SOAR MT. EVEREST!

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Summary

Let us learn to soar Mt. Everest! Living Tibetans and Nepali need to ascend to the heavens in the modem sailplane to follow the spirits of their ancestors and gods, but to once again return to live another day. With sufficient experience, as demonstrated by the current commercial climbing activities, ascents of Everest with sailplanes may become an alternative means to "climb" the peak, perhaps the ultimate ascent and, no doubt, the most environentally-friendly means.

Atmospheric soundings, made near the north-side of Mt. Everest, were analyzed using the ALPTHERM convection model. On the few days in late April and early May with the warmest and driest surface conditions and no stable layers aloft, the model predicted "blue" thermals strong enough to carry a sailplane to the summit of Everest. Sites for a temporary airstrip to winch launch and retrieve gliders were identified close enough to the summit that the soaring attempts would be local flights, not cross-country flights. Glider support from either the Chinese or Indians may be possible and logistic support would be straightforward using a commercial climbing agency.

Introduction

As beautifully depicted in the film "Himalaya" (1), the Tibetan people dispose of their dead by feeding the corpses to the magnificent soaring birds. They believe, through their Buddhist tradition, that the spirits of the deceased ascend to the heavens as the birds ascend in the rising convective bubbles. Further, the soaring bird is the symbol for Garuda, the vehicle of the sustaining god Vishnu in the Hindu "trinity" (2). So, the major spiritual systems that bound the flanks of the god-like Mount Everest use soaring flight as a visible manifestation of the unseen strength of their gods. So too the detritus of human activity (eg. air pollution) ascends to the heavens in the daily convective cycle (3). How fitting it would be for the living Tibetans and Nepali to ascend to the heavens on the wings of the modem sailplane following the spirits of their ancestors and gods, but to once again return to live another day. Therefore, let us learn to soar Mt. Everest!

Between 17 April and 9 May 1996, the first author was on the Tibetan plateau near the base of 8848 in Mt. Everest conducting surface meteorological measurements and observations (3).

From the surface temperature and dew point measurements, a maximum cumulus cloud base of 8875 ra MSL was calculated, a value which agreed with visually estimated bases (4). The "cotton- ball" cumulus clouds are the visible manifestation of rising thermals, along with the magnificent soaring birds (natural and human-produced). Consequently, Hindman (4) concluded an ascent of Mt. Everest via thermals using a glider may be possible once the significant diplomatic and logistical problems are overcome. To our knowledge no soaring ascent has been attempted. To help initiate such an endeavor, upper-air analyses, cloud modeling results, satellite observations and detailed logistics are presented here that demonstrate the feasibility of a soaring ascent of Mt. Everest from Tibet.

Upper-air analyses

The convective boundary layer (CBL) extends from the surface to the top of the thermals. CBL depths of 4000 m are common over the western USA (5), over Australia (6) and Africa (7, 8, Bezuidenhout (9) reported that a 5900m climb in thermals has been achieved from Bitterwasser Lodge in Namibia). Because of the incredible CBL depths over the western USA, soaring contests have recently been held at Tonopah, Nevada (10) and the first author traveled to Utah with his glider to fly a 500km Diamond distance. Over the Tibetan plateau, the CBL may reach 5000m (11, 12). What an improbable but spectacular place to hold the World Gliding Championships!

Although the CBL evidence is compelling, we investigated the CBL near Everest using atmospheric soundings to determine if a soaring ascent of Everest is feasible. The soundings were made by Chinese scientists in May and June of 1979 from Old Tingri (Fig. 1) and were obtained from National Space Development Agency of Japan (endo@frontier.bosai.gojp). These soundings were used because there are no routine soundings made in the vicinity of Everest.

An atmospheric sounding is the vertical distribution of temperature (T), dew-point (Td), pressure (p) and wind direction and speed. The 1900 Beijing Standard Time (UTC+8h or 17LT) soundings were analyzed in the following manner. The maximum surface value of T was determined by adding 2C to the measured 17LT temperature because the maximum temperature was assumed to occur at 15LT. This assumption was necessary because no surface meteorological measurements corresponding to the soundings could be obtained. The assumption was based on the following study conducted by Bennett and Figurero (14): maximum surface skin-temperatures from infrared satellite measurements at Las Vegas NV (a low-elevation analogue

