Alaska Department of Transportation & Public Facilities
Alaska University Transportation Center

Alaska Road Weather Project

Technical Performance Assessment Report

Fairbanks Field Demonstration 2013-2014

Mike Chapman
National Center for Atmospheric Research
Seth Linden
National Center for Atmospheric Research
Crystal Burghardt
National Center for Atmospheric Research

February 2014

Alaska University Transportation Center
Duckering Building Room 245
P.O. Box 755900
Fairbanks, AK 99775-5900

Alaska Department of Transportation
Research, Development, and Technology Transfer
2301 Peger Road
Fairbanks, AK 99709-5399

INE/ AUTC 15.01

ST-0106(15)

REPORT DOCUMENTATION PAGE			Form approved OMB No.
Public reporting for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestion for reducing this burden to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-1833), Washington, DC 20503			
1. AGENCY USE ONLY (LEAVE BLANK) ST-0106(15)	2. REPORT DATE January 2015	3. REPORT TYPE AND DATES COVERED Final Report 05/01/12 – 05/01/13	
4. TITLE AND SUBTITLE Alaska Road Weather Project: Technical Performance Assessment Report Fairbanks Field Demonstration 2013-2014			5. FUNDING NUMBERS Alaska DOT&PF: ST-0106(15) AUTC: RR12.01
6. AUTHOR(S) Mike Chapman, National Center for Atmospheric Research Seth Linden, National Center for Atmospheric Research Crystal Burghardt, National Center for Atmospheric Research			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) National Center for Atmospheric Research (NCAR) P.O. Box 3000 Boulder, Colorado 80307			8. PERFORMING ORGANIZATION REPORT NUMBER INE/AUTC 15.01
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) State of Alaska, Alaska Dept. of Transportation and Public Facilities Research and Technology Transfer 2301 Peger Rd Fairbanks, AK 99709-5399			10. SPONSORING/MONITORING AGENCY REPORT NUMBER ST-0106(15)
11. SUPPLENMENTARY NOTES			
12a. DISTRIBUTION / AVAILABILITY STATEMENT No restrictions			12b. DISTRIBUTION CODE
13. ABSTRACT (Maximum 200 words) The Alaska Department of Transportation and Public Facilities began implementation of a Maintenance Decision Support System in an effort to improve snow and ice control in the Fairbanks area. As part of the project the reliability of the weather forecast models were evaluated by comparing the forecast with the actual weather records. In general, the models were fairly accurate, but some bias was detected in the air and pavement temperatures and the dew point. All analysis used a 95% confidence level. The predicted air temperatures tended to be about -3º F between November 1, 2013 and March 30, 2014. The pavement temperature had a bias depending on the time of day and increasing as the forecast time lengthened. In the near term there was a slight warm bias. Beyond 12 hours there was a consistent cold bias of about 3ºF. The dew point predicted temperature had a small bias of about 1ºF.			
14- KEYWORDS : Anti-icing(Fmbsb), Deicing(Fmbsd), Snow and ice control(Fmbs), Winter maintenance(Fmbw)			15. NUMBER OF PAGES 18
			16. PRICE CODE N/A
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT N/A

ACKNOWLEDGEMENTS / CREDITS

The development of MDSS concepts and the functional prototype is a team effort involving several U.S. national laboratories. The current MDSS development team at NCAR consists of several scientists and software engineers including Mike Chapman, Jim Cowie, Seth Linden, Gerry Weiner, Paddy MacCarthy, Crystal Burghardt, and Amanda Anderson.

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

National Center for Atmospheric Research (NCAR):

Michael Chapman
Seth Linden
Crystal Burghardt

Questions and comments about this document should be directed to the primary author of this report:

Mr. Michael Chapman
Research Applications Laboratory
National Center for Atmospheric Research
P.O. Box 3000
Boulder, CO 80307
Ph: 303-497-8395
E-mail: mchapman@ucar.edu

1 PURPOSE

The technical performance results of the prototype Maintenance Decision Support System (MDSS) from the winter 2013-2014 Fairbanks field demonstration are described in this document. The time period covered the analyses in this report was 01 January 2013 to 20 January 2014. Several different aspects of the MDSS are discussed including bulk statistics on its forecast performance for air temperature, dewpoint temperature, wind speed, and pavement temperature during the entire field demonstration. Verification of mobile observations and specific cases for the evaluation of precipitation will follow this evaluation as an addendum to this report.

2 BACKGROUND

This MDSS Project is part of a federal procurement for research projects and deployment advocacy, which is funded primarily through the U.S. DOT Intelligent Transportation Systems (ITS) Joint Program Office (JPO).

