ATSC 201 - Meteorology of Storms   Week 12   Day 5

Learning Goals

Topic: **West-coast Weather & Local / Regional Winds**

At the end of this section, you should be able to:

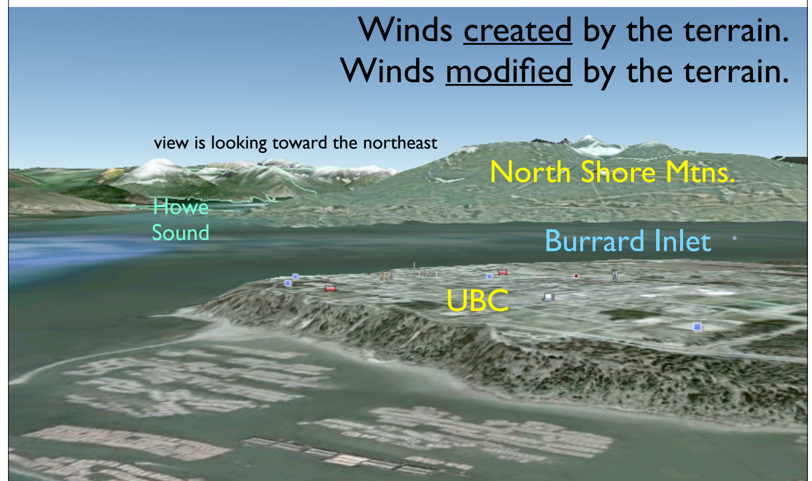
1. Synthesize all aspects of the general circulation, air masses, fronts, midlatitude cyclones to explain why we get the weather we do.
2. Describe west-coast weather phenomena including: pre-frontal jets, the pineapple express, outflow & gap winds, the cyclone graveyard, orographic precipitation, instant occlusions upon landfall, mountain waves, polar lows, etc.
3. Access web-based weather, satellite, radar, and numerical weather forecast info on current and future weather.
4. Describe and explain these local winds: anabatic wind, katabatic wind, mountain and valley winds, sea breeze, gap winds, coastally trapped jet, mountain waves, Bora, Foehn (Chinook) winds.

Discussion Points & Demos

1. Discussion & interaction on topics from readings (bring your clicker).
2. Look at transparencies from case-study West Coast extratropical cyclone.
2. Demonstrate the UBC NWP forecast web page.

Local Winds:

Winds created by the terrain.
Winds modified by the terrain.



Scales of Motion

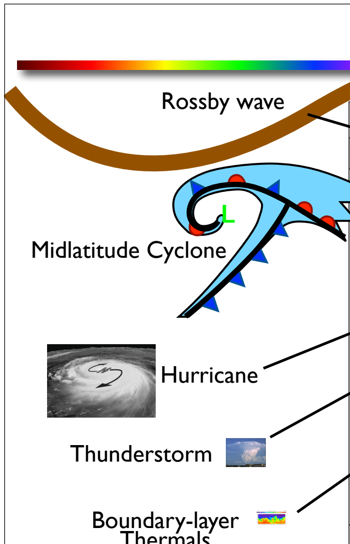


Table 10-6. Scales of horizontal motion in the troposphere.

Size	Scale	Name
40,000 km – 4,000 km	macro α	planetary scale
4,000 km – 700 km	macro β	synoptic scale*
700 km – 300 km	meso α	mesoscale**
300 km – 30 km	meso β	mesoscale**
30 km – 3 km	meso γ	mesoscale**
3 km – 300 m	micro α	microscale***: boundary-layer turbulence
300 m – 30 m	micro β	microscale***: surface-layer turbulence
30 m – 3 m	micro γ	microscale***: inertial subrange turbulence
3 m – 3 mm (300 mm, 30 mm)	micro δ	microscale***: fine-scale turbulence
3 mm – 0.3 µm	viscous	dissipation subrange
0.3 µm – 0.003 µm	molecular	mean-free path between molec.
0.003 µm – 0	molecular	molecule sizes

Note: Disagreement among different organizations.
*Synoptic: AMS: 400 - 4000 km; WMO: 1000 - 2500 km.
**Mesoscale: AMS: 3 - 400 km; WMO: 3 - 50 km.
***Microscale: AMS: 0 - 2 km; WMO: 3 cm - 3 km.

