

# Waves and Weather



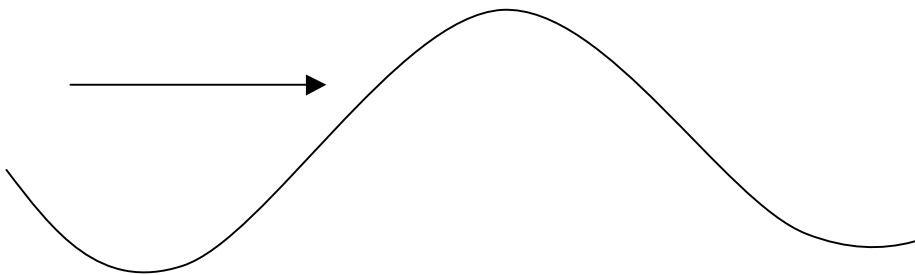
1. Where do waves come from?
2. What storms produce good surfing waves?
3. Where do these storms frequently form?
4. Where are the good areas for receiving swells?

# Where do waves come from?

**==> Wind!**

Any two fluids (with different density) moving at different speeds can produce waves. In our case, air is one fluid and the water is the other.

- Start with perfectly glassy conditions (no waves) and no wind.
- As wind starts, will first get very small capillary waves (ripples).
- Once ripples form, now wind can push against the surface and waves can grow faster.

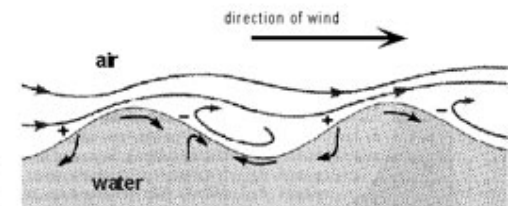
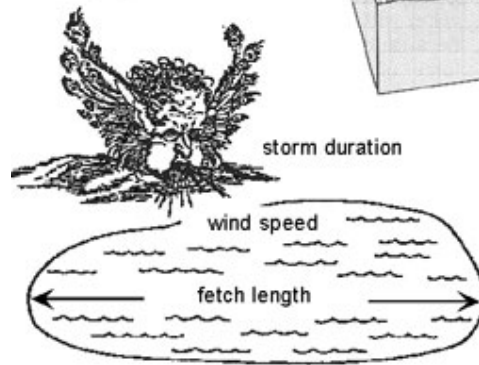
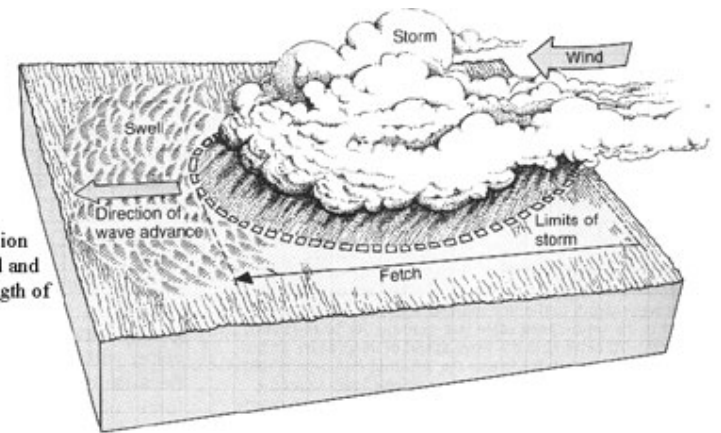


# How Big Will the Waves Get?

Height and Period of waves depends primarily on:

- Wind speed
- Duration (how long the wind blows over the waves)
- Fetch (distance that wind blows over the waves)

Waves are formed in a generating area where the wind begins to disturb the water surface, forming ripples and then waves. The size of waves generated is a function of wind speed, duration of coupling between the wind and the water surface, and the length of this coupling.



waves are formed by frictional drag of the wind across the water surface. Growth of the wave is from the sheltering effect of the wave crest.

"SMB" Tables

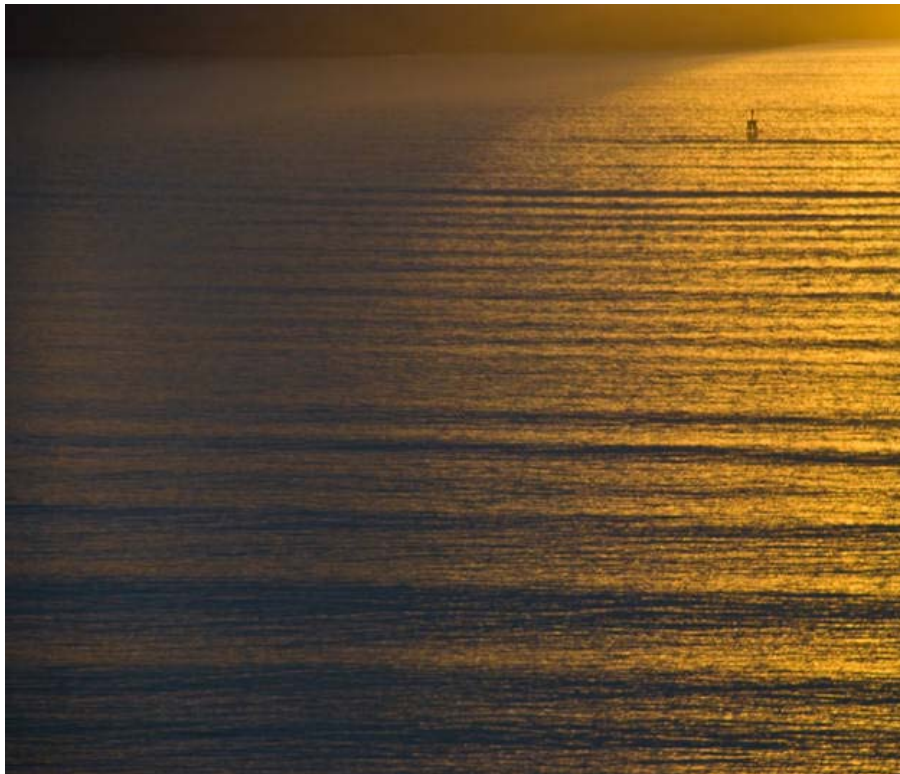


## Within Wave Source Region:

- all wavelengths and heights mixed together
- looks like washing machine ("Victory at Sea")



But this is what we want our surfing waves to look like:





How do we get from this



To this ????



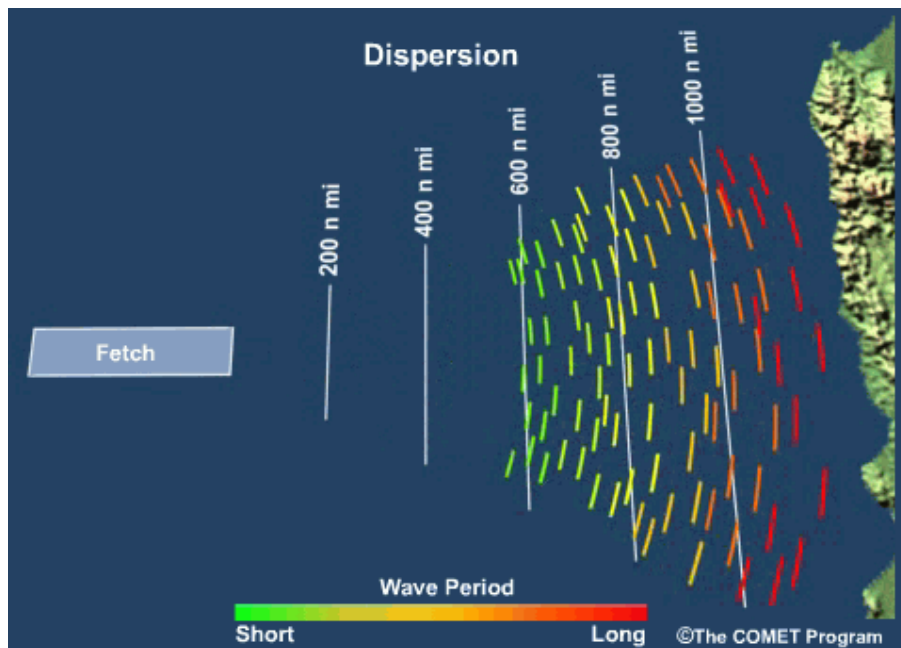
# ➡ DISPERSION !!

