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## ENG 505 Class Project

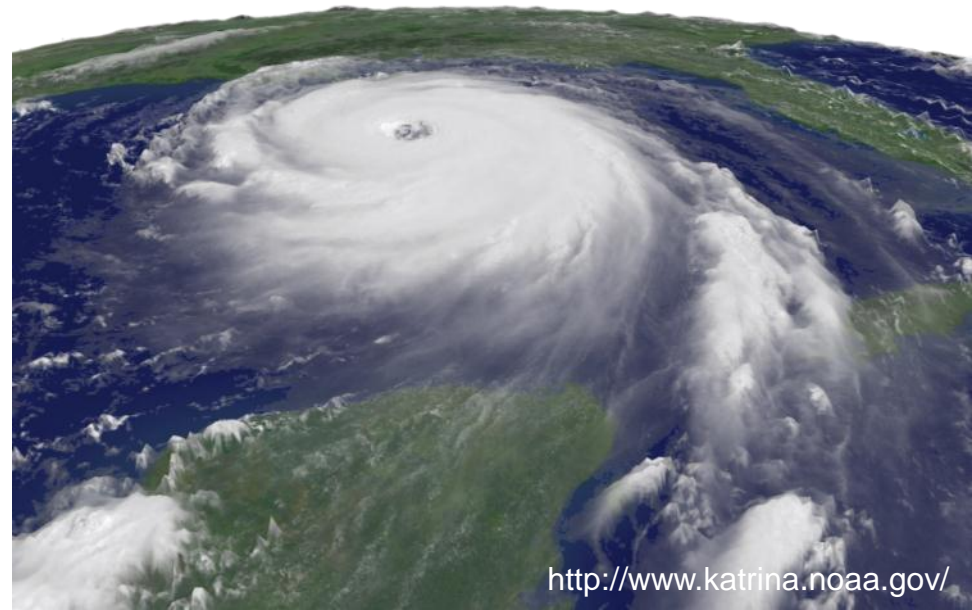
# Harvesting Hurricane Energy

*Flo Lucero (6524)*

*Al Brown (5764)*

*Amy Danielson (10664)*

*Exceptional service  
in the national interest*



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



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# Biography

## ■ Florian Lucero

- At Sandia since 1979
- MSEE, 1979 New Mexico State University – Electrical Power Systems
- PMTS in Department 6524, Systems Advance Concepts Engineering
- SME – Electrical Power Systems

## ■ Al Brown

- Received BSEET degree from Devry University
- Started at Sandia National Laboratories in 2002 as 2<sup>nd</sup> career
- Have been involved in R&D and Testing Electronics since starting at Sandia
- Will grow up and decide what I really want to be before I am 100, but until then I will continue to look at new and different ideas

## ■ Amy Danielson

- At Sandia since 2010
- Org 10664 – Strategic Business Enterprise Services
- Graphic Designer and Communications support for Center 6100

# Introduction

- Electricity from Hurricane winds
- Use information from presentation
- **Hydrogen production from tropical storms and hurricanes**
- Provides energy until infrastructure is rebuilt after hurricane
- Hydrogen tankers
- Full scale electric generation for USA
- Fuel cell powered vehicles
- Sodium metal and by products
- Sandia Opportunities



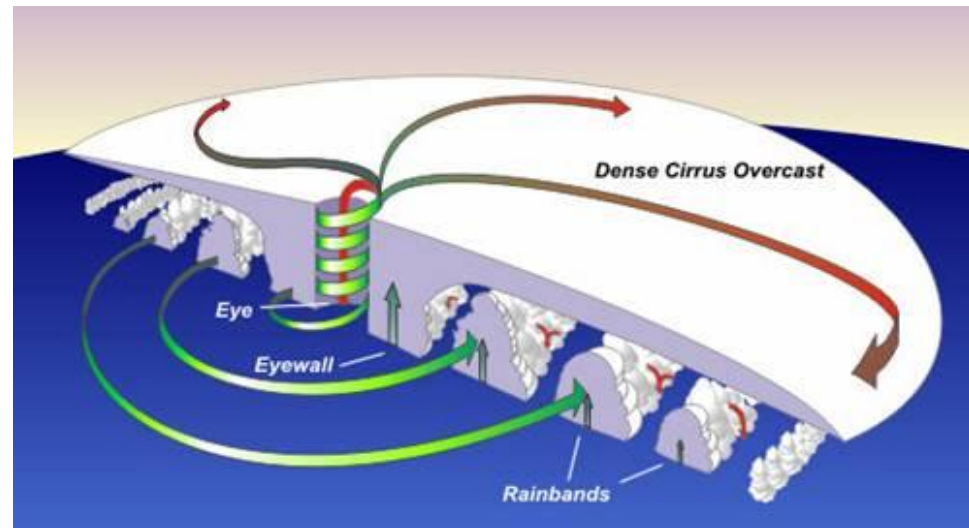
©WGHB/NOVA

[www.pbs.org/wgbh/nova/earth/hurricane-power](http://www.pbs.org/wgbh/nova/earth/hurricane-power)

**A hurricane can contain tremendous amount of energy in its winds. The winds of an average hurricane can easily pack some 1.5 trillion watts of power, which is equivalent to about half the world's entire electrical generating capacity in a year.**

# General Hurricane Facts

- Typical hurricanes are about 300 miles wide although they can vary considerably in size.
- The eye at a hurricane's center is a relatively calm, clear area is approximately 20-40 miles across.
- The eyewall surrounding the eye is composed of dense clouds that contain the highest winds in the storm.
- The storm's outer rainbands are made up of dense bands of thunderstorms ranging from a few miles to tens of miles wide and 50 to 300 miles long.

