Directional wave climatology for the Hawaiian Islands from buoy data and the influence of ENSO on extreme wave events from wave model hindcast

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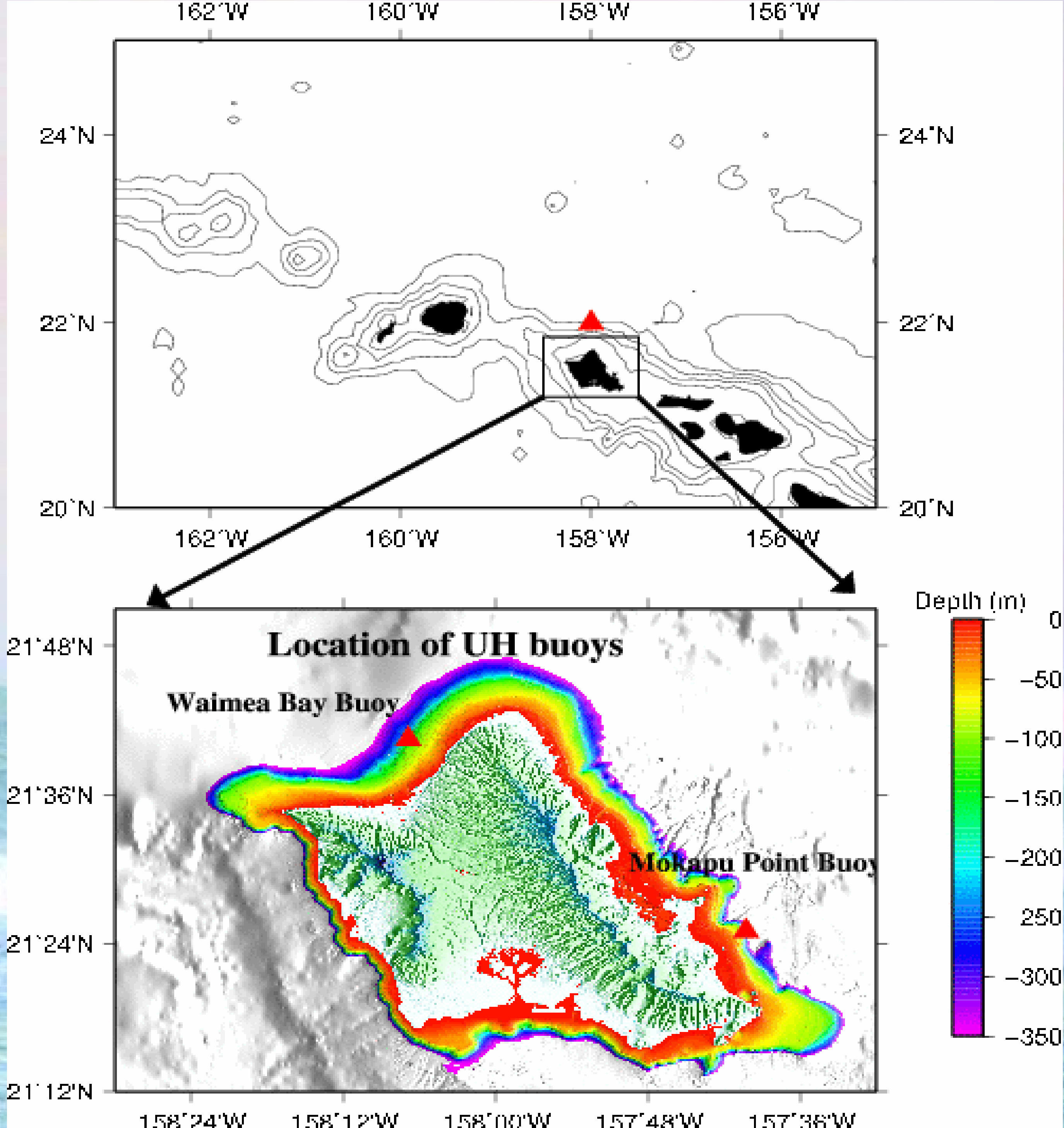
"Shoreline means the upper reaches of the wash of the waves, other than storm and seismic waves, at high tide during the season of the year in which the highest wash of the wave occurs, usually evidenced by the edge of vegetation growth, or the upper limit of debris left by the wash of the waves. Hawaii Revised Status, Sect.205A-1"

9TH Workshop on Wave Forecasting and Hindcasting, Victoria, Canada 2006

Outline

- Directional wave buoy data : quantitative wave climate.
    - Data reduction
    - Refraction Diffraction effects
    - Average monthly climate and statistics
- Extreme events distribution
- Relation to ENSO

