METEOROLOGICAL DATA ACQUISITION AND SERVICE DELIVERY FOR WGC 2001 IN MAFIKENG, SOUTH AFRICA

By Estelle Banitz and Lucian Banitz, South African Weather Service

Presented at the XXVII OSTIV Congress, Mafikeng, South Africa

SUMMARY

The World Gliding Championships for 2001, in which nineteen countries were expected to participate, was hosted by South Africa. This event took place over the central interior of South Africa and based from Mafikeng in the Northwest Province. Mafikeng is approximately 350km to the west of Johannesburg and 15km south of the Botswana border. Following the pre-world gliding championships of December 2000 a number of gaps in the meteorological observation network were noted. In order to bridge some of these gaps the South African Weather Service (SAWS) made a concentrated effort to upgrade and implement technology as far as finances and human resources would allow.

In this paper attention will be given to several aspects with regard to the facilities at Mafikeng in December 2001. First of all general climatological statistics will be provided describing soaring weather in Mafikeng. This will be followed by a description of the changes and improvements made in order to provide the area with enough real time data to make weather forecasts feasible. Aspects such as the AWS network and instrumentation, available satellite imagery, numerical weather prediction model output, information technology and upper-air data will be addressed.

In addition to the conventional radiosonde instrumentation package used to obtain information on the state of the upper atmosphere, a new, experimental method — called the glidersonde — will also be introduced at the Mafikeng championship. The glidersonde is a small unpowered autonomous sailplane that carries meteorological sensors for the collection of atmospheric data in comparable method to a a radiosonde. The glidersonde has a wingspan of less than two meters and an approximately total flying weight of 1.8 kilograms. The glidersonde contains a Global Positioning System (GPS) receiver and a small microcomputer used in determining relative position and making navigation decisions. The glidersonde is carried aloft by a conventional gas-filled balloon and measures pressure, temperature, humidity and position data as it ascends. At a present altitude, the glidersonde releases itself from the balloon. The aircraft naturally flies to a level attitude and the autonomous navigation system steers it to the home or alternative location. After reaching the home location, the glider circles while descending. At a preset altitude above ground, a parachute deploys and the glidersonde is recovered. The vehicle can then be reused.

The last part of the paper focuses on the different parameters for forecasting thermal soaring. The Mafikeng area is influenced by a tough line which marks the boundary between dry desert air to the southwest and humid air to the northeast. Along this air mass boundary, large cumulonimbus clouds often form producing extensive thunderstorms. This is the typical summer weather pattern marking the rainy season in the interior of South Africa. The airfield is at 4200 ft above sea level, however the terrain is basically flat. Virtually all thermals in this area are purely convective. The area is characterized by high-energy air in summer and forecasting the start of convection (and the first over-development) is very much like putting a pot of water on a cooker and trying to predict where the first bubble will pop up. The forecasting task in this area is thus not an easy one.

INTRODUCTION

The World Gliding Championship (WGC) for 2001, in which nineteen countries are expected to participate, will be hosted by South Africa. This event, scheduled for December 18-31, 2001 will take place over the central interior of South Africa and be based from Mafikeng in the Northwest Province. Mafikeng is approximately 350 km to the west of Johannesburg and 15 km south of the Botswana border (see Figure 1). The airfield of Mafikeng is about 10 km west of the town and has a 4.5 km paved surface. American aircraft used the airfield in the past and with an elevation of 4200 ft a fairly long runway is needed to get a fully laden Starlifter airborne, hence the paved surface.

