IBERSENSOR 2010
7^{TH} IBERO-AMERICAN CONGRESS ON SENSORS
NOVEMBER 9^{TH}-11^{TH} 2010, LISBON, PORTUGAL

Iber sensor

ISEL

IBERSENSOR 2010

7^{TH} IBERO-AMERICAN CONGRESS ON SENSORS
NOVEMBER 9^{TH}-11^{TH} 2010, LISBON, PORTUGAL

PROCEEDINGS

SPONSORS

inaoe
Instituto Nacional
de Astrofísica,
Óptica y Electrónica
www.inaoe.gob.mx

ASSOCIAÇÃO NACIONAL DOS ENGENHEIROS TÉCNICOS · ANET ·

PROGRAMA IBEROAMERICANO
CYTED
CIENCIA Y TECNOLOGÍA PARA EL DESARROLLO

FCT
Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

Caixa Geral
de Depositos

CRIC
CENTRE DE
RECERCA I
INVESTIGACIÓ
DE CATALUNYA

IEEE
PORTUGAL SECTION

lisboa

eDAQ

FiberSensing

INSTITUTO POLITÉCNICO

Brisa
Inovação

UNINOVA

CTS

Wireless Sensor Network for implementation of FACE experiment to study the impacts of Climate Changes in Agriculture

André Torre-Neto[1], Victor Bertucci Neto[1], Luiz Francisco de Matteo Ferraz[1], Danilo Mendes Dias Delfino da Silva[1], Rodrigo Rafael Meláré Corrêa[1], Rodrigo Ivata Mori[1], Rodolfo Godoy Palhares[2], Anamaria Ferreira Mayer Dentzien[2], Raquel Ghini[2]

[1] Embrapa Agricultural Instrumentation
Rua Quinze de novembro, 1452
13561-206, São Carlos, SP, Brazil
andre@cnpdia.embrapa.br

[2] Embrapa Environment
Rod. SP 340, km 127,5
13820-000 Jaguariúna, SP, Brazil
raquel@cnpma.embrapa.br

Abstract

Climate change is considered one of humankind's greatest challenges in the near future. The climate change is expected to interfere in the scenario of worldwide agriculture. Its economic, social and environmental impacts can be positive, negative or neutral, since these changes can decrease, increase or have no impact on plant diseases, pests or weeds depending on each region or period of time considered. A type of experiment called FACE, Free Air Carbon-dioxide Enrichment, has been conducted in the USA, UK, Germany, Japan, Australia, Italy, Denmark, among other countries to study particularly the impacts of the CO_2 concentration increasing on crops. In Brazil, the first FACE experiment in South America is being installed by a group of scientists of Embrapa (Brazilian Agricultural Research Corporation). Compared to the existing FACE projects, the Brazilian implementation innovates with a wireless sensor network approach. In this article it is described the details for that implementation and presented the preliminary results.

Keywords: Wireless Sensors, Environment Monitoring, Plant diseases, atmospheric CO_2 concentration

Introduction

The global atmospheric CO_2 concentration is increasing rapidly in the last decades and despite the international efforts for the reduction of CO_2 emission, it will probably continue increasing for decades and a long period will be necessary for it to return to the previous concentration [1]. The effects of high CO_2 atmospheric concentration are often observed in the host plant, resulting in alterations in the host-pathogen relationship. CO_2 enrichment promotes changes in plant metabolism, growth and physiological processes. There is a significant increase in the photosynthetic rate and a decrease in the transpiration rate per unit leaf area, while total plant transpiration sometimes increases, due to the larger leaf area. Despite the evidence of beneficial effects of CO_2 on the host plant, it is not well known whether these effects will still take place in the presence of pathogens, pests and weeds or other limiting factors, particularly in tropical countries [2]. Few studies were conducted in controlled conditions, which might not reflect plant responses in the field, where there are variations and interactions among temperature, precipitation, and other factors. The search for more realistic conditions has led to the use of open-top chambers (OTCs) or Free Air Carbon-dioxide Enrichment (FACE) experiments [3].

In Brazil, the first FACE facility has been installed near Jaguariúna city - state of São Paulo, besides the installation of six OTCs experiments throughout the country (Belém, PA; Petrolina, PE; Sete Lagoas, MG; Londrina, PR; Jaguariúna, SP; and Vacaria, RS). The project named "Impacts of climate change on plant diseases, pests and weeds", with the nickname "Climapest", has been supported by Embrapa (Brazilian Agricultural Research Corporation). The severity of diseases and pests, weeds, plant development, interaction with microorganisms, plant nutrition, production and others possible impacts will be evaluated. The Climapest-FACE is planned to discover the effects of high CO_2 concentration on coffee diseases, pests and weeds, as well as plant characteristics. The studies with forest species, apple, peach, soybean, grape, corn, cotton, castor beans, forage crops, coffee, cassava and banana will be conducted in the OTCs.