In deep water, wave speed (celerity)  $c = gT/2\pi$

Long period waves travel faster. Short period waves travel slower

Waves begin to separate as they move away from generation area

====> This is Dispersion





**Lesson 1: Don't want to be in middle of wave generating area for good surfing.**

BAD



GOOD





# How big will the waves get??

Assume Duration = 24 hours

Fetch Length = 500 miles

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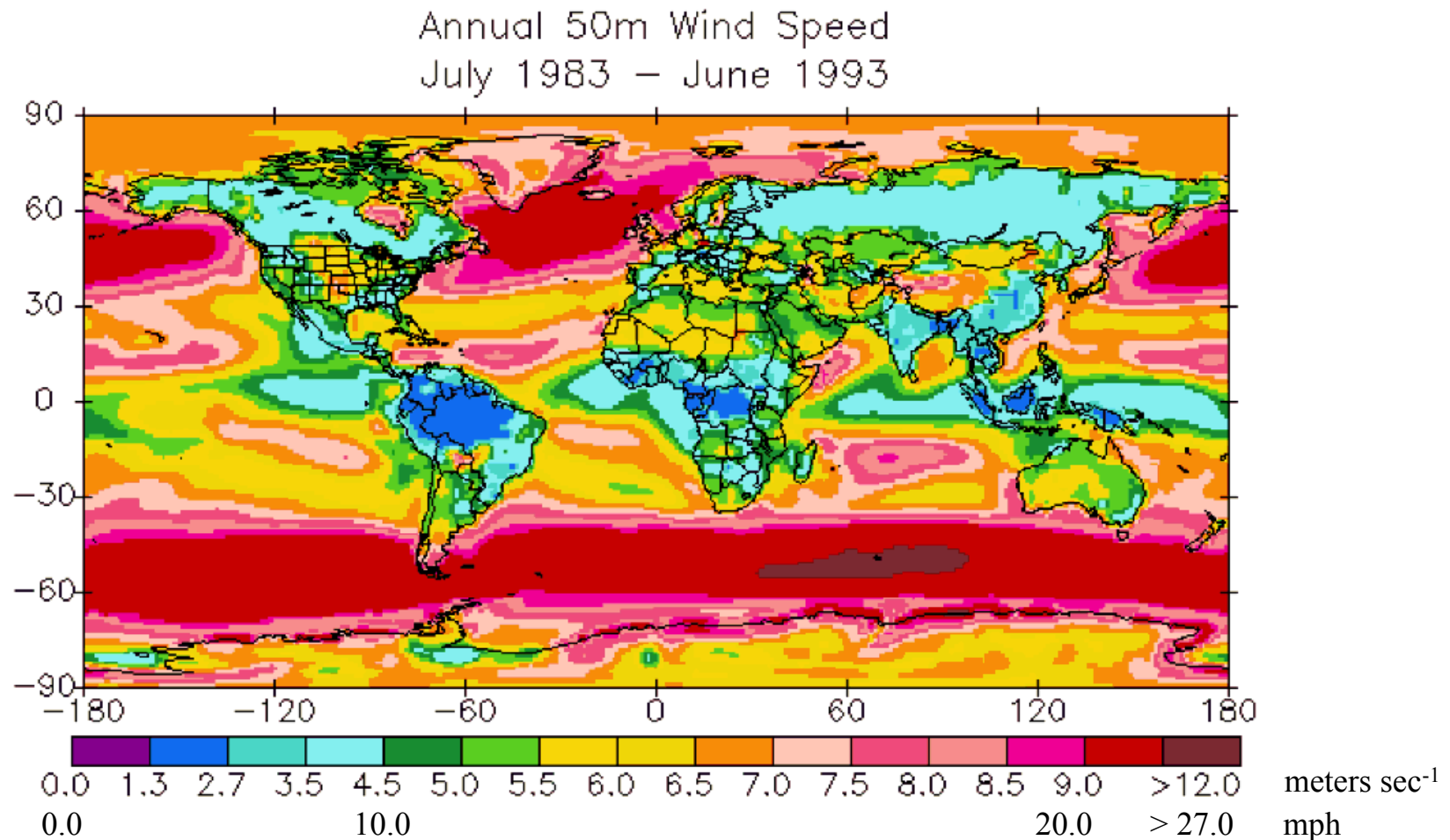
Fetch Length = 500 miles

Wind Speed	Significant Wave Height	Significant Wave Period
10 mph	2 ft	3.5 sec
20 mph	6 ft	5.5 sec
30 mph	12 ft	7.5 sec
40 mph	19 ft	10.0 sec
50 mph	27 ft	11.5 sec
60 mph	35 ft	13.0 sec

Wave height will decay as waves move away from source region!!!



### Map of Mean Wind Speed (near surface):



**==> Average winds would produce relatively small waves**

**==> Best waves for surfing, usually produced by organized storms**

## Storm Characteristics

Most storms are areas of low pressure:

In Northern Hemisphere, wind flows counter-clockwise around low pressure

In Southern Hemisphere, wind flows clockwise around low pressure

Why doesn't wind flow directly toward low pressure????



# Storm Characteristics

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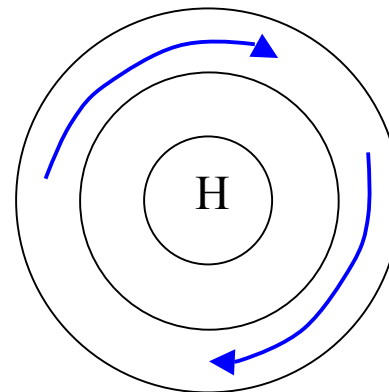
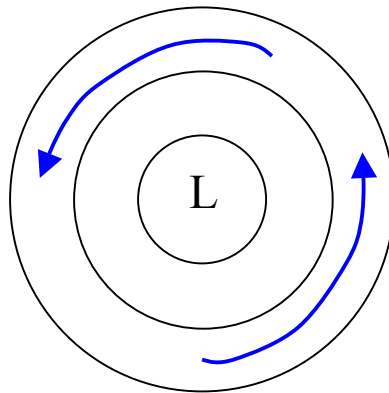
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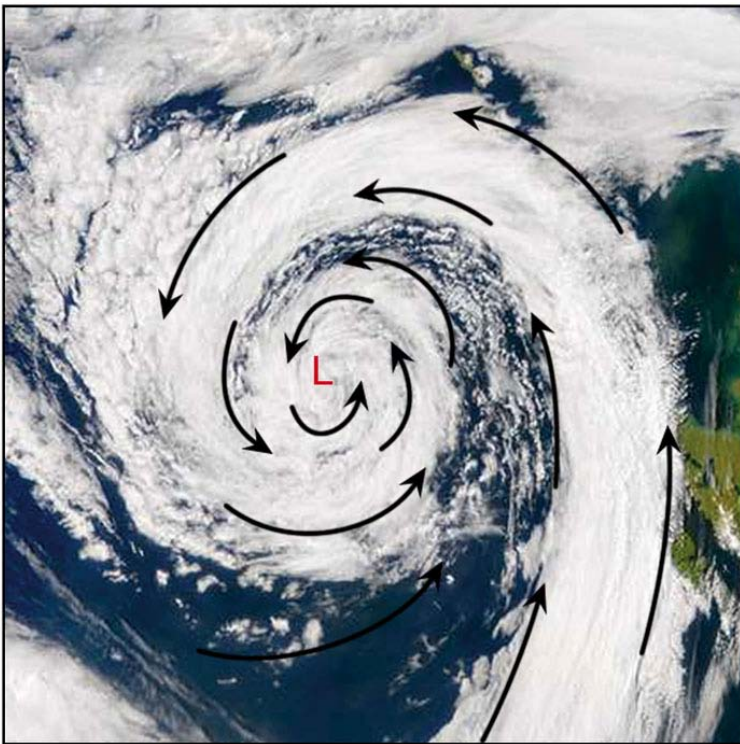
Why doesn't wind flow directly toward low pressure????

==> Because Earth is rotating and we are viewing events from rotating reference frame (Coriolis Force).

In Northern Hemisphere:



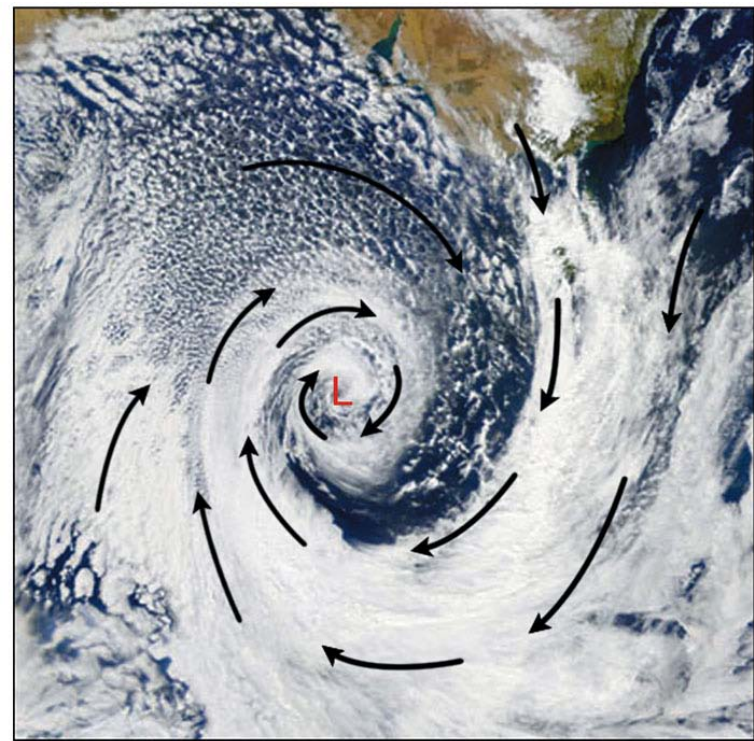
## Northern Hemisphere



(a) Northern Hemisphere

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## Southern Hemisphere



(b) Southern Hemisphere

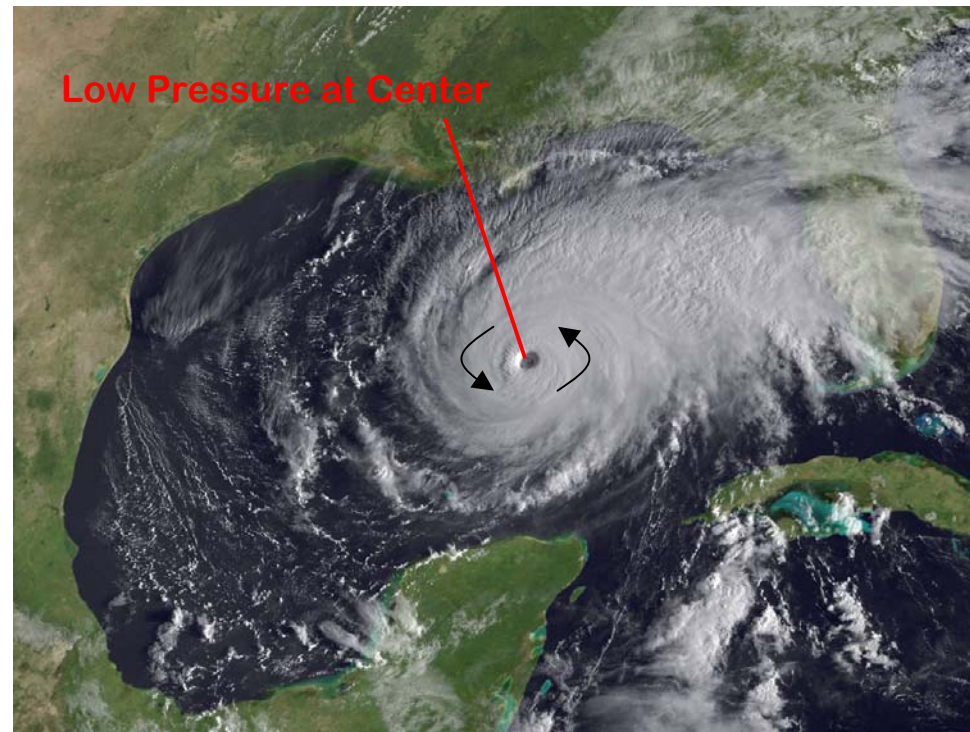
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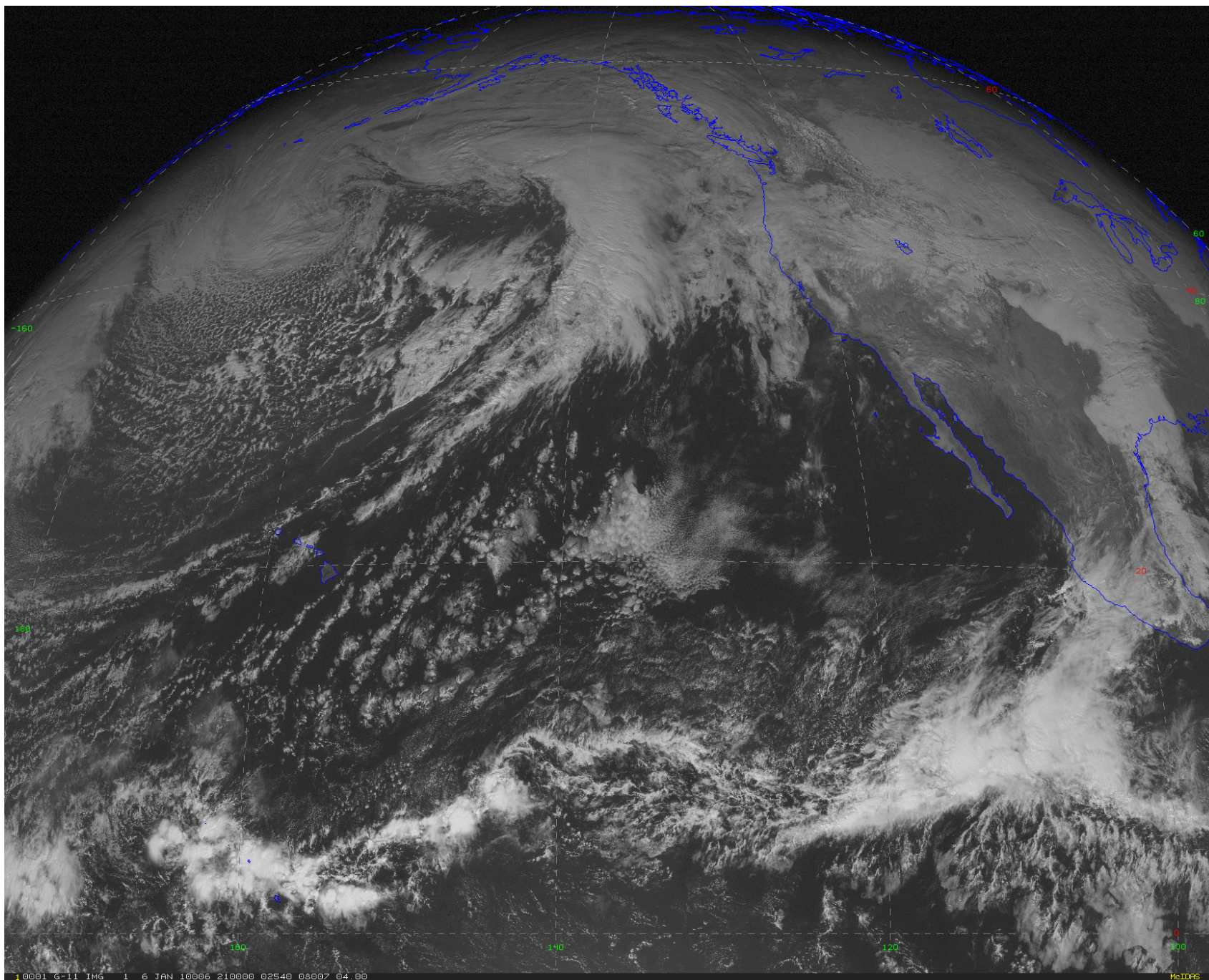


## Types of Storms:

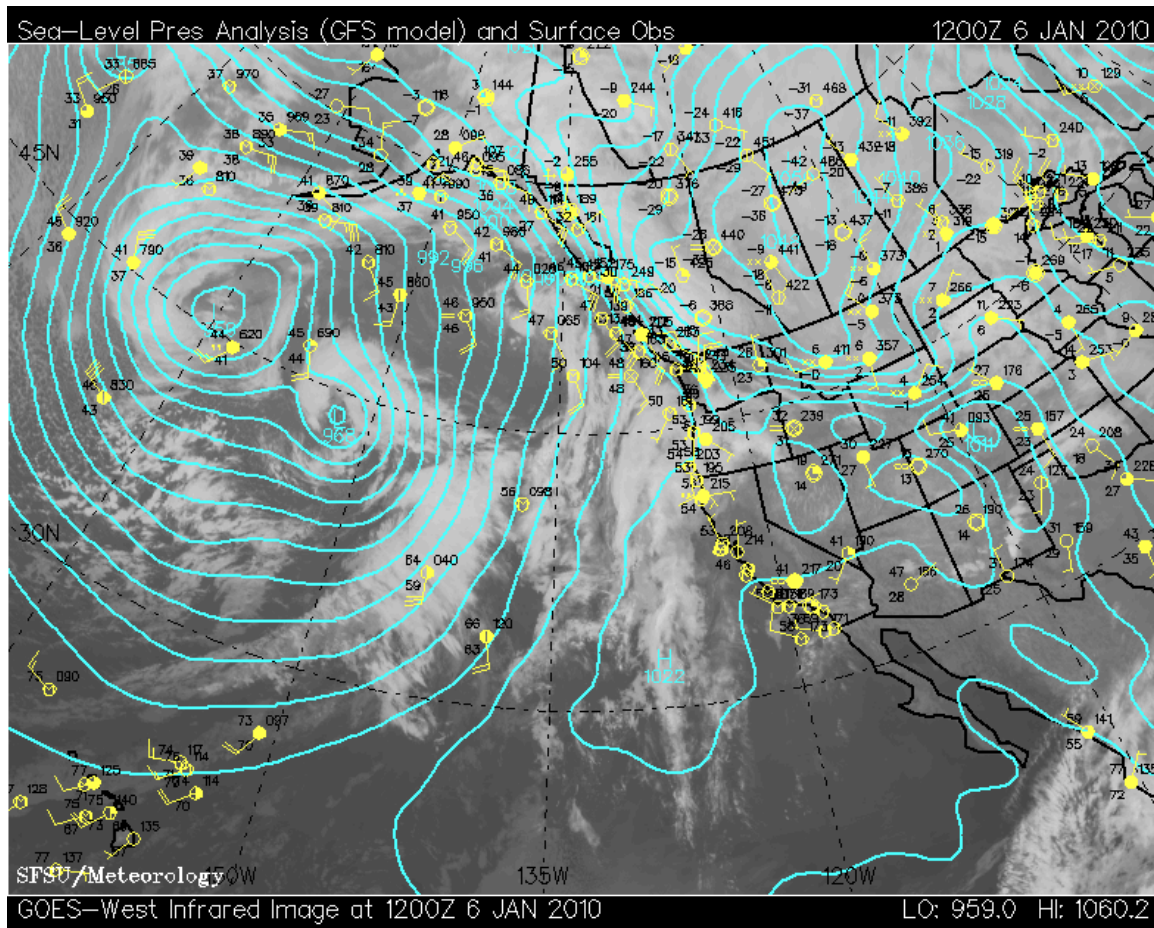
- Mid-latitude storm (Winter storms that impact California)
- Tropical Cyclone (aka, Hurricane, Typhoon)