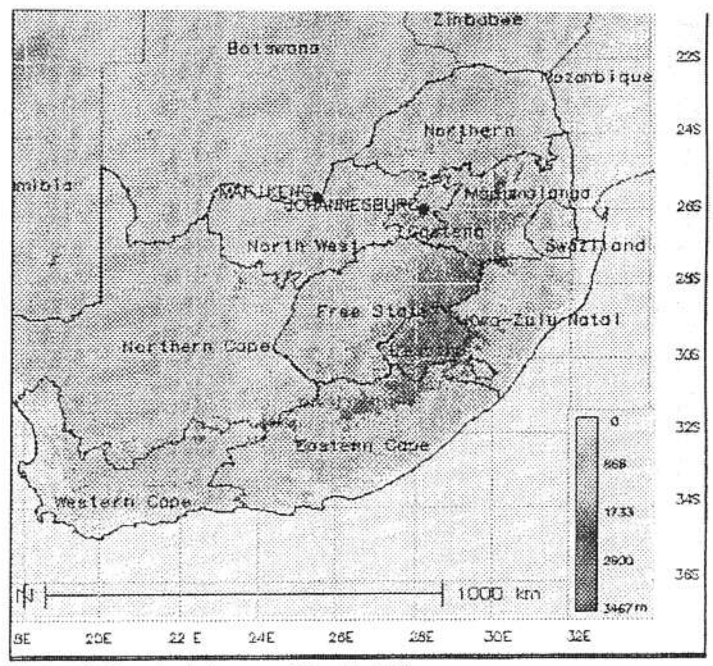

Figure 1 Provincial map of South Africa

Soaring weather in South Africa

In order to give a general idea of the climatic conditions in Mafikeng for the month of December, the following statistics are available for a 25 year period:

Maximum Temperature:	30.7 degrees C
Minimum Temperature:	16.8 degrees C
Dew point depression at 14.00 SAST	6 degrees C
Rainfall	67 mm
Days with rain	9
Cloud cover	4 octas

The Mafikeng area is influenced by a trough line which marks the boundary between dry desert air to the southwest and humid air to the northeast. Along this air mass boundary, large cumulonimbus clouds often form producing extensive thunderstorms. This is the typical summer weather pattern marking the rainy season in the interior of South Africa.

The airfield is at 4200 ft above sea level; however, the terrain is basically flat. The ground gradually rises 1000 ft or so to the east and falls gradually to around 3500 ft to the west of Mafikeng. The Vryburg road, which heads southwest from Mafikeng, is fundamentally the dividing line between the more fertile farming land to the east and drier progressively desert like terrain to the west. This arid area provides some excellent soaring conditions with cloud base heights averaging around 6500 ft, although cloud bases as high as 13000 ft and more are not uncommon in the area.

Mafikeng airfield itself is situated in a slight hollow and is surrounded by several small dams and rivers. The water table at the airfield is fairly high. As a result it is often necessary to tip toe out of the Mafikeng area on the first leg of the task before getting into the truly excellent soaring conditions in the surrounding area. For the same reasons thermals in the immediate vicinity of the airfield tend to die out earlier than in the surrounding areas and care should be taken on the final glide into Mafikeng, particularly when arriving late.

Virtually all thermals in this area are of a purely convective nature. The area is characterized by high-energy air in summer. Forecasting the start of convection (and the first over-development) is very much like putting a pot of water on a cooker and trying to predict where the first bubbles will appear.

Care should be taken when flying near or around thunderstorms. The area immediately ahead of a strong thunderstorm is often marked by a gust front with extremely high wind velocities. Likewise the area behind the storm is usually cool and wet from the precipitation and therefore void of any thermal activity.

The previous day's rainfall has a very significant influence on the start, as well as the strength of the present day's thermal activity. Before thermal activity can commence for the day, the ground first needs to be dried in order for the necessary dew point depression to be reached.

Mike Young participated in the gliding championship in Mafikeng in 2000 and offers his opinion (Young [1]) about soaring weather in Mafikeng:

"Leafing through the pages of my gliding logbook, out of 40 days of possible flying from Mafikeng only a couple of days have been lost because of bad weather. For the competition to be successful, the key ingredient, the weather, does not have to be good, but just a normal mix of SA conditions will be sufficient."

Soaring information needed in Mafikeng

In other countries around the world, soaring weather features include: valley/mountain winds, sea breezes, mountain waves, slope soaring, ridge soaring, wave lift and frontal lift (Pagen [2]). Although most of these conditions also apply in South Africa, most of them are only applicable in other parts of the country with mountainous terrain like the Drakensberg (southeastern parts) and in the Southwestern Cape. In Mafikeng — where the terrain is mostly flat — the conditions which play a role in the soaring weather are: convergence lines, thunderstorm outflow boundaries, cloud streets, man made heat sources (mines) and thermal waves.

Synoptic features which are looked at will be: areas of higher pressure, gradient winds, location of frontal systems and other air mass boundaries, energy of the air mass, dew points and visibility. From the upper-air sounding the following parameters will be determined: the depth of dry adiabatic layer, moisture content, depth of instability, dew point depression at inversion and humidity above convection level. In addition to these observed parameters, numerical weather prediction model output will be utilized to predict the weather for the following two days to give the competitors an idea of the weather in the near future.

