Technology transferred to operations/application and an assessment of their significance/impact on operations (1b)

Radar Technology Transfer

National Severe Storms Laboratory (NSSL) scientists have been transferring weather radar technology to operations for over four decades. Their research led to the Next Generation Radar (NEXRAD) WSR-88D network of 160-plus Doppler weather radars. Previous Research provided enhancements that improved the older WSR-57 network before its replacement by NEXRAD.

NSSL scientists were the first to discover the tornadic vortex signature and develop a detection algorithm for it and the mesocyclone. They were the first to operationally test use of Doppler radar for tornado and severe thunderstorm warnings (Joint Doppler Operational Project (JDOP), 1977-1979).

NSSL developed large segments of the original NEXRAD training materials and delivered many classroom lectures, in association with the National Weather Service (NWS) Warning Decision Training Branch (WDTB). Based on applied research with newly-installed WSR-88D radars and input from basic research (i.e. Verification of the Origins of Rotation in Tornadoes Experiment 1 (VORTEX1), NSSL prepared three Tornado Warning Guidance documents for the NWS.

NSSL scientists developed a guide for pilots entitled “Microbursts: A Handbook for Visual Identification”. The book was published in 1989 prior to TDWR as a mitigator for downburst-caused airline accidents.

NSSL scientists prepared several documents to help in the training of Doppler velocity interpretation, including “A Guide for Interpreting Doppler Velocity Patterns” and a chapter on Doppler velocity interpretation for the Federal Meteorological Handbook (FMH) 11.

When the NEXRAD original proprietary hardware became obsolete, NSSL designed and implemented an Open Systems Radar Product Generator (ORPG) to meet the expanding needs of the WSR-88D network. In addition, NSSL prototyped the Open Radar Data Acquisition (ORDA) system and designed and built an Open Principle User Processor (OPUP) for use by the Air Force.

NSSL developed the NEXRAD velocity dealiasing algorithm that was installed at the time of initial radar deployment, an algorithm, with NSSL updates, that is still used in NEXRAD today. In addition, NSSL developed a Multi-PRF Dealiasing Algorithm (MPDA) and new scanning strategy (VCP 121) that have been implemented on NEXRAD.

Many of the original algorithms in the NEXRAD WSR-88D were developed at NSSL. They were then improved and implemented in the ORPG. These algorithms were included:

- Mesocyclone detection algorithm (MESO and MDA)
- Tornadic Vortex Detection Algorithm (TVS and TDA)
- Hail detection algorithm (Hail and HDA)
- Storm Cell Identification and Tracking (SCIT and Filtered SCIT).

NSSL has developed several severe storm algorithms that will be run on the Terminal Doppler Weather Radar (TDWR) radars as their output is brought into the NWS Advanced Weather Interactive Processing System (AWIPS) and routine NWS use in warning and forecast operations.

In order to obtain the high-resolution moment data (Level II) for research and operational use, NSSL and co-project leaders at the University of Oklahoma (OU) collaborated with the Radar Operations Center (ROC), University Corporation for Atmospheric Research (UCAR) and National Climatic Data Center (NCDC) to archive and distribute the data in a demonstration project call Collaborative Radar Acquisition Field Test (CRAFT). CRAFT built upon NSSL technology used to communicate with the WSR-88D high-resolution data feed called the Radar Interface and Data Distribution System (RIDDS).

To gain input on early WSR-88D radar functionality and first-generation NSSL algorithms installed on WSR-88D radars, NSSL formed and hosted a tri-agency (NWS, Air Force Weather Agency (AFWA), and Federal Aviation Administration (FAA)) WSR-88D user group that met many times during the 1990s and was instrumental in establishing the need for and design of NSSL technology transfer applications for NEXRAD.

The Warning Decision Support System (WDSS) was first developed in the early 1990s to support implementation and testing of new single radar algorithms. WDSS was used operationally at several NWS Offices to display high-resolution output from multiple radars. A multi-radar, multi-sensor version was later developed called the Warning Decision Support System – Integrated Information (WDSS-II). Several ideas developed in this system have been transferred to the NWS AWIPS system: WDSS-II was implemented for the System for Convective Analysis and Nowcasting (SCAN); the Four-Dimensional Stormcell Investigator (FSI) that produces real-time vertical slices and Constant Altitude Position Plan Indicators (CAPPIs) was transferred to AWIPS, and is also being used in the Center for the Adaptive Sensing of the Atmosphere (CASA) system.

