Lase-Like Ocean Waves Generation in Straits with Reflective Booundaries

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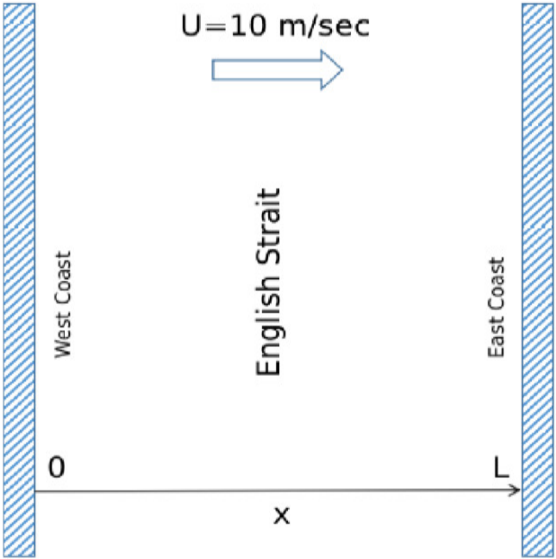
Overview

Introduction



Introduction

- Hasselmann Equation (HE))
  $$\frac{\partial \varepsilon}{\partial t} + \frac{\partial \omega_k}{\partial \vec{k}} \frac{\partial \varepsilon}{\partial \vec{r}} = S_{nl} + S_{in} + S_{diss}$$
- $\varepsilon = \varepsilon(\vec{r}, \vec{k}, t)$
- S_{nl} - nonlinear 4-waves interaction term
- S_{in} - wind input
- S_{diss} - wave-breaking dissipation
- Basis of operational models WaveWatch, WAM
- Study of physically based HE models is of urgent importance

- HE historical study focused on 2 sub-cases:
- Homogeneous case $\frac{\partial \varepsilon}{\partial t} = S_{nl} + S_{in} + S_{diss}$
- Stationary case $\frac{\partial \omega_k}{\partial \vec{k}} \frac{\partial \varepsilon}{\partial \vec{r}} = S_{nl} + S_{in} + S_{diss}$
- Both cases obey self-similar solutions (SSS) in the assumption $S_{in} \sim \omega^{s+1}$
- We formulate the model and present the first study of full physical statement of HE, partially based on SSS properties

Introduction

Self-similar solutions:

Стационарный случай	Случай разгона ветром
$\varepsilon = t^{p+q} F(\omega t^q)$	$\varepsilon = \chi^{p+q} F(\omega \chi^q)$
$E \sim t^p \qquad \langle \omega \rangle \sim t^{-q}$	$E \sim \chi^p \qquad \langle \omega \rangle \sim \chi^{-q}$
$9q - 2p = 1$	$10q - 2p = 1$
$p = 10/7 \qquad q = 10/7$	$p = 1 \qquad q = 3/10$
$s = 4/3$	$s = 4/3$

Problem statement

- $\frac{\partial \varepsilon}{\partial t} + \frac{1}{2}\frac{\omega_k}{k}\cos\theta\frac{\partial \varepsilon}{\partial x} = S_{nl} + S_{in} + S_{diss}$
- Deep water case $\omega = (gk)^{1/2}$
- Exact S_{NL}
- ZRP forcing $S_{in} \sim \omega^{s+1}$, $s = 4/3$ (Zakharov, Resio, Pushkarev 2010)
- Dissipation spectral tail $\sim \omega_k^{-5}$ starting from $f_{diss} = 1.1$ Hz
- Channel of 40 km width: La-Manche (English Strait)
- 40 points in real space, 5° angular resolution, 72 frequencies
- Wind 10 m/sec blowing from France to UK