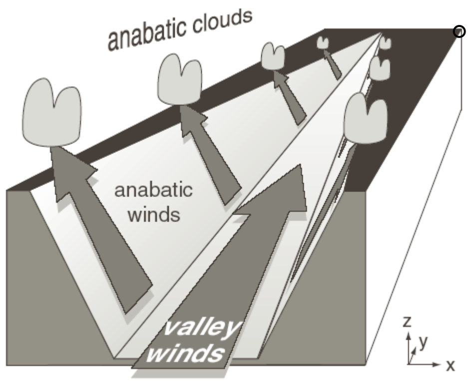
Winds Created by Terrain

... by differential heating of different terrain features.

Winds Created by Terrain

Daytime. Mountain slopes heated by sunlight.

Warm updrafts called **anabatic** winds hug the slopes.

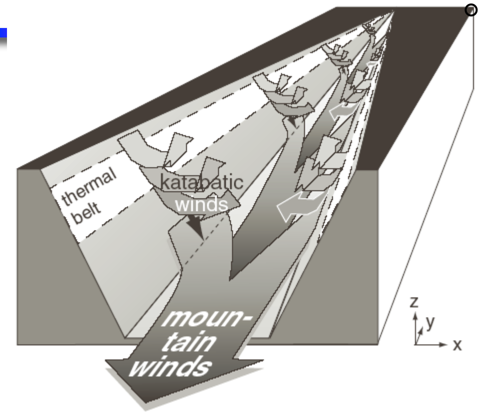


Conditions needed: light synoptic-scale winds, mostly clear, sunny skies.

Winds Created by Terrain

Nighttime. Mountain slopes cool by IR radiation to space.

Cold downdrafts called **katabatic** winds hug the slopes.



Conditions needed: light synoptic-scale winds, mostly clear skies.

Katabatic Wind Speed

where $|g| = 9.8\ \text{m·s}^{-2}$, T_{ve} is absolute temperature in the environment at the height of interest, α is the mountain slope angle, and s is distance downslope.

The average katabatic wind eventually approaches an equilibrium where drag balances buoyancy:

$$|U_{eq}| = \left[\left|g\cdot\frac{\Delta\theta_v}{T_{ve}}\cdot\frac{h}{C_D}\cdot\sin(\alpha)\right|\right]^{1/2} \qquad (17.9)$$

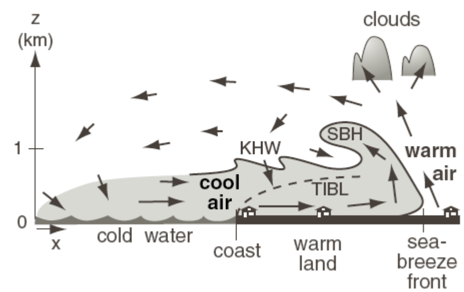
where C_D is the total drag against both the ground and against the slower air aloft, and h is depth of the katabatic flow. $\Delta\theta_v = \theta_{v\ environ.} - \theta_{v\ kat.air}$

Hint: if you are not given a humidity, then assume Tv = T.

Winds Created by Terrain

Daytime. Sun-heated land warmer than neighboring water.

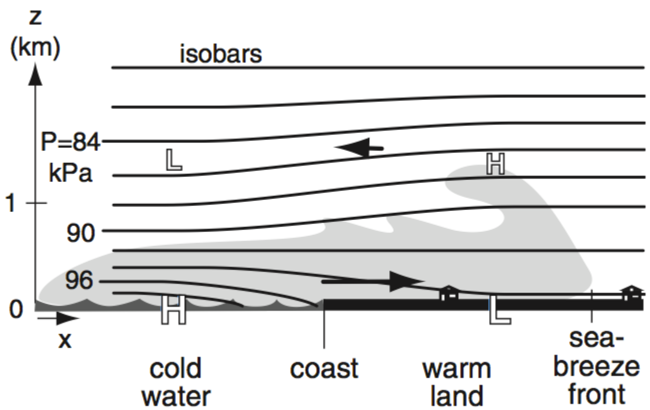
Sea Breeze



Conditions needed: light synoptic-scale winds, mostly clear, sunny skies.

