VertumPartners

DOE SBIR Phase II Final Report

Title: Assessing Climate Change Effects on Wind Energy

November 5, 2014

Department of Energy (DOE) Small Business Innovation Research (SBIR) Award No. DE-SC0006465
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Purpose of the Research

Specialized Atmospheric Science software tools were prototyped, tested and commercialized to allow wind energy stakeholders to assess the uncertainties of climate change on wind power production and distribution. In addition to climate variability and change over the lifetime of a wind production facility, other meteorological factors such as interannual variability and atmospheric turbulence were included.

Brief Description of the Research

To lay the foundation for this project, we integrated observed point-measurements, regional climate simulations, and global climate models to quantify the meteorological uncertainties in wind power production and distribution. The original focus was on a commercial prototype that incorporated climate change and other meteorological effects in assessing atmospheric resources for wind farm project analysis and risk assessment. During this project, we built a small client base of utilities and wind developers. Feedback from these commercial users prompted us to also focus on critical distribution issues like improved fire prediction to truly assess the effects of climate change on wind energy.

Findings, Results and Conclusions

This project resulted in three commercially proven products and a marketing tool. The first was a Weather Research and Forecasting Model (WRF) based resource evaluation system. This was tested with two wind industry companies, Torbellino NA and Renovare Renewables. The second was a web-based service providing global 10m wind data from multiple sources to wind industry subscription customers. The third product addressed the needs of our utility clients looking at climate change effects on electricity distribution. For this we collaborated on the Santa Ana Wildfire Threat Index (SAWTi), which was released publicly last quarter. Finally to promote these products and educate potential users we released “Gust or Bust”, a graphic-novel styled marketing publication.

Potential Applications of the Research

The commercially available products coming out of this project help quantify and reduce uncertainties of atmospheric related climate change factors in wind energy production and distribution. This will allow wind stakeholders the ability to lower costs and plan for the benefits and risks of a changing climate.

“Rights in Data - SBIR/STTR Program” provisions

This report does not include limited rights data or restricted computer software details.

This summary may be published by DOE and should not contain proprietary information.

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1. Acknowledgement and Vertum Commitment

Vertum Partners, LP (Vertum) would like to thank the Department of Energy (DOE) for your support as we grow our company and develop commercial software products. Our core team of equity-owners has remained focused and dedicated to developing Vertum Partners into a leader of environmental modeling solutions.

Vertum would also like to recognize the US Congress for reauthorizing this important SBIR/STTR Program through September 2017. We understand the associated emphasis on commercialization and will report here the small business success that this project has seeded.

Over the course of this project, the level of acceptance by the Renewables Industry for the work coming out of this project has exceeded our expectations. The successful commercialization of our software has demonstrated community benefits well beyond our original vision.

2. Vertum Background

Vertum is a climate analytics software company formed in Los Angeles in 2009 by two scientists—Dr. Alex Hall (UCLA) and Dr. Sarah Kapnick (Princeton)—and a business professional Cameron Whiteman (UCLA Anderson MBA). Our current Senior Science Partner, Dr. Scott Capps joined Vertum in 2011. In addition to this Small Business Innovation Research (SBIR) grant from the U.S. Department of Energy, a national Energy Research Scientific Computer Center (NERSC) super-computing resources award has also supported us.

Vertum's mission is to transform complex climate information for practical, commercial energy planning decisions within a user-guided software platform. Its approach is driven by the latest findings in climate science, predictive analysis and risk assessment. The Vertum team is recognized internationally for its expertise in climate variability and change.

Vertum serves the needs of clients in various sectors, including federal and local government agencies, the wind power industry, utilities, and large global corporations, to name a few.

