

# California Offshore Wind Energy Potential

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# California Offshore Wind Energy Potential



Coast north of Cape Mendocino at Somoa Beach

- Dvorak, Archer, Jacobson, *Renewable Energy* (2010)
- Found **174-224%** of **CA's electricity** demand could come from offshore wind
- Analyzed turbine **foundation** technology, wind **resource**, and **geographic context** of the resource
- Meteorological **drivers** behind the **summertime resource**



# Motivation - Coastal Population



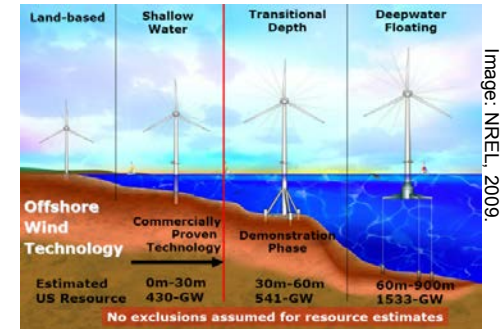
Chose California to study:

- **high price** of electricity (9<sup>th</sup>, retail 13.24 cents/kWh<sup>1</sup>)
- long history of **energy innovation**
- **large populations** near coast (LA & SF)
- presumed **too deep/costly** to develop

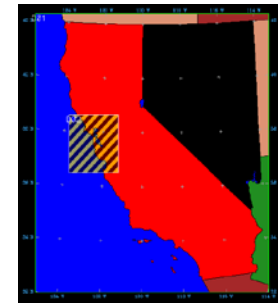


# Offshore Wind Resource Assessment Method

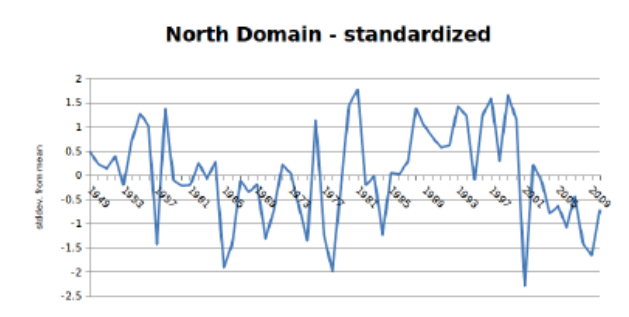
1) Locate potential turbine locations



2) Create a climate modeling configuration covering the shallow water



3) Determine climatologically significant years



# Offshore Wind Resource Assessment Method

4) Run multiple years on a supercomputer



Image: NCAR.

5) Validate the modeled winds

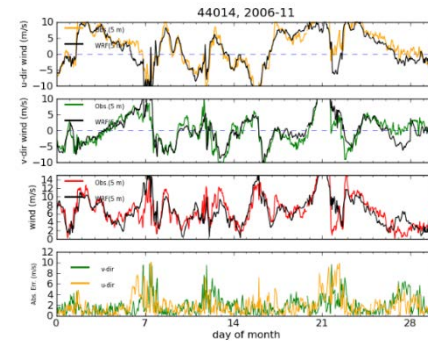
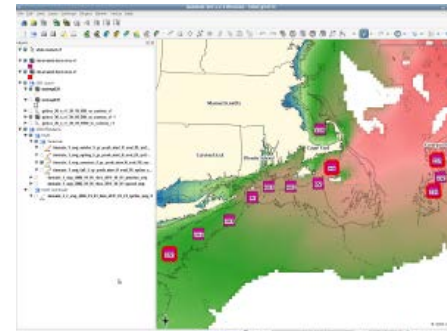


Image: NDBC.

6) Post-processing and analysis of wind fields with GIS



# Offshore wind foundations

## Turbine Foundation Classes<sup>1,2</sup>



**Monopile<sup>2</sup>:**  
**0-20 m depth**



**Multileg structure<sup>2</sup>:**  
**21m-50m**



**Floating<sup>3</sup>:**  
**51m-200m**  
**(future)**

**Increasing project cost**

Sources:

1. Dvorak, Archer, Jacobson (2010)

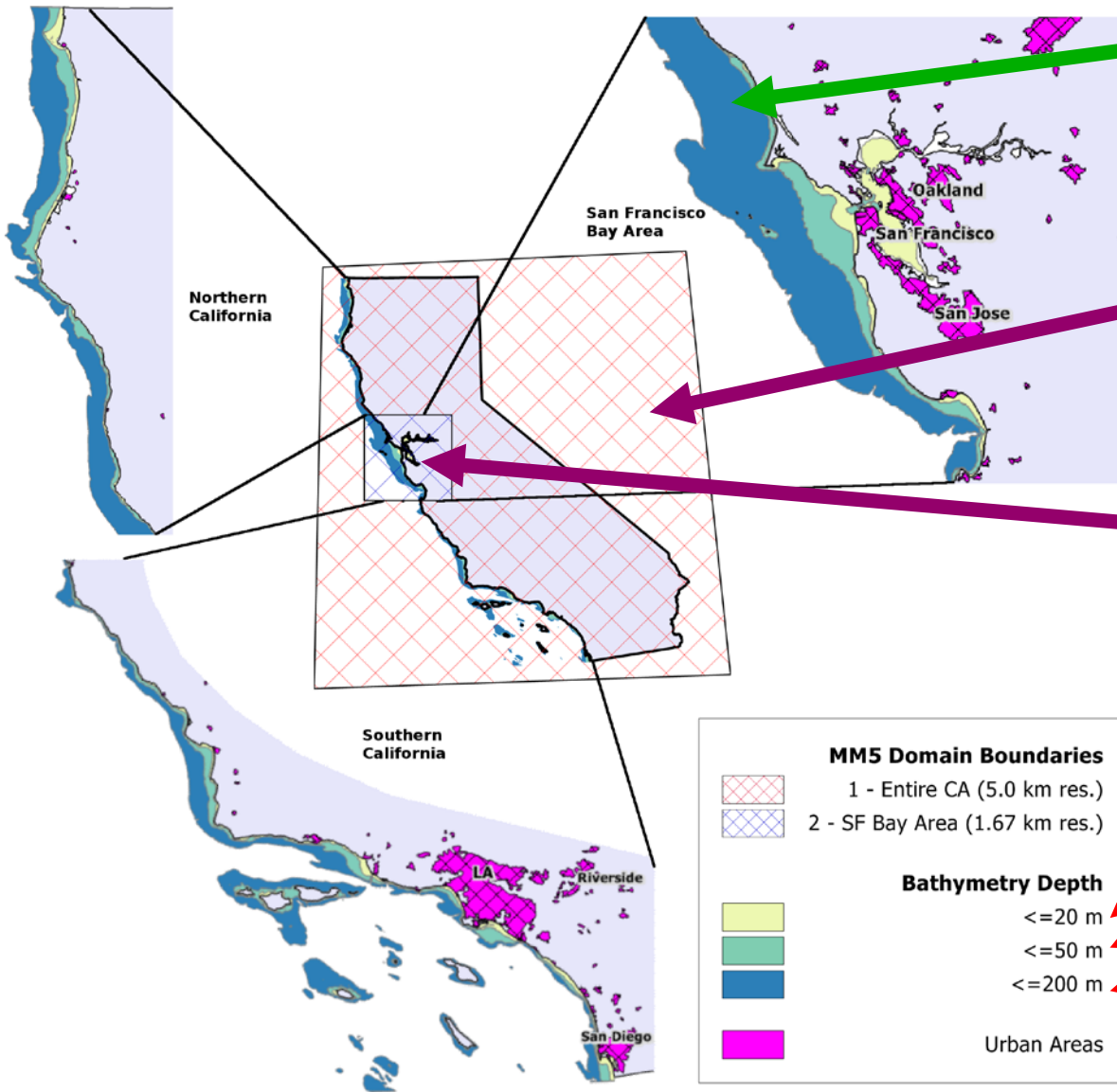
2. <http://offshorewindenergy.org>

3. Principle Power, Inc.



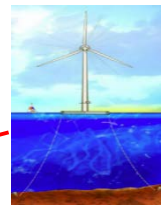
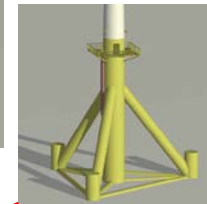
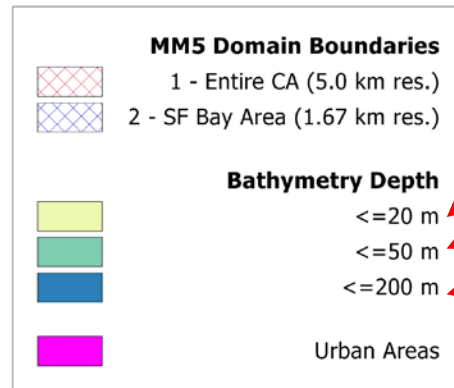
# Siting of turbines and modeling of wind

*Nat. Geophys. Data Center 3-arc second Coastal Relief (~30 m)*



*MM5 – 5.0 km domain, entire CA*

*MM5 – 1.67 km domain, SF Bay*

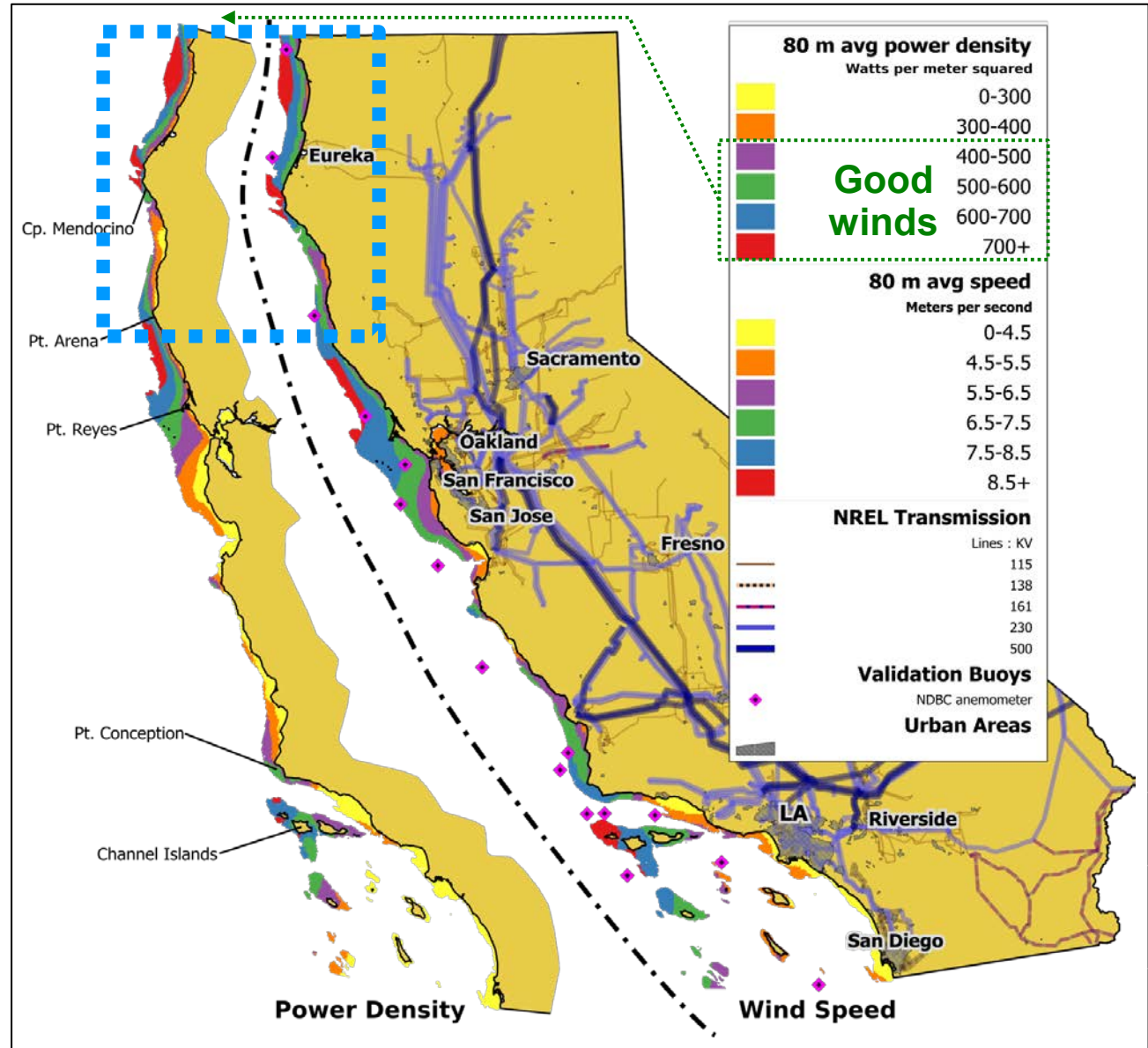


# California Geographic Context: Northern

- Could offset 7-11% of CA's current CO<sub>2</sub> emitting generation today

- Deep water tech could replace 114-235% of CA's CO<sub>2</sub> emitting generation

