FINAL VERSION

RECORD OF ACTIONS

I. OVERVIEW

On April 23, 2009, the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) hosted a mini-workshop on addressing the Federal community's critical skills shortages related to the field of meteorology (weather and climate). The objectives of this mini-workshop were to (a) identify the current and projected critical skills shortages in meteorology that are needed to sustain the Federal meteorological (i.e., weather and climate) workforce pipeline now and in the future for meeting agency/organization mission requirements and (b) provide recommendations to address these identified skills shortages.

This Record of Action (ROA) summarizes the mini-workshop presentations and provides an accounting of the identified skills shortages. This document is organized by federal agencies (Section II) and other organizations (Section III). Follow-on activities are captured in Section IV (Next Steps). It should be noted that the ROA does not capture each point made by each presenter. Rather, this ROA is a précis of each presenter's response to the following questions:

(1) What is the importance of your topic in advancing weather and climate services?

(2) What are the critical skills needed by your agency to advance weather and climate services?

(3) What are the current and projected critical skills shortages in your topic area that are needed to sustain the Federal meteorological workforce pipeline now and in the future?

(4) What is currently being done in your agency to address the current and projected critical skills shortages?

(5)What is the impact of these skills shortages on weather and climate products and services?

(6) What are the near-, medium- and long-term recommendations for addressing these critical skills gaps? Near-, medium-, and long-term recommendations are those which can be implemented in 0-2 years, 2-5 years, and 5 years or more, respectively.

Following the summary of each presentation, there is a table that annotates the critical skills gaps identified by the presenter. Appendix A of this ROA is a comprehensive list of each table's contents.

To view each presentation, press the control key and click the word "presentation", or go to: http://www.ofcm gov/homepage/text/spc_proj.htm

II. FEDERAL AGENCIES

DEPARTMENT OF COMMERCE

Mr. Douglas Forsyth
Chief, Radar Research and Development Division
National Severe Storms Laboratory (NSSL)
Office of Oceanic and Atmospheric Research (OAR)
National Oceanic and Atmospheric Administration (NOAA)

Presentation

Mr. Forsyth opened his presentation by noting radar meteorology is important in advancing weather and climate services within NOAA because weather radar

- serves as a primary severe weather observational tool
- is used to issue warnings by the National Weather Service
- is used to avoid severe weather by the Federal Aviation Administration and pilots
- is used to display the location of precipitation and associated severe weather to the public

Mr. Forsyth offered that the current and projected critical skills needs are (1) gathering, analyzing, and interpreting complex radar information (for operational and research radar meteorologists); (2) developing and testing new radars (for radar engineers); (3) developing radar information algorithms and attendant displays (for software engineers); and (4) testing and maintaining radars (for electronics technicians). He indicated that obtaining a doctorate in radar meteorology and/or electrical engineering would result in adequately skilled research radar meteorologists and radar engineers. A master's degree in computer science would result in adequately skilled software engineers and good technical training in electronics would result in adequately skilled electronic technicians. Additionally, he noted that the radar meteorology skills shortages in the Federal government are due to (1) the lack of U.S. citizens who are skilled in radar meteorology and (2) the private sector offering higher (than current Federal) salaries to people with a master's degree in radar meteorology and associated disciplines. Therefore there is little incentive for these individuals to pursue a doctorate to obtain the requisite Federal radar meteorology skills. Mr. Forsyth stated that the impact of these current and projected skills shortages on weather and climate services would be to make it difficult to deliver enhanced products and services to weather-/climate-sensitive entities in the private and public sectors.

To address these skills shortages, NSSL is currently

- increasing National Research Council (NRC) post-doctoral salaries to $70,000.
- hiring students with master's degrees and supporting those students' education through the doctoral level
- improving the pay scales for research engineers

- asking our Cooperative Institutes to hire individuals who are Foreign Nationals and then waiting for them to become U.S. citizens and possibly hiring them into the Federal government
- offering an attractive work environment with cutting edge technologies (e.g., phased array radar)
- engaging undergraduates to work at NSSL during semester breaks
- taking advantage of university programs offering an interdisciplinary curriculum which integrates radar engineering and meteorology. The University of Oklahoma has such a curriculum.

