Energy Potential for Florida by Mechanical and Solar Means

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ABSTRACT

Using observations, augmented by other data and model simulations, we address the potential for electrical energy generation for Florida by harnessing the energy sources of wind, sun, ocean currents and waves.

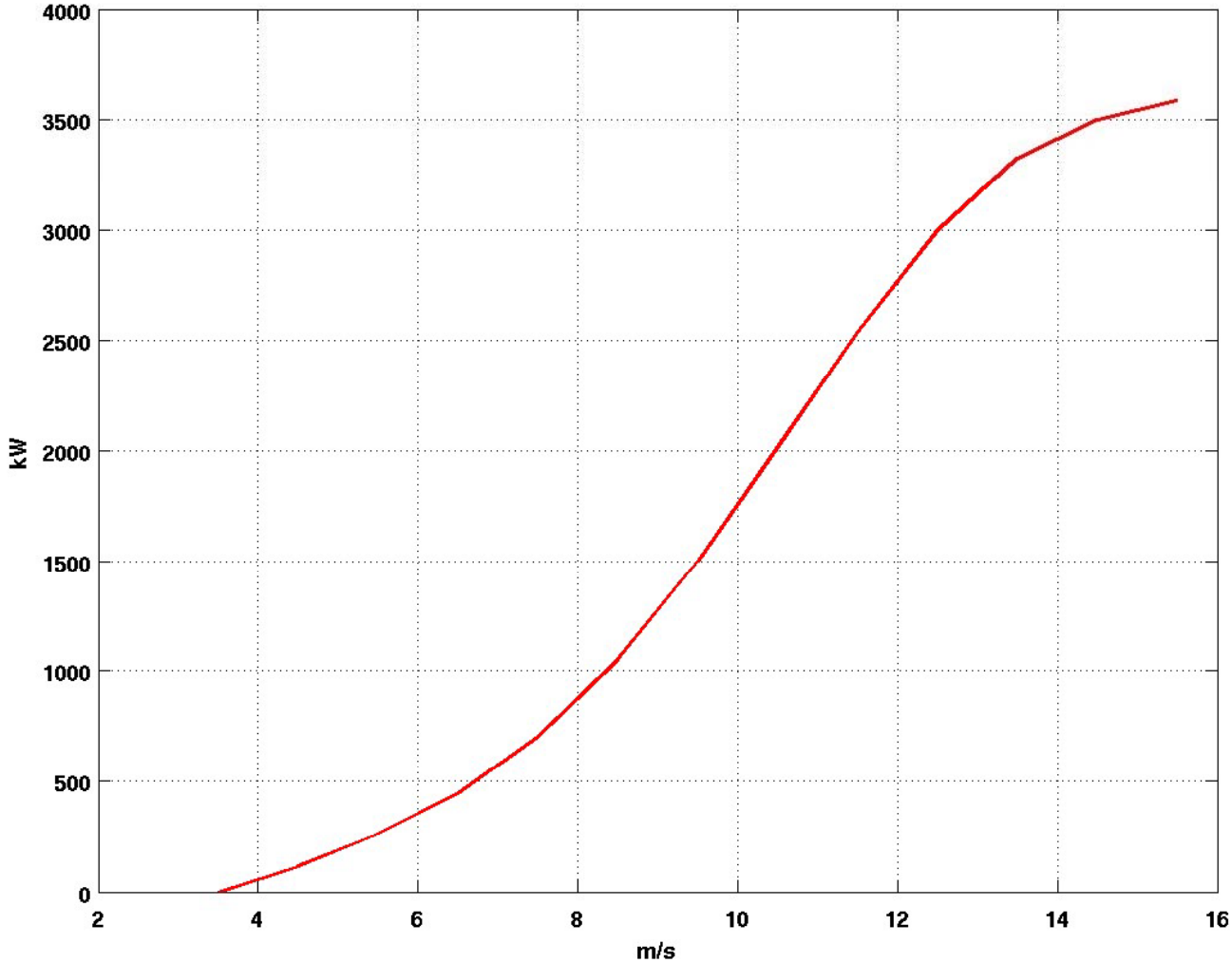
- **We identify what nature offers.**
- **We use specifications from commercially available devices to convert nature's bounty to power generation estimates.**
- **We make extrapolations on what these may mean in a practical sense.**

Conclusion:

Such power generation from alternative, natural energy sources may provide a supplement to traditional energy sources, but not a replacement.

Wind

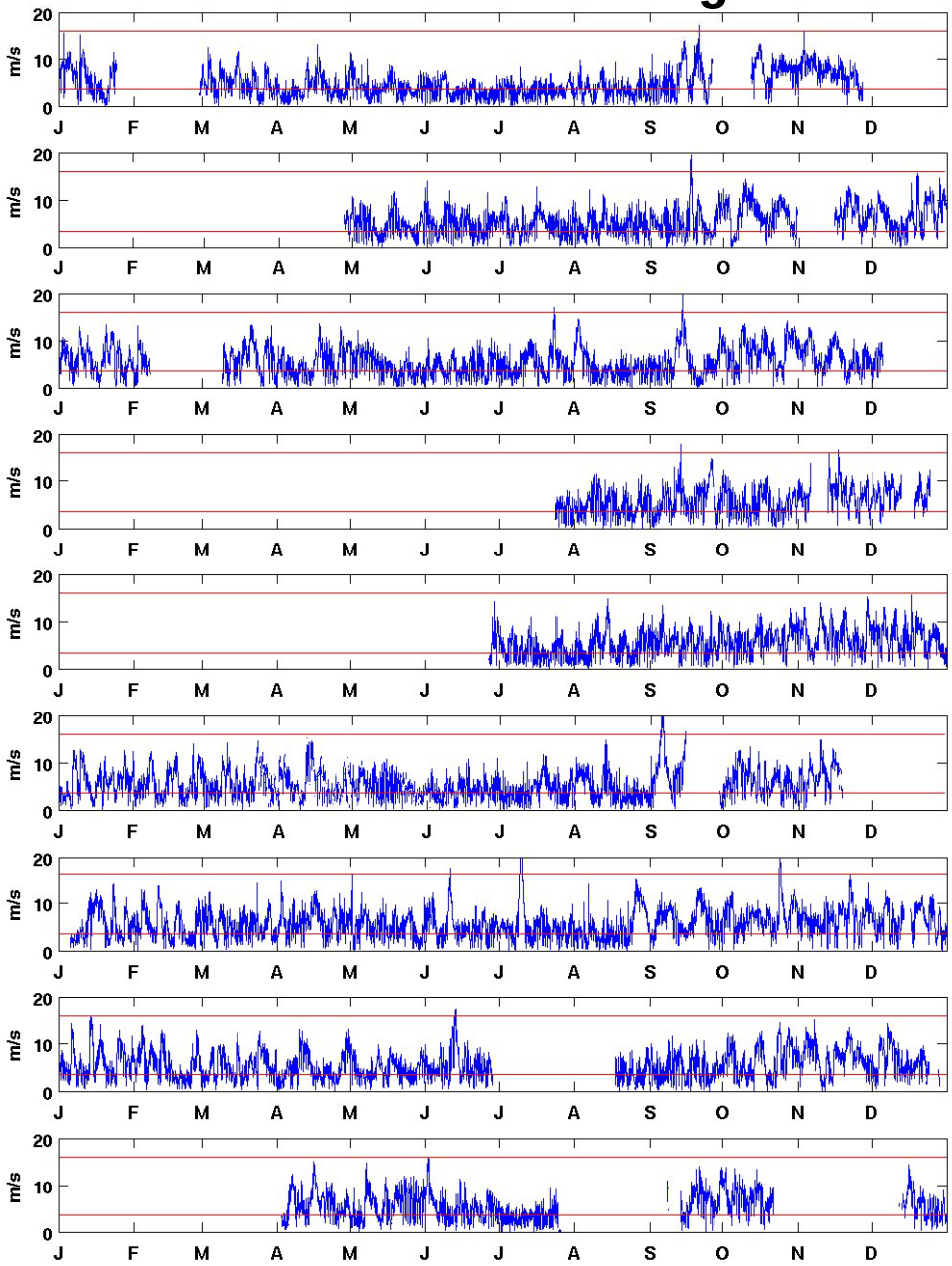
Power Curve Example: GE 3.6 MW Wind Turbine



Whereas a turbine may be rated at a given output, the output depends on wind speed. Here we see a cut off at 3.5ms^{-1} (~7kts) and a max. at 16ms^{-1} (~32 kts). WFS winds are often <7kts, even at 100m height.