Problem statement

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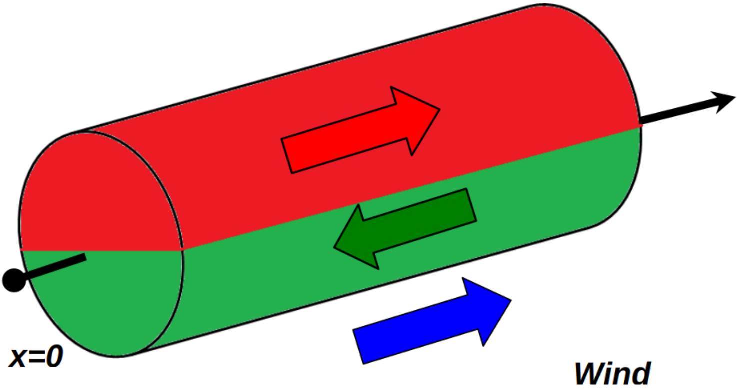
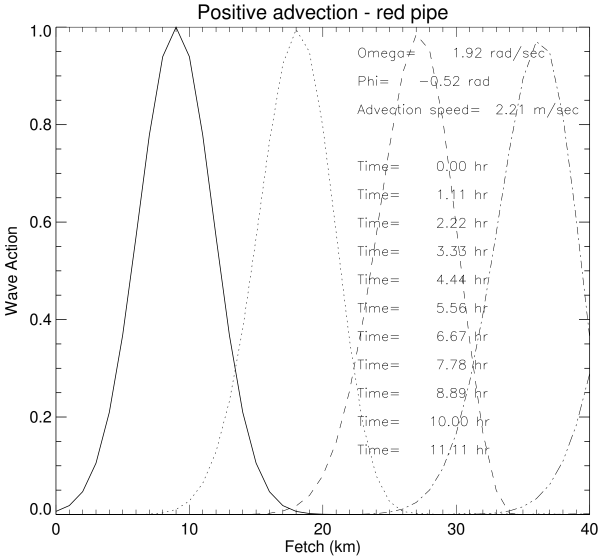


Dissipative boundaries case

Advective part of Hasselmann equation $\frac{\partial \varepsilon}{\partial t} + \frac{1}{2}\frac{\omega_k}{k}\cos\theta\frac{\partial \varepsilon}{\partial x} = 0$



Dissipative boundaries case

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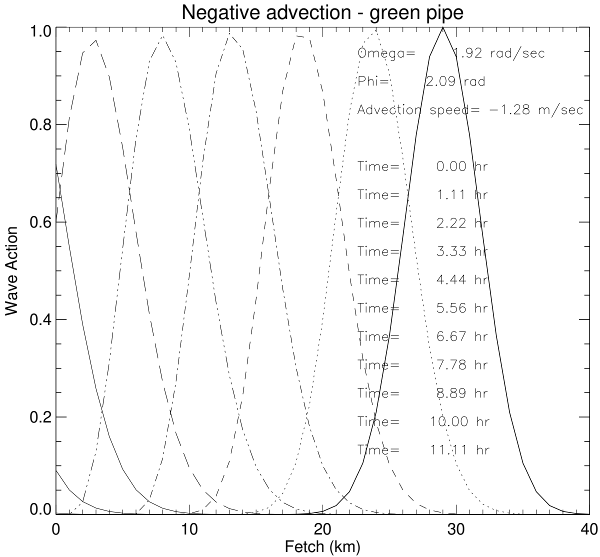
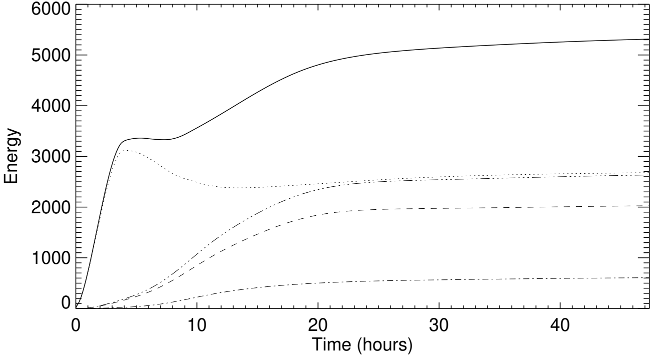


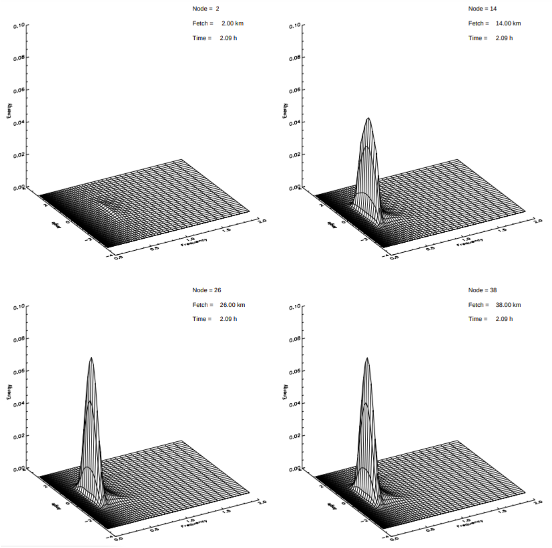
Dissipative boundaries case

Total energy of the fetch as the function of time:



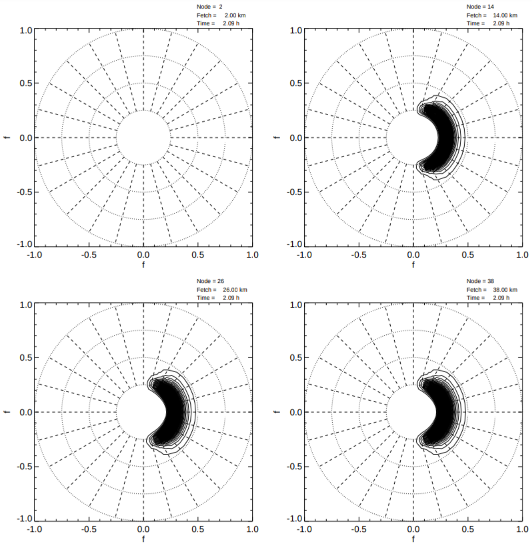
- thick solid line – total
- dotted line – in the wind direction
- dash-dotted line – normal to the wind
- dashed line – against the wind
- dash-triple-dotted line – not along the wind

Dissipative boundaries case



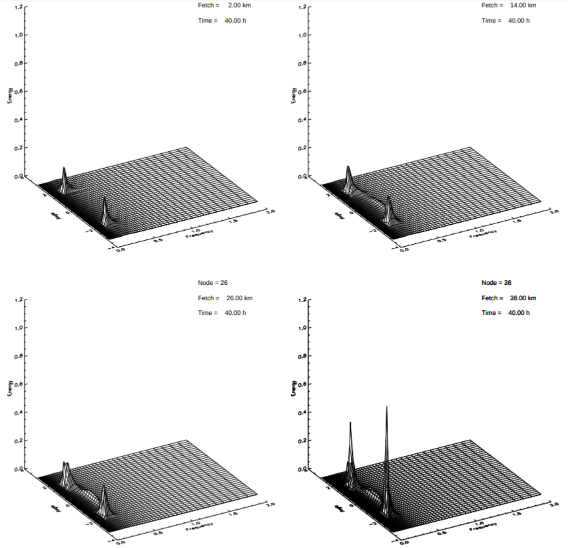
Energy spectra for 2 hours

Dissipative boundaries case



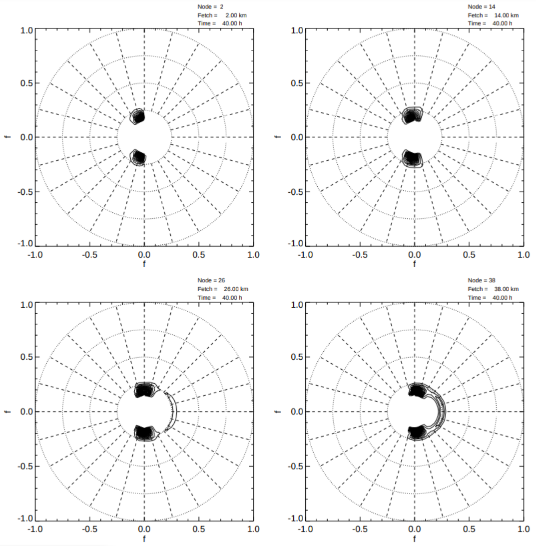
Energy spectra for 2 hours

Dissipative boundaries case



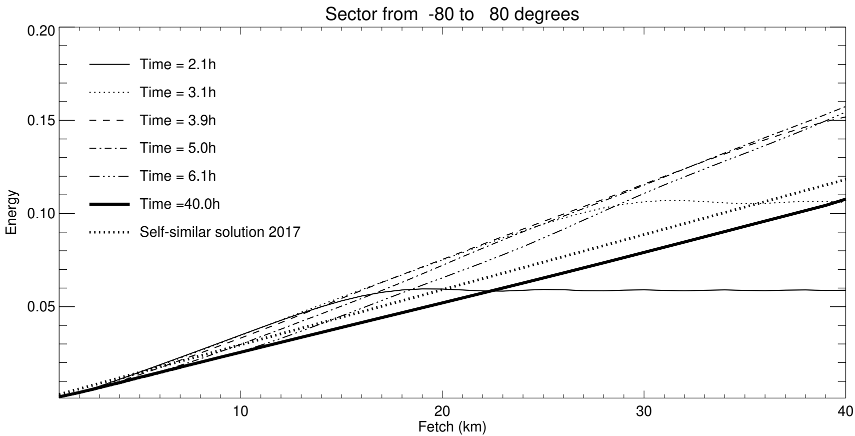
Energy spectra for 40 hours

Dissipative boundaries case



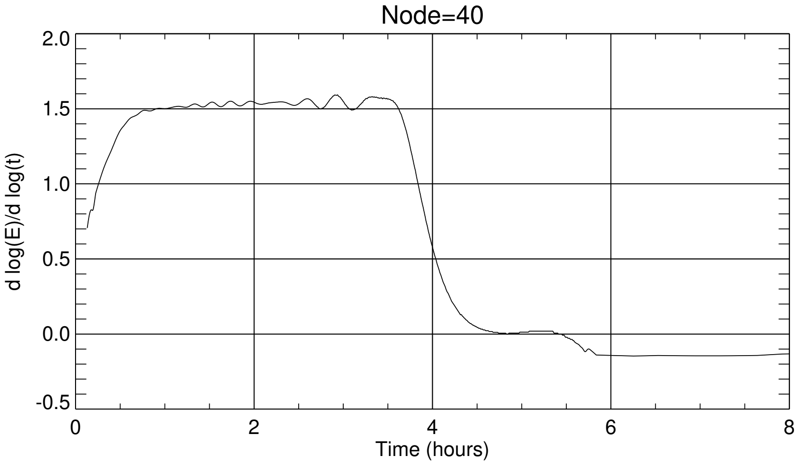
Energy spectra for 40 hours