The Meteorological Service

Forecasting (e.g. during the pre-World Championships) was quite difficult due to the South African Weather Service (SAWS) having to reduce the number of weather stations to the west of Mafikeng as well as the number of balloon ascents because of budget cuts. Fortunately, the situation is different for the World Gliding championships of this year. A number of improvements have been made in order to deliver a good service to the gliding community for the World Championships, which include:

A Communication

The Mafikeng Weather Office is linked to the SAWS Frame/Relay WAN for its meteorological data feed which is currently running over a 64 kilobit per second Diginet line. This setup proved to be adequate for the SAFARI 2000 event in Pietersburg which made use of the same infrastructure. The local LAN will be extended with a radio bridge to a HUB in the forecasting office (closer to the briefing facilities) on the airfield in Mafikeng.

A radio link will be installed between the Mafikeng Automatic Weather Station (AWS) and a laptop PC to allow the forecaster to interrogate the AWS from for example, the start line. AWS communication at three of the stations will take place through cell phone technology. This methodology was developed locally by South African data technologists. A processor is connected to the AWS logger, extracts the necessary data for SYNOPS and METARS and then sends a Short Message Service (SMS) to the weather office.

Cell phones are used on both sides of the communication, i.e. at the AWS and at the office. The main advantage of this system is the reduction of costs — it cuts the monthly costs down to R37 (using cell phone SMSs) compared to R300 (using the normal telephone line). The other advantage is the fact that the communication is much more reliable and accurate than when normal telephone lines which are often struck by lightning.

The MetGIS software and downloader will be running on a 1.2 Ghz AMD processor system with 17" display. Types of data display will include: real-time satellite images, radar images, numerical weather prediction model data, upper air data displays, synoptic data displays any ASCII message and METARS.

B. Available data input

SURFACE OBSERVATIONS

The eighteen AWSs relevent to the championships area are: Van Zylsrus, Kathu, Postmasburg, Kuruman, Pomfret, Kimberley Weather Office, Taung, Mafikeng Weather Office, Bloemhof, lichtenburg, Klerksdorp, Welkom, Ventersdorp, Potchefstroom, Pilansberg, Bloemfontein Weather Office, Vryburg and Ottosdal (Figure 2). Sixteen of the stations are existing stations of which thirteen needed to be upgraded to provide humidity measurements through new temperature and humidity sensors. A cheaper than normal temperature and humidity sensor was obtained from Holland and after intensive testing was found suitable for use in South Africa. The other two stations (temporary installations at Vryburg and Ottosdal) have also been equipped with new temperature and humidity sensors.

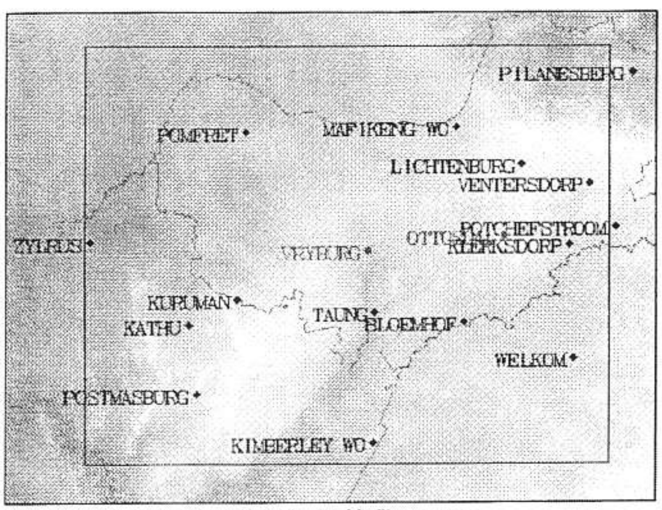

Figure 2 Location of the AWSs in the Mafikeng area

All the AWSs will be equipped to measure:

- Pressure (by means of a Vaisala or Honeywell sensor)
- Temperature (by means of Vaisala and Dutch sensors EE205)
- Humidity (by means of Vaisala and Dutch sensors EE205)
- Wind direction and speed (by means of a R.M. Young sensor)
- Rainfall (by means of a tipping bucket rain gauge).

