Title
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Publication Date
2007-04-09

Energy Development and Technology 011

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April 2007

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This paper is part of the University of California Energy Institute's (UCEI) Energy Development and Technology Working Paper Series. UCEI is a multi-campus research unit of the University of California located on the Berkeley campus.

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FINAL REPORT:

A New Design Tool for Visualizing the Energy Implications of California's Climates

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Introduction:

In California there are 16 different climate zones, as defined in the California Energy Code (Title24). The code requires slightly different types of buildings in each zone. These different building code requirements make it important for people who are designing, building, or maintaining these buildings to understand the unique attributes of their climate and how it will influence the design and performance of their buildings.

In this UCEI project we developed a simple, free, easy-to-use, graphic-based computer program called Climate Consultant 3, and we have posted it on the State of California's Flex Your Power web site and on the UCLA Energy Design Tools web site. Our objective is to make it freely accessible to architects, builders, contractors, and homeowners, etc., to help them understand their local climate and how it impacts their building's energy consumption.

Background:

The Department of Energy has recently made available at no cost, climate data for California's 16 zones, plus data for 21 other California cities, in its new EPW format. Each of these 37 California climates is defined by a file of dozens of attributes for all 8760 hours per year (in fact there are about a thousand stations from around the world available in this format). Climate

Consultant 3 translates this raw weather data into meaningful graphic outputs and design guidelines.

The California Energy Commission states that a third of California's energy consumption is used in buildings, of which about half is used in residential buildings, of which the majority is used for space heating and cooling.

The energy consumption of the vast majority of California buildings is determined by how well they respond to the local climate. These "envelope dominated" buildings include single family homes, low-rise multi-family homes, small commercial buildings, and schools, etc. The alternative category is "internal-loads dominated" buildings that includes large high-rise offices, hospitals, theaters, and factories, etc. which are relatively indifferent to the exterior environment.

These small envelope-dominated buildings outnumber internal-loads dominated building by a huge margin. For example, Southern California Edison supplies five residential ratepayers for every one non-residential ratepayer, and many of these non-residential ratepayers are also housed in envelope-dominated buildings, like small stores and offices.

California's big internal-loads-dominated buildings are served by sophisticated architectural and engineering firms, construction companies, and professional building managers, who have at their disposal an array of sophisticated tools for energy simulation, environmental analysis, computer aided design, etc.

Climate Consultant however is intended to support the other, larger constituency_ California's smaller consumers who design, own, manage and maintain this huge stock of internal-loads-dominated buildings. This constituency needs a simple, free, easy-to-use tool that will help them understand their local climate, and how it impacts their building's energy consumption.

RESEARCH PROJECT

Graphic Thinking The computer may `know' what the climate is like, but the most challenging task is to devise effective ways to communicate this information to the human. At UCLA over the past 30 years we have been working on ways to graphically display complex information that are easy and intuitive to comprehend. For example, we have developed a 3-D plotting technique that shows the state of a variable for every hour of the day for every month of the year. We have found that the general 'gestalt' of the resulting shape is easy to quickly interpret, while at the same time these plots are rich with information at the most detailed level. The beauty and power of these graphic approaches is that they communicate in a way that allows users to see extremely subtle distinctions that would otherwise be lost in a page full of numbers. If 'information' is defined as the recognition of small differences that make a difference, then this technique makes it possible to recognize some very subtle differences, indeed.

Energy Problem Addressed: Designing and remodeling buildings that are truly climate responsive depends first on gaining a detailed accurate understanding of the local climate. This project developed a new design tool called Climate Consultant 3.0 that is intended primarily for architects, students of architecture, builders, contractors, and knowledgeable homeowners. It automatically reads the local climate data for all 8760 hours per year in EPW (EnergyPlus Weather) format which now is available at no cost for hundreds of stations via the internet (see

our web page). For the chosen climate it will display dozens of different graphic images of various attributes of that climate, and can even suggest building design strategies appropriate for the unique characteristics of the local climate. The purpose is not simply to plot climate data, but rather to organize and represent this information in easy-to-understand new ways that shows the subtle attributes of the climate, and its impact on built form. Our goal is to help Californians create more energy efficient, more sustainable buildings, each of which is uniquely suited to its particular spot on this planet.