Wind speed, COMPS C10 (25mi from Sarasota), scaled to 100m hub height

% obs. data <3.5 m/s & >16 m/s



1999	26.25%
2000	16.17%
2001	19.73%
2002	14.66%
2003	15.73%
2004	19.68%
2005	18.36%
2006	19.92%
2007	18.04%

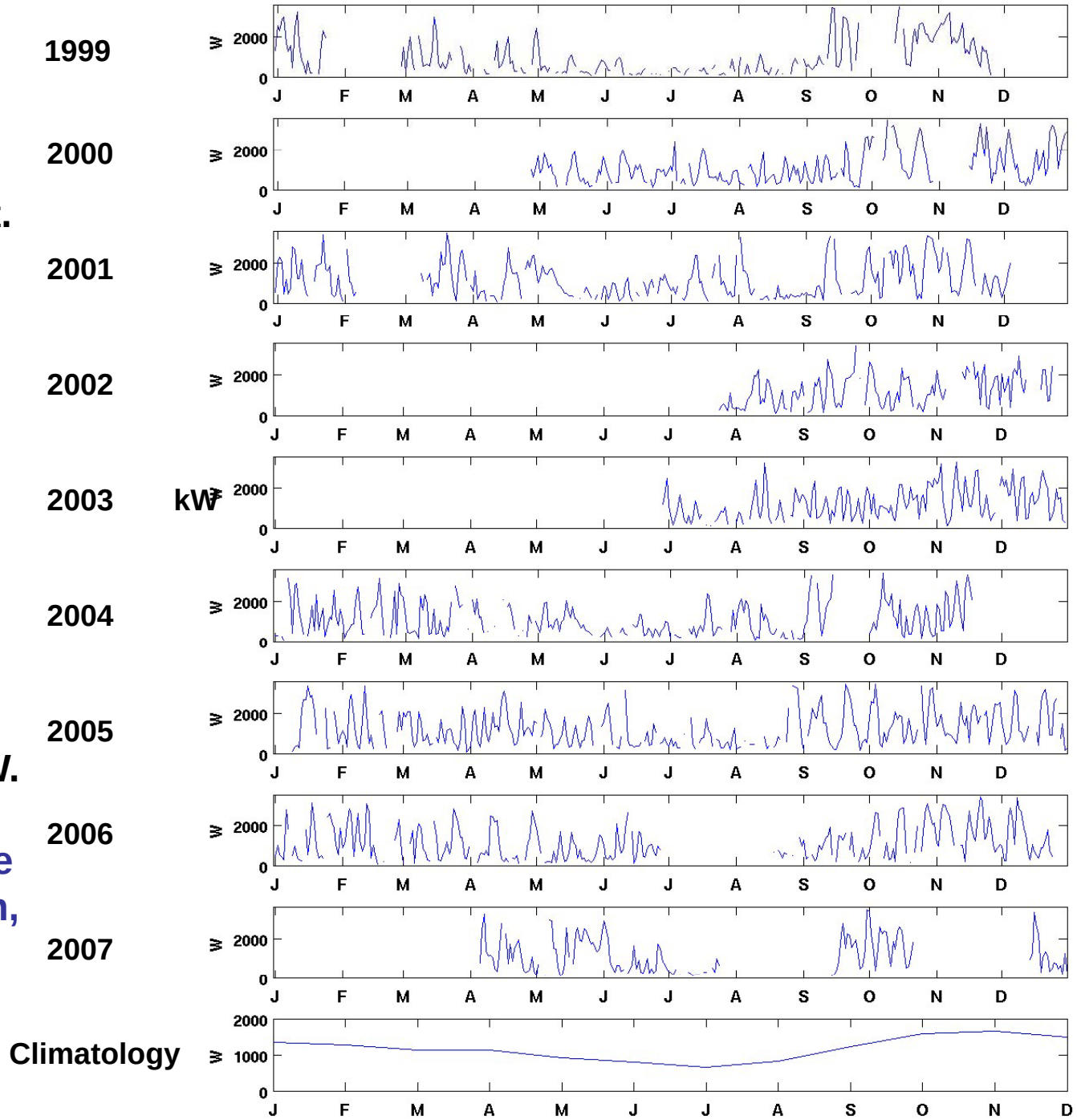
Daily Mean Power, Example: GE 3.6 MW Turbine with 100 m hub height.

Wind speeds are insufficient to drive the turbine at its rated amount.

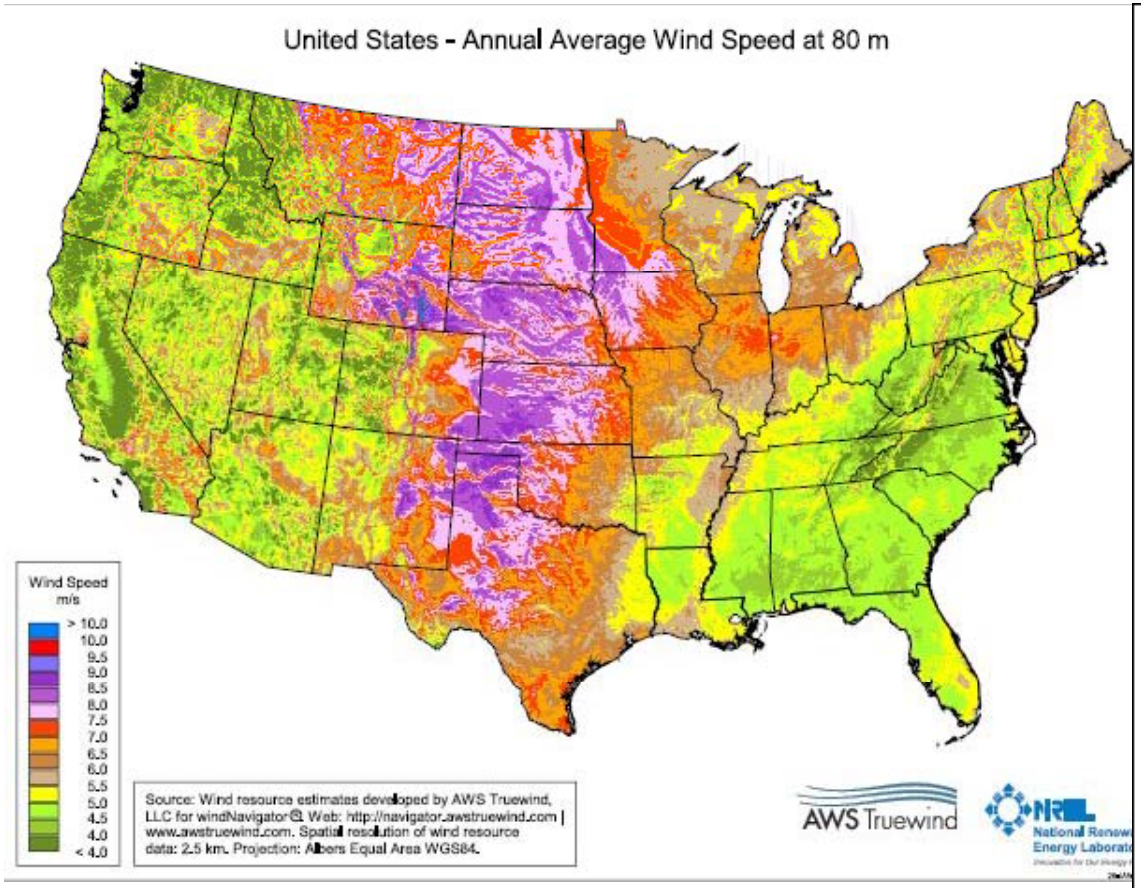
On monthly average:

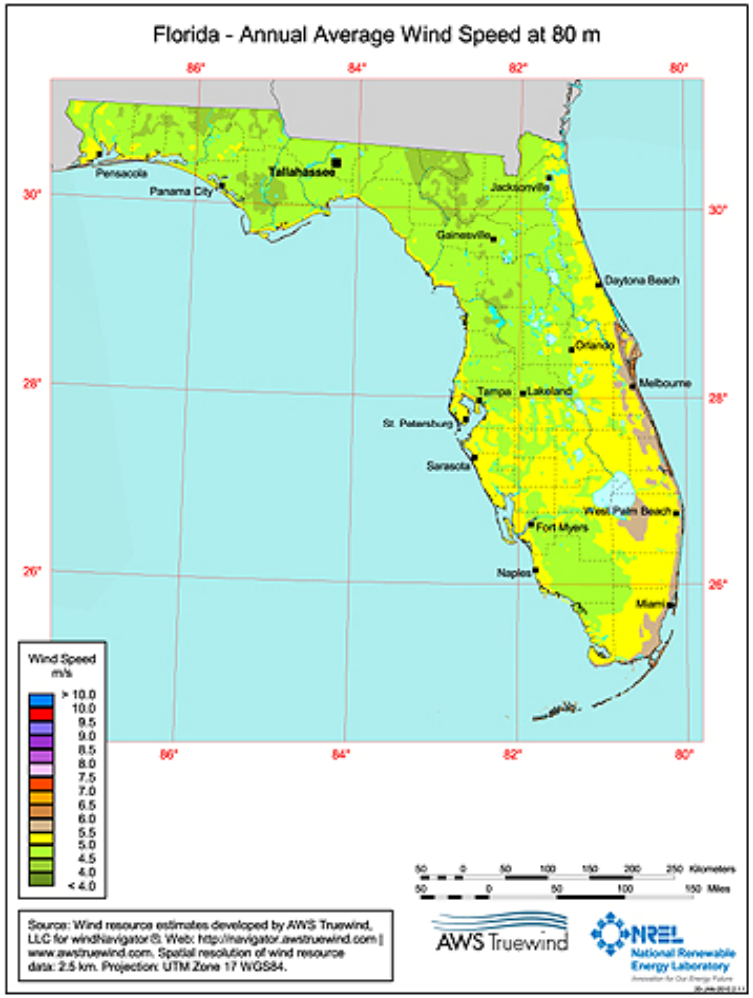
- **Minimum (summer) generation is ~ 0.6 MW.**
- **Maximum (fall) generation is ~ 1.8 MW.**
- **Annual mean is ~ 1MW.**

For design purposes we would use the minimum, not the maximum.



80m Mean Winds

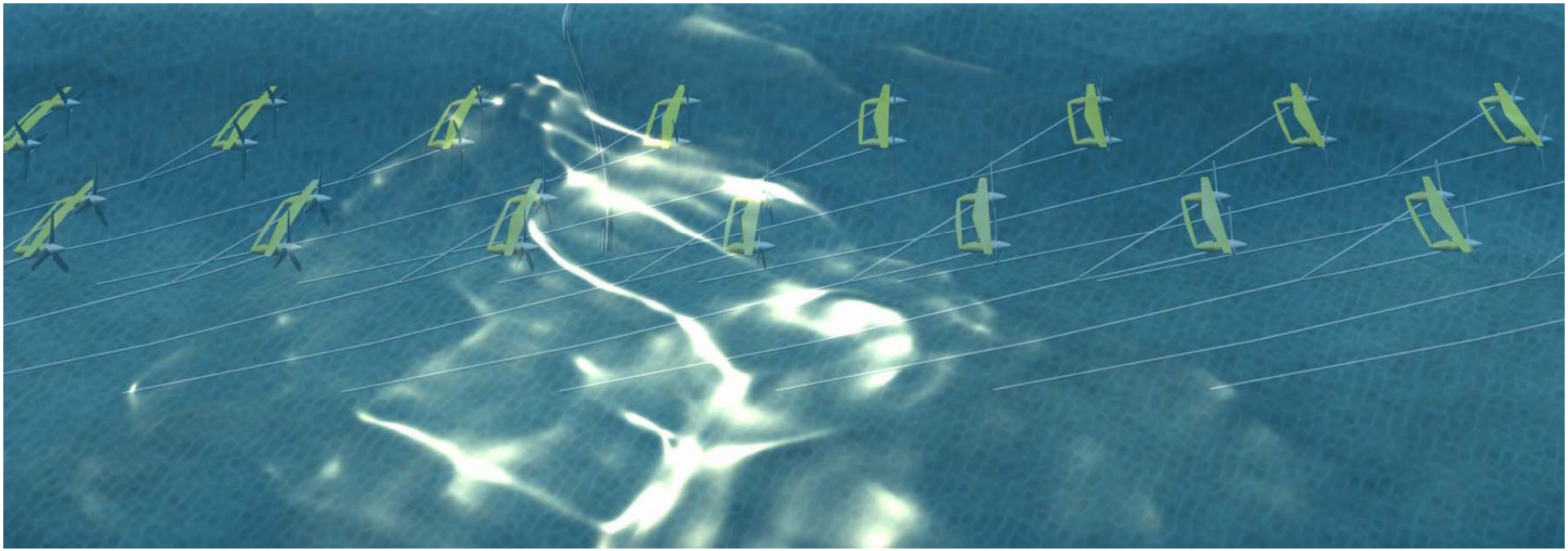




Given these mean wind distributions, is wind as good as touted to be?

