AIR MOTIONS IN THE KHUMBU HIMAL AND POSSIBLE SOARING FLIGHTS

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INTRODUCTION

Soaring flights have occurred in the Khumbu Himal, but not with a sailplane. Wick soared a single-engine, turbo-Porter aircraft up the face of Lhotse, the peak adjacent to Mt. Everest, to above the summit of Everest and glided back to Kathmandu (Hindman and Wick, 1990). Also, Simon Baker (1993, personal communication) soared a Guppie Raven ultralight to 24,000 ft in the West Cwm in the fall of 1986 but could not continue the ascent because of a lack of oxygen. From these flights and the numerous photos of the banner clouds generated by Everest and Lhotse, it appears the strong westerly winds which impinge on the Everest massif are funneled up the West Cwm and over the summits causing an enormous eddy in which the banner clouds form (Hindman and Wick, 1990a).

A path to the summit of Mt. Everest for a sailplane has been proposed by Hindman (1986). Meteorological observations and measurements made during the authors' treks into the Khumbu Himal region indicate that the proposed path appears feasible. We report the meteorological features relevant to soaring flights: the number of "soarable" days, dry-thermals rising up the valley slopes, the diurnal behavior of the Everest/Lhotse banner clouds which we suggest are linked to the up- and down-valley winds; up-valley winds blow with a maximum in the afternoon while down-valley blow with a maximum often just before sunrise (Whiteman, 1990). Based on these findings, a plan is presented for soaring flights coordinated with ground observations in the Khumbu Himal to explore the soaring path to the summit of Everest.

MEASUREMENTS AND OBSERVATIONS

Surface measurements of winds, air temperatures (T), frost-point temperatures (Tf) and observations of the formation and dissipation of clouds and the flights of soaring birds were made by Hindman between Lukla (2700 m elevation) and Kala Pattar (5545 m) and by Engber between Lukla and Gokyo Peak (5483 m). The measurements and observations were made every morning, noon and late afternoon. Late night observations were often made.

A sensitive anemometer was used to measure wind speeds and the ubiquitous prayer flags on nearby ridges to determine the wind direction. Upper-air wind directions were determined by observing the drift of clouds which often formed at the summits of the highest peaks. A sling psychrometer was used to measure the dry-bulb and wet-bulb (ice-bulb) temperatures and an altimeter to measure sea-level pressure (given our elevation). Numerous photographs were taken to document the cloud conditions. After Hindman's trek, daily upper-wind measurements over the Khumbu Himal for the period of the trek were obtained from the 300 mb charts prepared by HMG Department of Hydrology and Meteorology in Kathmandu.

SOARABLE DAYS

During Hindman's sixteen day trek (Table 1), ten days were sufficiently dry for afternoon clouds to be formed primarily in upslope flows along mountain slopes and ridges while the valleys remained clear; these days appeared to be soarable because of the presence of convective clouds. Six days were moist and clouds quickly formed on slopes lit by the morning sun and the

MORNING T, T_f MEASUREMENTS AND MORNING AND AFTERNOON CLOUD CHARACTERISTICS DURING THE HINDMAN TREK

Date	Time (NST)	Location	T (C)	T_f (C)	Morning	Afternoon
22 Nov 92*	0925	Lukla	8.5	-2	Cu on slopes	Cu on ridges, valley brkn StCu
23 Nov 92*	0900	Ghat	8.5	-1	Ovsct and rain	Ovsct and rain
24 Nov 92	0800	Jorsale	0.8	-2	Clear	Cu on ridges, valleys clear
25 Nov 92	0700	Namche	2.0	-19	Clear	Clear
26 Nov 92	0900	Namche	5.0	-13	Clear	Few Cu on ridges, valleys clear
27 Nov 92	0900	Tengboche	1.5	-14	Clear	Few Cu on ridges, valleys clear
28 Nov 92	0715	Dingboche	-5.0	-23	Clear	Few Cu on ridges, valleys clear
29 Nov 92	0735	Dingboche	-5.0	-20	Everest/Lhotse plumes, high Ci	Few Cu on ridges valleys clear
30 Nov 92	0800	Loubje	-3	-24	Lhotse plume, clear otherwise	Few Cu on ridges, valleys clear, undcst Imja Khola
01 Dec 92*	0930	Gorakshep	-10	-10	Foggy, snowing	Foggy, snowing
02 Dec 92*	0945	Pheriche	-4	-7	Ovsct	Foggy, snow shrws
03 Dec 92*	0900	Phortse	-2	-8	Clear	Overcast
04 Dec 92*	0925	Machermo	-6.5	-10	Clear	Overcast
05 Dec 92	0835	Khumjung	-2.5	-9	Clear	Few Cu on ridges, valleys clear
06 Dec 92	0915	Everest View hotel	2.5	-14	Lhotse plume, clear otherwise	Few Cu on ridges, valleys clear
07 Dec 92	0845	Everest View hotel	-0.5	-10	Clear valleys clear	Few Cu on ridges,