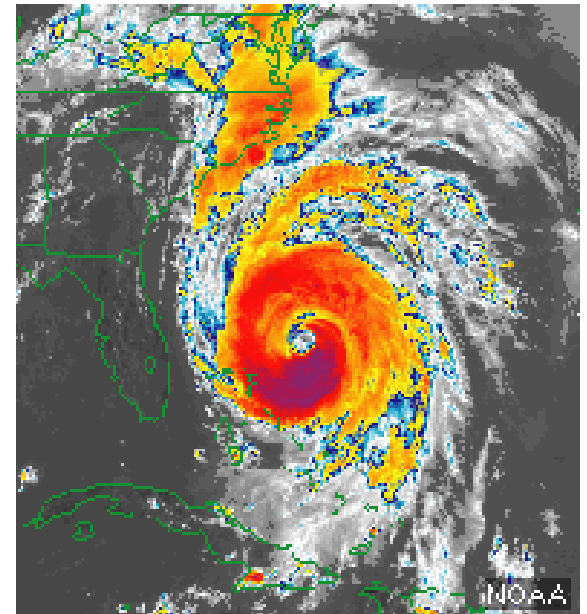


([www.hurricanes.noaa.gov](http://www.hurricanes.noaa.gov))

# General Hurricane Facts

- **Hurricane-force winds** can extend outward to about 25 miles in a small hurricane and to more than 150 miles for a large one.
- **Tropical storm-force winds** can stretch out as far as 300 miles from the center of a large hurricane.
- Right side of a hurricane is the most dangerous in terms of storm surge, winds, and tornadoes.
- A hurricane's speed and path depend on complex ocean and atmospheric interactions.
- It is very difficult to predict the speed and direction of a hurricane.
- Hurricanes are immense systems that can move in complex patterns that are difficult to predict.

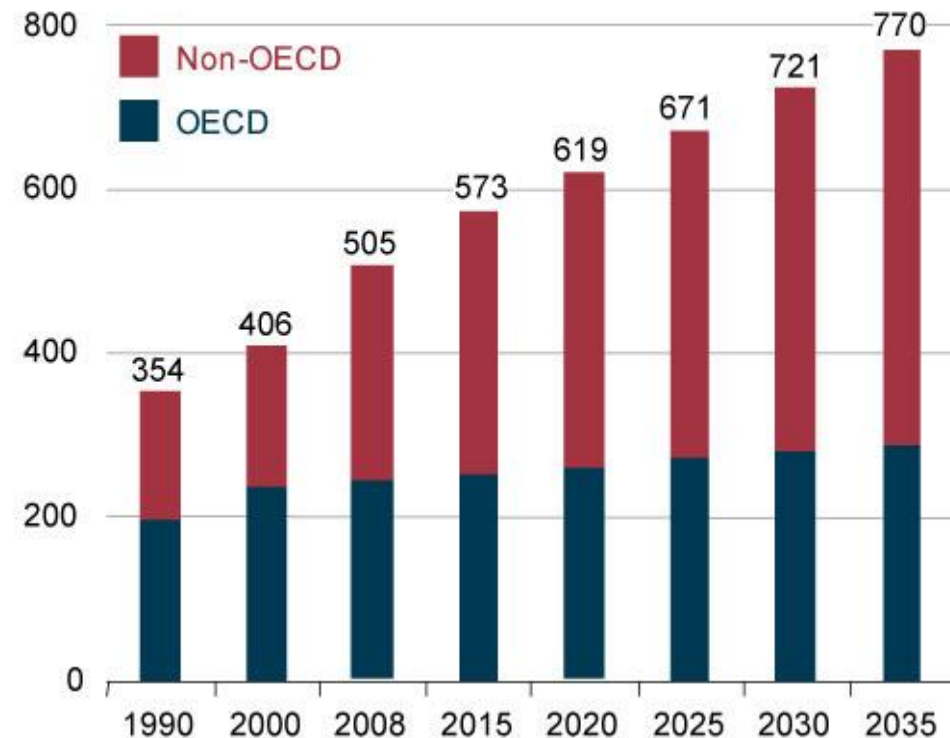
([www.hurricanes.noaa.gov](http://www.hurricanes.noaa.gov))



# Energy Problem

- Issues
  - Growing population and developing countries
  - Higher demand for energy
  - CO<sub>2</sub> issues
- Emerging concern
  - Alternate sources
  - Reduced CO<sub>2</sub>
  - Sustainable
  - Renewable
- System Challenges
  - Affordable
  - Scalable
  - Complementary

Figure 1. World energy consumption, 1990-2035  
(quadrillion Btu)



# Limitations

- Concentration on energy production and utilization
- High level concept – No detail analysis
- Found others working on this idea
- Numerous issues to resolve
- Economic impact touched on but not evaluated
- Safety and security – No detail analysis
- Policies and Laws were not considered
- Limited environmental discussion