Mr. Forsyth noted that short courses are not sufficient for addressing the critical skills shortages in radar meteorology. He offered the following concurrently near-, medium-, and long-term recommendations to address the critical skills shortages in radar meteorology:

- increasing the pay scales for radar meteorologists, electrical engineers, etc. (i.e., adjusting salaries so that they are comparable to university and industry scales)
- obtaining Direct Hire authority for electrical and electronics engineers

DOC/NOAA/OAR/NSSL Radar Meteorology Critical Skills Shortages
Ability to gather, analyze, and interpret radar information (in both a research and operational environment)
Ability to develop and test new radars (i.e., radar engineers)
Ability to develop radar algorithms and attendant displays (i.e., software engineers)
Ability to test and maintain radars (electronics technicians)

Dr. Stephen Lord [Presentation]
Director, Environmental Modeling Center (EMC)
National Centers for Environmental Prediction (NCEP)
National Weather Service (NWS)
National Oceanic and Atmospheric Administration (NOAA)

Dr. Lord's opening remarks expressed that (1) maintaining the scientific correctness and integrity of operational forecast modeling systems, (2) modifying current operational systems to adapt to ever-present external changes, (3) enhancing numerical forecasts by testing and improving NCEP's forecast model systems, (4) transitioning numerical forecast models from research status to operational status, and (5) developing operational numerical forecast models are the important roles that EMC's operational global and regional numerical modeling and prediction/data assimilation play in advancing weather and climate services. Dr. Lord continued his presentation by listing the critical skills in operational modeling needed by NWS to advance weather and climate services. These critical skills are in

- data assimilation
- forecast model development

- supercomputing programming
- atmospheric, oceanographic, land surface, ice, space weather, and ecosystems product development for operational forecasters, commercial users, etc.
- scientific management of all of the above to provide:
  - on-demand scope and risk analysis for specialized projects
  - on-demand supplemental personnel for emergency operational support
  - rapid employee recruitments to fill new positions and replenish employees

Dr. Lord enumerated the current and projected critical skills shortages needed to sustain the Federal workforce pipeline now and in the future for meeting NCEP's mission requirements. These skills include:

- scientific execution (e.g., understanding how to improve the complex numerical forecast systems, developing and "debugging" computer programs, and translating academic experience into independent productivity within the work environment)
- scientific management resulting from understanding the scientific process across all the domains' (e.g., meteorology, oceanography, land surface, etc.) applications. Scientific management also includes a capacity to (a) respond appropriately to and write reports and proposals, (b) understand and facilitate corporate visibility, (c) make presentations, (4) be responsive to requests from headquarters, etc.)

Shortages in these skills ultimately lead to a reduction in progress toward improved forecast systems and services.

Dr. Lord stated that the majority of universities do not provide sufficient practical training and experience to address these critical skills shortages. Short courses are equally inadequate for producing skilled modeling and data assimilation professionals. As a result, EMC trains all incoming personnel and considers them apprentices for 1 to 2 years. After this apprenticeship period, the individual is a "fully functioning team member." Additionally, EMC's Visiting Scientist programs can be a mechanism for recruiting talented post-doctoral students. However, Dr. Lord believes these programs will be ineffective unless the visiting scientist is engaged repeatedly (e.g., during and after a professor's sabbatical and throughout a student's academic career).

