CRH SSD
JUNE 1992

CENTRAL REGION TECHNICAL ATTACHMENT 92-12

A MOUNTAIN WAVE SOARING FORECAST SCHEME

Paul W. Gard, Jr.
National Weather Service Forecast Office
Denver, Colorado

Lewis J. Neyland
National Soaring Foundation Director
An Affiliate of the Soaring Society of America
Colorado Springs, Colorado

1. INTRODUCTION

For more than 25 years, the Colorado Front Range area, particularly the Pikes Peak region, has been a "Mecca" for soaring pilots from the world-wide soaring community who come here to fly in the spectacular and relatively predictable wave conditions. Over the years there have been thousands of high altitude flights from Black Forest Glider Port with a high percentage going above 30,000 feet MSL and a significant number above 40,000 feet MSL. From this experience a large body of anecdotal wave forecasting information has been developed in the minds of the local soaring pioneers. Most of this information has been undocumented. The present paper attempts to distill and translate to an objective technique the highly subjective skills developed by those pilots. The weighting factors used in the forecast are based upon Neyland's hundreds of conversations with many of these pilots as well as some 10 years of personal soaring in the Colorado wave. (Neyland is a retired professional meteorologist, USAF pilot, and a soaring altitude record holder.)

For the last four years, the National Weather Service Forecast Office in Denver has been issuing a daily mountain wave soaring forecast from October 1 through March 31 for the Colorado Front range from Fort Collins south to Colorado Springs. The forecast is based upon meteorological information from the early morning (1200 UTC) Denver upper air sounding and forecast winds aloft issued by the National Meteorological Center (NMC). The forecasting scheme incorporates most known wave soaring parameters in a weighting factor scheme which results in a soaring index forecast for the day.

2. METHODOLOGY

National Weather Service Forecasters Handbook No. 3, Soaring Meteorology for Forecasters, outlines the basic requirements for mountain wave formation:

1) Lower atmospheric stability in the form of a temperature inversion or isothermal layer aloft.

2) Wind speeds at mountain top level (14 thousand feet MSL for the Front Range of the Rockies) greater than 15 to 25 knots.

3) Wind speed increasing or remaining constant with height to the tropopause.

4) Wind directions not varying by more than 30 degrees from that perpendicular to the mountain ridge line.

Synoptically, along the lee of the Colorado Rockies, a jet stream is needed to provide the strong wind and wind shear necessary for the formation of mountain waves. The above requirements are most often met when the jet stream is immediately over or just north of the area. Experience has shown that soarable waves do not occur with the jet stream core south of the area unless it is more than 200 to 300 miles south.

In a paper by Burton (1971), it was shown that weak positive vorticity advection (PVA) at 18 thousand feet MSL (500 mb) increases vertical lift or reduces the effects of capping caused by stable layers at higher levels aloft, thus enhancing wave soaring capabilities. While strong PVA would also provide additional lift, such conditions would also favor the formation of increased cloudiness and precipitation, which would disrupt favorable soaring. Synoptically, weak PVA can be indicated by the approach of a surface front or trough aloft.

The height a glider will reach is also important in determining the quality of the soaring weather. In Colorado, a soaring pilot must reach nearly 30,000 feet MSL to earn recognition for an FAI Diamond altitude flight[1]. Forecasters Handbook No. 3 states that upper limits on a soarable wave are imposed when the upward

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[1] The Federation Aeronautic Internationale (FAI) in Paris, France, establishes criteria for and administers the awarding of recognition for achievements in all sport aviation. This includes soaring as well as aviation activities such as the recent world speed record set by the SR-71 aircraft.

vertical velocity decreases to zero, that is when the wind velocity starts to decrease with height or when the wind direction changes by more than 30 degrees from that at the top of the stable layer. These factors are used to determine the potential height a glider may reach.

Techniques for forecasting the wave strength (i.e. vertical velocities) in the laminar flow region of the wave are described in WMO Technical Note 158, Handbook of Meteorological Forecasting for Soaring Flight. However, perhaps due to the specifics of Colorado terrain or the non-representativeness of upwind data, they have been found to be of little use here and are not incorporated into this objective forecasting scheme.

It is emphasized that the weighting values assigned to each forecasting factor may well only apply to specific conditions in the Pikes Peak region and, to a somewhat lesser extent the entire Colorado Front Range region. However, the weighting technique, adjusted elsewhere, may be a useful tool for others.

