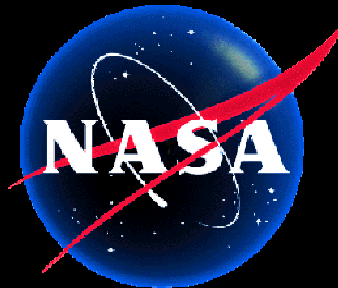**BIOGREEN 2010, Cancún, Mexico**

Obtaining Offshore Wind Climatology for Renewable Energy and Other Research

S. V. Nghiem

Jet Propulsion Laboratory
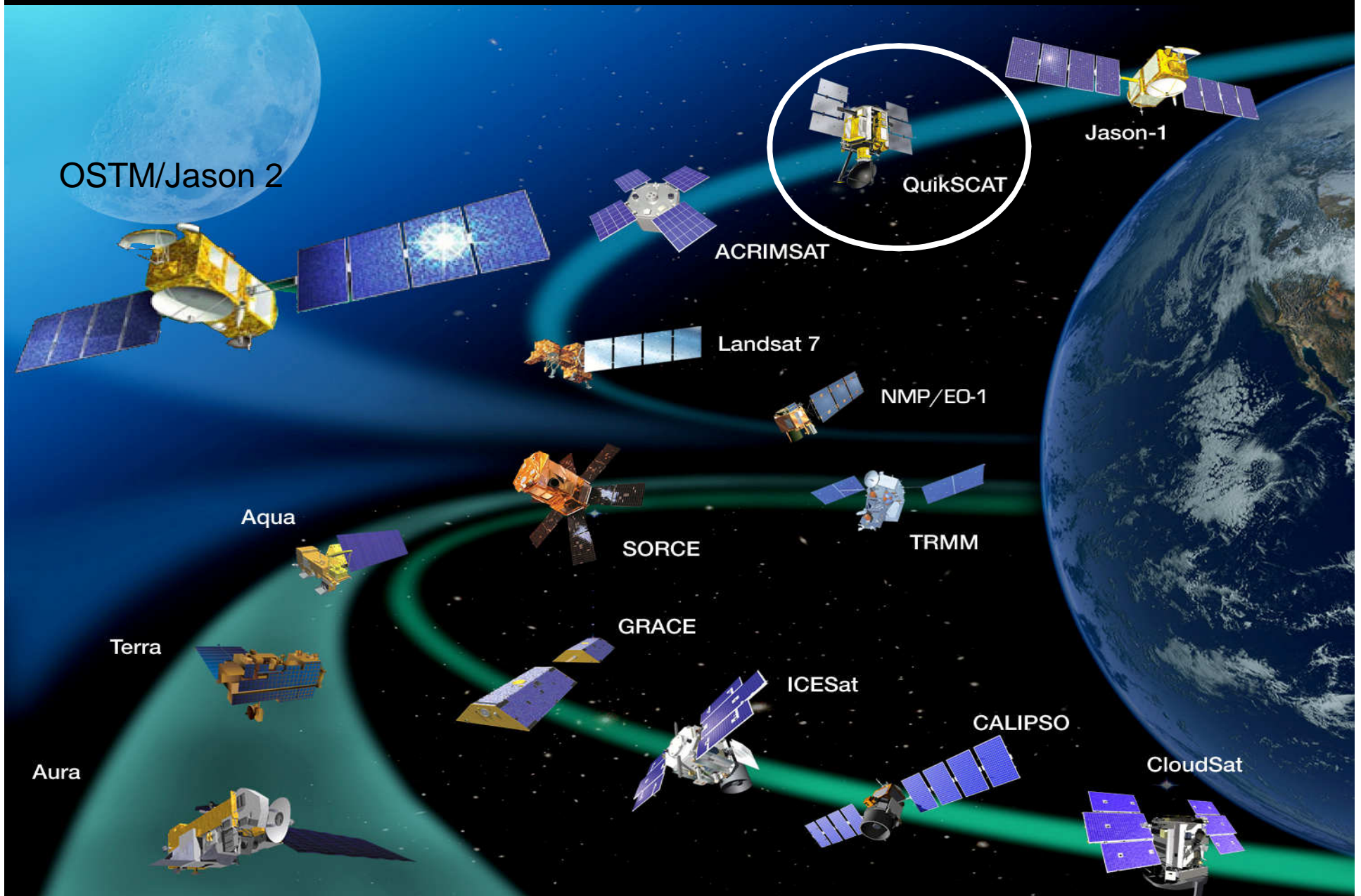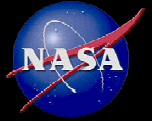**California Institute of Technology**
Pasadena, California, USA

Notable Developments

- **The Copenhagen Summit: UN COP-15, 12-2009**
- **Energy & Climate Ministerial of the Americas: DC 4-2010**
- **Energy Innovation Summit: ARPA-E, DC 3-2010**
- **Wind energy contributes to the overall energy portfolio**

Offshore Wind Climatology

- **Critical for offshore wind power development**
- **Buoys: sparse point data**
- **Models: different values, boundary, need verified**
- **New breakthrough for offshore wind measurement using satellite data**