Model extrapolation Point

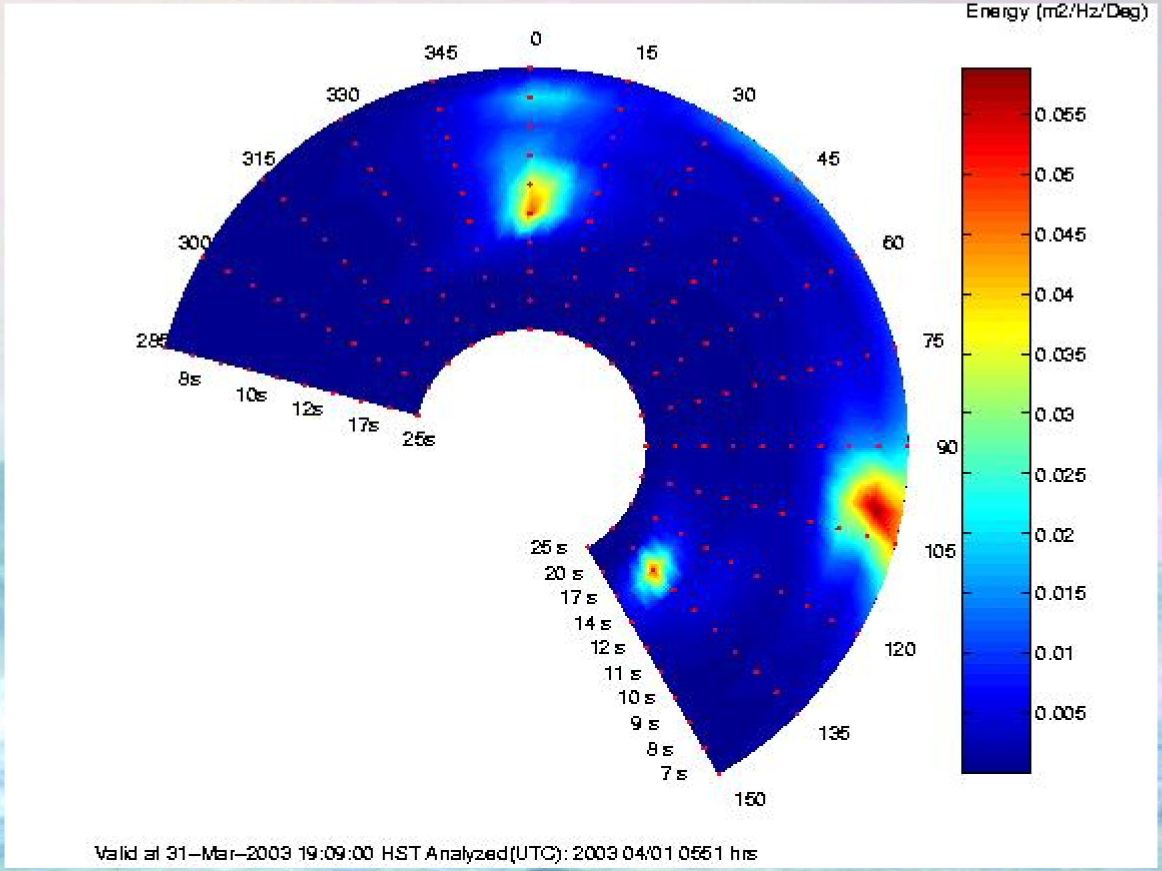


Buoy Locations

Qualitative Wave Climatology

3 Main sources of swells :
- Boreal Winter swells (NW)
- Trade winds (E)
- Boreal Summer swells (S)

Additional swells :
- Hurricanes
- Kona winds (SW)



Mokapu Buoy Data Availability

	2000	2001	2002	2003	2004	2005
Jan	0.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Feb	0.00%	100.00%	100.00%	100.00%	57.00%	100.00%
Mar	0.00%	100.00%	100.00%	100.00%	0.00%	100.00%
Apr	0.00%	100.00%	100.00%	100.00%	0.00%	100.00%
May	0.00%	100.00%	100.00%	100.00%	35.00%	100.00%
Jun	0.00%	100.00%	97.00%	100.00%	100.00%	100.00%
Jul	0.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Aug	30.00%	100.00%	100.00%	100.00%	93.00%	100.00%
Sep	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Oct	93.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Nov	80.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Dec	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Waimea Bay Buoy Data Availability

	2000	2001	2002	2003	2004	2005
Jan	0.00%	0.00%	100.00%	100.00%	100.00%	100.00%
Feb	0.00%	0.00%	100.00%	100.00%	100.00%	100.00%
Mar	0.00%	0.00%	100.00%	100.00%	100.00%	100.00%
Apr	0.00%	0.00%	100.00%	100.00%	100.00%	100.00%
May	0.00%	0.00%	100.00%	100.00%	100.00%	100.00%
Jun	0.00%	0.00%	100.00%	100.00%	100.00%	100.00%
Jul	0.00%	0.00%	100.00%	66.00%	100.00%	100.00%
Aug	0.00%	0.00%	93.00%	0.00%	100.00%	100.00%
Sep	0.00%	0.00%	80.00%	0.00%	100.00%	100.00%
Oct	0.00%	0.00%	97.00%	38.00%	97.00%	100.00%
Nov	0.00%	0.00%	100.00%	86.00%	83.00%	100.00%
Dec	0.00%	51.00%	100.00%	100.00%	100.00%	100.00%

Directional Spectrum Reduction

$$S(\theta,\omega) = E(\omega)D(\theta,\omega)$$

$$Hsig_{NW} = 4\sqrt{\int_{\theta=270^\circ}^{\theta=22.5^\circ}\int_{\omega=0.025\,Hz}^{\omega=0.58\,Hz}\overline{S(\theta,\omega)}\,d\theta\, d\omega}$$

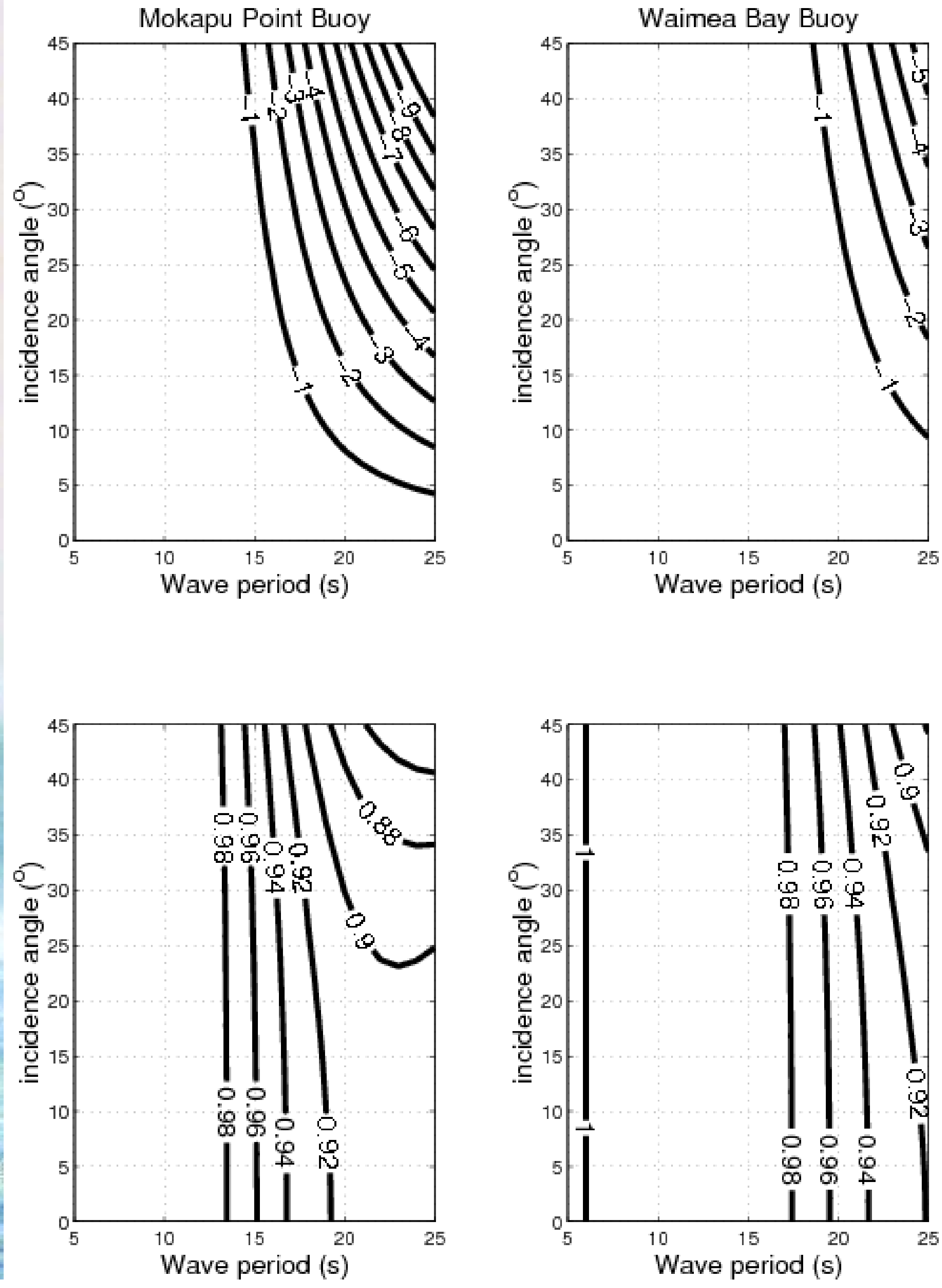
$$Hsig_{E} = 4\sqrt{\int_{\theta=22.5^\circ}^{\theta=135^\circ}\int_{\omega=0.025\,Hz}^{\omega=0.58\,Hz}\overline{S(\theta,\omega)}\,d\theta\, d\omega}$$