3. Vertum Team

Intimately familiar with most global and regional atmospheric datasets, Vertum scientists are experts in:

- Dynamical downscaling using Weather Research and Forecasting (WRF)
- Global operational forecasting system design, setup and maintenance
- Customized forecast / risk analyses, statistics, and verification
- Global long-term climate simulation design, operation and analysis (historical and future)

Vertum's high-performance computing specialists are efficient in:

- Multiple coding languages (Fortran, C++, Python, NCO, NCL)
- Climate reanalysis datasets (*e.g.,* MERRA, NCEP I and II, NARR, CFSR, CDAS, ERA) [1]
- Programming techniques including proprietary stochastic tools, used to improve targeted data quality and reduce processing time

[1] Datasets: MERRA (Modern-Era Retrospective Analysis for Research and Applications); NCEP I and II, (NCEP/NCAR Reanalysis I, NCEP-DOE AMIP-2 Reanalysis II); NARR (North American Regional Reanalysis); CFSR (Climate Forecast System Reanalysis); CDAS (Climate Data Assimilation System); ERA (ERA-Interim).

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4. Findings and Results

Our software development addresses wind energy industry needs for analytical tools primarily in the following three areas based on a changing climate:

a) Wind farm siting (and re-siting) that includes climate change analysis;
b) Wind energy revenue analysis and wind farm projections; and
c) Electricity distribution planning, including extreme event planning.

The core sources supporting our tools come from (1) reanalysis datasets, (2) the WRF model, and (3) new stochastic tools developed to improve targeted data quality and reduce processing time. These are the backbone for our global wind resource-modeling platform. They are complex programs capable of processing extremely large amounts of relevant data. Our "value-add" is proprietary software, expertise, central processing unit (CPU) intense resources and tools for on-demand access.

For this project, specialized Atmospheric Science software tools were prototyped, tested and commercialized to allow wind energy stakeholders to assess the uncertainties of climate change on wind power production and distribution. In addition to climate variability and change over the lifetime of a wind production facility, other meteorological factors such as interannual variability and atmospheric turbulence were included. To lay the foundation for this project, we integrated observed point-measurements, regional climate simulations, and global climate models to quantify the meteorological uncertainties in wind power production and distribution. The original focus was on a commercial prototype that incorporated climate change and other meteorological effects in assessing atmospheric resources for wind farm project analysis and risk assessment. During this project, we built a small client base of utilities and wind developers. Feedback from these commercial users prompted us to also focus on critical distribution issues like improved fire prediction to truly assess the effects of climate change on wind energy.

This project resulted in three commercially proven products and a marketing tool. The first was a WRF based resource evaluation system (4.1 below). This was tested with two wind industry companies, Torbellino NA and Renovare Renewables. The second (4.2) was a web-based service, called WindFetch™, providing global 10m wind data from multiple sources to wind industry subscription customers. The third product (4.3) addressed the needs of our utility clients looking at climate change effects on electricity distribution. For this we collaborated on the Santa Ana Wildfire Threat Index (SAWTi), which was released publicly last quarter. Finally to promote these products and educate potential users we released "Gust or Bust", a graphic-novel styled marketing publication (4.4).

4.1. WRF based resource evaluation system

In response to demand for wind farm siting tools with climate change analysis, we partnered with two companies, Renovare Renewables (www.renovarerenewables.com) and Torbellino SA (www.torbellinosa.com) and produced a WRF based resource evaluation system. To develop this tool, we optimized WRF to resolve hub-height level winds for turbine site selection over Chile South America. (WRF is a full time-varying 3D physical model of the atmosphere, solving all basic energy equations and allowing for targeted parameterizations.) The optimization evaluation process used observational data from 2 towers, one inland and one coastal.

Several model optimization strategies were employed in this study to improve high-resolution WRF simulations of near-surface and wind turbine hub-height winds across a moderately complex topographic region of South America. (This terrain has similar characteristics to our own Southern California region.) Using the validated long-term tower observations within our WRF domain, we methodically selected the optimal WRF configuration for this region.

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Our understanding of land surface and atmospheric characteristics, which are important for near-surface winds, guided us through the decision-making process from domain configuration to the final WRF simulation. Rigorous testing included validation of wind speed and air temperature across multiple time periods with various WRF configurations. The ensemble included many different configuration variations including domain setup, large-scale forcing datasets, short-term cycling vs. spectral nudging, and multiple microphysics, land-surface and boundary layer schemes.