Hurricane Katrina







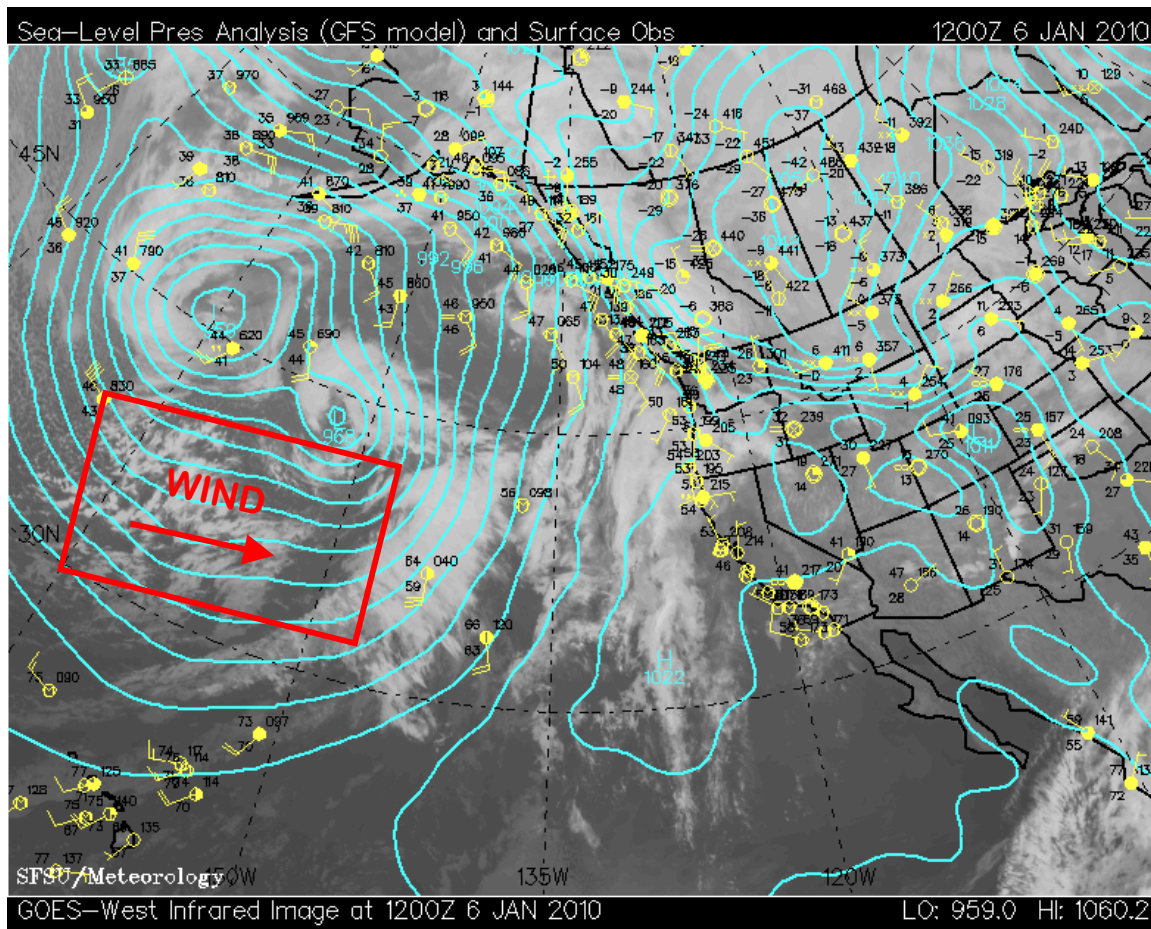


Blue lines are "isobars" = lines of equal pressure

Wind is close to parallel to isobars

Wind inversely proportional to isobar spacing  
(close isobars = fast winds)





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Geostrophic wind  $U_g = (1/\rho f)(\Delta p/\Delta d)$

Surface wind speed  $\sim 0.6 * U_g$  (due to friction)

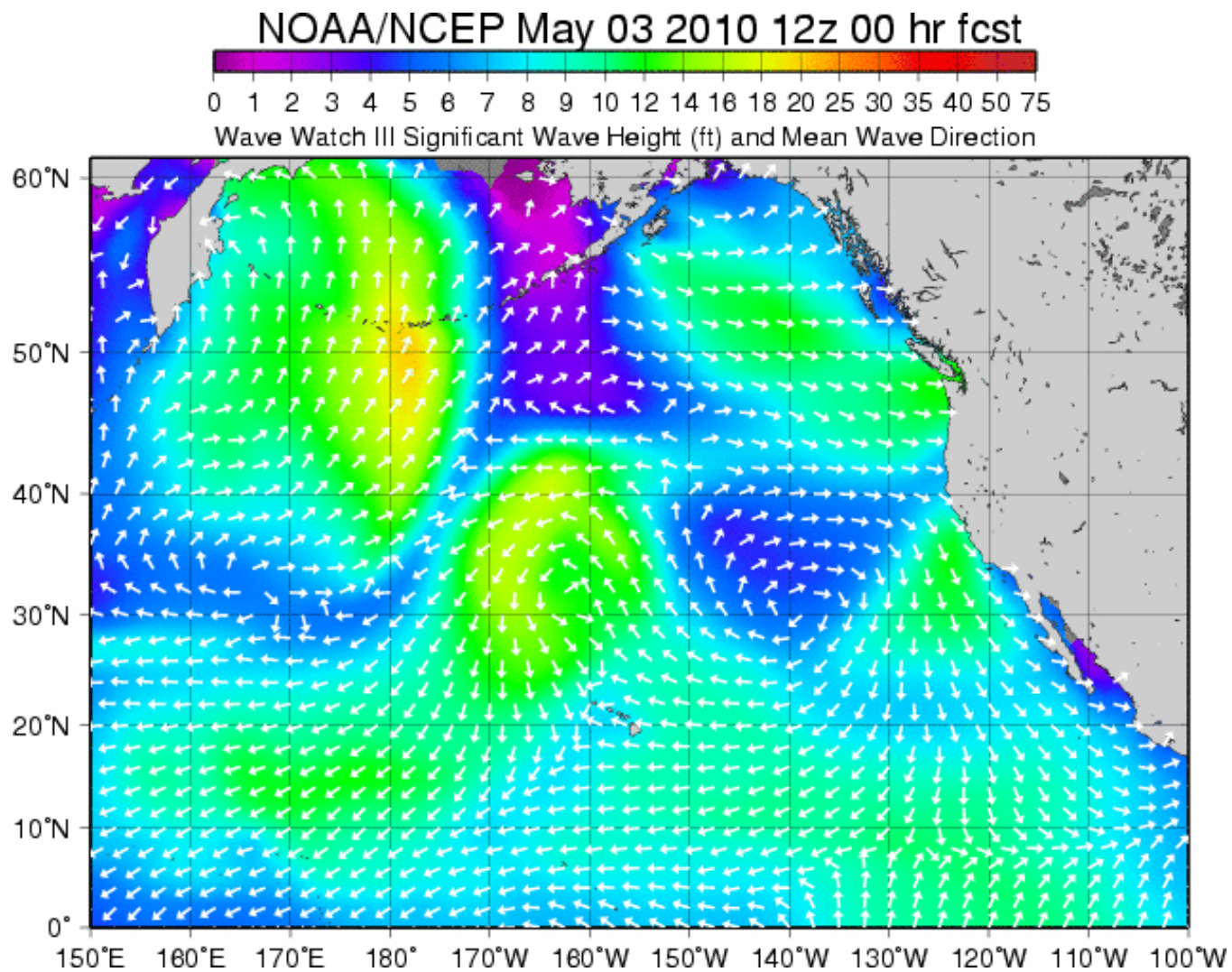
$f$  = coriolis parameter ( $2\omega \sin \phi$ )

$\phi$  = latitude

$\omega$  = rotation rate =  $2\pi/24\text{hr}$

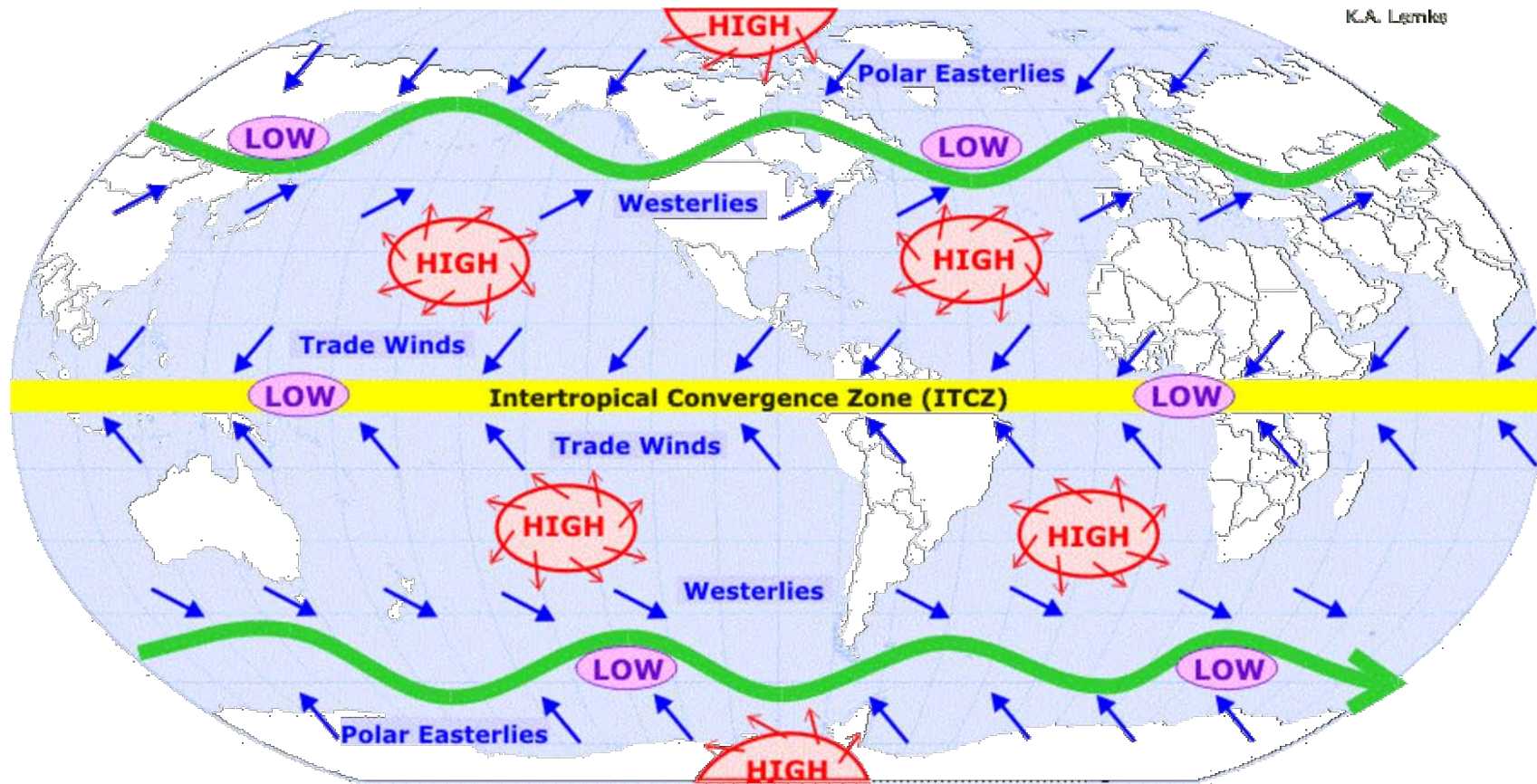
$\Delta p/\Delta d$  = horizontal pressure gradient