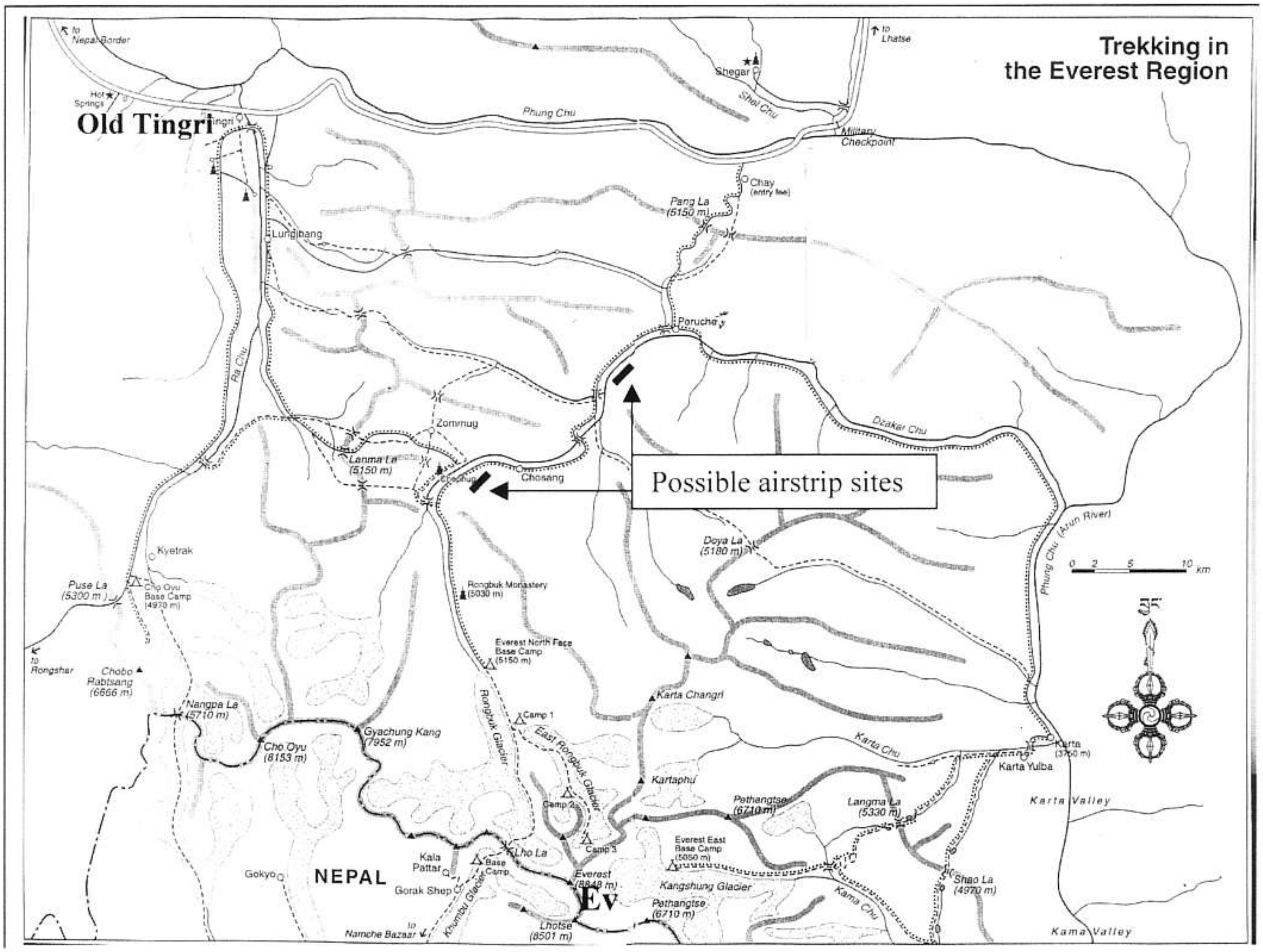

Figure 1 Loation of Old Tingri and Mt. Everest (Ev) in the Tibet Autonomous Region (TAR) of the Peoples Republic of China (PRC). The location of possible airstrip sites are indicated (discussed in the Logistics section). The map is from Buckley (13).

of the Tibetan plateau) occurred at 12LT and the corresponding maximum surface value of T occurred at 15LT. Similarly, maximum surface skin-temperatures at Old Tingri from infrared satellite measurements (global mollweide images to be discussed) occurred at 12LT, thus the maximum value of T is expected to occur at 15LT.

The following well-known relationship, which is based on simple adiabatic principles (assuming no stable layers aloft),

$$\text{CCL depth (m AGL)} = 125\,[T(C)-T_d(C)]$$

relates the convective condensation level (CCL) to the maximum surface value of T and corresponding value of Td. The CCL is related to the depth of the CBL as follows: the CCL is the upper limit of the CBL when "blue" thermals occur (no cumulus cloud formation) and the lower limit when cumulus clouds form. Using surface values from the Chinese soundings resulted in CCL depths that averaged 4000m above ground level (AGL) with a number of days over 5000m (Fig. 2). These extraordinary days occurred with the warmest and driest weather; TTd values of over 400 Further, we analyzed the soundings that produced the 5000m CCL's by plotting them on adiabatic diagrams and found only three of the days (2, 3 and 7 May 1979, JD = 122, 123 and 127) were the extreme CCL depths possible. The other days were eliminated because of upper-air stable layers inhibited the CBL to reach up to the CCL. We, then, picked the two most promising soundings (2 and 3 May) for analyses with the Liechti-Neininger ALPTHERM convective cloud model (15).

ALPTHERM model results

Briefly, given an atmospheric sounding, surface topography and surface conditions, ALPTHERM solves the vertical equation of motion to produce the evolution of the CBL as a function of time-of- day. Thermal strengths and cumulus cloud bases are predicted, necessary information for planning any soaring flight using thermals.

The 2 and 3 May 1979 07BST (05LT) Old Tingri soundings were used to initialize ALPTHERM for the region surrounding Everest. The region was defined by four points: a point 20 kin WSW of Cho Oyu, a point 10 kin NW of Old Tingri, by a point 20 km E of Shegar and by a point 20 Ian SSE of Makalu (Fig. 1). The elevation distribution for the region contained elevations from 3700 to 8600m MSL. For the analysis of the soundings, the layers below 4300m MSL were "filled up"; the low-spots were adjusted. to be at 4300m. Thus, the surface temperature obtained from the analysis was valid for 4300m MSL and, therefore, could be compared to the Old Tingri soundings around the end of convection (about I I UTC or 17LT).

The surface albedo and evaporation values were adjusted to obtain calculated T and Td profiles in agreement with the measured late afternoon soundings (I I UTC or 17LT) as follows:

Evaporation had to be set to essentially zero to obtain decreasing surface dew points during the day (caused by mixing down of dry air from aloft). This increased sensible heat fluxes and the maximum surface air temperature reached more than 20C towards the end of convection. That temperature is consistent with the analyses shown in Figure 2.

Albedo was set to 95% above a threshold elevation to limit sensible heat fluxes and surface temperature to the values found in the afternoon soundings (17 and 18C, respectively). The "threshold elevation" turned out to be 5000 in MSL. This elevation corresponds to the elevation above which the ground is covered by snow and ice. This was a conservative value. The first author observed permanent snow and ice began at elevations above about 6000 in.