Dr. Lord concluded his presentation by offering the following "long-term, strategic" recommendations to address the critical skills shortages:

- supporting Visiting Scientist programs across all EMC mission areas
- supporting the availability and use of operational numerical forecast systems within the scientific research community (i.e., operations to research (O2R))
- supplementing permanent staff to support training of new recruits and O2R capability

DOC/NOAA/NWS/NCEP Global and Regional Numerical Weather Prediction (NWP) Modeling/Data Assimilation Critical Skills Shortages
Competency in scientific execution - understanding how to improve complex numerical forecast systems - developing and "debugging" computer programs - translating academic experience into independent productivity within the work environment
Competency in scientific management resulting from understanding the scientific process across all the domains' (e.g., meteorology, oceanography, land surface, etc.) applications in order to - respond appropriately to and write reports and proposals - understand and facilitating corporate visibility - make presentations - be responsive to requests from headquarters - identify and articulate the relationship among resource shortages (e.g., skilled personnel) and services/special project execution

Dr. Thomas Bogdan Presentation
Director, Space Weather Prediction Center (SWPC)
National Centers for Environmental Prediction (NCEP)
National Weather Service (NWS)
National Oceanic and Atmospheric Administration (NOAA)

Dr. Bogdan explained that the importance of space weather in advancing weather services within NOAA lies in a number of Federal agencies and industries relying on NOAA space weather services to support such endeavors and infrastructure needs as (a) satellite launches and operations, (b) Department of Defense operations, (c) NASA human spaceflight activities, (d) commercial air traffic, (e) the GPS global navigation satellite system, and (f) the U.S. power grid.

Dr. Bogdan provided the following list of skills and educational background needed at SWPC to advance space weather services and meet the needs of customers:

- space science education (aerospace engineering, planetary science, astrophysics, etc.)
- information technology (IT) "savvy"
- an understanding of physics-based predictions and data assimilation forecasts
- multi-tasking
- working with other cultures and international centers to share/exchange space weather situational awareness

Dr. Bogdan considers the education and skills needs as shortages which need to be addressed in order to respond to the anticipated increase in (a) the number and type of space weather customers and (b) their service and product needs. This increase is

precipitated by the increased frequency of solar storms projected to occur in the 2012-13 timeframe. The absence of these space weather skills, especially during increased solar storm activity, will adversely impact product and service delivery and will negatively impact agencies' and industries' ability to execute their missions.

Dr. Bogdan stated that the extant University of Michigan's space weather specialization program and the nascent University of Colorado program provides/will provide its graduates with the skills needed to address the aforementioned skills shortages. In addition to the academic programs, Dr. Bogdan stated that "exporting talent to other parts of the world" to learn from others is another means for addressing these skills shortages.

Dr. Bogdan ended his presentation by providing the following, medium-term recommendations for addressing skills shortages in space weather:

- take an interdisciplinary approach (to space weather) which combines such disciplines as aerospace engineering, planetary science, atmospheric and oceanic sciences, and atmospheric and space physics
- investigate employment pool options of other public and private organizations which hire people who have the requisite space weather skills (e.g., NASA and private industry) to "siphon" talent from that pool
- provide a work environment that meshes with the work environment expectations of the skilled "Millennials" (individuals born between 1977 and 1995)

DOC/NOAA/NWS/NCEP/SWPC Space Weather Critical Education/Skills Shortages
Possessing a space science education (aerospace engineering, planetary science, astrophysics, etc.)
Possessing proficiency in information technology (IT)
Ability to understand physics-based predictions and data assimilation forecasts
Ability to multi-task
Ability to work with other cultures and international centers to share/exchange space weather situational awareness

DEPARTMENT OF DEFENSE

Dr. Walter Bach [Presentation]
Program Manager, Atmospheric Sciences
Army Research Office (ARO)
U.S. Army
Department of Defense (DOD)

Dr. Bach explained that the importance of atmospheric transport and diffusion (ATD) and planetary boundary layer (PBL) meteorology in advancing weather and climate services lies in the fact that (1) ATD and PBL research supports Army operations, (2) climate models are critically dependent on PBL processes to move energy and mass from the

surface to the free atmosphere, and (3) ATD and PBL research supports wind farm operations.

