Ocean Waves Generation Against the Wind: Fourier-Real Space Energy Pipelines DOES OCEAN LASER EXIST?

Pushkarev Andrei, Zakharov Vladimir

SkolTech, FIAN

dr.push@gmail.com

Overview

Introduction

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

Motivation of the research

- Observation of non-stationary limited fetch regime
- Connection to SSS in homogeneous case
  $\frac{\partial \varepsilon}{\partial t} = S_{nl} + S_{in} + S_{diss}$
- Connection to SSS in stationary case
  $\frac{\partial \omega_k}{\partial \vec{k}} \frac{\partial \varepsilon}{\partial \vec{r}} = S_{nl} + S_{in} + S_{diss}$

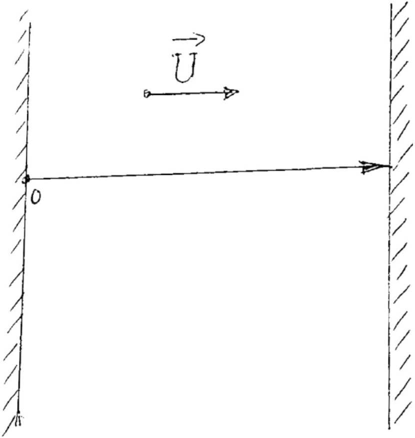
Motivation of the research

Stationary case	Non-stationary case
$\varepsilon = t^{p+q} F(\omega t^{q})$	$\varepsilon = \chi^{p+q} F(\omega \chi^{q})$
$E \sim t^{p}$ $\langle \omega \rangle \sim t^{-q}$	$E \sim \chi^{p}$ $\langle \omega \rangle \sim t^{-q}$
$9q - 2p = 1$	$10q - 2p = 1$
$p = 10/7$ $q = 10/7$	$p = 1$ $q = 3/10$
$s = 4/3$	$s = 4/3$

Problem statement

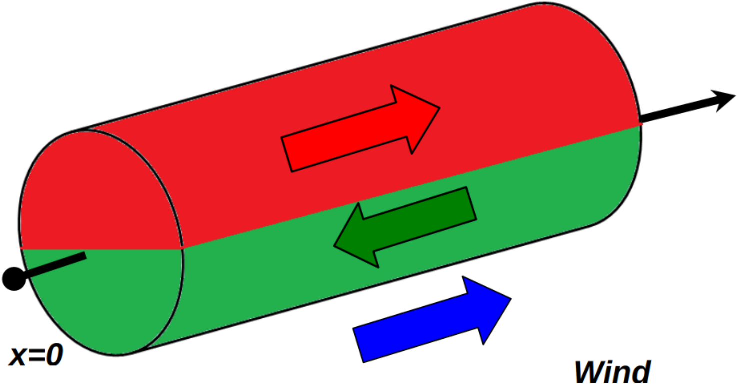
- $\frac{\partial \varepsilon}{\partial t} + \frac{1}{2}\frac{\omega_k}{k}\cos\theta\frac{\partial \varepsilon}{\partial x} = S_{nl} + S_{in} + S_{diss}$
- Exact S_{NL}
- ZRP (Zakharov, Resio, Pushkarev 2010) forcing
- Dissipation spectral tail $\sim \omega_k^{-5}$ starting from $f_{diss} = 1.1$ Hz
-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

