THE STATISTICS OF WRF

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1. INTRODUCTION

NCAR supports the Weather Research and Forecasting (WRF) Model (Skamarock et al. 2008) to a worldwide user community through code development and oversight, periodic releases, help services, tutorials, and workshops. The NCAR effort also attempts to measure the reach of the WRF system, in large part through the collection of demographic data. The statistics compiled illuminate the scope and impact of model use, and they support the argument that WRF has been the world's most popular NWP model.

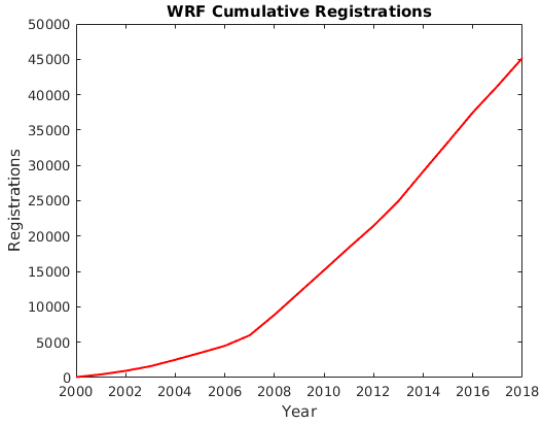
The WRF data considered here are derived from three sources: user registrations, bibliographic searches, and the NCAR support effort. The registration information has been collected from initial model release in 2000 to the present. When users register they indicate their country and institutional affiliation type, and this and the counting of registrants are valuable for the WRF program and its support.

The publication data analyzed have been generated using the scientific citation indexing service Web of Science. Publication searches have been conducted and have targeted articles in all languages which have the keywords WRF and Weather Research and Forecasting and variants of it, including WRF-NMM, WRF-Chem, and WRF-Hydro. An important aspect of the search analysis is that many occurrences of the acronym "WRF" are excluded, as the acronym appears across diverse disciplines unrelated to weather forecasting. Thus, the publications pulled from the searches have been checked to identify non-relevant uses of "WRF" to exclude them from the counts and refine future searches.

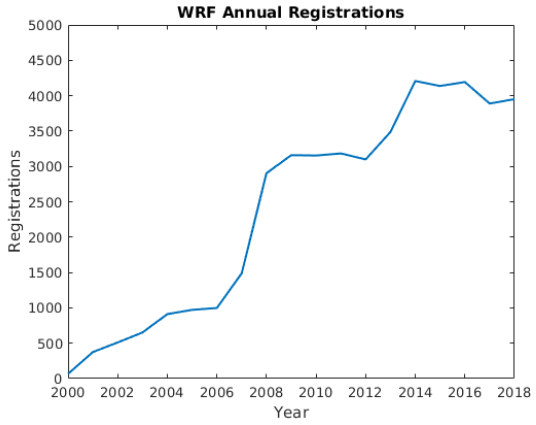
2. THE STATISTICS

The most basic metric maintained over the years is the cumulative number of WRF registrations. This now stands at over 42,900. Figure 1(a) shows WRF's steady growth in cumulative registrations since its initial release. Note that the registration number for the current year of 2018 reflects a projection to year's end via simple linear extrapolation.

A measure of the ongoing interest in WRF and the variations in the influx of users is the number of annual registrations (Fig. 1(b)). One can see a bump in the annual registrations in 2008, and this is correlated with the release of WRF Version 3.0. The increase in 2014 occurred in the year of the V3.6 release. Table1 presents the raw numbers of WRF registrations by year, with the number for 2018 projected. Note that the total grows continually, as WRF averages over 10 registrations/day. That WRF continues to be in demand is proven by the annual registration *average of over 3,900/yr* for the past five full years (2013–2017). And, the projected total for 2018 is also over 3,900.



(a)



(b)

Fig. 1: AMPS user registrations, 2000–2018. Values for 2018 are projections based on registrations to date. (a) Cumulative registrations. (b) Annual registrations.

The number of unique countries with WRF user registrations to date is 166, and Fig. 2 shows these. Thus, over the years, WRF literally has covered the

globe with registered users. The top five user registration countries and the cumulative registrations as of May 2018 are given in Tab. 2, below. The United States is first, followed by China.