Winds Created by Terrain

Sea Breeze



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Sea Breeze

Advancing cold air behind the sea-breeze front behaves somewhat like a **density current** or **gravity current** in which a dense fluid spreads out horizontally beneath a less dense fluid. When this is simulated in water tanks, the speed M_{SBF} of advance of the sea-breeze front, is

$$M_{SBF} = k \cdot \sqrt{|g| \cdot \frac{\Delta\theta_v}{T_v} \cdot d} \qquad (17.11)$$

where $\Delta\theta_v$ is the virtual potential temperature difference between the cool marine sea-breeze air and the warmer air over land that is being displaced, T_v is an absolute average virtual temperature, $|g| = 9.8$ m·s^{-2} is gravitational acceleration magnitude, d is depth of the density current, and constant $k \approx 0.62$.

When fully developed, surface (10 m height) wind speeds in the marine, inflow portion of the sea breeze at the coast are 1 to 10 m/s with typical values of 6 m/s. The relationship between sea-

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Winds Modified by Terrain

... when synoptically-driven winds hit mountains, etc.

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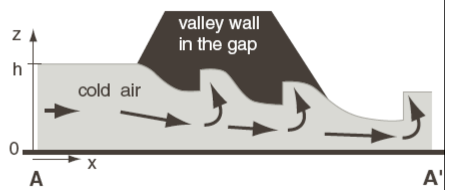
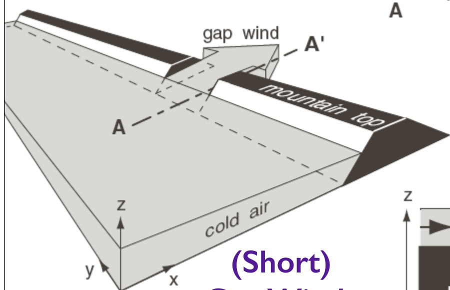
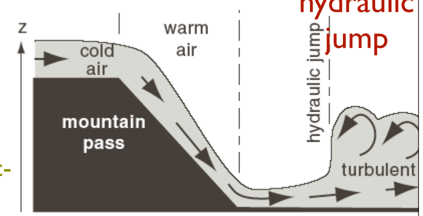
Winds Modified by Terrain





(Short) Gap Winds



hydraulic jump

Conditions needed: strong synoptic-scale winds, layer of cold air under warm (often in winter.)

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Strong gap winds (known locally as Squamish winds) flowing toward the south in Howe Sound damaged BC Ferry.

Winds were well explained by short-gap wind eq. based on Froude Number = 1:

$$M_{gap\ max} = \left[|g| \cdot \frac{\Delta\theta_v}{T_v} \cdot h \right]^{1/2}$$

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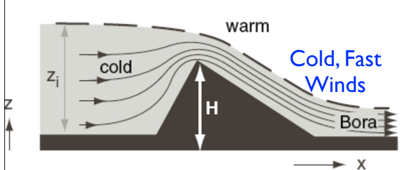
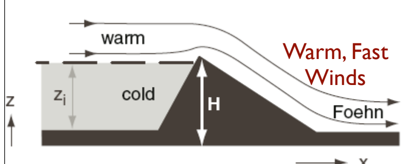
Bora . Foehn = Chinook.

Winds Modified by Terrain



Cold, Fast Winds

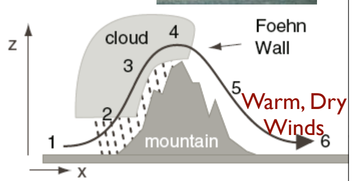


Warm, Fast Winds

Conditions needed: strong synoptic-scale winds, layer of cold air under warm (often in winter.)

Downslope Winds

YouTube Search:
Föehn effect - Bora on Feb 05th 2008
http://www.youtube.com/watch?v=9pDVMv2hT7g



Warm, Dry Winds

Conditions needed: strong synoptic-scale winds, humid air causing upslope precip. (often in winter.)

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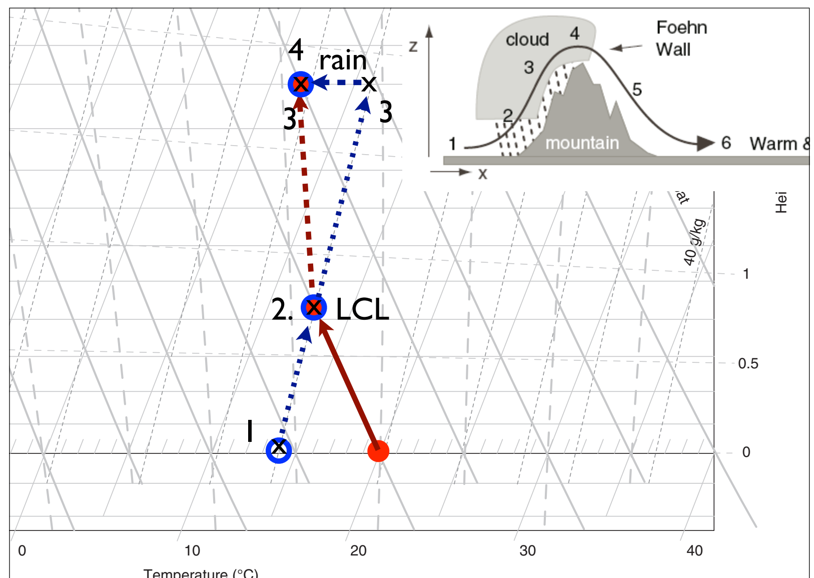