## Navy Models Forecast Wave Heights and Direction:





# Where do Storms Occur?

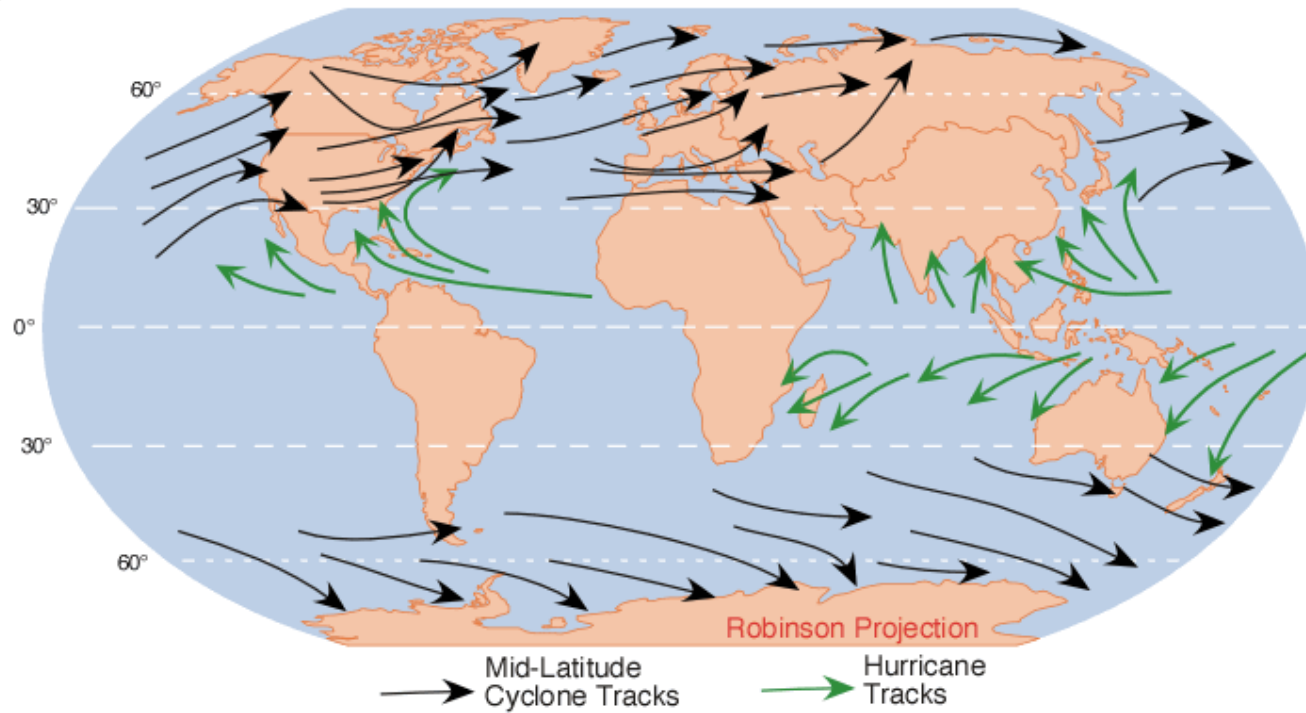


Mid-Latitude Storms generally form along polar jet stream (green lines)  
=> Strongest storms in winter season

Hurricanes form over warm ocean water ( $T > 80^{\circ}\text{F}$ ) ==> generally in tropics



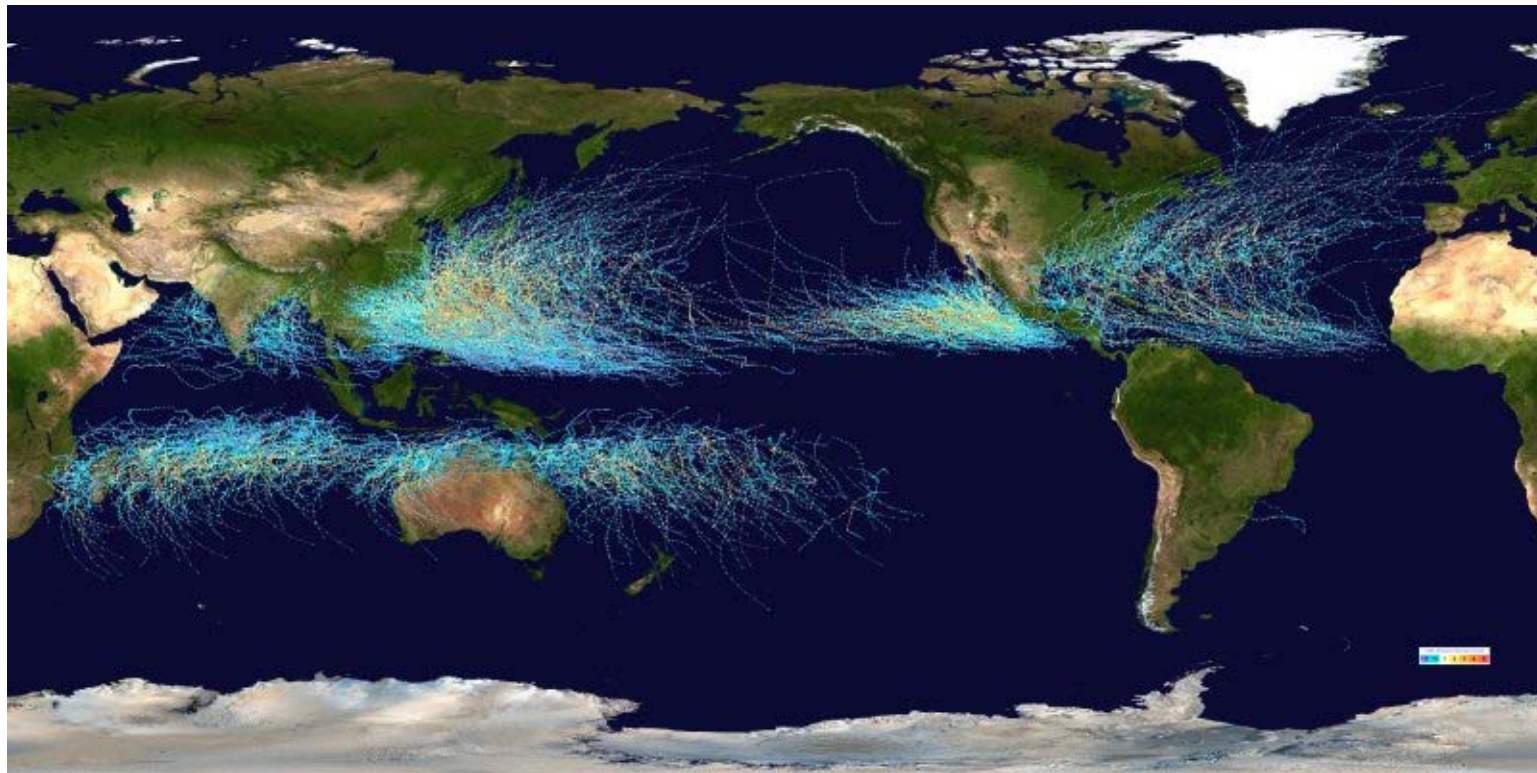
# Storm Areas



Note: Southern Ocean little or no land barriers so storms are not slowed down  
= More consistent wave generation

# Hurricane Tracks

- Generally move from equator towards poles
- No hurricanes in South Atlantic or South Eastern Pacific  
==> Water temps are too cold for hurricanes to form

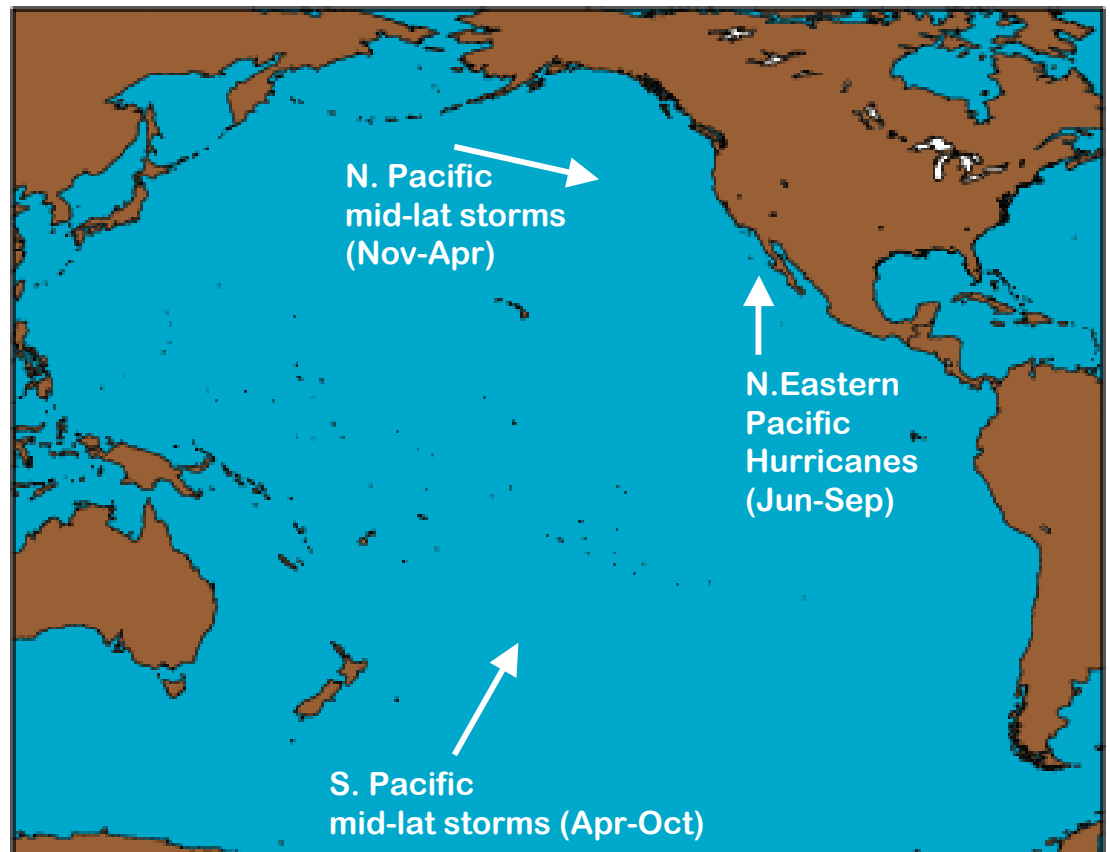


# California Wave Sources

Winter: Mid-latitude storms in North Pacific

Summer: Mid-latitude storms in South Pacific (surfing slang = Southern Hemis)  
Hurricanes off west coast of Mexico

