The Development of Real-time Airborne and Dropwindsonde Data Acquisition System on Laptops

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Abstract

A framework for real-time monitoring Gulfstrem-100 airborne data and dropwindsonde data in 2002-2005 DOTSTAR (Dropwindsonde Observations for Typhoon Surveillance near the Taiwan Region) flight missions is presented in this article. The data management tool on board called Madonna (management of airplane and dropwindsonde data and analysis) consists of MySQL database, window interface written by Delphi Language and digital coastline data from CIA World DataBank II. Madonna tool was installed on laptops computer (Notebook) with Microsoft Windows2000 Operation System for limited cabin space. The scientist crews monitored the real-time airborne data from his laptops and used track pad to zoom in/out the planned and real flight routes on the digital map. The time spent to next drop-point was updated automatically in 5 seconds on screen for reference. Four Skew T-log P thermodynamic diagrams of in-air dropwindsonde data was plotted at the same time to help the principle investigator watching the atmospheric sounding profiles immediately. Madonna tool had expected performance in 2003/2004 53-hr typhoon surveillance flight missions. Meanwhile, a developing toolkit for calculating typhoon center location on board was tested well in 2003 Typhoon Dujuan.

1. Introduction

DOTSTAR (Dropwindsonde Observations for Typhoon Surveillance near the Taiwan Region, Wu et al., 2004; http://typhoon.as.ntu.edu.tw/DOTSTAR/English/home2_english.htm) is an international research program conducted by meteorologists in Taiwan partnered with scientists at the Hurricane Research Division (HRD) and the National Centers for Environmental Prediction (NCEP) of the National Oceanic and Atmospheric Administration (NOAA). The experiment is based on successful surveillance missions conducted in the Atlantic with NOAA's Gulfstream-IV jet aircraft (Aberson, 1993). During the experiment, GPS dropwindsondes (Hock and Franklin,1999) from Vaisala are released from a jet aircraft (Gulfstream-100) flying above 43000 ft in and around tropical cyclones (TCs) approaching Taiwan to collect critical meteorological data for improving the analysis and the prediction of typhoons. Information from the surveillance flights is needed to be transmitted in near real-time to the Central

Weather Bureau (CWB) of Taiwan, as well as NCEP, FNMOC, and JMA. Then the data are assimilated into the operational global and regional numerical models of CWB, NCEP, FNMOC, and JMA. DOTSTAR provides valuable data to increase the accuracy of TC analysis and track forecasts from, numerical models, to evaluate targeted observing strategies, to validate/calibrate remote-sensing data, and to improve understanding of TC dynamics, especially in the boundary layer.

After one year of training, development and installation of all the needed software and hardware in the Gulfstream-100 (G-100) aircraft, the DOTSTAR research team initiated typhoon surveillance in 2003 when two missions (in Typhoons Dujuan and Melor) were conducted successfully. Nine more missions have been conducted in 2004 around 7 typhoons (Nida, Conson, Mindulle, Megi, Aere, Meari and Nock-ten). In total, the G-100 has flown 53-hr releasing 180 dropwindsondes. Eight to ten missions are expected to be conducted during the 2005 typhoon season. The management of air-borne flight and meteorological dataset on the first Taiwan scientific airplane is one of the challenges we need to overcome in DOTSTAR. The detail of Madonna (management of airplane and dropwindsonde data and analysis) framework will be described in next section, and the benefit of using laptops device in DOTSATR will be summarized in section 3. Section 4 gives the conclusions and the plan in the future.

2. Configuration of real-time data management on board

After visiting the NOAA G-IV operational procedure and its on-board WINDS software(Horton,1994), the authors reviewed status of G-100 airplane with its owner, AIDC (Aerospace Industrial Development Corporation). Laptop computer was selected instead of Sun workstation to satisfy the limited cabin working space. Figure 1 shows the arrangement of operational seats and their duties in air. The intranet network was also built for data sharing between the laptops and Vaisala AVAPS (Airborne Vertical Atmospheric Profiling System).