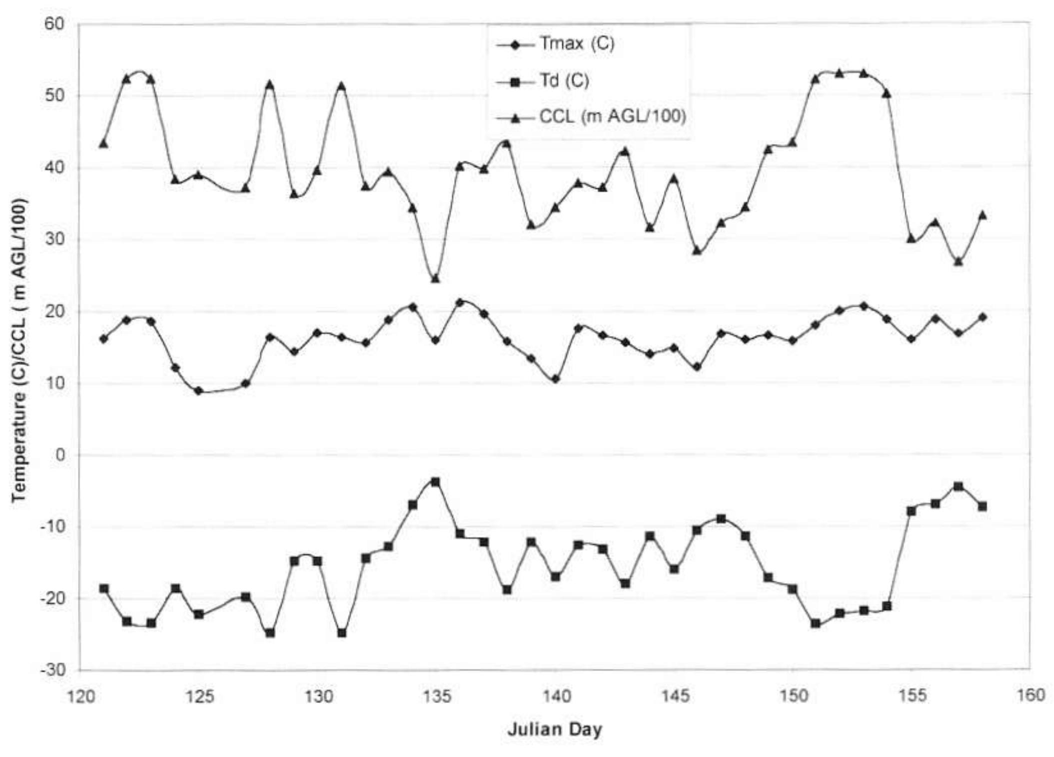

Figure 2 Maximum surface air temperatures (T_{max}), corresponding dew-point temperatures (T_d) and resulting CCL values (AGL) for Old Tingri, 1 May through 7 June 1979 (JD = 121-158). Note, the convective-condensation-level (CCL) is related to the depth of the convective boundary layer (CBL): if the cumulus are negligibly thick then CCL depth = CBP depth).