Dissipative boundaries case



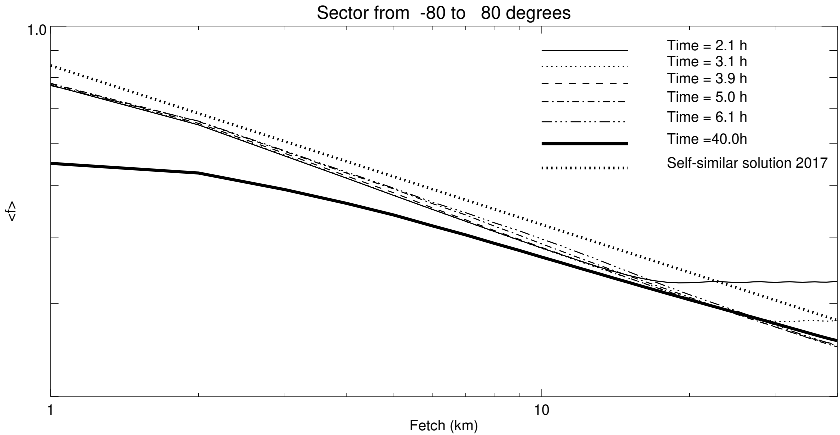
Decimal logarithm of wave energy distribution along the fetch for different moments of time, calculated in the angle spread $-80^\circ < \theta < 80^\circ$.

Dissipative boundaries case



Index of power growth at the East shoreline

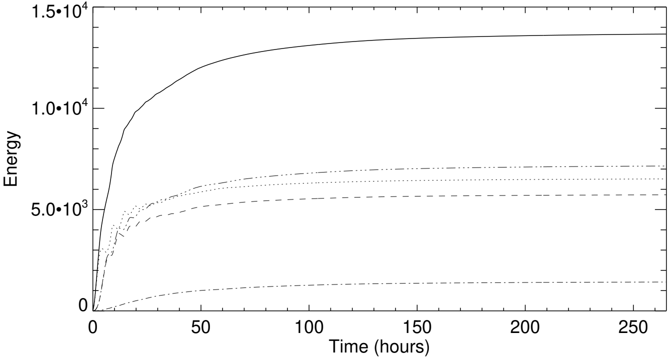
Dissipative boundaries case



Decimal logarithm of mean frequency distribution as the function of the decimal logarithm of the fetch for different moments of time calculated for angular spread $-80^\circ < +80^\circ$ with respect to wind direction θ_{wind}.