NASA Earth Satellite Missions

OSTM/Jason 2

Jason-1

QuikSCAT

ACRIMSAT

Landsat 7

NMP/EO-1

Aqua

SORCE

TRMM

Terra

GRACE

ICESat

Aura

CALIPSO

CloudSat

NASA SeaWinds Mission

- **Launched on the QuikSCAT satellite on 19 June 1999**

- **Orbited the Earth 14 times per day**

- **Collected global data for 10 years till November 2009**

- **Circled the Earth > 2 billion kilometers**

QuikSCAT Scatterometer

- The scatterometer is a stable and accurate radar

- 60 Watts power: like a light bulb in your house

- 800 km out in space: Cancún to Guatemala city

Ocean Wind Measurement across the World
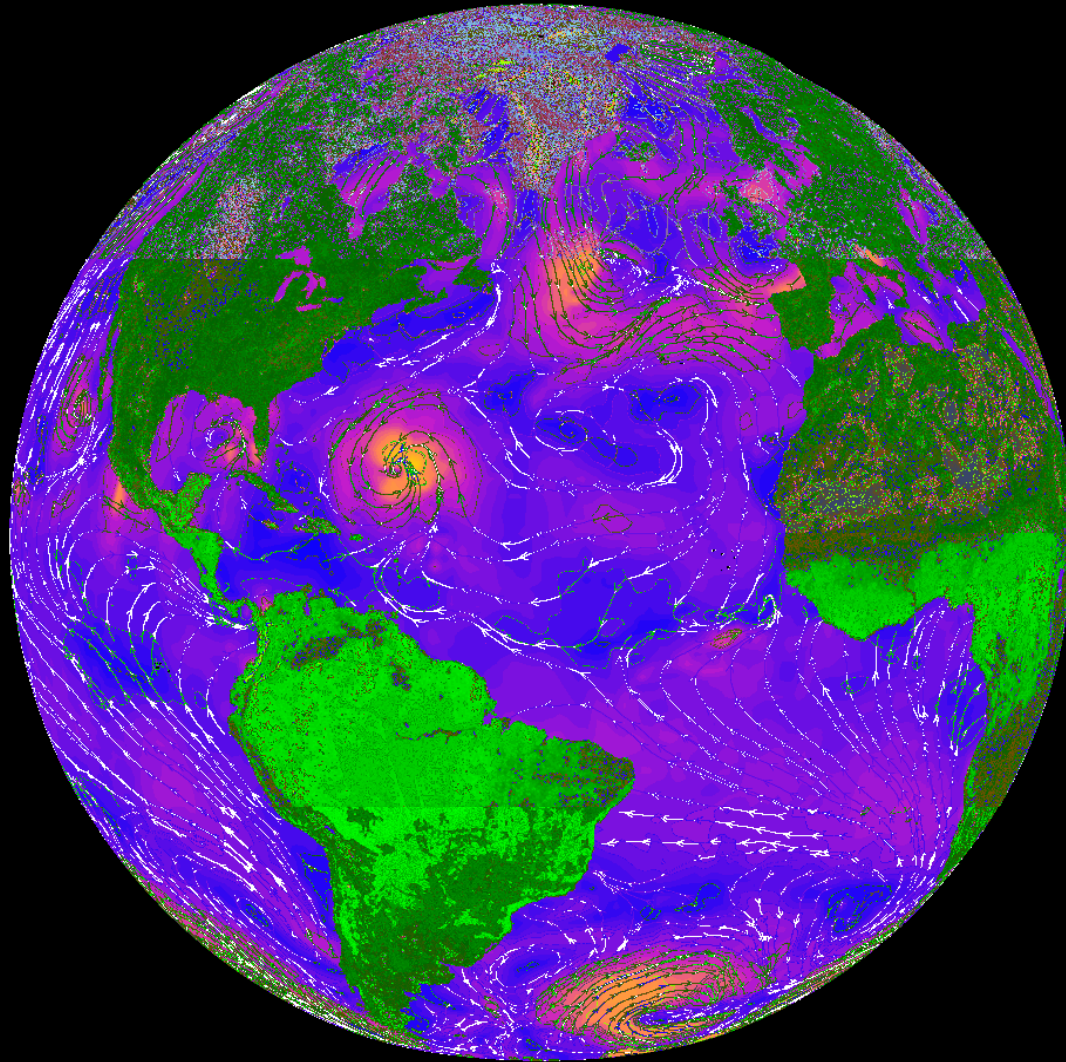
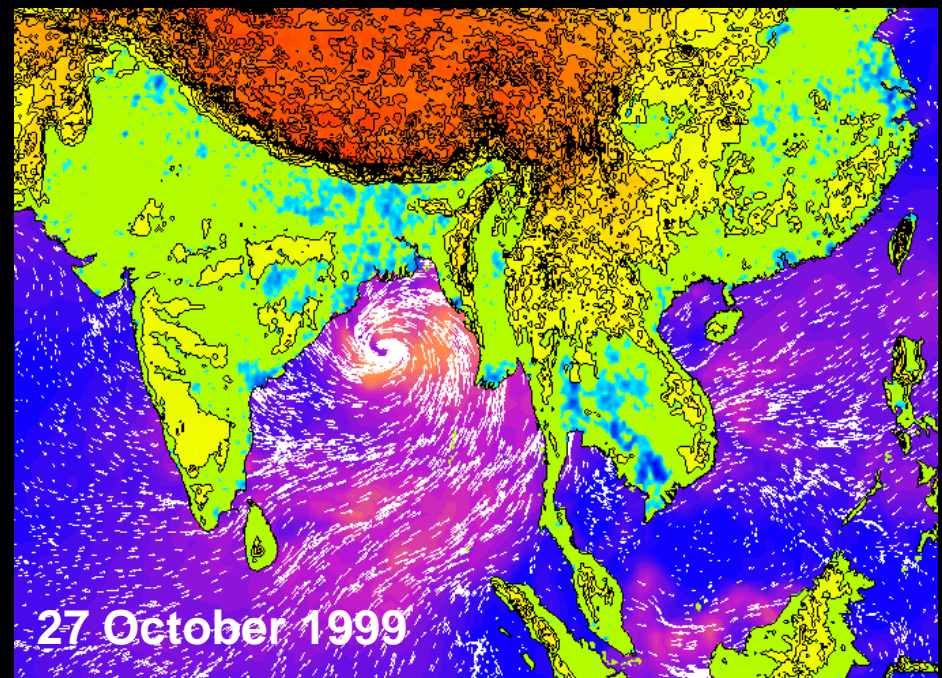- Covering 90% of the world in one day

- Coarse resolution of 25 km

- Valid at 50-60 km away from shore

The Orissa Disaster: Cyclones/Floods

16 October 1999

27 October 1999
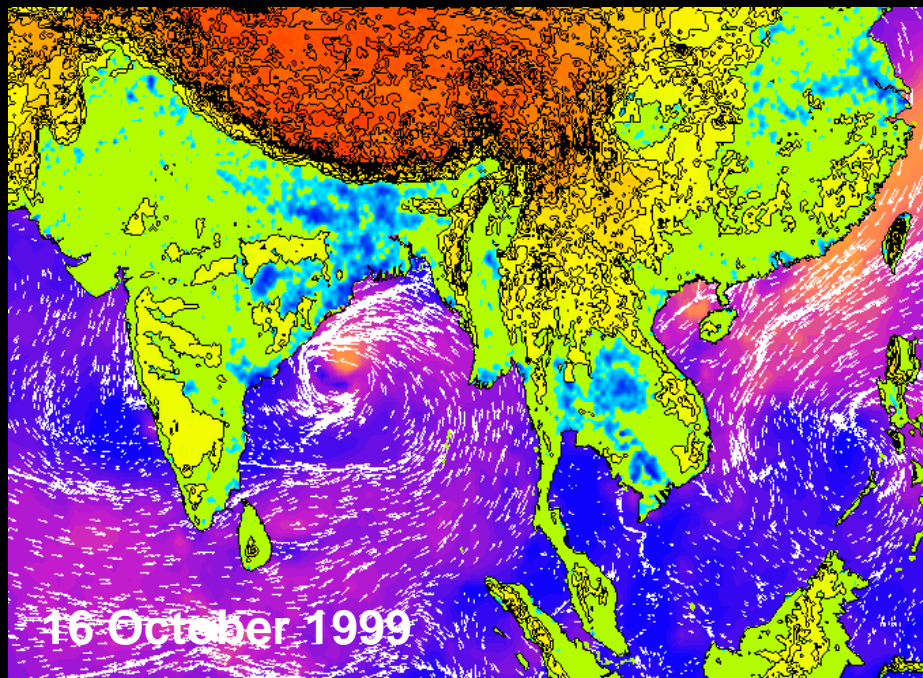
Polarization ratio (dB)

−5.7   −4.9   −4.1   −3.3

Wind speed (m/s)