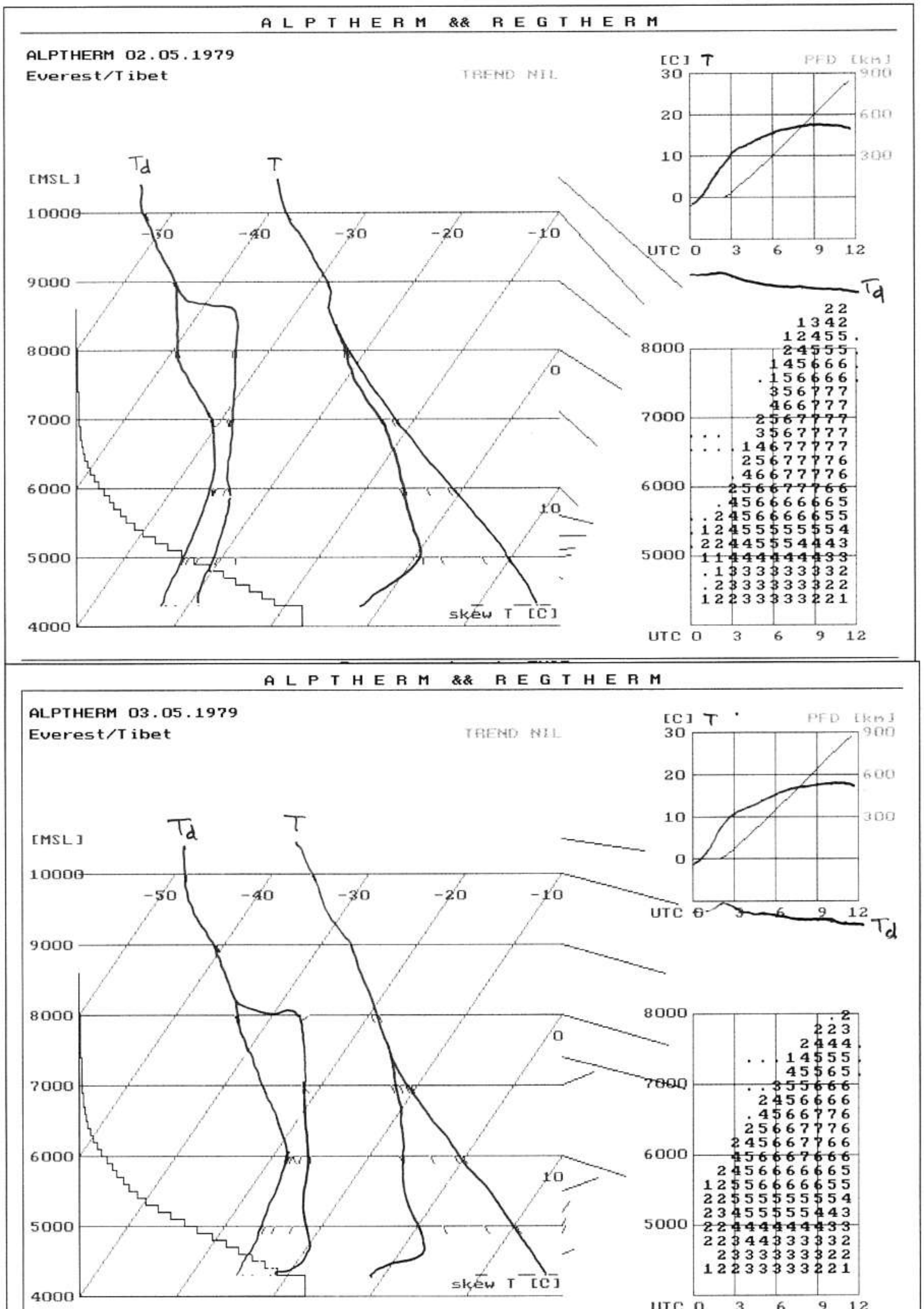

Figure 3 ALPTHERM results for 2 May 1979 (top) and 3 May 1979 (bottom) for Old Tingri soundings. In each figure, at the left is the sounding, in the lower right is the thermal strength (in units of 0.5 m/s or about 100 ft/min) as a function of altitude (m, MSL) and time (UTC) and in the upper right is the surface temperature and dewpoint as a function of time. The stair-step profile in the power left is the elevation distribution of the assumed topography.

The results of the ALPTHERM calculations are given in Figure 3. It can be seen that on 2 May 1979, the top of convection exceeded 8000m MSL during 5 hours (07-1 IUTC or 13-17LT) reaching a maximum of 8600m MSL still with thermals rising I m/s. On the following day convection reached up to 8000m MSL at I I UTC (17LT). It is important to note that if the "threshold elevation" for snow cover is just 100 m higher (ie. 5 100 in MSL) convection reaches the top of Mt. Everest! The reason is that the surface area with sensible heat flux increases by about 6% per 100 in with the area-elevation distribution that applies to the region. Up to 5000m MSL only 52% of the surface area heats the atmosphere, up to 5100m MSL 58% of the surface area heats it. Six-percent in relation to 52% is over 10% more sensible heat - which does the job increasing the top of the CBL from 8600m MSL to 8800m MSL on 2 May 1979.

The "Soar Everest" days from the ALPTHERM results may be "blue" thermal days; that is, days with extremely warm and dry surface conditions and no cumulus formation. The calculated Td profile in Figure 3 illustrates the T - Td depression at the upper limit of convection is on the order of 8C. This is too large for cumulus formation. Note that the mixing ratio profile (represented by Td profile) is predicted to be constant only below 6500 in MSL. Toward the top of Everest it decreases. The convective mass flux in such a deep CBL is not sufficient to produce a constant mixing ratio up to the top of the CBL. With more moisture, cloud base would be found below the summit and one would have to refer to instrument flight in clouds, well upwind, to climb to the summit of Everest.

These results indicate the elevation of permanent snow and ice cover is one of the critical factors along with the need for extremely warm and dry surface conditions. These conditions occur in late April and early May after the winter snows have melted and the ground has dried and before the onset of the moist air of the summer monsoon in June. Thus, "blue" thermals are expected to occasionally reach 8800m MSL over Old Tingri. According to ALPTHERM, there is hope for ascending Mt. Everest in thermals!

Satellite observations

There are no routine weather observations and measurements readily available for the Old Tingri region of the Tibetan plateau. However, since 1998, middle-Asia has been imaged every three hours with the Global Mollweide infrared satellite images available from the University of Wisconsin Space Science and Engineering Center (SSEC, www.ssec.wisc.edu). The images are analyzed using the Man-computer Interactive Data Acquisition System (McIDAS, www.unidata.ucar.edu/packages/mcidas/index.htmi) in the CCNY EAS Department weather station and computer lab.

A sequence of mollweide images captured for 2 and 3 May 1999 is illustrated in Figure 4. These images have 32km resolution, so assemblages of cumulus clouds and not individual cumuli can be detected. To give you a gray-shade reference, cold, high-clouds appear white and the warm, earth surface appears black. Notice how India and the Tibetan plateau appear gray (cool) in the morning and black (warm) in the afternoon. The "pop-corn" appearance of the plateau in the afternoon is due to the formation of cumulus clouds.

During the period 19-24 April 2001, using the mollweide images, clear mornings and cumulus-filled afternoons were detected over Old Tingri. The cumulus were widely scattered because reasonable surface skin-temperatures ($T_{surface}$) were measured from the images. The $T_{surface}$ measurements were made by placing the cursor at the latitude and longitude of Old Tingri and a algorithm based on the Stefan-Boltzman law built into McIDAS calculated the $T_{surface}$ value. For example, on 19 and 21 April 2001, the afternoon $T_{surface}$ values at 15LT were 19 and 24C, respectively. $T_{surface}$ was assumed to occur at 15LT (09Z) and $T_{max}= T_{surface\ at\ 09z}$ - 2C. Thus, maximum air temperatures (T_{max}) were estimated from these measurements to be, respectively, 17 and 22C. The value 2C was used following the Bennett and Figuereo analyses (14). These T_{max} values are reasonable when compared with the surface temperatures inferred from the 1979 Chinese soundings.

Higher resolution MeteoSatS infrared images (0.5h, 4 km) and visible images (0.5h, I km) of the Tibetan plateau have been obtained by the SSEC since March 1999. The infrared images can be used to refine the preliminary Tsf., estimates from the mollweide images. And, the corresponding visible images can be used to search for the "blue" thermal "Soar Everest" days.

Global models

Global numerical weather models exist that assimilate the sparse weather data from middleAsia and produce estimates of current and forecasted surface and upper air conditions at gridpoints spaced approximately 90 km apart. These data are available on the Internet from, for example, the USA NOAA Air Resources Laboratory web-page (www.arl.noaa.gov/ready.html). One product is the FNL atmospheric sounding and we explored its usefullness for Tibet.

The $T_{surface}$ values determined from the mollweide images and the corresponding archived FNL sounding were used to estimate CBL depths for Old Tingri. The 17 and 22C T.. values from the 19 and 21 April 2001 satellite images were used with the soundings for the coordinates of Old Tingri (28.6N, 87.1E) for 12Z (18LT) to estimate CBL depths of, respectively, 9200 and 9500m MSL (ignoring the Td values which are unrealistically high when compared to the 1979 soundings). These depths are consistent with the results from analyses of the May 1979 soundings and may be further evidence of an occasional 5000m CBL over Tibet.

