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Online Site-Specific Degree-Day Predictions Using GIS and Climate Map Technologies

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Abstract

As part of a regional web-hosted application server for phenology and pest outbreak risk models (http://pnwpest.org/wea), we have incorporated open source GRASS GIS mapping, plus online GIS interactivity, for site-specific degree-day estimates at locations without weather stations. Degree-day (DD) maps are created with GIS either daily or interactively via a web-based form by several steps. First, actual DDs are calculated from among the 900+ sites in the 5 state NW USA (currently; OR, WA, ID, MT, and WY). Second, historical climate map-based DD maps are computed from PRISM monthly temperature maps. Third, differences between actual and PRISM-based DDs are interpolated and then added to PRISM-based maps as a correction layer. These corrected DD maps are further "downscaled" from ca. 2 KM to 360 m resolution or better using elevation-based geographically weighted regression and gaussian smoothing. Final corrected and downscaled DD maps are displayed via the open source GRASSLinks web GIS interface for zooming, panning, and querying of site-specific degree-days, and to a DD calculator interface to nearest weather stations, and other accessory data.

Objectives

1. Develop automated phenological modeling for region wide site database of online weather data
2. Extend these model estimates geographically using GIS and related spatial analysis tools
3. Deliver phenological maps daily and interactively via the world-wide-web

Technologies Used

- Open source web application server - Linux/ Apache/CGI/Perl
- Open source GIS: GRASS 5.0, GRASSLinks 3.2b
- Oregon Climate Service PRISM climate maps (monthly temperature max and mins, available for USA, W. Canada, China)
- Resolution: 2 KM, downscaled to 360 meters using custom geographically weighted regression written in GRASS r.mapcalc
- Data management programs: Perl, UNIX shell
- Weather data database: free format text files for individual stations and years, flat- file attributes database
- SQL database of phenological models (23 fields, web-interface for distributed database management)

