A Summary of Meteorological Stations and Data Along the Beaufort Sea Coastal Plain

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and Michael Lilly

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*Picture of Cottle Island Met Station,
photo by M. Lilly, September 24, 2010.*

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by

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CONVERSION FACTORS, UNITS, WATER QUALITY UNITS, VERTICAL AND HORIZONTAL DATUM, ABBREVIATIONS AND SYMBOLS

Conversion Factors

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter (mm)
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
Acre	43560	square feet (ft^2)
Acre	0.4047	hectare (ha)
Square foot (ft^2)	$3.587X10^{-8}$	square mile (mi^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (l)
gallon (gal)	3785	milliliter (ml)
Cubic foot (ft^3)	23.317	liter (l)
Acre-ft	1233	cubic meter (m^3)
	Velocity and Discharge	
foot per day (ft/d)	0.3048	meter per day (m/d)
Square foot per day (ft^2/d)	.0929	square meter per day (m^2/d)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/sec)
	Hydraulic Conductivity	
foot per day (ft/d)	0.3048	meter per day (m/d)
foot per day (ft/d)	0.00035	centimeter per second (cm/sec)
meter per day (m/d)	0.00115	centimeter per second (cm/sec)
	Hydraulic Gradient	
foot per foot (ft/ft)	5280	foot per mile (ft/mi)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
	Pressure	
pound per square inch (lb/in^2)	6.895	kilopascal (kPa)

Units

For the purposes of this report, both US Customary and Metric units were employed. Common regulations related to tundra travel and water use on the North Slope, Alaska, uses combinations of both US Customary and Metric units. The choice of "primary" units employed depended on common reporting standards for a particular property or parameter measured. Whenever possible, the approximate value in the "secondary" units was also provided in parentheses. Thus, for instance, snow depth was reported in inches (in) followed by the value in centimeters (cm) in parentheses.

Physical and Chemical Water-Quality Units:

Temperature:

Water and air temperature is given in degrees Celsius (°C) and in degrees Fahrenheit (°F). Degrees Celsius can be converted to degrees Fahrenheit by use of the following equation:

$$°F = 1.8(°C) + 32$$

Snow Water Equivalent (SWE):

Water content of a given column of snow is determined by knowing the depth of the snowpack and density.

$$SWE = d_s * \rho_s / \rho_w$$

where:

d_s = snow depth

ρ_s = snow density

ρ_w = density of water.

Electrical Conductance (Actual Conductivity and Specific Conductance):

In this report conductivity of water is expressed as Actual Conductivity [AC] in microSiemens per centimeter (µS/cm). This unit is equivalent to micromhos per centimeter. Elsewhere, conductivity is commonly expressed as Specific Conductance at 25°C [SC25] in µS/cm which is temperature corrected. To convert AC to SC25 the following equation can be used:

Error! Bookmark not defined. $SC25 = \frac{AC}{1 + r(T - 25)}$

where:

SC25 = Specific Conductance at 25°C, in µS/cm

AC = Actual Conductivity, in µS/cm

r = temperature correction coefficient for the sample, in °C

T = temperature of the sample, in °C

<u>Milligrams per liter (mg/l) or micrograms per liter (µg/l)</u>:
Milligrams per liter is a unit of measurement indicating the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter. For concentrations less than 7,000 mg/l, the numerical value is the same as for concentrations in parts per million (ppm).

<u>Millivolt (mV)</u>:
A unit of electromotive force equal to one thousandth of a volt.

<u>Vertical Datum</u>:
"Sea level" in the following report refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929), a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called *Sea Level Datum of 1929*.

<u>Horizontal Datum</u>:
The horizontal datum for all locations in this report is the North American Datum of 1983 or North American Datum of 1927.