Deep enough water ?

$$\alpha_h = asin\left(\frac{C_{ph}}{C_{p\infty}} sin\alpha_{\infty}\right)$$

$$K_r = \left(\frac{cos\,\alpha_{\infty}}{cos\,\alpha_h}\right)^{1/2}$$

$$K_s = \frac{C_{g\infty}}{C_{gh}}$$



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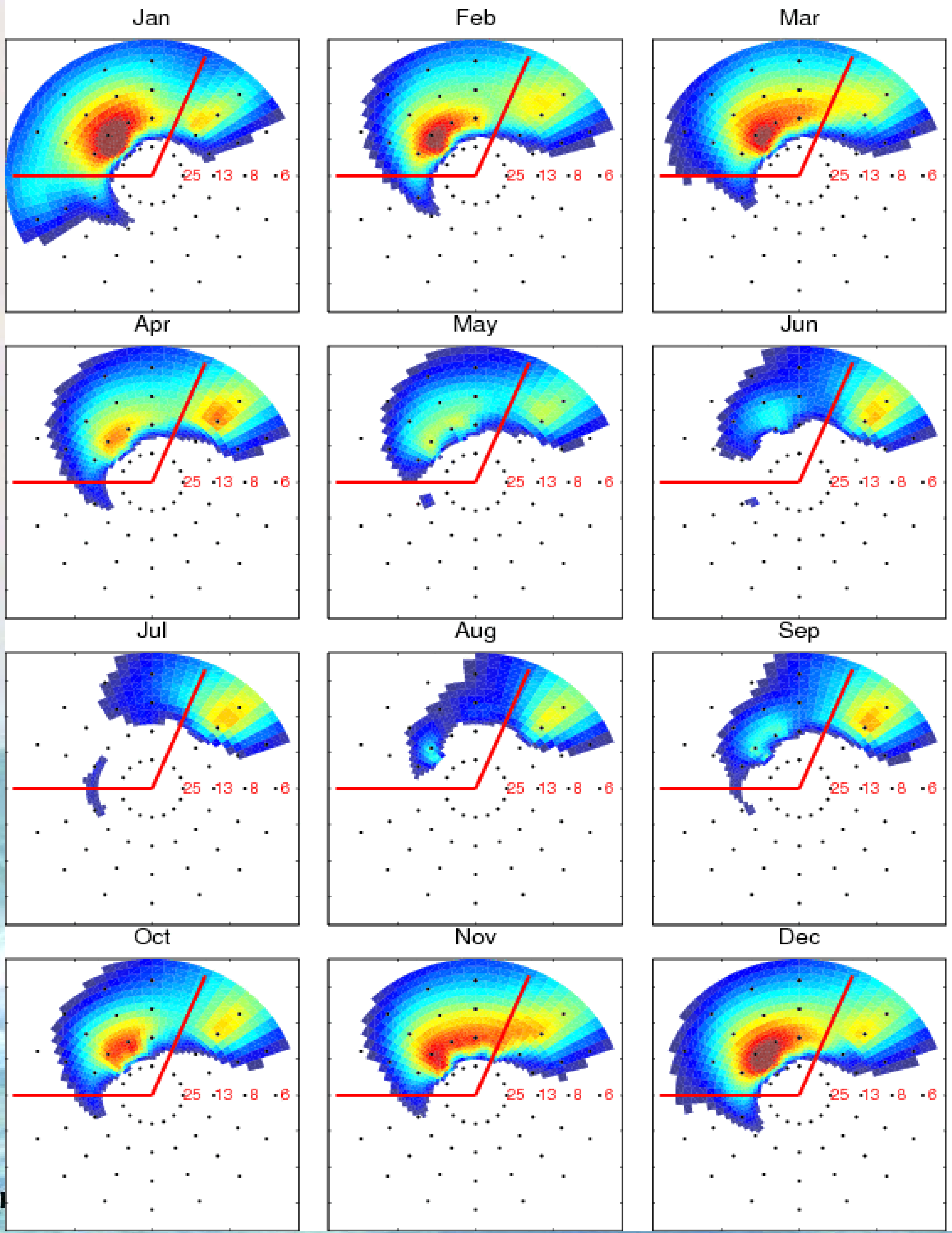
Waimea Bay buoy monthly averages

Northwest swell (315 º), predominant from November to March, nearly absent from June to September.