Three laptops with Microsoft Windows2000 Operation System were installed the Madonna tool for DOTSTAR flight mission. Window interface environment written by Delphi Language provides friendly text/graphic display for operators on board. The Madonna tool consists of two segments named AR429 and RD93 (Figure 2). The AR429 segment was designed to monitor the aircraft status through four sub-pages. MAP page (Figure 3) displays the flight route on the CIA World DataBank II (http://www.evl.uic.edu/pape/data/WDB/). A map shifting and zooming button allows the user to change the map size and central location. Latitiude-longitiude-height parameters of aircraft are listed besides the route map, and the flight times to four near waypoints are calculated and updated every 5 seconds or shorter. REAL-TIME page

(Figure 4) gives a list of all 27 parameters from cockpit panel. WAY-POINTS page (Figure 5) lists the waypoints table and the typhoon information (eye location, radius of typhoon, moving speed and direction) can be typed to produce a typhoon circle on the Map page. SYSTEM SETTING page provides the flexible turning on the time interval of text/graphic display (2~30 seconds) and the background color of map (not shown). RD93 segment is the major channel to watch the in-air dropwindsonde meteorological data. REAL-TIME (F1) Page can display a Skew T-log P diagram from one of four-channel AVAPS dropwindsonde by clicking the channel-selection button. Meanwhile, the F2~F7 Pages can show the parameters-time series diagram for reference (Figure 6).

MySQL, the most popular open source database, was installed in all of the laptops devices. The primary Laptops connected AR429 PCMCIA device and RS232 9-pin port from AVAPS takes the role of server device. The other Laptops computers are treated as client devices for data storing and re-processing.

Madonna tool does not include the data quality checking and WMO/TEMPDROP code editing. We install the ASPEN (Atmospheric Sounding Processing ENvironment) freeware from NCAR/ATD website on these laptops. The 2Hz sampling rate of RD93 dropwindsonde data (near half-one Mbyte) is reduce into 3Kb WMO message file, and be sent to CWB by satellite phone device.

3. Benefit of Madonna tool developed on laptops

Due to the limited cabin space and funding, the authors decided to use the cheaper-and-popular laptops device instead of big-and-expensive workstation on board. CPU performance of laptops was tested under multi-task execution at the same time, including MySQL data saving & query and graphics plotting every 5 seconds in 6-hr full running. After 11 flight missions (5-hr for one flight in average) from 2003 to 2004, no sudden shutdown of laptops happened in the air. The authors would like to share several benefits from the laptops device:

(1) Easy installation: The university owns these laptops and built-in software. For each flight mission, the authors bring these laptops and install them on board. Only one hour is needed before boarding time. After the flight, the crews plug out the laptops immediately. AIDC G-100 can keep its space clean for other customers.

(2) Easy price: The HP NC6000 lapstops with 512Mb RAM and one series port costs $1400 and be fixed in the rack during flight. It keeps working well under turbulent situation. Three laptops using on board have same configuration and can be replaced and reboot in 5 minutes.

(3) Easy maintenance: Two USB ports besides the laptops provide convenient

plug-in function for network setting, program upload and data download. Other type of laptops with new fashion and higher performance on the market can be accepted to replace the HP laptops.

4. Conclusions and Discussion

In a preliminary analysis based on the 11 flights from 2003 to 2004, the DOTSTAR dropwindsonde data provide an average 20% improvement to the 24-72-hr track forecast of the NCEP Global Forecast System (GFS). Further analyses are with other models are ongoing. The experiment marks the beginning of typhoon surveillance in the western North Pacific and is expected to yield impressive advances in typhoon research, observations and forecasting. Besides the scientific progress, the performance of laptops hardware and the Madonna software present expected quality and stability on board. It encourages us to develop more function on this laptops protocol as data acquisition system. For example, the on-board scientist may be interested to calculate the geo-location of typhoon eye through these surveillance dropwindsonde profiles during the flight. We assume typhoon system has symmetric pressure field over ocean and accept the pressure of typhoon eye is the same as the numerical model prediction (P_c). But the forecasted position of typhoon eye (D_c) needs to be modified. Any group of three surface layer of dropwindsonde data (pressure, latitude and longitude) is chosen to calculate the pressure gradients R_i (= $\triangle P_i$ / $D_{i,\ i,=1,3}$). D_i is the great-circle distance between the eye and dropwindsonde. Iteration keeps running by changing D_c until all of $R_{i,\ i=1,3}$ converge to a tolerance value. The final D_c is the expected location of typhoon eye. One typhoon case (Dujuan) in 2003 was used to test the above algorithm. Figure 7 and Table 1 show that the calculated result agrees with the estimation of Radar echo and geo-stationary satellite images.