* Denotes a moist day ($T-T_f \leq 6C$)

TABLE 1.

clouds filled the valleys by afternoon; these days were not soarable because of the afternoon IFR conditions. Engber observed eight dry days and 10 moist days during his eighteen day trek (Table 2). He noted the development of convective clouds over 8848 m Everest from 5483 m Gokyo Peak on April 5 which was a dry day. He also observed the characteristic banner cloud produced by nearby 8201 m Cho Oyu.

The difference between morning T and Tf values were T-Tf > 15C for dry days and T-Tf < 6C for moist days. Consequently, morning T and Tf measurements appear to be useful in predicting afternoon cloud development. This finding has support in local tradition.

The Dolpo people of northwestern Nepal use the sound that salt makes when thrown into a morning campfire to determine if a day will be dry or moist (Valli and Summers, 1993). If the salt is dry it crackles meaning any snowstorm is probably far away. If the salt is moist, it stays silent and a storm is probably approaching. This tra-

MORNING T, Tf MEASUREMENTS AND MORNING AND AFTERNOON CLOUD CHARACTERISTICS DURING THE ENGBER TREK

Date	Time (NST)	Location	T (C)	Tf (C)	Morning	Afternoon
27 Mar 93*	1316	Kusum Khola	10	6	Overcast	Overcast
28 Mar 93	1117	Jorsale	11	2	Clear	Few Cu on ridges, valleys clear
29 Mar 93	0900	Namche	-	-	Clear	Many Cu on ridges, valleys clear
30 Mar 93	0800	Namche	-	-	Clear	Few Cu on ridges, valleys clear
31 Mar 93*	0800	Thame	-	-	Clear	High peaks sunlit throughbksinovsct
01 Apr 93	0700	Khunde	-	-	Clear	Lhotse plume; few Cu on summits
02 Apr 93*	0900	Phortse	-	-	Overcast	Many Cu on ridges, valleys brkn
03 Apr 93	1000	Tenge between Luza & Machermo	-	-	Clear	No data
04 Apr 93	1000	near Gokyo	-	-	Clear, Cho Oyu plume	Many Cu on ridges
05 Apr 93	0930	Gokyo	-	-	Clear, Cho Oyu plume	Cu forming over summit Everest
06 Apr 93	0800	Gokyo	-	-	Clear, Cho Oyu plume	No data
07 Apr 93*	0800	Thare	-	-	Overcast	Overcast
08 Apr 93*	1000	near Pangboche	-	-	Brkn Ci, Everest, Lhotse plumes	Snowedovernight, StCu ovcst
09 Apr 93*	0800	Pangboche	-	-	Scud ridges, valley clear	Scud on ridges, valley clear
10 Apr 93	0900	Pangboche	-	-	Clear	Lhotse plume, clearotherwise
11 Apr 93*	1000	Dingboche	-	-	Undrcst moving up Imja Khola	Foggy
12 Apr 93*	0730	Dingboche	-	-	Clear, scud below Lhotse	Snow shower
13 Apr 93*	0800	Tengboche	-	-	Raining	Raining
14 Apr 93	0800	Namche	-	-	Clear, Everest plume	Clear
15 Apr 93*	0630	Phakding	-	-	Sun on peaks,	Rain cud on ridges
16 Apr 93	0930	Lukla	-	-	Clear	no data

* Denotes a moist day ($T-T_f \leq 6C$); when no $T-T_f$ measurements were made, broken to overcast conditions in the afternoon was considered a moist day.

TABLE 2.

Figure 1. Scene from Namche at 1045 NST 26 November 1992: Taweche peak (6501 m) is to the left, Everest summit (8848 m) is in the center, peeking over the 7855 m Nuptse ridge and Lhotse (8516 m) is to the right. No clouds are visible from these summits.

dition makes sense. Salt is dry if it has experienced a relative humidity below about 35%; salt absorbs water vapor if the humidity is greater than 75%.