Based on all of the above, the forecast worksheet and forecast format (shown in Figs. 1 and 2, respectively) were developed for preparing the daily Wave Soaring Index (WSI).

Because weather systems are fast moving and weather conditions can change rapidly during the 12 hour day, the forecast also incorporates a trend for improving or deteriorating soaring conditions based on the forecast criteria. Winds aloft from the morning (1200 UTC) Denver upper air sounding are included in the forecast. These are compared with the forecast winds aloft (FD3) to determine a wind speed trend at each level for the day. Due to the often difficult logistics involved in preparing for a soaring flight, an outlook for the next day is included at the request of soaring pilots. The outlook is based on changes in the synoptic and wind patterns for the next day that the forecaster believes would change the wave soaring conditions.

The wave soaring forecast is disseminated daily to the Denver FAA Automated Flight Service Station where it is recorded on an automatic answering telephone for easy access by soaring pilots in the area. The telephone receives an average of 25 to 30 calls a day. This demonstrates that the forecast is well received by the soaring community.

3. REFERENCES

Burton, E. B., 1971: Positive Vorticity Advection, *Soaring*, August, 30-32.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, 1972: Soaring Meteorology for Forecasters, *National Weather Service, Forecasters Handbook No. 3.*

World Meteorological Organization, 1978: Handbook to Meteorological Forecasting for Soaring Flight, *Technical Note No. 158*, (WMO-No. 495).

An excellent handbook for the practical application of mountain wave conditions to soaring flight:

Palmer, M., 1990: Practical Wave Soaring, *Soaring Society of America.*

WAVE SOARING FORECAST WORKSHEET

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WSI	TOTAL POINTS
EXCELLENT	GREATER THAN 17
GOOD	10 - 17
FAIR	7 - 9
POOR	LESS THAN 7

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FACTOR		PTS.
Wind Direction at 14 thsd ft MSL:	240-300 degrees	+5 points
	210-230 deg or 310-330 deg	+2 points
	other	-5 points _____
Wind Speed at 14 thsd ft MSL:	>25 and <50 kts	+5 points
	20-25 kts or >50 kts	+2 points
	<20 kts	-3 points _____
Wind Gradient - velocity increases with height from stable layer (or 14 thsd ft MSL) upward?	yes	no points
	no	-10 points _____
Stable Layer - inversion or isothermal layer between 12 and 18 thsd ft MSL?	well defined	+6 points
	poorly defined	+3 points
	none	-5 points _____
Jet Stream - nearby:	north of FCL	+3 points
	south of COS	-4 points
	over area	no points _____
Front or Upper Trough Passage - probable within next 24 hours:		+2 points
	weak PVA next 12 hours	+2 points
	weak NVA next 12 hours	-2 points _____

WSI _____ **Total pts.** _____

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Height above stable layer (or 14 thsd ft MSL) where
wind velocity no longer increases with height: _____ thsd ft MSL.
wind direction changes by 30 degrees or more: _____ thsd ft MSL.

POTENTIAL HEIGHT OF WAVE (lowest value above): _____ thsd ft MSL.

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FIGURE 1

WAVE SOARING FORECAST

DENALGDEN
Wave Soaring Forecast for Colorado Front Range
National Weather Service Denver CO

_____ AM MST _____ _____ _____ 19____
(Time) (Day) (Month) (DD) (Yr)

WAVE SOARING INDEX (WSI) _____
WSI TREND (till 500 PM today) _____
STABLE LAYER ALOFT (12-18 thsd ft MSL) _____
JET STREAM LOCATION _____
WEAK PVA/NVA (next 12 hours) _____
POTENTIAL HEIGHT OF WAVE _____ **FT MSL**
REMARKS: _____

_____

WINDS ALOFT AND TREND (**I**-increasing, **D**-decreasing, **S**-same, till 500 PM today)

12 THSD FT MSL	_____/_____ _____	20 THSD FT MSL	_____/_____ _____
14 THSD FT MSL	_____/_____ _____	25 THSD FT MSL	_____/_____ _____
16 THSD FT MSL	_____/_____ _____	30 THSD FT MSL	_____/_____ _____
18 THSD FT MSL	_____/_____ _____	35 THSD FT MSL	_____/_____ _____

CONVECTIVE INDICES: K INDEX _____ **LIFTED INDEX** _____
(Only during transition months of **October** and **March**)

OUTLOOK _____: **WSI** _____
(Next Day)

FIGURE 2