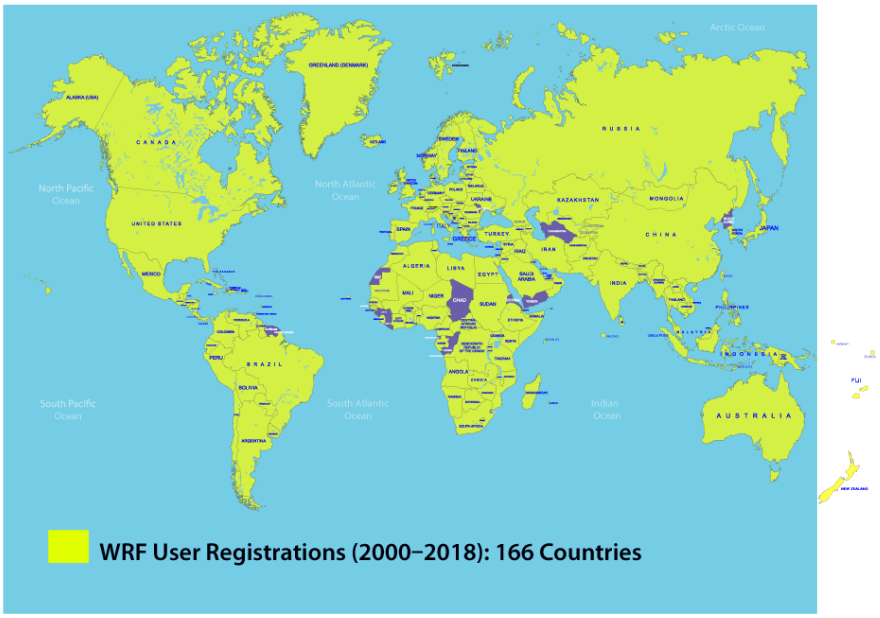


Fig. 2: Map of counties with WRF registrations through 2018.

Table 1: WRF Annual Registrations

2000	67
2001	375
2002	511
2003	652
2004	911
2005	972
2006	998
2007	1488
2008	2904
2009	3159
2010	3154
2011	3183
2012	3099
2013	3487
2014	4208
2015	4137
2016	4193
2017	3889
2018	3959*

* Projection to end of 2018 from registrations as of May 2018.

Table 2: Top 5 User Registration Countries

1) United States (>11,680)
2) China (>8560)
3) India (>2110)
4) Japan (>2090)
5) South Korea (>1580)

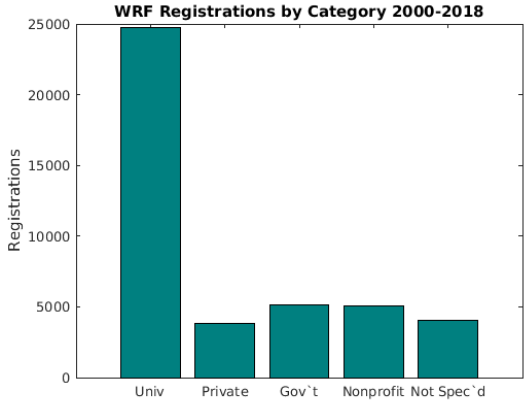


Fig 3: WRF user registrations by category. Totals as of May 2018.

Figure 3 shows a breakdown of WRF users by institutional affiliation type, reflecting what users have indicated upon registration. Note that not every registrant has indicated an affiliation, as prior to 2009 approximately 9% of users did not specify one. From that time the registration page has used a menu to prescribe the options for affiliation types, so unspecified entries do not occur.

The affiliation categories in Fig. 3 are: university (Univ), private companies and individuals (Private), governmental organizations (Gov't), nonprofit entities

(Nonprofit), and affiliation not specified (Not Spec'd). It is obvious that university affiliations dominate. Of the cumulative registrations with specified affiliations (>91% of all registrations), university users account for 63.8%. These are followed by government at 13.3%, nonprofit at 13.0%, and private at 9.9%.

Table 3: WRF User Registration by Category (2000–May 2018)

University	24841
Private	3834
Government	5153
Nonprofit	5072
Not specified*	4049
Total	42949

*Registrations without an affiliation type specified.

Table 3 shows the cumulative numbers in these groups through May 2018. As in Fig. 3, the categories are university, government, private, nonprofit, and not specified.