THERMALS ON VALLEY SLOPES

During the afternoon of November 25, 1992, a dry day, Hindman discovered the Sherpa "variometers". These consisted of small prayer flags attached to a rope which was draped horizontally between two large boulders on the slopes of the amphitheater which surrounds Namche Bazar (3446 m). The flags and rope drooped when the upslope flow was weak and billowed upslope when the flow strengthened indicating the passage of a thermal. Furthermore, three rows of flags were positioned directly above each other. The passage of a thermal drifting up the slope caused the lowest row of flags to billow while the two rows above drooped. As the thermal moved further up the slope, the two lowest rows and finally all the rows billowed. Correspondingly, the bottom row of flags was the first to droop and so on as the thermal rose above the "variometers".

At 1100 NST on December 6, 1992, another dry day, Hindman positioned himself about 100 m down the slope from the wind sock on the Syangboche airstrip which is at the top of the Namche amphitheater. He measured the time it took gusts passing his location to cause the drooping sock to inflate. The gusts took an average of 20 to 30 s to travel the distance which translates to a speed of about 4 m/s. The wind speed in the gusts was about 4 m/s. So, assuming the thermals to be well mixed, that is, horizontal speed equal to vertical speed, these updrafts could have had vertical speeds of about 4 m/s.

Additional evidence for thermals above Namche came from Dr. Doug Ostergren, who observed from his clinic in Namche, which is about half-way up the amphitheater, para-pente flights from the Syangboche air strip around noon on a mid-November 1992 day (para-pente are high-performance parachutes with L/D's of 8:1 and Vmin of 1.2 m/s). He reported most of the pilots glided to landings near the large *chorten* in the center of Namche. One pilot was seen to glide from the air strip into the amphitheater and ascend back up to the strip; thus a human soaring flight has been made above Namche. Para-pente flights in the Khumbu region have been reported by Schellhammer (1992).

Simon Baker (1993, personal communication) flew the Guppie Raven from this airstrip in August through October of 1986 and reported it to be "very lifty". He also reported the location clouds up fast.

DIURNAL WIND AND CLOUD PATTERNS

During the dry days, a diurnal wind and cloud pattern

Figure 2. Scene from Tengboche at 1525 NST 26 November 1992: Everest summit (8848 m), center, peeking over the 7855 m Nuptse ridge and Lhotse (8516 m), right. A well-developed banner cloud streams from Lhotse while a poorly-defined banner cloud streams from the Everest summit. Clouds are forming on the Nuptse ridge. Ama Dablam (6812 m) is far right with a modest plume.

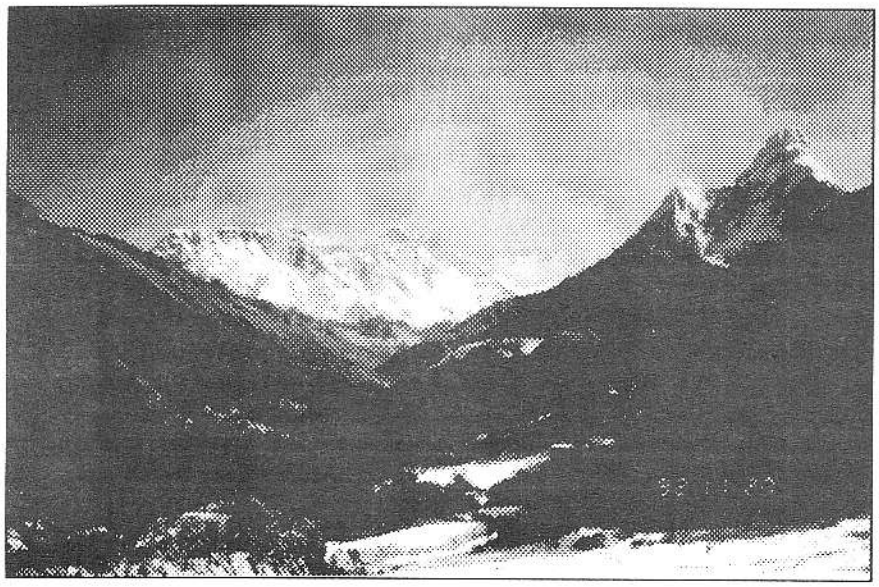

Figure 3. Scene from Tengboche at 0900 NST 27 November 1992: Everest summit (8848 m), center, peeking over the 7855 m Nuptse ridge, Lhotse (8516 m), right and Ama Dablam, far right. No clouds are visible from these summits.

occurred. The mornings were calm and clear (Figure 1). An up-valley wind developed by midmorning (3-4 m/s, gusts to 6 m/s). The first clouds formed on the SE facing slopes of Lhotse (8516 m) and Nuptse (7855 m). A short time later, clouds began to form on the SE facing slopes of the Everest pyramid (8848 m). By early afternoon, the up-valley winds increased to 4-5 m/s with gusts to 6-7 m/s, the Lhotse and Everest banner clouds were fully developed and the valley T and Tf values increased from the morning values (Figure 2). These speeds are consistent with those reported by Nakajima (1976); he also reports the depths of the up-valley winds to be 200-300 m based on observations of cloud motions.

