Anticipating Winds Near Complex Terrain



David Craft Aviation Program Leader National Weather Service Albuquerque



Overview



1. Terrain-forced flows:

- Flow over and around terrain,
- Mountain waves and lee waves,
- Visible signs,
- Mechanical turbulence,
- Gap Winds.
- 2. Diurnal mountain winds:
 - Downslope and downvalley winds,
 - Timing.



Altocumulus Standing Lenticular Cloud Indicating the Presence of Mountain Wave Near Gallup, NM, 1 FEB 06

Terrain-Forced Flow





Mountain Meteorology, C. David Whiteman

AND ATMOSPL

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Air Force Manual 51-12, Weather for Aircrews (1974)



Mountain Wave Features









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Low-level turbulent zone

• Sign of severe turbulence.

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- Near top of rotor circulation:
 - Near or below mountain-top level,
 - Within 20 miles downwind of ridgeline,
 - Often under a lenticular cloud.
- May makeup the entire low-level turbulent zone.



Trapped Lee Waves







GOES Satellite Visible Loop

Trapped wave clouds indicate turbulence more than 100 miles downstream from mountain ranges



Trapped Lee Waves





Mountain Wave Intensity

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<u>Intensity</u>	Up/Down Draft <u>Speed</u>	Aircraft Speed Change	Aircraft Altitude <u>Change</u>
Moderate:	350-599 FT/MIN	+/- 15-24 KT	500-999 FT
Severe: Altocumulus Stan	<u>> 600 FT/MIN</u> ding Lenticular Clouds (AC	+/- 25 KT SL) • Criteria consis	> 1000 FT a for forecast tency,
		No "off for cor	icial" ICAO criteria isistency exists,
		PIREP importa wave f	details are very ant for mountain orecasts.

N



Decoders May Miss Lenticular Clouds



• METAR:

KABQ 051456Z 00000KT 10SM FEW001 SCT050 SCT100 BKN200 M05/M09 A2998 RMK AO2 SLP177 FU FEW001 MTN TOPS OBSC NE-E SCSL NE-E ACSL NE AND SE T10501094 56010

• **DECODED METAR (**http://aviationweather.gov/adds/metars/index.php):

Conditions at: KABQ (ALBUQUERQUE, NM, US) observed 1456 UTC 05 February 2011 Temperature: -5.0°C (23°F) Dewpoint: -9.4°C (15°F) [RH = 71%] Pressure (altimeter): 29.98 inches Hg (1015.3 mb) [Sea-level pressure: 1017.7 mb] Winds: calm Visibility: 10 or more miles (16+ km) Ceiling: 20000 feet AGL Clouds: few clouds at 100 feet AGL scattered clouds at 5000 feet AGL broken clouds at 20000 feet AGL Weather: no significant weather observed at this time



Visible Signs of Terrain-Forced Flow





February 20, 2010 around 5:30pm Clouds over the Mogollon Mountains. Image taken from Pleasanton, NM (Photo Courtesy of David Thornburg)

Mountain Meteorology, C. David Whiteman



Visible Signs of Terrain-Forced Flow





Waterfall clouds overtopping the Capitan Mountains

Cold front banked up against east slopes of the Sandia Mountains (not a cap cloud or waterfall cloud)





G-12 IMG 3 1 MAR 06060 141500 02706 09261 01.00

https://wx.erau.edu/faculty/mullerb/Wx365/Mountain_waves/mountain_waves.html

Aviation Weather Center's Graphical Turbulence Guidance



 Rapid Refresh Model (RAP) forecast for:

NOAA

- Clear air turbulence,
- Mountain wave turbulence,
- Combo CAT/MTW
- No forecaster in the loop, so monitor
 SIGMETs for actual mountain wave forecast.
- Valid on the hour, not for a time range.



https://aviationweather.gov/turbulence/gtg



Mechanical Turbulence







Meteorology for Aviators, R.C. Sutcliffe

R.C. Sutcliffe's Rule of Thumb

- MDT TURBC: Wind > 30 KT
 < 3,000 FT AGL,
- SVR TURBC: Wind > 45 KT
 < 3,000 FT AGL.