- Lack of coastal transmission



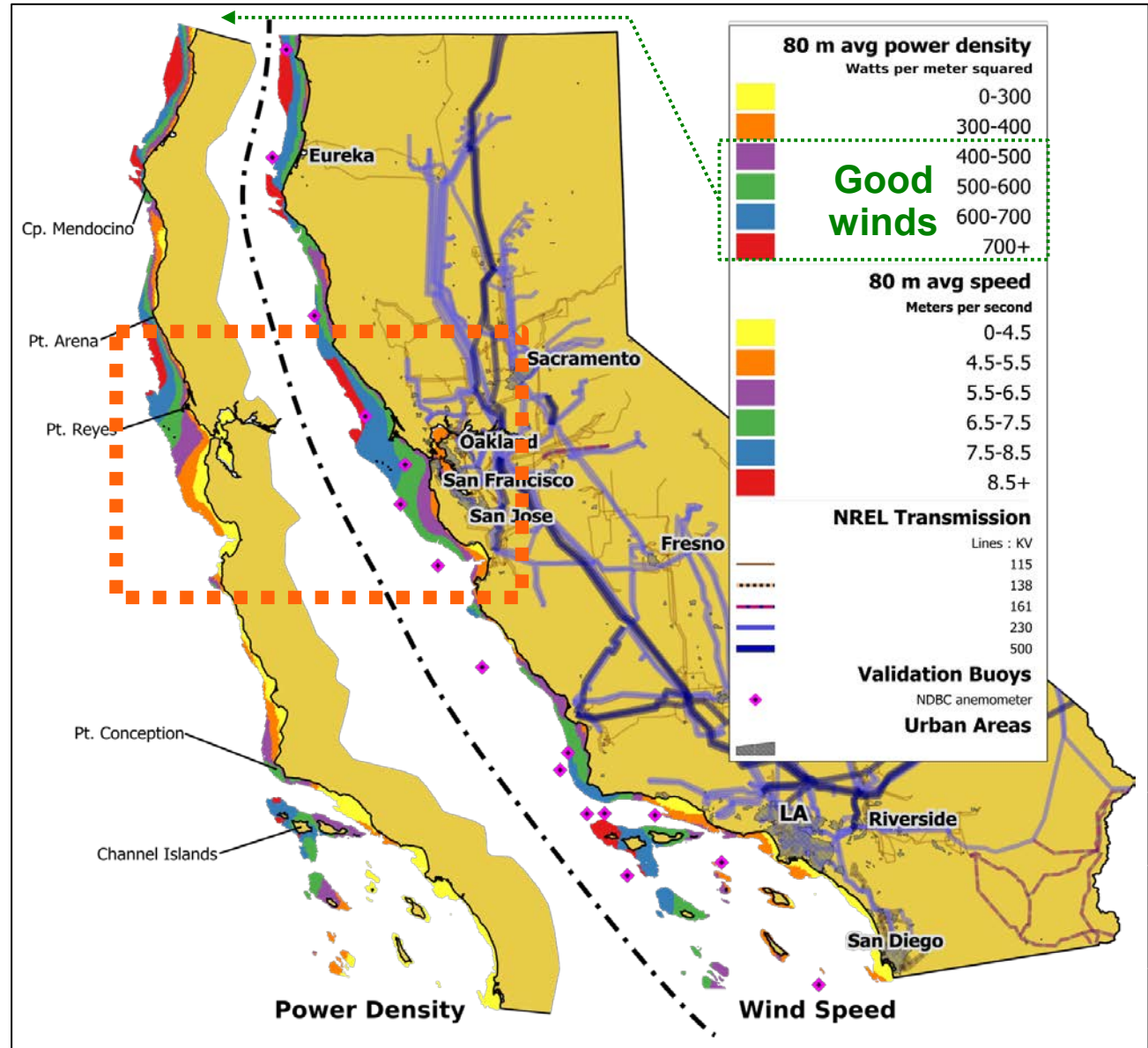
80 m wind climatology from 2005, 2006, 2007





# California Geographic Context: Central

- **Good resource** and transmission **far** from San Francisco and in **deep water**
- Farallon Islands potentially interesting...
- San Francisco Bay not adequately resolved for conclusion