By early evening, the up-valley winds were replaced by down-valley winds with subsequent dissipation of clouds on the slopes and ridges. Nights became clear, with pulsating mountain winds of 2-3 m/s and only the banner clouds of Everest and Lhotse persisted; these clouds vanished by morning (Figure 3).

The banner cloud produced by Lhotse often appeared before the Everest banner cloud because the south-facing, mostly black Nuptse-Lhotse ridge was the first ridge the early morning up-valley wind encountered. Although the up-valley wind was dry, it apparently transported sufficient moisture to cause cloud formation at the high elevation of the Lhotse summit.

To test this idea the measured T and Tf values were used to predict cloud formation in an adiabatically rising parcel. For example, the measured values at 0900 NST, November 27, 1992 at Tengboche (3867 m) were, respectively, 1.5 C and -14C; the corresponding valley wind was about 3 m/s in puffs (Figure 3). Clouds were predicted to form on the Nuptse-Lhotse ridge at about 5800 m; clouds were observed to form at about 6000 m on the ridge beginning at about 1000 NST (Figure 4). Thus, the air which flowed up-valley past Tengboche could have been involved in the formation of these clouds.

The up-valley wind is expected to develop later in the West Cwm than in the Imja Khola valley, because the Everest banner cloud formed later than the clouds along the Nuptse-Lhotse ridge. When the down-valley winds developed in the evening, the moisture advected up the valleys during the day was flushed down the valley. The clouds on the slopes and ridges were the first to dissipate; the Lhotse and Everest banner clouds were the last to dissipate apparently after exhausting the remaining low-level moisture. A schematic of the diurnal air flow constructed from these observations is illustrated in

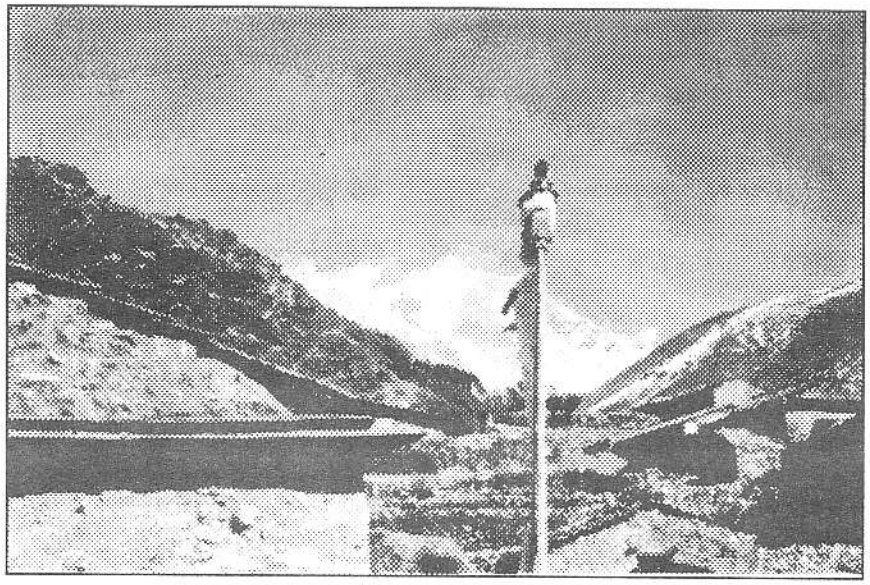

Figure 4. Scene from Pangboche at 1130 NST 27 November 1992: Clouds are forming on the Nuptse ridge and the slopes of Lhotse (8516 m), center.

