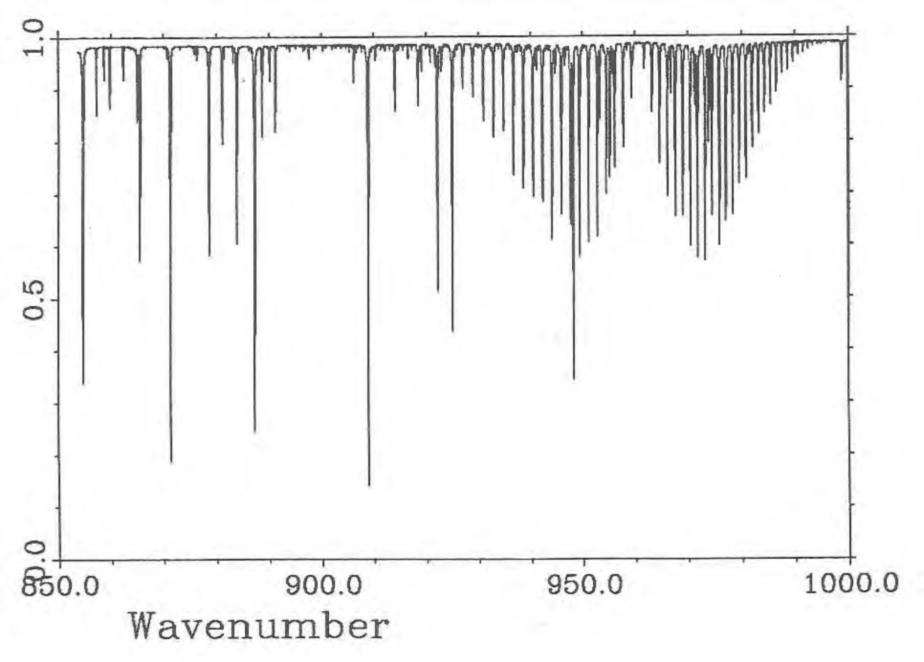


Split-window atmospheric correction

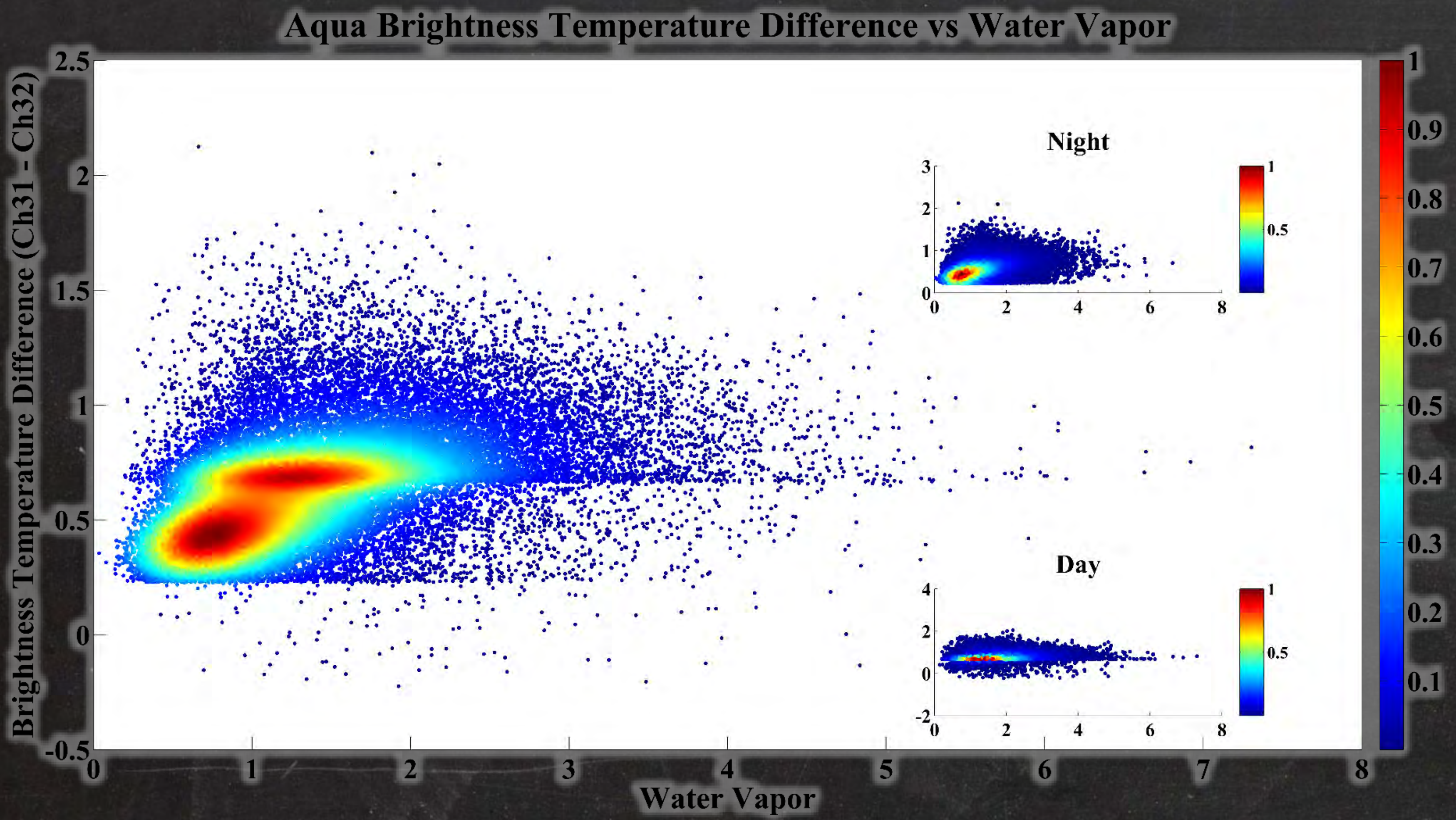
The NLSST atmospheric correction algorithm is based on the differential atmospheric effect in the 10-12 µm spectral range.



Warm, moist high-latitude conditions



Cold, dry high-latitude conditions



The MODIS brightness temperature difference demonstrates a weak correlation with water vapor.