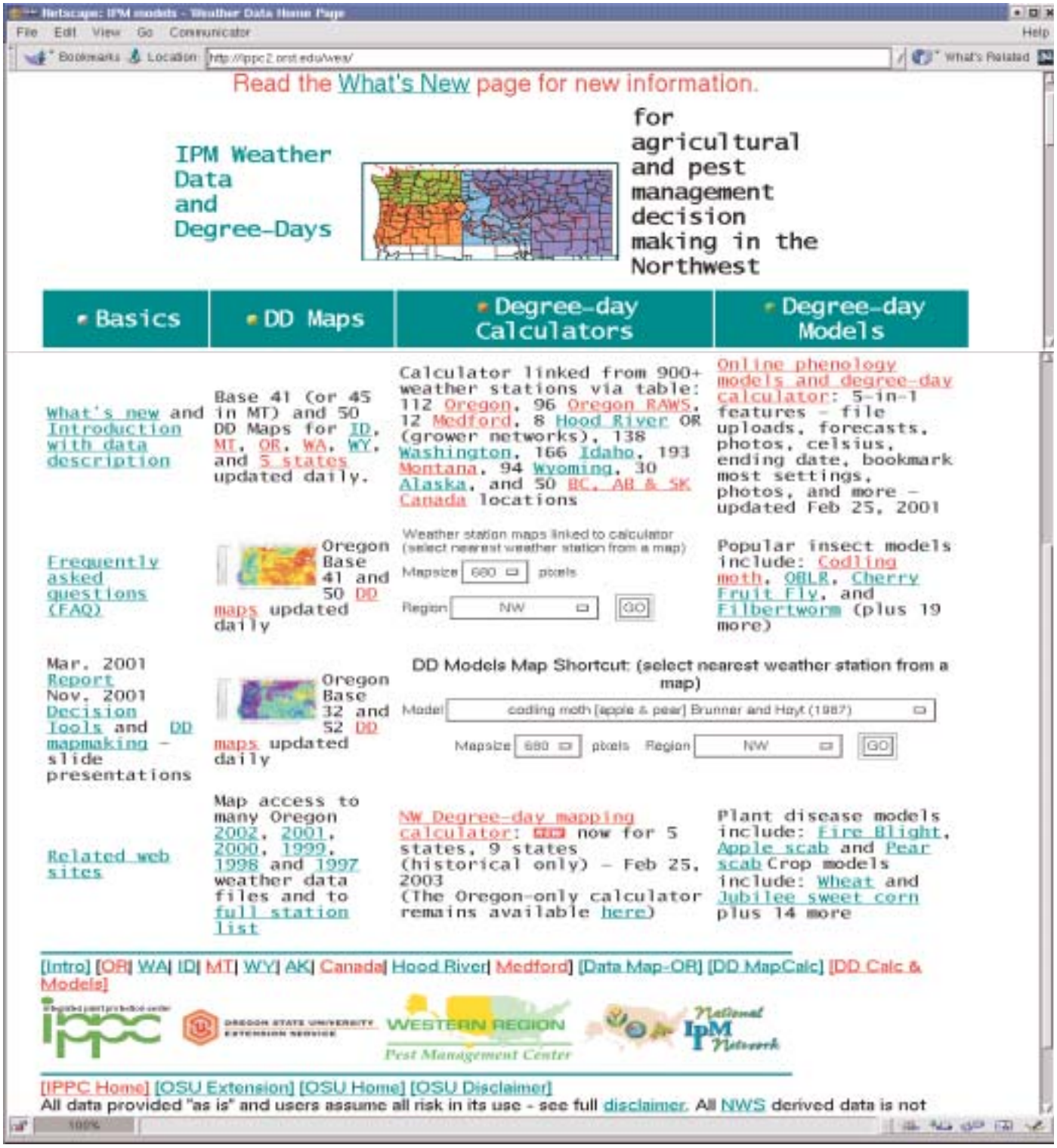

Fig 1. Homepage at http://pnwpest.org/wea The specific products described here are the daily DD maps and the NW DD mapping calculator

Database Description

- Weather database currently includes a total of 900+ stations (data for each station and year in single text files, station attributes stored in a flat file database)
- All GIS datalayers (PRISM monthly temperature maps, elevation, roads, county lines, etc) stored within GRASS database
- Single-site phenology modeling program linked to database of 44 models (23 insect, 3 disease, 16 crop, 1 weed, 1 mating disruption dispenser)
- Mapping phenology program includes 4 types of degree-days (simple average, single and double triangle, growing degree-days)