Abbreviations, Acronyms, and Symbols

AC	Actual conductivity
ADOT&PF	Alaska Department of Transportation and Public Facilities
ADNR	Alaska Department of Natural Resources
ASTM	American Society for Testing and Materials
atm	Atmospheres
ATN	Arctic Transportation Networks
BOEMRE	Bureau of Ocean Energy Management, Regulation and Enforcement
C	Celsius (^oC)
cm	Centimeters
DO	Dissolved oxygen
DVM	Digital voltage multi-meter
F	Fahrenheit (^oF)
ft	Feet
GWS	Geo-Watersheds Scientific
in	Inches
kg	Kilograms
km^2	Square kilometers
kPa	Kilopascal
lb/in^2	Pounds per square inch
m	Meters
mg/l	Milligrams per liter
μg/l	Micrograms per liter
mi^2	Square miles
mm	Millimeters
μS/cm	Microsiemens per centimeter
mV	Millivolt
NGVD	National Geodetic Vertical Datum
NRCS	Natural Resources Conservation Service
NWIS	National Water Information System
ORP	Oxygen-reduction potential
ppm	Parts per million
QA	Quality assurance
QC	Quality control
Sag	Sagavanirktok River
SC25	Specific conductance at 25 °C
SWE	Snow water equivalent
UAF	University of Alaska Fairbanks
USACE	U.S. Army Corps of Engineers, Alaska District
USGS	U.S. Geological Survey
WERC	Water and Environmental Research Center
WWW	World Wide Web
YSI	Yellow Springs Instruments

PROJECT NETWORK COOPERATORS

- U.S. Department of the Interior, Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE)
- U.S. Department of Energy, National Energy Technology Laboratory (NETL)
- ConocoPhillips Alaska, Inc. (CPA)
- Bureau of Land Management
- Alaska Department of Natural Resources
- North Slope Borough
- National Weather Service
- Geo-Watersheds Scientific
- Idaho National Laboratory

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A Summary of Meteorological Stations and Data Along the Beaufort Sea Coastal Plain, 2011

INTRODUCTION

The former Minerals Management Service (MMS), currently Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) and the University of Alaska Fairbanks (UAF), Institute of Northern Engineering (INE), signed a Memorandum of Understanding in 2006. As a result of this agreement, BOEMRE transferred five meteorological stations along the Beaufort Sea Coast, Alaska (Figure 1) to INE. The purpose of the Memorandum was the expansion of the data collection network for the North Slope Lakes Project, a research project conducted at that time by the University of Alaska Fairbanks and Geo-Watersheds Scientific (GWS), funded by the Department of Energy (DOE). Three stations, named as Badami, Milne Point – F Pad, and Cottle Island, remained in their original locations, while the other two stations, Northstar Production Island and Endicott, were decommissioned due to site logistics on offshore installations. Data collection at Badami, and Milne Point, began in 2001 and from Cottle Island in 2002 and continued through September 2006, under a previous contract between Hoefler Consulting Group and BOEMRE (Wilcox and Veltkamp, 2007). Under the MOU between the University of Alaska, Fairbanks, Institute of Northern Engineering and Bureau of Ocean Energy Management, Regulation and Enforcement, data collection and station upgrades were continued through 2010. GWS, UAF and the Idaho National Laboratory (INL) are working on the Arctic Transportation Network (ATN) research project, funded by DOE. The project focuses on improving management tools for operating Arctic transportation networks on the Alaskan North Slope. Information collected from these coastal stations is being used in the ATN project for hydrologic, weather, and geotechnical applications.

Data collected by these remote stations is not only valuable for the ATN project team, but also for other research efforts focused, for instance, on off-shore oceanographic studies, model verification, and oil and gas operations. Several other stations are also mentioned in this report to help represent the series of stations operated under the ATN Beaufort Coastal Network. These stations include the Duck Island, F-Pad Tundra, and Alpine area L9312 stations, which are both a lake monitoring and weather station. The data and information from these stations are used for a variety of different applications by various supporting groups in the network. The applications vary from real-time weather conditions for forecasting and traveler weather information, to use in the development of water and tundra-travel management tools. The length of the data records vary with each site, depending on the site history. Some of the sites likely date back to the early development of the Prudhoe Bay, Badami, and Kuparuk operating fields and were likely focused on early design and permitting objectives at the time of development.