# Energy Storage

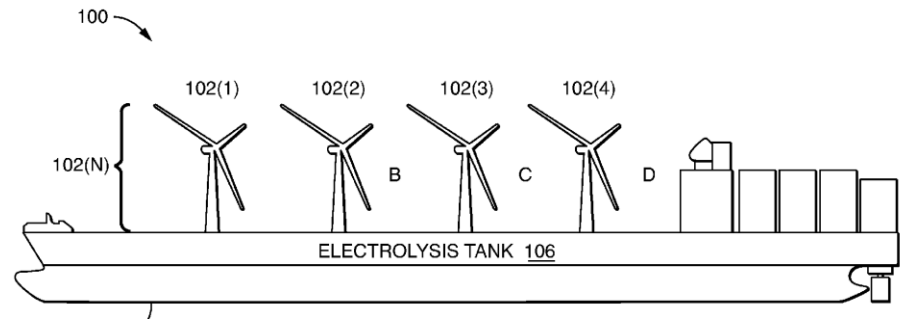
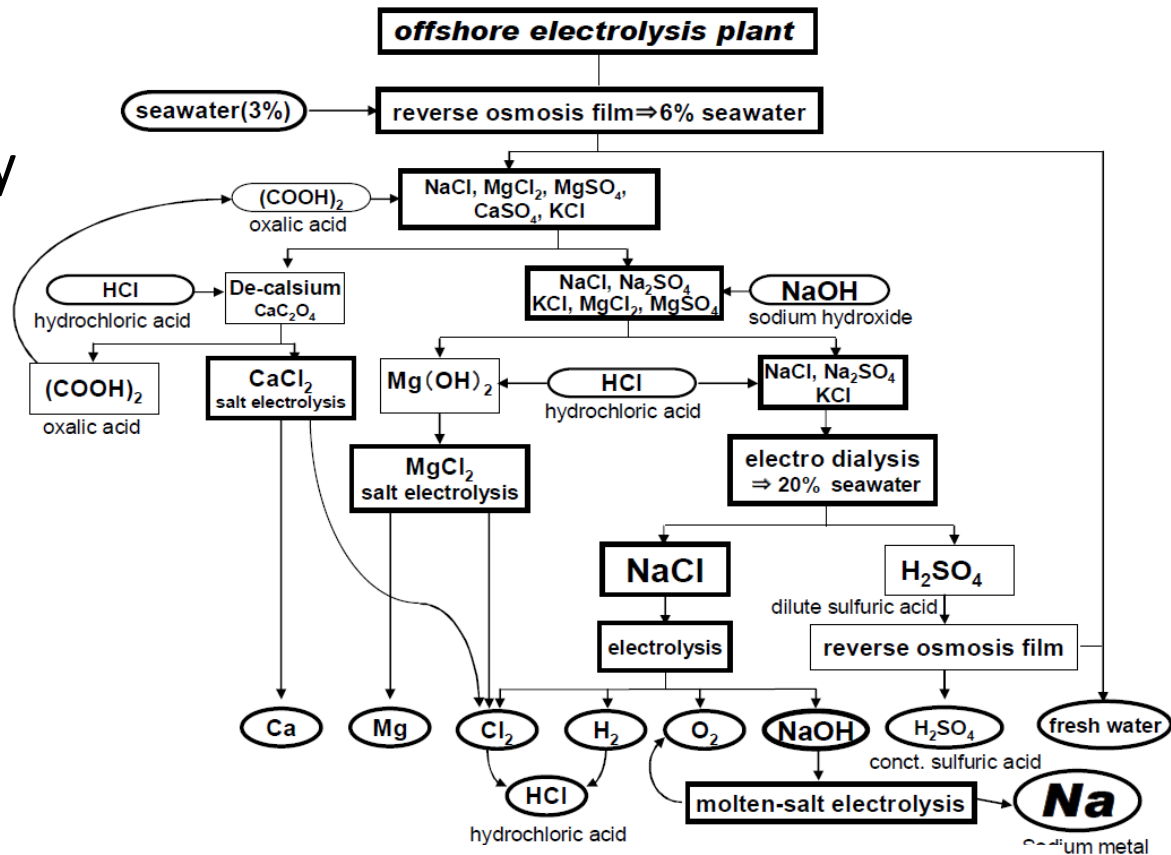
- **Hydrogen**
  - Different storage techniques and systems
- **Sodium Metal**
  - Potential
- **Other options:**
  - Batteries
  - Springs
  - Compressed Air
  - Hydraulic Pressure
  - Weights



Electrolysis of Water to Produce Hydrogen  
(ORNL)

# Hydrogen Production

- Needs a lot of electricity and a lot of saltwater
  - Both highly available during a hurricane or tropical storm
- Use twin axel or wave motion to produce electricity
  - Select ideal wind and wave conditions
- Hydrogen can be separated by electrolysis from sea water



# Hydrogen Production

- Hydrogen may not be the only product

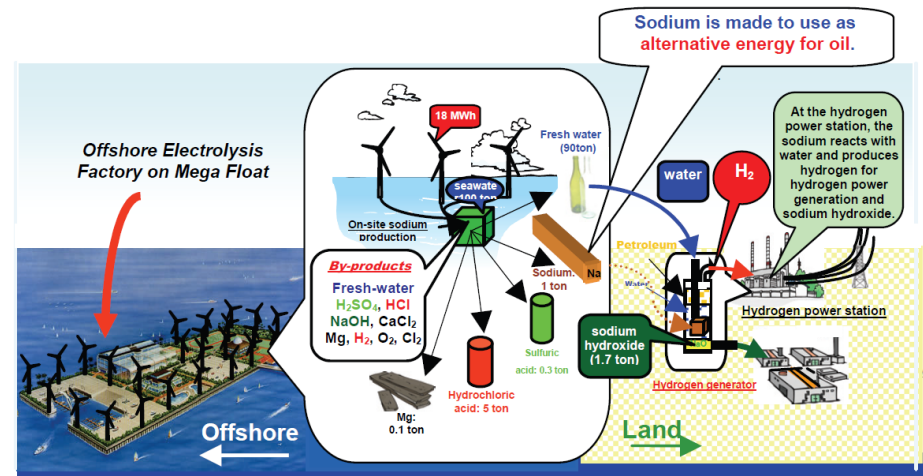
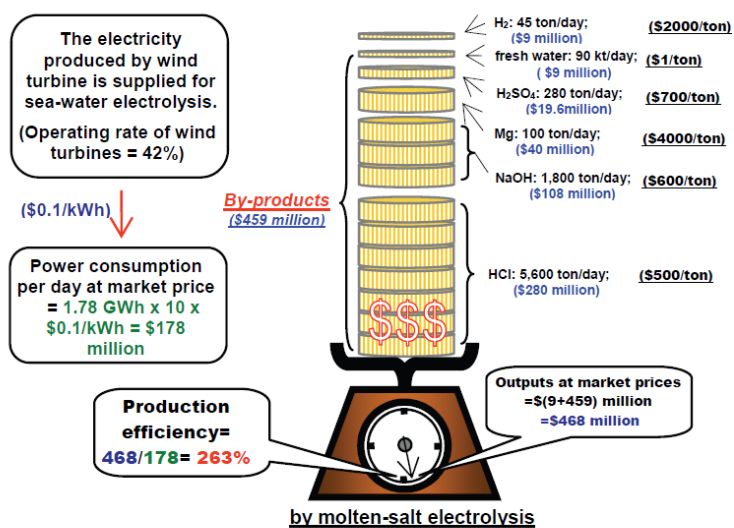


Figure 6. Comparison of power consumption and outputs of main product (H<sub>2</sub>)/by-products (fresh water, H<sub>2</sub>SO<sub>4</sub>, Mg, NaOH, & HCl) at market prices. Assuming the operating time is 10 hours per day, 0.1 Mton of seawater is processed by using electricity at 1.78 GWh to produce 1,000 tons of sodium metal. From the 1,000 tons sodium metal, not only hydrogen but also various by-products are produced.

