

Winds and Waves
Alaska Department of Natural Resources
Coastal Processes Seminar
6-7 October 2009 Anchorage

UAA UNIVERSITY of ALASKA ANCHORAGE
School of Engineering

NOAA References

- National Weather Service, Hydrometeorological Prediction Center, <http://www.hpc.ncep.noaa.gov/>
- National Climatic Data Center (NCDC), <http://www.ncdc.noaa.gov/oa/ncdc.html>
- National Data Buoy Center, <http://www.ndbc.noaa.gov/>
- Center for Operational Oceanographic Products and Services (CO-OPS), <http://tidesandcurrents.noaa.gov/>
- National Environmental Satellite Data and Information Service (NESDIS), <http://www.goes.noaa.gov/>
- National Geophysical Data Center, <http://www.ngdc.noaa.gov/>
- Pacific Marine Environmental Laboratory, Center for Tsunami Research, <http://www.tsunami.noaa.gov/>
- National Weather Service, West Coast & Alaska Tsunami Warning Center, <http://wcatwc.arh.noaa.gov/>
- NOAA Meteorological Development Lab, <http://www.weather.gov/mdll/>

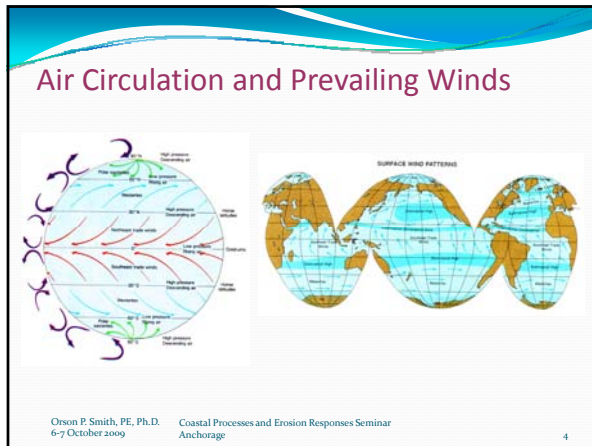
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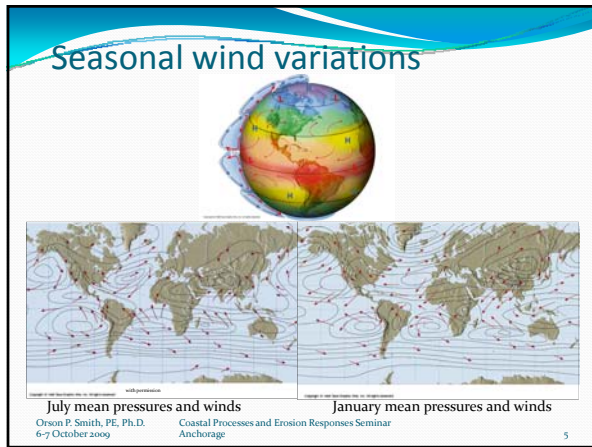
Wind cells

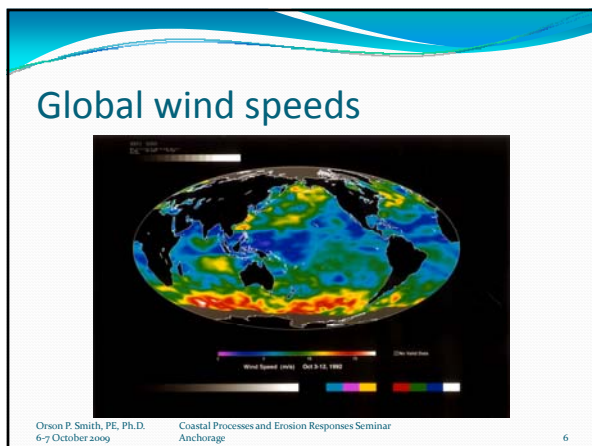
Hypothetical non-rotating Earth

Realistic Earth atmosphere circulation

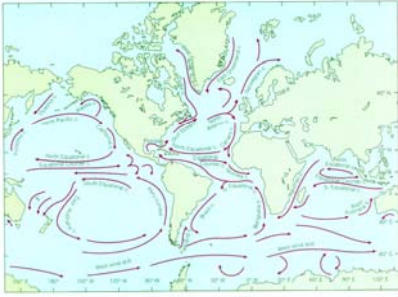
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Sea Surface Circulation




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Wind directions

- Weather reports refer to the direction from which the wind blows
- Use “-ward” to talk about the direction toward which the wind blows



A south wind blows northward

A north wind blows southward

“...You don't need a weatherman to know which way the wind blows...”
Bob Dylan


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Monsoon

- Winter
 - Interior cools and air sinks above
 - Wind is pushed offshore
- Summer
 - Interior warms and air rises above
 - Wind is drawn landward



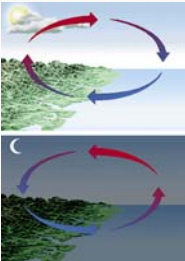
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Land and Sea Breezes

- Summer Days
 - Land heats up and air rises above
 - Wind is drawn landward from cooler sea
- Summer Nights
 - Land cools and air sinks above
 - Wind is pushed offshore

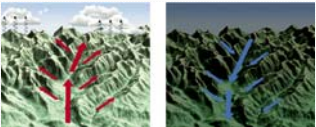


"...By this time the cool air from the mountains began to descend, and floating over the heated sea, it formed a light land-breeze, that blew in an exactly contrary direction to that, which about the same hour, came off from the adjacent continent..."
James Fenimore Cooper, *The Wing and Wing*