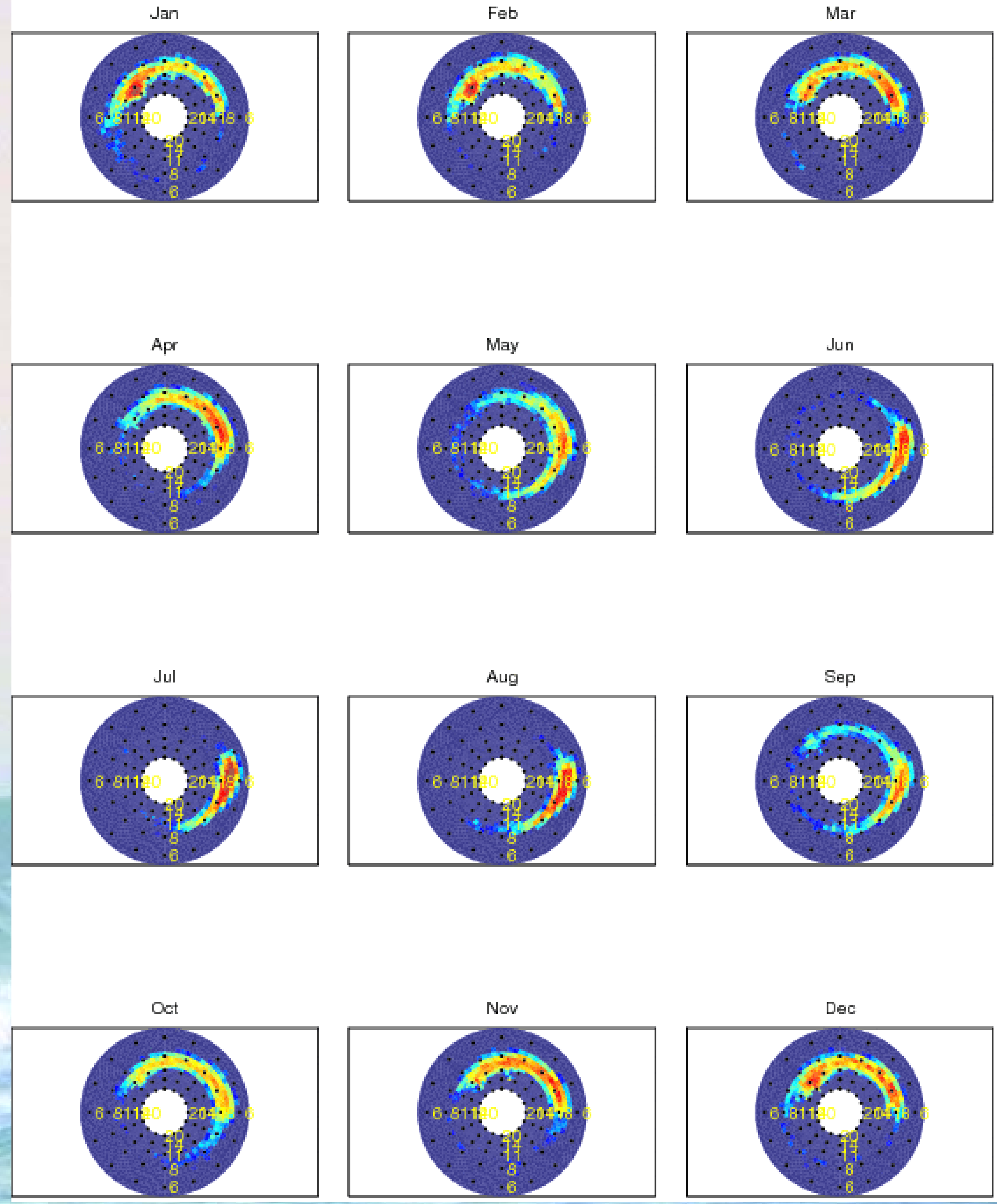
Kona winds (SW-NW, short period) in January.

Trade winds and South swell visible but partly sheltered from the island.