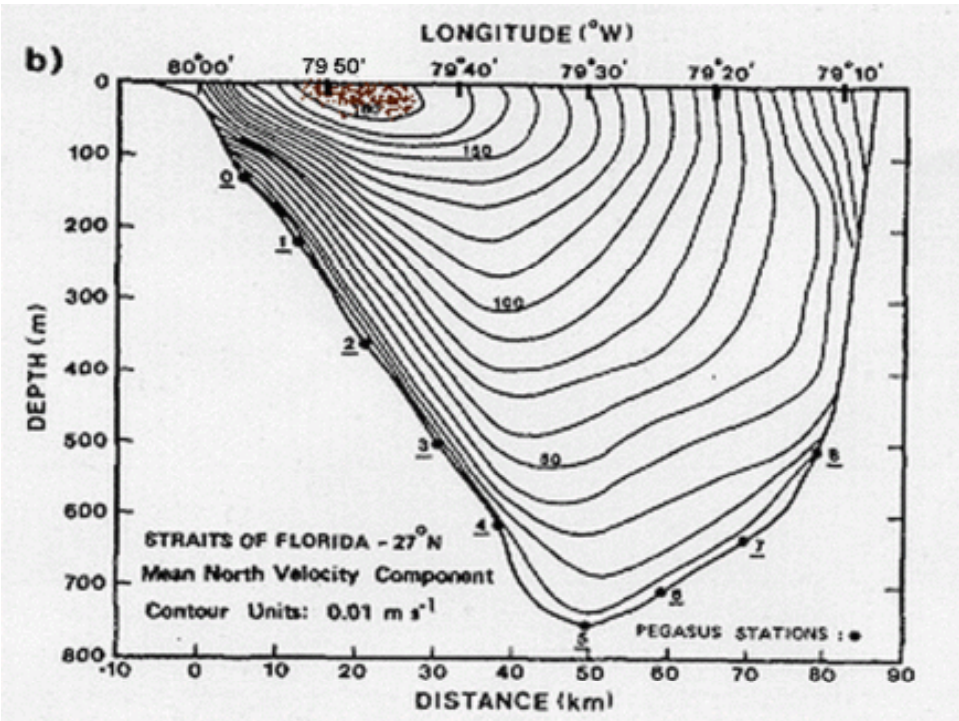
- **Ratings do not equal performance.**
- **There are times when no output is achievable.**

Currents



The Gulf Stream

Kinetic Energy Flux = 1/2 $\rho V^3 A$ (units = Watts)



Gulf Stream velocity cross section

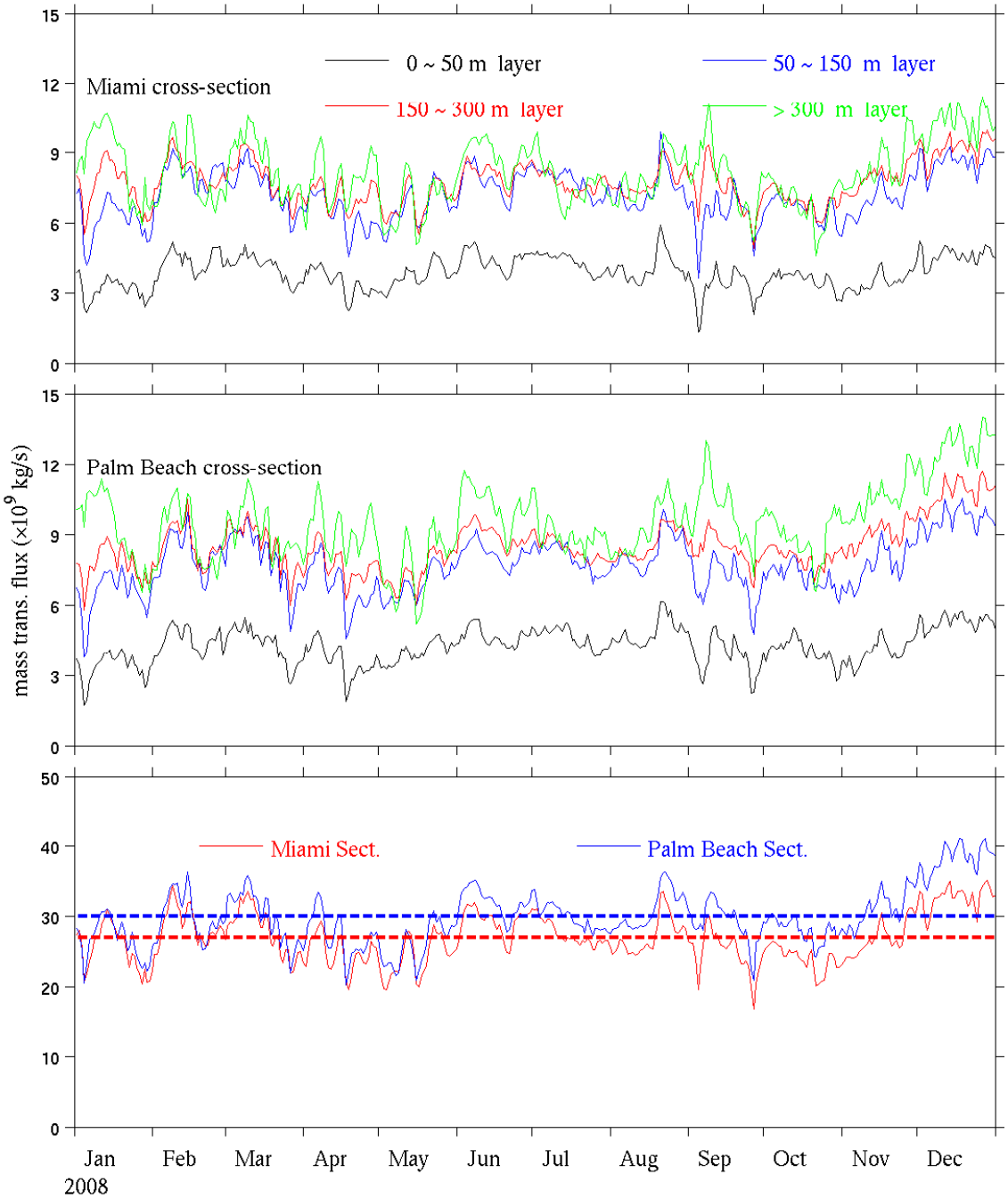
Courtesy of NOAA AOML and UM RSMAS STACS Program

The Gulf Stream is a baroclinic current whose velocity decreases with depth. Maximum speeds are generally above 50m.

Because of large waves, it would be difficult to deploy machinery in the upper 50m of the water column.

Such baroclinicity and waves limit the region over which kinetic energy may be extracted from the Gulf Stream.