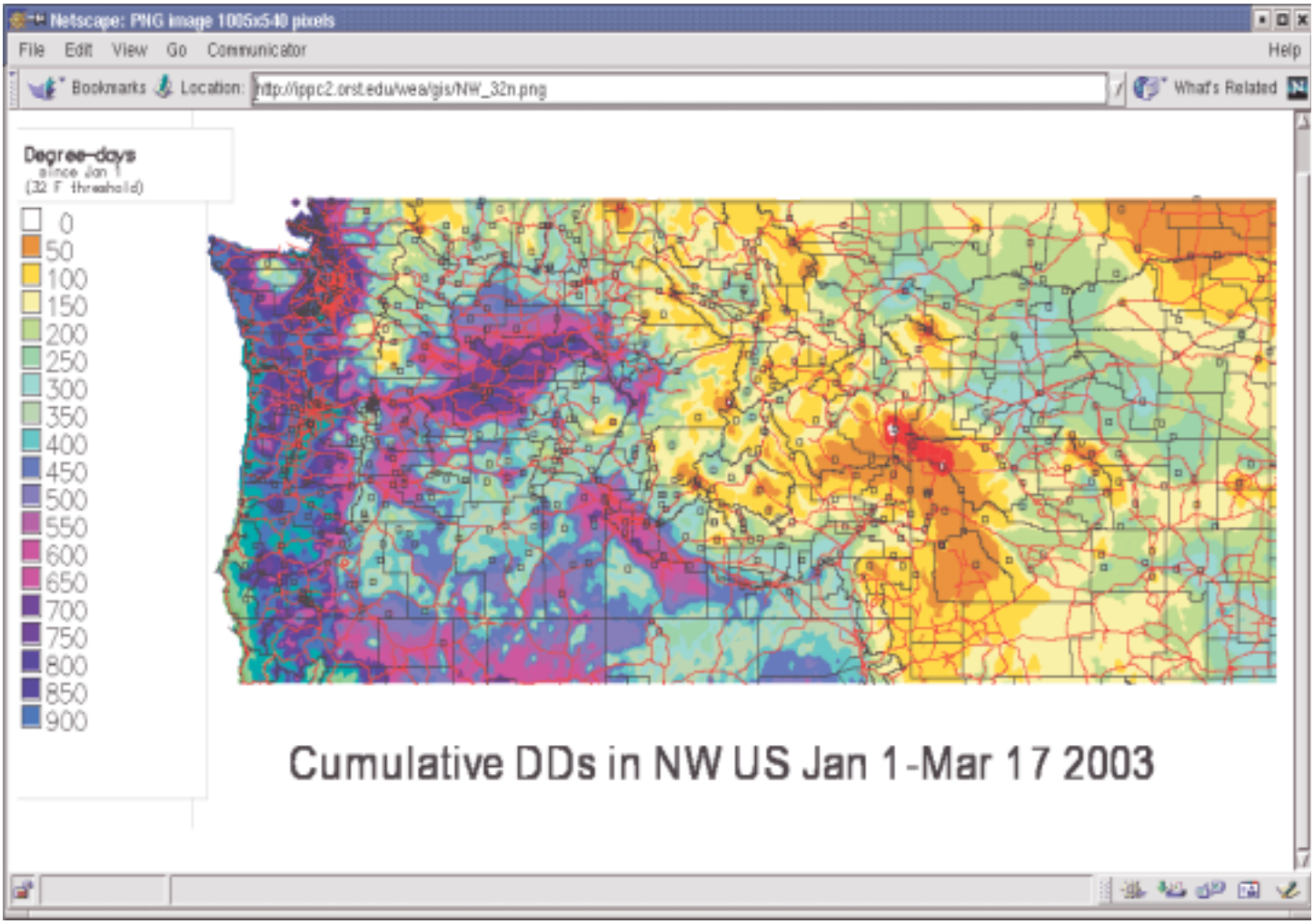

Fig 2. Daily degree-day maps are available for each of 5 NW states, all 5 states (shown here), and individual selected growing regions in Oregon