REPORT OBJECTIVES

This report constitutes the final project report, under contract # M07PX13228 between UAF and BOEMRE. BOEMRE provided valuable supporting resources through this effort, which contributed to the continued operations of the network stations. These efforts were in coordination with the ATN project. The emphasis of this report is the conveyance of quality controlled meteorological data to BOEMRE from these stations, which is provided in Appendix A in electronic format. The data follows a Microsoft Access database format. Data analysis is not an objective of the present report, though some selected discussion is provided. As a secondary objective, this document also constitutes a status report for other supporting network parties.

GENERAL OVERVIEW OF METEOROLOGICAL STATIONS

The meteorological stations in the Beaufort Coastal Network were all started from a variety of different objectives. Many references to existing data stations on the North Slope include stations that may only have short periods of record. The stations discussed in this report do not include other types of important agency or university stations in the region. Some of the stations are operated by university projects that will vary in duration from only a year or two, to long-term stations that are part of International networks such as the Circumpolar Active Layer Monitoring (CALM) network. The stations typically collect shielded air temperature, relative humidity, wind speed and wind direction. Some stations may additionally collect barometric pressure, solar radiation, snow depth and summer precipitation (shielded or unshielded). It is also common for stations used for watershed analysis, tundra travel management, or permafrost studies to collect soil temperature and moisture profiles.

The stations discussed in this report and within the database include from east to west; Badami, Duck Island, Cottle Island, F-Pad and L9312 (Figure 1). The F-Pad (Milne Point) site currently includes the station on the Pad, and a newer station (F-Pad Tundra) is located adjacent to the pad on the tundra. The locations of the stations are reported in Table 1. These stations cover a region from just east of the Shaviovik River (Badami) to the Colville Delta (Alpine L9312). This is also the central coastal region of the southern Beaufort Sea (Figure 1). Most of these stations are in the active oil field areas and could not be accessed without coordination with the appropriate field operators.