0.75   13.5   20.25

The 1999 Orissa Disaster: In middle of October, a super cyclone hit Orissa in eastern India causing severe flooding. Shortly afterward, another one hit Orissa again causing more destruction and damages. This disaster affected 15 million people according to United Nations' report.
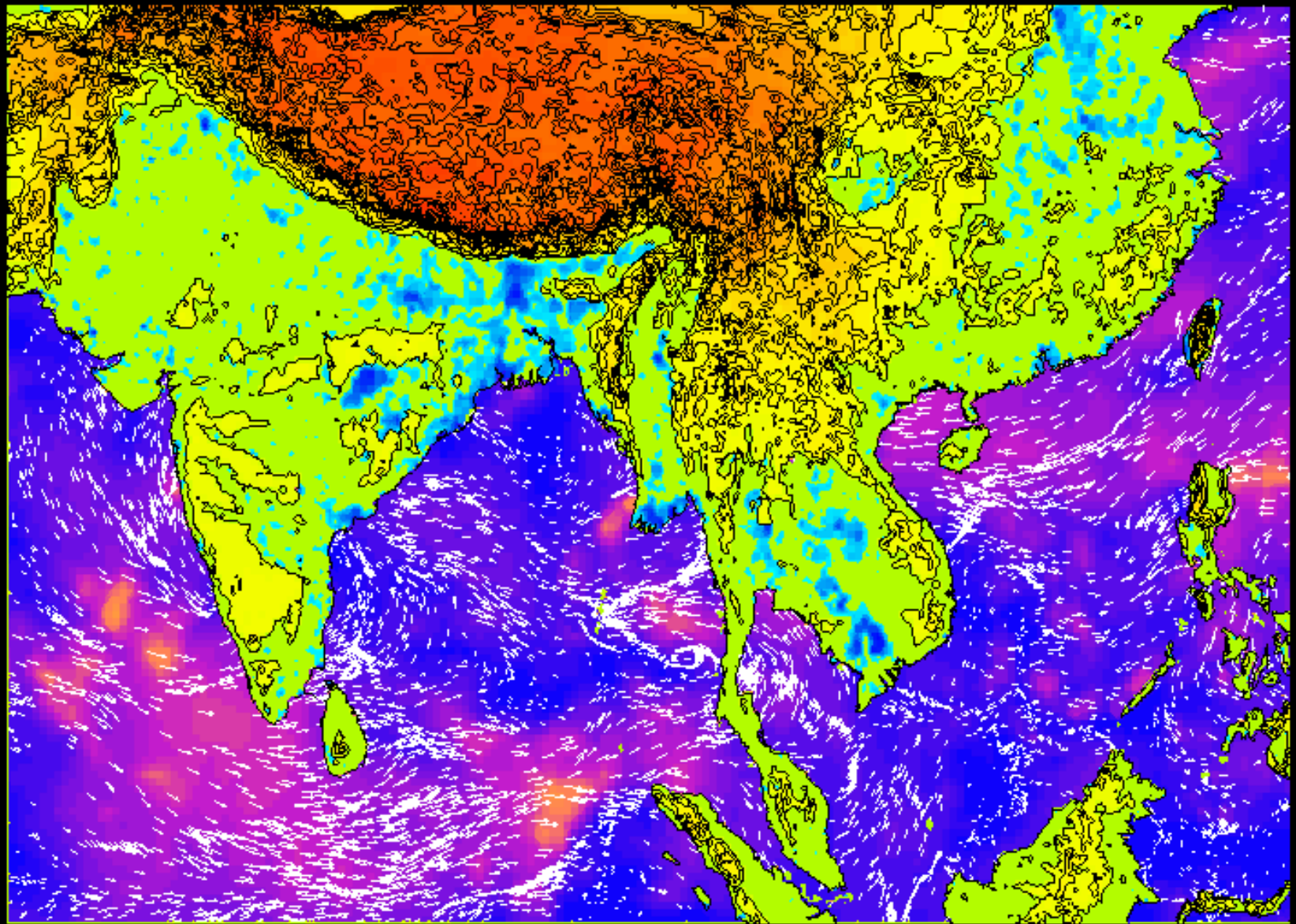
Sigma 0 (dB)

-6.50   -5.70   -4.90   -4.10   -3.30   -2.50
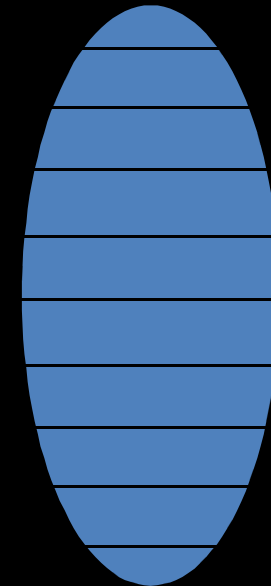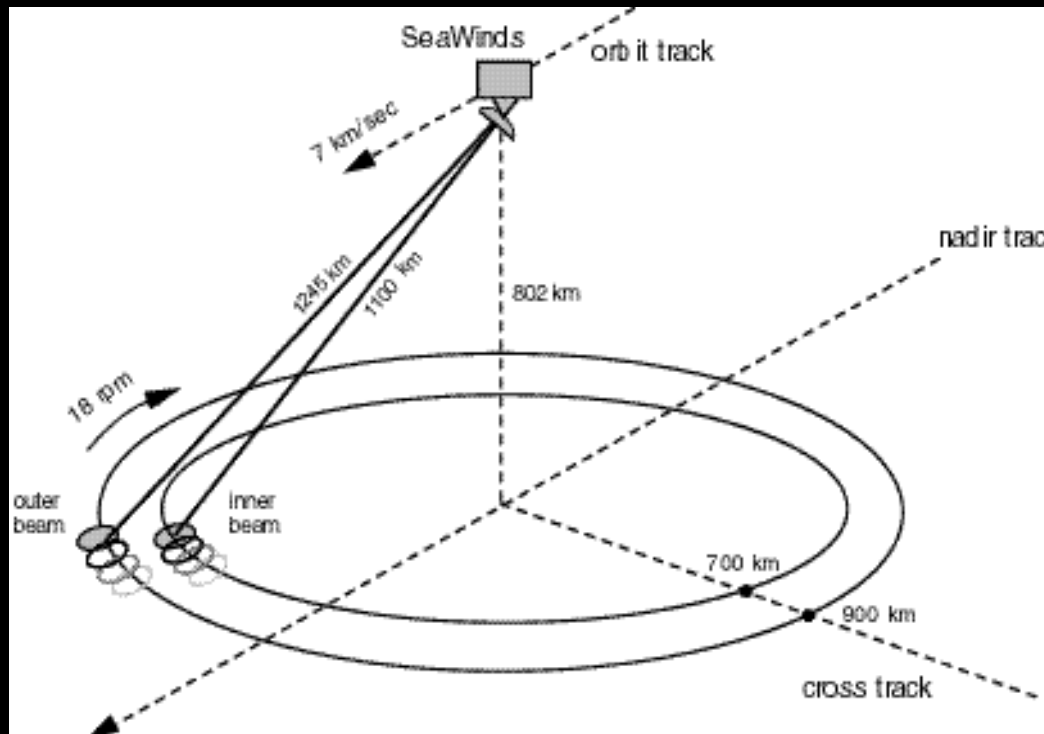
Wind Speed (m/s)

0.00   6.75   13.50   20.25   27.00

JPL

1999/10/14

QuikSCAT Scatterometer Data

- Conical scan with constant incidence angles
- Drifting orbits allow more azimuth diversity
- Footprint of radar around 25 km x 37 km
- Chirp transmission to get slice data: 6 km x 25 km

The New Method

$$P_{Ri} = \frac{P_{Ti}\lambda^2}{(4\pi)^3 R^4} \iint_A dx\, dy\, G(\phi_i, x, y)\, \sigma_0(\phi_i, t_i, x, y)$$

$$P_{Ri} = \frac{P_{Ti}\lambda^2}{(4\pi)^3 R^4}\, \overline{\sigma}_0(\phi_i, t_i) \iint_A dx\, dy\, G(\phi_i, x, y)$$

$$\overline{\sigma}_0(\phi_i, t_i) = \frac{1}{\Gamma_A} \iint_A dx\, dy\, G(\phi_i, x, y)\, \sigma_0(\phi_i, t_i, x, y)$$

The New Method

$$\overline{\sigma}_0 = \frac{1}{N} \sum_{i=1}^{N} \overline{\sigma}_0(\phi_i, t_i) = \frac{1}{N \Gamma_A} \sum_{i=1}^{N} \iint_A dx\, dy\, G(\phi_i, x, y)\, \sigma_0(\phi_i, t_i, x, y)$$

$$\sigma_0(\phi_i, t_i, x, y) = \overline{\sigma}_0(x, y) + \varepsilon(\phi_i, t_i, x, y)$$