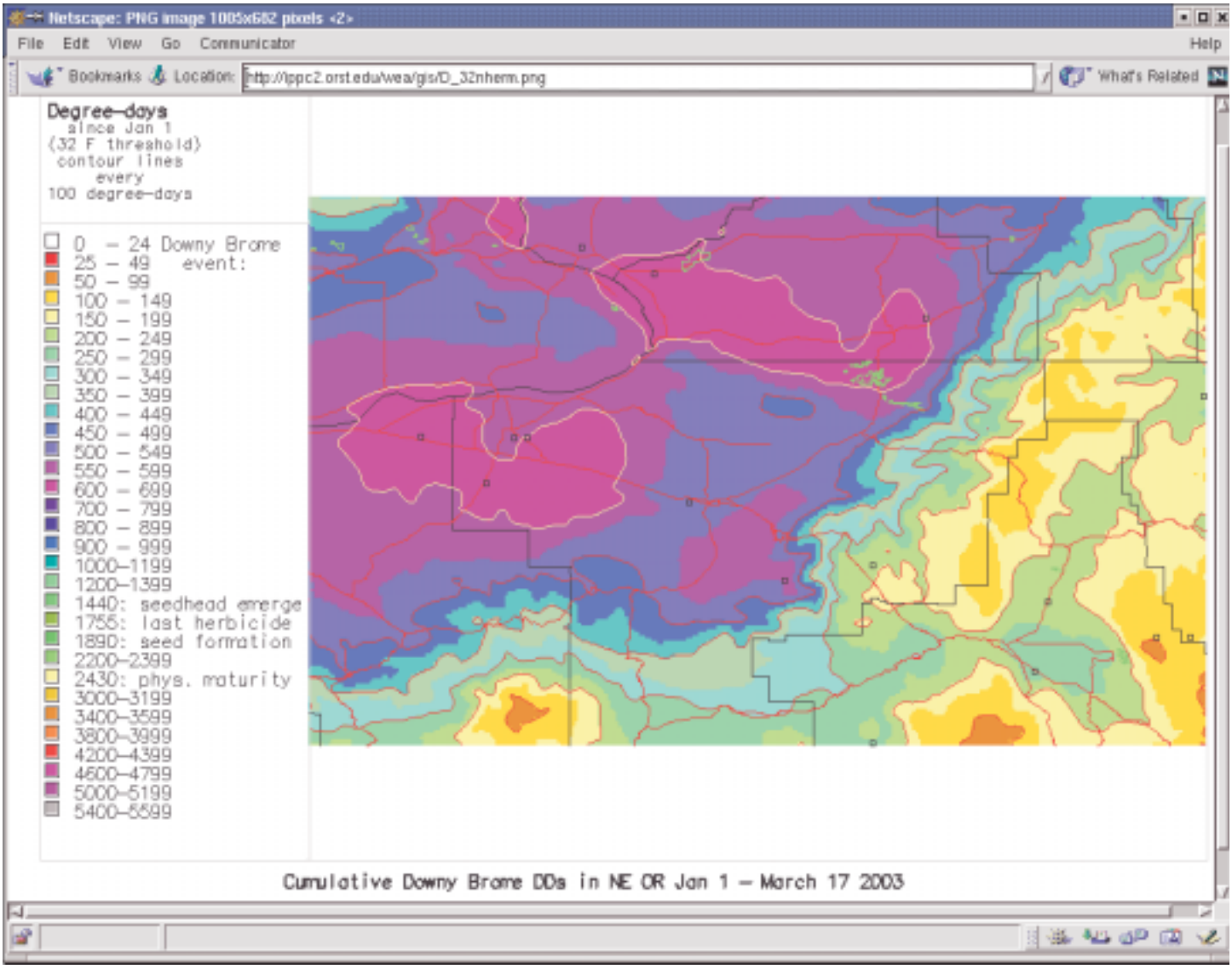

Fig 3. Example of a specific pest phenology model produced daily for a local growing region: Downy Brome degree-days in NE Oregon