We found that at both towers, WRF had a fast wind speed bias, which increased with height. We also found that WRF performed consistently better at the inland tower. A dramatic reduction in wind speed error was realized when changing the land use dataset, land surface model and introducing nudging. (Errors were reduced by 20% in the spectral nudging case.) As a result of this evaluation we determined an optimal WRF configuration for this region, which may be similar to other "Mediterranean" regions such as Southern California.

The results of this innovative work were presented by Dr. Scott Capps, Vertum's Senior Science Partner, at the 15th Annual WRF Users' Workshop held at NCAR's Center Green Campus in Boulder, CO. The annual workshop provides a forum for Weather, Research and Forecasting Model (WRF) users to share new developments, present research highlights, and discuss issues of interest to both the users and developers. To view abstract: click here

4.2 WindFetch™: providing global 10m wind data from multiple reanalyses

Our first prototype product, Vertum WindFetch™, was launched on May 5th, 2013. Our value is that we are converting data that is in an originally esoteric format into a simple text file that anyone can use. After a successful trial period, the product has now been launched as a subscription based service. An example customer using the product is a European pioneer in wind energy and now a main player in the renewable energy sector. The company builds throughout the world, including in Europe and in Africa.

To access the software, users simply use our company website (www.vertumpartners.com) to link to the product web page. Here, there is a platform for downloading reanalysis time-series data for wind speed and direction.[2] The user interface leverages the familiar and user-friendly Google Maps product to allow users to pick a location anywhere in the world by clicking on a Google map and indicating the time period in which they are interested. They are then able to choose which reanalysis data sets and time periods of coverage they wish to download. (See Figure 1 below.)

[2] Reanalysis Data Definition: Reanalysis data is a term used to identify a meteorological data set that is comprised of historical observations. Various observations covering different time periods and spatial domains are integrated using a single assimilation technique (also known as an analysis scheme) to create a single extended data set without gaps in time or space.

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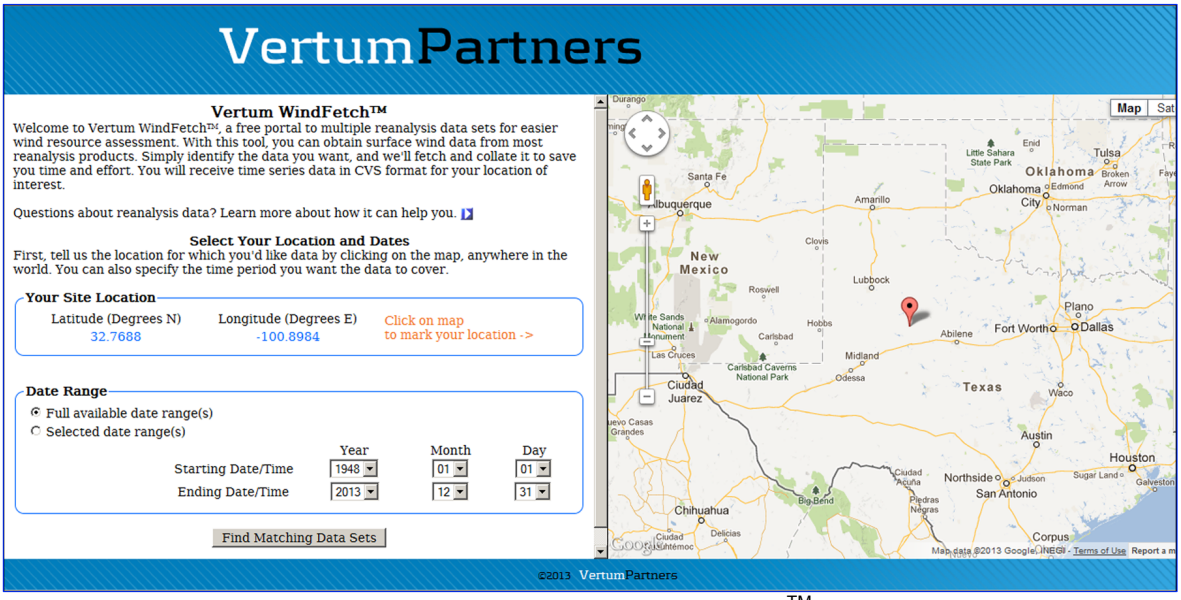

Figure 1. Screen shot of complete first page of Vertum WindFetch™ product.