It is anticipated that components of the prototype MDSS developed by this project will be enhanced, integrated with other operational components, and deployed by road operating agencies, including state DOTs and commercial airports, and generally supplied by commercial weather service providers.

3 RELATED DOCUMENTS

For additional information on the MDSS Project, the reader is directed to the related project documents and web sites listed in Table 4.1.

Table 4.1. MDSS Project Related Documents

Document and/or Web Sites	Primary Source
STWDSR– Version 1.0 (User Needs Analysis): http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/9dc01!.pdf	Federal Highway Administration
STWDSR– Operational Concept Description (OCD): Version 2.0 http://www.itsdocs.fhwa.dot.gov/jpodocs/EDLBrow/401!.pdf	Federal Highway Administration
Maintenance Decision Support System (MDSS) Release-5.0 Technical Description, Version 1.1 Dated 15 November 2007: http://www.ral.ucar.edu/projects/rdwx_mdss/documents/MDSS_Tech_Description_15Nov2007.pdf	National Center for Atmospheric Research

Maintenance Decision Support System (MDSS) Project Web Site at FHWA: http://ops.fhwa.dot.gov/weather/mitigating_impacts/programs.htm#3	Federal Highway Administration
Maintenance Decision Support System (MDSS) Project Web Site at NCAR: http://www.rap.ucar.edu/projects/rdwx_mdss/index.html	National Center for Atmospheric Research

4 METHODS

This document provides prototype MDSS results from the Fairbanks 2013-2014 MDSS field demonstration. Objective analyses of the weather forecasts were performed. In addition, analyses of the road temperature model and mesoscale weather model components are provided.

Surface weather observation quality from standard road weather information systems was assessed in 2003 via coincident observations of state and road parameters (Bernstein et. al. 2003). Differences apparent in the observations themselves set an acceptable threshold of deviation of the forecast from the observations, or a lower bound for the accuracy one can expect from the MDSS forecasts; for if the observations can only be measured within a certain tolerance, then differences between such observations and the MDSS forecasts are attributable to uncertainty in the observations themselves.

Objective verification is achieved via direct comparisons of MDSS forecasts to reliable observations from National Weather Service and roadside Environmental Sensor Stations. These results are presented through diagrams of root mean squared error (RMSE) and bias for state parameter fields (e.g. air temperature, dew point, and wind speed) and road and bridge temperatures.

5 MDSS SYSTEM CONFIGURATION

All of the MDSS core technical components were operated centrally at NCAR in Boulder. A server at NCAR communicated (via the Internet) with local PCs running the display application at the Fairbanks office of the Alaska DOT.

The Road Weather Forecast System (RWFS) is tasked with ingesting reformatted meteorological data (observations, models, statistical data, climate data, etc.) and producing meteorological forecasts at user-defined forecast sites and forecast lead times. The forecast variables output by the RWFS are used by the Road Condition and Treatment Module (RCTM) to calculate the road surface temperature and to calculate a recommended treatment plan. In order to achieve this goal, the RWFS generates independent forecasts from each of the data sources using a variety of forecasting techniques.

A single consensus forecast from the set of individual forecasts is provided for each user-defined forecast site based on a processing method that takes into account the recent skill of each forecast module. This consensus forecast is nearly always more skillful than any component forecast. The RWFS is designed to optimize itself using available site observations along or near the routes (e.g., RWIS, METARS). The forecast modules that perform the best are given more weight over time. In addition, Dynamic Model Output Statistics (DMOS) are calculated weekly using observations and model output. The DMOS process is used to remove model biases. The optimization period of the RWFS is approximately 90-100 days.

7 DATA - Verification

Data Sources: Weather Observations

The following weather observation data sources were used for verification and analysis:

a) Alaska DOT RWIS
b) NWS ASOS/AWOS

8 OVERALL PERFORMANCE RESULTS

In this section, performance results are described for the winter 2013-2014 Fairbanks field demonstration for specific components of the MDSS. Bulk statistics based on the weighted average root mean square error (RMSE) and bias (forecast minus observation) are calculated. The statistics were calculated for RWIS sites in and around Fairbanks. The weighted average RMSE is calculated in the following manner: for each lead-time, RMSE is calculated for each site and then weighted based on the total number of valid errors for that site. The RMSE values (for each site) are then summed over all sites and divided by the sum of the errors for each site. The average bias over all sites was also computed. The results of those statistics are simply interpreted as any negative results indicates a forecast that is colder than observed (negative bias) and vice versa.