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Mountain effects


- Thermals – Mountain & Valley Breezes
 - Mountain slopes heat during days
 - Warmed air rises up valley slopes drawing moist air up off the sea
 - Moist air rises thousands of feet to cooler altitude
 - Moisture condenses into clouds
 - Cooling air sinks to bottom of valleys at night



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Mountain effects

- Windward-leeward
 - Moisture precipitates on windward side
 - Leeward side is dry
 - Also known as the "island effect," e.g., windward-leeward conditions on Maui



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Winds over the Ocean

- Geostrophic winds:**
 - Wind directions are parallel to the isobars and to right of the pressure gradient (northern hemisphere)
- Ekman region:**
 - friction between layers
- Surface winds:**
 - generally constant shear stress

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Gulf of Alaska Coastal Winds

Summer

- Clockwise circulation around Pacific High pressure brings moist air to Gulf of Alaska coast
- Storms formed in Bering Sea follow west-to-east tracks north of Alaska Peninsula

GOES Alaska IR Image
<http://www.goes.noaa.gov/>

National Weather Service,
Hydrometeorological Prediction Center
<http://www.hpc.ncep.noaa.gov/>

Winter

- Bering Sea storms follow west-to-east tracks south of Alaska Peninsula to enter Gulf of Alaska
- Winds along Gulf coast tend to veer from southeast to northwest as storms go by

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NOAA National Data Buoy Center

<http://www.ndbc.noaa.gov/>

Station Legend

- NOBC Buoyed Buoy
- NOBC C-Frame Station
- NOBC Alaska Region Station
- NOBC Station
- Canadian Buoy
- Drifting Buoy
- NOBC DART Buoy

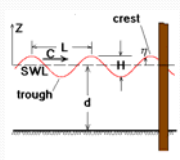
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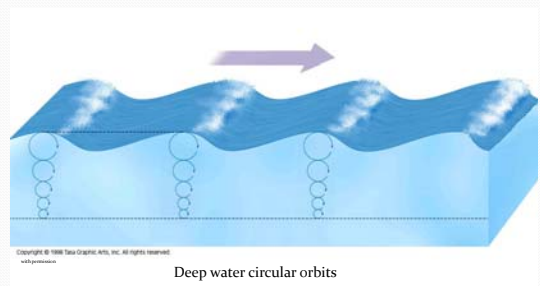
Wave Parameters

- Wave length (L)
- Wave height (H)
- Still Water Level (SWL)
 - Datum for relative elevations
- Still water depth (d)
- Water surface height (η)
- Celerity (phase speed, C)
- Period (T)
 - time for 2 crests to pass a fixed point
 - $C = L/T$



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Wave-induced Water Particle Motion




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Deep water circular orbits

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Shoaling and Breaking

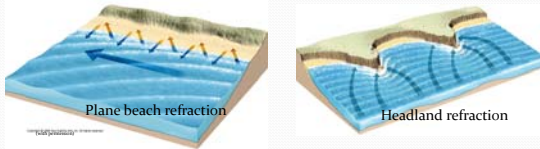
- Depths less than $\frac{1}{2}$ the deepwater wavelength slow wave propagation and shorten wavelength
- Wave heights increase in shallow water to become unstable and finally collapse (break)



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Refraction

- Waves reaching shallow water at an angle tend to bend parallel to depth contours (refraction)
- Refracted waves on breaking move sediment along the shore

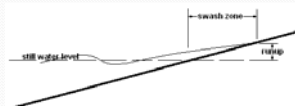


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Wave Runup



- Vertical distance above the still water level on a beach or structure reached by wave “swash”
- On a beach, the area affected by runup is called the “swash zone”

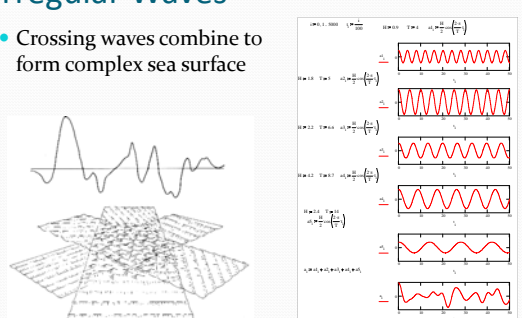
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Irregular Waves

- Crossing waves combine to form complex sea surface



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Wave Generation by Wind

- Major parameters
 - **Wind speed:** energy is proportional to square of wind speed
 - **Fetch:** distance over water that the wind blows
 - **Duration:** time for which wind exceeds a given speed
 - **Depth:** a constraint on wave height
- **Fully-developed sea**
 - Unconstrained by fetch, duration, or depth

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Wave spectra

WAVE ENERGY IN FULLY DEVELOPED SEA
74 kilometers per hour

Wave energy (square feet)
Period (seconds)
Frequency (cycles per second)

Strong winds generate a wide range of heights and periods

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Wave Statistics


Rayleigh Distribution of wave heights in a sea state

$H_s = H_{1/3} = 1.60 H_{average}$ Significant Wave Height, $H_s = H_{1/3}$
 $H_{max} = 1.6 H_{1/3} - 2.0 H_{1/3}$ (average of highest 1/3 wave heights)

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Seas & Swell

- **Seas:** diverse heights and periods in zone of generation
- **Swell:** Longer-period waves are faster and leave zone of generation

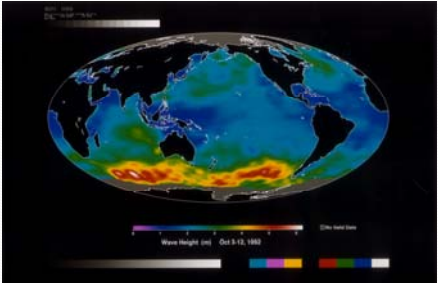


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Global wave heights



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Break time!



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