Users click on the map to the right, setting a marker to choose their location. Then they select a desired data range on the left, or accept the full available date ranges supported by the available data for their location.

After clicking on a map to choose their location and desired data range on the first page, users are prompted to choose one or more from among the available datasets applicable to their selected site location and time range. Figure 2, on the following page, shows part of the second page of the WindFetch™ tool, where this selection is made.

Figure 3, also on the next page, illustrates the search algorithm that finds the appropriate time-series data for the user-selected site location. The software determines which grid cell contains the site, obtains the time-series data, and also reports the distance from the grid cell centroid to the user-selected site

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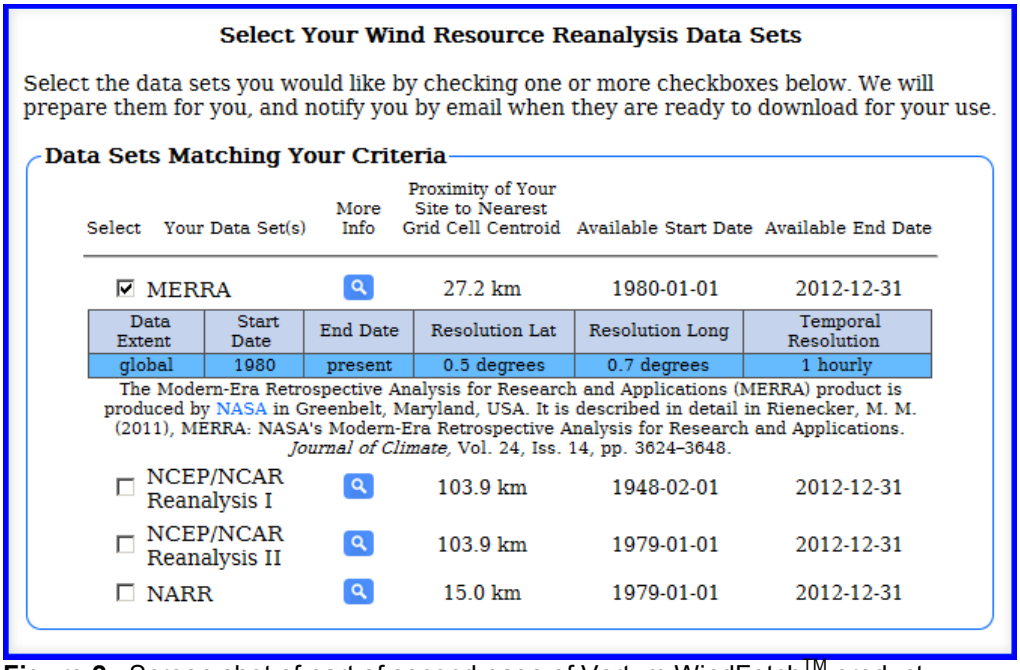

Select Your Wind Resource Reanalysis Data Sets

Select the data sets you would like by checking one or more checkboxes below. We will prepare them for you, and notify you by email when they are ready to download for your use.

Data Sets Matching Your Criteria

Select	Your Data Set(s)	More Info	Proximity of Your Site to Nearest Grid Cell Centroid	Available Start Date	Available End Date
☑	MERRA		27.2 km	1980-01-01	2012-12-31

Data Extent	Start Date	End Date	Resolution Lat	Resolution Long	Temporal Resolution
global	1980	present	0.5 degrees	0.7 degrees	1 hourly

The Modern-Era Retrospective Analysis for Research and Applications (MERRA) product is produced by NASA in Greenbelt, Maryland, USA. It is described in detail in Rienecker, M. M. (2011), MERRA: NASA's Modern-Era Retrospective Analysis for Research and Applications. *Journal of Climate*, Vol. 24, Iss. 14, pp. 3624–3648.