SATELLITE IMAGERY [http://www.eumetsat.de/]

Satellite observations are an essential input to numerical weather prediction systems and also assist the human forecaster in the diagnosis of potentially hazardous weather developments. EUMETSAT is an intergovernmental organization created through an international convention agreed by 17 European Member States. EUMETSAT geostationary satellite programs include the continuation of the current Meteosat system until at least the year 2003 with a Meteosat Second Generation (MSG) system under development for continuation and improvement of the service well into the next decade. The Meteosat system provides continuous and reliable meteorological observations from space to a large user community.

Images of the globe are taken routinely by EUMETSAT Meteosat satellites from a geostationary orbit about 36000 km above the equator. Currently EUMETSAT operates Meteosat satellites at 0 degrees longitude and at 63 degrees E. The images (in three spectral channels: Visible, Infrared and Water Vapor) are taken on a half-hourly basis and, after processing at their control center in Darmstadt, are redisseminated via the satellites to the user community.

In Mafikeng the forecaster will be making use of Meteosat images (of all three channels) overlaid with a GIS background in order to see how the cloud patterns relate to the geography of the surface.

NUMERICAL WEATHER PREDICTION MODEL OUTPUT

Output from two numerical weather prediction models will be used during the WGC 2001:

The regional Eta model:

The local version of the National Centers for Environmental Prediction (NCEP) ta-coordinate, "step-mountain" Eta model (Mesinger et al. [3]; Black [4]; Black et al. [5]; Janjic [6]; Rogers et al. [7]; Rogers et al. [8]; Rogers et al. [9], together with a matching data assimilation system, has been running operationally at he South African Weather Service since November 1993 (Poolman et al. [10]. Thee Eta system provides regional, short-range forecast guidance to forecasting offices with several other internal and external clients. The Eta modeling system is upgraded regularly at he SAWS with the latest Eta upgrade at the SAWS having become operational on 30 November 1999. Currently the model operates at 48 km horizontal resolution with 38 levels in the vertical.

There are two operational runs of the Eta system to 48 hours every day at 00Z and 12Z following 12-hour data assimilation process with a 3-hour analysis/forecast cycle. The analysis system is the NCEP three dimensional variational (3DVAR) scheme. Preliminary guess fields for the initial analysis at t-12h are provided by the in-house GSM model (see below), or by an NCEP global analysis from the GTS, while guesses for the subsequent analyses are 3-hour forecasts from the Eta model itself. Observations are included from a 3-hour window around each analysis time.

The global GSM model:

The SAWS operates two Cray supercomputers, a J-90 (since September 1996) and an SV-1 (since November 1999).

This computing power permits running two general circulation models for longer-range applications. One of these is the T126 version of the National Centers for Environmental Prediction (NCEP) global spectral model, implemented locally as the Global Spectral Model (GSM).

The GSM model was developed at NCEP (Sela [11]) for global medium-range forecasts.. The T126 version is used at the SAWS for twice-daily forecasts to 168 hours ahead and is utilized locally for two-week forecasts. The horizontal grid of 384 by 192 points has a resolution of about 100 km, or 1x1 degree. The vertical coordinate is the terrain-following sigma parameter with 28 unevenly spaced sigma levels.

Operational software packages for display and application of NWP products will be:

- PCGRIDDS [http://www.lib.noaa.gov/pcgridds/a-b.html],
- GrADS [http://www.iges.org/grads/],
- BUFKIT [http://tgsv5.nws.noaa.gov/er/buf/bufkit/bufkitdocs.html] and
- RAOD [http://www.raob.com]

UPPER AIR DATA

Radiosonde observations are a vital component of our atmospheric observations system. They provide most of the data used for atmospheric analysis at levels other than the surface. The data normally includes pressure, temperature, humidity, latitude and longitude. The usual method of deployment is to launch the radiosonde attached to a hydrogen balloon, and then receive the data via radio transmission until the balloon bursts and/or drifts out of range. Once the balloon bursts, the small (0.3 kg) instrument package falls to the ground. The instrument package is considered expendable, and is not usually recovered because the cost of recovery generally exceeds the cost of the package itself.

Once daily pressure, temperature, humidity upper air soundings will be done at Mafikeng during the championship using a normal radiosonde with Vaisala ground equiment, balloon filling equipment and hydrogen from AFROX. The SAWS has asked the Botswana meteorological Services to make a special effort to make the Gaborone upper-air sounding data available to the championship due to the importance of this type of data.