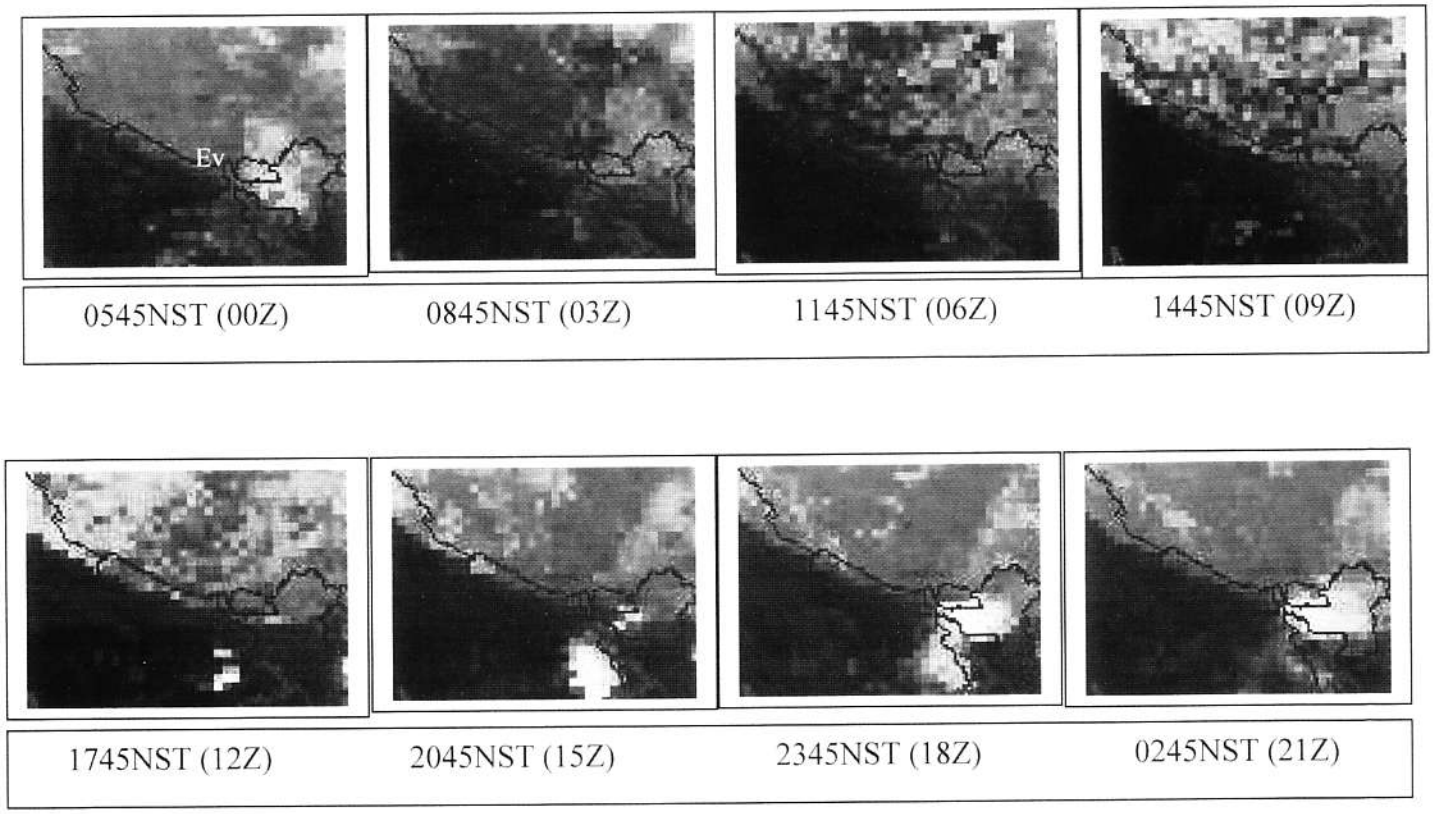

Figure 4 A sequence of 32 km resolution infrared Global Mollweide images of the Tibetan plateau and northern India for 2 and 3 May 1999. NST stands for Nepal Standard Time (Z + 5h 45m). The location of Mt. Everest is identified by the Ev symbol in the first image.

Figure 5 depicts the average vertical wind profiles for the 2 and 3 May 1979 Old Tingri soundings. A classic pattern is illustrated of "mixing down" higher-speed winds aloft within the CBL (16): calm mornings with strong afternoon surface winds. Note, the strong afternoon surface winds will help reduce the high touchdown true-air speeds of a glider operating at 4300m elevation (nevertheless, the glider should have a "beefed-up" wheel brake). Additionally, the wind speeds above 8000m were greater than 35 knots indicating a "battle" must have occurred between the rising convective bubbles and the high-speed winds. However, the wind shears above 7000m are not large suggesting the absence of severe-turbulence.

Logistics

The Rongbuk valley that drains the north-side of Mt. Everest contains terraces in the flood plain which the Tibetans use to grow their crops. Using an aerial photo ftom the Shuttle orbiter (Fig. 6), sites for a 1-km air strip were located. The closest site is only 36 km ftom the summit, a local soaring flight, indeed. The terrace should be able to be rolled and oiled using the equipment used to maintain the nearby Friendship Highway that runs between Kathmandu, Nepal and Beijing, China. Figure 7 is a photo the first author took from the 5150 m Pang La in May 1996 showing a terrace in the valley below that may support a temporary airstrip. The photo was taken at about 09LT and the first cumulus are forming. Everest is producing its famous "banner" cloud. Strong winds aloft plus sufficient surface moisture produced the banner cloud, thus, this would not have been a "Soar Everest" day. In fact, deadly cumulonimbus clouds engulfed Everest on that day and the next as immortalized by Krakauer (17) and explained by Rosoff, et al. (18).