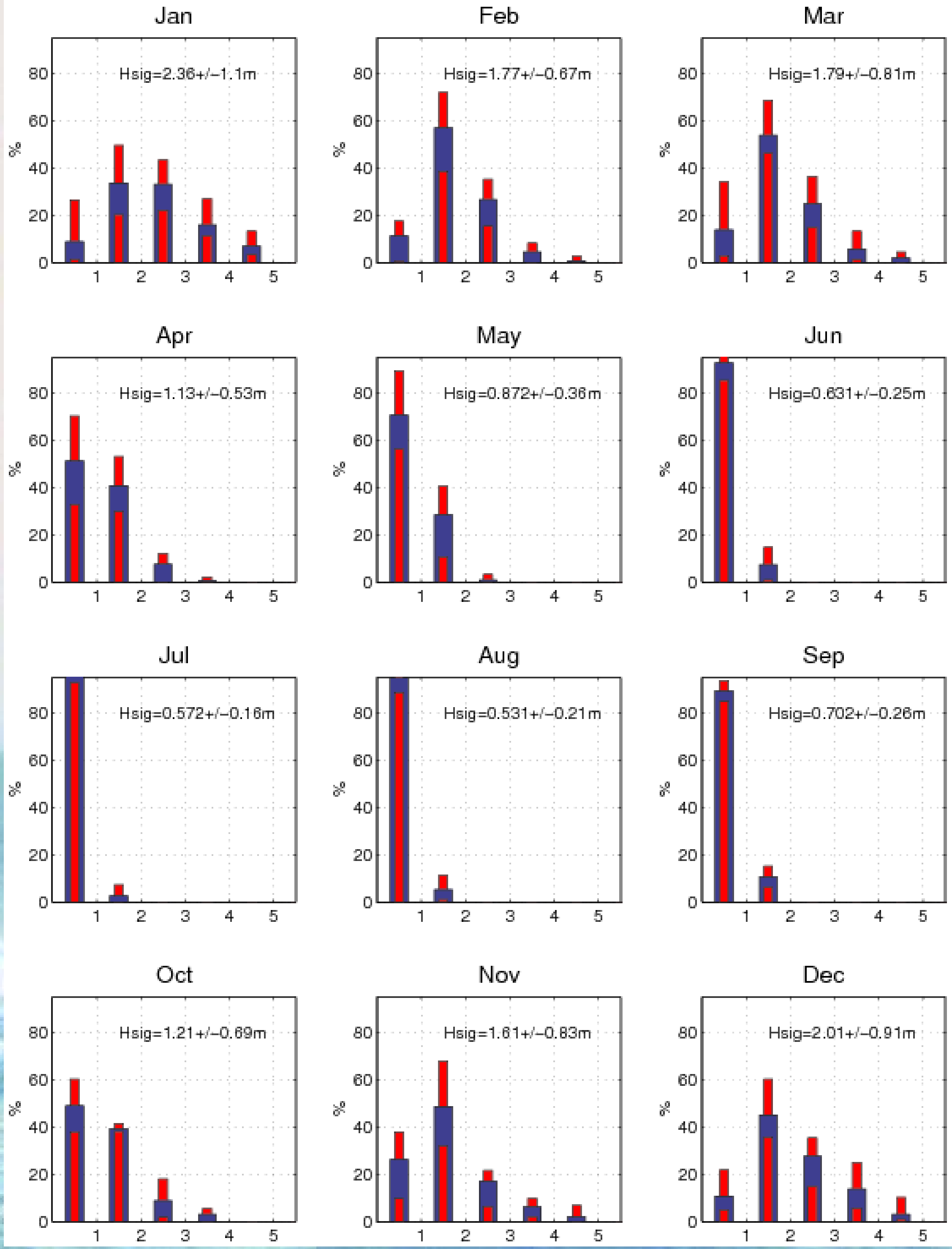


Similar distribution possible with {Hsig,Tp,Dp} from ECMWF model.

Directional spectrum from model would allow direct comparison.



Waimea Bay buoy : monthly statistics for $Hsig_{NW}$

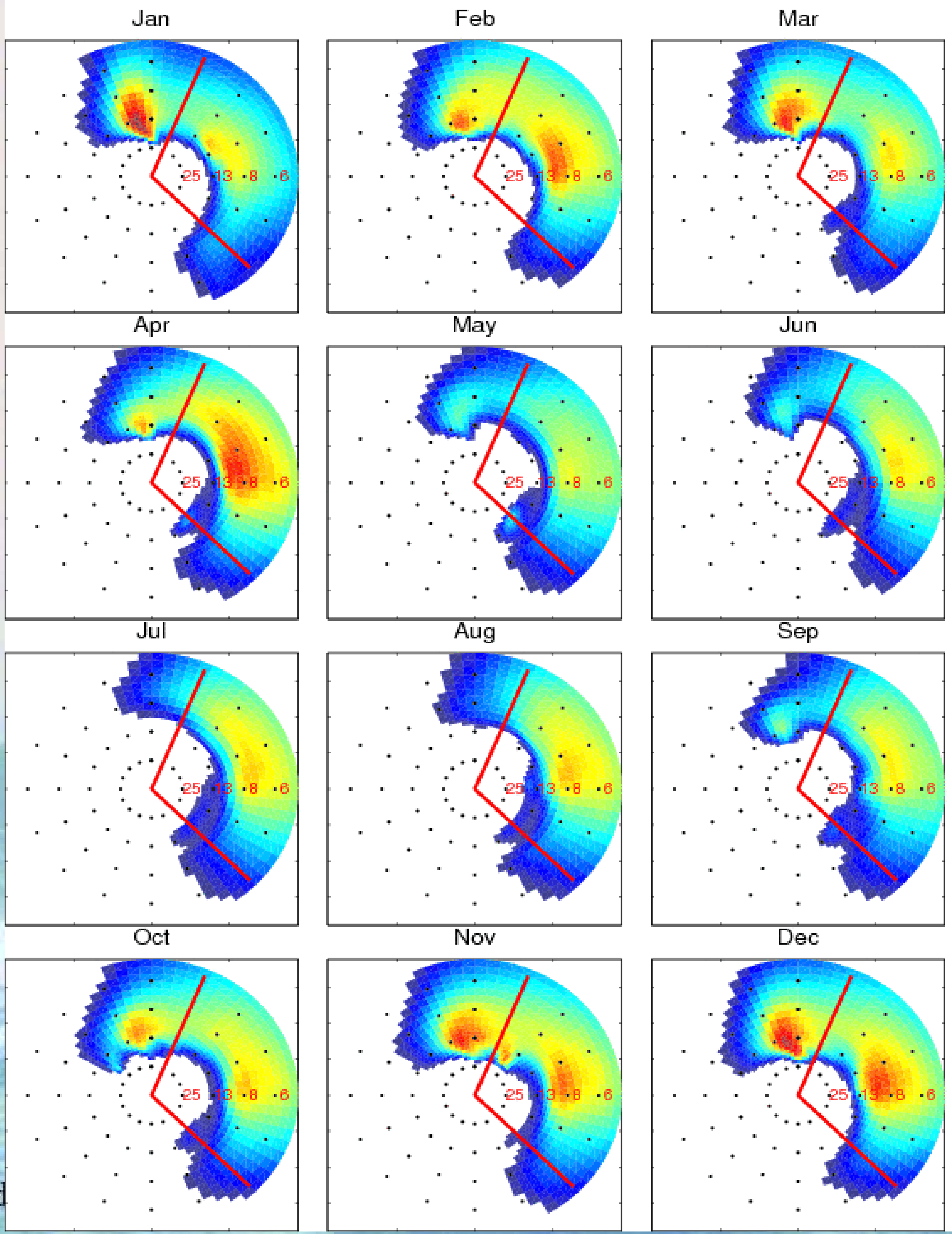


Mokapu buoy monthly averages

Trade wind swell present year round on average.

Winter NW swell visible

South swells visible (SE quadrant)

