# The Advanced Research WRF Effort at NCAR

Jordan G. Powers and Joseph B. Klemp
National Center for Atmospheric Research[1], Boulder, Colorado

## 1. Introduction

The Weather Research and Forecasting (WRF) Model has been under development from the late '90's and its research capabilities and operational readiness are now maturing. WRF Version 2.0 (Dudhia 2004), which offers a nesting capability and new physics options, was released in May 2004. In addition, the NCEP WRF Test Plan was completed over 2003–2004, and the results are being analyzed (*see* Seaman *et al.* (2004)).

In light of WRF's evolution, and in light of the missions and goals of the National Center for Atmospheric Research (NCAR), NCAR is undertaking an effort for the support of a WRF configuration tailored for research applications. This "Advanced Research WRF" effort is described herein.

## 2. The ARW Effort and Motivations

NCAR focuses on important atmospheric research problems that require major commitments of resources and a wide range of scientific talent over extended periods of time. By housing scientific programs and providing a wide variety of research facilities, facilities support, and related services, NCAR serves the specialized needs of the university research community.

Within NCAR the Mesoscale and Microscale Meteorology Division (MMM) seeks to advance the understanding of the meso- and microscale aspects of weather and climate, and to apply this knowledge to benefit society. The division strives to address the most important and fundamental scientific themes in mesoscale and microscale meteorology, with emphases on understanding and forecasting weather and on evaluating the influence of meso- and microscale processes on larger-scale phenomena. MMM has a history of supporting mesoscale models to the research community, from the MM4 to the MM5, to, now, the Weather Research and Forecasting (WRF) Model.

In light of these missions and goals, and MMM's history of model support to the research community, MMM is leading an effort at NCAR to conduct the cutting-edge research required to advance the understanding and prediction of mesoscale weather, develop and utilize an advanced WRF capability in support of this research, and support this capability for the benefit of the broader research community. This is aimed to be consistent with MMM's research directions, which include: predictability studies to clarify the limitations of advanced forecast models; investigation of the life cycles of convective systems to identify the critical elements for improving their prediction; development and evaluation of advanced data-assimilation techniques (such as the Ensemble Kalman Filter approach and 4DVAR) for use in mesoscale models; and the development of new verification techniques that better measure the quality of high-resolution forecasts. This research will require a flexible, state-of-the-art mesoscale modeling capability, and will, in turn, contribute to the advancement of the model.

The modeling capability that NCAR can support will be a subset of WRF codes constituted to serve the needs of studies such as described and the diverse scientific investigations of meteorological research. It will have portable codes, both well-tested and experimental, that are appropriate for a wide range of applications and for which NCAR has sufficient expertise and resources to support. A working title for this capability is the Advanced Research WRF core (ARW), and at present this is constituted by WRF Version 2.0 (V2.0; see Sec. 3). It is to be noted that its ARW effort does not diminish NCAR's commitment to participate in the broader WRF program, to adhere to the WRF partners' Agreement in Principal, and to pursue WRF collaborations with other institutions.

The idea for the ARW effort stems from NCAR's desire to further its mission by contributing to the development and support of a next-generation mesoscale modeling capability that serves the requirements of the research community. NCAR recognizes that this community needs such a capability with the following attributes:

- Versatile, supporting a wide range of research applications;
- Cutting-edge in improvements and experimental approaches;
- Built with research community input

[1] The National Center for Atmospheric Research is supported by the National Science Foundation.

and guided by community needs; and
- Well-supported.