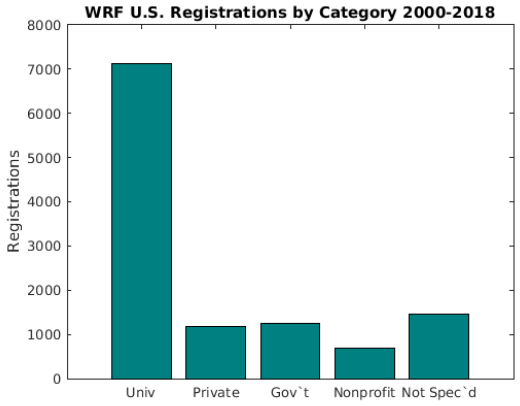


Fig. 4: WRF U.S. user registrations by category. Totals as of May 2018.

Table 4: WRF U.S. User Registration by Category (2000–May 2018)

University	7131
Private	1180
Government	1243
Nonprofit	680
Not specified*	1456
Total	11690

*U.S. registrations without an affiliation type specified.

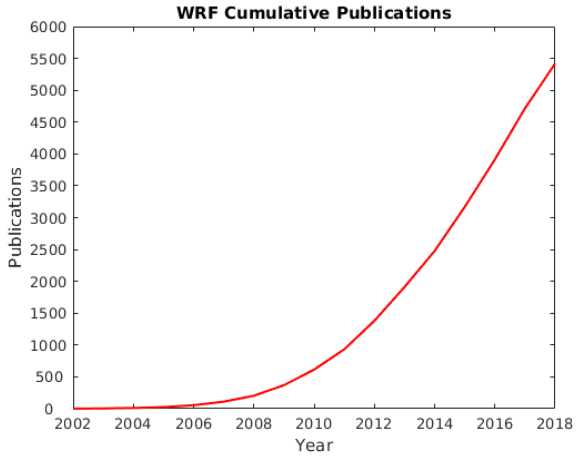
Focusing on just the American registrants, Fig. 4 shows these affiliations through May 2018. Of the registrations from the U.S. with specified affiliations, as with the global figures, university users are the biggest group. University registrants account for 69.7%, slightly higher than the global average. The fractions for government users and private users are comparable, at 12.2% and 11.5%, respectively. The nonprofit segment of U.S. registrations has been 6.7%. Table 4 presents the raw numbers for the American registrations by category to date.

WRF's impact on science can be inferred from the catalog of WRF-related publications, and publication statistics have been compiled from the literature citation search summarized in the introduction. Figure 5(a) shows the cumulative number of journal publications involving WRF since initial model release. The total is currently over 5,400 and has grown nonlinearly in recent years. Figure 5(b) shows the annual numbers of publications, and the total for the last full year (2017) was 803. The average for the past five full years of 2013–2017 is 667. A change in the publication rate appears in the period 2008–2010 in Fig. 5(b), and from then through 2017 there is a roughly linear increase in the annual number of publications. It is important to note that the apparent dropoff in 2018 cannot be assumed to have significance at this time, as the number (703) is a projection. The number is simply based on the publications recorded to date in 2018, and thus a nonlinear rate of publication in the latter part of the year is not considered (i.e., the possibility of more papers appearing in the second half of the year). Still, using this number, the projected publication rate for the most recent five-year period (2014-2018) would be *701/yr*, an impressive figure.

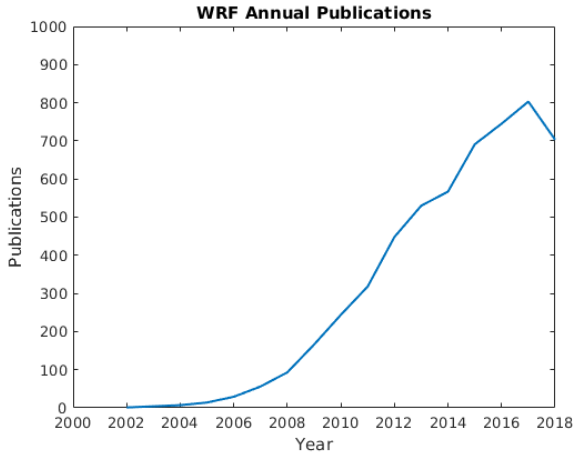
The WRF support group at NCAR provides services to assist and train the broad and renewing population of model users. The current number of subscribers to *wrfnews*, the model information and update e-mail list, is over 7800. The support effort keeps track of model inquiries and assistance requests, which range from questions on input data, to model configuration and compilation, to run-time problems. These are running 340/month. NCAR provides two tutorials a year for the community, and these offer an enrollment of 60 each. NCAR hosts the annual WRF Users' Workshop, which now also covers the Model for Prediction Across Scales (MPAS) (Skamarock et al. 2012), and this has averaged 200 attendees in recent years. While WRF code downloads have not been recorded in the past, these will be monitored with the release of WRF V4.0.