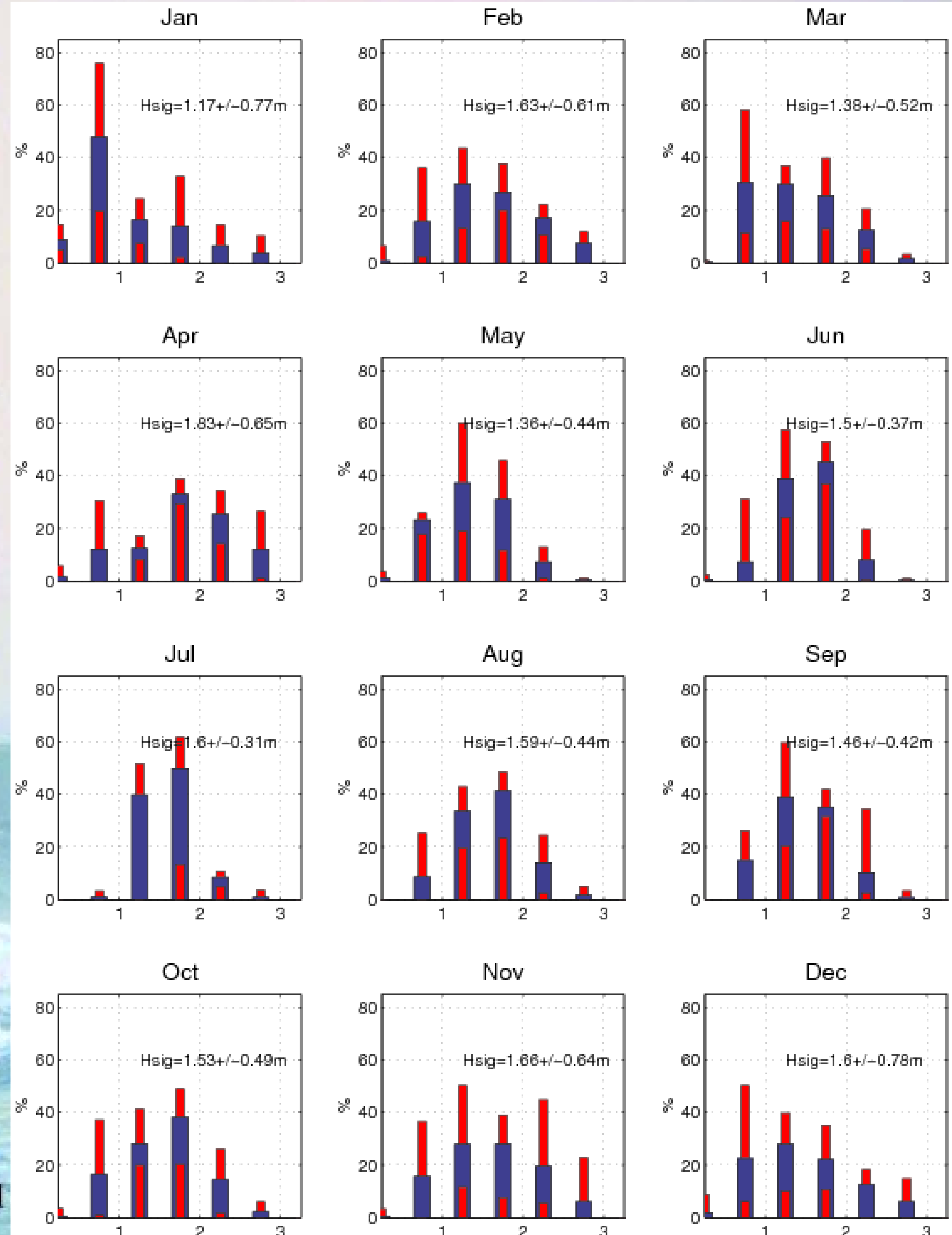


Mokapu buoy monthly statistics for $Hsig_E$

Trade wind swell most regular in summer :

1m < $Hsig_E$ < 2m 90% of the time

In January, trade wind swells can be absent for long period of time, when replaced by Kona winds.



Wave height from global models fields extracted for Hawaii.

Hsig from wave models, for directions between 270 (W) and 22.5 (NNE) :ECMWF ERA-40 , and NOAA WaveWatch III (WW III)