50% reflection boundaries case

Total energy of the fetch as the function of time:



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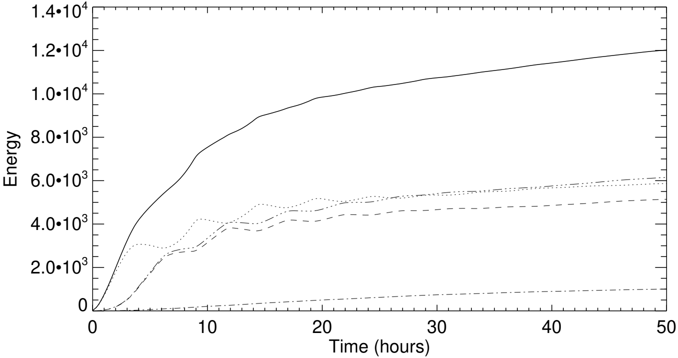
50% reflection boundaries case

Total energy of the fetch as the function of time – zoomed:



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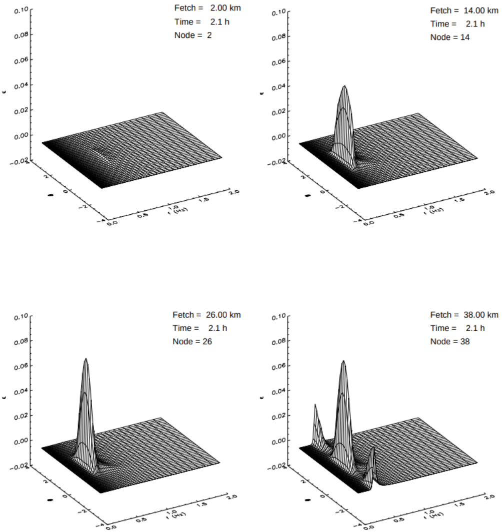
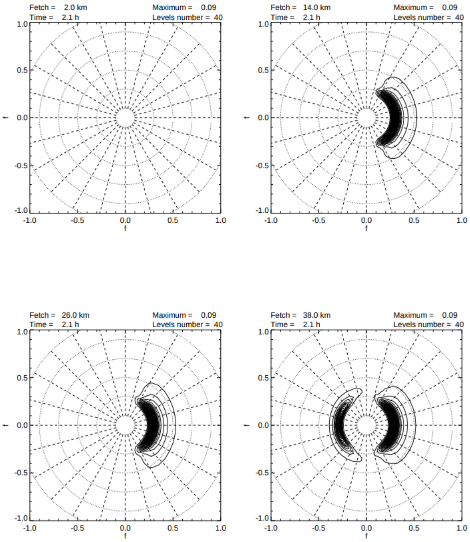
50% reflection boundaries case