There are a number of specialized versions of WRF, such as WRF-Chem, WRF-Hydro, and WRF-Fire. Their support groups have not, in general, maintained consistent records of registrants for the systems. The WRF-Hydro support effort, however, is an exception and does maintain some statistics for that model. Over the last three years the average annual number of downloads for the WRF-Hydro code has been 1,328/yr, and this has been across 70 countries. While that number is the average, the number of downloads per year has been steadily increasing, and

it may accelerate from expanded applications due to WRF-Hydro's adoption by NOAA as the National Water Model. The WRF-Hydro user subscription list is approximately 150 users, and support in the past year has serviced 90 unique users.



(a)



(b)

Fig. 5: Cumulative and annual WRF-related publications. Entry for 2018 represents a simple extrapolation form publications as of May 2018. (a) Cumulative publications. (b) Annual publications.

While registrations are not identified solely for WRF-Chem, intended uses of WRF-Chem have been indicated by users upon registration. These show over 3700 cumulative registrations to date, with about 430 in the past year alone.

As noted above, university users are the largest segment of the WRF population, and they represent an impressive number and breadth of institutions both in the U.S. and abroad. For the period 2012–2017, the number of *distinct* American universities with user registrations was 245. The appendix lists these. The registration database also had three secondary school affiliations, indicating interest in WRF also occurs in earlier education. As for foreign universities, the number of distinct schools with registrations during the same period was 1243. Table 5 presents the university numbers for the survey period.

Table 5: Universities with WRF User Registrations
(2012–2017)

United States:	245	
International:	1243	(excl. U.S.)

SUMMARY

Though WRF is a mature model, statistics reveal the continuing strength and impact of the system. The data show that new model registrations are continuing at high levels, over 3,900/yr, and the cumulative total of WRF registered users is now over 42,900. University users make up the majority of WRF users, approximately 64%. The need for WRF support by the user base is reflected both in the ongoing demand for help requests that run 340/mo and in continuing requests for tutorials at NCAR and abroad. Most importantly, the model has been applied productively, and there were over 800 model-related publications in 2017, with an average for the past five full years of 667/yr. Lastly, analyses of university user institutions provide an impressive picture of the breadth of WRF's support of atmospheric research globally.

REFERENCES

Skamarock, W.C., J.B. Klemp, J. Dudhia, D.O. Gill, D.M. Barker, M.G. Duda, X.-Y. Huang, W. Wang, and J.G. Powers, 2008: A description of the Advanced Research WRF Version 3. NCAR Tech. Note, NCAR/TN-475+STR, 113 pp. doi: 10.5065/D68S4MVH.

Skamarock, W. C., J. B. Klemp, L. D. Fowler, M. G. Duda, S.-H. Park, and T. D. Ringler, 2012: A multiscale nonhydrostatic atmospheric model using centroidal Voronoi tesselations and C-grid staggering. *Mon. Wea. Rev.*, **140**, 3090–3105. doi: 10.1175/MWR-D-11-00215.1

Appendix:
WRF User Registrations— U.S. Universities
(2012–2017)

Count: 245

Appalachian State University
Arizona State University
Auburn University
Austin College
Ball State University
Bentley University
Boise State University
Boston College
Boston University
Bowie State University
Brown University
California Institute of Technology
California State University, Chico
California State University, East Bay
California State University, Long Beach
Carnegie Mellon University
Central Michigan University
Central Washington University
Chapman University
City College of New York
City University of New York
Clemson University
Coastal Carolina University
College of Charleston
College of DuPage
Colorado School of Mines
Colorado State University
Columbia University
Cornell University
Creighton University
Dartmouth College
Duke University
East Carolina University
East Stroudsburg University
Eastern Michigan University
Embry-Riddle Aeronautical University
Emory University
Florida Institute of Technology
Florida International University
Florida State University
Fresno State University
George Mason University
Georgia Institute of Technology
Harvard University
Hinds Community College
Hood College
Howard University
Illinois Institute of Technology
Indiana State University
Indiana University, Bloomington
Indiana University, Purdue University Indianapolis
Interamerican University of Puerto Rico
Iowa State University
Jacksonville State University
James Madison University
Kansas State University
Kennesaw State University
Kent State University
Lamar University
Louisiana State University
Loyola University Chicago
Lyndon State College
Massachusetts Institute of Technology
Medical College of Wisconsin
Metropolitan State University of Denver
Michigan State University
Michigan Technological University
Mississippi State University
Missouri University of Science and Technology
Montana State University
Montclair State University
Morehead State University
Morgan State University
Naval Postgraduate School
New Jersey City University
New Jersey Institute of Technology
New Mexico State University
New York University
New York University Polytechnic School of Engineering
North Carolina Agricultural and Technical State University
North Carolina State University
North Dakota State University
North Seattle College
Northeastern University
Northern Arizona University
Northern Illinois University
Northland College
Ohio State University
Ohio University
Old Dominion University
Oregon State University
Pennsylvania State University
Plymouth State University
Portland State University
Prairie View A&M University
Princeton University
Purdue University
Rice University
Richard Stockton College of NJ
Rochester Institute of Technology
Rockford University
Rocky Mountain College
Rutgers University
Saint Louis University
Saint Mary's College of California
San Francisco State University
San Jose State University
Scripps Institution of Oceanography
Slippery Rock University
South Dakota School of Mines & Technology
South Dakota State University
Southern Methodist University
Southwestern Oklahoma State University
St. Cloud State University
Stanford University
Stevens Institute of Technology