Figure 1. Process of power storage for transport to land. Sodium metal is prepared electrolytically and is stored in kerosene for transport to the hydrogen power stations on land. The sodium metal is brought into reaction with water in order to generate hydrogen and sodium hydroxide as by-products.

# Hydrogen Utilization

- Transfer Hydrogen to tankers
- Hydrogen to fuel hydrogen vehicles after hurricane
- Hydrogen to run the electric generator on ship after hurricane

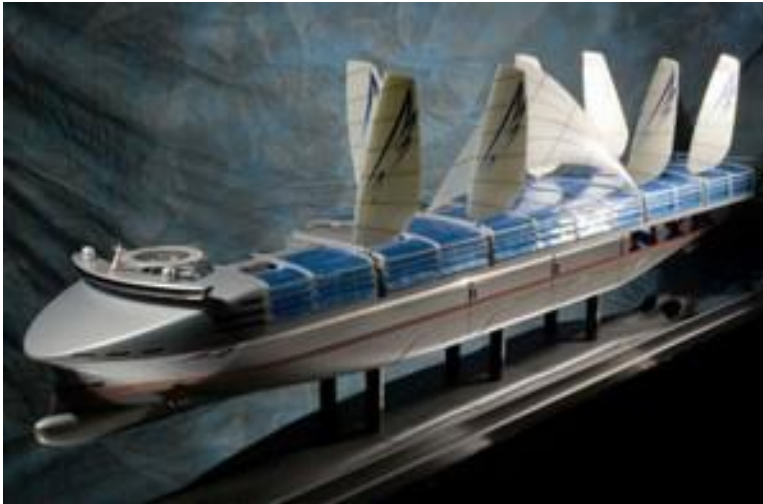
**Future** – Significant electric generation



## Hydrogen Challenger – Germany

A 66 meter (216' 6") refitted coastal tanker for mobile hydrogen production, it is fitted with a vertical axis wind turbine that generates electricity for the electrolysis of water to fill the hydrogen storage tanks. (wikipedia.org)

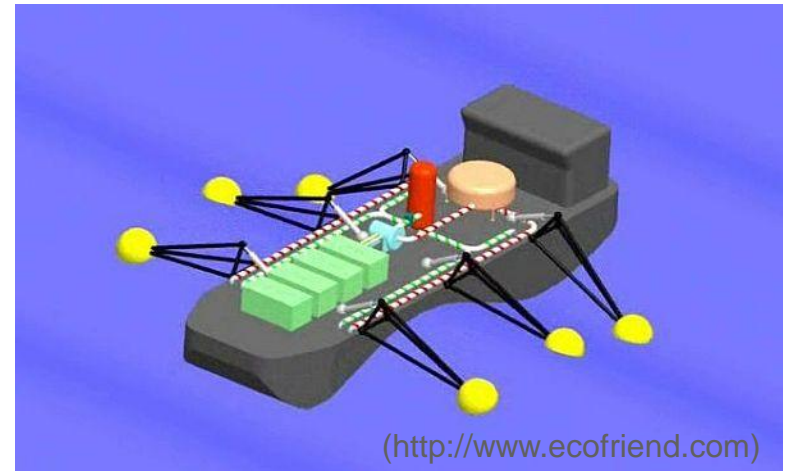
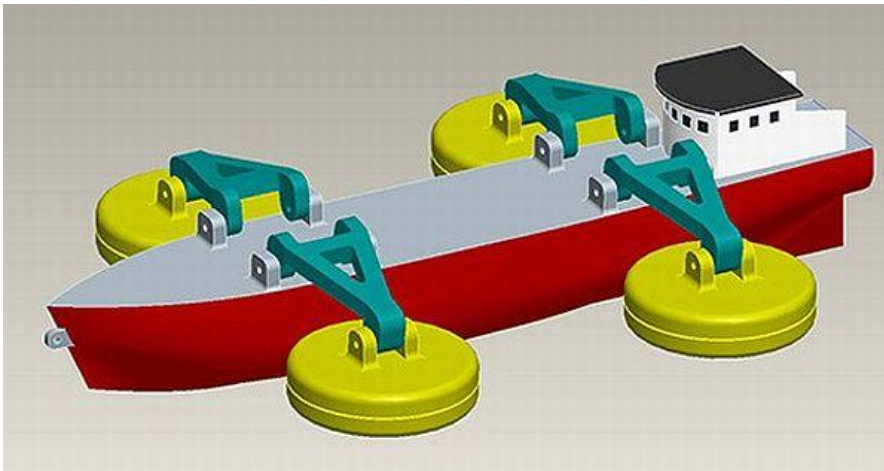
# Eco Friendly Concept Ships



## NYK Super Eco Ship 2030

The Super Eco Ship 2030, which is currently in design stage, will be 353 meters long and will lead to a reduction of CO<sub>2</sub> by 69% per container carried. The ship will be powered by fuel cells capable of generating 40MW electricity to power its massive engines. The designers state that the ship's fuel cells can be fueled by natural gas or **hydrogen** and the propulsion power will be enhanced by the use of onboard solar and wind energy generating systems. If all goes well, the ship could reach the seas by 2030.  
(<http://www.ecofriend.com>)

## Wave Energy Generating Ships



# Hurricane Winds

- Wind and waves around hurricanes and cyclones can be mapped and speed and size determined using Synthetic Aperture Radar (SAR).
- Winds can also be measured using Dual Frequency Scatterometry using Ku and C band. So far much of the measurement work has been done to predict conditions upon land fall and deep ocean measurements appear to be lacking.