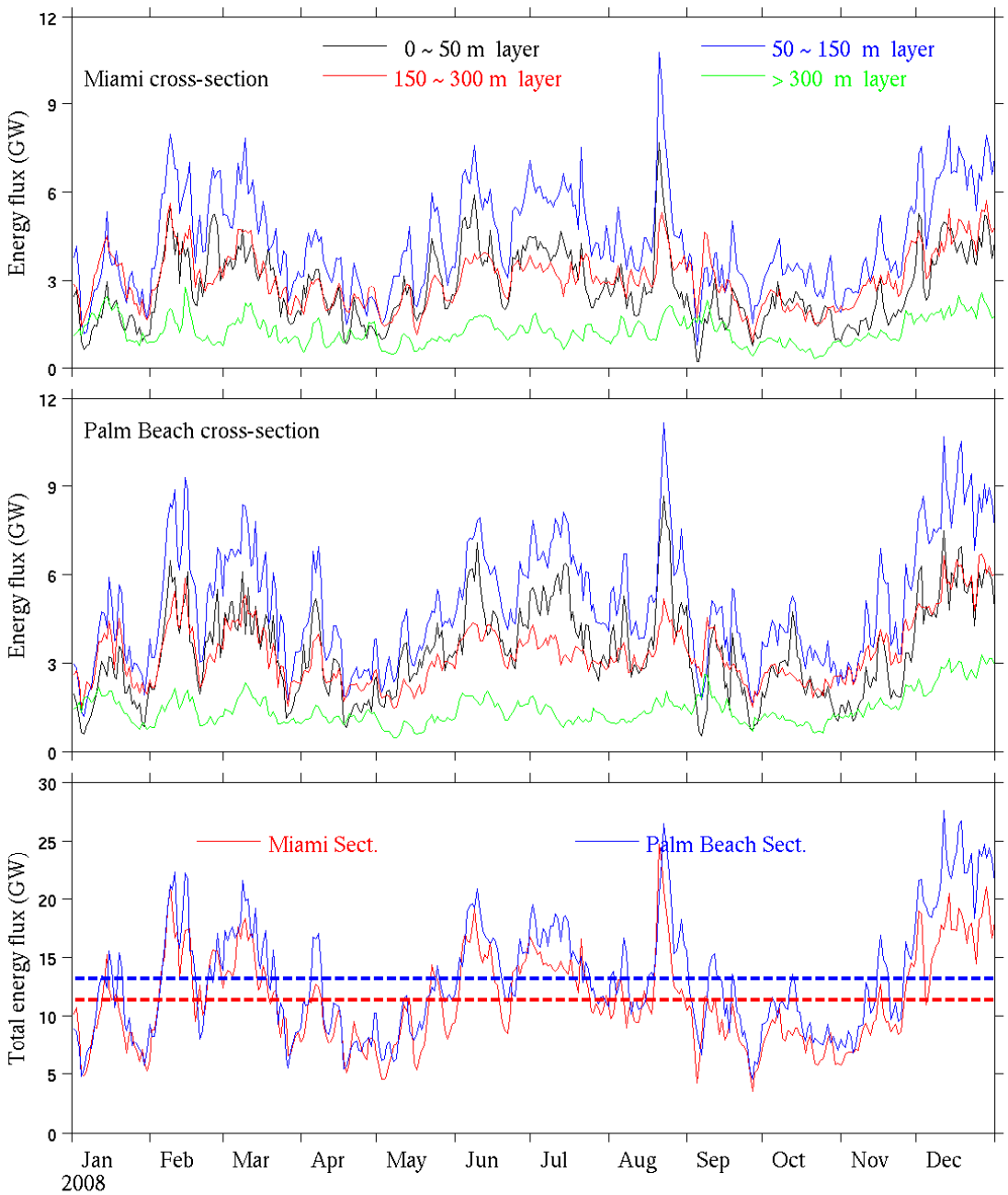
Gulf Stream Mass Flux at Miami and Palm Beach



Sectionally integrated mass flux for 2008 using a Global HYCOM simulation.

Note that the total mass transport is generally recognized to be ~ 30 Sv, consistent with what is calculated here. In other words, this provides a quality assurance check on the model simulation.

Gulf Stream KE Flux at Miami and Palm Beach



Sectionally integrated K.E. flux for 2008 using a Global HYCOM simulation.

The annual average total K.E. transport is 11-13GW.

Not all of this may be harnessed. Betz's law provides a 59% limit, which is further reduced by rotor losses to 40-50%.

Using 50%, and excluding the upper 50m, Palm Beach yields ~ 4.5GW.

Because it is impossible to cover the entire section with turbines 4.5GW is a gross overestimate. 10% of this may be more realistic.

Turbines in the Gulf Stream:
The Environmental Problem

The Gulf Stream is the conduit for the northward heat flux of the N. Atlantic Subtropical Gyre, one of the most important determinants of Earth's climate.

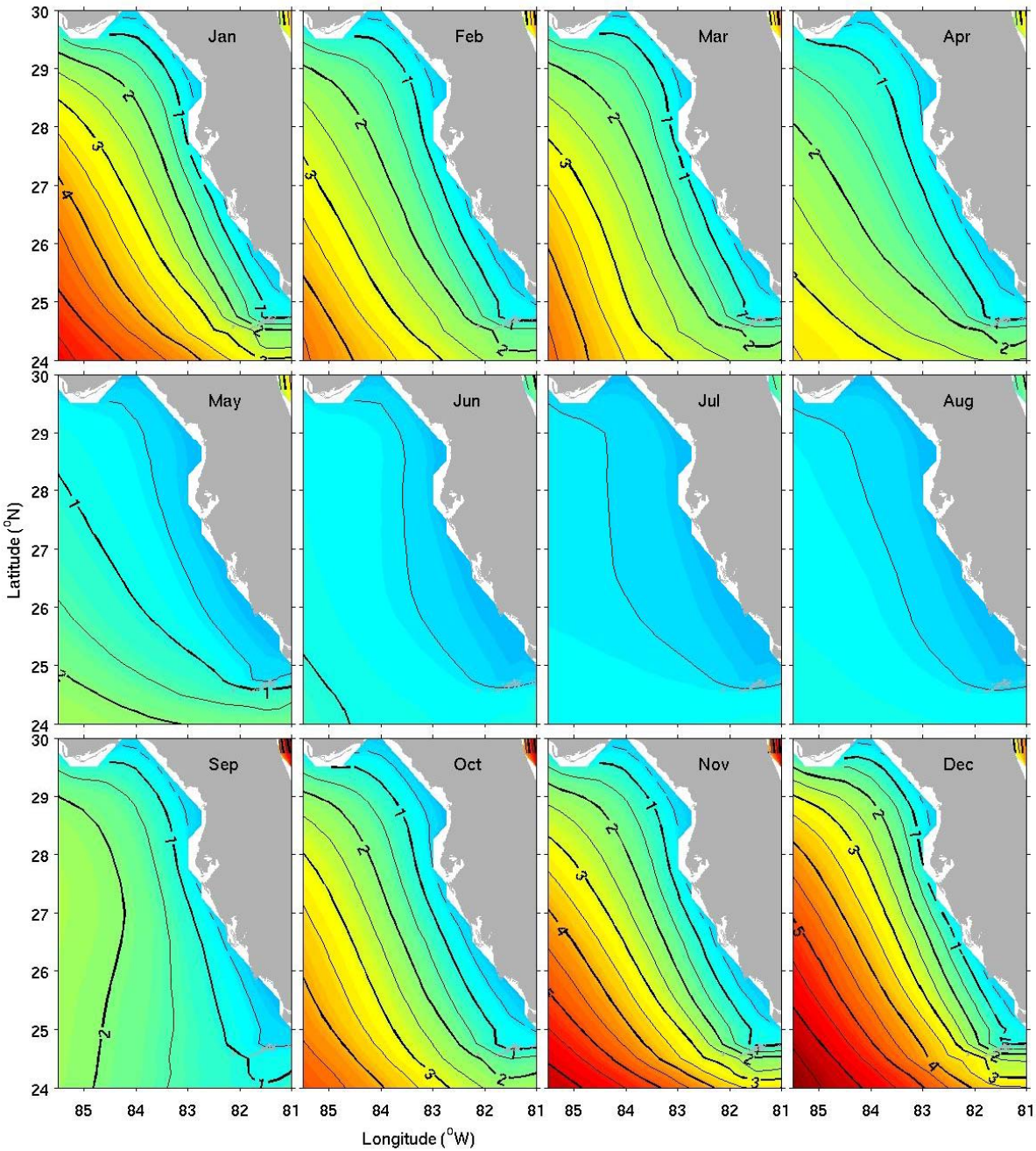
Significantly reducing the K.E. flux through the Florida Straits could cause the western boundary current to reorganize to the east of the Bahamas (the Antilles Current). While this might not have global climate consequences, it would greatly alter the flow through the Caribbean and the Gulf of Mexico, substantially impacting the climate of the America's.

Thus the environmental problem is not with the turtles and the fish, but with all of us humans who live within this sector of the planet.

Waves

Examples of mechanical devices that either flex or pump vertically.
These are big, expensive machines.