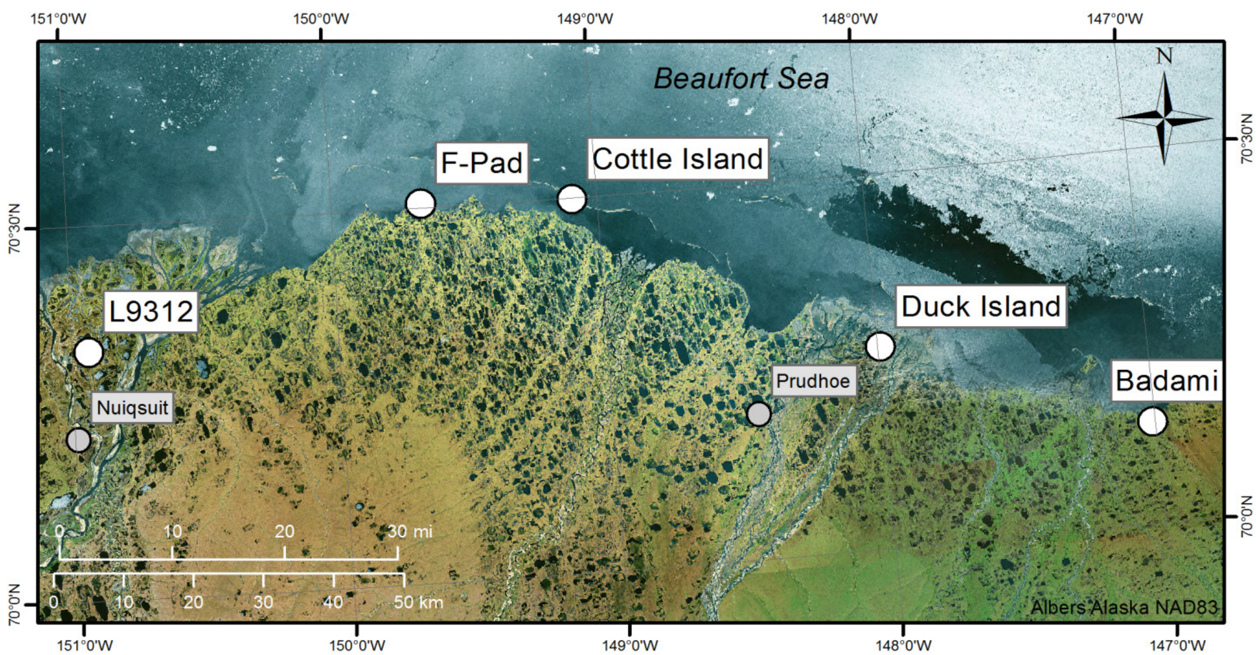

Figure 1. Map of Beaufort Sea Coastal Plain with Meteorological Stations.

There are a number of stations further inland that are part of the ATN project and other data networks operated by the UAF Water and Environmental Research Center. Information from these stations can currently be accessed at the following project websites;

- Arctic Transportation Networks Project: http://www.arctic-transportation.org
- Umiat Hydrology Project: http://ine.uaf.edu/werc/projects/foothills/foothills.html
- Kuparuk Watershed Studies: http://ine.uaf.edu/werc/projects/NorthSlope/northslope.html
- NPR-A Hydrology Data Network: http://ine.uaf.edu/werc/projects/npra-hydrology/

The USGS also maintains several surface-water stations in the region. The National Weather Service and FAA also have stations at Deadhorse and Nuiqsut. The National Resource Conservation Service maintains two SNOTEL sites in the region, but they are not on telemetry. An additional source of information is the Alaska Ocean Observing System, which lists certain data networks run by other organizations over the state of Alaska. These resources can be accessed at the below websites;

- SNOTEL Network Information: http://www.wcc.nrcs.usda.gov/snotel/Alaska/alaska.html
- National Weather Service Listing: http://www.arh.noaa.gov/obs.php
- Alaska Ocean Observing System Data Portal: http://data.aoos.org/maps/sensors/

Table 1. Meteorological station coordinates.

Station Name	Latitude (DD MM.MMM)	Longitude (DDD MM.MMM)	Latitude (DD.DDDDD)	Longitude (DD.DDDDD)
L9312 (ALPINE)	70 19.982N	150 56.181W	70.33303	-150.93635
F-Pad (Milne Point)	70 30.402N	149 39.725W	70.50670	-149.66208
Cottle Island	70 29.920N	149 05.571W	70.49867	-149.09285
Duck Island	70 16.191N	147 59.262W	70.26985	-147.98770
Badami	70 08.171N	147 00.522W	70.13618	-147.00870

*all coordinates in WGS84

STATION HISTORIES

This section discusses a brief history for each of the stations shown in Table 1. Future efforts in collaboration with other regional data analysis projects will continue to improve the historical information for these and other sites. There are very few long-term stations on the North Slope and it is common for some stations to have started for one series of objectives, which then changed over time as various sources of funding where used to help continue the operations of the stations.

BADAMI METEOROLGICAL STATION

The Badami station is located on the northeast corner of a working pad just south of the Badami airfield. The station has been operated under a variety of projects going back to the early development of the Badami facility. The most recent station was established in January, 2001 by Hoefler Consulting Group, for MMS. They supported the station through September 2006. Ownership and support of the station was then transferred to UAF and is currently operated by the ATN project. During 2009 and 2010 a collocated station was operated by AECOM for air quality. The current primary purpose of this station is basic weather information.

DUCK ISLAND METEROLOGICAL STATION

The Duck Island Station was installed on Duck Island in 2009 along the Endicott access road. Duck Island is just seaward of the Sagavanirktok River Delta. The station was located at a point where a pull-off allowed safe access and meteorological conditions and snow cover conditions could both be measured for applications to tundra travel management. The current primary purposes of this station are tundra travel management information and basic weather information.