Dr. Bach enumerated the skills that are needed to advance weather and climate services. These skills require proficiency in

- incorporating (into models) horizontal grid spacing ranging from fronts (10 to 100 km) down to the urban scale (10 to 100 km)
- modeling atmospheric waves, turbulence, heat mass, and momentum fluxes as a function of PBL scales
- measuring atmospheric parameters and inert chemical tracer concentrations at the frontal and urban scales to yield a comprehensive view of multi-scale processes in the PBL
- quantifying and interpreting uncertainty

Dr. Bach stated that currently there is a skills gap in these areas. In addition to these skills, additional expertise/skills are needed to sustain the Federal meteorological workforce pipeline now and in the future. These skills require competency in

- designing instrumentation to remotely sense (volumetrically or by line of sight) the atmosphere at PBL scales
- understanding electromagnetic and acoustic propagation in the atmosphere
- coupling observations to atmospheric processes or states

Because climate models are critically dependent on PBL processes, improvements to forecasts could be lost or delayed if these skills are not developed and incorporated into the Federal workforce. Additionally, not addressing the skills gap could adversely impact DOD/Army operations.

Dr. Bach stated that supplemental education and training was not necessarily sufficient to meet the critical skills shortages. To become skilled, individuals "must actually do the work." To encourage this hands-on experience and consequently address the skills gap, the ARO is funding innovative measurement approaches through such programs as DOD's Defense University Research Instrumentation Program and the Small Business Innovation Research Program.

Dr. Bach concluded his presentations by offering the following medium-term recommendations to address the identified skills shortages:

- work with academia to promote
  - student involvement in instrument development
  - student collection, manipulation, and analysis of data
  - academic partnerships
- recognize the importance of PBL processes in addressing scientific and user needs and the inability of forecast models to capture these PBL processes

- increase the Federal and academic emphasis on development of measurement systems for PBL processes
- reach outside the meteorological core discipline for ideas on capturing observations within the PBL and for methods to enhance understanding of PBL processes, analyses, and modeling

DOD/U.S. Army/ARO Atmospheric Transport and Diffusion/Boundary Layer Meteorology Critical Skills Shortages
Ability to incorporate (into models) horizontal grid spacing ranging from fronts (10 to 100 km) down to the urban scale (10 to 100 km)
Ability to model waves, turbulence, heat mass, and momentum fluxes as a function of PBL scales
Ability to measure atmospheric parameters and inert chemical tracer concentrations at the frontal and urban scales to yield a comprehensive view of multi-scale processes in the PBL
Ability to quantify and interpret uncertainty
Ability to design instrumentation to remotely sense (volumetrically or by line of sight) at PBL scales
Ability to understand electromagnetic and acoustic propagation in the atmosphere
Ability to couple/associate observations to atmospheric processes or states

III. OTHER ORGANIZATIONS

Dr. Robert Palmer [Presentation]
Tommy C. Craighead Chair and Professor, School of Meteorology
Director, Atmospheric Radar Research Center
University of Oklahoma

Dr. Palmer's initial remarks focused on the importance of radar meteorology in advancing weather and climate services. He noted that radar provides valuable information about the location and intensity of precipitation. In addition, advanced radar technology provides high resolution reflectivity and estimated velocity data which are vital to short-term forecasting and severe weather prediction.

Dr. Palmer stated that radar meteorology represents an amalgam of electrical engineering and meteorology disciplines. Accordingly, the radar meteorology skills set required for advancing weather and climate services combines skills sets from both disciplines and include:

- appreciating statistical uncertainty
- designing/troubleshooting radar system
- developing software
- interpreting/understanding radar limitations

- understanding/appreciating both meteorology and engineering and their interdependence
- working effectively within an interdisciplinary team
- working with other cultures and international centers to share/exchange space weather situation awareness

Dr. Palmer acknowledged that these skills also represent the current and projected critical skills shortages needed to sustain the Federal meteorological workforce pipeline now and in the future.

Dr. Palmer expressed that short courses are insufficient for producing "well-trained and skilled radar meteorologists." He stated that the most productive method for addressing these current and projected shortages was to involve students in a radar meteorology "project that people care about." In addition, a full, interdisciplinary curriculum (which combines meteorology and electrical engineering) is needed. He offered the University of Oklahoma's interdisciplinary approach in its radar meteorology curriculum as an exemplar and noted that without this type of education (and the resulting skilled professionals), the accuracy and timeliness of forecast and warning products and services could be adversely impacted.