The glider operations are envisioned as follows. At the site, using a winch with I km of cable and a suitable two-place glider (perhaps a L-23 Blanik or a the higher performance IS-32), it should be possible to launch to 300 to 400 m AGL, based on scaling from winch launches conducted by the first author at 2600m MSL Walden in the northern Colorado Rocky Mountains (19). Such launches are expected to enable the glider to reach the nearby ridges in the first convection. From there, soaring flights are anticipated along the N-S oriented ridges toward the Everest summit. If the CBL reaches 9500m MSL, the glider should easily rise above the summit of Everest in thermals. In the event cumulus bases form below the summit of Everest, cloudflying well upwind of the summit may be required to

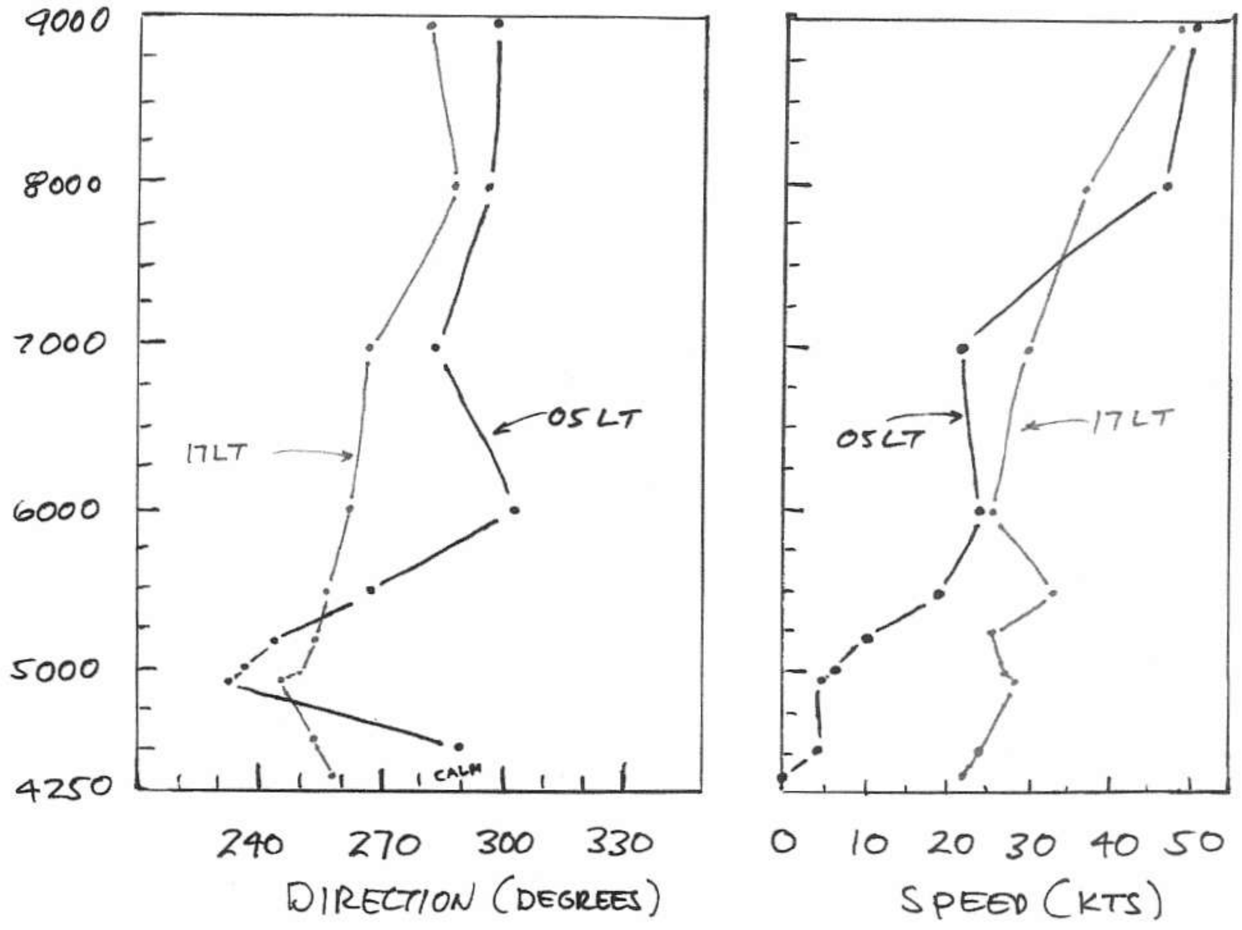

Figure 5. The results of averaging the wind speeds and directions for the 2 and 3 May 1979 soundings from Old Tingri, TAR, PRC.

rise to an altitude above that of the summit. Then, a glide clear-of-clouds to the windward face of the summit would be possible.

All flights will be conducted as local flights, eg. always upwind of the mountain and with enough altitude to always be in a safe gliding range of the airstrip to offset the effects of unexpected heavy sink and headwinds; there are no possibilities for safe off-field landings. In the unlikely event of an emergency landing, appropriate survival equipment must be aboard the glider. The flights are expected to mimic the successful ascents of Everest by foot: a series of ascents and retreats until the optimum route is discovered and suitable weather occurs for a successful ascent to the summit.

There are no gliders, to our knowledge, operating in either the TAR or in Nepal. Thus, the gliding equipment would have to come from elsewhere. The glider and winch could come from a Government Gliding Center in India via the Friendship Highway through Kathmandu and onto the plateau. The winch would have to be a turbocharged-diesel to have sufficient performance on the plateau. Further, the winch line should be made of Kevlar to minimize the weight the glider must lift. Finally, spare parts, instruments, tools, etc. will be necessary to repair any 11prangs" to the glider and/or winch; there are no aircraft mechanics in the Everest region.

In June 2001, the first author had encouraging conversations about the project with Mr. P. N. Sharma, the Chief Pilot of the Gliding Centre in Pune, India. The PRC may be another source. The PRC delegate to the Federation Aeronautique Internationale (FAI) Gliding Commission, as of July 2002, is Mr. Haiqing Shen (asfc_b_f@sina.com). Correspondence with them in August 2002 verified no gliders are in the TAR and they are busy with their 2000 km flight research (20).