All Seasons: Local wind swell  
This is usually moderate winds close to California  
Produces short interval swell





# California Wave Sources

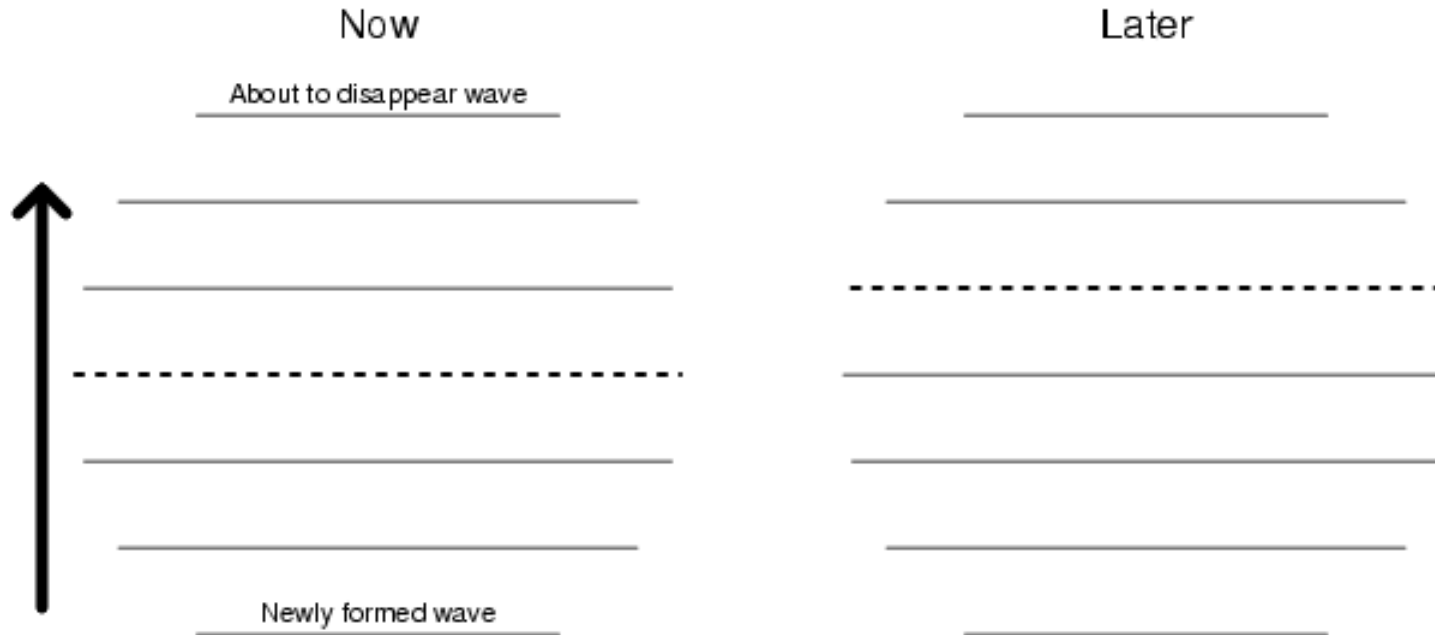
Travel Time for 15 second period wave

- in deep water,  $C = gT/2\pi$

BUT, this is the "wave speed", the speed that the wave form travels.

- the wave energy travels at  $C_g$  (also known as "group" speed),  
where  $C_g = 0.5 C$

- so, the energy travels slower than the waves themselves.



# California Wave Sources

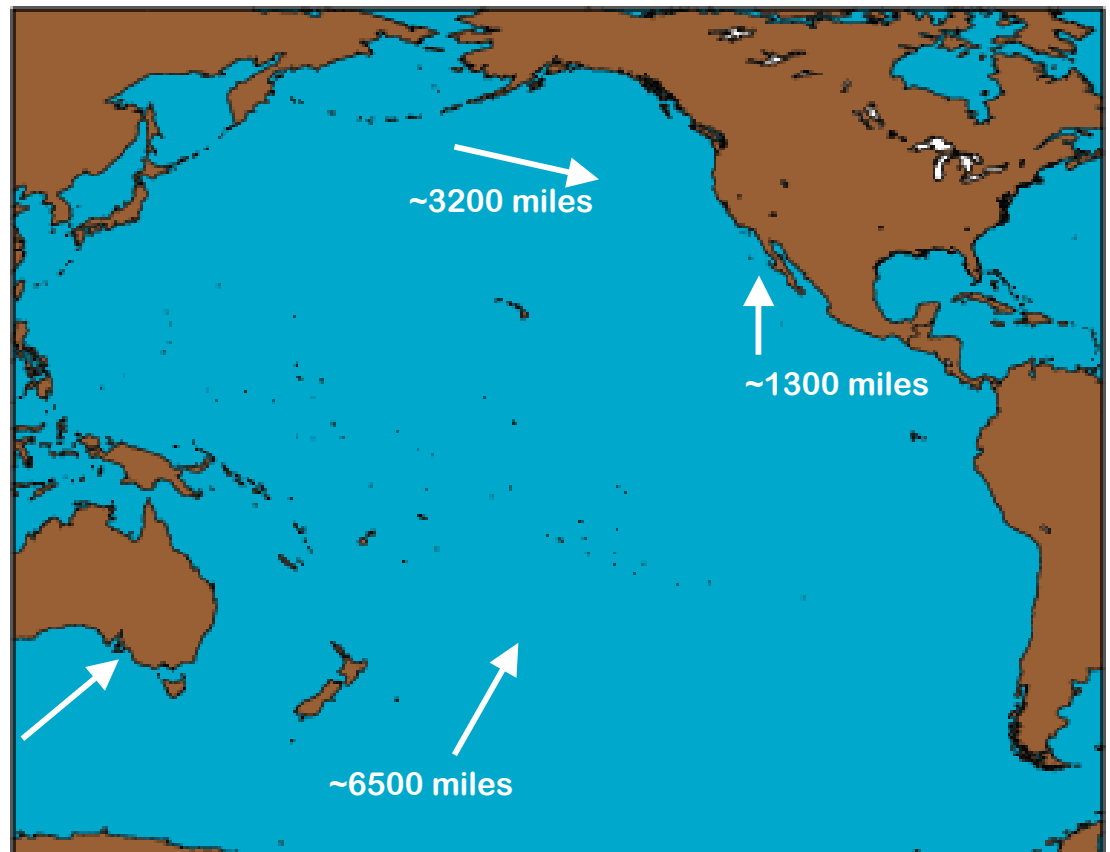
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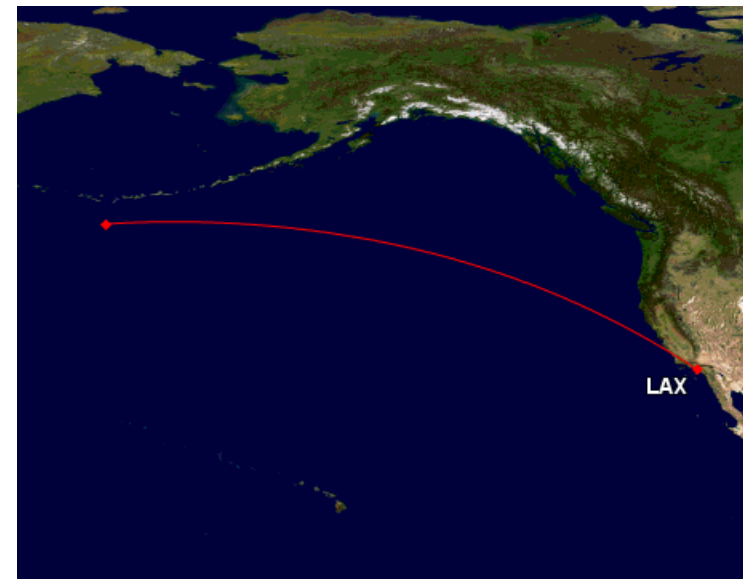
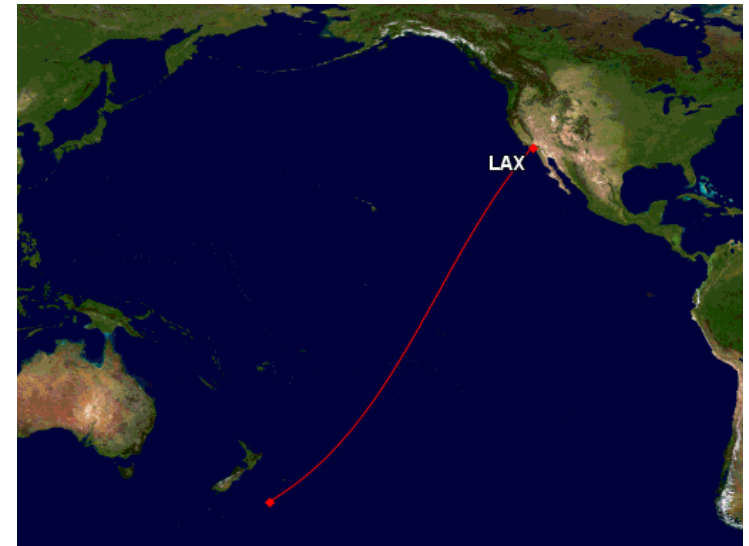
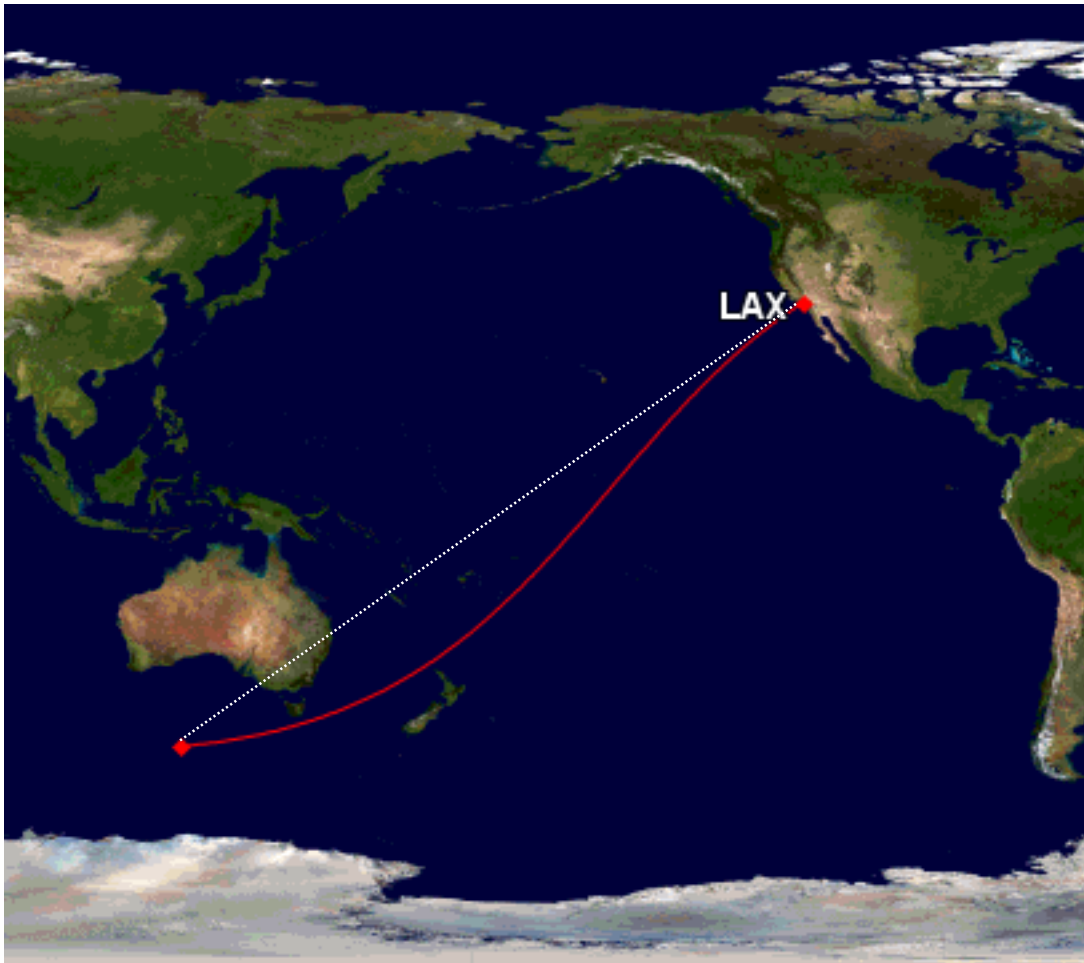
If  $T=15$ ,  $C = 23\text{m/sec} = 52\text{ mph}$   
So,  $C_g = 26\text{ mph}$