Content of the New Climate Consultant 3.0: Climate Consultant 3.0 contains the following screens. This list will give some idea of the richness and power of this new energy design tool. Notice that there are five different generic types of screens, each of which can be loaded with a variety of kinds of data:

Text Screens:

- Title Screen: Basic Instructions with information on how to download EPW data
- Measurement Units Selection (pop up): Metric or Imperial
- Select Weather Station: (two EPW stations are included with download)
- Design Criteria Definitions: All the variables in the program including Comfort Range, Design High and Low Temperatures

2-D Plots:

- Temperature Range Bar Chart (Mean, Records and Design High and Low for 12 Months)
- Radiation Bar Chart Beam and Horizontal Recorded and Theoretical Maximums
- Sky Cover plus Radiation Bar Chart (Mean and Record High and Low for 12 Months)
- Wind Speed Timetable (for 24 Hours x 365 Days with Comfort Zone Overly)
- Relative Humidity vs. Temperature Monthly Plots (12 Months for 24 Hour Averages)
- Sun Shading Chart (Hourly Bearing and Altitude, Color Coded for Comfort Temperature)
- Sky Cover Timetable (for 24 Hours x 365 Days with Comfort Zone Overly)
- Radiation Timetable (for 24 Hours x 365 Days with Comfort Zone Overly)
- Sun Chart (Hourly Bearing and Shadow Length, Color Coded for Comfort Temperature)
- Bio-Climatic Chart (Temperature 24 Hours x 356 Days with Comfort Zone Overlay)

3-D Surface Plots (Monthly or Daily):

- Dry Bulb Temperature Plot (for 24 Hours x 356 Days Color Coded for Comfort Ranges)
- Wet Bulb Temperature (for 24 Hours x 356 Days Color Coded for Comfort Ranges)
- Wet Bulb Depression (difference below Dry Bulb Color Coded for Evaporative Cooling Feasibility)
- Relative Humidity (for 24 Hours x 356 Days Color Coded for Comfort Ranges)
- Wind Speed (for 24 Hours x 356 Days Color Coded for Comfort Ranges)

Psychrometric Charts (with Design Strategies for 13 Zones Overlaid):

- With Temperature Color Coded: 8760 Hourly or Daily High/Low Data Points
- With Wind Speed Color Coded: 8760 Hourly or Daily High/Low Data Points,
- With Radiation Color Coded: 8760 Hourly or Daily High/Low Data Points
- With Sky Cover Color Coded: 8760 Hourly or Daily High/Low Data Points
  - Plus All of the Above with User-Selected Hourly Ranges or Date Ranges

Wind Wheel: (Color Coded for Wind Velocity, Humidity, Temperature for Each 10 Degrees)

- For Full Year or For Selected Hourly Ranges or Date Ranges
- Static or Animated for Daily or Monthly Ranges

By simply hitting the “Next” button (lower right of screen) the program will go to the next logical screen in the sequence. This is in effect a built-in demonstration sequence that shows the first-time user all the different kinds of information that is available by displaying each screen in order for a selected site. Context specific “Help” is available on each screen to define every term and to explain how this screen’s data can be used to shape building design in order to reduce energy consumption.

However beyond these basic plots are much more sophisticated graphic analysis options-- the kind that begins to show the power of this new design tool. It must be emphasized that the purpose is not simply to plot climate data, but rather to overlay it with various comfort ranges and building design criteria. This will show how comfortable humans could be in indoor spaces with these characteristics, or more importantly how to design buildings that can modify these external conditions to create comfortable indoor environments.

The following screen images from Climate Consultant 3.0 (Figs. 1, 2, 3 and 4) show three typical charts for California’s Climate Zone 12, that includes Sacramento and Stockton. They illustrate

examples of how climate data plus design criteria can be organized and represented to help show subtle implications of this particular climate on building form.