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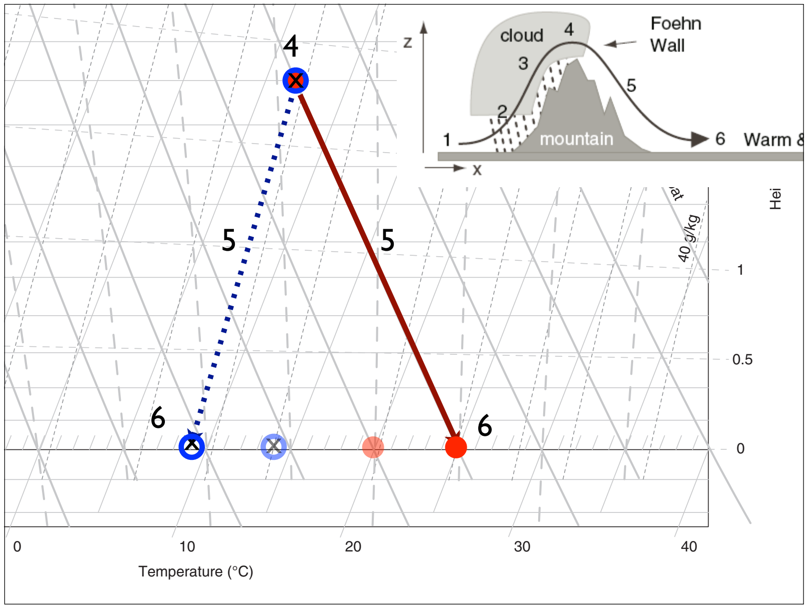

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MOUNTAIN WAVES

Mountain Waves = Lee Waves

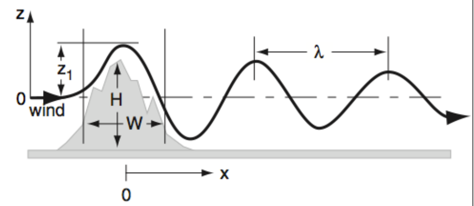

Figure 17.29
Mountain-wave characteristics.

$$N_{BV} = \left(\frac{|g|}{T_v} \cdot \frac{\Delta\theta_v}{\Delta z}\right)^{1/2}$$

$$\Delta\theta/\Delta z = \Delta T/\Delta z + \Gamma_d$$

Natural Wavelength

When statically stable air flows with speed M over a hill or ridge, it is set into oscillation at the Brunt-Väisälä frequency, N_{BV}. The natural wavelength λ is

$$\lambda = \frac{2\pi \cdot M}{N_{BV}} \qquad \bullet(17.30)$$

Longer wavelengths occur in stronger winds, or weaker static stabilities.

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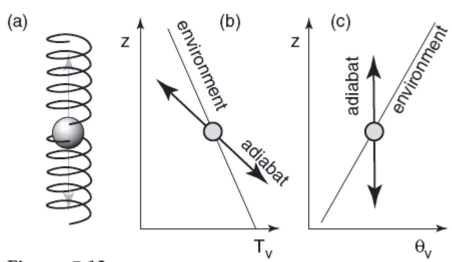
Brunt-Väsäilä frequency (from Ch 5)



Stronger static stability creates a stronger restoring force, giving a faster oscillation.

