Mannava V. K. Sivakumar
James Hansen
Editors

Climate Prediction and Agriculture

Advances and Challenges

World Meteorological Organization
Weather • Climate • Water

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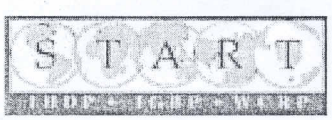
With 102 Figures and 55 Tables

World Meteorological Organization



Global Change System for Analysis, Research and Training

The International Research Institute for Climate and Society

Springer

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Library of Congress Control Number: 2007921994

ISBN-10 3-540-44649-4 **Springer Berlin Heidelberg New York**
ISBN-13 978-3-540-44649-1 **Springer Berlin Heidelberg New York**

Springer is a part of Springer Science+Business Media
springer.com

Cover design: WMXDesign, Heidelberg
Typesetting: Uwe Imbrock, Stasch · Verlagsservice, Bayreuth (stasch@stasch.com)
Production: Agata Oelschläger

Printed on acid-free paper 30/2132/AO – 5 4 3 2 1 0

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Web-Based System to True-Forecast Disease Epidemics – Case Study for Fusarium Head Blight of Wheat

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25.1 Introduction

Disease forecasting has become an established component of quantitative epidemiology. The mathematics of disease dynamics is the core of several disease forecast models that have been developed in the last four decades. However, many models have not lived up to the expectations that they would play a major role and lead to a better disease management. Amongst the reasons, the presumption of a disease forecast model is that it makes projections of major events in disease development and most present forecast models do not (Seem 2001). An exciting development in this area is the possibility to use weather forecasts as input into disease models and consequently output true disease forecasts. As weather forecasts improve together with more accurate estimations of micro environmental variables useful for plant disease models, as such precipitation and leaf wetness duration, it will be possible to provide seasonal estimates of disease likelihood and forecast outbreaks. This is especially interesting for field crops for the reason that unnecessary sprays has a significant impact on production costs, and no timely applications may result in inadequate control.

The present work illustrates an approach towards that direction by the use of novel programming languages and technology for the development of a web-based prototype for model implementation and delivery. The case study is FHB, a disease of great concern for wheat production worldwide as well as for southern Brazilian wheat areas. Despite all research done for many years, the control of this disease is still challenging given its complex nature (McMullen et al. 1997) and some factors as dose rate, application timing and spray quality for adequate coverage of the spike tissues are key in fungicide efficacy for a good control (Reis 1986; Picinini and Fernandes 2001). FHB forecast models are considered an important tool for the decision-making, allowing producers to timely and effectively apply fungicides in conjunction with other control strategies (McMullen et al. 1997; Xu 2003). Different approaches for modeling this disease are found in the literature and comprehensive information on several FHB models has been reviewed (Del Ponte et al. 2004).

Critical knowledge on the epidemiology of a disease needs to be available in developing a decision support system. The epidemiology of FHB has been studied in southern Brazil since late 1980s. Climatic conditions are most suitable in that region, and disease has a periodical occurrence. The distinct climate conditions observed along the years have helped in identifying the main factors affecting regional epidemics. A mechanistic process-based simulation model, named GIBSIM, has been developed and

improved along the years with previous knowledge and a series of local studies on the interaction of pathogen, host dynamics, and the environment. The model has been validated with epidemic cases observed in Passo Fundo location, Brazil. The data has been collected on experimental plots in 5-years and distinct planting dates each year. The accumulated risk infection index simulated by the model explained 93% of variation in disease severity (Del Ponte et al. 2005). In this work, GIBSIM model is the core of a web-based prototype system designed to gather site-specific and forecast weather data and deliver true-forecasts for FHB for one location in southern Brazil.

25.2 Material and Methods

The web application, called GibSimWeb was developed based on the Model-View-Controller (MVC) design pattern. The model part is the business logic; the view presents images and data on WebPages; and the controller determines the overall flow of the application (Fig. 25.1). The server programs are: weather data management server (WDMS), database server (DBS), disease forecasting model server (DFMS), and web