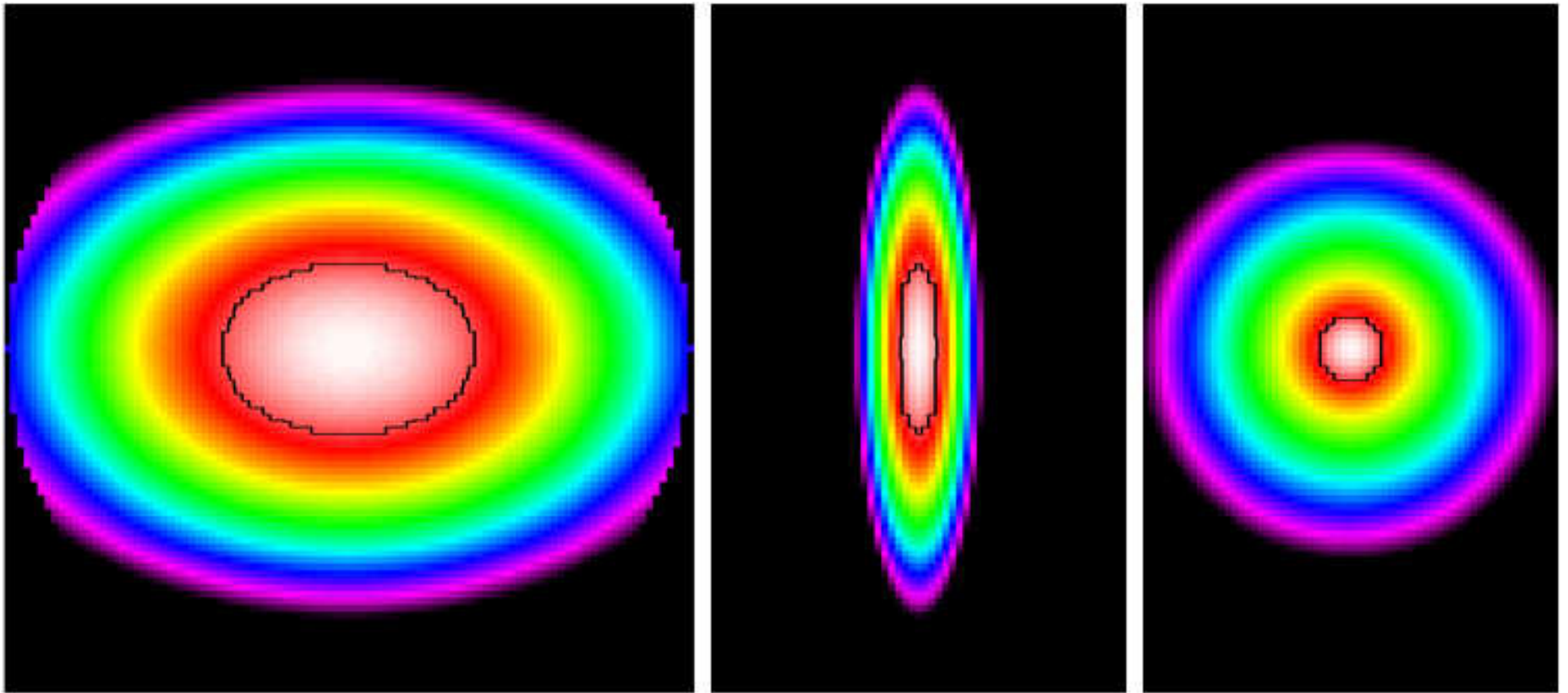$$\overline{\sigma}_{0M} = \frac{1}{\Gamma_A} \iint_A dx\, dy \left[\sum_{i=1}^{N} \frac{G(\phi_i, x, y)}{N} \right] \overline{\sigma}_0(x, y)$$

$$\mathcal{R} = \frac{1}{\Gamma_A} \iint_A dx\, dy \sum_{i=1}^{N} \left[\frac{G(\phi_i, x, y)}{N}\, \varepsilon(\phi_i, t_i, x, y) \right]$$
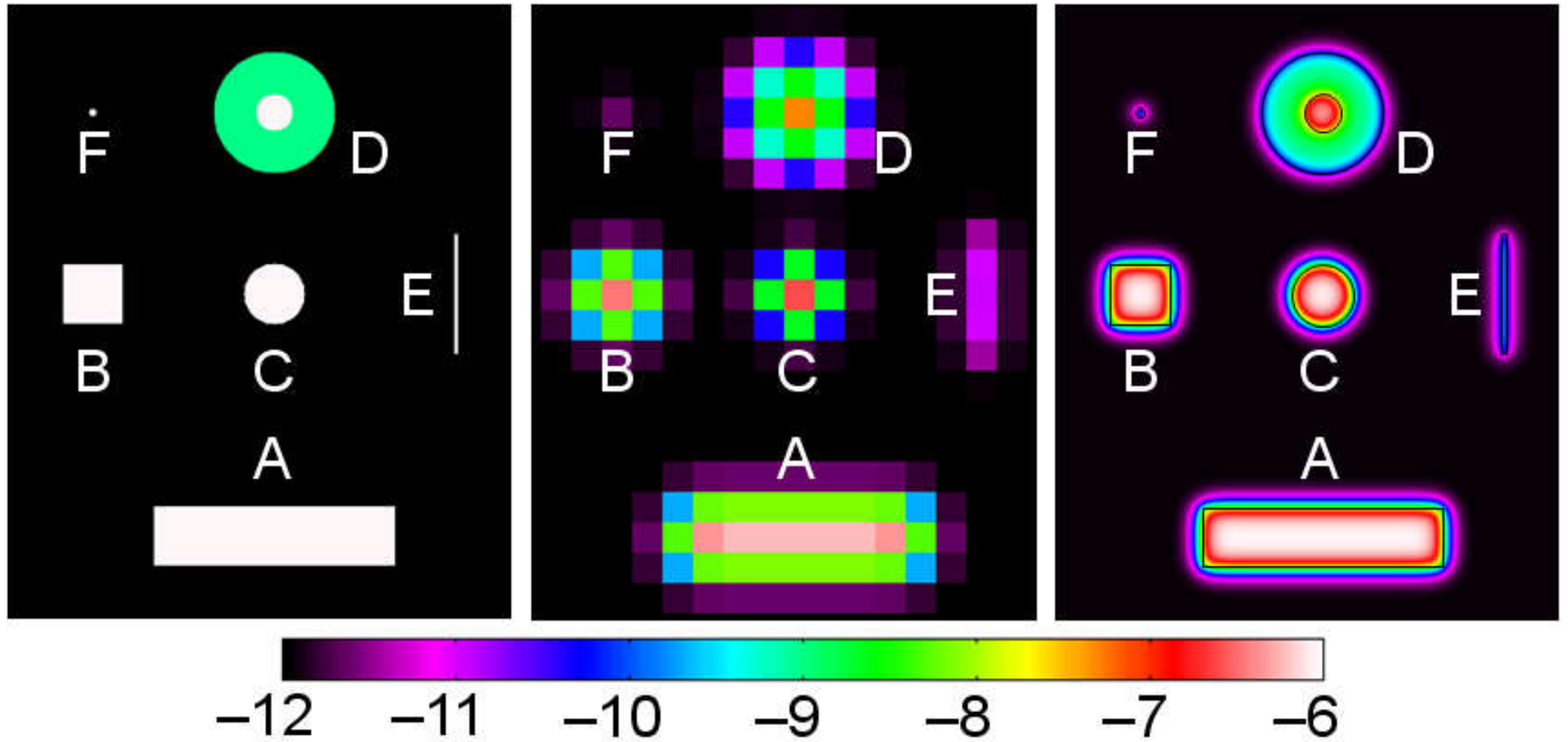
Effective Footprints
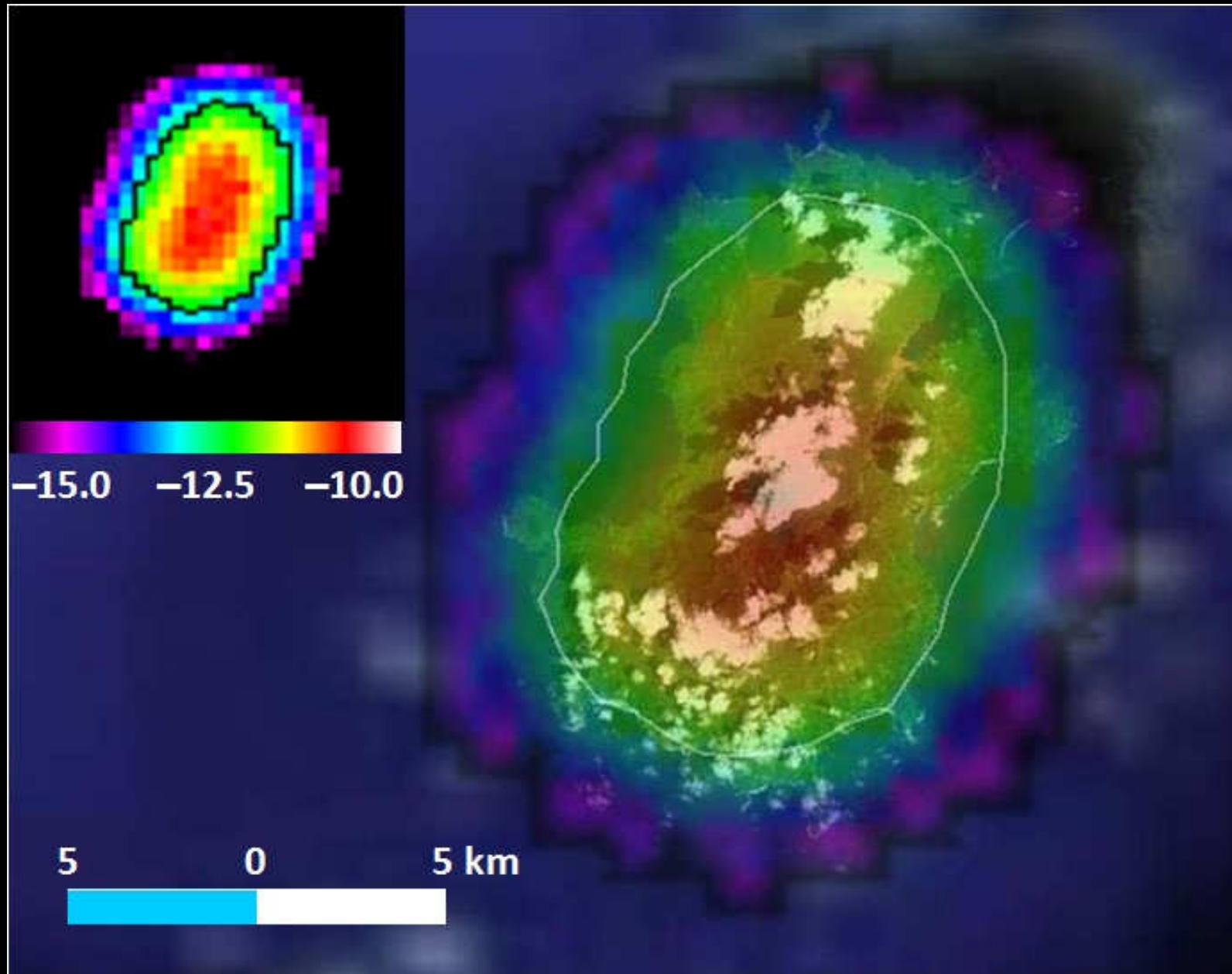
# Simulation