While radiosonde packages are considered expendable, the cost is certainly not negligible. With the recent shift from OMEGA to Global Positioning System (GPS) navigation technology, the cost of one instrument package has nearly doubled. Worldwide more than 1000 expendable sondes are launched daily with a total daily expenditure worldwide of about $100,000. Should a full conversion to GPS systems occur, the daily costs will increase to approximately $200,000 worldwide. This is a significant cost increase for many weather services to absorb.

The ideal solution would be a reusable vehicle that is launched in a manner consistent with current practice (i.e. by balloon) but would return to the launch site or to another recovery site. This would allow the reuse of the vehicle and the instrumentation, and a subsequent significant reduction in the cost of the operation. To provide an expanded distribution the ideal device would need to be designed to the lowest possible acquisition cost. This concept will provide the weather service with a flexible means to balance the trade-off between the accuracy of prediction and the cost constrains for daily predictions and research efforts. Additionally, given the large numbers of devices launched daily, the negative environmental impact of the disposable devices would be eliminated.

THE GLIDERSONDE CONCEPT (Howard et al. [12])

The concept for a recoverable or reusable sonde was first proposed by Dean Lauritsen of the National Center for Atmospheric Research (NCAR). In Patent Number: 5,186,418 granted on February 16, 1993, Lauriten proposed developing a recoverable radiosonde that would fly back to its launch point or suitable location with the vehicle guidance during descent utilizing a GPS based navigation control system.

Since 1999 the SAWS has had research involvement in the glidersonde project of the National Severe Storms Laboratory (NSSL) in Norman, Oklahoma. Two subsequent visits to the USA made the exchange of ideas and

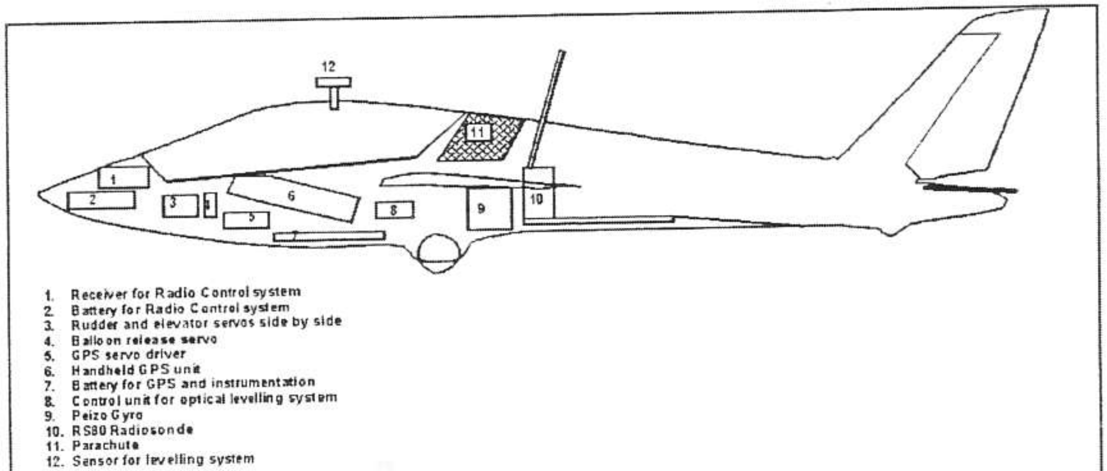

Figure 3 Schematic diagram of the glidersonde

expertise possible and since then extensive development of the concept has culminated in a locally developed, experimental system which will be used at WGC in Mafikeng.

The current local experimental systems to be incorporated into the design include:

A. Instrumentation package

Data recovery can take one of two forms:

- The data can be stored internally in re-writable memory and downloaded after the vehicle is recovered.

- Alternatively (as being used in Mafikeng) the glider carries a standard Vaisala RS80 radiosonde. The data is then telemetered to the Vaisala ground equipment as for any normal radiosonde sounding.

The data collection is equivalent in both accuracy and continuity to a standard radiosonde sounding. However, employing the Glidersonde vehicle, the meteorological sensor package is safely returned to be utilized again. The Glidersonde has the potential to augment many of the current radiosonde systems around the world, and would allow most countries to increase substantially both the frequency of soundings and the number of observing sites.

B. Navigation system

A schematic diagram of a complete Glidersonde is shown (not to scale) in Figure 3:

Navigation is based on GPS using a Garmin hand held GPS unit to determine position, ground track and required heading. The GPS unit provides RS232 communication of the National Marine Electronics Association (NMEA) protocol data to a GPS servo driver, which translates the heading information to rudder servo position and steers the aircraft along the required flight path. Active stability of the aircraft is achieved by using a gyro to control the roll axis and a pilot-tube to control the speed of the glider using the elevator to achieve best glide and in so doing controlling the pitch axis. This concept is in everyday use on full size gliders.