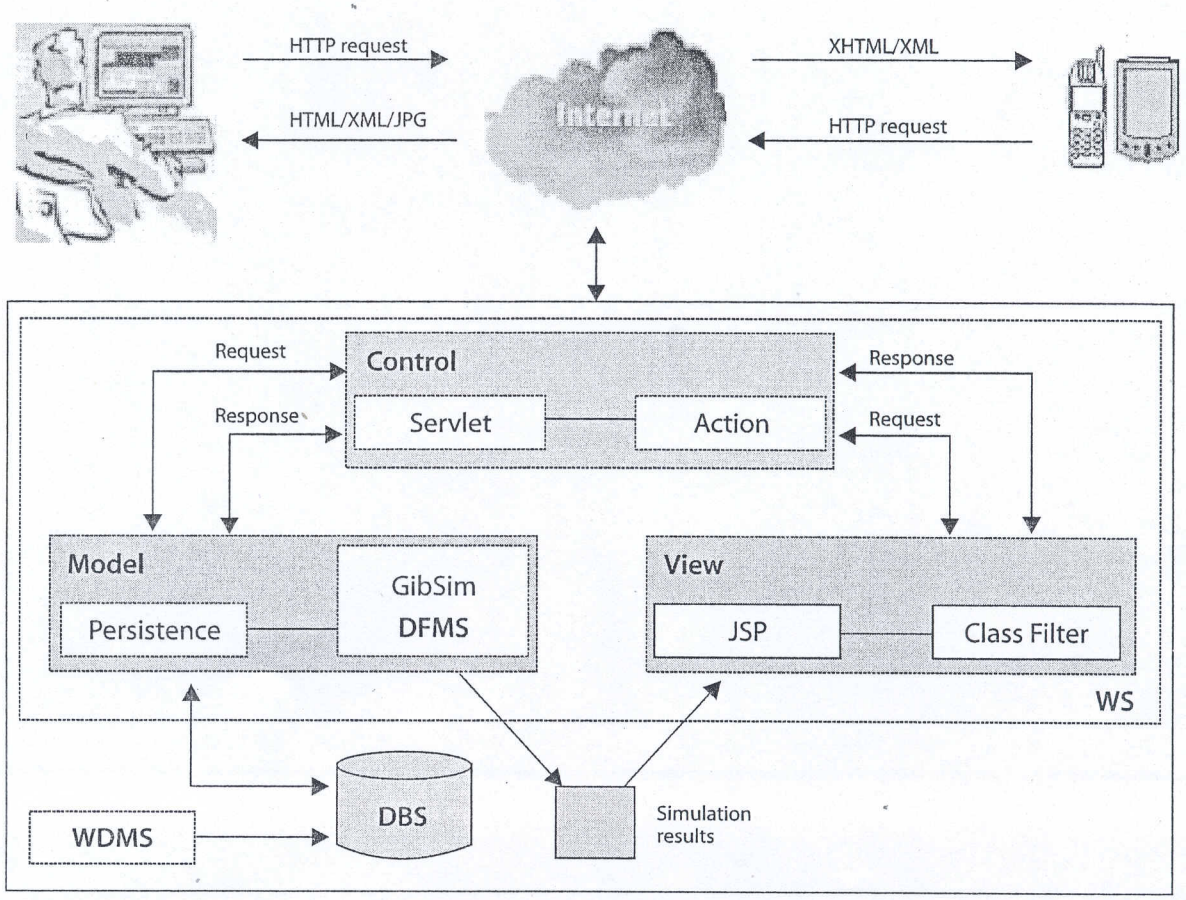


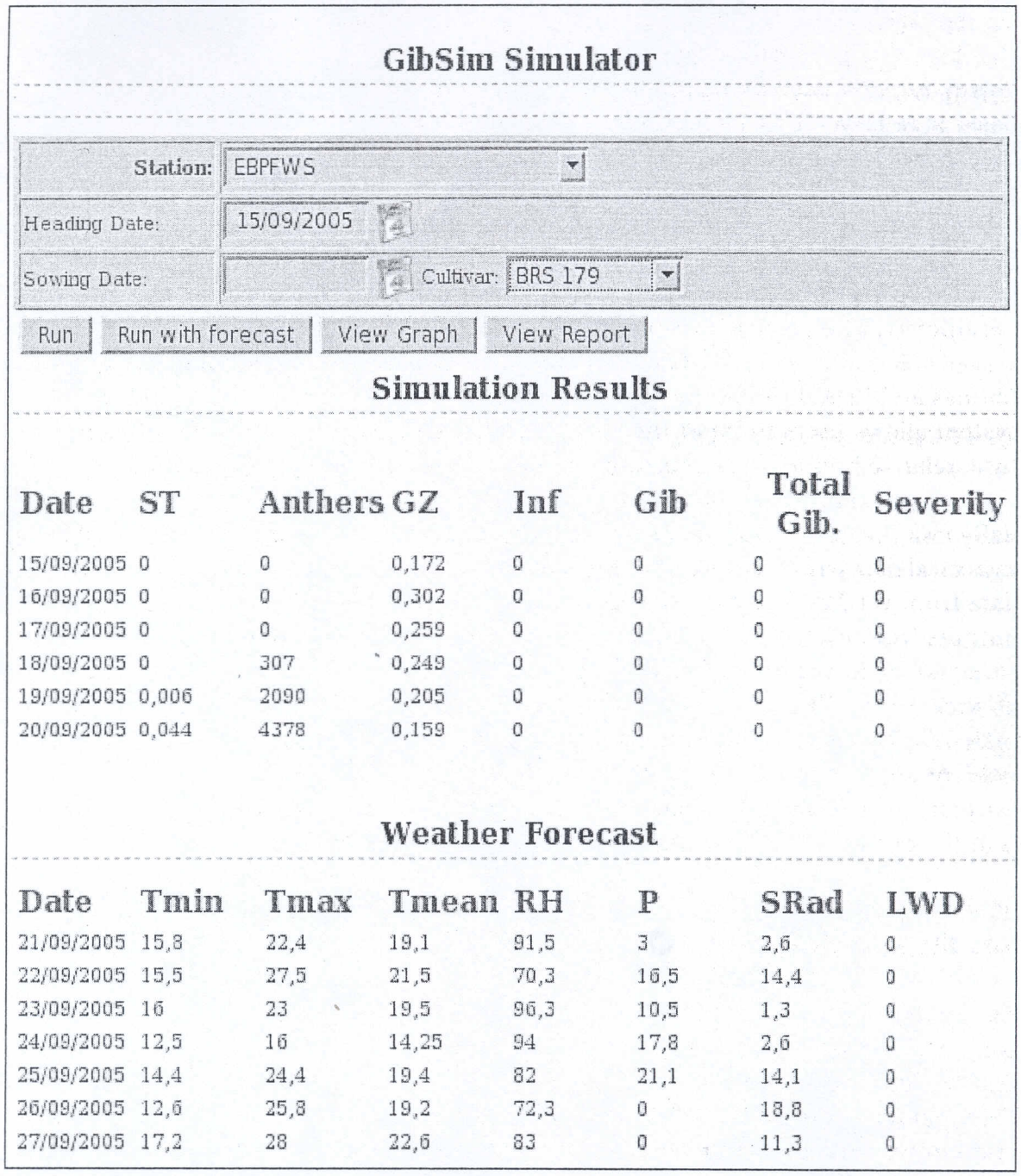
Fig. 25.1. Architecture of the web application designed for gathering and storing actual and forecast weather data to run a simulation model to forecast risk of Fusarium head blight of wheat. The server programs are: weather data management server (*WDMS*), database server (*DBS*), disease forecasting model server (*DFMS*), and web server (*WS*)

server (WS). WDMS consists of a module for weather data retrieval from automated weather stations located at remote sites. Data is updated at 10 minutes interval. In addition, forecast data, living on the INPE (National Institute for Space Research) databases is retrieved by FTP protocol. PostgreSQL is the core of DBS and stores weather data, as well the identifiers for weather station and run-time parameters such as cultivar, planting date, previous crop, etc. DBS is interfaced with WDMS and DFMS using a Java API, and with WS using an SQL module in a JSP script engine. WS retrieves information from DBS upon request by users through a client-side (web-browser) interface. In addition, it provides a simple request form for defining the run-time parameters. The output is displayed either in textual or graphical format by using a server-side plotting script. The system is also set to deliver simulation output to cell phones and PDA. Besides the option of defining a weather station in the database, the system allows users to input their own weather data, such as precipitation, temperature, relative humidity, etc. customizing the results for site-specific conditions.

The system uses either hourly or daily weather data from DBS, and DFMS produces daily risk infection index by using near real-time and anticipated risks by combining historical data with 7-day weather forecast. During the simulation, each sub-model uses data from WDMS. The daily output is a risk infection index calculated based on daily outputs from each sub-model. The forecast risk combines both historical and 7-days forecast of hourly weather data, generated by the ETA model using a grid of 40 km× 40 km. Since the model accounts for the effect of wheat development to estimate disease severity, the simulation starts on the day the first heads emerge in the field. At any time since then, actual as well as future weekly accumulated risk index is estimated. Once an accumulated risk level of concern is projected and the simulation is at the critical time for control, the model warns that fungicides may be needed.