Dr. Palmer concluded his presentation by offering the following medium-term recommendations to address the identified skills shortages:

- reshape the perception that radar meteorology is an interesting but esoteric subfield of electrical engineering
- devise an interdisciplinary approach to improve the effectiveness of engineering and meteorology disciplines
- develop a closer interaction between Federal agencies and universities
- fund real-world research and development projects for both undergraduate and graduate students
- provide time for/recognition of Federal engineers/meteorologists who participate in education (e.g., employees who take on collateral, educational duties)
- enhance internship programs at both the undergraduate and graduate levels
- make salaries of engineering graduates in weather radar competitive with the general radar industry

University of Oklahoma/School of Meteorology/Atmospheric Radar Research Center Radar Meteorology Critical Skills Shortages
Ability to appreciate statistical uncertainty
Ability to design/troubleshoot radar system
Ability to develop software
Ability to interpret/understand radar limitations
Ability to understand/appreciate both meteorology and engineering and their interdependence
Ability to work with effectively within an interdisciplinary team

Dr. Delores Knipp
National Center of Atmospheric Research (NCAR)
Emeritus U.S. Air Force (USAF) Academy

Presentation

Dr. Knipp began her presentation by stating that her remarks are not attributable to any organization, but reflect her opinions and those of her presentation collaborators. She noted that satellite remote sensing observations provide approximately 90% of input to the data assimilation algorithms that drive global NWP. Therefore, the importance of satellite remote sensing in advancing weather and climate services is that these remotely sensed observations support the production of accurate weather forecasts and timely watches and warnings.

Dr. Knipp enumerated the remote sensing knowledge and abilities required to advance weather and climate services. The requisite knowledge[1] includes an understanding of

- calculus-based electromagnetics
- qualitative and quantitative electromagnetic radiation transmission
- retrieval theory and applications
- dynamics and thermodynamics

Requisite skills[1] include the ability to

- identify the characteristics, typical uses, and relevance of channels, or combinations thereof in meteorological applications
- use channels and products to identify and distinguish cloud types and amounts, cloud clusters and systems, and synoptic features (e.g., fronts, jet streams, sea ice, etc.)
- integrate satellite data with other meteorological data to assess the prognosis of the NWP guidance for various applications

The aforementioned knowledge and skills also represent current critical knowledge and skills gaps. In addition to these knowledge and skills sets, the following skills[1] were deemed critical to sustaining the Federal meteorological workforce pipeline now and in the future:

- ability to interpret and apply the radiative transfer equation
- ability to execute computer modeling
- ability to understand strengths and shortcomings of data assimilation
- ability to understand and apply passive/active/hybrid sensing theory
- ability to couple tropospheric dynamics to the upper atmosphere (e.g., stratosphere and ionosphere)

These knowledge and skills requirements are currently being addressed with supplemental education and training, such as on-the-job training; the use of the Cooperative Program for Operational Meteorology, Education and Training (COMET)

materials; short courses; the annual 3-day Satellite Curriculum Development Workshop; and the Virtual Institute for Satellite Integration Training (VISIT).

Dr. Knipp stated that not addressing these skills may "compromise analysis and forecasting accuracy." To address these current and future skills requirements, Dr. Knipp offered a number of near-term and long-term recommendations. A subset of the recommendations[2] includes

- begin developing COMET/VISIT data assimilation materials related to satellite and remote sensing (near-term)
- begin/continue developing materials related to space weather, upper atmosphere, and the broader range of sensing techniques (near-term)
- increase human-to-human interface training to improve knowledge transfer and retention (long-term)
- consider developing mathematical techniques modules to facilitate knowledge in radiative transfer, statistics, etc. (long-term)