C. Control actuators (servos)

The control surfaces (rudder , elevator and ailerons) as well as the balloon and parachute release mechanisms are driven by standard radio control servos. These servos are basically a motor driven pot which moves a control arm connected to the control surface. Servos require a constant 5V to operate and the servo position is determined by a digital duty cycle.

D. Power supply

The instrument package, navigation system and radio control equipment all operate on different voltages. Therefore in order to use a single power source (to save weight and space) a simple power supply is used to provide the required voltages from a 2.4 Ah, 18 V lithium-ion battery.

E. Recovery system

There are two recovery systems available for the glidersonde. The first consists of a parachute (mounted on the glider's center of gravity) which deploys when the aircraft is 150 ft above the ground. This system was developed to allow the operation of the glidersonde by personnel not skilled in radio control flight. The second system comprises a full radio control system allowing a pilot on the ground to take over control from the navigation system and land the glider in an appropriate place and manner. The latter system will be used in Mafikeng.

F. Airframe

The airframe used for the glidersonde is an off the shelf radio control kit of a 1/6 scale Fox glider. The glider consists of a fibre-glass fuselage and tailplane. The wings are made of polystyrene foam covered with fibre glass and obechi veneer. It has a wing span of just under 2 m and a wing loading of 25 oz per square foot.

The glidersonde mission

The tail of the glidersonde is attached to a gas filled weather balloon and carried aloft to a present altitude where a servo triggers the release mechanism and the glider is detached from the balloon and dives until sufficient airspeed is achieved. As a backup to the system the pressure is monitored continuously and if it were to increase (implying that the balloon has burst premately) the release mechanism would also be triggered so as to rid the glider of string and balloon debris. Once the glider is free from the balloon it stabilizes itself, establishes where it is relative to home and proceeds to navigate home. The glider would then circle above the home point until it reaches 150 ft when the parachute would be deployed or the RC pilot takes over control. Should the aircraft not reach the home point for whatever reason the parachute will be deployed at 150 ft regardless of the aircraft location. Recovery would then be done using a homing system.

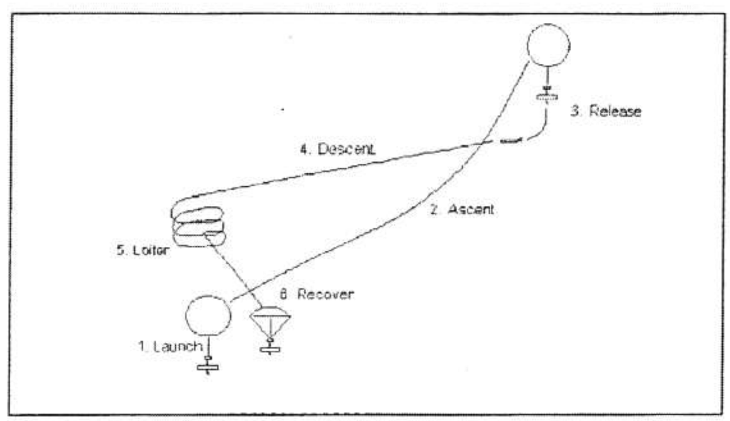

Figure 4 The glidersonde mission

The glider forecast

The forecast required for this event is a mesoscale forecast which covers an area from 25 to 29S and 22 to 27E. Each morning by 0600z the task setting team will be informed as to which area is the most suitable to complete the tasks safely. By 0800z there will be a follow up on the forecast and the turn points for the task will be finalized.

Forecast products required at hourly intervals:

- Time when the first thermals will reach 3000 ft AGL, to the nearest 15 minutes
- Cloud amount
- Satellite imagery

	Max height of dry adiabatic lapse rate	Mean rate of climb
Cloudless thermals	1 km 2 km 3 km	1.0 m/s 2.0 m/s 3.0 m/s
Cloud-capped thermals	1 km 2 km 3 km	1.2 m/s 2.4 m/s 3.6 m/s
Cloud-capped thermals with cold advection occurring	1 km 2 km 3 km	1.5 m/s 3.0 m/s 4.5 m/s

- Cloud base
- Thermal strength which is related to cloud base as shown in Table 1.:
- Surface temperature
- Surface dew point
- Wind speed and direction p to 16000 ft
- Time and location of the first over-development, to the nearest 15 minutes and 20 km
- Direction of movement of storms
- Time and location of subsequent over--development.