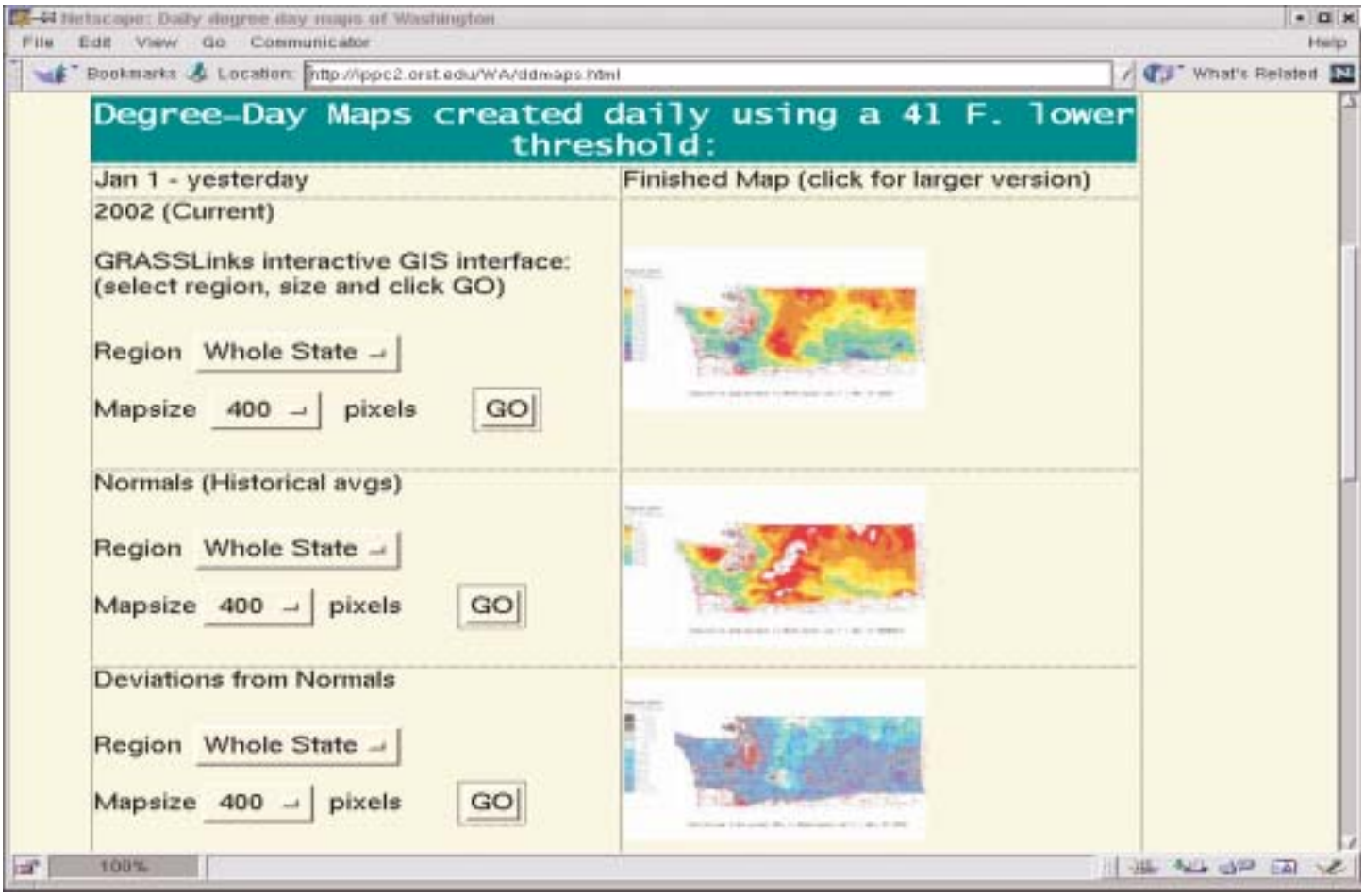

Fig 4. Example of a daily series (WA) displaying at a glance, for Jan 1 - March 31, 2003, the current (top), historical average (middle), and deviations from normal (bottom) degree-days. Thus far in 2003, most of southern and western WA exhibit warmer than normal weather. In addition, user may click on maps for full size versions, and (on left), forms for entry into the GIS interactive interface allowing for more advanced zooming, queries, etc. (see Fig. 5)

Acknowledgements

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- Medford and Hood River Grower Networks for data
- NOAA NWS, Agrimet, Hydromet, RAWS public weather networks for data
- Oregon Climate Service for data and access to PRISM maps