☐	NCEP/NCAR Reanalysis I	103.9 km	1948-02-01	2012-12-31
☐	NCEP/NCAR Reanalysis II	103.9 km	1979-01-01	2012-12-31
☐	NARR	15.0 km	1979-01-01	2012-12-31

Figure 2. Screen shot of part of second page of Vertum WindFetch™ product

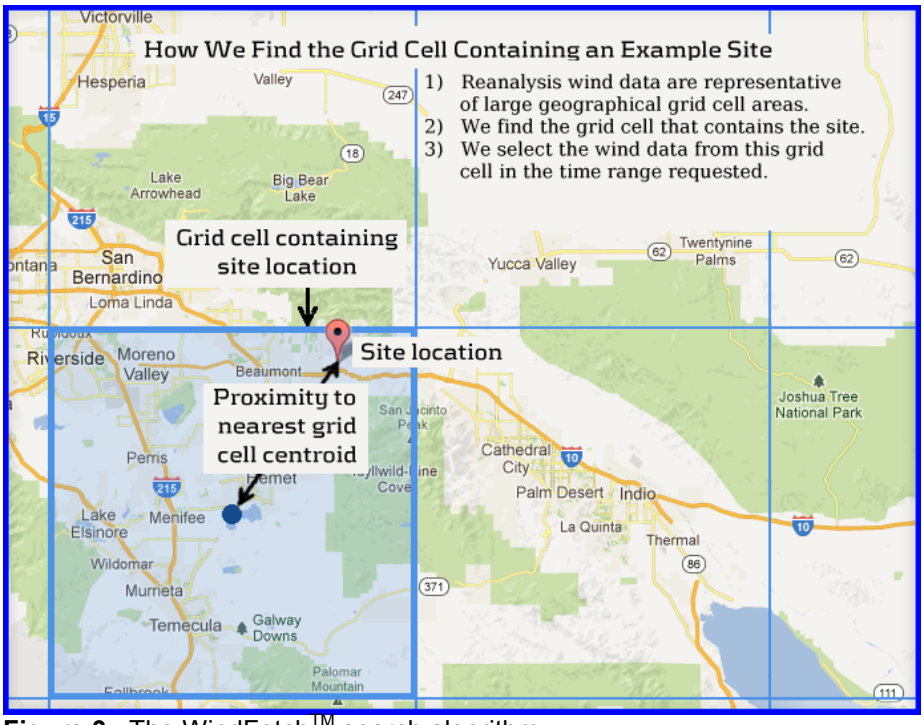

Figure 3. The WindFetch™ search algorithm

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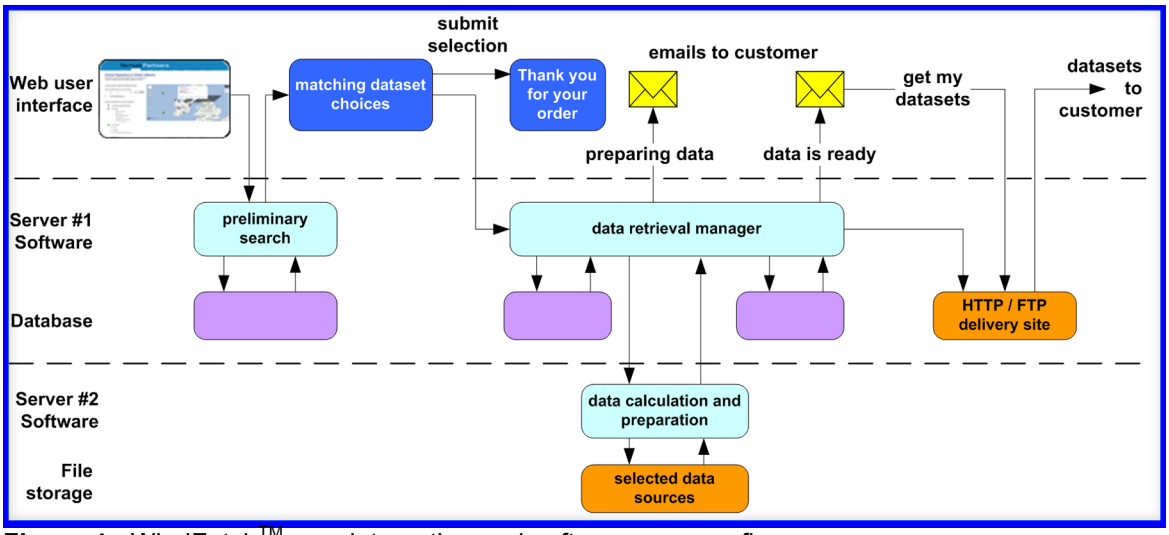

Figure 4: WindFetch™ user interaction and software process flow

Figure 4 illustrates schematically the entire order entry and fulfillment process. Reading from left to right, shown are the actions of the user and data flow through various software components as the dataset request is made and fulfilled.