There are more than 30 FACE facilities around the world. They consist of a set of circles having pipe rings around them for the CO_2 fumigation. The circles can be as large as 30m in diameter. The main operational issue is to maintain acceptable fluctuations and gradients of the CO_2 concentration inside the circles, which are affected mostly by the wind. Many installations follow the octagonal arrangement of pipes. Each octagon segment has individual gas valves to compensate the wind direction and flow control devices to compensate wind speed changes. The OTCs have smaller circles, around 2m in diameter, and are surrounded by a plastic cover with an open top. The basic instrumentation for the FACE and OTCs experiments usually consists of an Infra Red Gas Analyzer (IRGA) to measure the CO_2 concentration, an anemometer, a proportional and/or on-off valves and environmental sensors like air temperature and humidity, solar radiation and precipitation. The improvement planned for the Brazilian FACE and OTCs instrumentation is to operate all those devices based on the Wireless Sensor Network technology, already present in the rural area [4] and which is the expertise of the Brazilian FACE implementation group [5]. The expectation is to facilitate the system installation and maintenance and to improve its electromagnetic compatibility, since lightning is a huge issue in Brazil.

Materials and Methods

By the time this project started (January 2009), most necessary instruments were not commercially available as wireless devices. Therefore, the decision was to buy conventional sensors and actuators, as well as wireless modules and to develop a general-purpose interface circuit to integrate those parts to achieve the required wireless sensor network devices. In Table 1 it is shown a list of the chosen devices and the features considered for the interface circuit development. The CO_2 Sensor 1, the GMP343, was chosen for the FACE experiment and the Sensor 2, the GMM222, for the OTCs experiment. The weather devices, i.e. the anemometer, the air temperature and humidity and the rain and barometric pressure sensors are all part of the same instrument, the WXT520 weather station.

Table 1 - List of sensors and actuators and the features considered for the development of the general-purpose interface board.

Device	Operation method	Signal interface / Protocol	Power requirements	Response time	Supplier	Model / Comments
CO_2 Sensor 1	IRGA	Serial RS-232/ASCII or analog (0-2.5V)	12 Vdc (11 to 36) / 1 W (max. 3.5 W)	2 s (no filter, no average)	Vaisala	GMP343 / Difusion probe
CO_2 Sensor 2	IRGA	Serial TTL/ASCII or analog (0-2.5V)	12 Vdc (11 to 20) / 2.5 W	20 s	Vaisala	GMM222 / OEM / Difusion probe
Anemometer	Ultrasound	Serial RS-232/ASCII	12 Vdc (5 to 32) / 36mW (with no heating)	0.25 s	Vaisala	WXT 520
Air Temperature	Capacitive			immediate		
Air Humidity	Capacitive			immediate		
Rain	Piezoelectric			immediate		
Barometric Pressure	Capacitive			immediate		
Solar radiation	Silicon photodiode	Analog (mV)	None	immediate	Li-cor	LI-90 (Quantum) and LI-200 (Pyranometer)
Flow Controller	Differential precision temperature sensor windings	Serial RS-232/ASCII or analog (0-5V)	12 Vdc / 9.6W	2 s	Aalborg	GFC 17 with optional RS-232
Solenoid Valve	Latching	Direct and reverse pulses	12 Vdc / 24W (100ms pulses)	immediate	Jefferson	BA222-70

The wireless modules were purchased from Telegesis Inc., specifically the ETRX3 series. They incorporate the ZigBee protocol and operate in 2.4 GHz. They are IEEE 802.15.4 compliant and they are expected to operate in the planned range of 100 meters from each other with an on-board antenna. They also have all necessary digital and analog inputs/outputs, besides a serial interface and five counter/ timers. A set of proprietary AT commands facilitates their software development.

The general-purpose interface circuit was designed with the following features:

- It is powered by a 12Vdc external source or a 4.2Vdc internal lithium-ion battery;
- It has serial communication with either EIA or TTL levels;
- It provides four analog single ended inputs with fixed gain individually adjustable;
- It has a switchable 12Vdc output, which is compatible with the power requirements of the sensors/actuators devices;
- The remaining I/O pins and power supply lines are available in a connector for a secondary interface board.

The block diagram of the achieved circuit can be seen in Figure 1. Two light emitter diodes (LEDs) inform the system operation mode. The 3.3Vdc regulator is a low dropout and low quiescent current circuit since the internal battery mode is supposed to be low power giving long battery life operation. This basic circuit was used to interface all devices listed in Table 1 but the latching Solenoid Valves. For those valves it was developed a secondary board with H bridge circuits to provide the direct and reverse pulses for up to four solenoids. A supercapacitor is firstly charged before enabling the H bridges outputs. This avoids the overload of the CMOS transistor used to switch the 12Vdc.