8.1 RWFS Forecast Modules

The RWFS was configured to utilize and integrate four different forecast modules for the winter 2008-2009 demonstration. Numerical Models that were ingested into the RWFS included the North American Model (NAM), Global Forecast System (GFS; formerly called the Aviation Model by the NWS) and Rapid Refresh (RAP). Aviation Model Output Statistics (MAVMOS), Localized Aviation MOS Program (LAMP), and NAM/MET MOS were also used as input. Dynamic Model Output Statistics (DMOS) were calculated within the RWFS for each of the model inputs. The four weather forecast modules that were used to predict the weather parameters for each MDSS forecast point were:

1) GFS DMOS
2) LAMP MOS
3) MET MOS
4) NAM DMOS
5) RUC DMOS
6) RAP DMOS

The RWFS integration process independently optimized the forecasts based on recent skill at each prediction site for each parameter and forecast lead time, except for precipitation. Forecast modules with the most skill get more weight in the RWFS integration process that generates the consensus forecast. More information on the RWFS can be found in the MDSS Technical Description (see Table 4.1 for reference information).

The RWFS also applied a Forward Error Correction (FEC) scheme, which is used to ensure that the forecasts produced by the RWFS more accurately reflect the current conditions in the near term. The forecasts valid at the current time are forced to match the available observations. Then, in the first forecast hours, the forecast time series is forced to trend toward and blend seamlessly into the RWFS consensus forecast.

8.2 Overall Performance of the Road Weather Forecast System

The RWFS consensus forecast was compared to the forecasts from the individual models included in the ensemble in order to discern whether the RWFS statistical post processing methods and techniques added value (e.g., increased skill).

<u>Error Analysis</u>

Bulk statistics were computed for the six individual models listed in section 8.1 and the RWFS final consensus forecast for three meteorological variables (air temperature, dew point temperature and wind speed). The results are based on average RMSE and bias per lead time (out to 72 hours) of forecasts initiated at 12 UTC for the entire season (01 January 2013 to 20 January 2014).

For all three variables, the RWFS performed well with the consensus forecasts having lower RMSE values compared to the individual forecast module components for all lead times (Figs. 8.1-8.3). Forward Error Correction (FEC), which is applied to all the verifiable variables (variables that have corresponding observations), reduces the RMSE within the first three hours.

The reduction in overall error provided by the consensus forecast is most evident for air temperature and dew point temperature. In general, there is a more pronounced difference in skill (i.e. larger spread among the forecasts) between the final consensus forecast and its components for air temperature and dew point temperature than for wind speed (Figs. 8.1 and 8.2).