West Florida Shelf Waves



West Florida monthly mean wave energy flux (kW/m) estimated from a (1999 – 2007) reanalysis the WAVEWATCH III model.

$$F(kW/m)=EC_g$$

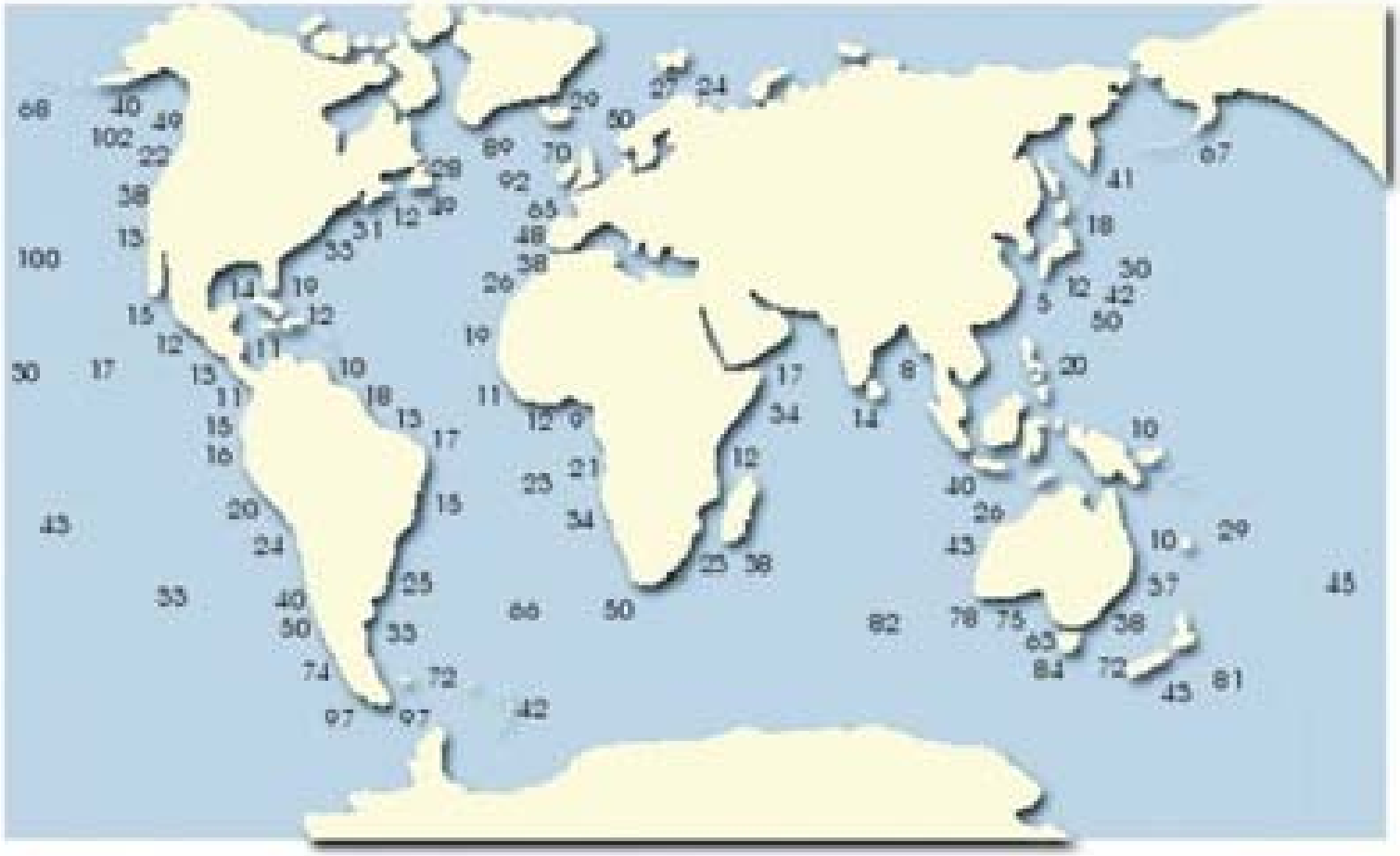
$$F(kW/m)=0.5H_s^2T$$

$$Power(kW)=FL$$

At 1kW/m, a 4m device generates 4kW.

Industry brochures argue that 15kW/m may be cost effective.

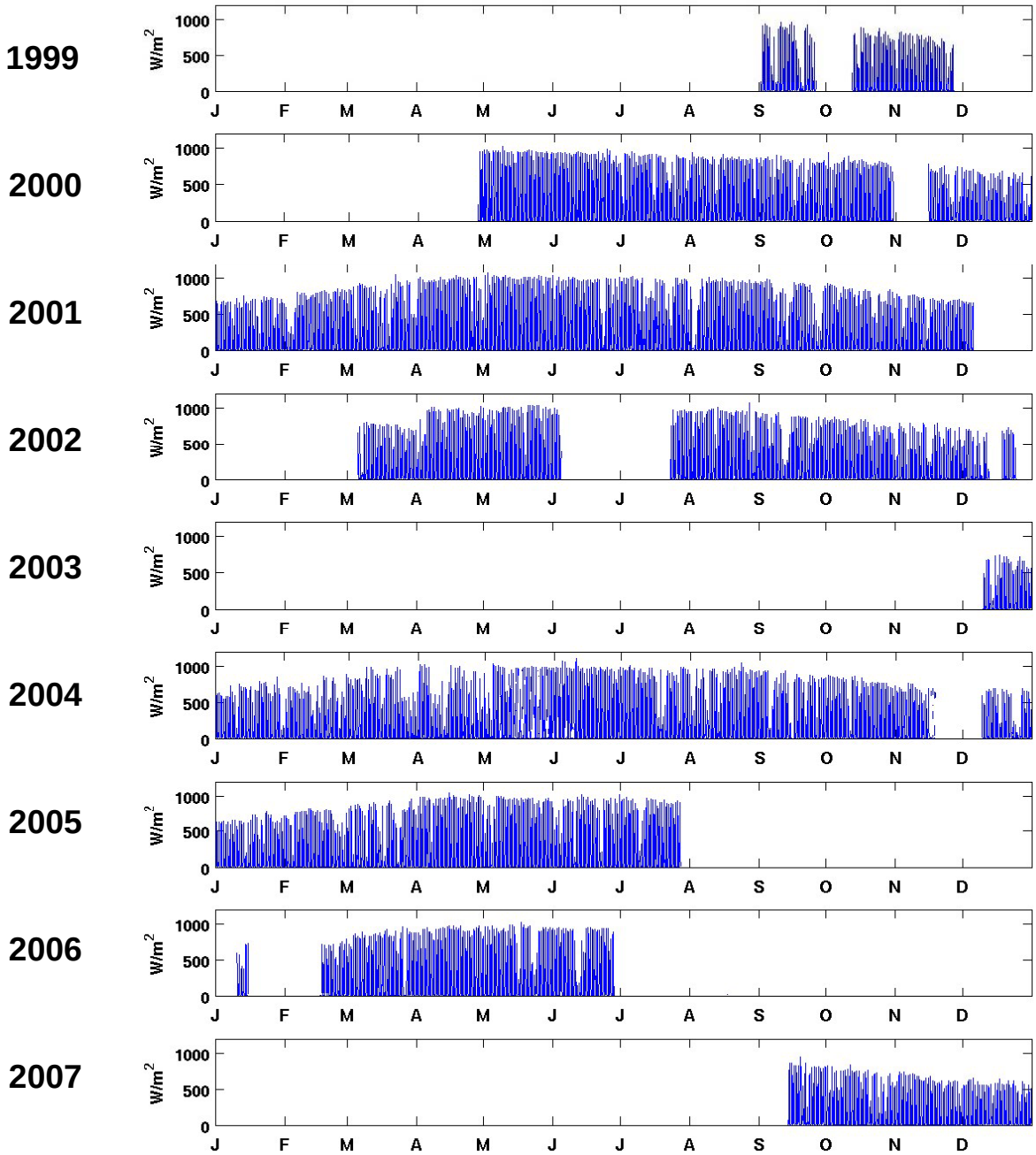
Mean Wave Energy Distributions (kW/m)