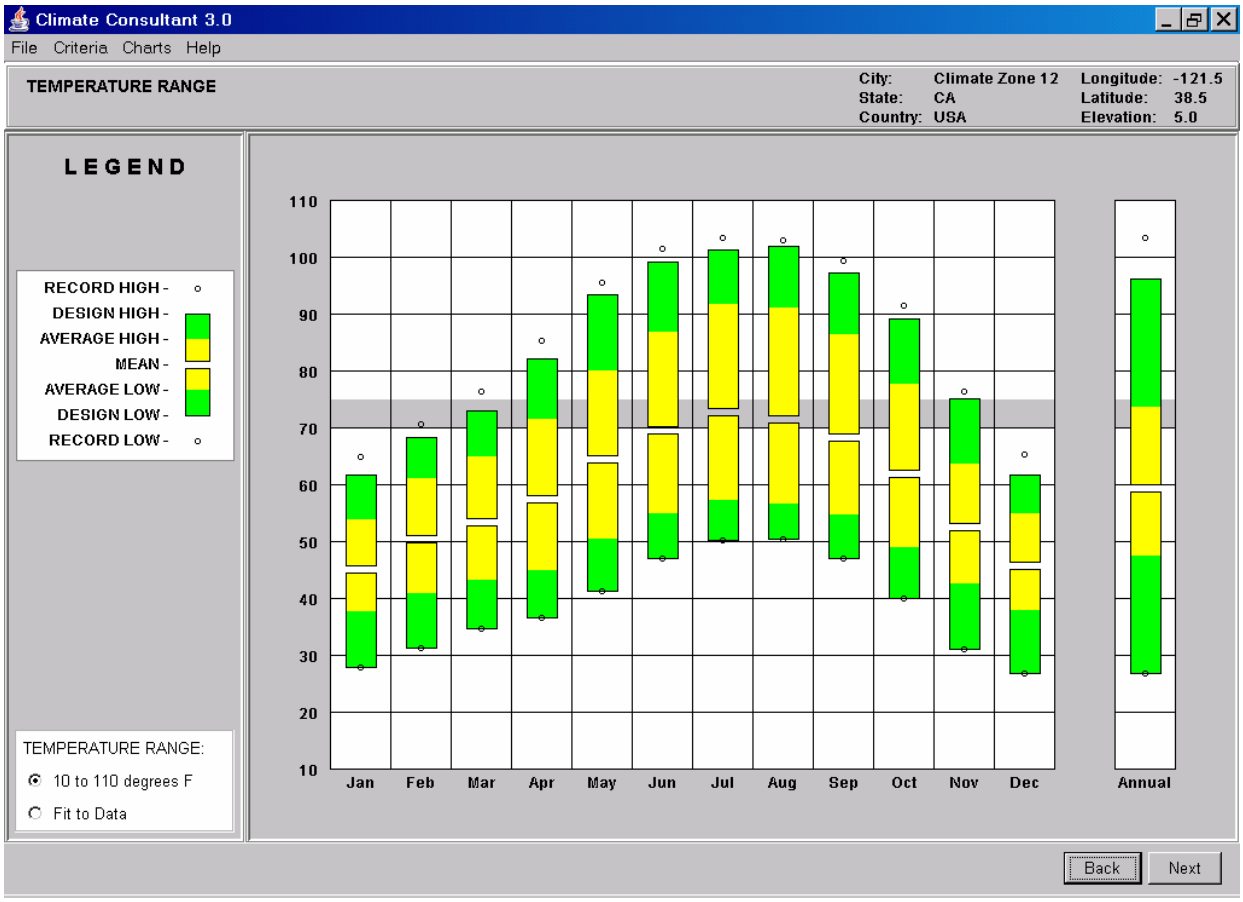

Fig. 1 TEMPERATURE RANGE BAR CHART: This is the simplest of all charts and shows for each month the dry bulb temperature ranges enclosing Record Temperatures (round dots) and Design Temperatures (green) from .25% to 100% of the hours which is the range defined in the 2005 California Energy Code (Title 24). The Average High and Low Temperatures (yellow bars), and Monthly Mean (midpoint) are also shown. This example shows that for Climate Zone 12 the annual record temperatures (right hand bar) fall between 104 and 27º. The gray bar running from 70 to 75º is the comfort range as defined in the 2005 California Energy Code (Title 24).