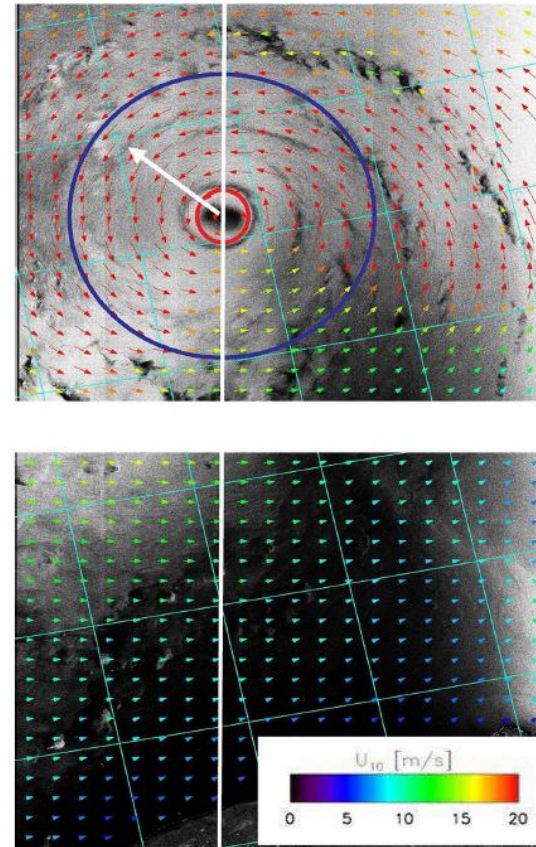


Fig. 1. Calibrated Envisat ASAR wide-swath images of hurricane Katrina acquired over the Gulf of Mexico on August 28, 2005, at 15:50 UTC. Superimposed is the wind field retrieved using the CMOD5 GMF. The red and blue circles represent the radius of the maximum wind speed and the radius of the hurricane wind speed, respectively. The white arrow shows the direction of the storm's movement.

# Complex Systems

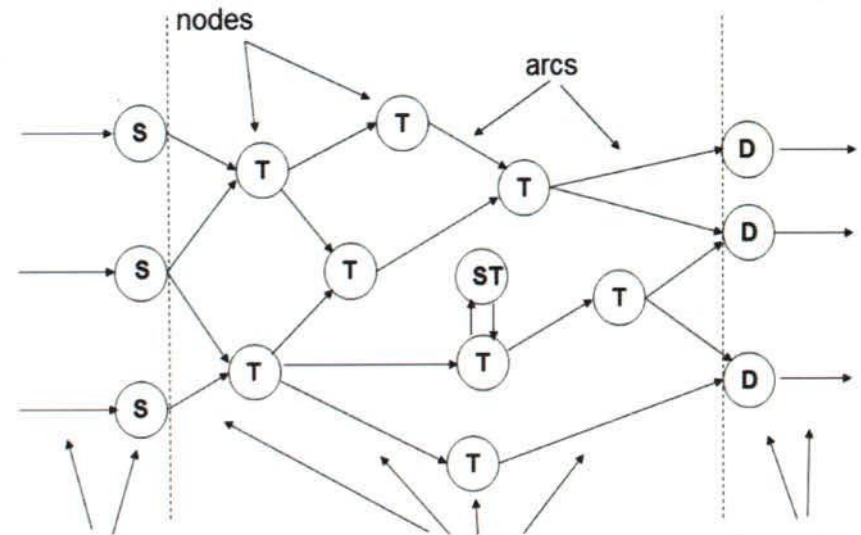
- Complex system requiring massive integration and interconnection between components and subsystems, feedback, and redundancy
- Operated automatically or by remote controls
- Operates in harsh conditions
- Performs predictably in unpredictable conditions
- Unanticipated perturbations can disable system
- Must be robust to continuously evolve and adapt to threats and opportunities
- Corrosion-resistant turbines needed
- Un-orthodox design, analysis and synthesis of engineered systems needed

# SNL Modeling Opportunities

- Scalable Complex Adaptive Control System Modeling
- Adapt for opportunities, unpredictable harsh conditions, take advantage of available resource, effective energy to shore transfer
- Hurricane wind modeling for best position for ship
- Control systems with feedback loops for changing conditions
- Models of hydrogen production efficiency and time to fill vessel
- Ship construction and stress (wind collection structure – wave collection)
- Wind or wave system modeling (mechanical system stress points and limitations)
- Generation systems, conversion and storage – Sodium Metal
- Scalable financial modeling and break even analysis