NCAR Remote Sensing Critical Skills Shortages[1]
An understanding of calculus-based electromagnetics
An understanding of qualitative and quantitative electromagnetic radiation transmission
An understanding of retrieval theory and applications
An understanding of dynamics and thermodynamics
Ability to identify the characteristics, typical uses, and relevance of channels, or combinations thereof in meteorological applications
Ability to use channels and products to identify and distinguish cloud types and amounts, cloud clusters and system, synoptic features (e.g., fronts, jet streams, sea ice, etc.)
Ability to integrate satellite data with other meteorological data to assess the prognosis of the NWP guidance for various applications
Ability to interpret and apply the radiative transfer equation
Ability to execute computer modeling and data assimilation
Ability to understand and apply passive/active/hybrid sensing theory
Ability to couple tropospheric dynamics to the upper atmosphere (e.g., stratosphere and ionosphere)

IV. NEXT STEPS

At the conclusion of the presentations the participants identified the following subjects for future mini-workshops: (1) climate services, (2) hydrology, (3) fire weather, (4) mountainous terrain meteorology, (5) surface transportation, (6) data assimilation, (7) tropical meteorology, (8) social science (from a weather and climate aspect), (9) marine meteorology, and (10) energy meteorology. Lastly, the participants recommended that representatives from other organizations such as the National Science Foundation, the Department of Energy, Fleet Numerical Meteorology and Oceanography Center, the Naval Post Graduate School, and NOAA/NWS/NCEP/Hydrometeorological Prediction Center participate in future mini-workshops.

[1]The list of knowledge and skills shortages should not be considered exhaustive. Please see Dr. Knipp's presentation for the complete list of skills and skill shortages.

[2]The list of recommendations should not to be considered exhaustive. Please see Dr. Knipp's presentation for the complete list of recommendations.

APPENDIX A
Summary of Critical Skills Gaps Related to the Field of Meteorology (Weather and Climate)
April 23, 2009

#	AGENCY/ ORGANIZATION	CRITICAL SKILLS GAP DESCRIPTION	CATEGORY	OPERATIONAL OR RESEARCH
1	DOC/NOAA/NWS/NCEP/EMC	understand the scientific process across all the domains' (e.g., meteorology, oceanography, land surface, etc.) applications in order to: - respond appropriately to and write reports and proposals - understand and facilitating corporate visibility - make presentations - be responsive to requests from headquarters - identify and articulate the relationship among resource shortages (e.g., skilled personnel) and services/special project execution	Administrative/Scientific Management	Operational/Research
2	DOD/U.S. Army/ARO	measure atmospheric parameters and inert chemical tracer concentrations at the frontal and urban scales to yield a comprehensive view of multi-scale processes in the PBL	Analysis	Operational/Research
3	DOD/U.S. Army/ARO	design instrumentation to remotely sense (volumetrically or by line of sight) at PBL scales	Analysis	Operational/Research
4	DOC/NOAA/OAR/NSSL	gather, analyze, and interpret radar information	Analysis	Operational/Research
5	University of Oklahoma	appreciate statistical uncertainty	Analysis/Forecasting	Operational/Research
6	University of Oklahoma	interpret/understand radar limitations	Analysis/Forecasting	Operational/Research