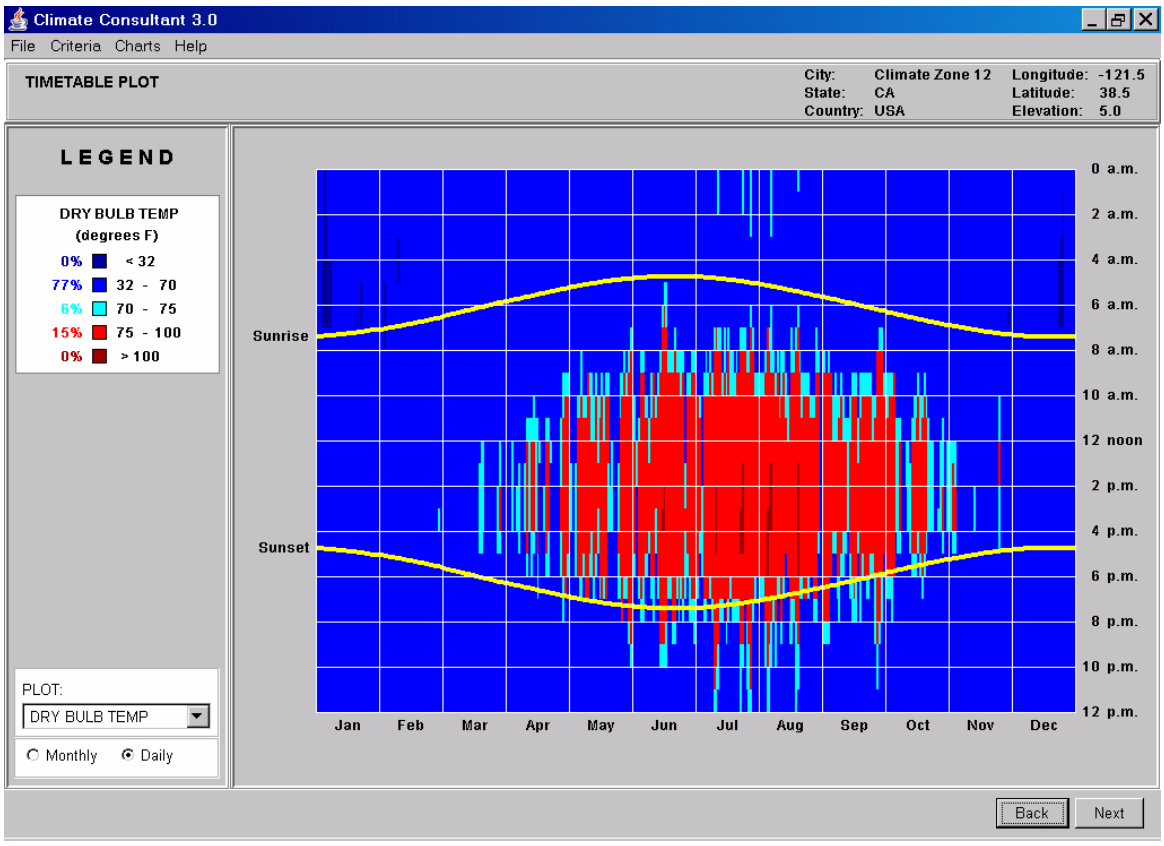

Fig 2: BIOCLIMATIC TIMETABLE: Olgyay developed this powerful graphic analysis technique he called the Timetable of Bioclimatic Needs. It is like a topographic plot of dry bulb temperatures for every hour of the year. The sunrise and sunset lines (orange) bracket the daylight hours when passive solar heating is possible or when shading may be needed. This example for Climate Zone 12 shows that although many hours are too hot for comfort (red), every day of the year the temperature starts below the comfort range (dark blue) and then on most months rises into the comfort range (light blue), and then quickly on into the red (overheat zone). This small comfort zone is because the 2005 code specifies such a narrow comfort range (70 to 75º). Because on every night temperature falls below the comfort range, it means that passive nighttime cooling is possible if the building has enough internal mass to store this "coolth" through the next hot day. This chart shows the times of day and months of the year when windows need sun protection (the red area plus light blue area). Conversely, the cold regions (all dark blue) indicated on this chart when windows should be fully exposed to maximize passive solar gain.