The base camp required at the temporary airstrip could be equipped from one of the climbing companies operating on Everest since the airstrip would be located alongside the

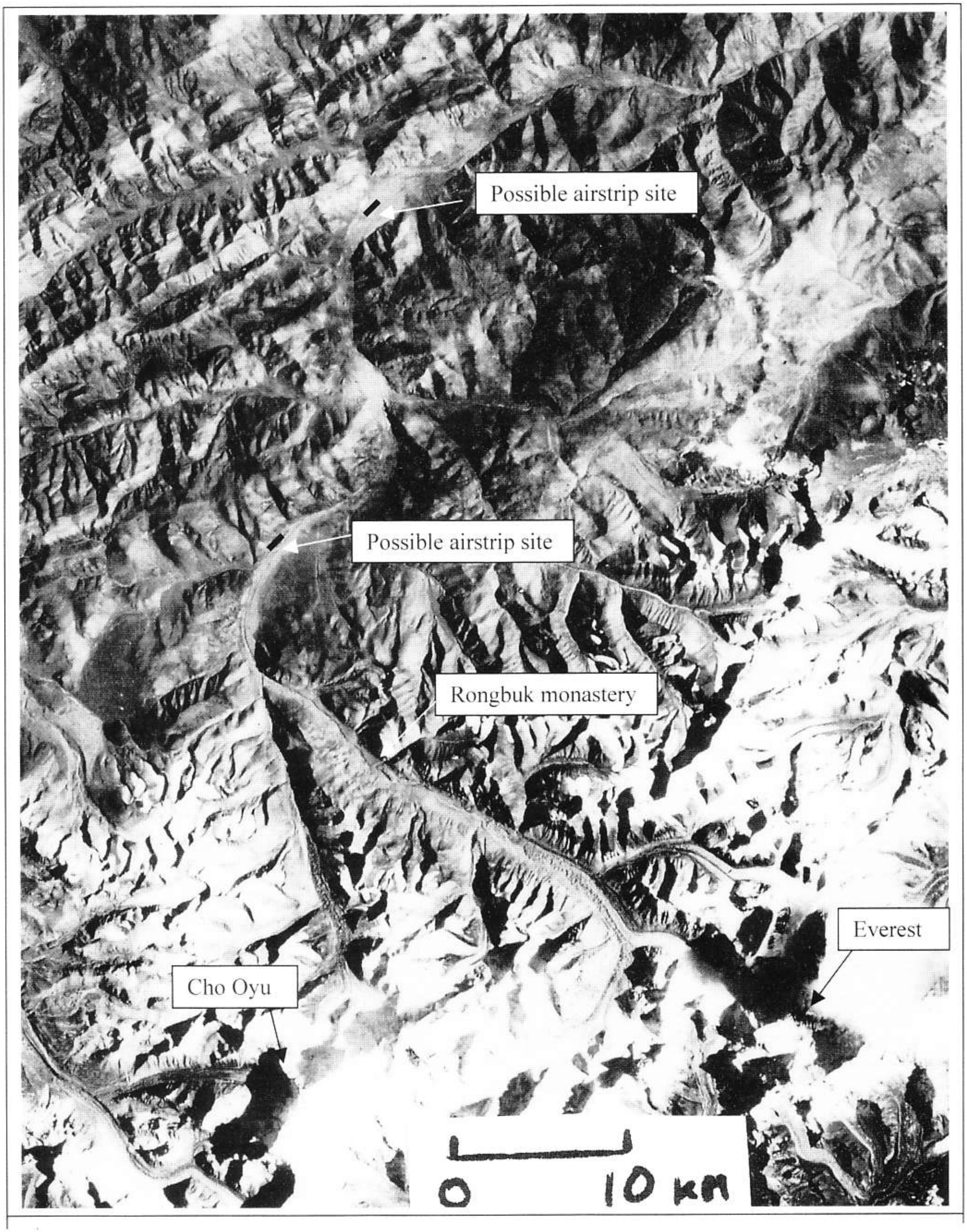

Figure 6. A "birds-eye" view of the Mt. Everest regions with possible sites for a temporary air strip to support glider operations. The images in oriented N-S.