Where Local Speedups Occur*



- On hillsides where flow parallels the crest's contour.
- Over crests:
 - o Greatest speedups over gently inclined triangular shaped hills,
 - Intermediate speedups over rounded mountain tops (KCQC),
 - Smallest speedups over flat-topped mesas.
- Channeling through passes and gaps in the ridgeline.



Adapted from Mountain Meteorology, C. David Whiteman

*Assuming relatively stable flow



Gap Winds

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- Strong winds through openings in mountain ranges, channels between subranges, or through mountain passes.
- Produced by:
 - Strong pressure differences either side of the range,
 - Thunderstorm outflow rushing through the gap.
- Strongest winds typically occur at the gap exit region.



ABQ East Canyon Wind





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- High impact on the ABQ Sunport and Santa Fe Airport.
- Stronger events also impact Taos, Grants, and Carrizozo Airports.
- Over-the-top events can cause hurricane-force winds in Albuquerque:
 - 124 mph in 1987 at base of Sandia Peak Tramway,
 - 108 mph in 1990 in ABQ's eastern foothills,
 - 90 mph (sustained) in 1943 at KABQ.



Coastal Range Gap Winds



- Winter Strong east winds develop due to higher pressure and colder air over higher elevation, inland basins.
- **Summer** Moderately **strong west** winds develop due to lower pressure and hot air over inland basins with colder air and higher pressure over the Pacific Ocean.
- Other famous gap winds:
 - Cascade Mountains:
 - Snoqualmie Pass,
 - Naches Pass,
 - Stampede Pass,
 - Fraser Valley,
 - Strait of Juan de Fuca,
 - Caracena Strait.
- Monitor TAFs and Aviation Forecast Discussions for gap wind information.



Columbia River Gorge Topo Map





Downslope & Downvalley Winds





Peaks during the evening. 2 to 5 mph

From the S290 Intermediate Wildland Fire Behavior Course (www.meted.ucar.edu)

Starts after midnight, then peaks during early morning. 5 to 10 mph



Time of Downvalley Wind Varies by Valley Aspect





Valley Aspect	Time of Max Upvalley Wind	Time of Max Downvalley Wind
East	8-11 am	2-6 am
South	12-3 pm	5-9 am
West	3-7 pm	6-10 am

Times valid at the peak of summer.



Summary



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Sandia and Manzano Mountains, NM

Anticipating Winds Near Complex Terrain





David Craft Aviation Program Leader National Weather Service Albuquerque (505) 243-0702 ext. 0 David.Craft@NOAA.Gov



Mountain Wave Sounding







Altocumulus Standing Lenticular Cloud Indicating the Presence of Mountain Wave Near Gallup, NM, 1 FEB 06 Albuquerque's 12Z Sounding 1 FEB 06



Separation Eddies



- Form over steep slopes or cliffs on either the windward or leeward side.
- Elongated, horizontal-axis eddies that can extend along entire length of barrier.
- The eddies reduce near ground wind speeds on the slopes, even though flow above the eddies speeds up as it crosses the barrier.
- Indicated by sand-dune-like deposits, snow cornices and/or banner clouds.



Mountain Meteorology, C. David Whiteman



Vortex Pairs





Mountain Meteorology, C. David Whiteman



Slope Winds Diurnal Cycle



- EZ = top of mixed layer
- Orange wavy lines = thermals
- Blue lines = slope winds



Adapted from Mountain Meteorology, C. David Whiteman



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Meteorology for Aviators, by R.C. Sutcliffe

heights downwind*

*From Mountain Meteorology, C. David Whiteman



Foehn Wall



Foehn - A warm, dry wind on the lee side of a mountain range.





Common Western U.S. Foehn Winds