Oscillation + wind = mountain wave

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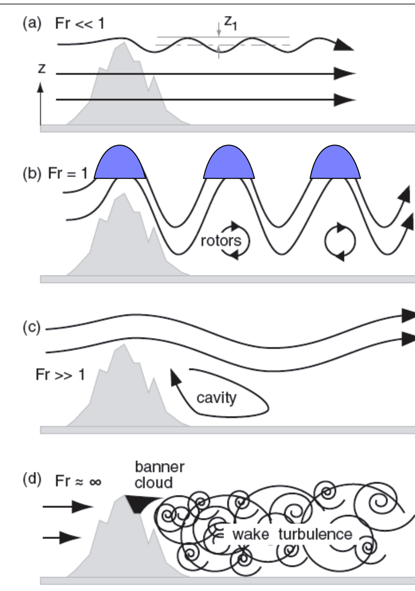
Mountain Waves = Lee Waves

Froude Number =

$$Fr_3 = \frac{\lambda}{2 \cdot W}$$

= natural wavelength / (2 · Mtn.Width)



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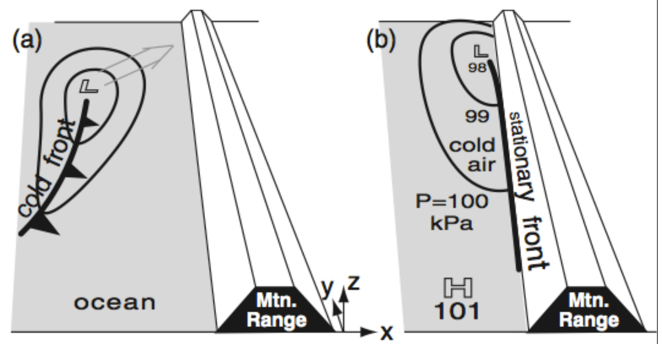
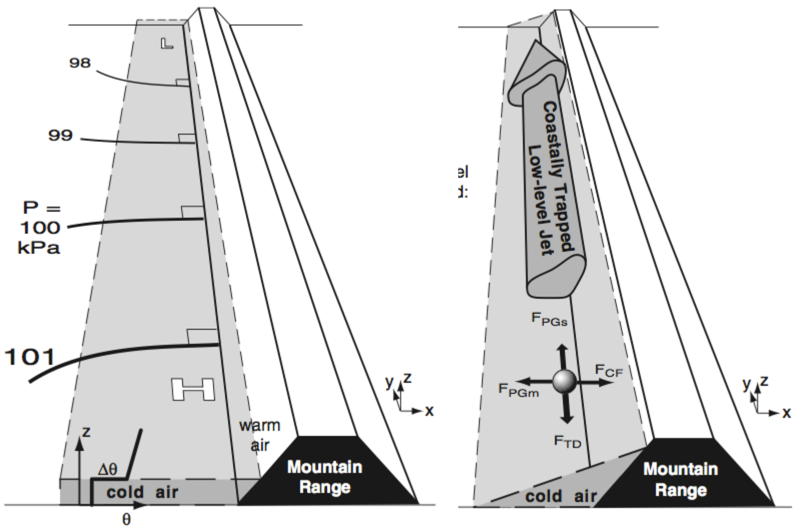
Lenticular clouds,
at the crests of
mountain waves

Coastally-trapped Low-level Jet (Barrier Jet)