COTTLE ISLAND METEROLOGICAL STATION

The steel tower on Cottle Island pre-dates the installation of the MMS meteorological equipment in August 2002 by Hoefler Consulting Group. Hoefler Consulting Group maintained and collected meteorological data from the Cottle Island Station through September 2006. Ownership of the Cottle Island Station was transferred over to UAF in 2006. It is located on the south side and near the east end of the island. The station area is a frequent polar bear denning location. The current primary purpose of this station is for tundra travel management information and basic weather information.

F-PAD (Milne Point) METEROLOGICAL STATION

The F-Pad meteorological station is composed of two stations. The original station is located on the pad on top of the existing piping infrastructure at an elevation of 11 meters. The second newer station is located just east of the pad on the natural tundra surface. The second station was installed to help measure snow depth, wind speed conditions at a lower elevation, and soil

conditions. The station on top of the pad was established under the original MMS installation in January 2001 and includes the data collection for wind speed, wind direction, shielded air temperature, relative humidity, and solar radiation. The original data from this station can be found within OCS Study MMS 2007 – 011 located at
http://www.alaska.boemre.gov/reports/2007rpts/akpubs07.HTM

L9312 (ALPINE) METEROLOGICAL STATION

The L9312 station was originally started as a lake monitoring station and then added to also collect meteorological information. The station began collecting data in March 2006. The station is located on the western side of the lake, just north of the Alpine facility pump house. The station data collection includes air temperature, wind speed and direction, summer precipitation, snow depth, lake water levels and temperature.

DATA PROCESSING PROCEDURES

The following data processing procedures represent the current general practices used for the stations discussed in this report. All of the network stations, except Badami, have data retrieved on an hourly schedule via radio telemetry from the station to a series of local base stations. Local data servers in Fairbanks are used to retrieve data from the data stations via the Internet, where it is then made accessible on various public websites or internal servers. Data from Badami are currently manually retrieved during annual site visits. Additional data from the Badami Station are included in Appendix A from a co-located station run by AECOM for Shell Exploration and Production Co. (AECOM, 2010, 2011). Data procedures and quality control for these Badami data sets are described in the referenced reports. Data was evaluated for quality assurance and quality control (QA/QC) processing prior to electronically transferring the data to BOEMRE for incorporation into their meteorological databases.

There are a number of challenges inherent to the operation of Automated Weather Stations (AWS) in Arctic conditions. Those challenges range from sensor inaccuracies in extreme cold conditions to the physical effects of ice and snow build-up on instruments. Such conditions frequently create circumstances under which automated QA/QC would require complex algorithms and would still need to be monitored by staff for accuracy. Because of the overall comparatively low data volume, we chose to rely on manual QA/QC methods performed by experienced staff.

Comma separated ASCII station meteorological data were imported into Microsoft Excel where the following operations were performed:

- Missing value codes such as 7999 are generally used to represent missing values. Missing value codes are not used by the BOEMRE database format, so a final processing step removed these codes for the final files created for the BOEMRE database format (Appendix A.). Unless otherwise stated data that have been removed from the data set due to QA/QC processing has been replaced by a blank cell in Excel which for BOEMRE purposes is equal to NODATA.
- Generally out-of-range data such as unrealistic spikes in data values or clearly erroneous data values such as NAN were removed from the data.
- Data for each sensor was graphed in Excel to assist in identifying potential data issues. Graphing was especially helpful in identifying out-of-range data or other discontinuities as well as comparing primary to backup sensor data values.
- Relative humidity (RH) values greater than 100% were identified via an Excel cell formula. If found, those values were removed. For some sites, data collection programs automatically adjusted RH values between 100 and 108 to 100 following Campbell Scientific Inc. (manufacturer) recommendations.
- Data values for wind speed and wind direction were carefully observed to identify times when the anemometer iced up and froze in place. Such anemometer outages are common occurrences at Arctic AWS and do not indicate a problem with design or implementation of the station. Once conditions change and the anemometer thaws it returns to normal service. Occasionally, there can be multiple freeze/thaw cycles affecting the anemometer, but ordinarily this issue is limited to a few consecutive days to weeks in mid-Winter. It should be noted that ice and snow conditions can impact anemometers before and after total freeze-up in ways that cannot be detected without redundant sensors or frequent manual or camera observations of the sensors.