Single Channel Retrieval

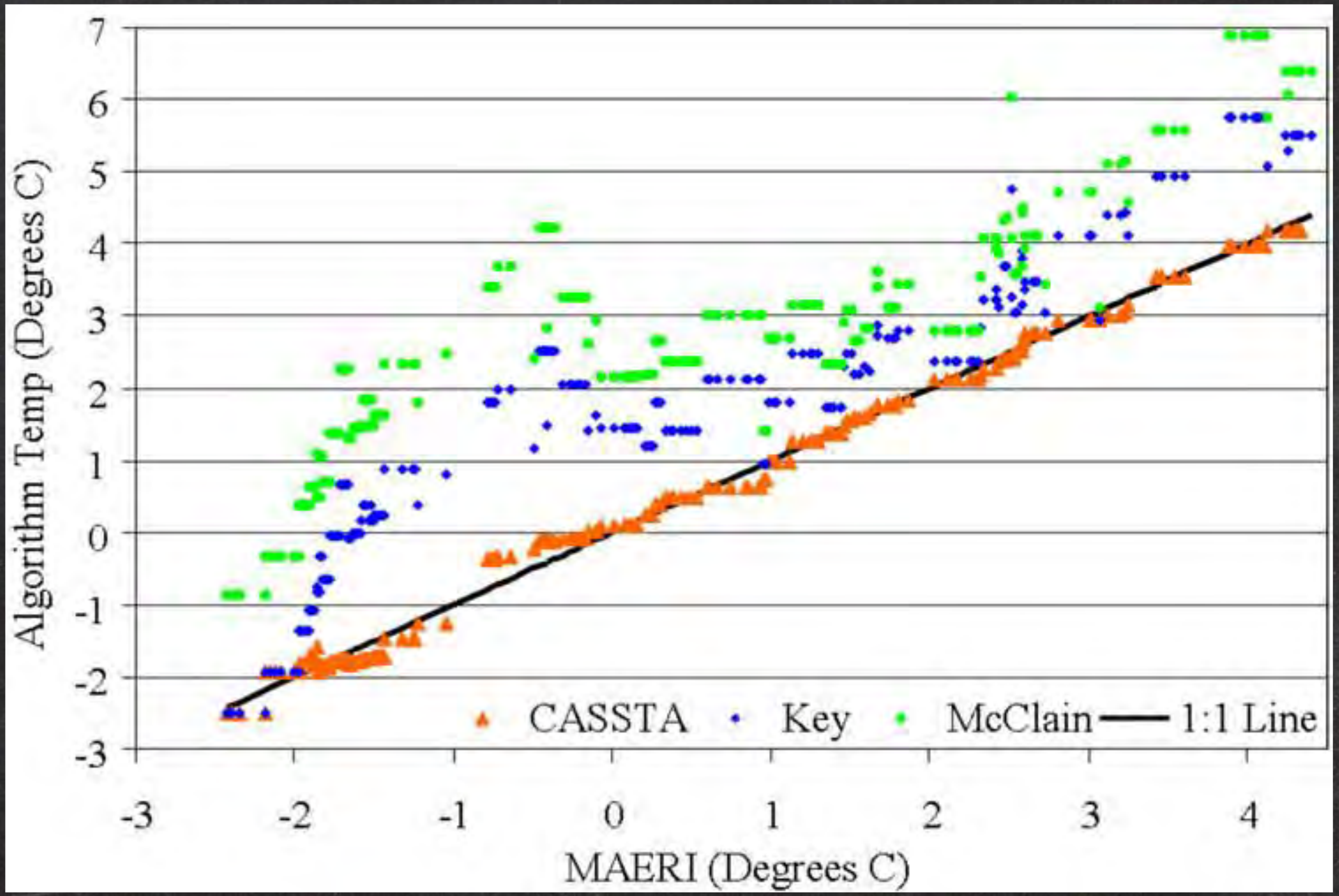
1. Vincent et al., (2008) developed an atmospheric correction algorithm based on single channel brightness temperatures for AVHRR.

2. It was better than the standard split-window algorithm, in their study regime, the North Water polynya.

3. To test the applicability of such single channel algorithm for the whole Arctic, we conducted the same regression:

$$SST_{Arctic} = a + b * T_{11} (or\ T_{12})$$

Single channel SST algorithm, AVHRR



From Vincent, R.F., Marsden, R.F., Minnett, P.J., Creber, K.A.M., & Buckley, J.R. (2008). Arctic Waters and Marginal Ice Zones: A Composite Arctic Sea Surface Temperature Algorithm using Satellite Thermal Data. Journal of Geophysical Research 113, C04021. 10.1029/2007JC004353

Results

Single channel retrieved SST error statistics

Single Channel	11μm			12μm		
	Mean	Median	Std	Mean	Median	Std
Aqua	-0.170	-0.012	0.922	-0.170	0.013	1.099
Terra	-0.170	-0.009	0.931	-0.170	0.025	1.090

Standard NLSST retrieved SST error statistics

Standard NLSST	Mean	Median	Standard Deviation
Aqua	-0.535	-0.475	0.603
Terra	-0.513	-0.455	0.647

Future Work

Derive coefficients for the standard atmospheric correction algorithm using MUDBs for conditions north of 60°N and assess the accuracies of the derived MODIS SST-
See Kilpatrick et al. poster #25

Determine improvements, if any, of including MODIS measurements at other channels in atmospheric correction algorithms using the MUDBs and RTTOV simulations.
To start soon.

Use the fast-radiative transfer model RTTOV to conduct simulations to determine the form of an explicit emissivity term or terms in the atmospheric correction algorithm-
Underway.

Use Optimal Estimation SST retrieval approach.

See Szczodrak & Minnett Poster #40

Thank You！