Verification - Príncipe Island

Procedure to Obtain Global Offshore Wind Climatology

- Use the DECADE of NASA QuikSCAT satellite scatterometer collected GLOBALLY

- Apply the new method for high-resolution data processing over offshore waters

- Calculate wind fields from empirical formulation [Yueh et al., 2001; Nghiem et al., 1997, …]

- Validate high-resolution results with available surface measurements from buoys and ships

- Variability at different time scales: Diurnal, seasonal, and interannual

ATLAS of HIGH-RESOLUTION WIND

Offshore Wind Pattern Of Hawaiian Islands
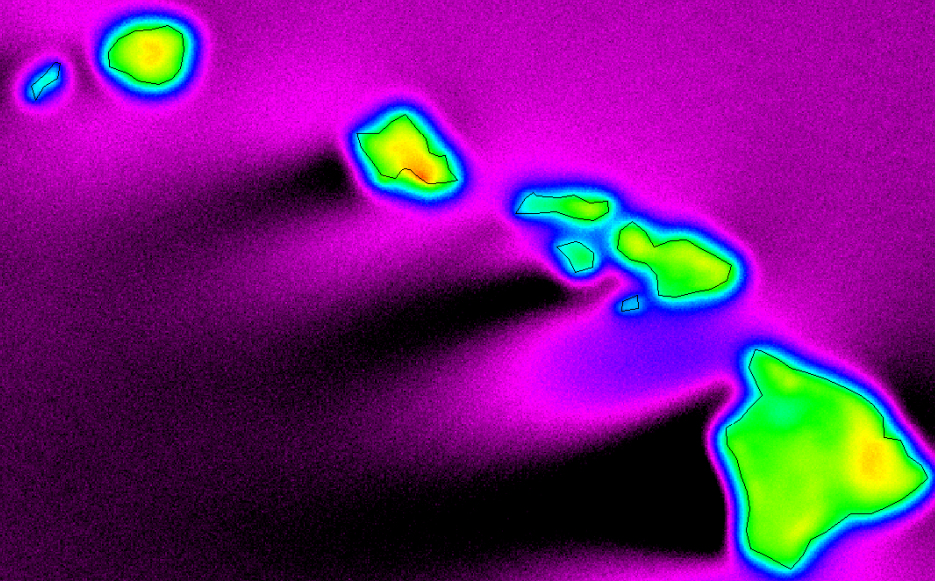
National Renewable Energy Laboratory (NREL) Wind Power Classes

Table 1-1 Classes of wind power density at 10 m and 50 m[a].

Wind Power Class[*]	10 m (33 ft)		50 m (164 ft)	
	Wind Power Density (W/m^2)	Speed[b] m/s (mph)	Wind Power Density (W/m^2)	Speed[b] m/s (mph)
1	0	0	0	0
2	100	4.4 (9.8)	200	5.6 (12.5)
3	150	5.1 (11.5)	300	6.4 (14.3)
4	200	5.6 (12.5)	400	7.0 (15.7)
5	250	6.0 (13.4)	500	7.5 (16.8)
6	300	6.4 (14.3)	600	8.0 (17.9)
	400	7.0 (15.7)	800	8.8 (19.7)
7	1000	9.4 (21.1)	2000	11.9 (26.6)