Products from WDSS-II are distributed on the internet in support of AWIPS and N-AWIPS operations. An off-line version called WSR-88D Algorithm Testing and Display System (WATADS) has been used by NWS forecasters and others for developing their own radar applications.

A WDSS-II algorithm control system was developed to allow algorithms to run on many different radars at one time within NSSL (i.e. start, stop, log, etc.)

NSSL scientists adapted the Velocity Azimuth Display algorithm and the VAD wind profile display for NEXRAD Doppler radar use.

NSSL is working in collaboration with the NWS Warning Decision Training Branch (WDTB) to develop a tool (VCP Explorer) to help forecasters visualize the interaction of a radar beam path with the terrain surrounding the radar.

NSSL developers wrote a new Human Computer Interface (HCI) that was implemented in the ORPG and replaced the Unit Control Position, improving the usability of several WSR-88D features including adjustment of the Pulse Repetition Frequency.

NSSL scientists developed a gust front algorithm for the identification of gust fronts and a damaging downburst algorithm and tested them in the NWS Office in Phoenix, AZ. Parts of these algorithms are implemented on the Federal Aviation Administration's Terminal Doppler Weather Radar (TDWR).

For the entire NEXRAD period, and now continuing, NSSL has maintained and is adding to a robust database of operational WSR-88D radar and experimental system (e.g. KOUN dual-polarization) data sets. These data sets include environmental observation data, numerical model data, and verification information. The database is diverse with respect to areas of the United States and hazardous weather types (i.e. severe convective storms, winter storms, flash floods, land-falling hurricanes, etc). The database is used by NSSL, ROC, and university scientists for applications development and testing.

NSSL "On-Demand" Severe Storm Verification system, funded by the National Oceanic and Atmospheric Administration (NOAA) High-Performance Computing and Communications Program (HPCC) is a web-based query tool designed to help National Weather Service meteorologists quickly verify their severe thunderstorm and tornado warnings. This system uses two new algorithms developed by NSSL:, the Maximum Expected Size of Hail (MESH) and the rotation tracks obtained from the linear least squares vorticity estimations.

The Severe Hazards Analysis and Verification Experiment (SHAVE) is a unique project that blends high-resolution radar data with geographic information. The primary objective of this experiment is to collect high temporal and spatial resolution data that describe the distribution of hail sizes, wind damage and flash flooding produced by severe thunderstorms. SHAVE has been adopted by numerous NWS Offices to improve verification of severe weather events.

NSSL developed and tested a "Rapid Update" system that produced algorithm output on every elevation scan in stead of at the end of a volume scan, giving faster updates for the Mesocyclone, Tornadic Vortex Signature, and SCIT. The MDA and TDA rapid updates were implemented in the WSR-88D system.

NSSL Collaborated with National Center for Atmospheric Research (NCAR) on their Weather Support to Deicing Decisions Making System (WSDDM) by providing real-time radar calibration data.

NSSL scientists have long worked to reduce/eliminate the "Doppler dilemma" – long (short) range of coverage gives small (large) velocity measurement interval. Range/velocity ambiguities arising from the dilemma were reduced for initial NEXRAD deployment by introducing separate scans for reflectivity and velocity estimation. This solution created regions where velocity estimates could not be made, so-called areas of "purple haze." To help eliminate "purple haze", NSSL scientists have more recently developed phase coding and staggered Pulse Repetition Times (PRT). Phase coding has already been installed on WSR-88Ds, and staggered PRT will be introduced soon. These changes have the potential to all but eliminate WSR-88D range/velocity ambiguities.

NSSL has provided a corrected spectrum width estimator so that its computations are unbiased. The new estimator is in the process of being deployed on all WSR-88D radars.