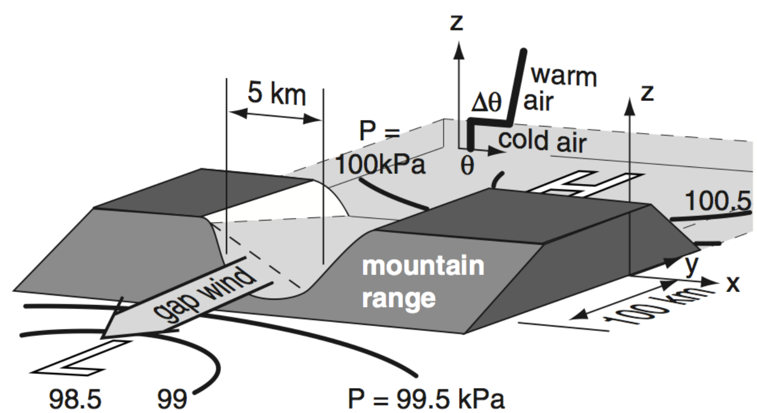
Synoptic
set-up

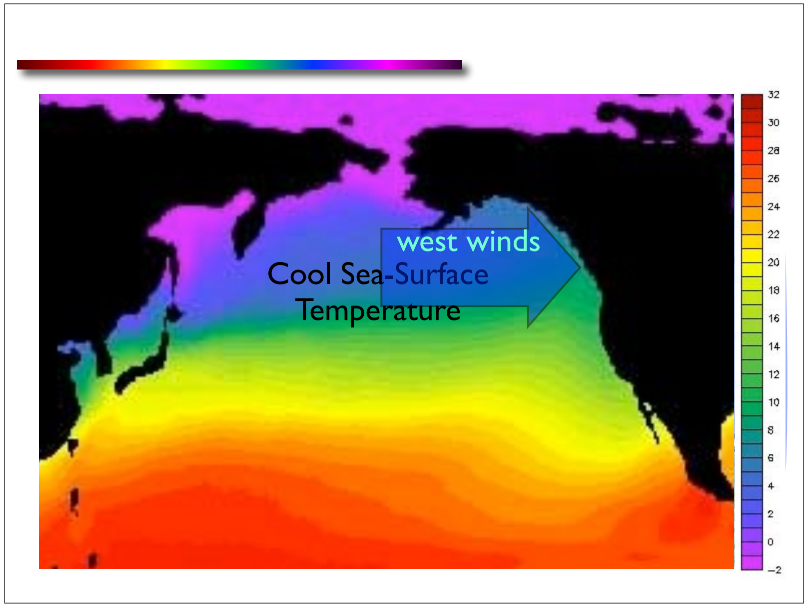


Coastally-trapped Low-level Jet



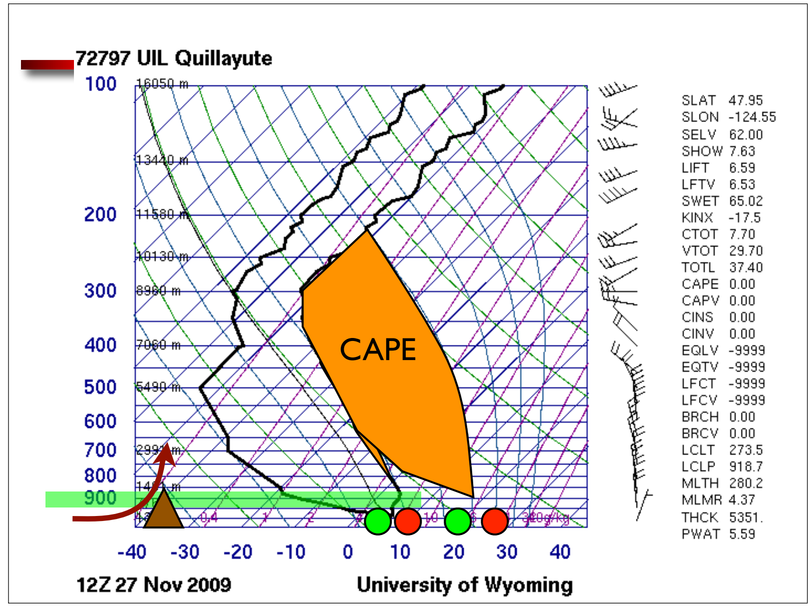
Long-gap Winds





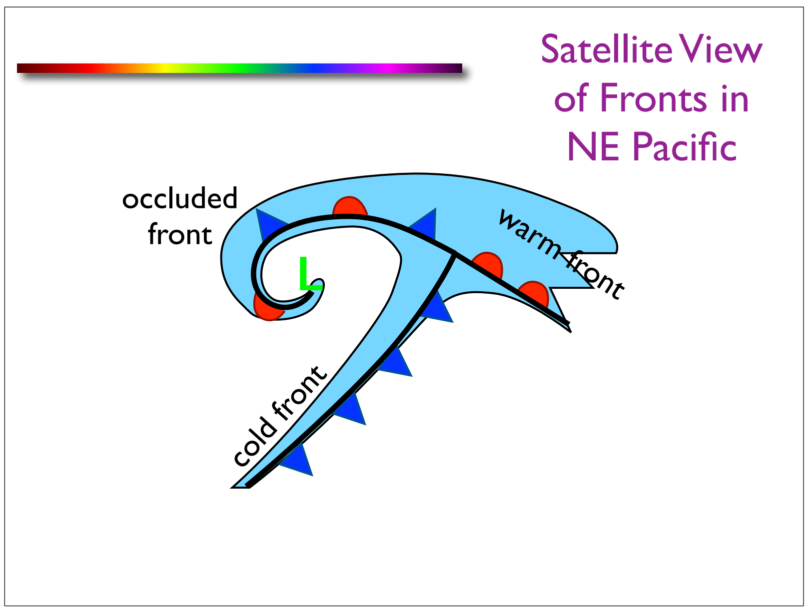
west winds
Cool Sea-Surface Temperature
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-2