Source: Wind Energy Resource Atlas of the United States
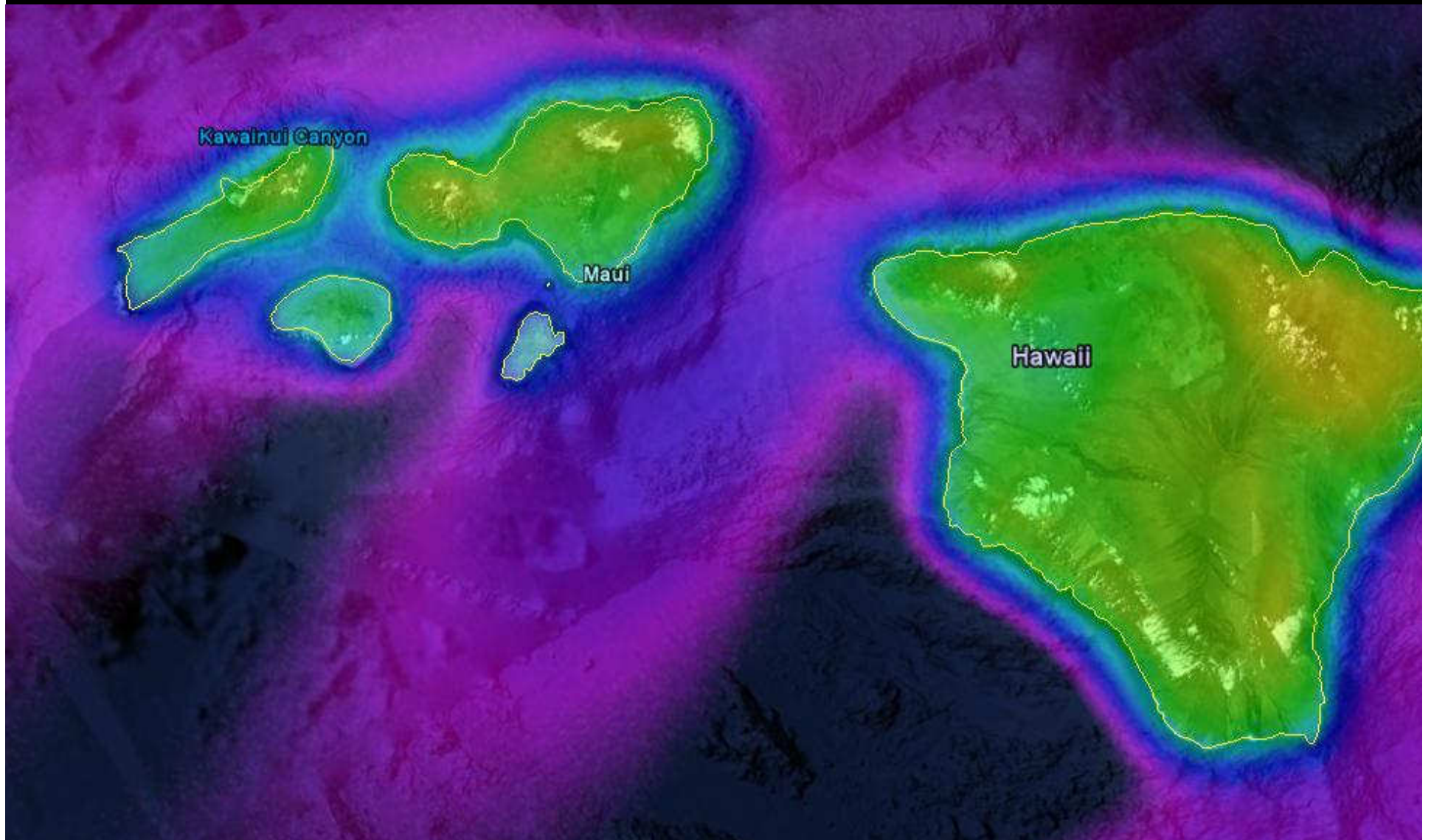
Comparison with NREL Classes
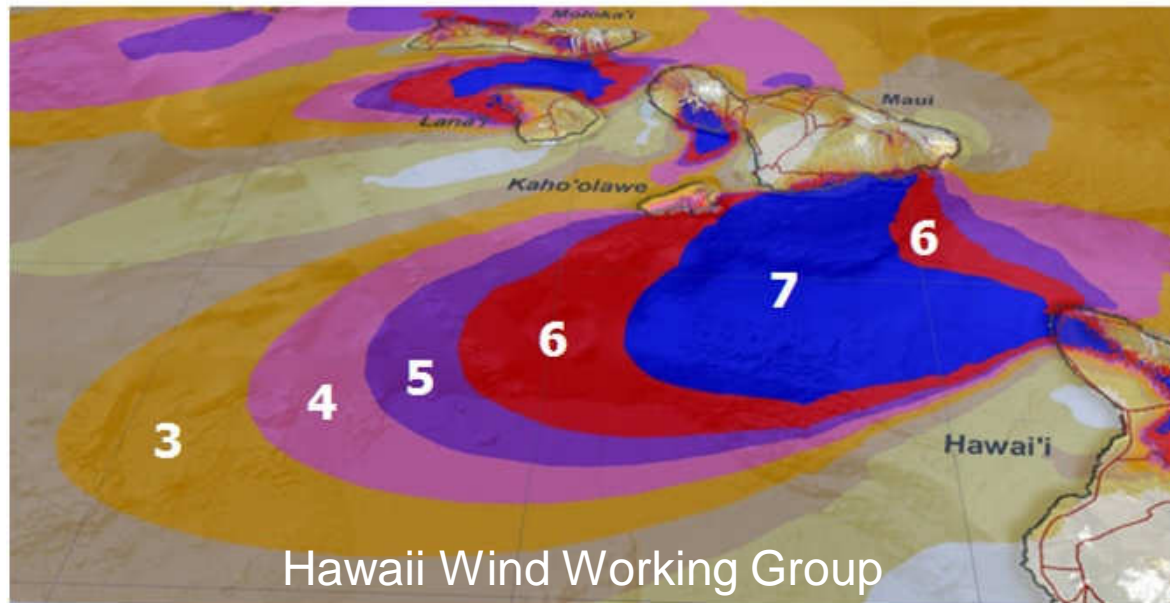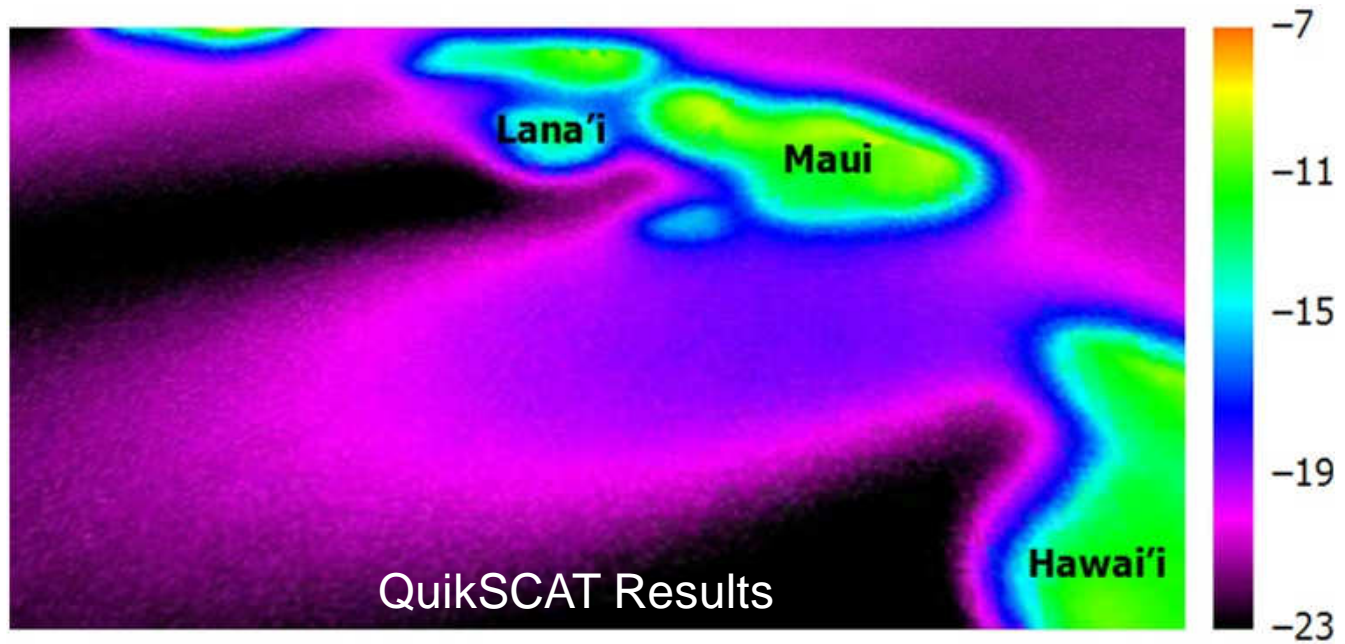
Translucent Overlay on NREL Wind Power Classes
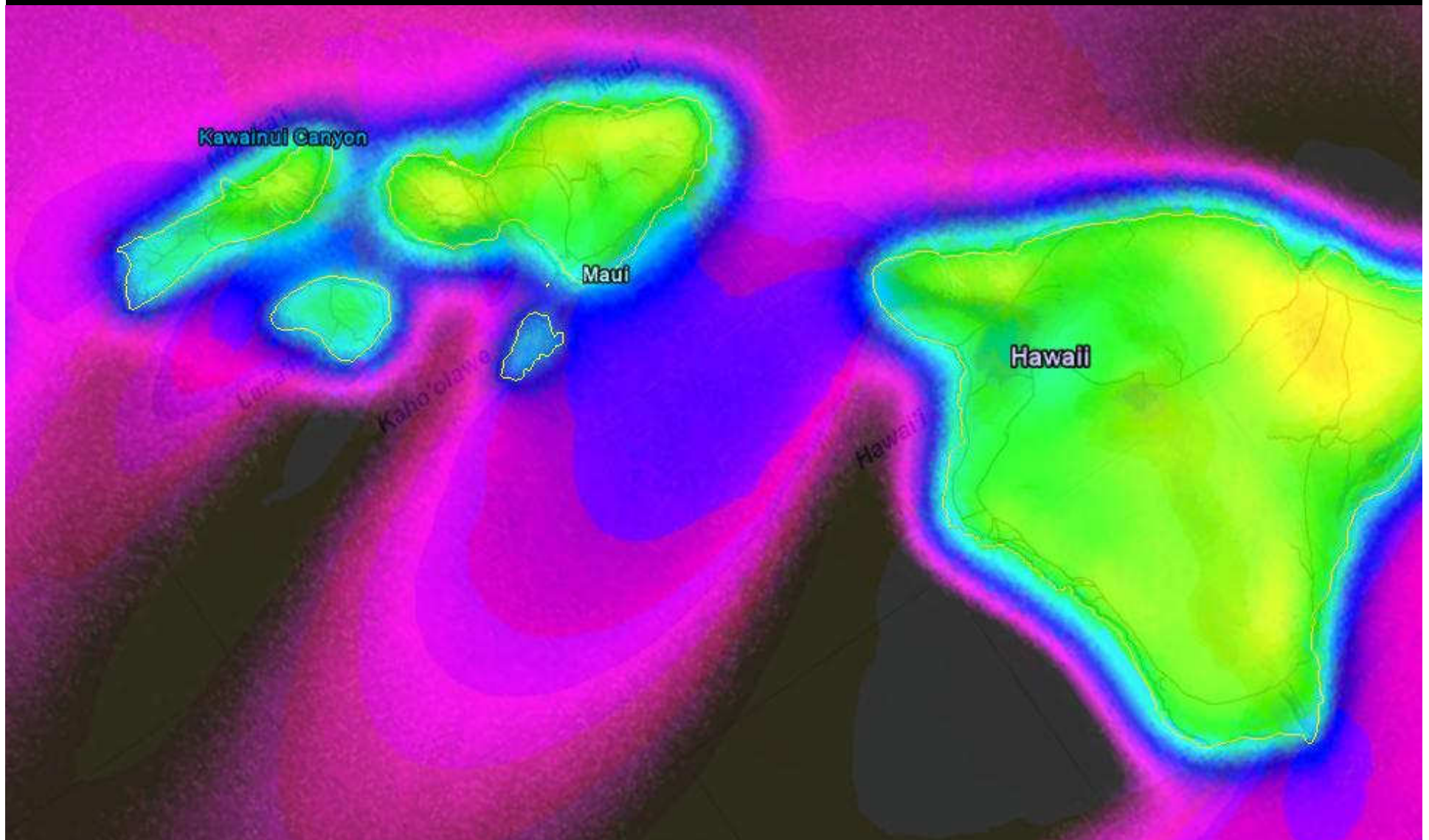
Translucent Overlay on Bathymetry