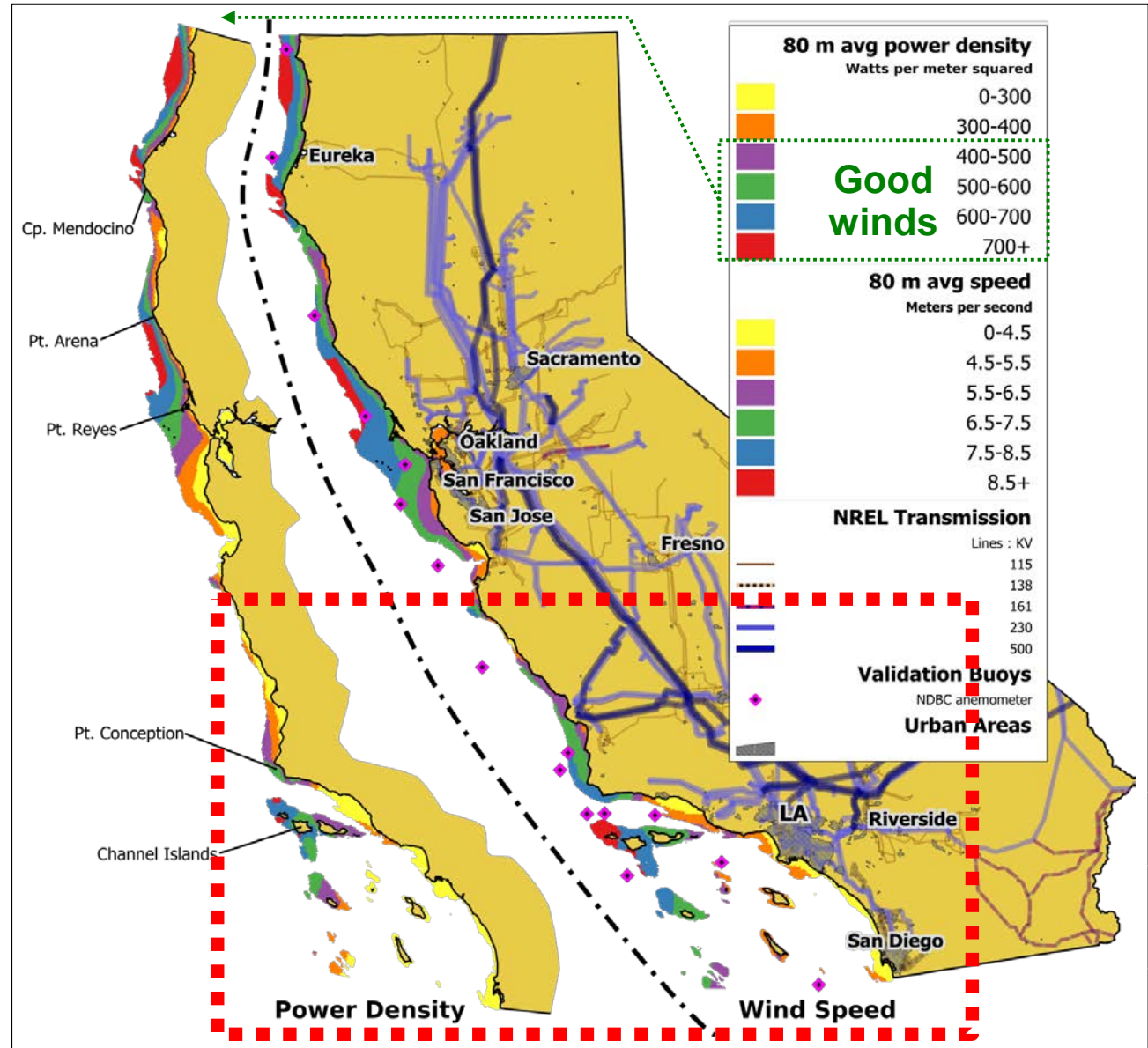


80 m wind climatology from 2005, 2006, 2007



# California Geographic Context: Southern

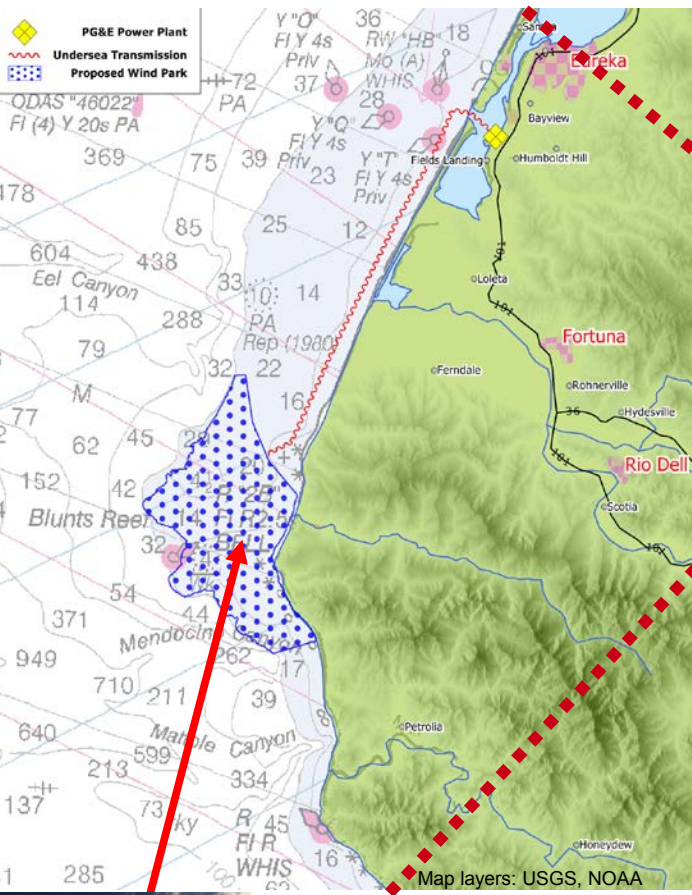
- **Highest pop.** but least easily developable resource
- Good winds far offshore in **deep waters**
- Good **transmission access** near LA but poor winds
- Pt. Conception good winds but deep



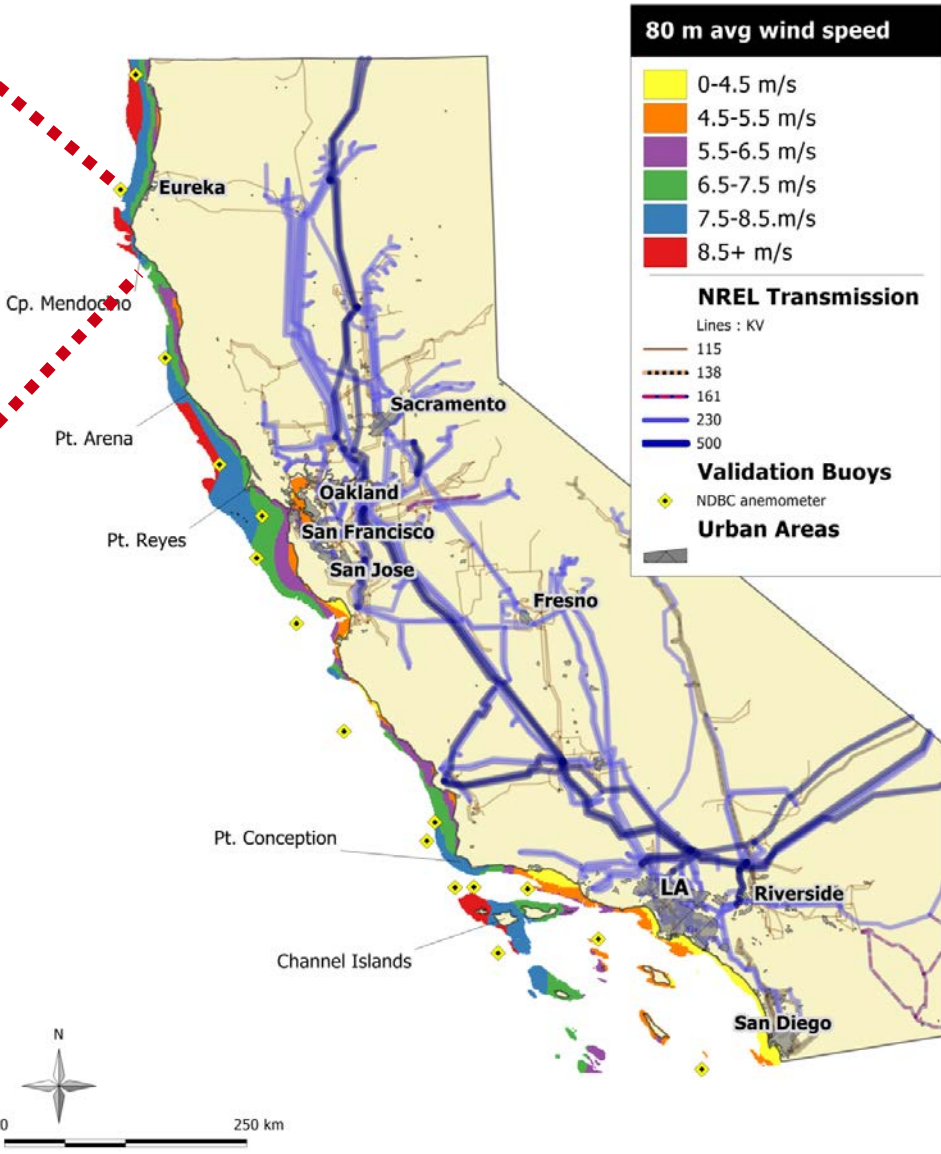
80 m wind climatology from 2005, 2006, 2007



# Proposed Cape Mendocino Wind Park



Source: Dvorak, Archer, Jacobson, 2009.