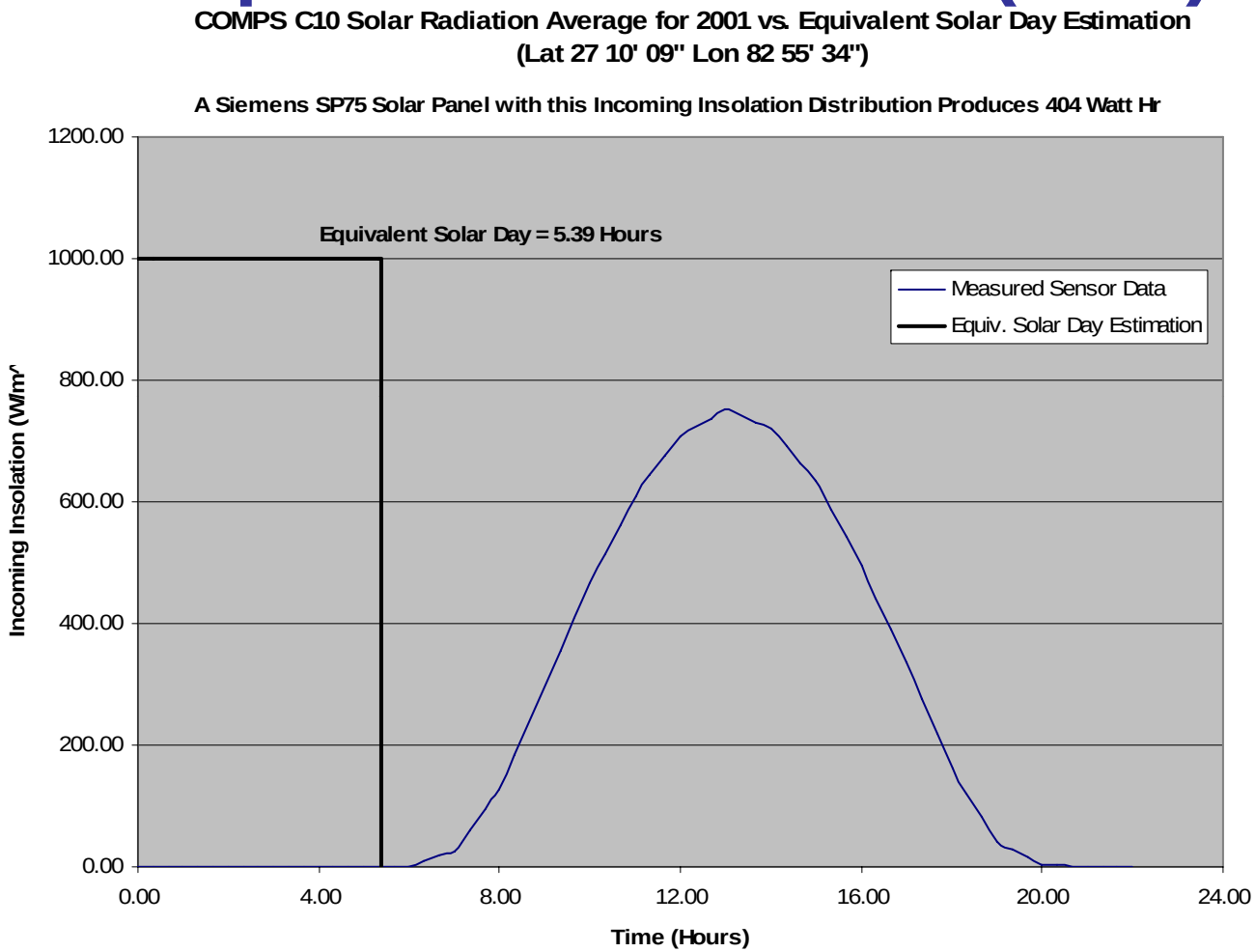
Given these mean wave energy distributions (kW/m), is wave energy extraction economically feasible?

Solar

Hourly Shortwave Radiation, COMPS C10 (25mi offshore from Sarasota).



Method for obtaining solar panel output. Example: Siemens SP75 (75W) solar panel



2001 annual average

Area under daily insolation curve gives equivalent illumination hrs at 1000 Wm^{-2}.

Equivalent hrs X 75W = 404Whrs.

Dividing by 24 hrs gives average output of 16.8W for a 24 hr day.

Dividing by solar panel area (0.63 m^2) gives 26.7Wm^{-2} for this solar panel.

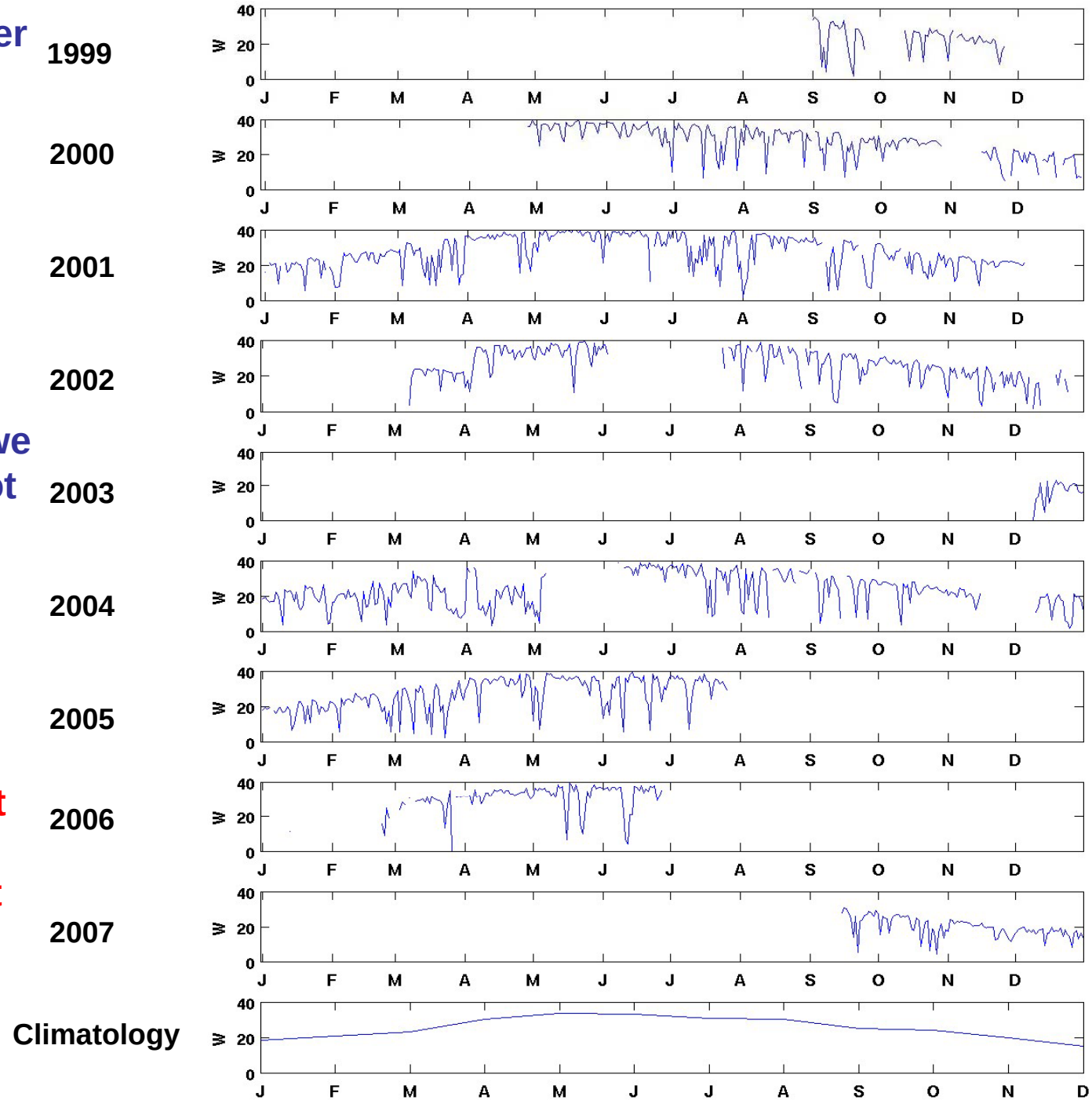
Daily Mean Solar Power for an SP75W panel scaled to 1 m^2.