25.3 Results and Discussion

The preliminary runs of GibSimWeb prototype showed that the system successfully collected hourly weather data including solar radiation, temperature, precipitation and relative humidity from Embrapa's automatic weather station and forecast data from INPE servers, and stored them in the DBS. After defining the location, heading date, and cultivar, the prototype is set to present the results in the webpage in a tabular (Fig. 25.2), graphical (Fig. 25.3) and report format (Fig. 25.4). The table shows model output and weather variables. The graph shows the daily increase of infection index, and some environmental variables. Infection indices and related risk are computed in a daily basis since first day of the simulation and the anticipated risk take into account actual and forecast data. The report is a summary and interpretation of the risk of outbreaks, that may be used to base decision-making. The reports are sent to emails and cell phone provided by registered users who set a specific date for heading and the system runs automatically on a daily basis using pre-set parameters. Numerical infection index is converted to 4 categorical levels (no, low, moderate and high epidemic risk) that will base decision-making on fungicide application, along with other factors. The GibSimWeb URL is *http://inf.upf.br:8080/gib/GibSimWeb.jsp*.



GibSim Simulator

Station: EBPFWS

Heading Date: 15/09/2005

Sowing Date: Cultivar: BRS 179

Run | Run with forecast | View Graph | View Report

Simulation Results

Date	ST	Anthers	GZ	Inf	Gib	Total Gib.	Severity
15/09/2005	0	0	0,172	0	0	0	0
16/09/2005	0	0	0,302	0	0	0	0
17/09/2005	0	0	0,259	0	0	0	0
18/09/2005	0	307	0,249	0	0	0	0
19/09/2005	0,006	2090	0,205	0	0	0	0
20/09/2005	0,044	4378	0,159	0	0	0	0

Weather Forecast

Date	Tmin	Tmax	Tmean	RH	P	SRad	LWD
21/09/2005	15,8	22,4	19,1	91,5	3	2,6	0
22/09/2005	15,5	27,5	21,5	70,3	16,5	14,4	0
23/09/2005	16	23	19,5	96,3	10,5	1,3	0
24/09/2005	12,5	16	14,25	94	17,8	2,6	0
25/09/2005	14,4	24,4	19,4	82	21,1	14,1	0
26/09/2005	12,6	25,8	19,2	72,3	0	18,8	0
27/09/2005	17,2	28	22,6	83	0	11,3	0

Fig. 25.2. Computer screen showing model inputs and simulation results

The prototype proved functional and can be easily extended to other locations where automatic weather stations are available with the capability to send data to DBS using the same protocol. In addition, the system may contain modules to allow a user to set weather retrieval from his own on-site automatic station directly to the DBS or from there to his computer and access a local database, besides retrieving forecast data from INPE. Therefore, the user may run the model for his location from any computer or mobile device accessing the web. The user will have the option to either make his