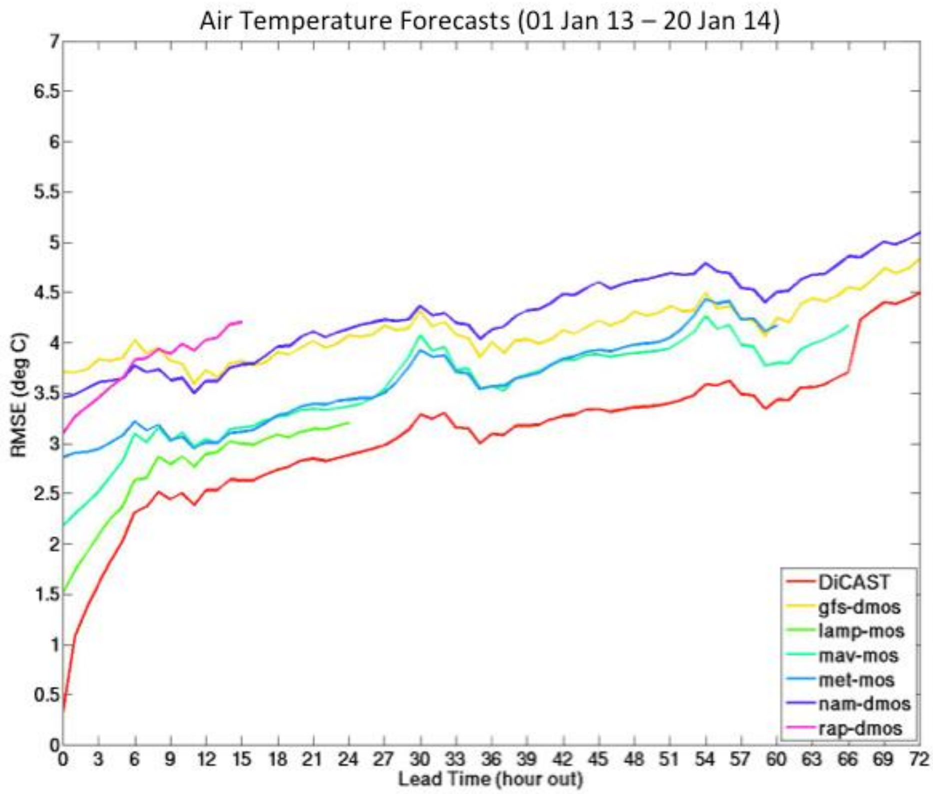

Fig. 8.1: Weighted average air temperature RMSE computed from the 12 UTC forecasts for the entire demonstration season (01 January 2013 – 20 January 2014). The consensus forecast (red line) and the individual forecast module components for the Alaska RWIS sites are shown.

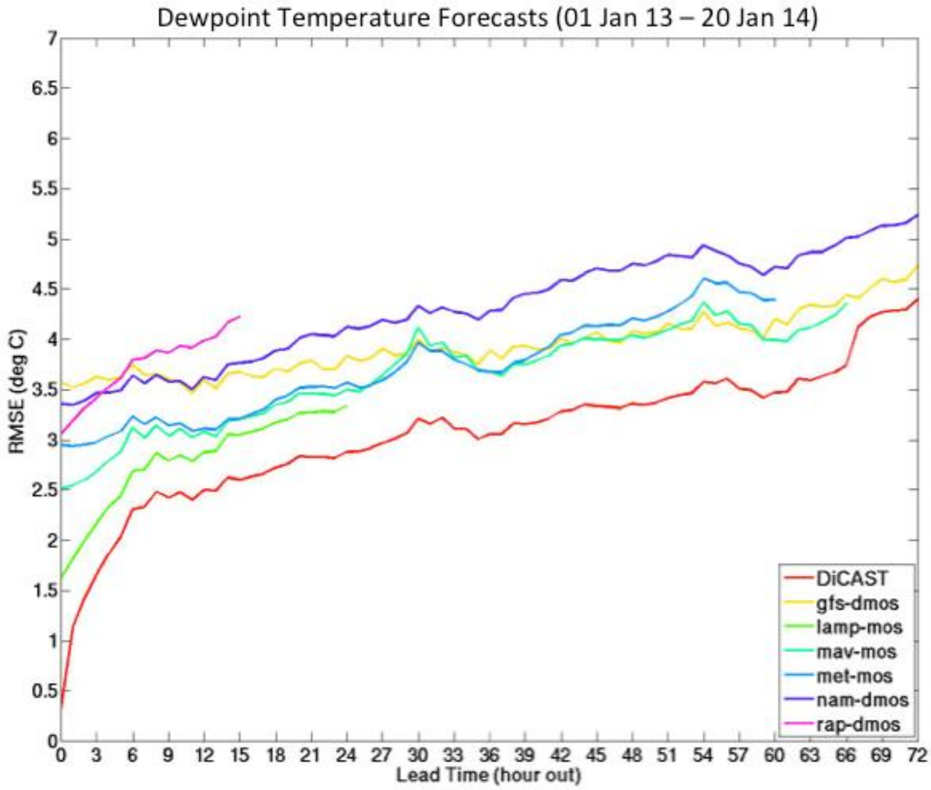

Fig. 8.2: Weighted average dew point temperature RMSE computed from the 12 UTC forecasts for the demonstration season (01 January 2013 – 20 January 2014). The consensus forecast (red line) and the individual forecast module components for the Alaska RWIS sites are shown.