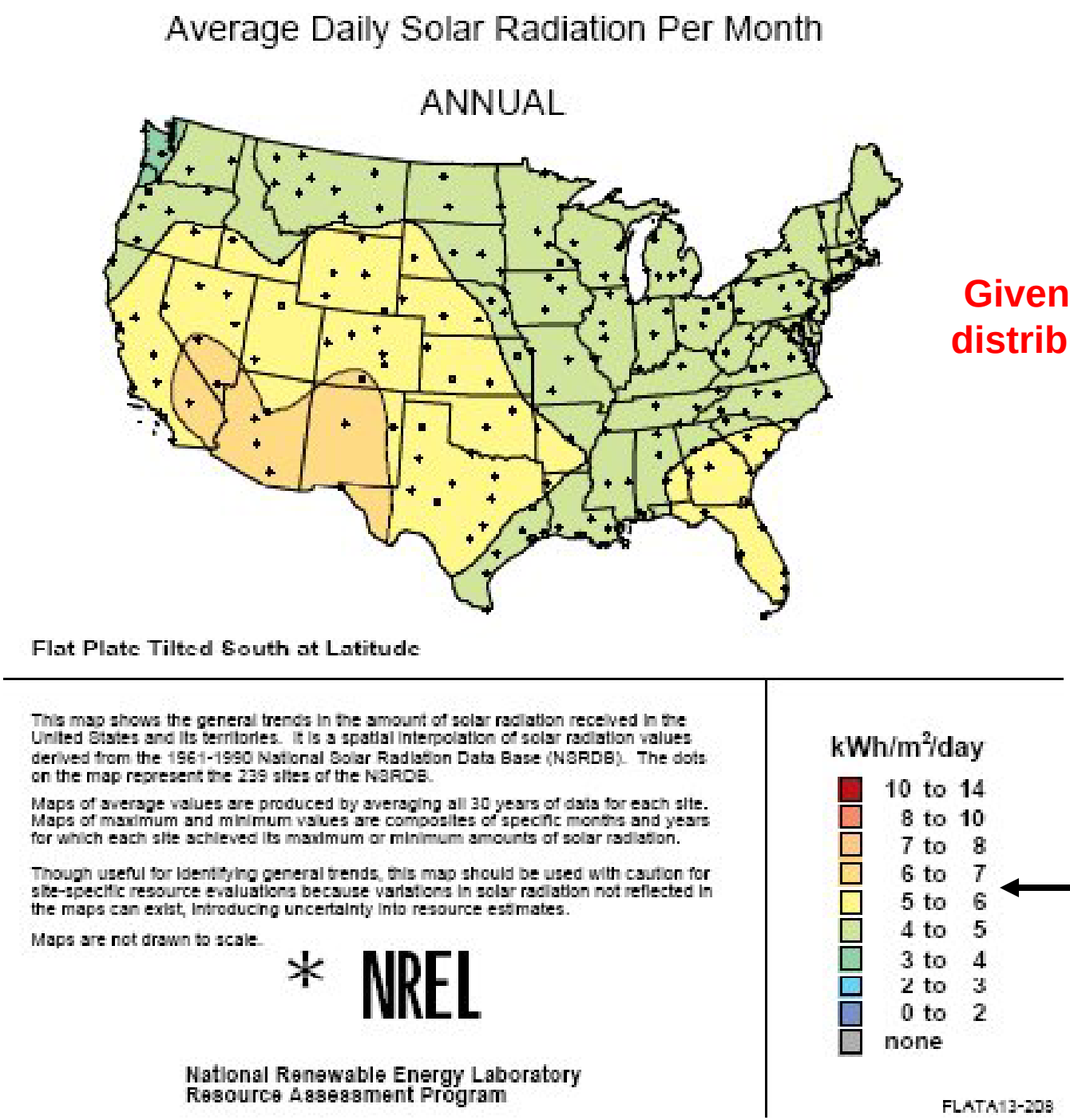
Monthly averages:
- **Min. (winter) ~ 20W.**
- **Max. (spring) ~ 38W.**
- **Annual mean ~ 25W.**

For design purposes we would use the min., not the max.

<u>Examples</u>

- **A 2.0 kW house requires 100 m^2 of panels.**
- **A 1.8 GW power plant requires 90 km^2 of panels, or a major part of the city to be powered.**





Given these mean insolation distributions, is solar as good as touted to be?

250 W/m²

Winds, Currents, Waves and Solar Summary

- **Currents are not feasible relative to wind for two reasons:**

  1. **Watermill and windmill areas are equal for an equal amount of energy, so why cope with ocean challenges when the same can be achieved more easily in air?**

  1. **Windmills operate in the atmospheric boundary layer, continually replenished by the geostrophic interior. Watermills operate in the geostrophic interior with no replenishment.**

- **Wave energy for Florida is too low.**
- **Solar energy, even for the Sunshine State (Florida), is also low.**

Economics

Cost of Electricity

My annual averaged consumption is ~ 1.7kW, which costs me ~ $140/mo.

Wind

If west Florida wind power averages 1MW for a large commercial turbine, such turbine could power 588 1.7kW houses, which presently costs $140/mo x 12mo = $988,000/yr, including profit and shareholder returns. For cost effectiveness, the amortized cost/yr, plus maintenance, storage, distribution, etc. would have to be much less than $1 million/turbine/yr. However, published costs are between $5-10 million just to purchase and install.

Waves

If wave power is argued to be cost effective for coastlines with a minimum flux of 15kW/m then the 4m machine shown earlier would have to cost less than $59,000/yr for amortization, maintenance, transmission, storage, etc. I doubt that one could even pay the ship-time costs to deploy the machine for that amount of money, even if the machine was otherwise free.

Solar

Solar panel system costs are estimated as $95/ft^2 or ~$1022/m^2. With 26.7W/m^2 being the annual average solar panel output under Florida insolation, the cost is ~$38/W, or $65,000 to power my house. Relative to $140/mo ($1,680/yr), it would take 38 yrs to recover the cost.

A Sense of Scale

The approximate scale of a large offshore wind turbine in relation to Raymond James Stadium stood up on end

How do you think Florida coastal residents would like an array of these offshore?

Acknowledgments

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