After submitting the necessary information for data retrieval, the user reaches a reply page advising the timeframe in which to expect to receive the data (presently 48 hours), and the order is placed on the Vertum server.

Vertum-developed algorithms retrieve the various data sets, which are also stored on the Vertum servers. We have also designed algorithms to directly download the data from servers housing reanalysis data where they are produced, but found that the time for retrieval had a wide range (from hours to several days), and would thus not respond to customer needs in an efficient way. These algorithms can be accessed as a backup by the platform however, if there is a problem with our server. We have created these multiple-retrieval options to ensure that data can be accessed in the highly unlikely event of an issue with our server. After the data has been retrieved and is ready for a user, the user receives an email with a link to a compressed file to download it. By sending users a download link, we avoid having to send large files via email.

"I think Windfetch is coming to fill a market spot still open in wind industry, congratulations for the idea!" - João Caldas, Wind Resource Assessment, Casa dos Ventos Energias Renováveis S.A. (Brazil's largest wind project developer).

In launching our prototype product, we focused on the wind resource assessment organization as our potential user. We found that wind resource development companies typically have a single project manager looking after the development of about three wind farm sites. They will manage the whole project from signing land owners to the project, doing environmental surveys, obtaining planning permits, gaining grid connections, negotiating with an off-taker[3], negotiating turbine supply agreements and various engineering/procurement/construction contracts, and related work. We also

[3] The purchaser of electricity generated by a wind project (e.g., a utility).

needed to focus on independent Resource Analysts that work on the project. Our customer base is a mixture of these types of professionals.

4.3 Climate Change Effects on Wind Power Operations

For our California region of focus, Climate Change has meant a dramatic shift in risk of fire from increased Santa Ana Winds and from dry conditions. This has become critical to the utilities distributing the electricity produced from both wind farms and traditional methods. In working with the utilities in Southern California we found a demand for improved forecasting systems with a superior understanding of weather and vegetation supporting proactive emergency operations.

The Santa Ana Wildfire Threat index (SAWTi) is a successful product that addresses the significant shift in risk to electricity distribution operations as a result of Climate Change. As part of this SBIR project, we collaborated on this important tool and developed both the US Forest Service and San Diego Gas and Electric (SDG&E) into new clients during this project. See the next section for a description of this tool.

Groundbreaking Santa Ana Wildfire Threat Index
Dr. Scott Capps collaborates with UCLA, SDG&E and the US Forest Service

The team announced that the Santa Ana Wildfire Threat Index (SAWTi) has been released to the public; an index that will help save lives and property from destructive wildfires. This project benefitted from an important partnership between the US Forest Service, SDG&E, UCLA and Vertum. The state-of-the-art in applied fire science has truly been advanced through the integration of big data analytics into wildfire threat assessment.

SAWTi models wind speed, low-level atmospheric dryness and, importantly, several crucial wildfire fuel moisture components. Key to the system is the network of 149 high tech monitors that have been placed in the field for observational data.

"I think most people in Southern California are not so concerned that it's going to be a windy day. What they're most concerned about is that, is there going to be a major wildfire today due to Santa Ana winds, and are they going to have to evacuate their home?" Tom Rolinski (U.S. Forest Service meteorologist)

"We not only have a new, deeper understanding of how the San Diego-area terrain influences weather, especially wind, which is crucial to SDG&E's operations; but we also have been able to make improvements in weather modeling that will benefit forecasters around the world." Dr. Rob Fovell (UCLA Professor)