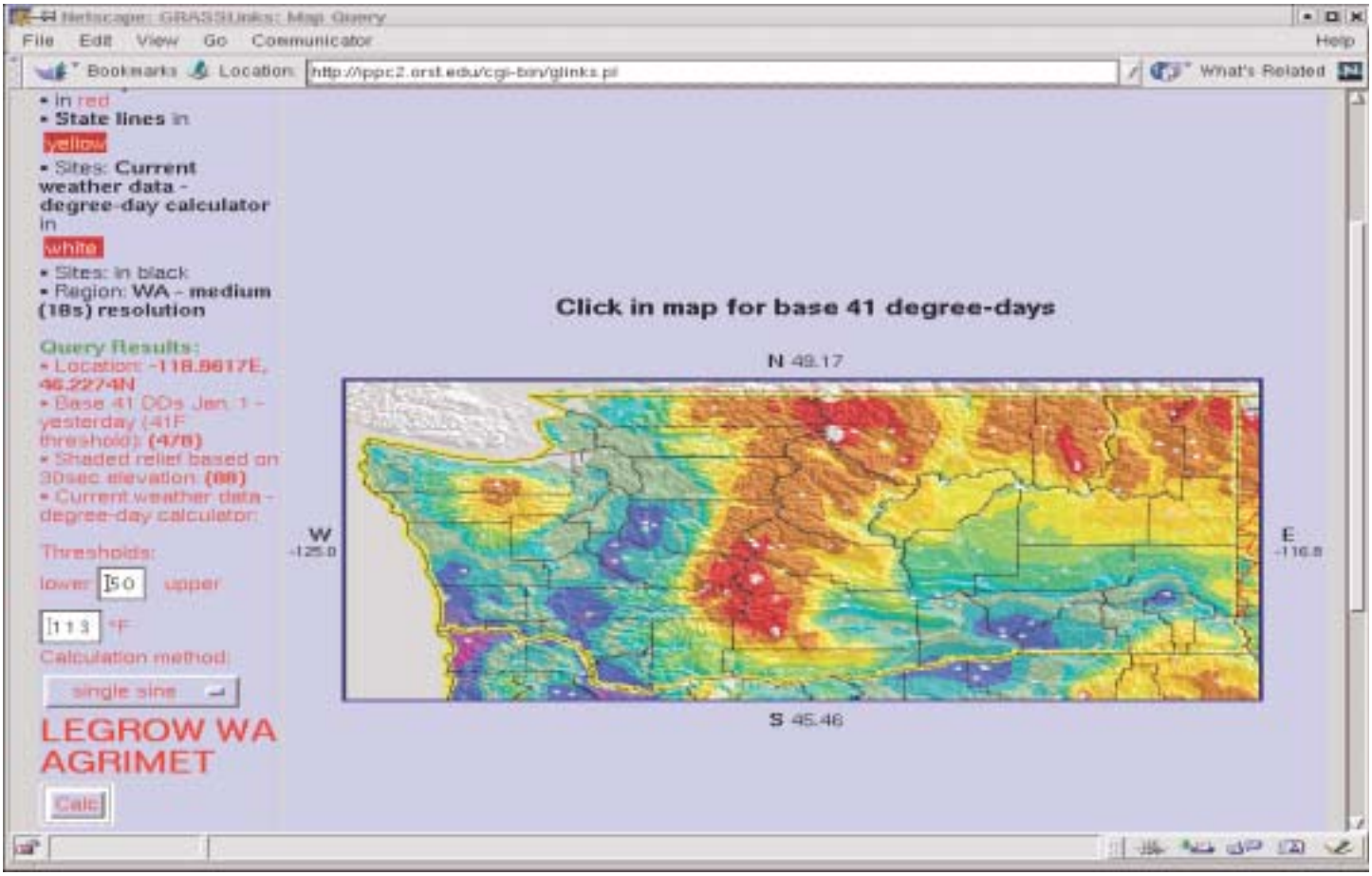

Fig 5. Example of the web-based interface to daily degree-day maps. The GRASSLinks GIS web interface allows online users to zoom, pan and query maps, and bring up accessory tools such as the site DD calculator. In this case, the user clicked near Legrow WA, showing the accumulation of 478 degree-days specific to that site, plus a DD calculator linked to data from the nearest weather station.