Due to the successful experience of G-100 cabin setup, we will extend the Madonna tool on the coming scientific airplane, Super King Air 350, in 2006. This airplane will be used on the research of city pollution, remote sensing on sea surface and cloud microphysics.

References:

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Wu, C. C., P. H., Lin, S., Aberson, T. C. Yeh, W. P., Huang, K. H., Chou, J. S., Hong, G. C., Lu, C. T., Fong, K. C., Hsu, I. I., Lin, P. L., Lin, C. H., Liu, 2004: Dropwindsonde Observations for Typhoon Surveillance near the Taiwan Region (DOTSTAR): An Overview. Accepted by *Bull. Amer. Meteor. Soc.*

Table1：The geo-location estimation of typhoon eye from different instruments and subjective analysis(case: Dujuan, 06:00UTC, 1 September, 2003).

	Subjective analysis	GOES-W estimation	Ken-Ding Radar estimation	Madonna Tool estimation
Longitude(˚)	123.8	123.7	123.73	124.3~124.5
Latitude(˚)	20.9	20.8	20.98	20.8~21.0

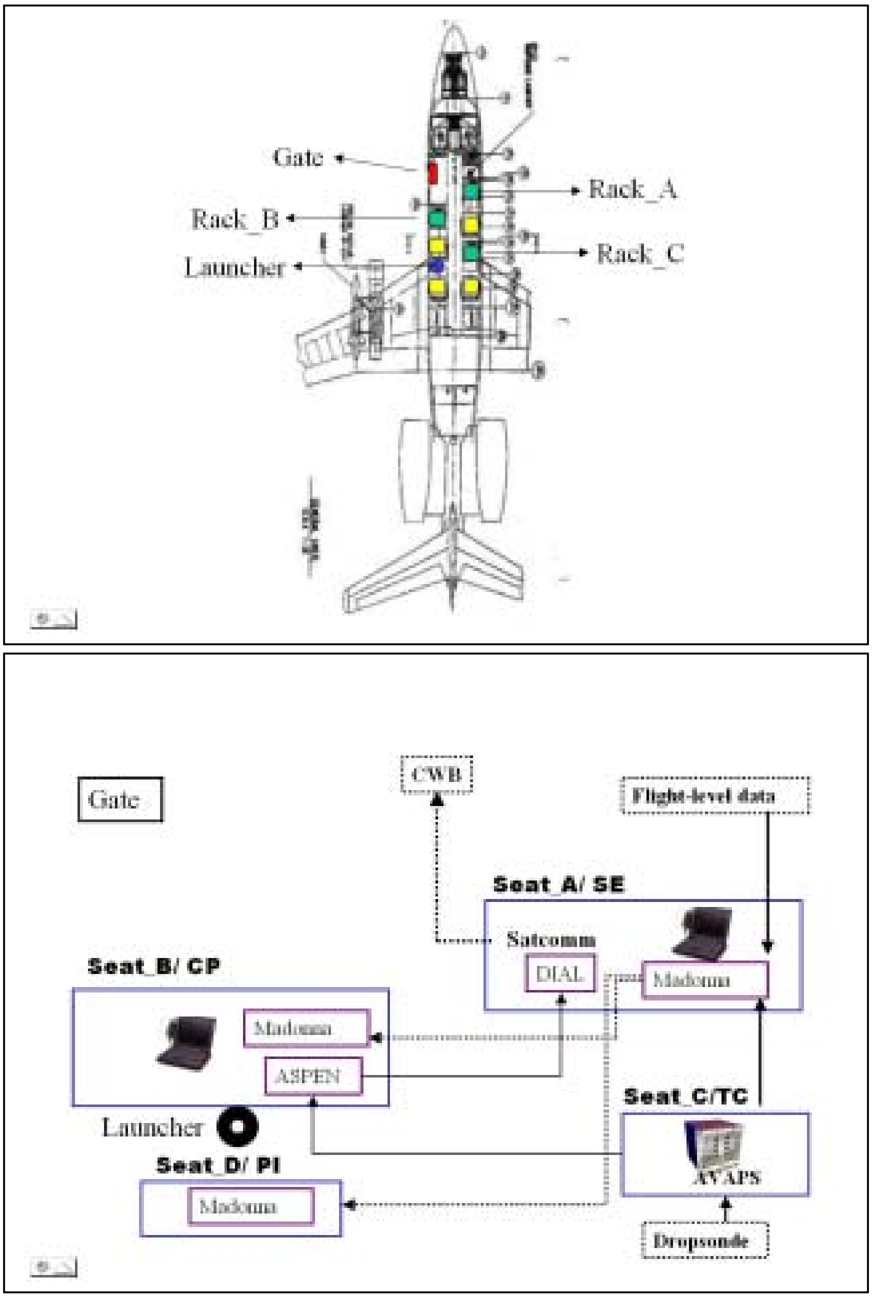

Figure 1: Four seats arrangement in AIDC Gulfstream-100 cabin. TC is technical crew, CP is data coding person, SE is system engineer and PI is principle investigator. Satcomm means satellite phone communication.

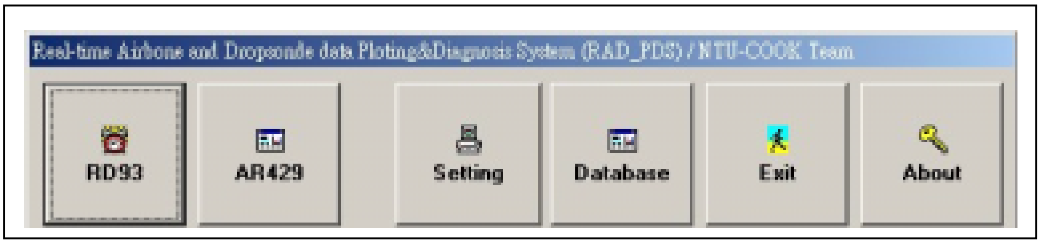

Figure 2: Main panel of Madonna tool (management of airplane and dropwindsonde data and analysis) .