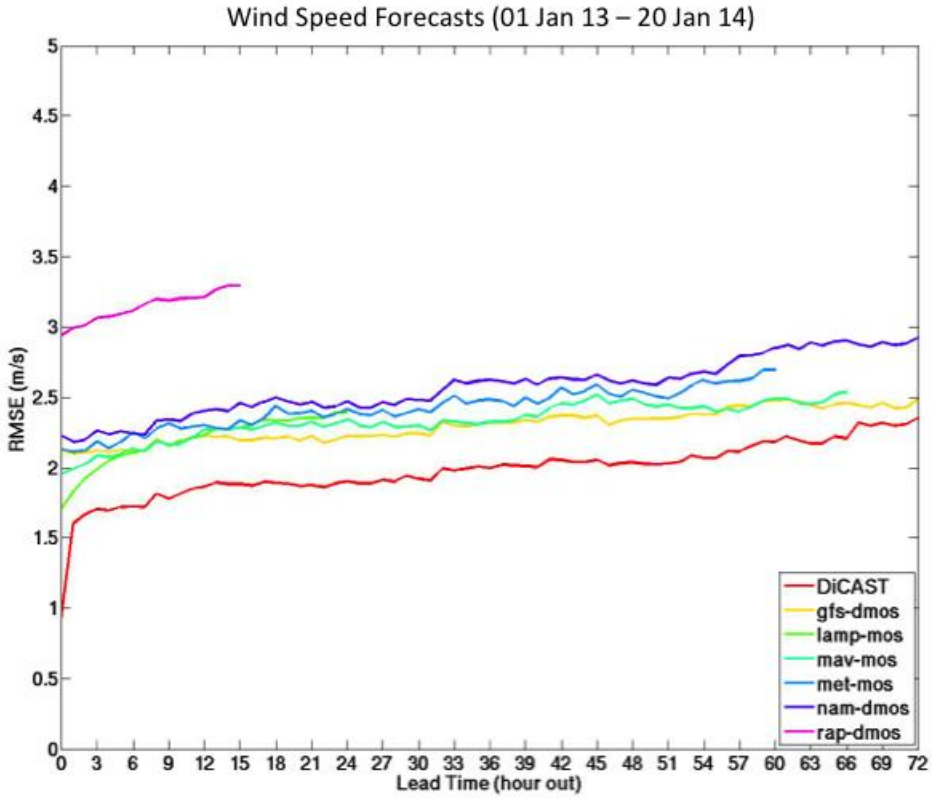

Fig. 8.3: Weighted average wind speed RMSE computed from the 12 UTC forecasts for the entire demonstration season (01 January 2013 – 20 January 2014). The consensus forecast (red line) and the individual forecast module components for the Alaska RWIS sites are shown.

Results Summary: The statistical methods and techniques utilized by the RWFS do improve the predictions on average for all verifiable parameters. It is clear from the analyses that no single model performs better for all parameters; although the LAMP appears to stand out slightly as have better accuracy overall. For all three of these parameters, the consensus forecast (DiCast) outperformed every individual component forecast for every variable.

Bias Analysis

Bias was examined separately for the consensus forecast over every lead time. Overall, the RWFS exhibits no significant bias for the three meteorological state variables examined (Figs. 8.4-8.6). There is a slight wet bias in dew point over almost all of the lead times and small positive bias in wind-speed.

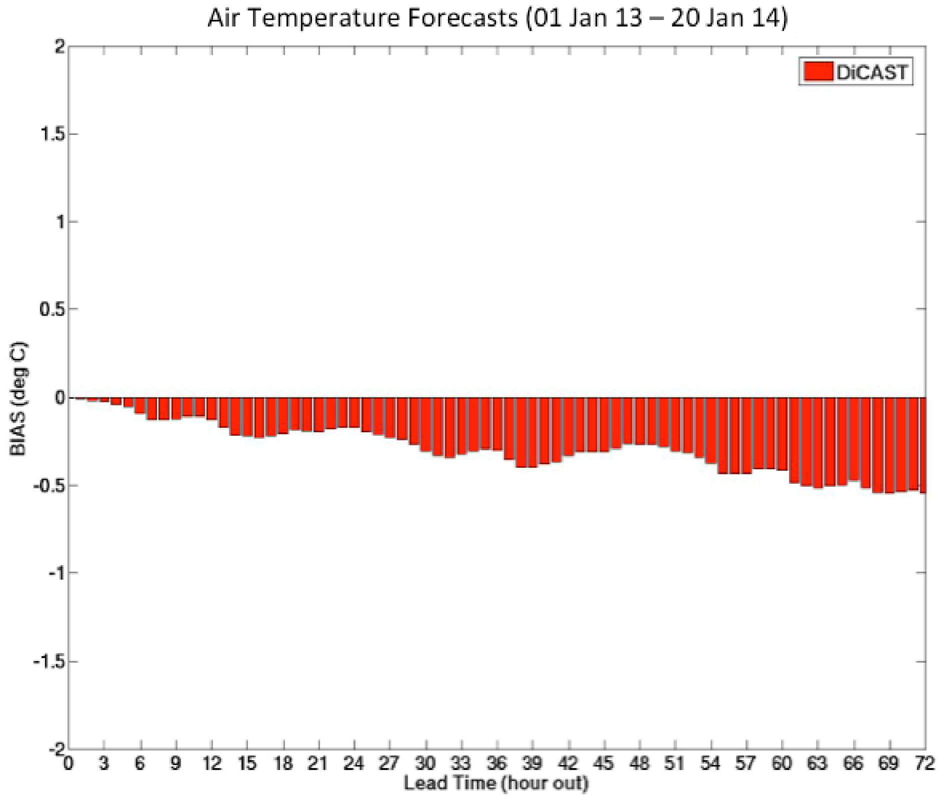

Fig. 8.4: Weighted average air temperature bias computed from the 12 UTC RWFS output for the entire demonstration season (01 January 2013 – 20 January 2014) for the Alaska RWIS sites.