SUNY Albany
SUNY Buffalo
SUNY College of Environmental Science and Forestry
SUNY Oswego
SUNY Plattsburgh
SUNY Stony Brook
Syracuse University
Temple University
Tennessee State University
Texas A&M University, College Station
Texas A&M University, Corpus Christi
Texas A&M University, Kingsville
Texas Southern University
Texas Tech University
The College at Brockport
The Johns Hopkins University
The Ohio State University
The University of the Incarnate Word
Tufts University
Tufts University
Tuskegee University
U.S. Air Force Academy
U.S. Naval Academy
University of Alabama, Huntsville
University of Alabama, Tuscaloosa
University of Alaska, Fairbanks
University of Arizona
University of Arkansas, Fayetteville
University of Arkansas, Little Rock
University of California, Berkeley
University of California, Davis
University of California, Irvine
University of California, Los Angeles
University of California, Merced
University of California, Riverside
University of California, San Diego
University of California, Santa Barbara
University of Central Florida
University of Chicago
University of Cincinnati
University of Colorado, Boulder
University of Colorado, Denver
University of Connecticut
University of Dayton
University of Delaware
University of Georgia
University of Hawaii
University of Houston
University of Idaho
University of Illinois
University of Iowa
University of Kansas
University of Louisiana, Lafayette
University of Louisiana, Monroe
University of Louisville
University of Maine
University of Maryland, Baltimore County
University of Maryland, College Park
University of Massachusetts, Amherst
University of Massachusetts, Dartmouth
University of Massachusetts, Lowell
University of Memphis
University of Miami
University of Michigan, Ann Arbor
University of Michigan, Dearborn
University of Michigan, Flint
University of Minnesota
University of Mississippi
University of Missouri, Columbia
University of Missouri, Kansas City
University of Montana
University of Nebraska, Kearney
University of Nebraska, Lincoln
University of Nevada, Las Vegas
University of Nevada, Reno
University of New Hampshire
University of New Mexico
University of North Carolina, Asheville
University of North Carolina, Chapel Hill
University of North Carolina, Charlotte
University of North Carolina, Wilmington
University of North Dakota
University of North Texas
University of Northern Colorado
University of Notre Dame
University of Oklahoma
University of Pittsburgh
University of Puerto Rico, Mayaguez
University of Puerto Rico, Rio Piedras
University of Rhode Island
University of Rochester
University of San Diego
University of South Alabama
University of South Carolina
University of South Florida
University of Southern California
University of Tennessee, Knoxville
University of Tennessee, Martin
University of Texas, Arlington
University of Texas, Austin
University of Texas, Dallas
University of Texas, El Paso
University of Texas, San Antonio
University of the Pacific
University of the Virgin Islands
University of Utah
University of Vermont
University of Virginia
University of Washington
University of West Florida
University of West Georgia
University of Wisconsin, Madison
University of Wisconsin, Milwaukee
University of Wyoming
Utah State University
Valparaiso University
Virginia Institute of Marine Science
Virginia Polytechnic Institute and State University
Washington State University
Wayne State University
Wellesley College
Western Carolina University
Western Connecticut State University
Western Illinois University

Western Kentucky University
Western Michigan University
Wheaton College
Wichita State University
Yale University