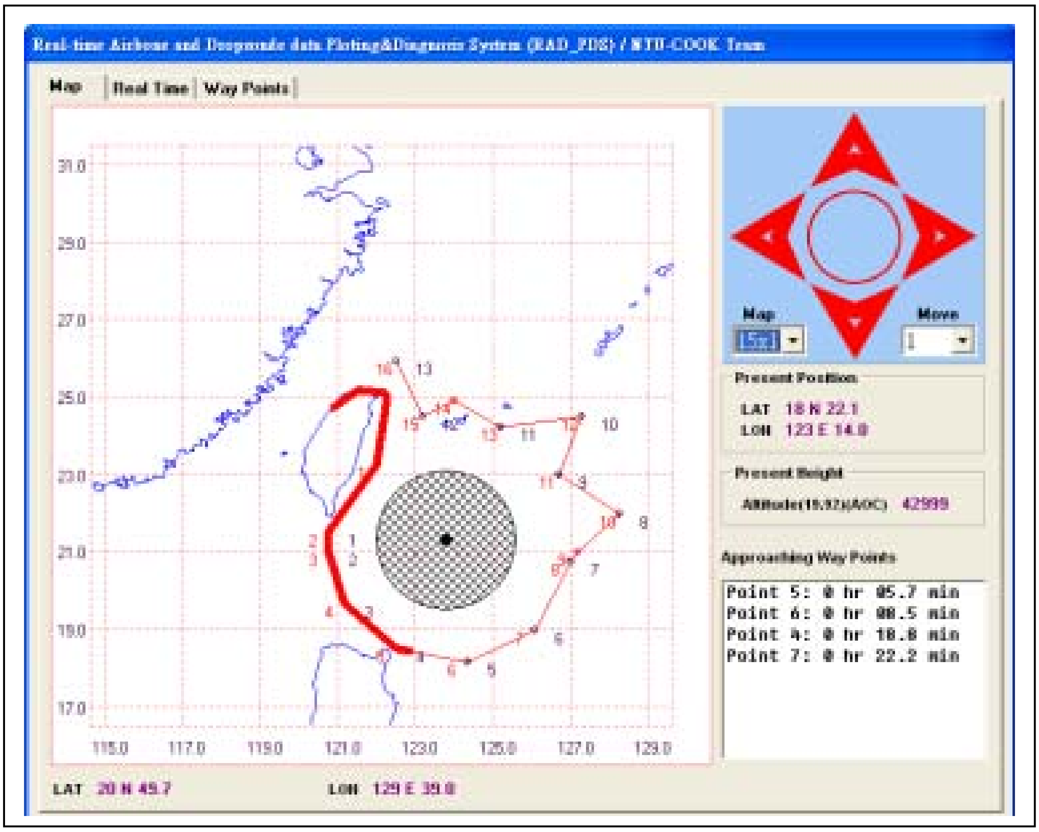

Figure 3: MAP page of AR429 segment in Madonna tool. Planned route and real flight track in Typhoon Neck-ten (12:00 UTC, 24, October, 2004). The map zoom/shift panel is on the right corner of screen. Approaching time was calculated under airplane cruise speed.

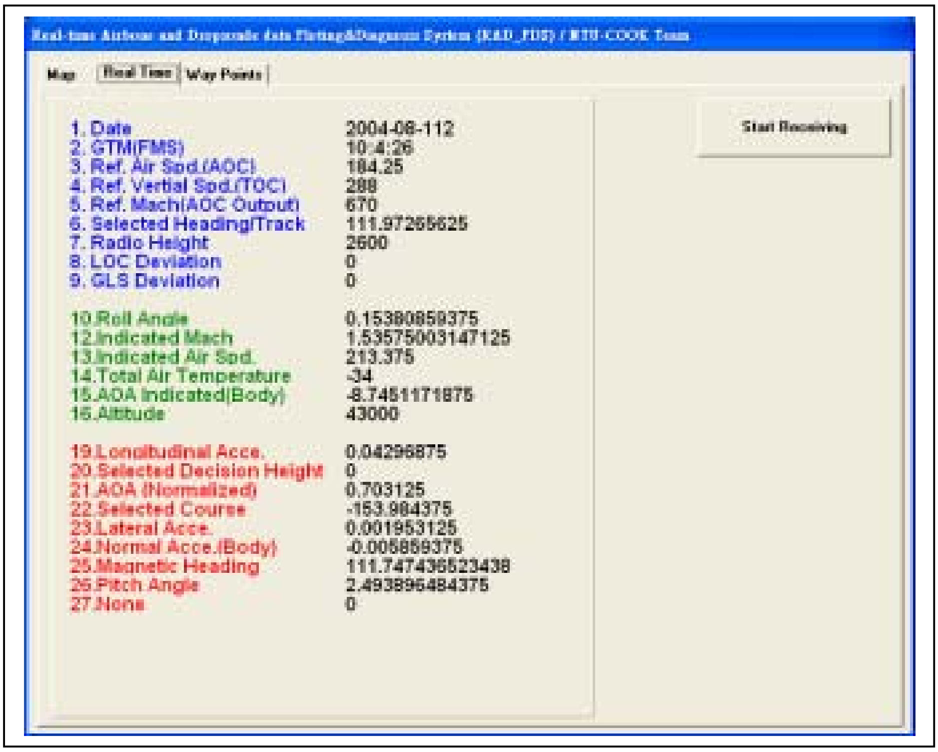

Figure 4: REAL-TIME page of AR429 segment in Madonna tool. (case: Typhoon Neck-ten ,12:00 UTC, 24, October, 2004).