- Data users should be aware that the same ice build-up that temporarily affects the anemometer may also affect the solar radiation measurement; however, no solar radiation data have been removed from the data set based on possible sensor icing.

Once data were reviewed by project staff, data sets were processed into the required BOEMRE data formats. Appendix B lists the Metadata for the data sets provided in Appendix A.

SELECTED RESULTS

The purpose of this section is to present selected portions of the data to help show some of the climate differences across the region. More detailed applications of the data are reported by those projects and groups that are ongoing or future data users. Two of the current projects using this data at the time of this report include the Arctic Transportation Networks Project (www.arctic-transportation.org) and the Beaufort/Chukchi Seas Mesoscale Meteorology Modeling Study (mms-meso.gi.alaska.edu). The National Weather Service regional forecasters also use the online information for short term forecasts on a daily basis.

The wind speed conditions for 2010 along the central Beaufort Sea coast are shown for three stations in Figure 2, Figure 3, and Figure 4. These data display local differences in the wind speed conditions, relative to where they are located along the coast. Some of these differences are related to the relative height of the sensors to the surrounding terrain. The figures prominently display the variation in wind direction between the three sites. An example of the 2010 air temperature differences is shown in Figure 5. The regional trends are fairly consistent across the different sites. One of the applications of this data is oil field operations. Wind chill factors, calculated from a combination of wind speed and air temperature, are commonly used to determine different levels of activity that is safe for field workers. While the air temperature conditions are more uniform across the sites, the wind chill conditions will be more variable due to the differences in wind speed conditions.