**80 m avg wind speed**

- 0-4.5 m/s
- 4.5-5.5 m/s
- 5.5-6.5 m/s
- 6.5-7.5 m/s
- 7.5-8.5 m/s
- 8.5+ m/s

**NREL Transmission**

Lines : KV

- 115
- 138
- 161
- 230
- 500

**Validation Buoys**

- NDBC anemometer

**Urban Areas**

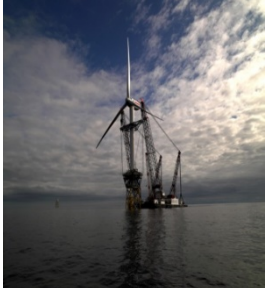
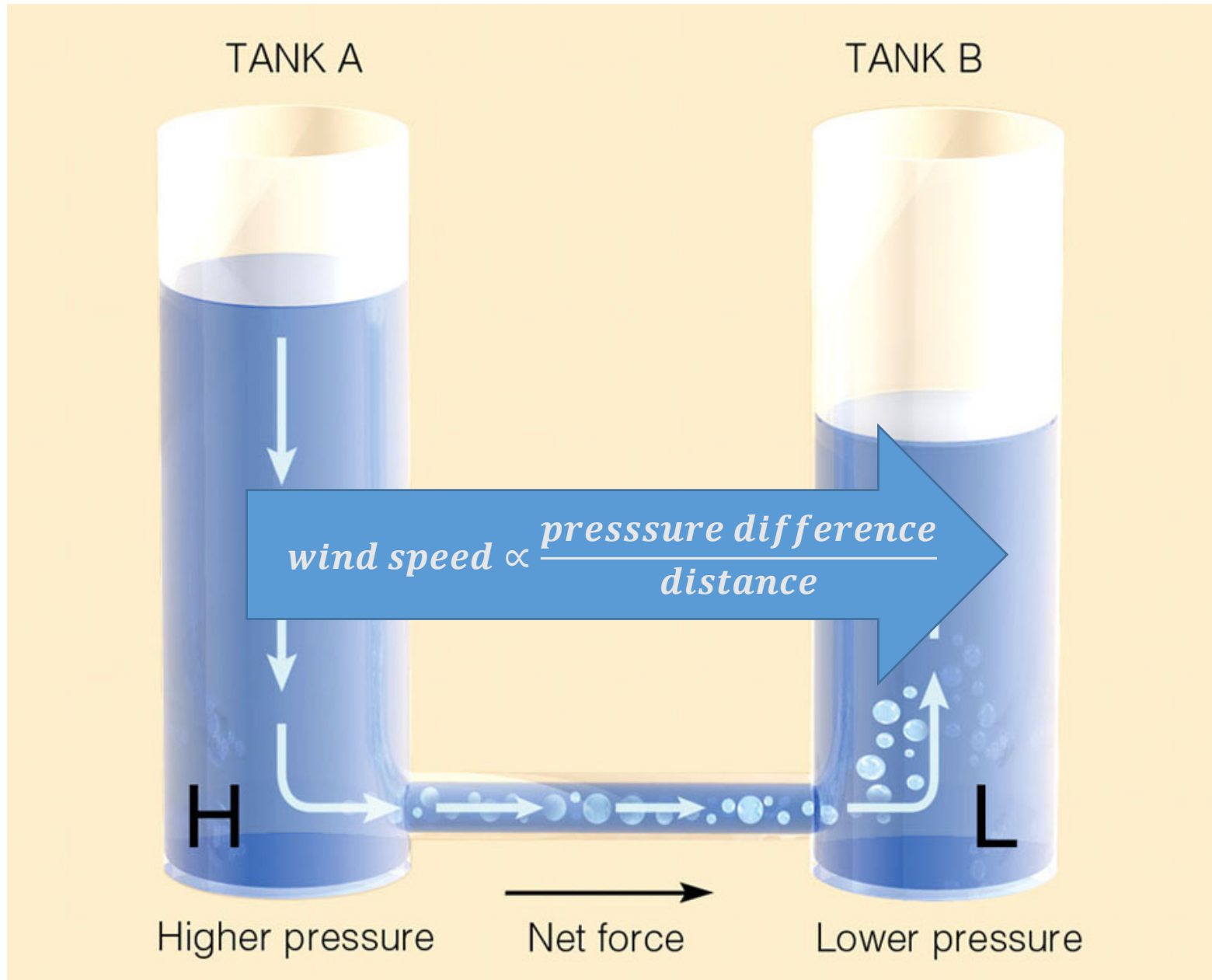


Photo credit: GE

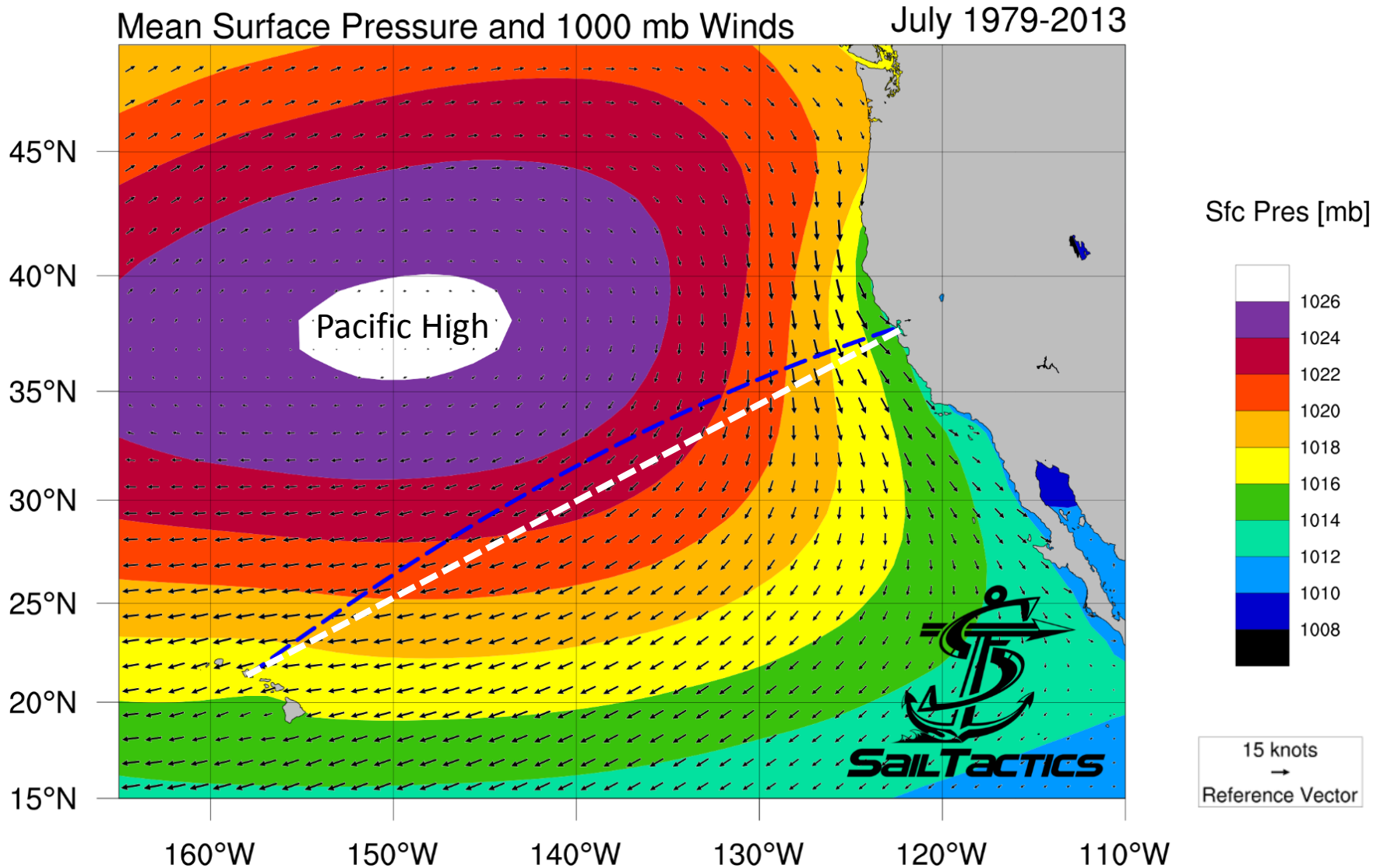
- 300 REpower 5M 5.0 MW turbines
- 600 MW avg output
- 4.0% (gross) CA's current carbon emitting generation (40% CF)