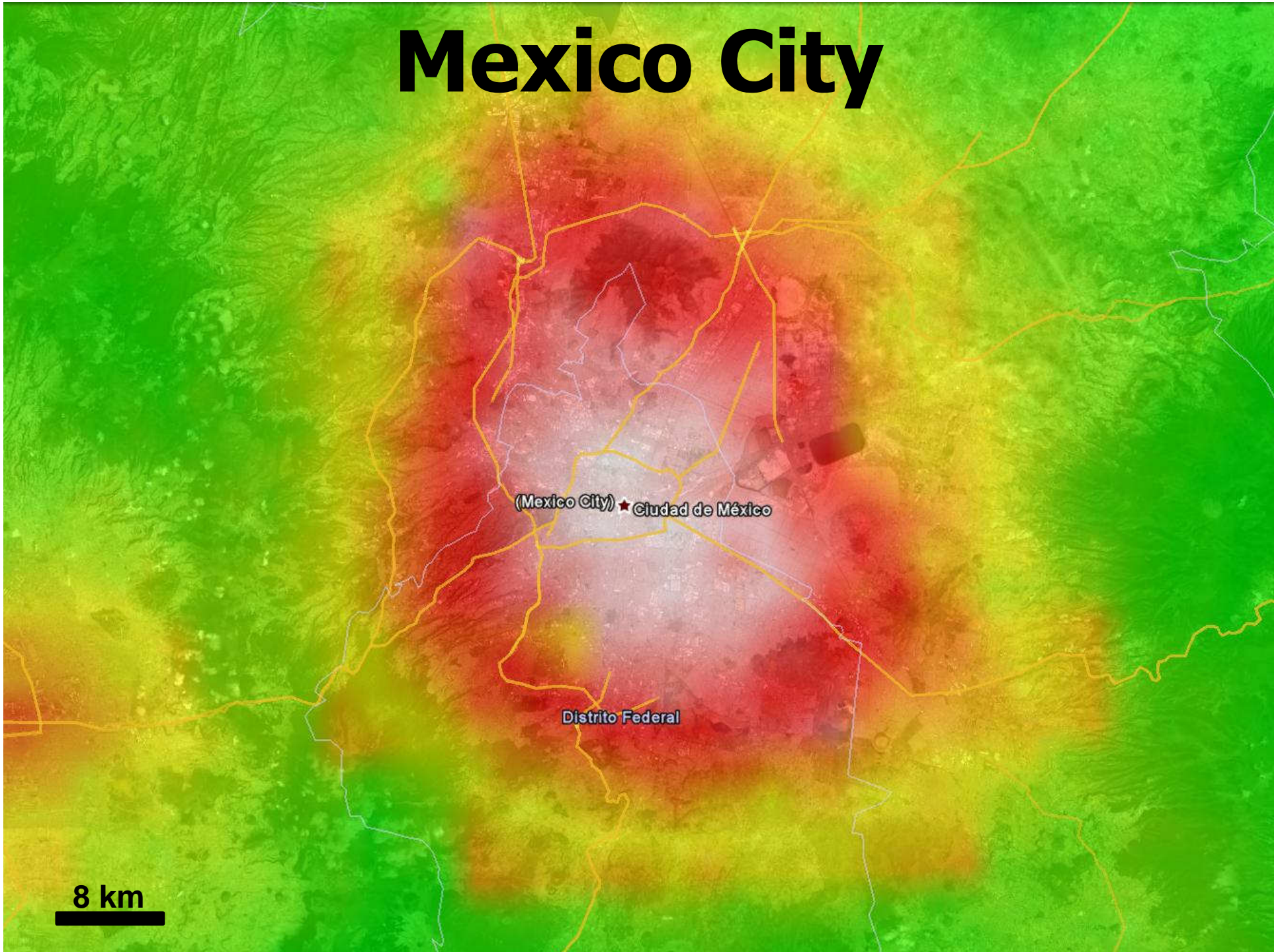# Other Science Research and Applications