"This product is the culmination of a major collaborative effort between government, academia and the private sector. It is truly the most comprehensive wildfire threat index available to the public today drawing upon leading edge atmospheric and fuels modeling, powerful computing resources, reputable observational data and the expertise of some of the best minds in the field. Vertum is proud to be a major contributor to the success of this product." Dr. Scott Capps (Vertum)

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4.4 Gust or Bust – A marketing tool focused on educating our potential users

The vast majority of Wind Industry workers have very limited education in scientific modeling or even atmospheric physics. With this lack of understanding comes skepticism over the benefits that can be provided by integrating higher-level scientific information. The wind resource assessment professionals have recently developed sophisticated modeling skills and an understanding of resource uncertainty but have few tools to share this knowledge within the developer community. We consider easily accessed educational online tools to be an important part of our product promotional campaign. We are developing a library of enjoyable educational guides for our clients. We will embed information about data sets, wind resource analysis practices, and financial analyses within our products to help users understand and explore available wind data and its relationship to their operations. This information will allow users to explore information at their own pace and have it directly linked to various options that they chose. In so doing, we will create an interactive software information tool to both educate users as they fill out the prompts to download data and reports pertinent to their needs. This documentation is like an embedded publication explaining to the user how to use the data with options to explore more information about the data and options if desired.

Gust or Bust: Understanding Climate Models and Wind Power is an educational marketing tool written in the graphic-novel style. Its purpose is to provide a working knowledge of some of the important lessons behind wind power and climate modeling—fields that are likely to be understood at a surface level by most non-scientists, but with varying levels of depth and clarity beyond that. The book utilizes one of the key tenets of a successful graphic novel: the images and the text avoid being as redundant to each other as possible, all the while enriching the other's presence. This combination of image and text allows for the strengths of visual and aural learners to be accessed.

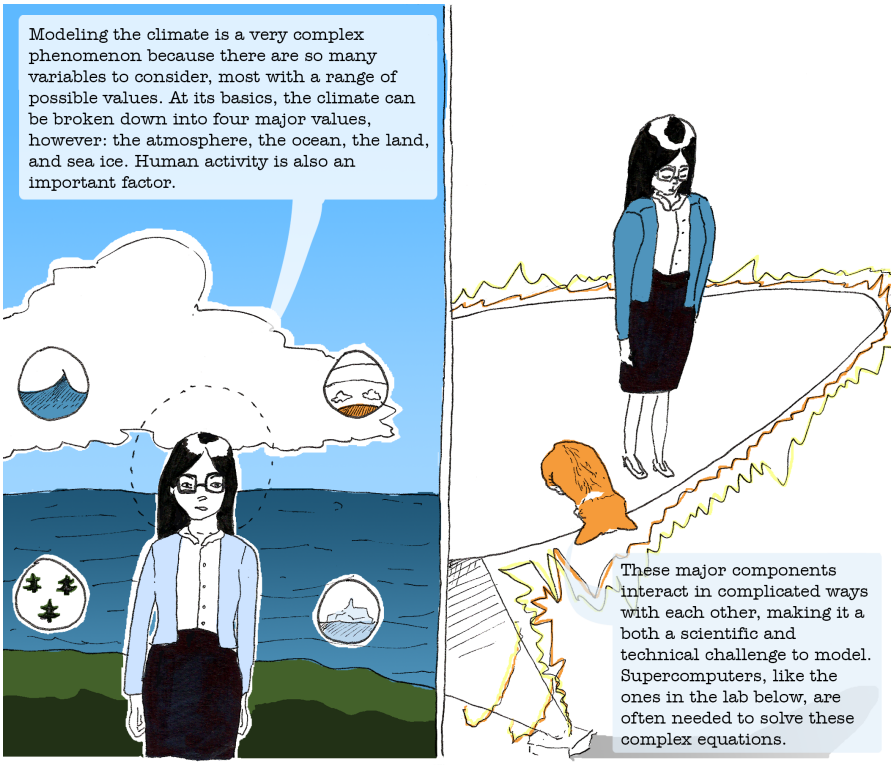

Figure 5: An excerpt from Gust or Bust: Understanding Climate Models and Wind Power