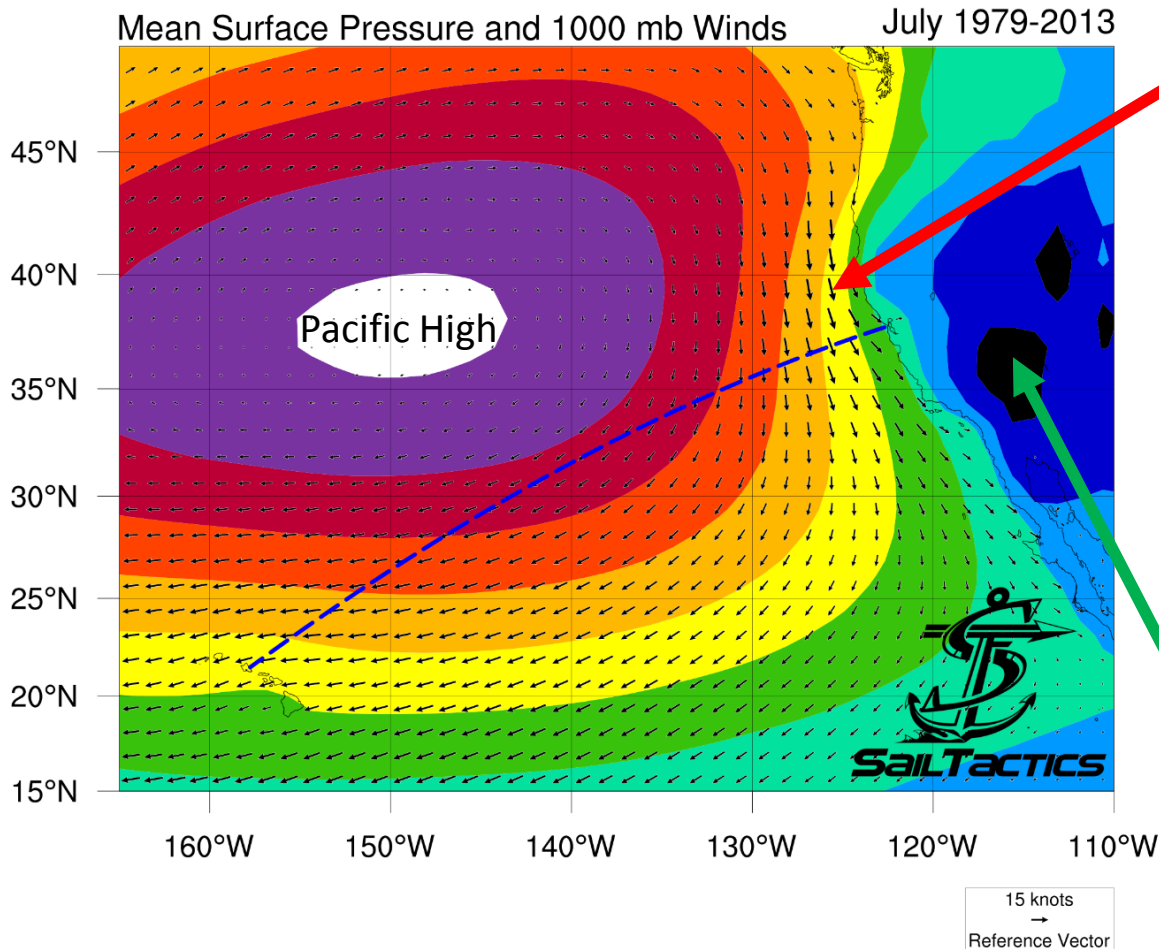
# Recipe for Wind - Simple



# Ocean Sailor's Perspective on Summertime Winds



# Summertime California Coastal Winds

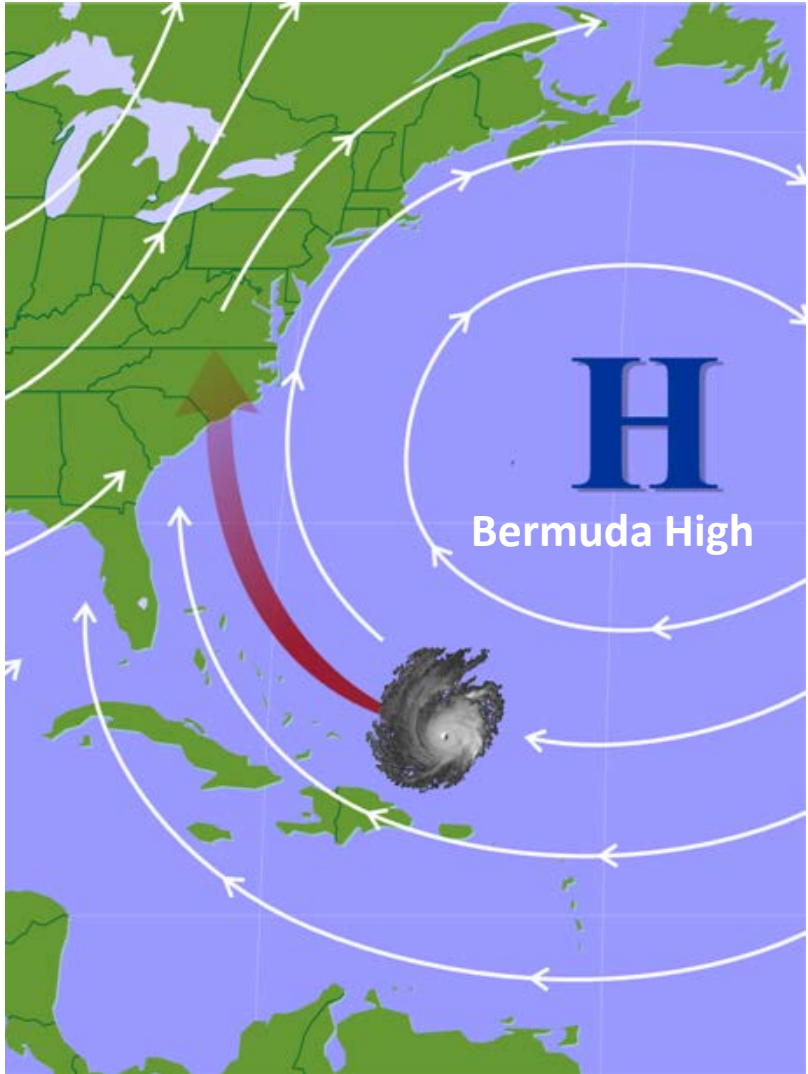


**Driven by:**  
Steep Pacific  
High pressure  
gradient