# Future - Modeling Opportunities

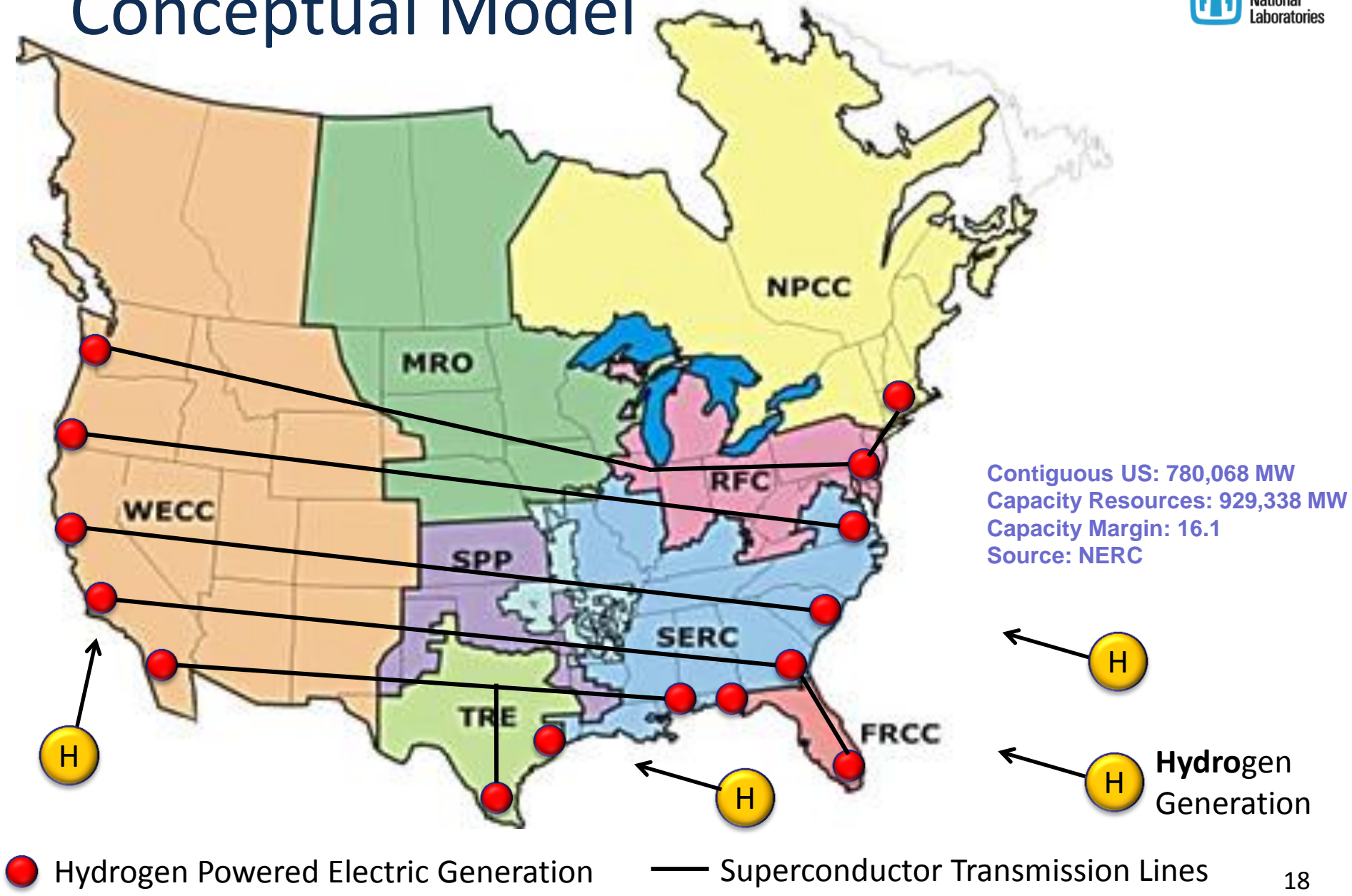
- Systems capable of moving into higher wind zones
- Harvest heat energy presently released to the atmosphere
- Reduce destruction effects
- Study global effects of removing energy from hurricanes
- Using known technologies
- Model futuristic power system
- Assuming ideal systems
- Identify research opportunities



# Future – Modeling Ideal Power System

- Limitless hydrogen source
- Ideal superconductors
- Adequate hydrogen storage systems
- Ideal hydrogen transport system
- Effective fuel cell electric generation
- Reduced spending on CO2 reduction
- Reduced spending on alternate energy sources
- Not abandoning existing energy sources

# Conceptual Model



● Hydrogen Powered Electric Generation

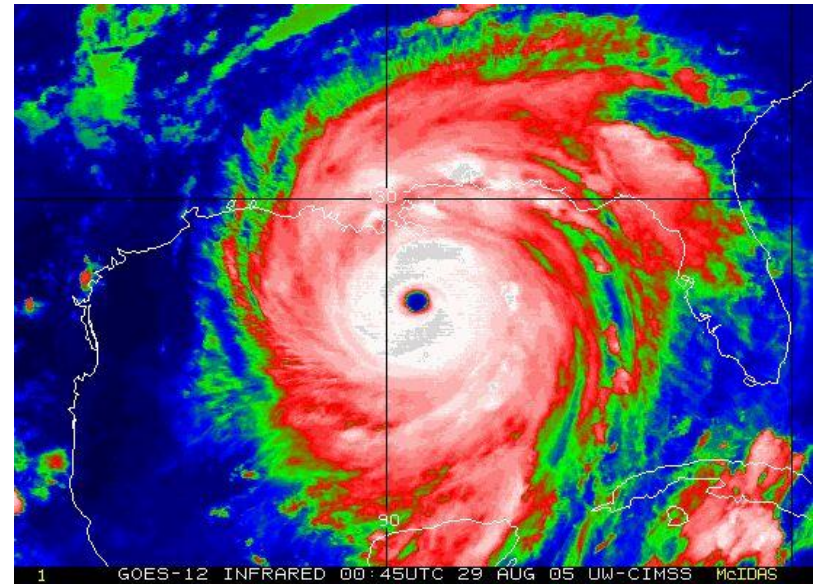
— Superconductor Transmission Lines

Contiguous US: 780,068 MW  
Capacity Resources: 929,338 MW  
Capacity Margin: 16.1  
Source: NERC