#	AGENCY/ ORGANIZATION	CRITICAL SKILLS GAP DESCRIPTION	CATEGORY	OPERATIONAL OR RESEARCH
7	University of Oklahoma	understand/appreciate both meteorology and engineering and their interdependence	Analysis/Forecasting	Operational/Research
8	DOC/NOAA/NWS/NCEP/EMC	understand how to improve complex numerical forecast systems (scientific execution)	Analysis/Forecasting	Operational/Research
9	DOC/NOAA/NWS/NCEP/SWPC	possess a space science education (aerospace engineering, planetary science, astrophysics, etc.)	Analysis/Forecasting	Operational/Research
10	DOC/NOAA/NWS/NCEP/SWPC	understand physics-based predictions and data assimilation forecasts	Analysis/Forecasting	Operational/Research
11	DOD/U.S. Army/ARO	understand electromagnetic and acoustic propagation in the atmosphere	Analysis/Forecasting	Operational/Research
12	DOD/U.S. Army/ARO	incorporate (into models) horizontal grid spacing ranging from fronts (10 to 100 km) down to the urban scale (10 to 100 km)	Analysis/Forecasting	Operational/Research
13	DOD/U.S. Army/ARO	model waves, turbulence, heat mass, and momentum fluxes as a function of PBL scales	Analysis/Forecasting	Operational/Research
14	DOD/U.S. Army/ARO	quantify and interpret uncertainty	Analysis/Forecasting	Operational/Research
15	DOD/U.S. Army/ARO	couple/associate observations to atmospheric processes or states	Analysis/Forecasting	Operational/Research
16	Dr. Delores Knipp and Presentation Collaborators	understand calculus-based electromagnetics	Analysis/Forecasting	Operational/Research
17	Dr. Delores Knipp and Presentation Collaborators	understand qualitative and quantitative electromagnetic radiation transmission	Analysis/Forecasting	Operational/Research
18	Dr. Delores Knipp and Presentation Collaborators	understand retrieval theory and applications	Analysis/Forecasting	Operational/Research
19	Dr. Delores Knipp and Presentation Collaborators	understand dynamics and thermodynamics	Analysis/Forecasting	Operational/Research

#	AGENCY/ ORGANIZATION	CRITICAL SKILLS GAP DESCRIPTION	CATEGORY	OPERATIONAL OR RESEARCH
20	Dr. Delores Knipp and Presentation Collaborators	identify the characteristics, typical uses, and relevance of channels, or combinations thereof in meteorological applications	Analysis/Forecasting	Operational/Research
21	Dr. Delores Knipp and Presentation Collaborators	use channels and products to identify and distinguish cloud types and amounts, cloud clusters and system, synoptic features (e.g., fronts, jet streams, sea ice, etc.)	Analysis/Forecasting	Operational/Research
22	Dr. Delores Knipp and Presentation Collaborators	integrate satellite data with other meteorological data to assess the prognosis of the NWP guidance for various applications	Analysis/Forecasting	Operational/Research
23	Dr. Delores Knipp and Presentation Collaborators	interpret and apply the radiative transfer equation	Analysis/Forecasting	Operational/Research
24	Dr. Delores Knipp and Presentation Collaborators	execute computer modeling and data assimilation	Analysis/Forecasting	Operational/Research
25	Dr. Delores Knipp and Presentation Collaborators	understand and apply passive/active/hybrid sensing theory	Analysis/Forecasting	Operational/Research
26	Dr. Delores Knipp and Presentation Collaborators	couple tropospheric dynamics to the upper atmosphere (e.g., stratosphere and ionosphere)	Analysis/Forecasting	Operational/Research
27	DOC/NOAA/OAR/NSSL	develop and test new radars	Hardware Engineering	Research
28	DOC/NOAA/OAR/NSSL	test and maintain radars	Hardware Engineering	Operational/Research
29	DOC/NOAA/NWS/NCEP/SWPC	possess proficiency in information technology (IT)	IT	Operational/Research
30	DOC/NOAA/NWS/NCEP/EMC	develop and “debug” computer programs (scientific execution)	Software Development	Operational/Research
31	DOC/NOAA/OAR/NSSL	develop radar algorithms and attendant displays	Software Engineering	Research
32	University of Oklahoma	develop software	Software Engineering	Operational/Research
33	University of Oklahoma	work effectively in an interdisciplinary team	Work Environment	Operational/Research

#	AGENCY/ ORGANIZATION	CRITICAL SKILLS GAP DESCRIPTION	CATEGORY	OPERATIONAL OR RESEARCH
34	DOC/NOAA/NWS/NCEP/EMC	translate academic experience into independent productivity within the work environment (scientific execution)	Work Environment	Operational/Research
35	DOC/NOAA/NWS/NCEP/SWPC	multi-task	Work Environment	Operational/Research
36	DOC/NOAA/NWS/NCEP/SWPC	work with other cultures and international centers to share/exchange space weather situation awareness	Work Environment	Operational/Research