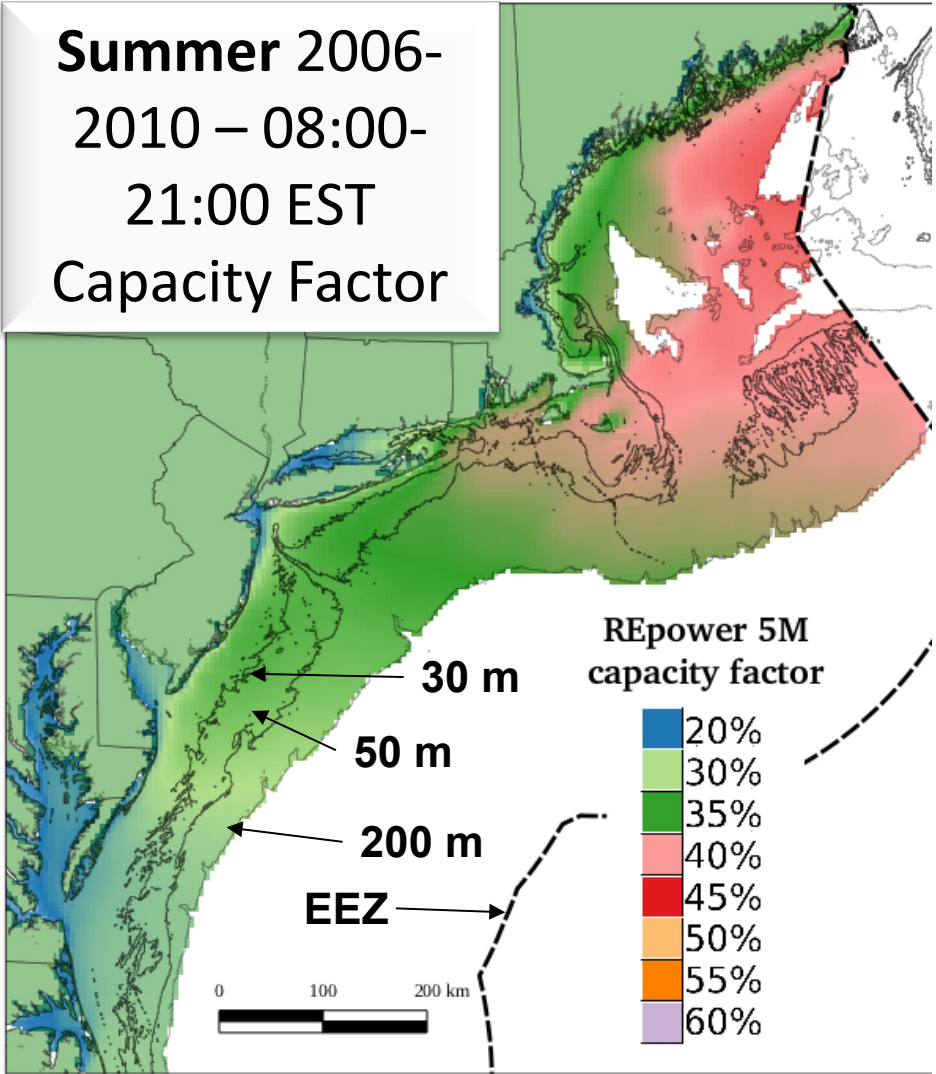
**BIG PRESSURE  
DIFFERENCE  
over SHORT  
DISTANCE  
=  
BIG WINDS**

Southwest  
Thermal  
Low

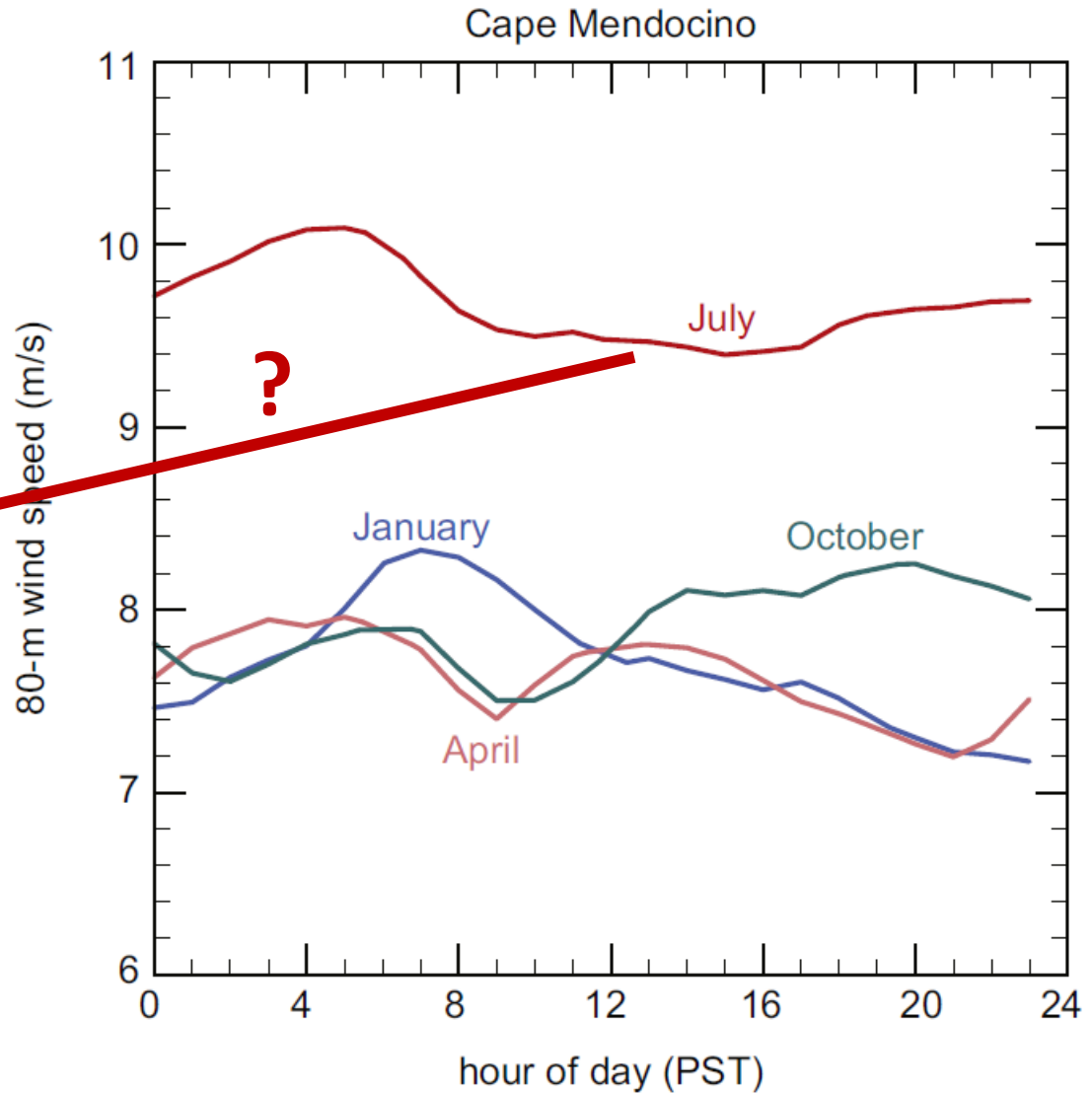
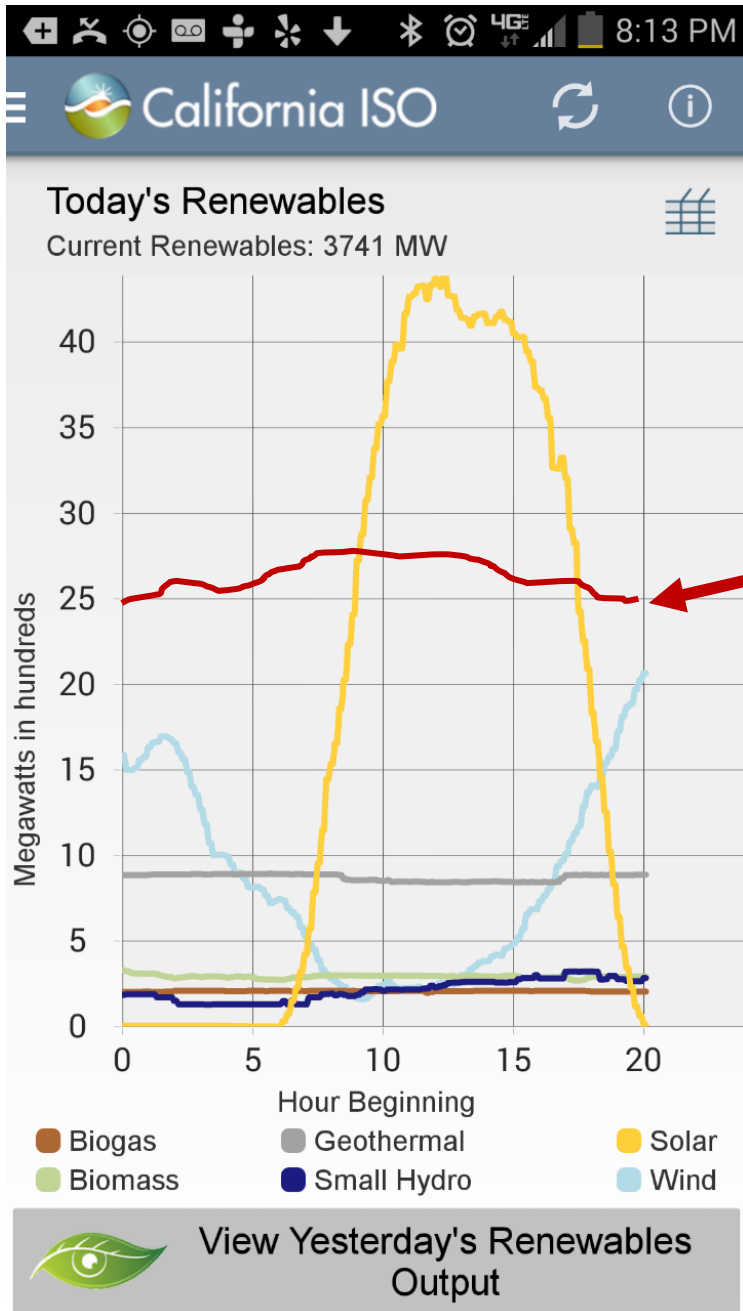
# West vs East Coast – High Pressure Situation