The forecast needs to be monitored on a continuous basis until approximately 1600z so that any hazardous weather can be communicated to the team managers. In addition to the daily forecast, the competitors will also receive a basic five day outlook forecast and a detailed forecast for the next day.

Conclusion

For the first time in 27 years South Africa has the opportunity to host a huge international gliding event. The South African Weather Service has shown its commitment to provide an excellent service. Despite difficulties with finances and infrastructure an enormous effort has been made to provide the maximum amount of surface and upper air data, a sufficient number of communication lines and good quality forecasts. In the light of the excellent soaring weather in this county, it is to be hoped that the World Gliding championship could again be held in South Africa in the near future.

Acknowledgements

Although only two authors actively contributed to the writing of this paper, contributions were received from several people whom we would like to acknowledge. They are: Hilarie Riphagen, Karel de Waal, Izak Deysel, Warren Tennant, Riaan Lourens and Dr Deon Terblanche. Without their help we would not have been able to put this paper together.

References

1. Young, M. 2000. Soaring the African Skies at Mafikeng: Gliding and Motorgliding International. The online magazine community for glider pilots worldwide. Edited by Gillian Bryce-Smith. Issue 10/2001.

2. Pagen, D. 1992. Understanding the sky – a sport pilot's guide to flying conditions. ISBN – 936310-03. Printed by Dennis Pagen.

3. Mesinger, F., Z. I. Janjic, S. Nickovic, D. Gavrilov and D. G. Deaven 1988. The step-mountain coordinate: Model description and performance for cases of Alpine lee cyclo genesis and for a case of an Appalachian redevelopment. Mon. Wea. Ev., 116, 1493-1518.

4. Black, T.L. 1994. The new NMC mesoscale model: description and forecast examples. Wea. Forecasting, 9, 265-278.

5. Black, T.L., E. Rogers, M. Bladwin, K. Mitchell, Q. Zhao, f. Chen, Z. Janjic, F. Mesinger, G. Manikin, K. Brill and G. DiMego 1997. Changes to the Eta forecast systems. NWS Tech. Proc. Bull. 441, National Oceanic and Atmospheric Administration/National Weather Service, 16 pp. [Available from National Weather Service, Office of Meteorology, 1325 East-West Highway, Silver Spring, MD 20910].

6. Janjic, Z.I. 1994. The step-mountain Eta coordinate model: Futher developments in the convection, viscous sublayer and turbulence closure schemes. Mon. Wea. Rev., 122, 927-945.

7. Rogers, E., D.g. Deaven ad G.J. DiMego 1995. The regional analysis system for the operational eta model: Original 80 km configuration and recent changes. Wea. Forecasting, 10, 810-825.

8. Rogers, E., T.L. Black, D.g. Deaven and g.J. DiMego 1996. Changes to the operational "Early" Eta analysis/forecast system at the National Centres for Environmental Prediction. Wea. Forecasting, 11, 391-413.

9. Rogers, E., and co-authors, 1998. Changes to the NCEP operational "early" Eta analysis/forecast system. [Available only at http://www.nws.noaa.gov/om/447/body.htm].

10. Poolman, E.R., H.A. Riphagen, R.D. Sewell, W.A. Krige and N. de Villiers 1994. Regional prediction at the South African Weather Bureau with NMC's step-mountain eta coordinate model. Preprints, Tenth Conf. On Numerical Weather Prediction, Portland, Oregon, 18-22 July 1994, Amer. Meteor. Soc., 555-557.

11. Sela, J. 1980: Spectral modeling at the National Meteorological Center. Mon. Wea. Rev., 108, 12.

12. Howard, K.W., D. Egle, F.W. Gallagher III, N. Renno, M.W. Douglas 2001: Recent developments in the design and testing of the Glidersonde. Preprints AMS 11th Symposium on Meteorological Observations and instrumentation.

13. WMO Technical Note. 158 Handbook of Meteorological Forecasting for Soaring flight 2nd Edition WMO-No. 495 Secretariat of the World Mteorological Organization – Geneva – Switzerland 1993. Prepared b the OSTIV secretariat c/o Instutut fur Physik der Atmosphare DLR 8031 Oberpfaffenhofen, Germany.