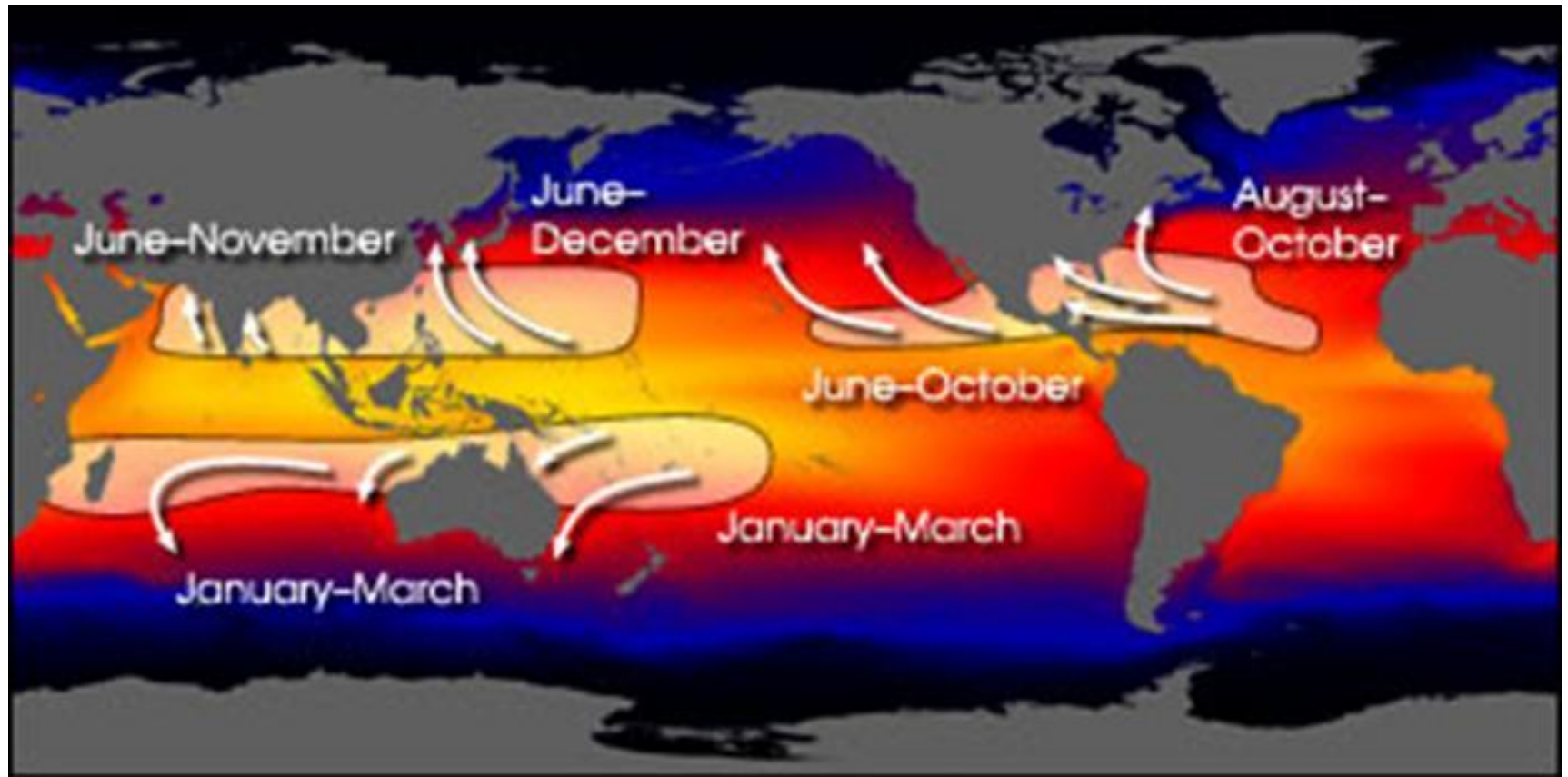
⬅ (H)  
⬅ (H) Hydrogen Generation

# Harvesting Hurricane Energy Conclusions

- Alternative Energy source
- Complimentary Energy source
- Green – Reduce CO<sub>2</sub>
- Sustainable, Scalable, Abundant
- Uses available technologies
- Economic analysis needed
- Environmental effects not evaluated
- Challenges – harsh environment, unpredictable, technology refinement, storage, affordability, development
- Excellent modeling, research and engineering opportunities for Sandia National Laboratories



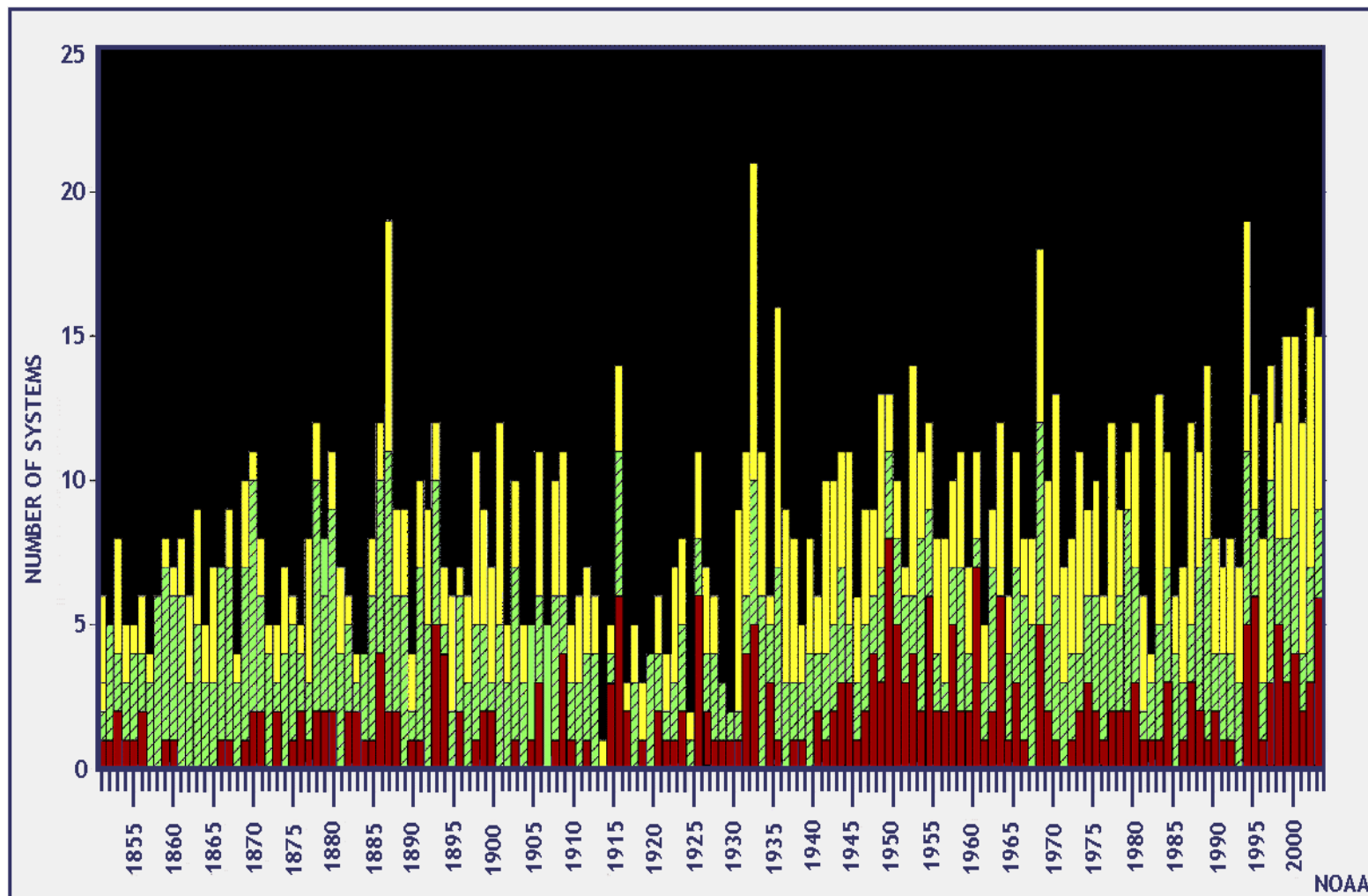
# Hurricane Seasons



Sea Surface Temperature (°C)