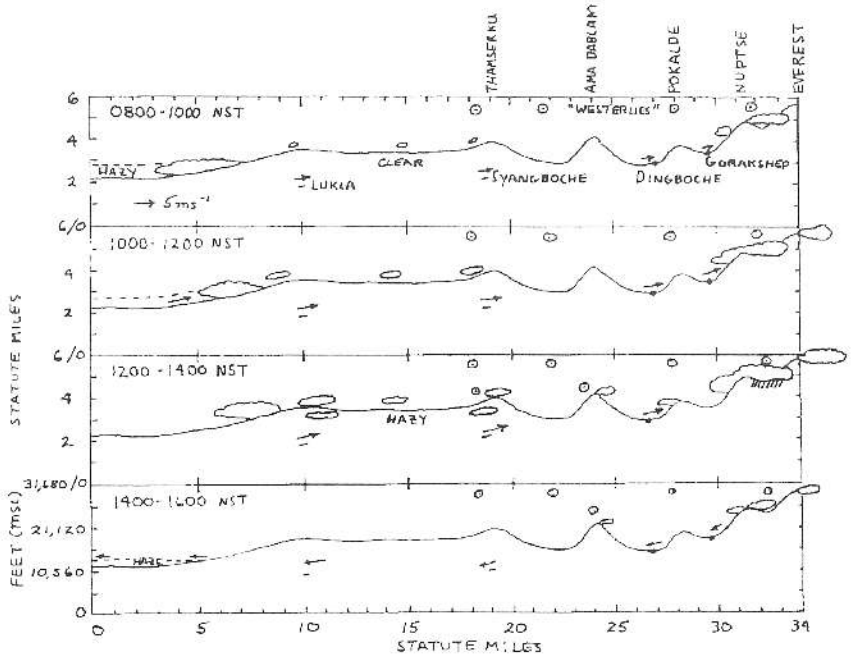

Figure 5. Schematic of the diurnal wind and cloud patterns observed during the dry days in November and December 1992.

Figure 5.

POSSIBLE SOARING FLIGHT

It may be feasible to launch a sailplane from the Syangboche airstrip (3700 m elevation [12,152 ft], 348 m length [1143 ft]) into the thermal which has been shown to form frequently over adjacent Namche Bazar. A climb in this thermal should take the sailplane to nearby Khumbila peak (5761 m) which may be ascended in thermals expected to form on its black, south-facing slopes. A glide north to the black, south-facing Taweche peak (6501 m) with an ascent to the summit would permit a glide to the Nuptse-Lhotse ridge with assistance from expected thermals triggered by black, south-facing Pokalde peak (5806 m); at 0950 LST on 28 November, Hindman observed a large gaggle of Choughs soaring on the slopes of Pokalde. At the summit of Nuptse, the strong westerlies are expected to be encountered; during Hindman's trek the westerlies were 25-30 m/s.

From the summit of Nuptse, It should be possible to enter the west

Cwm and repeat the ascents by Wick and Baker, but continuing above the summit of Everest, the ultimate ascent. This is the route proposed by Hindman (1986).

THE SECOND HIMALAYAN SOARING EXPEDITION

The reported thermal locations need to be verified and their strengths measured by flights of a high-performance, instrumented motor-glider. Waibel (1993, personal communication) states the ASH-26E motorglider could operate from the Syangboche airstrip; the much lower elevation Lamidanda airstrip (35 statute miles down the Dudh Kosi from Syangboche) may be a more realistic location to begin the flights and then shift operations to Syangboche. The flights should be coordinated with simultaneous surface and satellite measurements. The surface data will define the thermodynamic and dynamic structure of the valley air; high-resolution images from NOAA satellites will document the behavior of the Everest banner cloud. Knowledge and experience gained from these flights should lead to the ascent of Everest by a skilled pilot flying a sailplane. These activities will constitute the Second Himalayan Soaring Expedition which Hindman is planning for the fall of 1995 and the spring of 1996. The first soaring expedition was conducted in February 1985 exploring the up- and down-valley winds in the Kali Gandaki valley of western Nepal with a motor glider (Weickmann, 1988).

CONCLUSIONS

From surface meteorological data, it appears that an adequate number of dry days occur during the fall and spring transition seasons to permit morning and early afternoon aircraft operations in the Khumbu Himal. Morning air temperature (T), frost-point temperature (T_f) measurements appear to be useful in predicting afternoon cloud development. It has been demonstrated that thermals exist above Namche Bazar which are expected to support sailplane flights. A diurnal wind and cloud pattern was observed; the Everest banner cloud was diurnal. These qualitative findings need to be quantified through surface observations coordinated with measurements from soaring flights. The "Second Himalayan Soaring Expedition" planned for the fall of 1995 and spring of 1996 is expected to explore the soaring path to the summit of Everest.

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