In Figure 2 it is shown the final assembly for the GMM222 Wireless Device. Due to the power requirements of this probe it was utilized an external power source. It consists of a photovoltaic cell associated to a lead-acid battery and a charging controller.

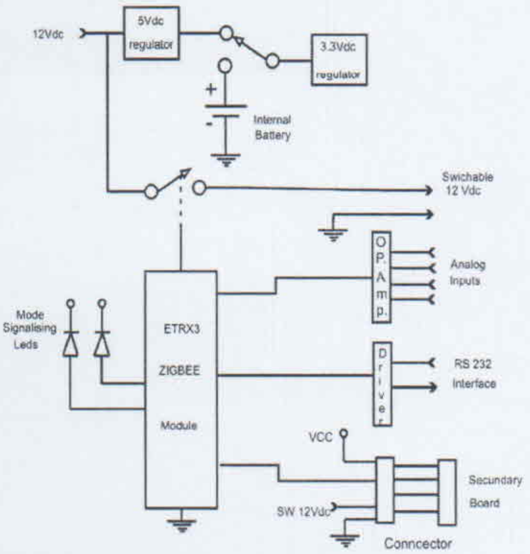

Figure 1 - The block diagram for the Wireless Sensor Network Nodes.

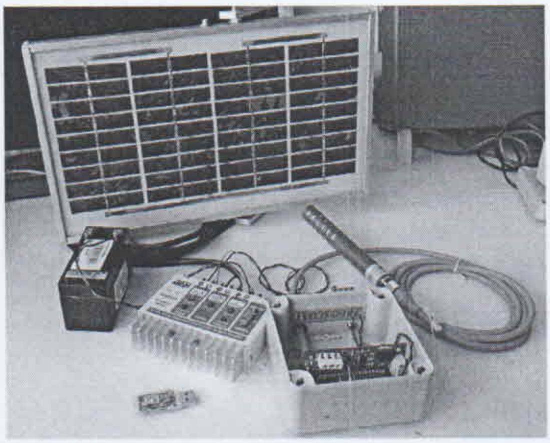

Figure 2 - The GMM222 probe adapted as a ZigBee Node with an external power source.

The communication between a PC computer and the wireless devices is provided by an USB-ZigBee interface, also purchased from the Telegesis Company. This USB stick has been used with the Windows 7 and Ubuntu Linux version 10.4 operating systems through, respectively, the *Telegesis Terminal* and the *minicom terminal,* to send the AT command lines directly to the modules. In this way, basic tests were conducted to: switch power; perform serial data communication; acquire signals from the modules; and open and close valves. Based on the set of the most useful AT commands, a high level program was written in the LabView 8.2 graphical development environment to perform data collection and system control.

Results and Discussion

So far, only one OTC experiment was settled with the obtained Wireless Devices (Figure 3). Eight GMM22 CO_2 probes were spread inside a ring and one WXT520 weather station was placed at its center, at 2m in height. Also one Aalborg was installed to control the CO_2 flow for that ring. This arrangement allowed injecting a constant flow and monitoring the CO_2 concentration fluctuations as well as the wind speed and direction.

This very preliminary test, conducted in Jaguariúna, SP, Brazil, allowed obtaining the graphs showed in Figure 4. It was a short-term evaluation for the response time of CO_2 concentration and wind conditions measuring. During the first ten minutes there was no CO_2 fumigation. After that the flow was kept constant at three liters a minute. The most important observation is that the wireless instrumentation offers no significant time delay and allows quickly following the changes in concentration according to the wind, like the ones occurred around the times 13:00, 13:30 and 14:20h. Also, due to the position of the probes, which are distributed equally spaced around the midway from the border to the center of the circle, the effect of wind direction could be noticed as shown in the Sensor number 4 graph, which most of the time presents values slightly lower compared to the other sensors. This sensor position is against the predominant wind direction.

Also, a middle-term evaluation has currently been carried out. At first, the Wireless Sensor Network had often hung up. The problem was identified as some ZigBee modules getting stuck in a data mode. This mode is used for serial data communication with most devices, and despite of the correct sequence of the Telegesis AT commands supplied to open and close this mode, the transmission may eventually fails. A self-recovery solution came up by the use of a timed function implemented in the ZigBee modules to leave the data mode automatically. This function is also available among the Telegesis AT commands. This operational evaluation has included the system software, which has presented very few bugs.