- **Oceanography**
- **Coral biodiversity**
- **Aviation safety**
- **Tourist information**
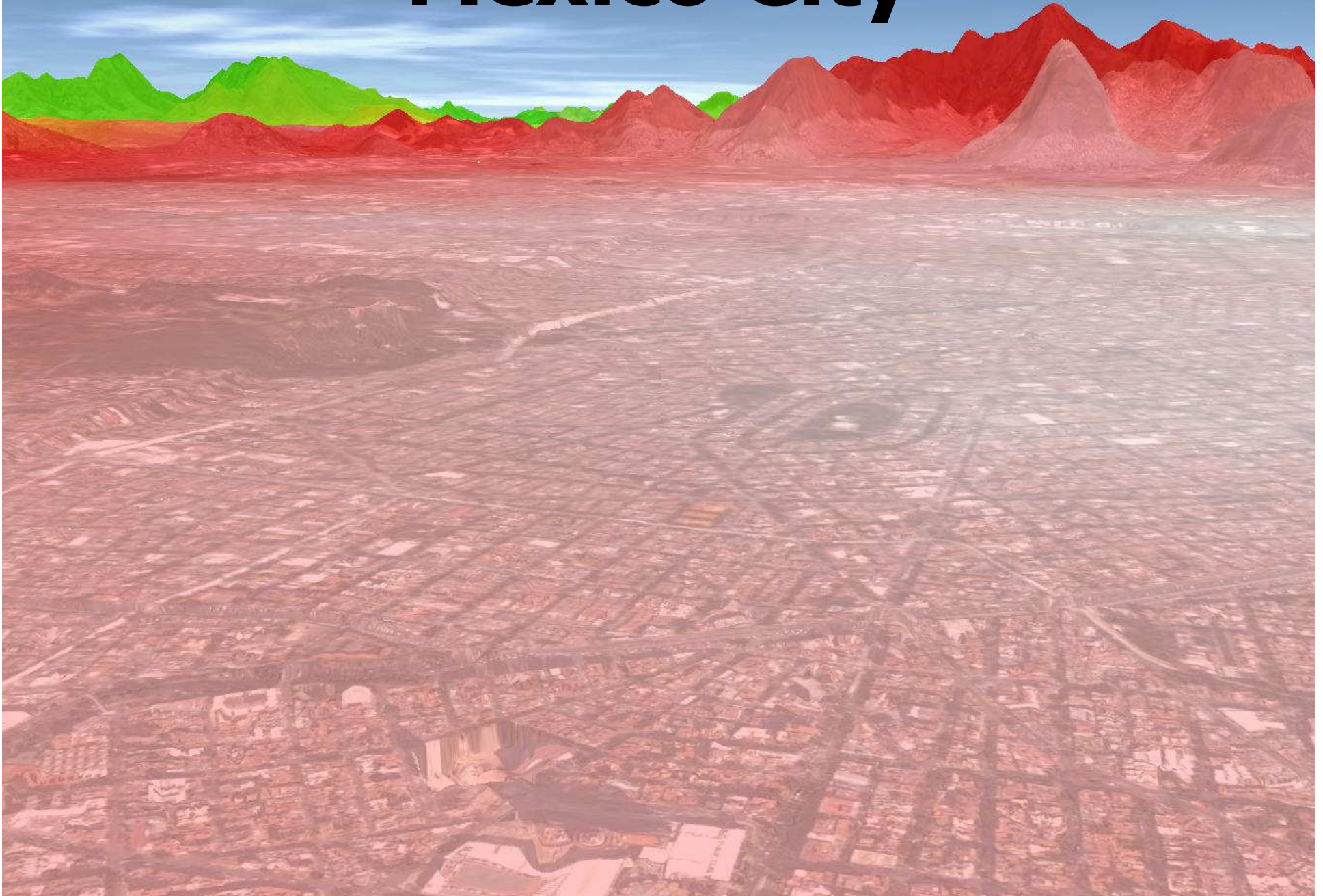- **Urban/suburban**

Mexico City

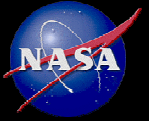(Mexico City) ★ Ciudad de México
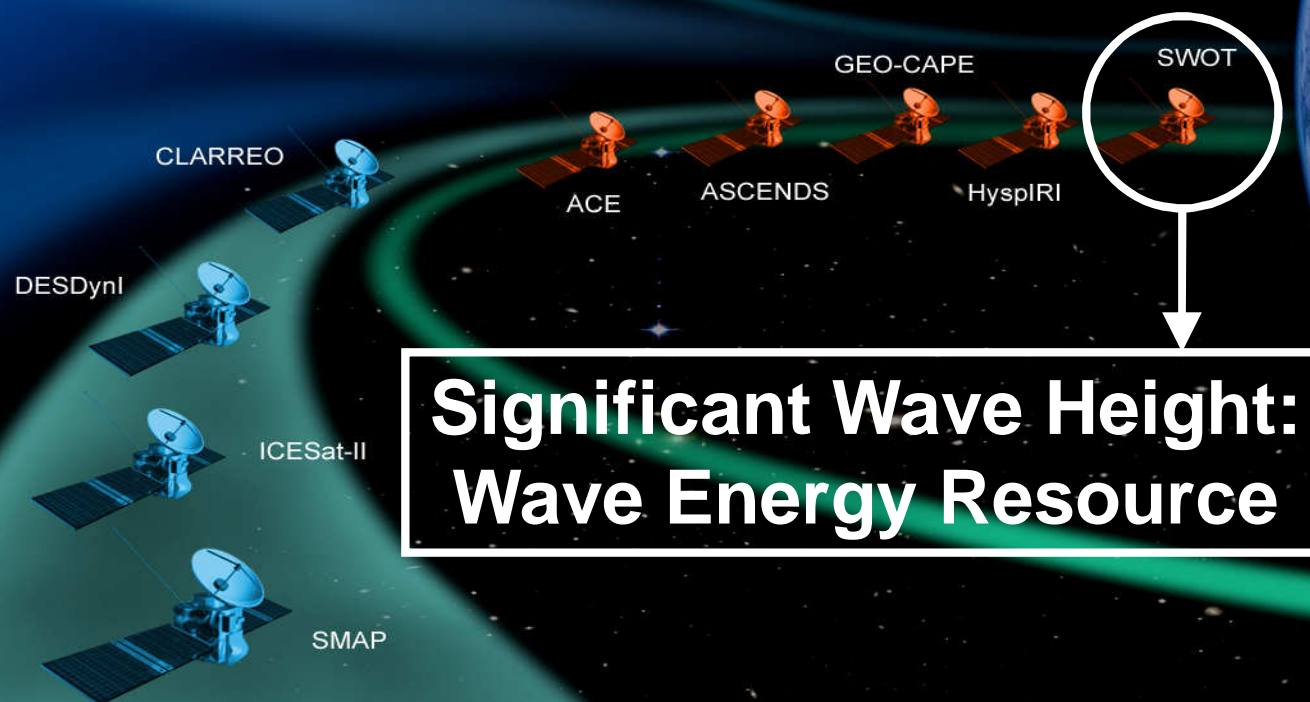
Distrito Federal

8 km

Mexico City

Mexico City

Mexico City

Looking into the Future:
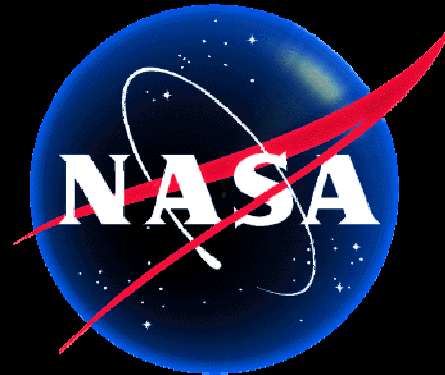## Decadal Survey Mission Recommendations

Contact

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