25



72797 UIL Quillayute
100
200
300
400
500
600
700
800
900
16050 m
13440 m
11580 m
10130 m
8960 m
7060 m
5490 m
CAPE
-40 -30 -20 -10 0 10 20 30 40
12Z 27 Nov 2009
University of Wyoming
SLAT 47.95
SLON -124.55
SELV 62.00
SHOW 7.63
LIFT 6.59
LFTV 6.53
SWET 65.02
KINX -17.5
CTOT 7.70
VTOT 29.70
TOTL 37.40
CAPE 0.00
CAPV 0.00
CINS 0.00
CINV 0.00
EQLV -9999
EQTV -9999
LFCT -9999
LFCV -9999
BRCH 0.00
BRCV 0.00
LCLT 273.5
LCLP 918.7
MLTH 280.2
MLMR 4.37
THCK 5351.
PWAT 5.59

26



Satellite View of Fronts in NE Pacific
occluded front
L
warm front
cold front

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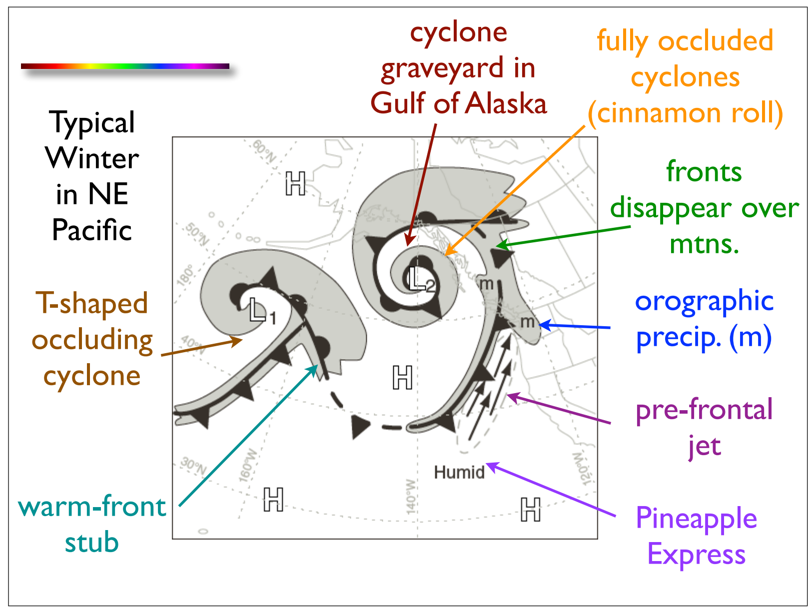

Typical Winter in NE Pacific
cyclone graveyard in Gulf of Alaska
fully occluded cyclones (cinnamon roll)
fronts disappear over mtns.
orographic precip. (m)
pre-frontal jet
Pineapple Express
T-shaped occluding cyclone
warm-front stub
H
L1
L2
m
Humid

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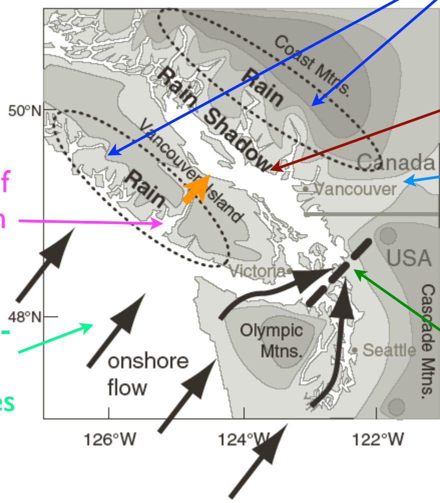
Zooming in.
Winter.

Heavy orographic precipitation

Rain shadow

cA airmass -> very cold outflow from Fraser Canyon

Channeling of wind through gaps



mP airmass -> Mild temperatures winter & summer

Olympic Mtn convergence zone

Book by Cliff Mass, 2008: “The Weather of the Pacific Northwest”, Univ. Washington Press.

Demo of UBC Weather Forecast web pages.

Q: Look at current weather maps, and pick out features. (Perhaps Questions on the fly.)