Future works include testing the operation of a large number of devices and writing the proper algorithm to control the fumigation and maintain the CO_2 concentration at the necessary level (usually around 550 ppm) inside the OTC rings. For the FACE rings, besides controlling the flow, the latching valves devices will be used to compensate also the effects of the wind direction.

Figure 3 – The OTC experiment instrumented with the ZigBee based wireless devices.

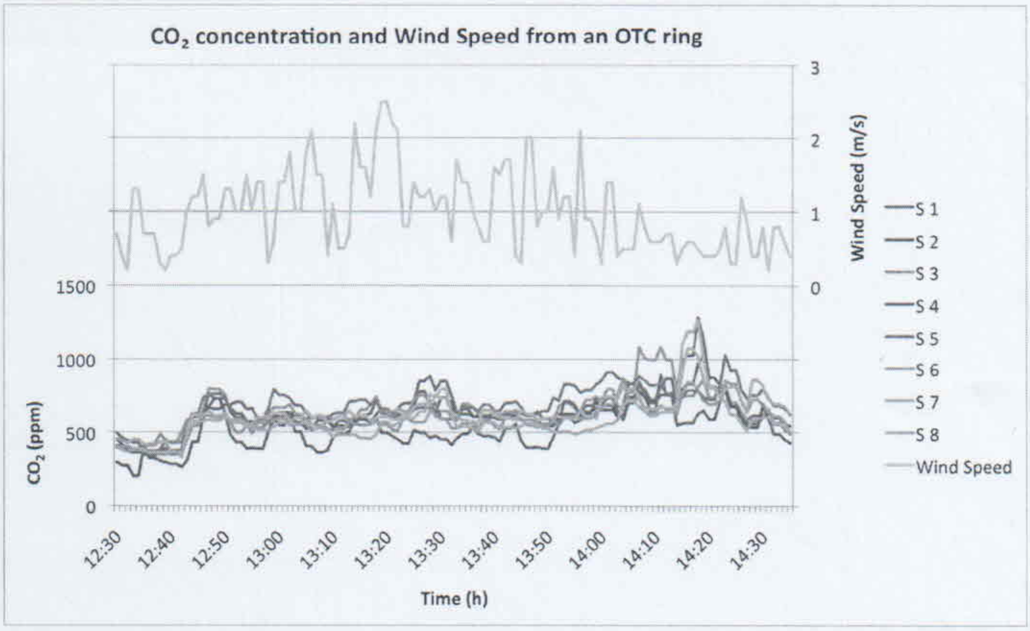

Figure 4 - Data obtained from an OTC ring for a short-term evaluation of the achieved system.

Acknowledgments

The authors are grateful to:

The funding agencies:

- The Brazilian Agricultural Research Corporation, Embrapa, Macroprogram project "Impacts of climate change on plant diseases, pests and weeds": http://www.macroprograma1.cnptia.embrapa.br/climapest

- Latin America Science & Technology Development Programme, CYTED project "Redes de sensores y microsistemas para el control del impacto de la producción agricola y la mineria en los acuiferos (REDSENSA)": http://www.cyted.org/cyted_investigacion/detalle_accion.php?un=07c5807d0d927dcd0980f86024e5208b&lang=pt

- National Council for Scientific and Technological Development, CNPq and The State of São Paulo Research Foundation,FAPESP in Brazil– project INCT NAMITEC: http://namitec.cti.gov.br/

The people:

The technicians at Embrapa Agricultural Instumentation Center, especially Mr. Gilmar Victorino

References

[1] Intergovernmental Panel on Climate Change, IPCC Web Page: http://www.ipcc.ch/index.htm Access: oct. 2010.

[2] R. Ghini and E. Hamada, "Mudanças Climáticas: Impacto sobre Doenças e Plantas no Brasil", Embrapa, first edition, Jaguariúna, SP, Brazil, 2008.

[3] G.R. Hendrey and F. Miglieta, "FACE Technology: past, present and Future" In: Nosberger J, Long SP, Norby RJ, Stitt M, Hendrey GR, Blum H (eds) "Managed ecosystem and CO_2", Springer, Germany, Vol. 187, 2006.

[4] N. Wang, N. Zhang, M. Wang, "Wireless sensors in agriculture and food industry-Recent development and future perspective", Computer and Electronics in Agriculture, No.50, pp.1-14, 2006.

[5] A. Torre-Neto, R. Ferrarezi, D. Razera, E. Speranza, W.C. Lopes, T.P. Lima, L. M. Rabello and C.M.P. Vaz, "Wireless sensor network for variable rate irrigation in Citrus." Proc. of the 7th Information & Technology for Sustainable Fruit and Vegetable Production, Montpellier, France, Abstracts and CD ROM, v. 01. pp. 18-118, 2005.