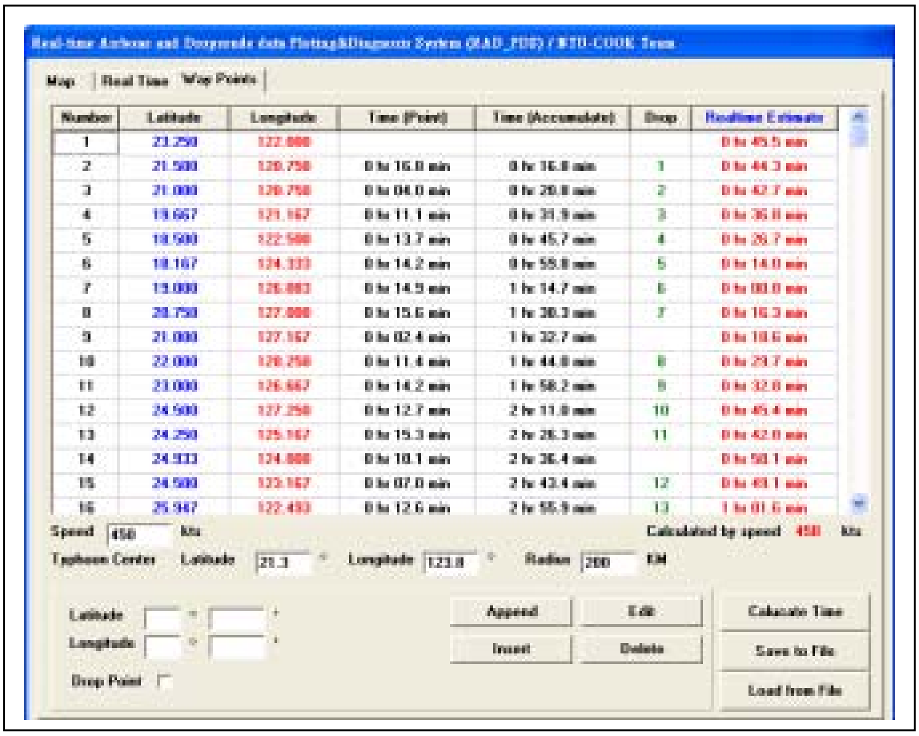

Figure 5: WAYPOINT page of AR429 segment in Madonna tool. (case: Typhoon Neck-ten ,12:00 UTC, 24, October, 2004).