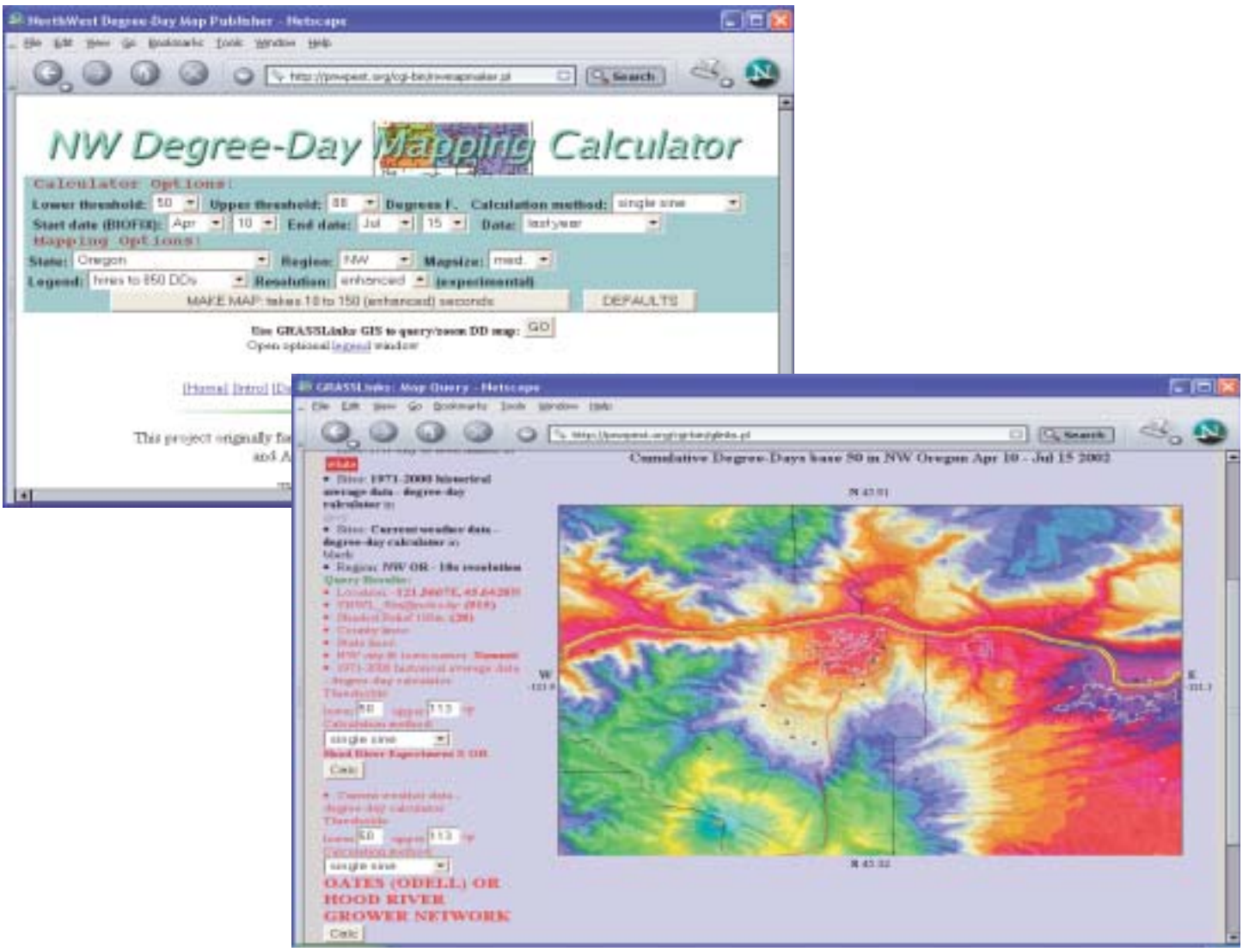

Fig 6. Custom interactive web-based degree-day map example. The online user has created, via a web-browser form (shown behind main image), a custom phenology map, for the settings shown, and clicked "GO" to use the GRASSLinks interface. The user then zoomed into the Mid-Columbia Oregon growing region, and queried site-specific degree-days near the Odell weather station. At the selected low elevation orchard, 915 DDs indicate first generation codling moth egg hatch has completed, while orchards at higher elevation can expect 25% additional egg hatch. This program is available for OR, WA, ID, MT, and WY, and additionally for N. CA, NV, UT, and CO for historical degree-days.

Degree-Day Mapmaking Strategy and Procedures

- Local temperature variation is largely a function of elevation and other terrain characteristics. The PRISM (Parameter-elevation Regressions on Independent Slopes Model) expert system, at Oregon State University's Oregon Climate Service, http://ocs.orst.edu, has resulted in a series of digital and paper climate maps for all of the USA, W. Canada, and China. This system produces high quality average precipitation, temperature, and other climate parameter maps using locally derived parameter vs. elevation regression analyses. Current spatial resolution is ca. 2 KM per cell border. Every available high quality historical dataset is used for PRISM analysis. Current PRISM maps are produced from 30-year 1971-2000 data
- Online weather station networks (currently up to 900 stations) are used as inputs to computing actual site DDs
- PRISM-based degree-day (DD) maps are calculated from PRISM monthly max and min termperature GIS datalayers for user-selected thresholds, dates, and calculation method (via a regular web browser; Fig. 6) using the GIS GRASS 5.0
- For all sites, the difference between actual and PRISM-based DDs are computed
- These site differences are then interpolated to make a correction maplayer (inverse-distance^2 interpolation, using nearest 6 points) in the GIS
- This correction maplayer is then added to the PRISM-based DD map, effectively correcting historical average DDs to actual DDs
- This new corrected maplayer now has estimated DDs for the entire map surface - all values at weather station sites are accurate.
- Any zooming of regions, smoothing of data to a higher cell resolution, addition of site labels, contour lines, roads, county boundaries, legends, and other user-selected options are added within the GIS before conversion to final web graphic formats (PNG). The GRASSLinks web interface makes alternative mapping data available according to custom needs of users.
- An optional downscaling step using local 5x5 geographically weighted regression to improve degree-day map resolution from 2 KM down to 360 or better resolution

Scope for Future Improvements

- Develop a new missing data estimation system based on climate map and current weather data for terrain-based GIS interpolation
- Develop disease forecast and risk mapping capabilities, initially focusing on pear scab and fireblight (funded by WR-IPM R&E 2003-2005)
- Expand forecast and risk maps for multi-region pest monitoring networks (with Montana State University, refer to poster P7-P), and for local pest scouting and trapping networks
- Develop an improved downscaling algorithm that can also use slope, aspect, and proximity to water as required for sub-50 meter estimates
- Continue to serve and expand weather networks without cost to end users
- Improve forecasting capabilities
- Continued automation of all activities to minimize maintenance and support costs