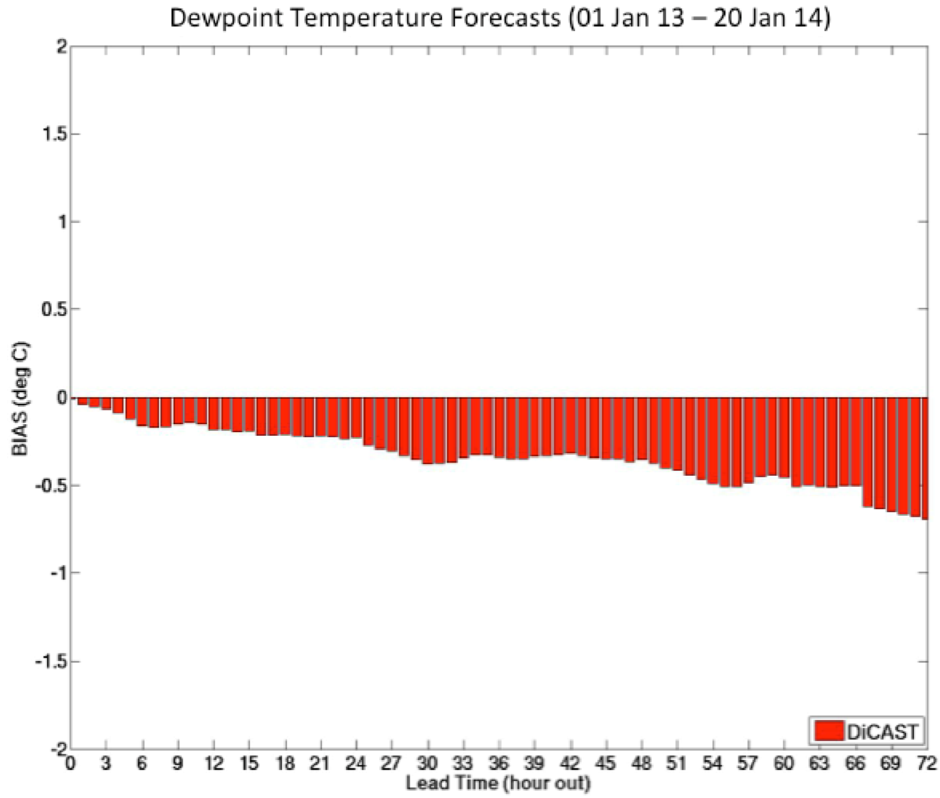

Fig. 8.5: Weighted average dew point temperature bias computed from the 12 UTC RWFS output for the entire demonstration season (01 January 2013 – 20 January 2014) for the Alaska RWIS sites.