While WRF provides a basis for this, as the total array of WRF software and components is beyond what NCAR can support, and as the system in its entirety goes beyond a tool tailored for purely research needs, support of the full WRF code set is inconsistent with the missions of NCAR and MMM. The vision for the ARW core is a state-of-the-art, experimental numerical weather prediction capability, encompassing largely contributed code (as defined under the Developmental Testbed Center, see below), tuned for the research community. Thus, the ARW core represents a subset of the total WRF system codes. Its many potential uses include:

- Basic research;
  - idealized simulations
  - atmospheric process studies
  - simulation of weather systems
  - geophysical fluid dynamical applications
- Parameterization research;
- Data assimilation research;
- Real-time prediction and research;
- Coupled model applications; and
- Teaching

To advise NCAR on the core's development needs and directions, and reflecting the community side of the effort, there will be an external advisory panel called the Community Advisory Panel (CAP). The panel's members should have an active interest in WRF, and they will be drawn from the university and research communities. The panel will provide recommendations to ARW effort management on system development, priorities, and support issues.

## 3. The ARW Core

The ARW core currently coincides with WRF Version 2.0. The dynamical core in V2.0, and thus that for the ARW capability, is the Eulerian mass core. Perhaps the most anticipated improvement in V2.0 is a multiple-domain capability with 1- and 2-way nesting. The nesting allows for flexible grid ratios of grid sizes, *i.e.*, they are not restricted to 3:1 ratios. In addition, the SI (standard initialization) package allows for the creation of nested inputs.

The V2.0 software provides efficient parallelism, and the code runs on many computer architectures, including Linux clusters. New physics schemes in V2.0 include the unified Noah LSM, the RUC LSM, the YSU PBL scheme, and the Grell-Devenyi ensemble cumulus scheme (see www.wrf-model.org for full details). In addition, V2.0 presents an updated WRF 3DVAR package. New documentation on the V2.0 code and on WRF 3DVAR has also been produced and is available on-line.

## 4. Guidelines and Organization

### *4.1 Effort Goals and Guidelines*

The goal for the ARW effort is the establishment of a premier NWP research tool tailored to the needs of the atmospheric research community. NCAR's role shall encompass the following:

- Leadership and management of the ARW effort;
- Oversight and development of the ARW core;
- Support to the community of the ARW core;
- Organization of users' workshops and tutorials; and
- Hosting of advisory panel meetings.

To serve researchers and scientists effectively, NCAR desires to foster the capability that best accords with its goals and expertise. However, to make sure that NCAR's aims are achieved within the bounds of its mission and resources, the following guidelines are identified for the ARW effort/core.

- The ARW effort must be manageable by MMM.

- The ARW effort should serve the needs of the research community.

- The ARW core will be a subset of the WRF codes.

First, the effort and system must be supportable by available resources: NCAR cannot manage and support all codes associated with WRF. Furthermore, the core must be one for which NCAR has adequate development and support expertise.

The second guideline recognizes that the development priorities should reflect research community needs. These needs will be assessed via CAP feedback, users' workshops, and NCAR–community collaborations and interactions. In this vein, participation of the research community researchers in core development and testing will be encouraged.

As to the third guideline, the ARW core will be limited to a selected subset of "contributed", "reference", and "operational" WRF code (as defined by the DTC). Collectively this will be referred to as "contributed" code. Moreover, given NCAR's resource and expertise limitations, there will be restrictions on components and dynamical cores, and

initially only the Eulerian mass dynamical core will be present. In addition, as the configuration will be supported as resources and expertise permit, full support of some codes may be the responsibility of the contributors.

*4.2 Effort Organization*

***NCAR Management and Staff*** The ARW effort's management consists of the scientists at NCAR currently managing WRF activities plus an ARW Guidance Committee (composed of personnel within NCAR). The Guidance Committee is separate from the CAP. It will provide an in-house body that has technical command of the issues facing the ARW effort, and it will determine, decide upon, direct, and oversee ARW core development and support activities.

The NCAR personnel contributing to the ARW effort are organized in the areas of software engineering, system development, and community support. The first group consists of the software engineers involved in code development, porting, and parallelization. The second group consists of the scientists developing and implementing numerics, data assimilation techniques, physical process schemes, etc. The third group provides support such as user inquiry help and code management.

***Community Advisory Panel*** To advise effort management on the needs of the research community and on priorities for the capability, there will be a Community Advisory Panel (CAP) composed of external (non-NCAR) scientists. The six-member CAP will represent the research community and its interests and ideas. It will be charged with making recommendations to ARW effort management on capabilities, development needs, support concerns, and future directions.