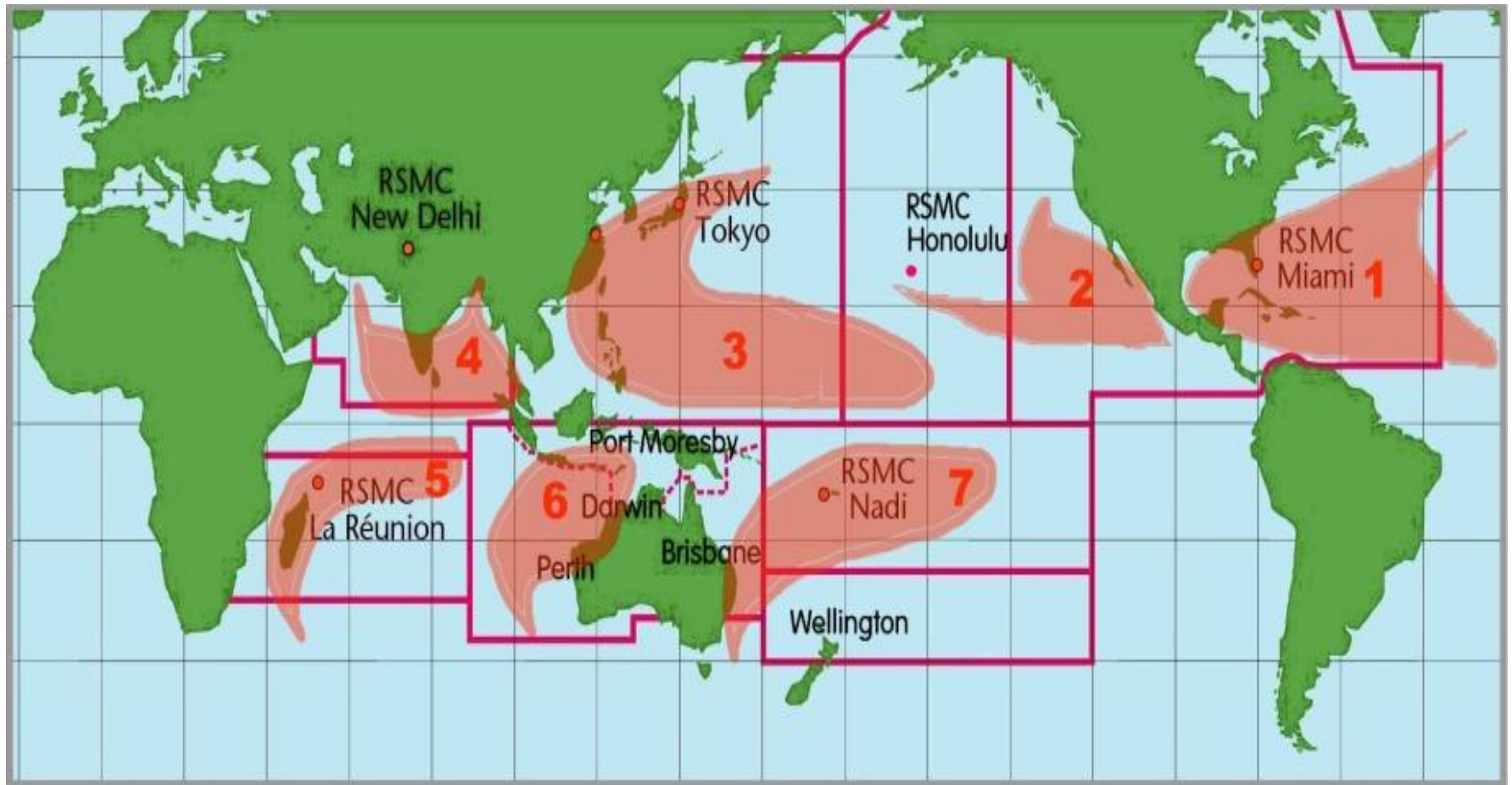


# Number of Hurricanes



Bars depict number of named systems (open/yellow), hurricanes (hatched/green), and category 3 or greater (solid/red), 1886-2004

# Hurricane Regions



*Source: Chris Landsea*

# Number of Storms

**Record number of storms by basin**  
**Based on data from 1981-2010**  
**(1981/82 to 2010/2011 for the Southern Hemisphere):**

Basin	Tropical Storm or stronger (greater than 17 m/s sustained winds)			Hurricane/Typhoon/Severe Tropical Cyclone (greater than 33 m/s sustained winds)		
	Most	Least	Average	Most	Least	Average
Atlantic*	28	4	12.1	15	2	6.4
NE Pacific**	28	8	16.6	16	3	8.9
NW Pacific	35	14	26.0	23	7	16.5
N Indian	10	2	4.8	5	0	1.5
SW Indian	14	4	9.3	8	1	5.0
Aus SE Indian	16	3	7.5	8	1	3.6
Aus SW Pacific	20	4	9.9	12	1	5.2
Globally	102	69	86.0	59	34	46.9

\* These data includes subtropical storms in the Atlantic basin numbers.

\*\* These data includes storms and hurricanes that formed in the Central Pacific.

[\(Neumann 1993\)](#) and [\(Landsea 1993\)](#)