NSSL has created Super Resolution data (250 m range gates and 0.5 deg azimuths) for products for forecaster use and re-combined data (1 km range gates (where needed) and 1.0 deg azimuths) for use by the current algorithms. NSSL is currently working on versions of the algorithms tailored to the use of Super Resolution data. As they are completed, they will be implemented on the WSR-88Ds to replace the current algorithms.

Several new Volume Coverage Patterns (VCPs) have been proposed, tested and implemented on the WSR-88Ds including VCP 12 to increase the low-level vertical resolution and decrease the time between volume scans to approximately 4 minutes.

Research has continued on visualization techniques including iso-surface display and real-time volume navigation. In addition, products are available in Google Earth.

Much research has been accomplished with applications to hydrometeorology. They include a radar reflectivity quality control product that has significantly improved very short-term Quantitative Precipitation Forecasts (QPFs) in the operational Rapid Update Cycle (RUC) model, 3-D radar reflectivity mosaic technique, multi-sensor Quantitative Precipitation Estimate (QPE) version 2 (Q2) products with automatic precipitation classification, and a Radar Reflectivity comparison tool used by the ROC extensively to assess real-time performance of the WSR-88D network.

A Quality Control (QC) algorithm for the NEXRAD Doppler Velocity data has been developed for use by National Centers for Environmental Prediction (NCEP).

Research in dual-polarization weather radars is leading to the implementation of dual-polarization on the WSR-88D. Over this time, researchers have developed dual-polarization algorithms including the hydrometer classification (HCA), melting layer and rainfall accumulation (QPE) algorithms, enhanced the dual-polarization sensitivity, worked on the calibration of both differential reflectivity and phase and provided dual polarization measurements at low Signal to Noise Ratios (SNR). With the additional dual-polarization fields, a new format for archive II data was collaboratively developed.

Build11 (2009) -- The dual-polarization algorithms scheduled to be included in Build 11 were implemented for non-operational integration and testing while the retrofit is still under development. The Automatic Volume Scan Evaluation and Termination (AVSET) is being tested by NSSL on data collected by ROC. NSSL put Build MDA Bug Fix into TDA. (3/12/09)

Build 10 (2008) – NSSL provided engineering requirements and guidance on how super-resolution data should be calculated at the RDA. NSSL provided a "recombination" algorithm for the RPG that ingests super-resolution data and outputs it in its "original" resolution to support legacy algorithms that have not been tested or evaluated on the super-resolution data stream. NSSL made enhancements to the Mode Selection Function to improve automatic switching between clear-air and precipitation modes. An MDA Bug Fix was put in to correct a problem with VCP 12 clutter residue. (3/12/09)

Build 9 (2007) -- Phase III of the Mesocyclone Detection Algorithm was implemented for the use of MDA in output in other algorithms. Also included was the SZ-2 Algorithm which minimizes the range ambiguity (“purple haze”) in velocity data to maximize the amount of useful velocity data. (3/12/09)

NSSL collaboratively looked at ways to support the NWS during radar outages using the Shared Mobile Atmospheric Research & Teaching Radar (SMART-R) systems (mobile C-Band Doppler radars) and satellite transmission of the data. Also using the same techniques to support Debris-Flow experiments in California, data is uplinked and used in Q2 for real-time warning decisions by the NWS.

NSSL worked with the NWS in Monterrey, CA to provide commercial television radar information (KPIX) for use in a Weather Forecast Office to cover an area not seen well with the WSR-88D.

NSSL provided hardware to implement Doppler capabilities on the NOAA P-3 aircraft along with improved scan strategies and coordination activities during various field experiments.

On-going research has resulted in a new and improved distributed signal processing Linux PC Cluster that provides a scalable processing capacity for meeting the needs of our weather radar research using the National Weather Radar Testbed – Phased Array. New clutter identification and removal schemes as well as faster data acquisition methods such as over-sampling and whitening and beam multiplexing have been developed.

Lightning Technology Transfer

NSSL developed a lightning threat algorithm for Weather Data Inc. using current lightning and radar data and a radar nowcast product to predict the lightning strike possibility.

NSSL developed displays of total lightning mapping for use by forecasters in the Weather Forecast Office (WFO) and Storm Prediction Center (SPC).