<u>Source</u>	<u>Travel Time</u>
North Pacific	~ 5 days
Mex. Hurricanes	~ 2 days
South Pacific	~ 10 days



# Great Circle Paths

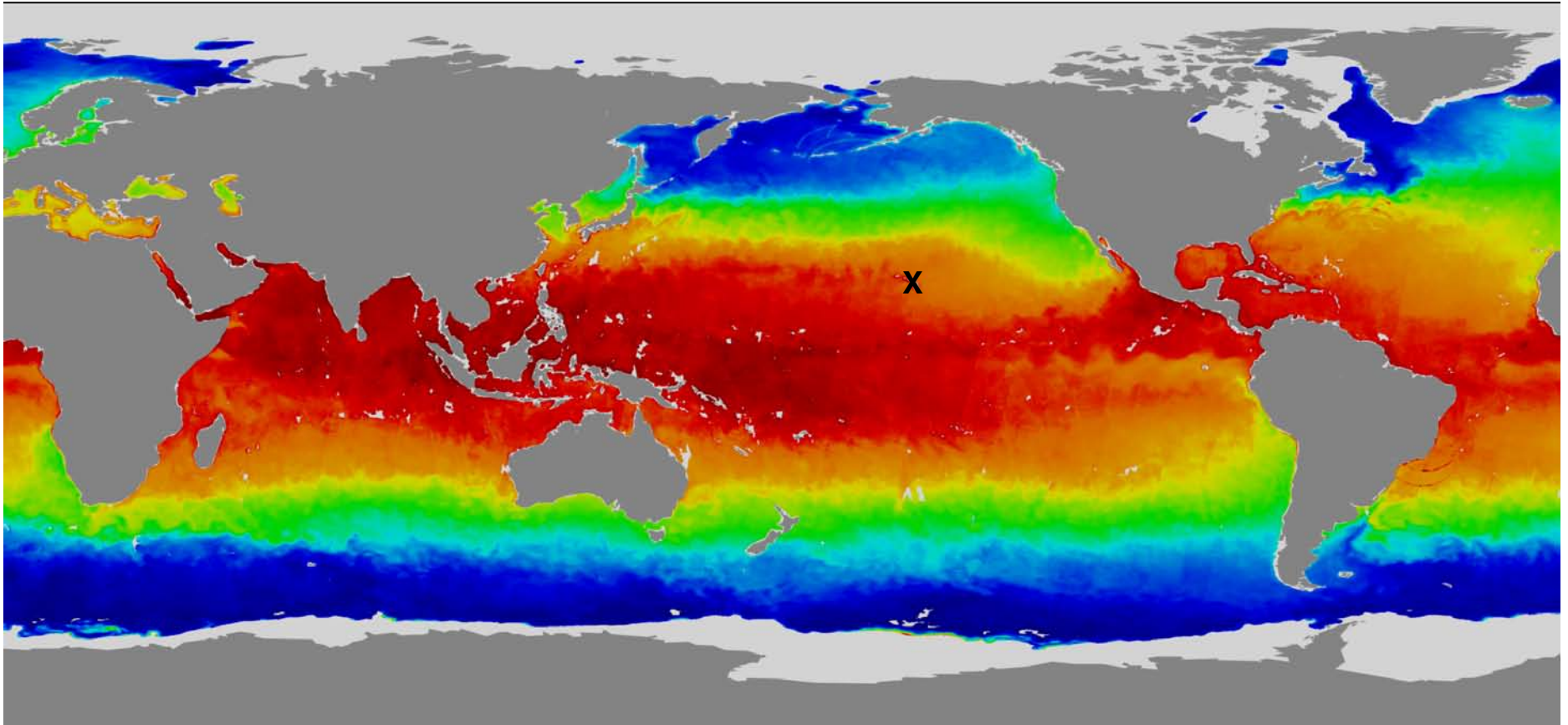
maps are flat, but Earth is a sphere!





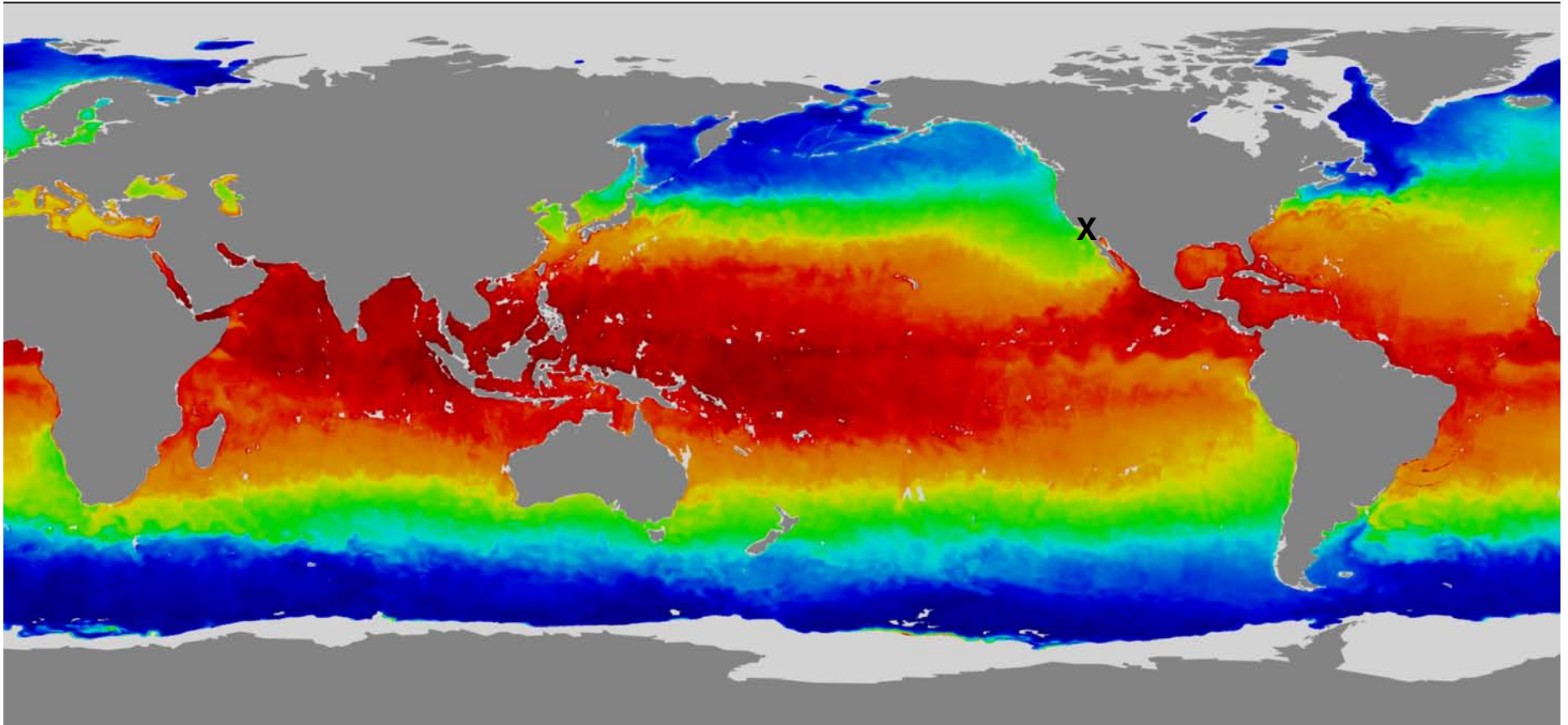
## What areas are best for surfing?