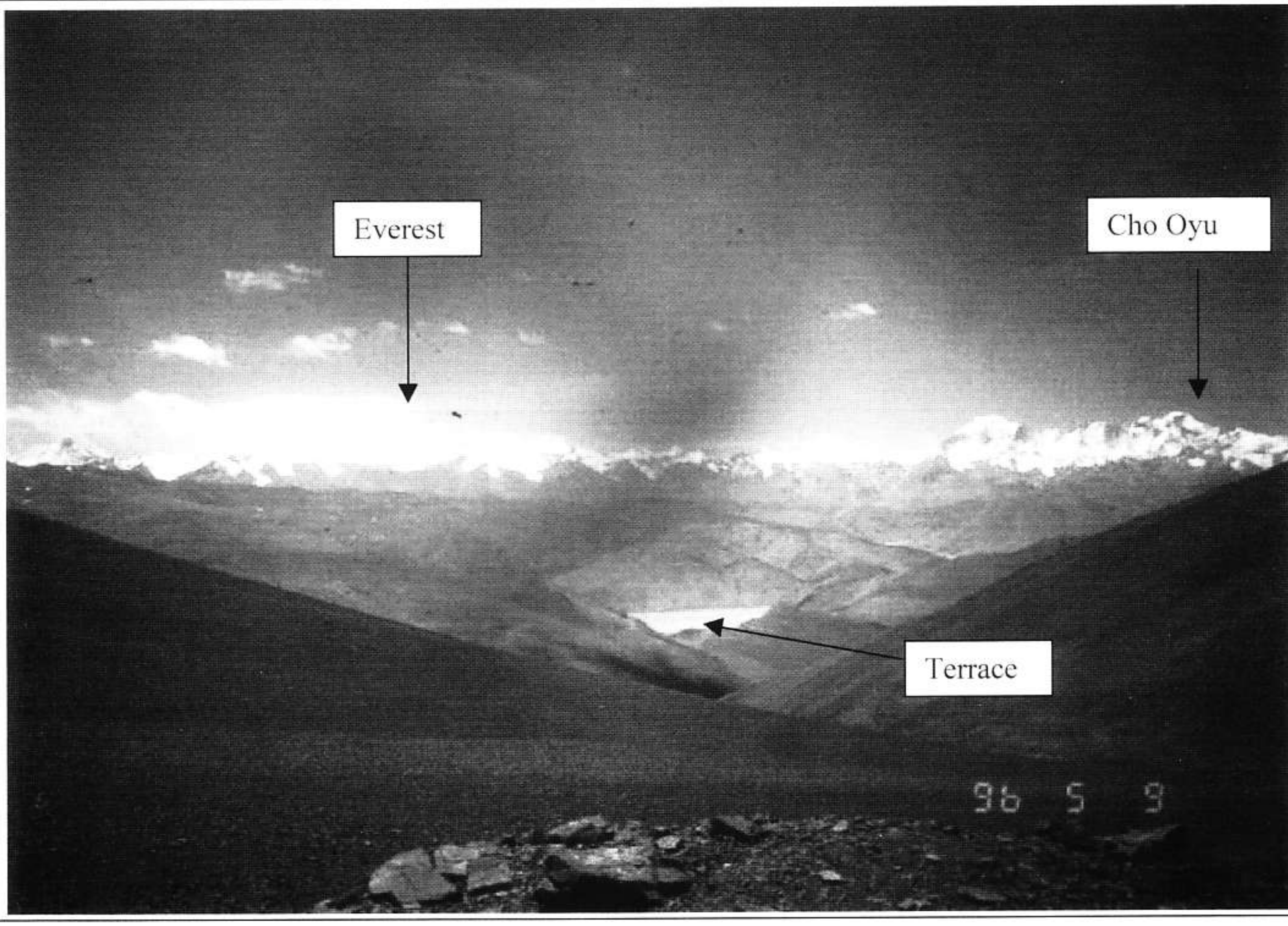

Figure 7. Picture of Everest (8848m MSL) and Cho Oyu (8153 m MSL) from the 5150 m Pang La on 9 May 1996 at 0900 LT.

road to the Everest base camp (Fig. 1). Commercial climbing operations from Kathmandu to Everest are ubiquitous (eg. www.cybernetl.com/himalaya/everesthtm). They have the necessary contacts to handle all required Nepalese and Chinese permits. Permission (as an international humanitarian and scientific collaboration) to operate in airspace on both sides of the border would be needed. Moreover, our proposed flights might open up the whole China/Nenal Himalaya crest for some fabulous cross-country flights in the ffiture.

The required weather data will come from local surface measurements made at the temporary airfield to adjust the FNL soundings obtained from the Internet using a satellite link. The first author has used the FNL soundings adjusted with local surface measurements to successfully predict CBL behavior for soaring contests in the USA (21). The necessary satellite images are, likewise, available from the Internet. The Global Mollweide satellite images are available from www.atmo.arizona.edu/products/wximagery/globalir.htm, the India satellite (INSAT) images from www.imd.emet.in/section/satmet/dynamic/ccd.htm and the MetSat5 images from www.cumetsat.de.

Summary and conclusions

Atmospheric soundings made near Mt. Everest in 1979 by the Chinese were used to identify days suitable for ascending Everest with a sailplane using thermals. The results of calculations using the ALPTHERM convection model with the 2 May 1979 sounding revealed the top of convection exceeded 8000m MSL during 5 hours reaching a maximum of 8600m MSL with thermals still rising at I m/s. From the ALPTHERM results, the "Soar Everest" days, may be "blue" thermal days; that is, days with extremely warm and dry surface conditions (T-Td > 40C) and no cumulus formation. These rare conditions were found to occur most frequently in late April and early May. A classic pattern of "mixing down" of higher-speed winds aloft within the convective boundary layer (CBL), calm mornings with strong afternoon surface winds, was detected from the soundings. The strong afternoon surface winds will help reduce the high touchdown true-air-speeds speeds of a glider operating at the field elevation of 4300 m MSL.

The Internet produced useful weather data for the Mt.

Everest region. Global infrared satellite images revealed the "pop-corn" appearance of cumulus clouds forming over the Tibetan plateau in the afternoon. Such images can be used to identify the "blue" thermal days on the north slopes of Mt. Everest expected to be the optimum "Soar Everest" days. Analyses of soundings available from the Internet produced CBL depths consistent with the results from analyses of the May 1979 Chinese soundings and may be finther evidence of an occasional 5000 meter CBL over Tibet.

Using an aerial photo from the Shuttle orbiter, sites for a temporary airstrip were located. The closest site is only 36 km from the summit; a local soaring flight. Thus, all flights will be conducted as local flights, eg. always within gliding range of the airstrip; there are no possibilities for safe off-field landings. The flights are expected to mimic the successful ascents of Everest by foot: a series of ascents and retreats until the optimum route is established and suitable weather occurs for a successful ascent of the summit.

There are no gliders, to our knowledge, operating in either Tibet or in Nepal. Thus, the gliding equipment would have to come from, most likely, India or China.

With sufficient experience, as demonstrated by the current commercial activities on Everest, ascents of Everest with sailplanes may become an alternative means to "climb" the peak, perhaps the ultimate means and, no doubt, the most environnientally-friendly means. In fact, D. Ellis (USA), after listening to the presentation of this paper at Mafikeng, said to the first author "why not use a hang glider?"

Acknowledgements

EH received partial travel support to Mafikeng from the Division of Science, CCNY. EH's student Kamal Thapa (who is from Nepal) produced the satellite images in Figure 4. M. Reinhardt, Oberpaffenhofen, Germany, provided the Shuttle Orbiter photograph used in Figure 6. Conversations with D. Jones, Aspen CO, materially improved this paper.

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