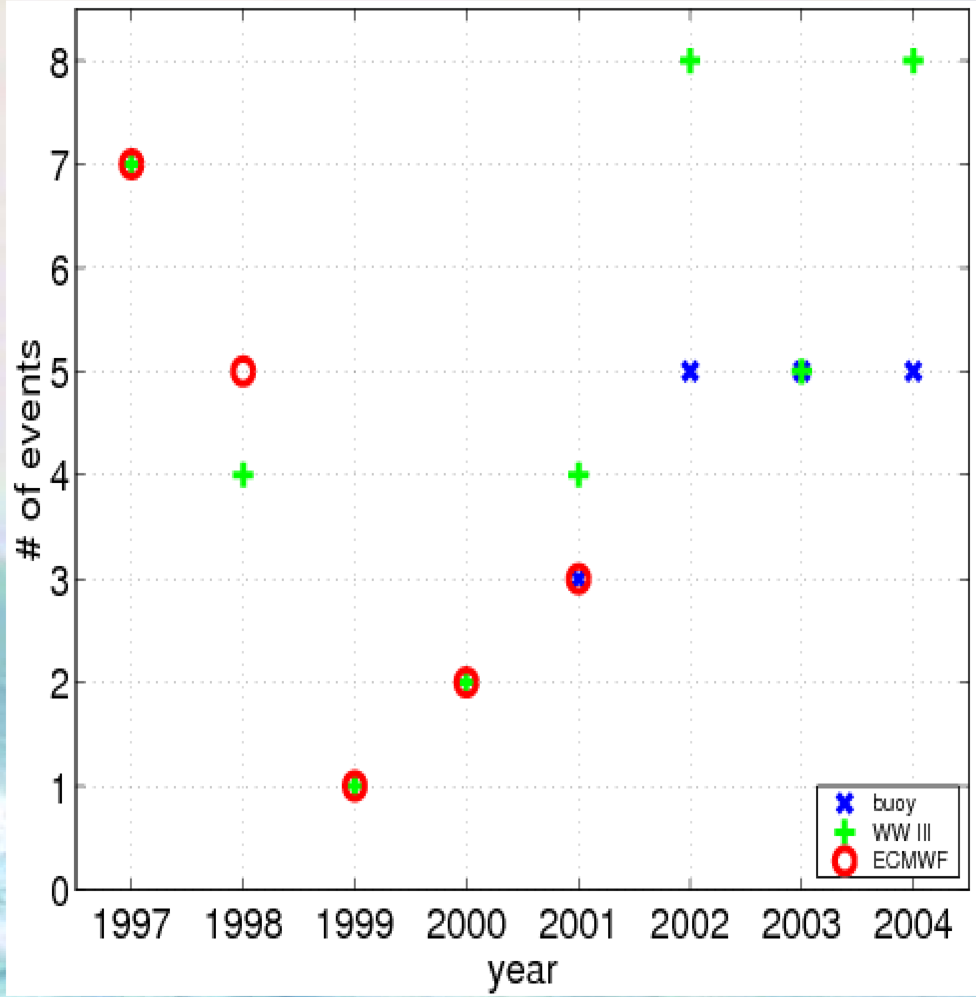
$$Hsig^2 = Hsig_{NW}^2 + Hsig_E^2$$

During large NW events, $Hsig_{NW}^2 >> Hsig_E^2$

$$Hsig \sim Hsig_{NW}$$

NW Extreme events

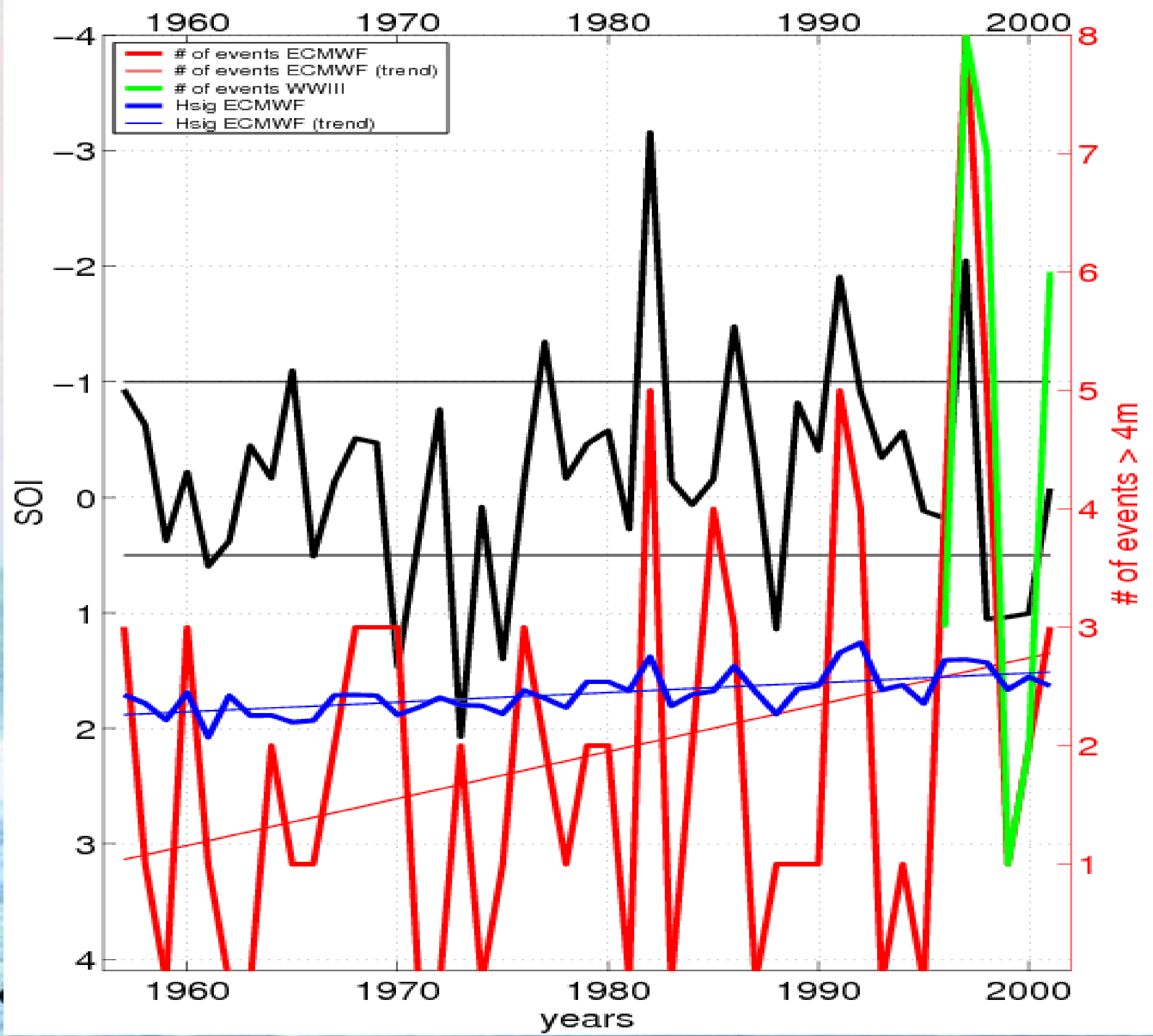
- Hsig from wave models, for directions between 270 (W) and 22.5 (NNE) :
  - ECMWF ERA-40
  - NOAA WaveWatch III (WW III)
- Buoy data, $Hsig_{NW}$
- Daily average
- Local maxima detection



Extreme events trends and climate index 1957-2002

Averages from November to March :

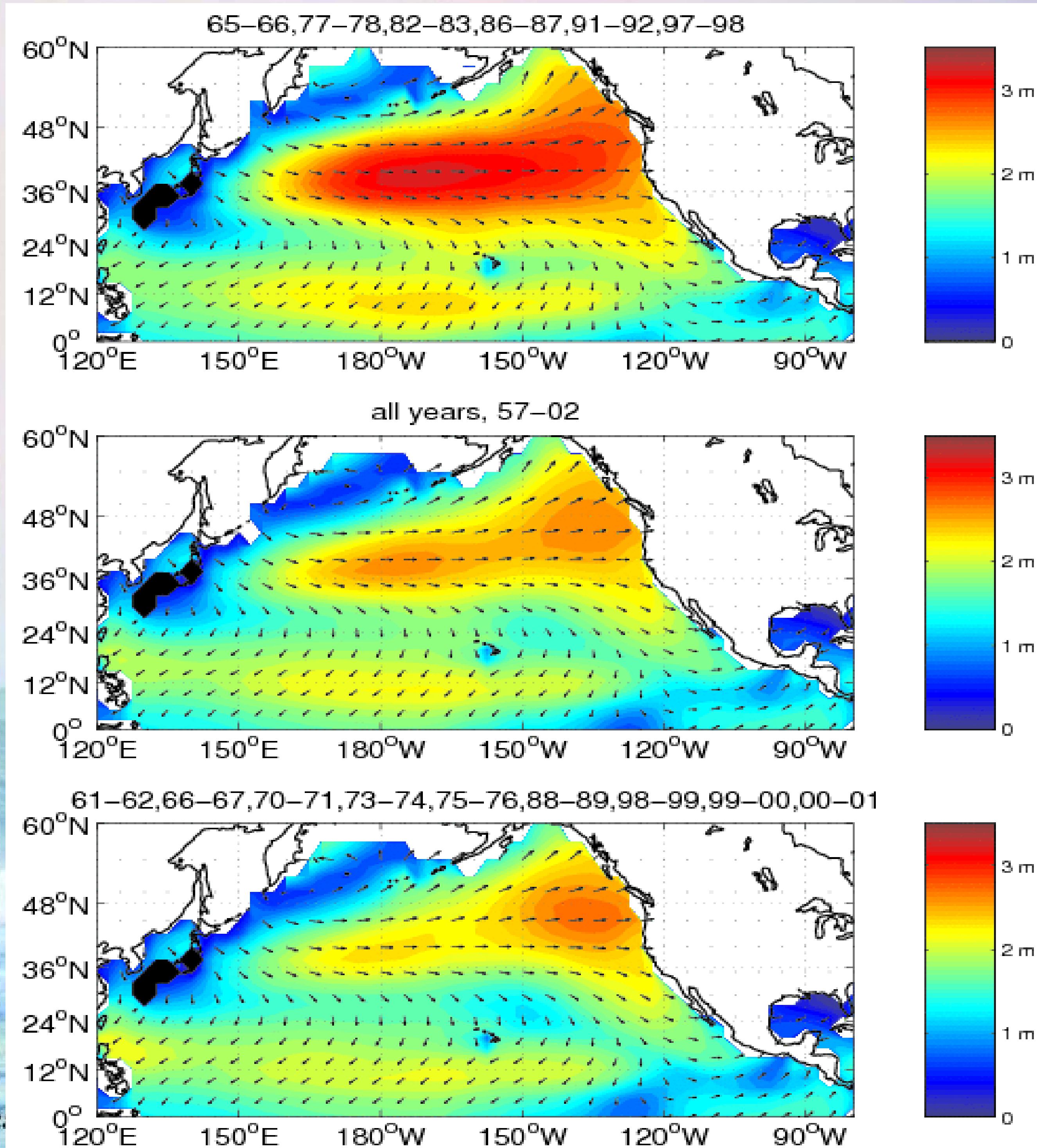
- SOI
- # of event > 4m
  - ECMWF ERA 40
  - WWIII
- Median Hsig (ERA40)