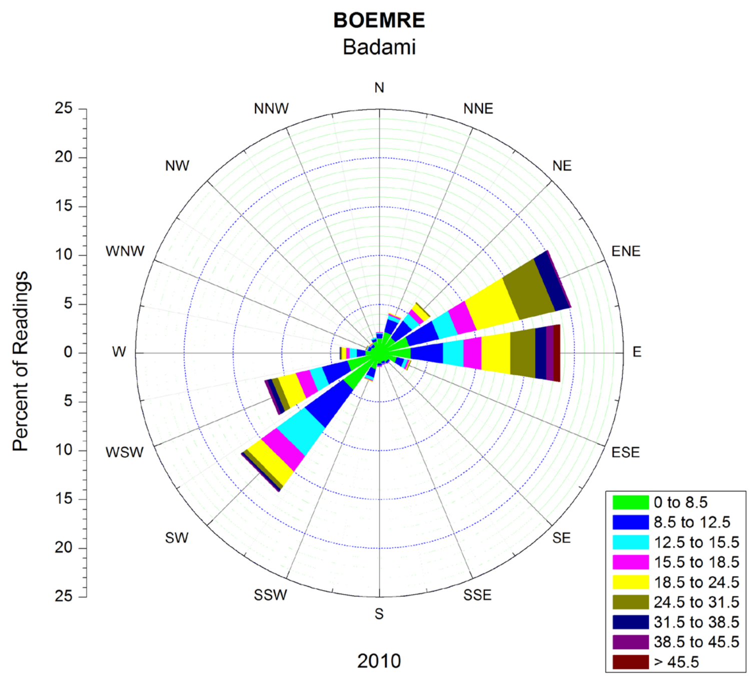

Figure 2: Badami hourly wind conditions 2010

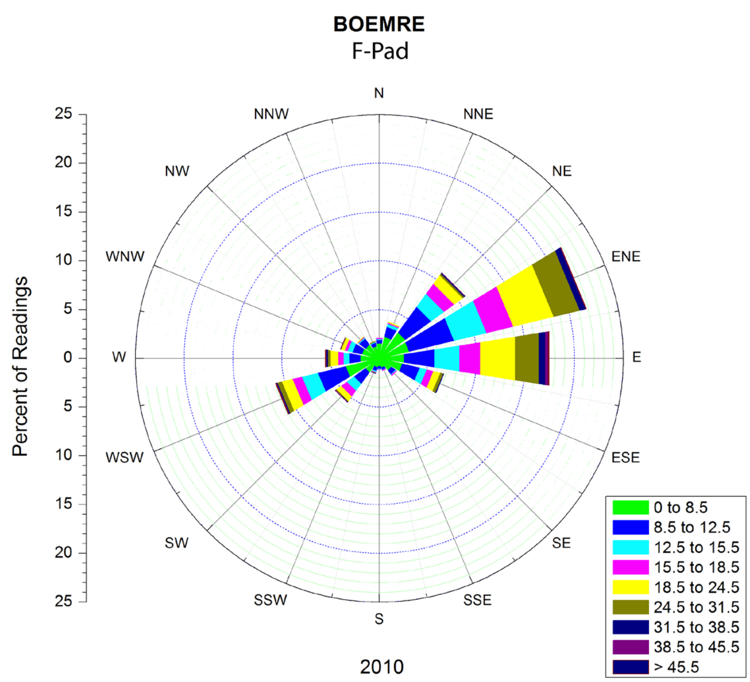

Figure 3: F-Pad (Milne Point) hourly wind conditions 2010

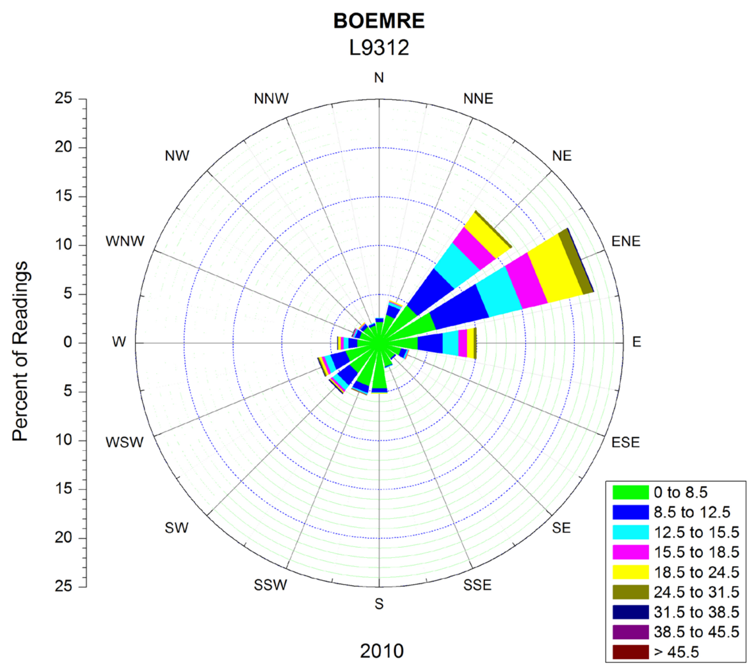

Figure 4: L9312 (ALPINE) hourly wind conditions 2010

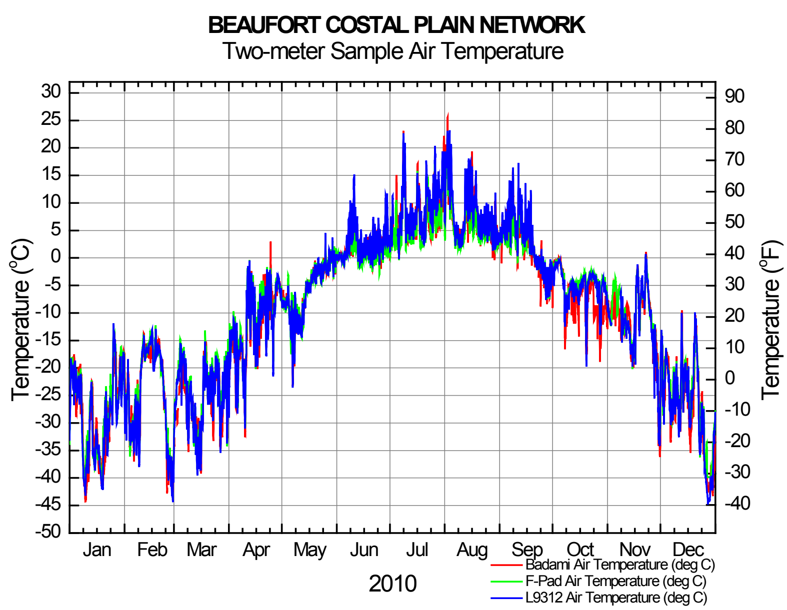

Figure 5. Air temperature conditions for Badami, F-Pad, and L9312 stations.

SUMMARY AND RECOMENDATIONS

The network of stations covered by this report covers a wide operational area and depends on a number of supporting projects, and logistical support from oil field operators. Primary data-collection objectives at each station and over time have varied with funding sources. The operation of the stations and resulting data quality are affected by three main issues; arctic weather conditions, site access logistics, and sensor technology changes. Based on the experience gained during the last four years, meteorological stations located in remote and extreme areas in Alaska require adequate funding to cover costs associated with station visits, preventative maintenance, operation, data communication (telemetry) and regular quality control data processing. Additionally, the needs of multiple data uses, such as current conditions and regional climate analysis, need to be part of the operational designs for current and future stations to maintain a collaborative base of support from the multiple organizations and stakeholders along the Beaufort Coastal Network.

The success of a network of stations along the Beaufort Coast requires the convergence of multiple factors which include adequate economic and logistic support. The need for improved data in this region has been identified as one of the emerging issues on the North Slope (Science Technical Advisory Committee, 2009). Economic support needs to include State and Federal Agencies, as well as private companies. Logistic support along the Arctic Coast mainly comes from oil companies and regulatory agencies operating in that area. The contributions of BP Exploration Alaska, ConocoPhillips Alaska, and Shell for field logistical support and data sharing are acknowledged and serve as good examples of industry support. The nature of field operations, extreme climate conditions and safety goals requires a cooperative environment with industry.