Source: e-education.psu.edu



Source: Dvorak, M.J., et al., 2013. [US East Coast offshore wind energy resources and their relationship to peak-time electricity demand](#). *Wind Energy*.

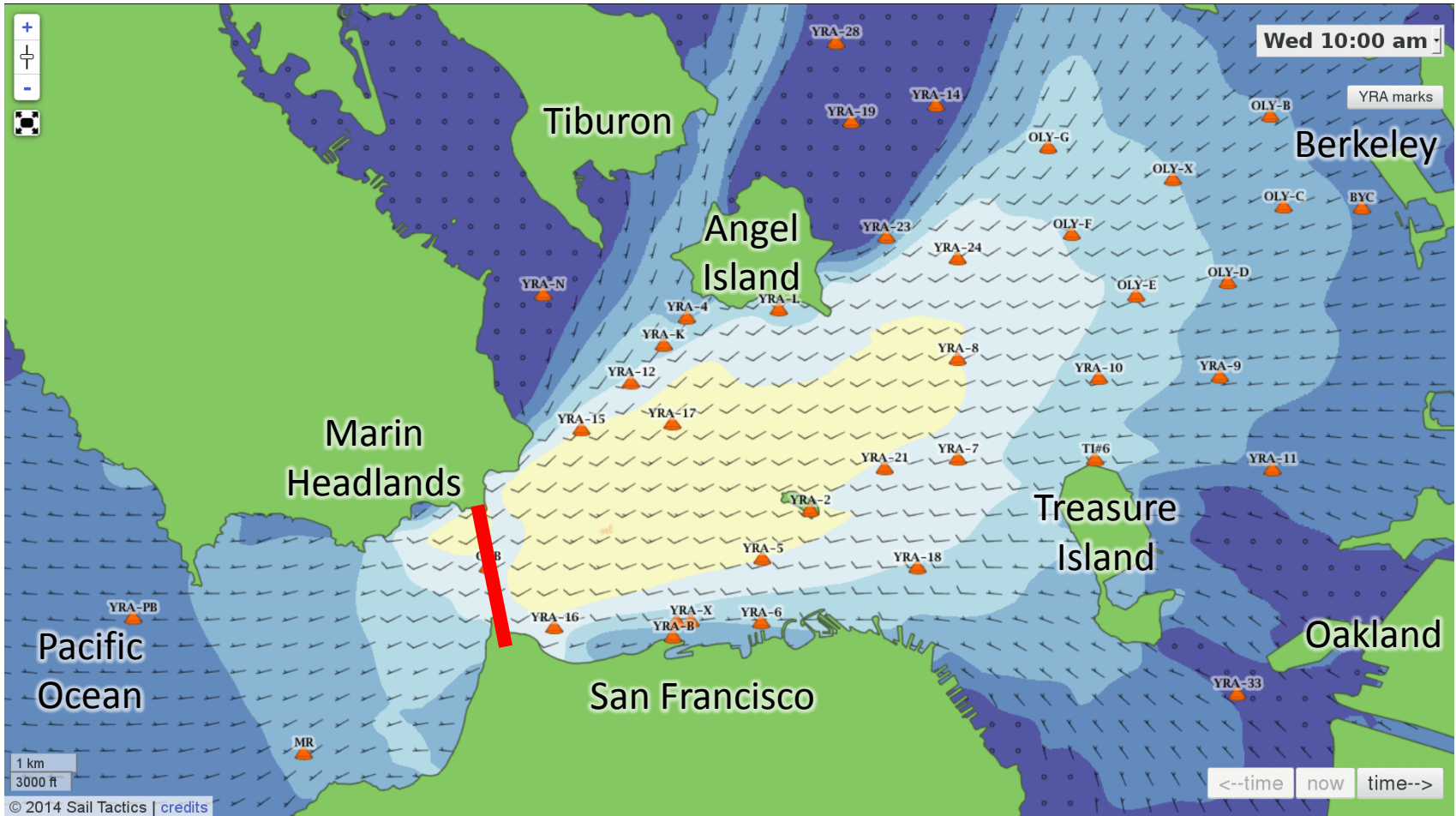


Source: Dvorak, M. J., Archer, C. L., and Jacobson, M. Z., (2010). California offshore wind energy potential. *Renewable Energy*





# Typical summer sea breeze conditions



# Conclusions

- California's offshore **resource vast...**
- and will **increase in value** as we push towards AB32 **emissions goals**
- **Levelized cost of energy** of offshore will not sell offshore wind in California in near term...
- need to investigate the **value** of offshore wind as a **more diverse renewable resource**



# Thanks! Questions?

Mike Dvorak

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Sailor's Energy



Photo credit: Sharon Hind-Smith

Sea Star finishing a race at the Berkeley Marina