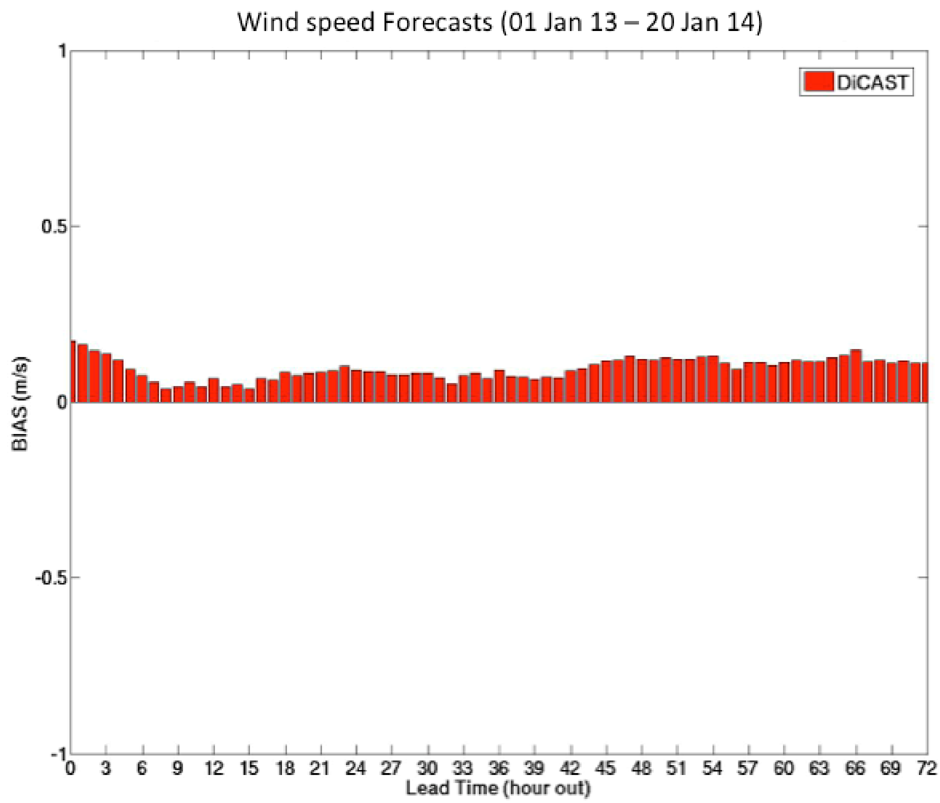

Fig. 8.6: Weighted average wind speed bias computed from the 12 UTC RWFS output for the entire demonstration season (01 January 2013 – 20 January 2014) for the Alaska RWIS sites.

<u>Results Summary</u>: The RWFS exhibits a slightly cold bias for temperature (but less than 0.5°C), a small wet bias for dewpoint (also less than 0.5°C for most of the period) and a slight over-forecast of wind speed during the 2013 - 2014 season. These results are promising because they indicate that the consensus forecast is reasonably tuned for Alaska.

8.3 Overall Performance of the Pavement Temperature Module

This section examines the road temperature forecasts using recommended treatments as determined within the MDSS Road Condition and Treatment Module (RCTM). Measurement differences between the predictions and pavement sensors were used to calculate median absolute error (RMSE) and average bias (forecast minus observation) per lead time (e.g., 1-hr to 48-h) for 12 UTC forecasts generated over the entire season (01 January 2013 – 20 February 2014).

The road temperature RMSE (Fig. 8.10) ranges from around 1.0-5.5°C for this analysis. There is no diurnal variability evident in these results, which is different than the results for the same model in the lower 48 states of the US. There is a very consistent cold bias evident in the over all lead times (Fig. 8.8).

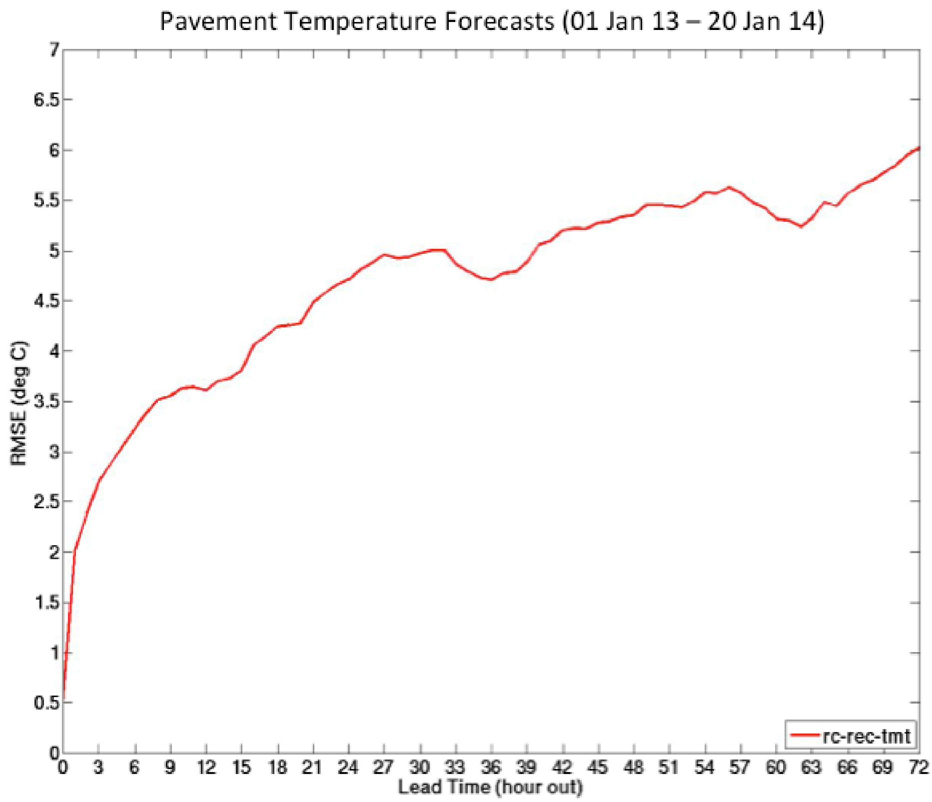

Fig. 8.7: Road temperature RMSE, computed based on 12 UTC forecasts from 01 January 2013 – 20 January 2014 for the Alaska RWIS sites.