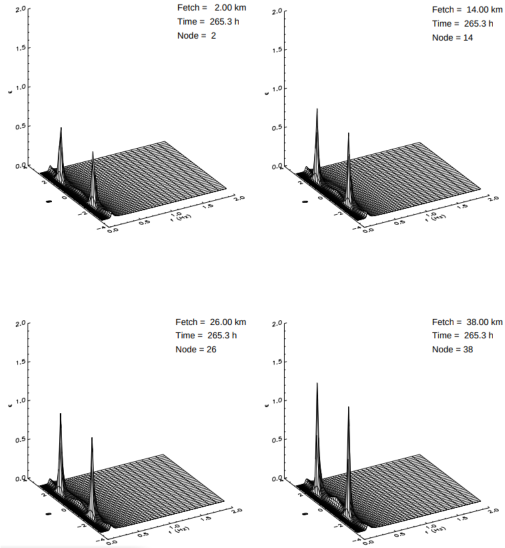
Energy spectra for 2 hours

50% reflection boundaries case



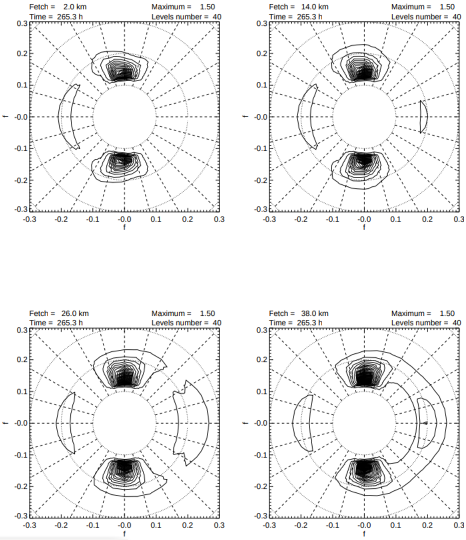
Energy spectra for 2 hours

50% reflection boundaries case



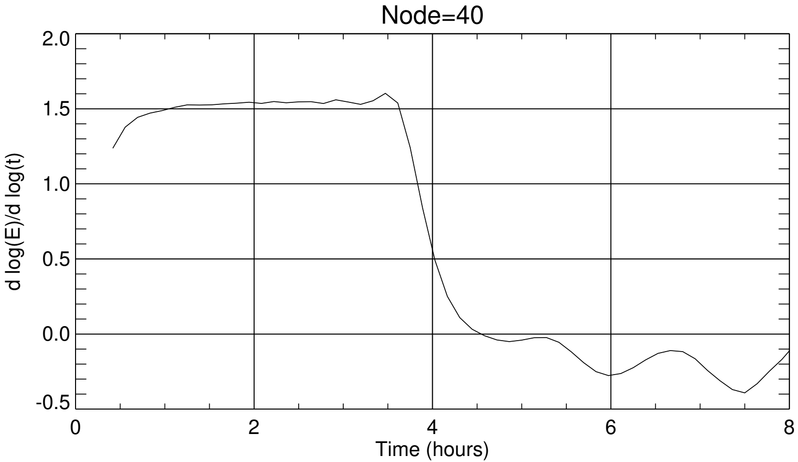
Energy spectra for 265 hours

50% reflection boundaries case



Energy spectra for 265 hours

50% reflection boundaries case

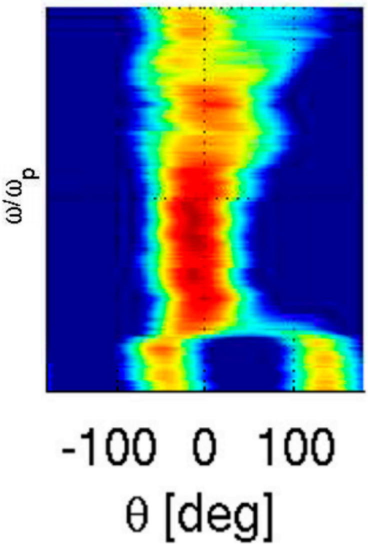


Index of power growth at the East shoreline

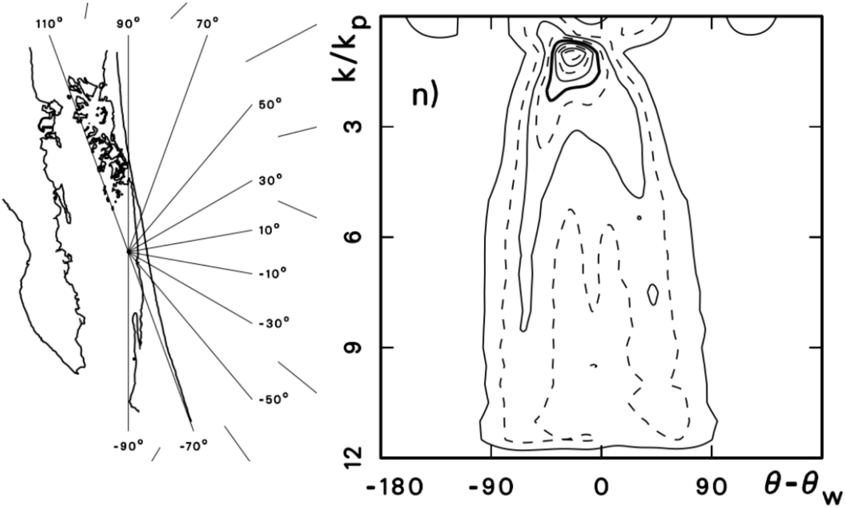
Experimental evidence

CONOCO PHILLIPS Ecofisk platform

A. Simanesew et al., 2017



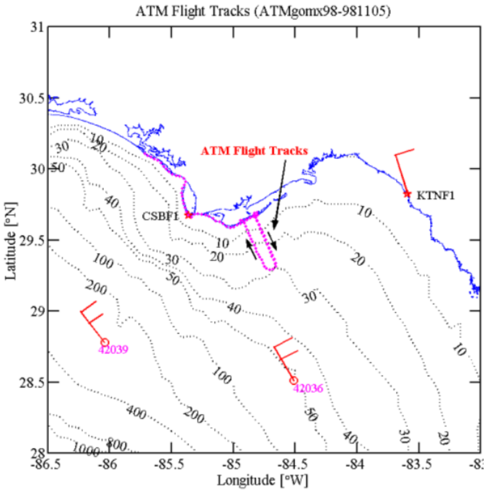
Experimental evidence

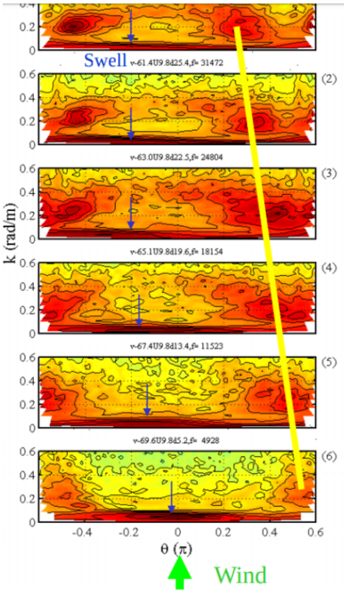


Outer Banks, Duck, NC

C. Long, D. Resio, 2008

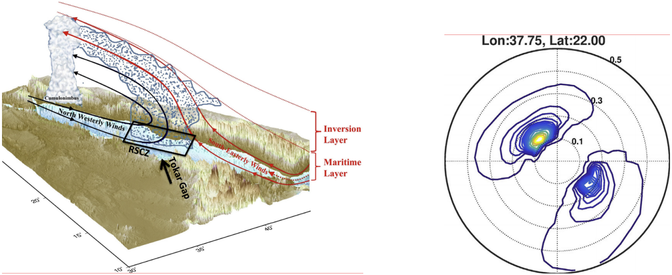
Experimental evidence





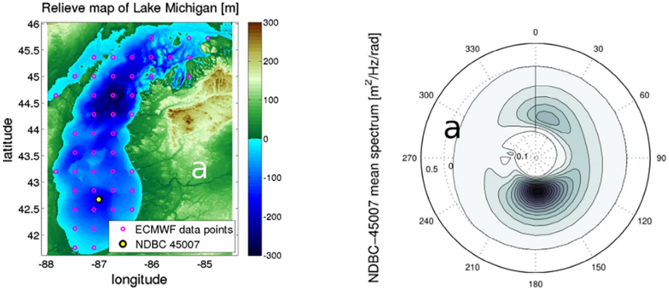
Mexican Gulf
Paul Hwang et al, 2000

Experimental evidence



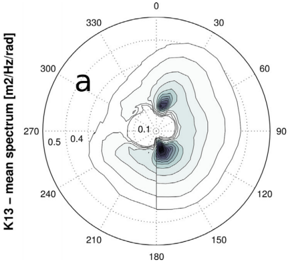
Red Sea spectra (Langodan et al., 2014)

Experimental evidence



Lake Michigan spectra (Dee et al., 2011)

Experimental evidence



The spectrum measured at K-13 plathform, Dutch North Sea, (Cavaleri et al., 2018)

Conclusions

Nonlinear **O**cean **W**aves **A**mplifier

NOWA

Conclusions

1. Turbulence splits into different regimes in space and time:
   - Initial threshold-like unimodal dual SSS regime
   - Mix of self-similar wind sea and monochromatic waves
2. Quazi-monochromatic waves tilt from 90° to 105° to the wind
3. Both cases evolve to asymptotic stationary state
4. NOWA regime could be Bose-condensation
5. Qualitative similarity of cases - asymptotic stationarity, NOWA effect, dual SSS threshold-like propagation
6. About 3x amplification of NOWA effect in 50% reflective case
7. Billiard effect in 50% reflections case with time period defined by spectral peak speed propagation
8. Better isotropization of the spectrum in reflective case
9. Multiple experimental confirmations
10. Apparent ubiquity of NOWA effect: it is caused by inhomogeneity in straits and limited fetch situations due to shores as well as open sea due to wind change