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Science Technical Advisory Panel, 2009. Emerging Issue Summaries. North Slope Science Initiative. October 8, Revised December 1, 87 p.

APPENDIX A. DATA CD DESCRIPTION

This final report contains a CD with selected data sets following the required BOEMRE data transfer formats. The BOEMRE data requirements were met by creating a Microsoft Access database with specific field names to match existing BOEMRE databases. Processing data to BOEMRE-required format was done in Microsoft Excel where some data sources present in the original data were removed. Those data sources, such as the battery voltage and solar panel temperature, are of operational importance and can assist in QA/QC efforts but were not required by BOEMRE. The Excel data was imported into Access, the database was appropriately named to reflect which station the data belongs to, and the database was saved in legacy format (Access 2003) to create the MDB file output. Table 2 describes the Access database column headers.

Table 2: Access database header description

Field Name	Data Type	Units	Sampling
Date Sampled	datetime	n/a	Hourly
StationID	integer	n/a	n/a
Wind Speed	float	m/s	hourly average
Wind Direction	float	degrees	hourly average
Wind Sigma	float	degrees	hourly average
Temp	float	C	hourly average
Backup Temp	float	C	hourly average
Barometric Pressure	integer	mbar	hourly average
Solar Radiation	float	W/m2	hourly average
High Temp	float	C	hourly extreme
Low Temp	float	C	hourly extreme
Humidity	float	%	hourly average
Max Wind Speed	float	m/s	hourly extreme

APPENDIX B. STATION METADATA

FGDC compliant metadata for each station data file is included in the digital distribution of the data under the following file names:

- boemre_0462011_badami_meta.xml for Badami
- boemre_0462011_cottle_meta.xml for Cottle Island
- boemre_0462011_duck_meta.xml for Duck Island
- boemre_0462011_fpad_meta.xml for F-Pad (Milne Point)
- boemre_0462011_l9312_meta.xml for L9312 (ALPINE)