NSSL evaluated Cloud to Ground (CG) lightning mapping technologies for the Office of the Federal Coordinator for Meteorological Services (OFCM) and combined NSSL network to produce the first national network for CG mapping. CG mapping data is used extensively in aviation weather, fire weather, FAA terminal operations, various Department of Defense (DOD) applications, and by the National Aeronautical and Space Administration (NASA) in launching the space shuttle.

Model simulation studies and analysis helped justify inclusion of an optical lightning mapper on Geostationary Operational Environmental Satellite R-Series (GOES-R).

NSSL established that stratiform precipitation regions of mesoscale convective systems are highly electrified and that anvils of severe storms are also highly electrified. These have had important implications for shuttle and rocket launch criteria and safety of personnel at the Kennedy Space Center since lightning flashes can occur several tens of kilometers from the storms.

NSSL collaborated with the University of Oklahoma to develop the most advanced cloud model incorporating lightning and electrification processes.

NSSL showed that lighting flash rates are correlated with various storm parameters related to severity.

NSSL developed mobile laboratories and mobile ballooning including upper air measurements used in operational forecasts, and cutting edge communication systems used to transmit data from the field back to operational forecasters.

Numerical Modeling Technology Transfer

NSSL scientists led in the initial evaluation and further development of Short-Range Ensemble Forecasting (SREF) to benefit NWS operations in collaboration with NCEP. SREF is now a routine part of the operational forecast system and is heavily used by the SPC in the production of outlooks.

An algorithm for assimilating cloud-to-ground and total lightning data into mesoscale models was developed for the US Navy for use in the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS).

NSSL scientists led in the operational implementation of the Kain-Fritsch convective parameterization scheme in the operational SREF, with specialized output available to SPC forecasters. The scheme is used worldwide at various modeling centers (NCAR, NCEP, US Navy, US Air Force, Japanese Meteorological Agency, and Environment Canada).

A 3.5D variational (3.5DVAR) radar data assimilation package was developed in collaboration with scientists at OU/Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) and Naval Research Laboratory (NRL) Monterey. This package has been successfully tested with the Navy's COAMPS model for improving predictions of high-impact weather and will be implemented into Navy shipboard operations.

A radar data quality control (QC) package has been developed and improved in collaboration with scientists at OU/CIMMS, NCEP and NRL. The Y2007 version has been installed into the Navy's nowcast system for processing real-time radar data and was delivered to NCEP where it is being implemented for operational use.

A 2D variational (2DVAR) radar wind analysis package was developed in collaboration with scientists at OU/CIMMS to retrieve real-time vector wind fields from WSR-88Ds. This package has been selected for real-time implementation over major urban areas by the Biological Warning and Incident Characterization program supported by the US Department of Homeland Security.

Forecast Technology Transfer

NSSL developed an operational algorithm, called "Mesoscale Convective System (MCS) maintenance probability", to forecast the longevity of severe convective systems in collaboration with the SPC. The algorithm has been transferred to NWS forecast offices through the AWIPS data stream.

Stand-alone versions of the Kain-Fritsch and Betts-Miller-Janjic convective schemes have been incorporated into the SPC's "NSHARP" sounding analysis program to assist in sounding diagnostics. This enhanced sounding analysis program has been shown to be very valuable to SPC forecasters in defining the severe weather threat.

NSSL scientists were the first to establish that cloud-to-ground lightning flashes lowering positive charge to ground (+CG flashes), instead of the usual negative charge, can occur naturally in severe storms and can be an indicator of storm severity. This result has spurred a great deal of on-going research on what inferences can be drawn about the storms in which these flashes are observed.

NSSL developed a practically perfect forecast verification scheme for the Storm Prediction Center, which is used for operational forecast verification.

NSSL developed local daily climatological probabilities of severe thunderstorm hazards in the US, which are used in SPC forecasts and by risk assessment groups. In addition, they developed climatologies for heavy rainfall events and derechos that are used by NWS forecasters.