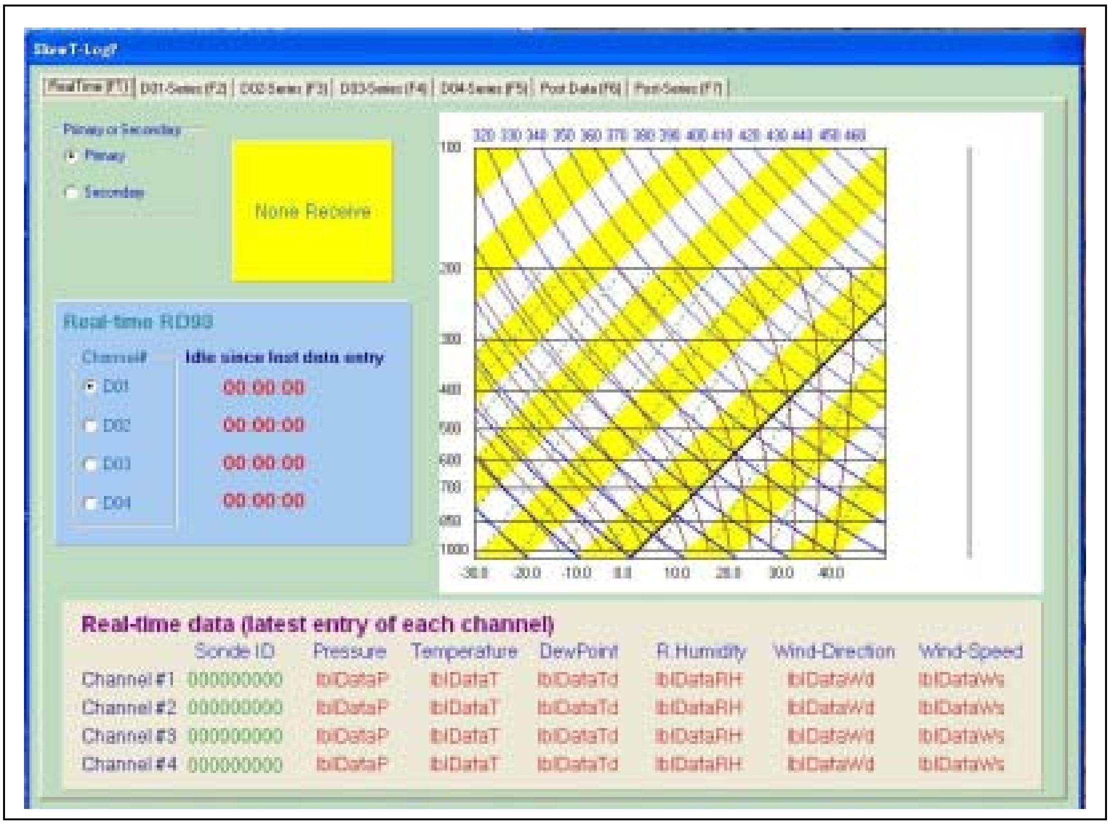

Figure 6: REAL-TIME page of RD93 segment in Madonna tool. Four channels of RD93 dropwindsonde data from AVAPS can be plotted in Skew T –log P diagram on the right panel. Instant data stream is shown on the bottom panel.

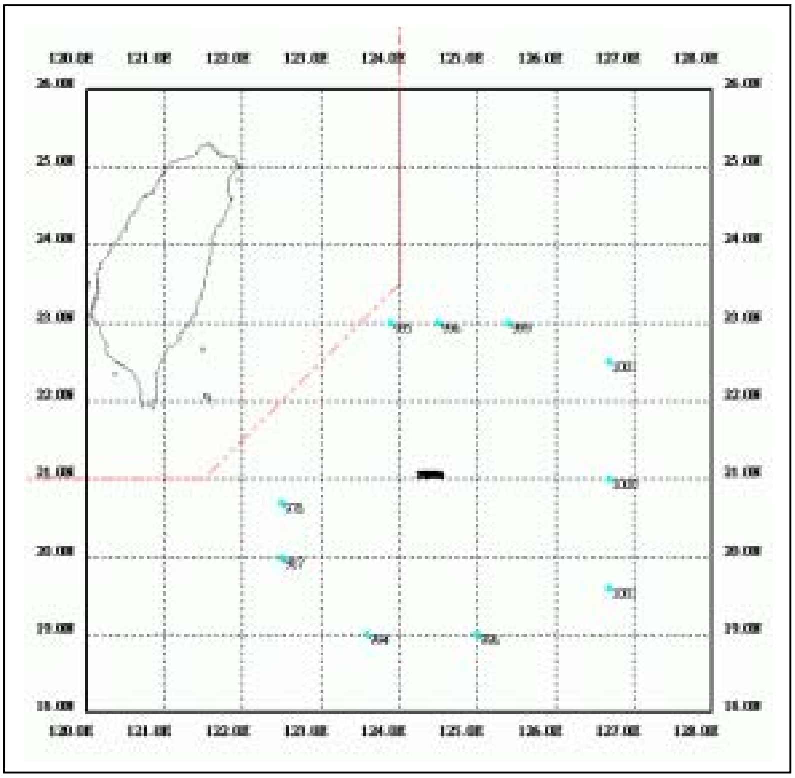

Figure 7: 10 surface pressures of dropwindsonde data were marked as blue points in the flight mission of Typhoon Dujuan (06UTC, 1, September, 2003). Black box presents the calculated position of typhoon eye from Madonna tool.