The appeal of a graphic novel approach to learning is manifold. The format allows for visual examples to be easily given without clunky or awkward verbal explanation. Memorable images, such as a diagram with simplified graphics and bright colors, can be recalled when trying to later apply concepts. However, such images are not lost in the brain without context, because a successful graphic novel will ensure that image and text are linked inextricably. Second, the addition of illustration combined with the paring down of text result in a document that is only somewhat longer than it would be in solely text format. However, it is faster to read, making it an advantageous format for those who need to gain information about a field quickly—e.g., a nonscientist preparing to meet with scientists in a similar field of work. Because it is quick to read, it invites being reread as well, promoting better information retention. Third, the format has an appeal that reaches beyond trade uses: those in unrelated businesses, students, and the general public will find them accessible and enriching to read for the reasons listed above. This creates a common set of references between groups, allowing for better communication. Having a narrative makes text compelling and memorable, allowing the book to cross boundaries of potential use. Fourth, because graphic novels have such a wide potential audience, less educational material need be created, meaning that less money and time can be spent on the task and/or more money and time can be spent on educating in more breadth and depth on environmental, climate, and energy topics.

Vertum's next project, Fire and Spatial/Temporal (FAST) Models, is a continuation on that line of thought. FAST Models is, as of the writing of this report, an in-progress interactive educational tool that utilizes visual, written, aural, and kinesthetic teaching to explain concepts that pertain to environmental and climate modeling. The project includes recurring characters from Gust or Bust, a young woman and her dog, named Gail and Wendy, who guide the user through concepts that begin simply and become more complex. The target level of complexity will be low enough such that the viewer will understand and retain the information without too much effort, but high enough to leave informed about how scientists make use of climate and environmental models. The areas upon which Vertum has decided to focus for the project reflect the interests of Vertum's clients as they pertain to the services it can provide. These areas include storm modeling, solar reflectivity modeling, wind modeling, and fire modeling.

FAST Models builds upon the benefits laid down by Gust or Bust by allowing for a more customized user experience. Whereas Gust or Bust covered two topics, addressed in succession, FAST will have no particular order in which it is to be experienced, and will not need to be experienced in its entirety if not all of the addressed subjects are relevant to the user. With FAST, the reader becomes the user, as the graphic novel format becomes applied to a library of information. The information will also have interactive components to improve information retention by appealing to kinesthetic styles of learning. It will also contain more location-specific examples that expand outside of Southern California, the focus of Gust or Bust and location of Vertum Partners.

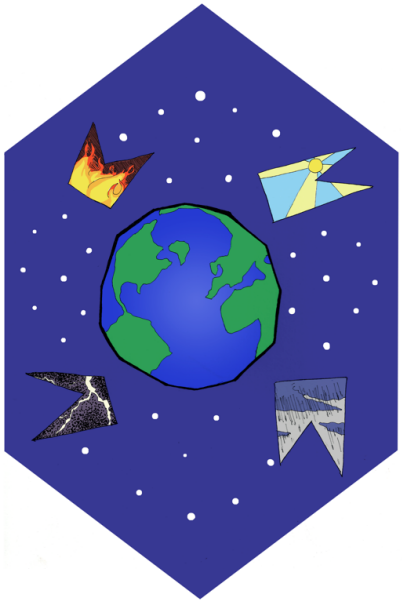

Figure 6: FAST Models graphic

Such improved learning tools will be helpful with the immediacy of FAST's subject matter: as Gust or Bust focused on predictive models on the middle and long term, FAST focuses on predictive models to be used in the very short term or even immediately. It is important that such information stick clearly for two reasons: first, it has the potential to be used sooner. Second, dealing with climate change and environmental issues in an accommodating manner rather than a preventative one is a relatively underexplored idea to the public. Ushering in a new mode of learning with a new subject will help understand the subjects at hand and the power of immediate action—if such a new educational tool can be created in the short term, then short term solutions can be done quickly and thoughtfully as well.

5. Conclusions

Each of the areas of focus has led to successful business results. The commercially available products coming out of this project help quantify and reduce uncertainties of atmospheric related climate change factors in wind energy production and distribution. This will allow wind stakeholders the ability to lower costs and plan for the benefits and risks of a changing climate.