Conceptual models of the physical processes associated with severe weather events have been developed or expanded by NSSL scientists and are routinely used by NWS forecasters. These conceptual models include conditional symmetric instability, moisture convergence and convective initiation, dryline evolution and convective initiation, derecho longevity, electrical structures of severe storms and convective systems, flash flood forecasting, Gulf of Mexico return flow, severe weather environmental sounding diagnosis and parameter evaluation (including helicity), and tornadogenesis.

Conceptual models of an ingredients-based forecasting process have been developed by NSSL scientists and routinely used by NWS forecasters.

Satellite-based products such as mesoscale winds (upper-level), fire locations, surface wetness, winter precipitation efficiency, and MCS tracking have been made available to the SPC and National Environmental Satellite, Data, and Information Service (NESDIS) Satellite Analysis Branch. Forecasters have used these products to provide national guidance regarding severe storms and fire weather.

VORTEX1 produced a number of forecast-related technology transfer outputs, in addition to the warning-related technology transfer outputs mentioned in the Radar Technology Transfer section. The warning-and-forecast-related outputs were transferred to operational NWS use through WDTB training materials (Tornado Warning Guidance Training issued In 1997, 1999, and 2002), and through formal publications and public presentations by NSSL scientists. Important forecast guidance from VORTEX1 included: 1) large variability in low-level shear, buoyancy, and other variables that were observed on storm scales, but were not observable on larger-scale observations commonly available to warning forecasters, 2) higher values of environmental, sub-cloud relative humidity greatly aided potential tornadogenesis by reducing cold-air production in storm downdrafts and preventing outflows from becoming too-strong, and 3) shallow, small-scale boundaries and baroclinic zones (arising from outflows from preceding storms, cloud-cover-to-sunshine zones, anvil shadows, and other sources) produced enhanced storm-relative helicity on their cool sides and were associated with many observed instances of tornadogenesis.

Hydrometeorology Technology Transfer

In an effort to improve radar derived rainfall estimates, NSSL scientists developed a WSR-88D evaluation tool, called the "Radar Reflectivity Comparison Tool or RRCT, to monitor in real-time the radar echoes from all WSR-88D radars to ascertain potential calibration offsets and transmitter drift by comparing reflectivity at similar altitudes and ranges from overlapping radars. The RRCT was transferred to the NWS Radar Operations Center and has become a critical tool for monitoring and troubleshooting the nation's WSR-88D system. The tool has become indispensable to the ROC for assessing the impacts of engineering and software upgrades to the WSR-88D system. The RRCT will play a significant role in assessing the dual polarization upgrades as well as the utilization of gap-filling radars. (3/12/09) The tool has a web-based interface that allows the analyst to select the level of integration from hours to months, over which the comparison takes place. It is used by the NWS Radar Operations Center in daily operations.

NSSL scientists have developed a real-time system to develop, test, and assess advanced techniques related to precipitation estimation. The system, called Q2, integrates radar information provided by the national WSR-88D radar network, FAA Terminal Doppler Weather Radars, and Canadian weather radars to provide a seamless rain fall estimate every 5 minutes across the continental US. Q2 components include a quality control module, a data integration module, and a precipitation estimation module. Q2 is being transitioned to the NWS for use in model assimilation of radar information.

NSSL has ported code to the National Centers for Environmental Prediction for the creation of high-resolution national 3-D reflectivity grids. NSSL[1]s 3-D mosaic code is currently running operationally at NCEP and is used in the Rapid Update Cycle (RUC). (3/12/09)

NSSL has ported and is running operationally at the Salt River Project and NWS Forecast Office in Phoenix Arizona an advanced precipitation-monitoring system. The NSSL Q2 system is being used operationally for flood monitoring and water resources management of reservoirs and rivers in the southwest United States. (3/12/09)

NSSL in real time provides 7 River Forecast Centers with hourly high-resolution grids of precipitation rate and type. These grids are then used for operationally prototyping NSSL[1]s advance Q2 system as input to their operational Stage 4 product which feeds the nation's river models. (3/12/09)

NSSL develop the first national high spatial resolution database for the delineation of flash flood base. This data set is the backbone database to the NWS Flash Flood Monitoring and Prediction system used operationally for the issuance of FF warnings. The data base has been put online and is used by a number of Federal and state agencies in addition to every NWS forecast office. (3/12/09)