- Need exposure to good swell generating regions
- Generally on west coasts of continents better than east coasts
  - mid-latitude storms move west-to-east => usually stronger winds aimed at west coasts
- Islands
  - Coasts facing all directions - can pick up swells from many different sources
- Areas away from storm regions
  - at least areas with normally light winds
- Warm water
  - not necessary, but nice



X = Hawaii

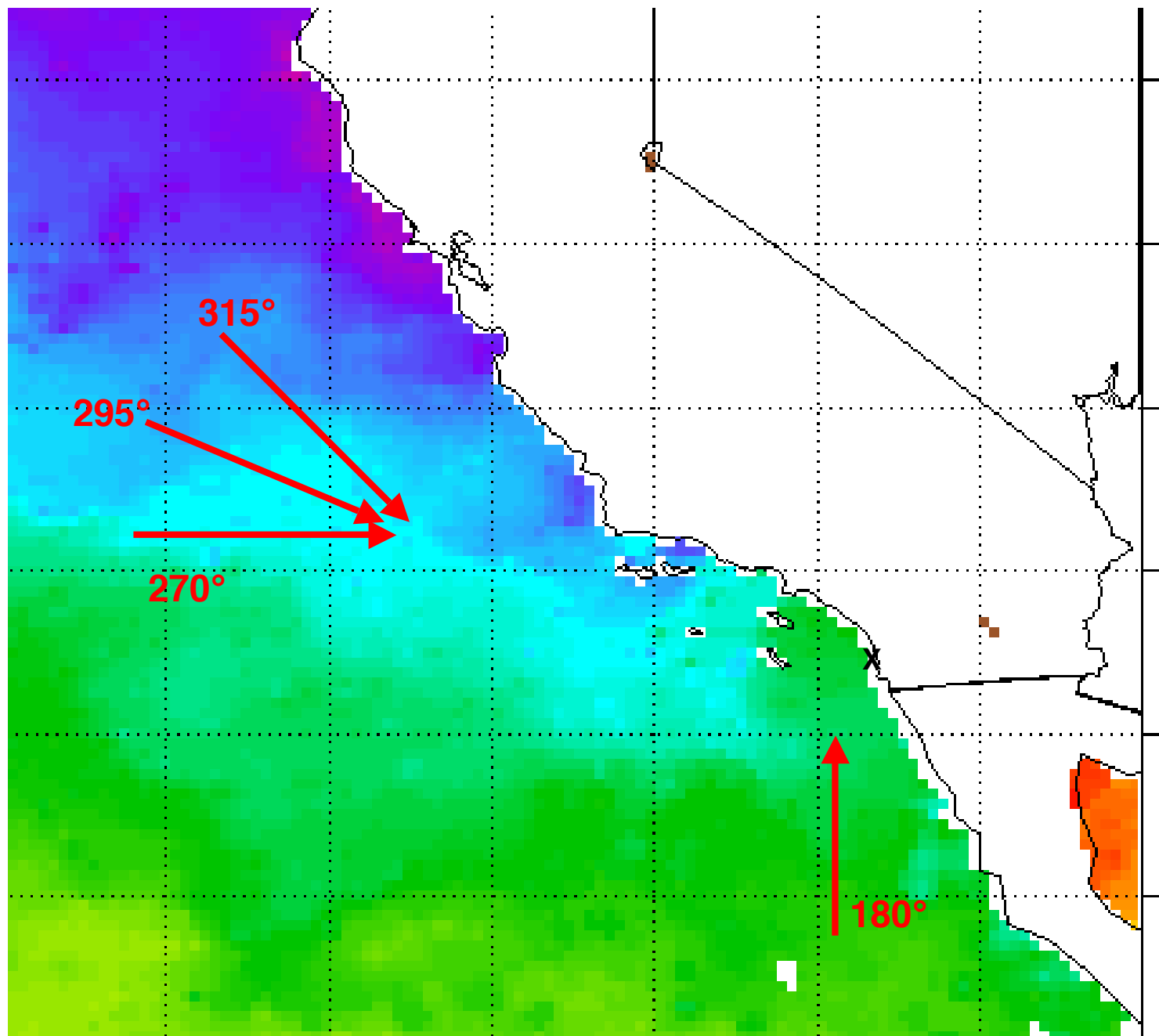
- Exposure to N. Pacific storms, S. Pacific storms, and some Mex. hurricanes
- light-moderate tradewinds (consistent direction year round)
- warm water ( $\sim 75^{\circ}\text{F}$ )
- short transition from deep to shallow water (waves do not lose much energy)

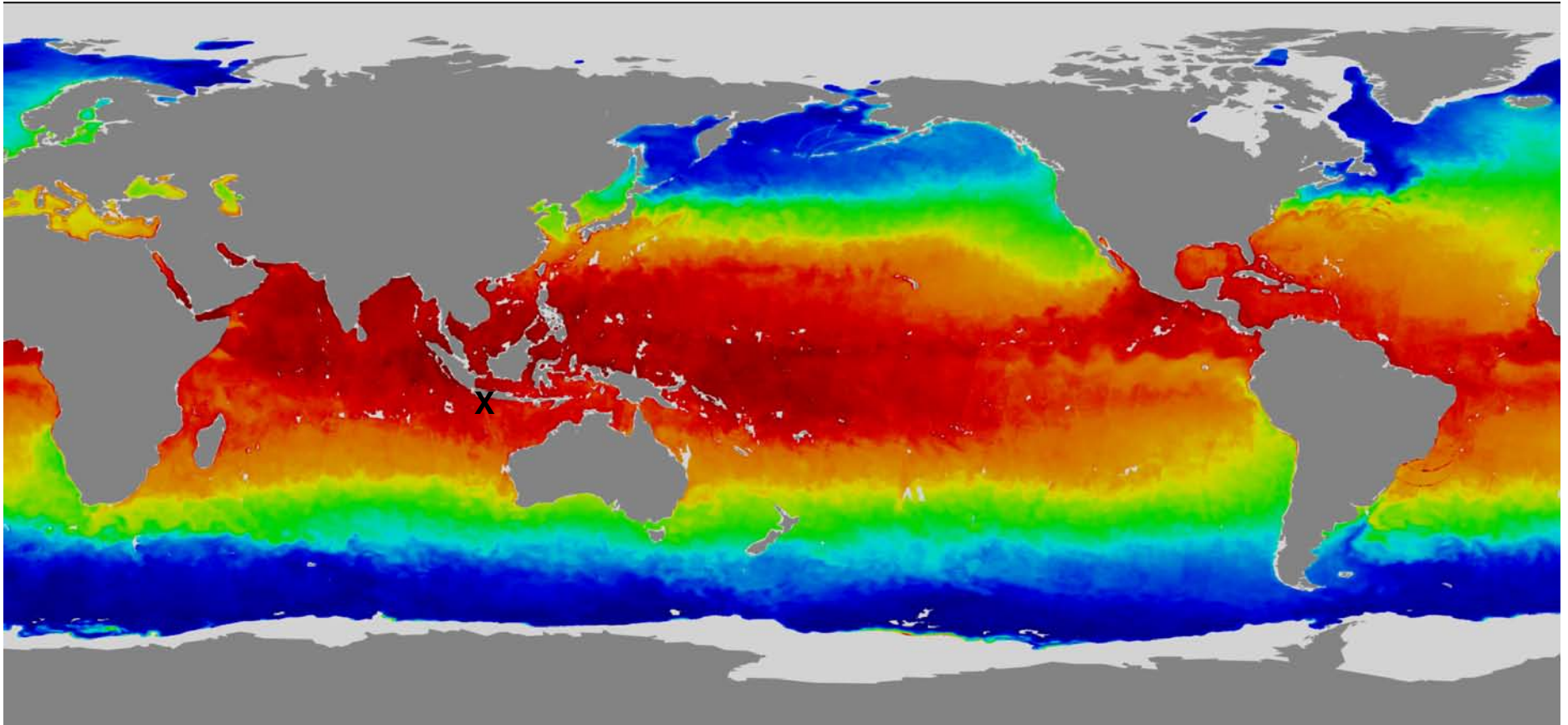


X = San Diego

- Exposure to N. Pacific storms, S. Pacific storms, and Mex. hurricanes
- generally light winds (sea-breeze in summer not great)
- cold-warm water ( $\sim 58-72^{\circ}\text{F}$ )
- moderate transition from deep to shallow water (waves do lose some energy)
- also, waves must wrap around (refraction) Point Conception and Channel Islands  
==> more energy loss







X = Indonesia

- Exposure to S. Pacific storms, and some hurricanes
- light-moderate winds (monsoonal circulation = direction changes seasonally)
- very warm water ( $\sim 85^{\circ}\text{F}$ )