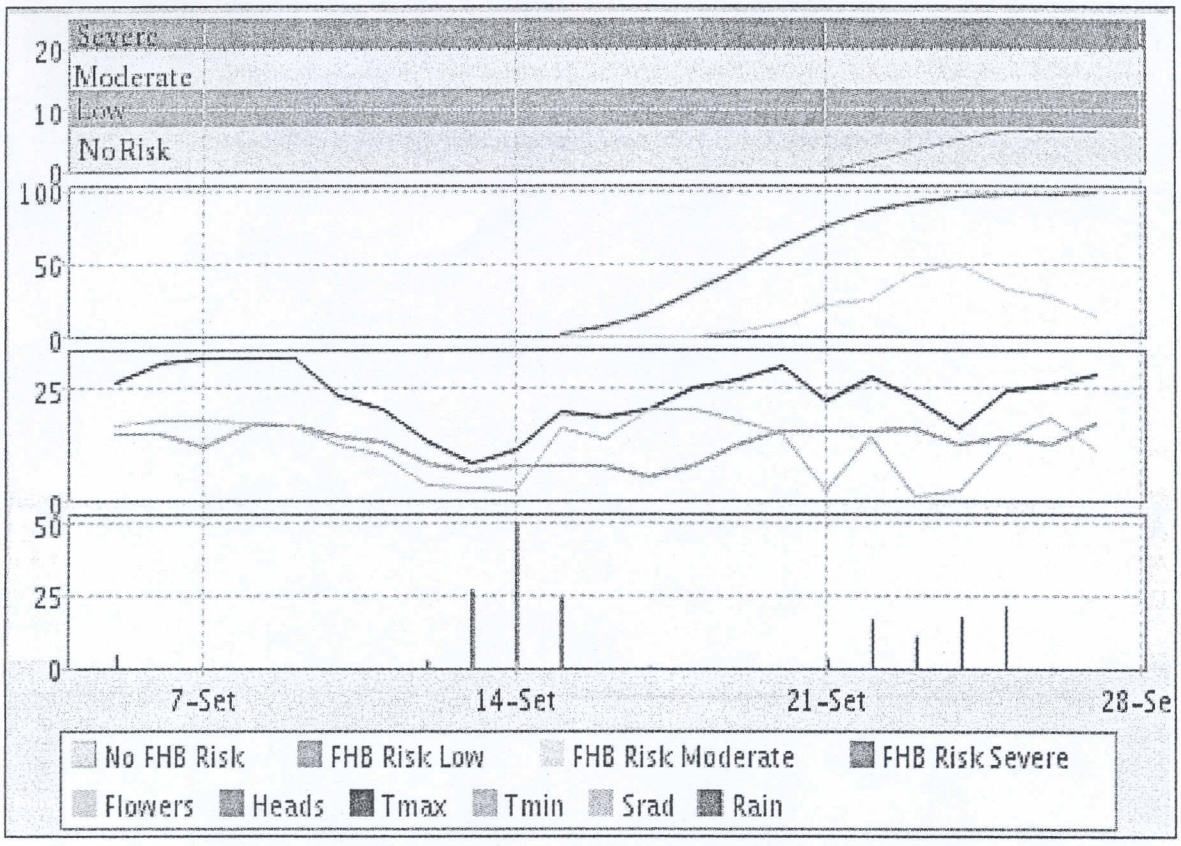


Fig. 25.3. Computer screen showing model output in graphical format

data public or private. This would be an alternative to computerized weather stations that are more costly.

A tactical utility of the web application for the management of FHB is the potential to improve disease control by allowing timely fungicide applications. When a high risk of outbreaks is anticipated, application of fungicides soon after infections, if weather permits, would help improve fungicide efficacy with a curative effect. Besides that, once weather data are available for several locations in a region, the model can be used to assess spatial variability of regional epidemic. Once long-term historical weather dataset is available for several locations in a production region, the model can be used to map climatic suitability for the epidemics. Effects of planting dates and crop rotations could be evaluated without the need of local experimentation. This system may also be used to hindcast past scenarios to test the accuracy of the system.

The modularity of the system allows the implementation of other disease models especially those requiring more complex data such as hourly weather information and leaf wetness duration. The disease simulator may be easily layered with crop models such as the CERES-Wheat from the Decision Support System for Agrotechnology Transfer (DSSAT) suite, using phenological data output by the latter (Ritchie et al. 1998). Fernandes et al. (2004), linked process-based models to assess the potential impact of climate change in the epidemics of Fusarium head blight in wheat growing regions in southern Brazil, Uruguay and Argentina.

FHB Risk Warning

Forecast starting in 09/21/2005

Model inputs:

Starting of Heading date: 09/15/2005
Cultivar: BRS179
Location: Passo Fundo

Simulation outputs:

Today is: 09/20/2004
Estimated peak of flowering: 09/24/2004
Accumulated infection risk today: 0.0
Accumulated 7-days forecast infection risk: 3.89
Projected severity: 6.43%

Interpretation:

Today is 4 days before peak of flowering date. Computer models are projecting a NO RISK of the disease reach epidemic levels in the next 7 days. No control measure is need at this time but scenario may change according to daily predictions.

Disclaimer:

The risk generated by computers models is under validation for areas other than Passo Fundo, RS, Brazil. Projected disease risk depends on weather forecasting for the next seven days, which has uncertainties. The information provided is experimental and offered to the public for informational purpose only and shall not be used for decision making of any kind. Embrapa Trigo, University of Passo Fundo and National Institute for Space Research - INPE or their employees assume no liability from the use of this information, nor do they warrant the fitness of the forecasts for any use.

Fig. 25.4. Fusarium head blight (FHB) simulation report

Acknowledgements

This research was supported in part by a grant from the Embrapa Macro Programa 2 and a grant from AIACC LA27 project. The support received from CNPq is also acknowledged. Thanks also for the programming assistance received from the participants in the Simuplan project.

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