El Nino seasons

All seasons (1957-2002)

La Nina years



Conclusions :

-Statistics from buoys should be useful for planners.

-Comparison with model will improve with full directional spectrum from models.

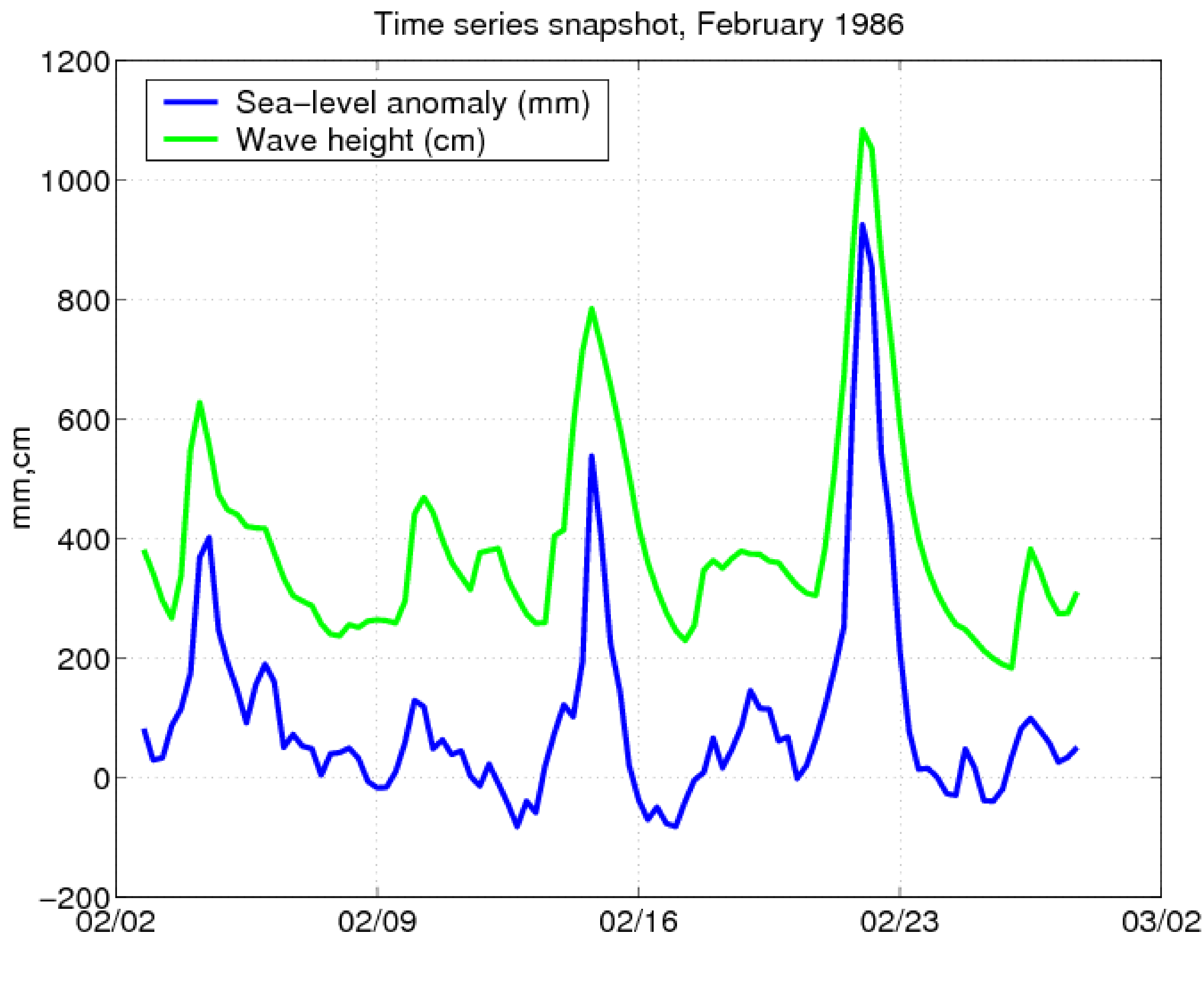
-Increasing trend of the number of large events, and El-Nino years affect the number of events and the repartition of high waves in the North Pacific.

Acknowledgments :

-Mark Merrifield, University of Hawaii Sea Level Center (UHSLC).

-ERA-40 Data provided online by ECMWF

-Val Swail


Time series snapshot, February 1986
Sea–level anomaly (mm)
Wave height (cm)
mm,cm
1200
1000
800
600
400
200
0
−200
02/02
02/09
02/16
02/23
03/02

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