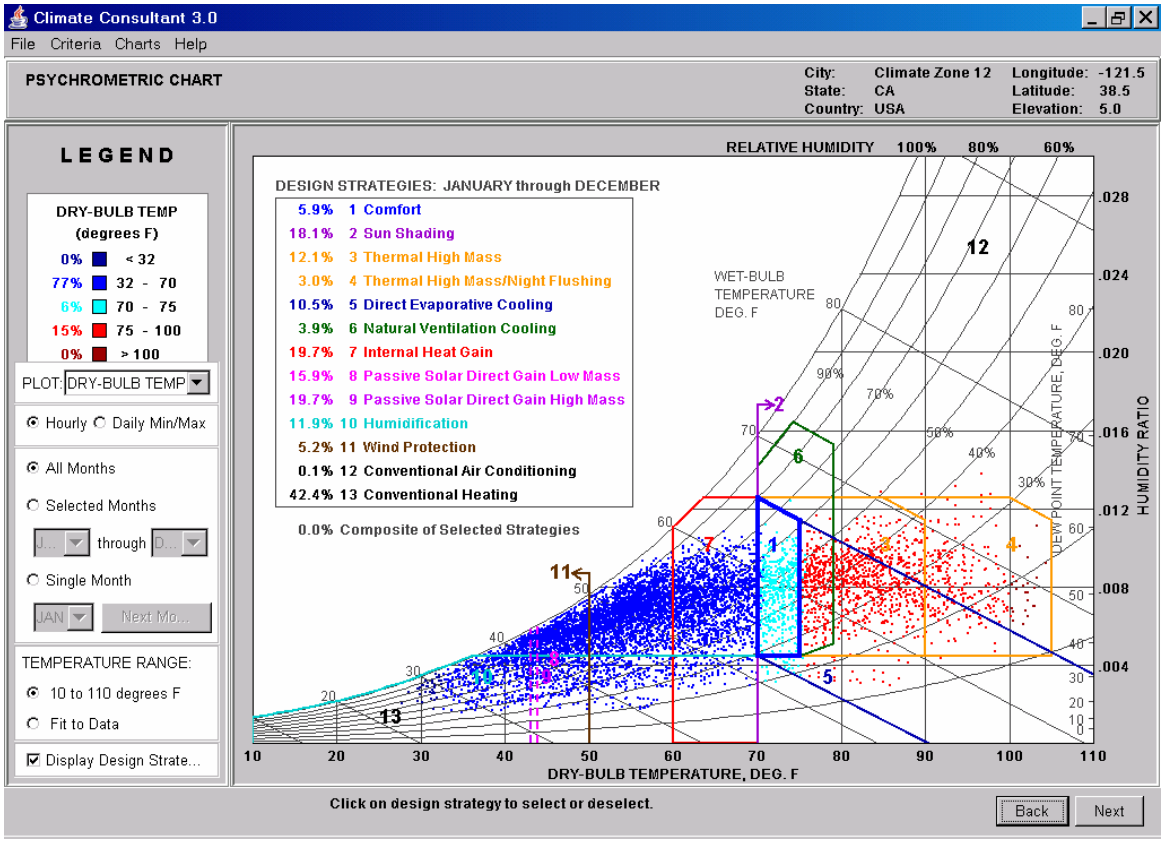

Fig. 3: PSYCHROMETRIC CHART: This is one of the most powerful graphic design tools because it not only shows which building design strategies to use but also quantifies how effective each will be. In Climate Consultant 3.0, data can be plotted on Psychrometric Charts in many different ways, to reveal different phenomenon. In the example here, every hour of the year is plotted with the color indicating whether if it above (red) or below (dark blue) the comfort zone. Each of the building design strategy zones are also laid out on the chart. The Table of Effective Design Strategies (upper left) shows that Climate Zone 12 has about 5.9% of the hours per year in the comfort range. Note that High Thermal Mass with Night Flushing (12.1% plus 3.0% of the hours per year) is the best design strategy for hot conditions. An alternative would be Direct Evaporative Cooling (10.5% of the hours). Sun shading of course is the best single cooling strategy, applying to over 22% of the hours On the heating side 19.7% of the hours would be comfortable indoors because of the addition of internal loads like (lights and appliances and people). Passive Solar Direct Gain High Mass (19.7% of the hours) is the most attractive passive heating option. However 42.4% of the hours in a low mass building would require conventional heating.

This Graph allows a number of other representations, one of which plots only the daily high and low temperatures for any month or for all twelve months, each in a different color. This is useful to understanding the diurnal temperature range, which gives an indication of how effective passive strategies like thermal mass and evaporative cooling will be on a daily basis.