The CAP shall be primarily from the university community, although not necessarily exclusively, as there may be other institutions with strong interests in ARW core. The panel members should have interest and expertise in the spectrum of topics affecting the ARW core's composition and reflecting its applications. To provide a link to the oversight of the full MMM program, one member of the CAP should also be on the MMM division's advisory committee. The terms of CAP members are two years, and members are eligible for reappointment.

## 5. Relationship to External WRF Activities

The WRF activities at NCAR currently are taking place within MMM, taking advantage of its expertise in modeling, data assimilation, software engineering, and user support. The ARW effort will be well-connected to the broader WRF program and to the research community.

- ***The Research Community***

The research community will connect with the ARW effort through the CAP, users' workshops, and collaborations and communications with NCAR personnel. Scientists in universities, agencies, and other institutions applying the ARW core in their research will be encouraged to provide feedback to the CAP and to developers at NCAR. The NCAR personnel will have collaborations with developers and users of the core in the research community and that this will provide feedback for the effort. Workshops will also be forums for input.

- ***The Broad WRF Program***

The WRF program is an interagency partnership that encompasses the relationships, agreements, plans, investments, and work between the principal WRF partners in the development of the modeling system as a whole. This effort has a management framework including an Executive Oversight Board, a Research Applications Board, an Operations Requirements Board, a Program Coordinator, and working groups. It also spans the DTC, and in the future should encompass Operational Testbed Centers. NCAR's coordination of the ARW effort does not diminish or conflict with its involvement in the broader program; NCAR shall continue to contribute to it and to collaborate with the WRF partners, administration, and working groups.

In the interaction of the effort with the broader WRF program, first, NCAR will meet periodically with the WRF Program Coordinator to discuss the plans for, and status of, the ARW core. Second, NCAR will inform the WRF Research Applications Board of the activities of the ARW effort, while effort management will receive the latest news on the directions and plans discussed by the Board. Third, the NCAR representative on the WRF Executive Oversight Board would apprise that body of significant ARW developments and would provide a communication path at the highest levels of WRF management. Fourth, ARW core components would be made available to the broader WRF system through input to the DTC.

- ***The DTC***

The Developmental Testbed Center will be a facility for the development, testing, and evaluation of codes for the WRF modeling system. Many of these codes will emerge from the university research community. Ideas and codes will also spring, however, from government agencies and the operational centers.

The DTC will also be responsible for supporting WRF reference code.

Elements of the ARW core could potentially be drawn from all WRF code classes. In interacting synergistically with the DTC, the ARW effort could draw tested WRF components from it, while new physics schemes, software, processors, etc. that may be developed through the ARW effort could be provided to the DTC as contributed code for testing and evaluation. It is envisioned that contributed code will make up a significant portion of the ARW core, although not exclusively.

## 5. Summary

To advance its institutional mission and research goals, and to serve the university community, NCAR is supporting to the atmospheric sciences research community a capability known as the Advanced Research WRF core (ARW). This is designed for research applications, will offer experimental approaches, and will be made up largely of contributed code. The first configuration of the ARW core coincides with WRF V2.0. While the effort will be managed by NCAR, a Community Advisory Panel will provide input from the research and university community on priorities and directions for the core. Ultimately, information on the ARW core and updates to it will be available via links on the WRF home and/or users' pages.

## References

Dudhia, J., 2004: The Weather Research and Forecasting Model (Version 2.0). *2nd Int'l Workshop on Next Generation NWP Model*. Seoul, Korea, Yonsei Univ., 19–23.

Seaman, N.L., R.L. Gall, L.B. Nance, S.E. Koch, L.R. Bernardet, G.J. DiMego, Z. Janjic, J.G. Powers, and F. Olsen, 2004: The WRF process: Streamlining the transition of new science from research into operations. *1st Joint WRF/MM5 Users' Workshop*, Boulder, CO, Nat'l Center for Atmos. Res.