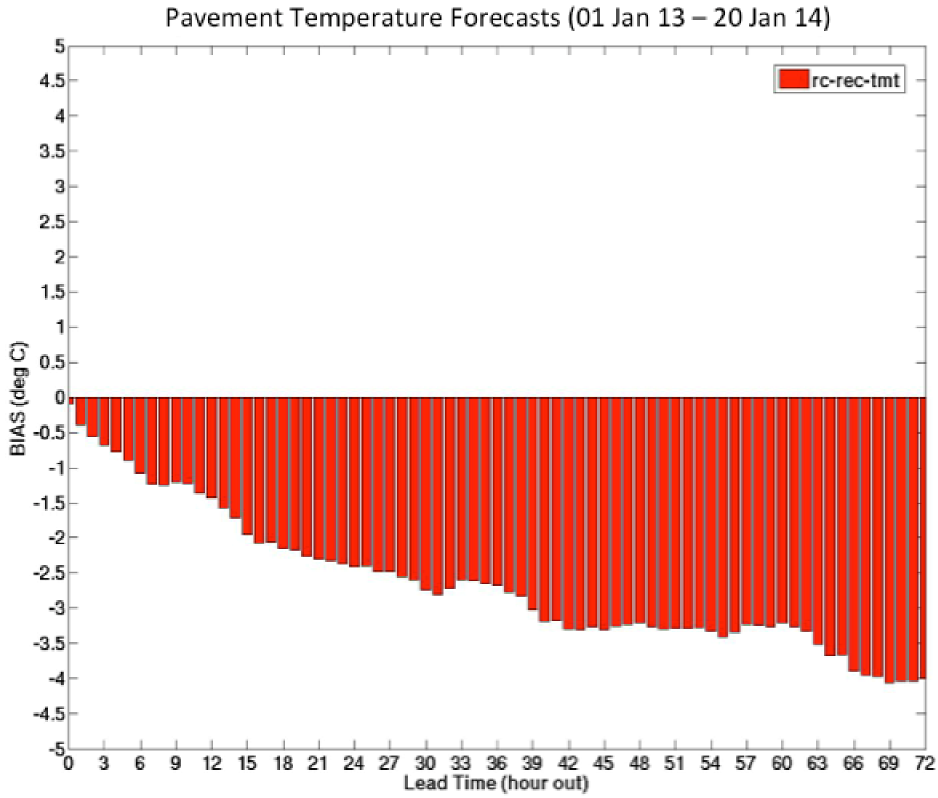

Fig. 8.8: Average road temperature bias from the 12 UTC forecasts for 01 January 2013 – 20 January 2014 for the Alaska RWIS sites.

Results Summary: The results in this section show that the pavement temperature model has consistent cold bias out to 72-hours. In the first 12 hours the bias is small (< 1.5°C). The cold bias increases to around 2.5°C out to 36 hours. The consistency of the bias over these time periods suggests that a simple post processing bias correction could be done to make the final forecast more accurate. This should be considered should the project move forward in the near future.

10 REFERENCES

Bernstein, B. C., J. K. Wolff, and S. Linden, 2003: Verification Report for the MDSS 2003 Demonstration at the Iowa Department of Transportation.

Chapman, M.B. and S. Linden, 2008: Technical Performance Assessment Report, Colorado Field demonstration 2007-2008, National Center for Atmospheric Research Technical Report

Greenfield, T., 2005: Bridge Frost Prediction by Heat and Mass Transfer Models. M.S. Thesis, Iowa State University.

Linden, S. and K.Petty: 2007: Technical Performance Assessment Report, Colorado Field demonstration 2006-2007, National Center for Atmospheric Research Technical Report

Rasmussen, R., M. Dixon, F. Hage, J.Cole, C. Wade, J. Tuttle, S. McGettigan, T. Carty, L. Stevenson, W. Fellner, S. Knight, E. Karplus and N. Rehak, 2001: Weather Support to Deicing Decision Making (WSDDM): A Winter Weather Nowcasting System. *Bull. Amer. Soc*, **82,** pp. 579-595.

NCAR, 2005: Technical Performance Assessment Report, Iowa Field Demonstration 2003-2005.