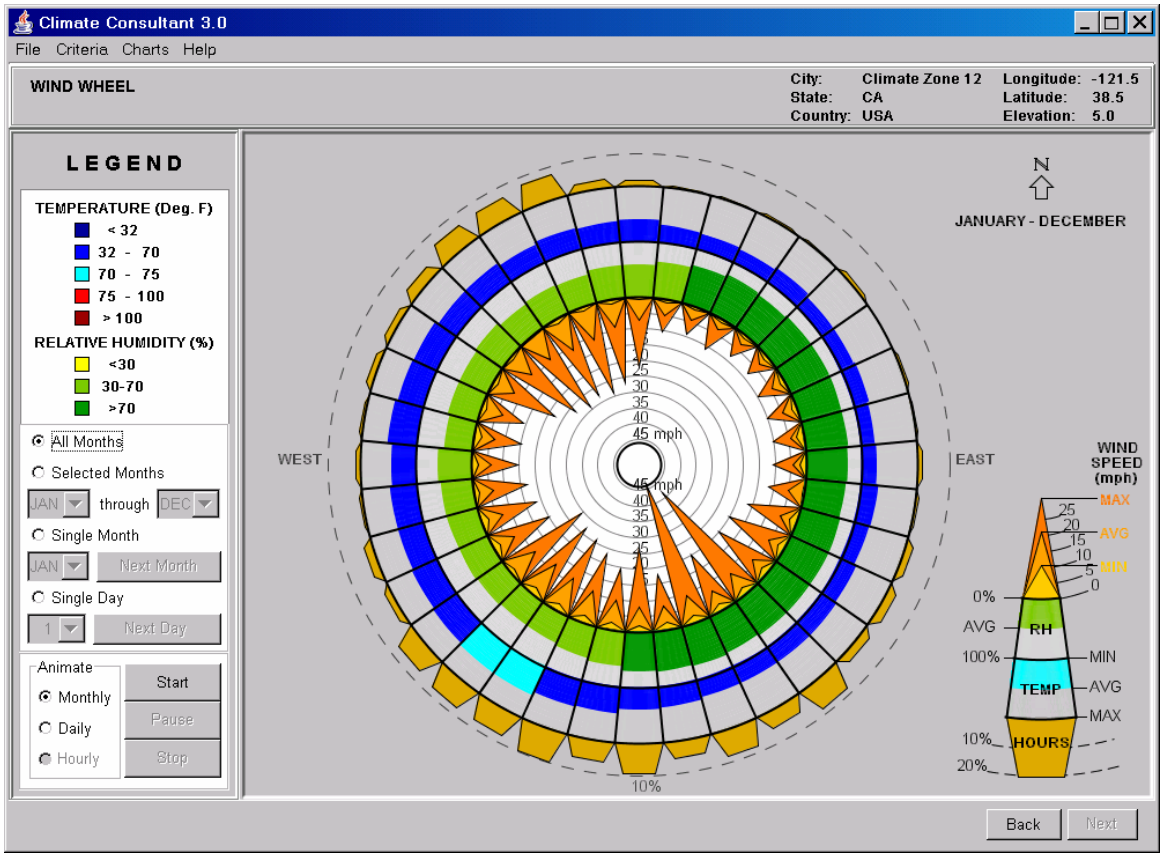

Fig. 4: WIND WHEEL: This is a new kind of graphic added to Climate Consultant 3, that shows on one diagram a number of variables of the local climate related to wind direction. This example for climate zone 12 is for a full year (8760 hours), but individual days or months can also be plotted. The Outermost ring shows the percentage of hours when the wind comes for each direction. On the next ring the height and color of the bars shows the average temperature of the wind coming from that direction (light blue is in the comfort zone and dark blue is cool). The next ring shows average humidity (light green is considered comfortable at 30% to 70%, while dark green is too humid above 70%), which shows that winds from the west are dryer on average. The innermost circle shows the minimum, average, and maximum velocity of the winds from each direction, in this case the fastest wind came from the South Southeast and reached 45 mph.

One of the most interesting options in Wind Wheel is to animate any set of days or months and watch how wind direction and velocity changes.

WEB SITE:

Climate Consultant 3.0 is available at no cost from:

http://www2.aud.ucla.edu/energy-design-tools/