Problem statement

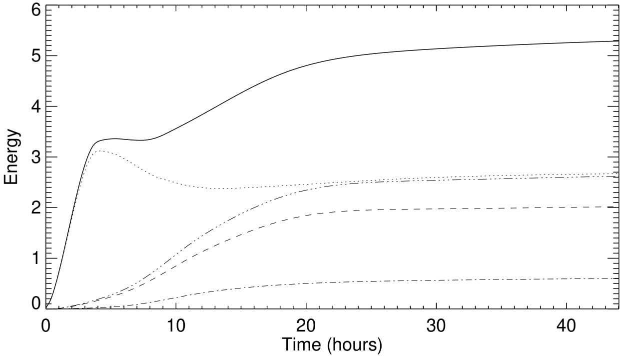


Problem statement

Problem statement

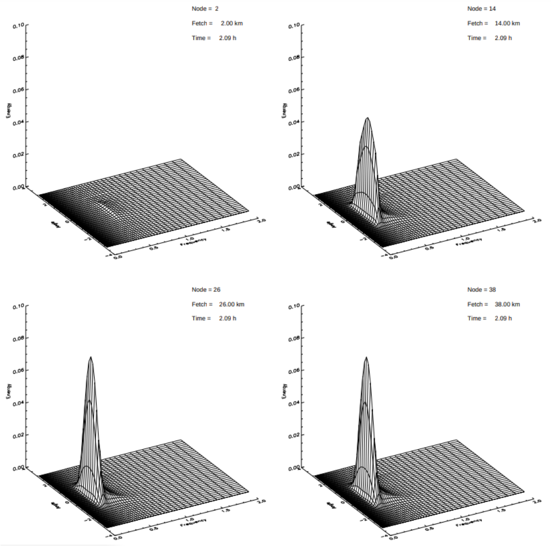


Results



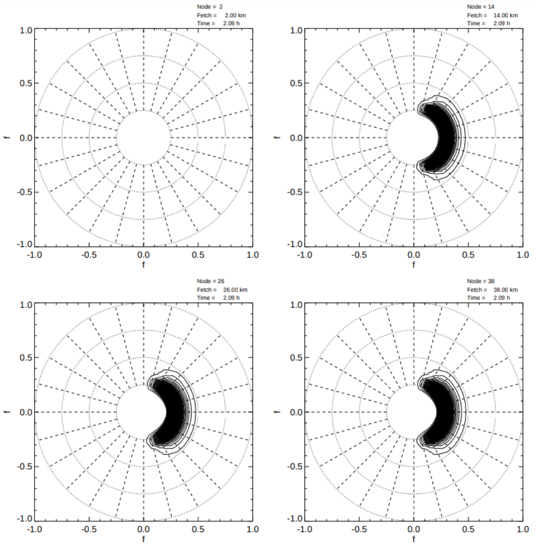
- thick solid line – total
- dotted line – in the wind direction
- dash-dotted line – normal to the wind
- dashed line – against the wind
- dotted line – not along the wind

Results



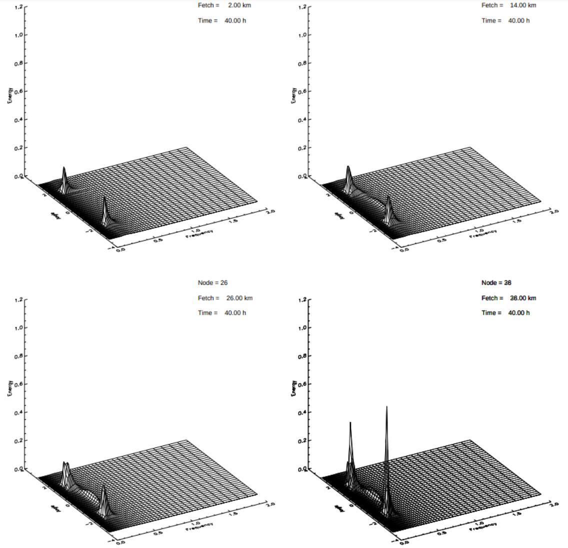
2 hours

Results



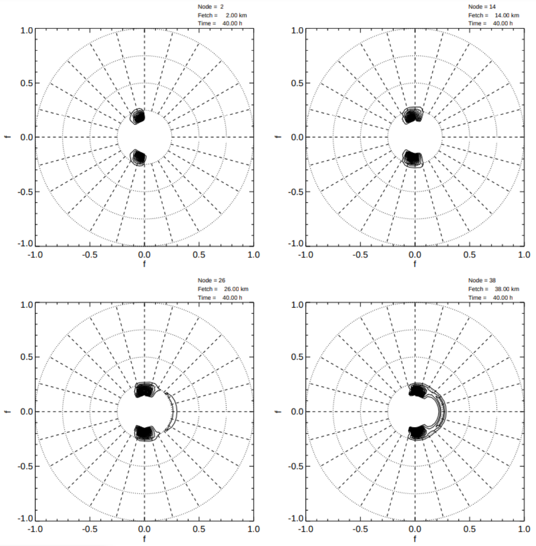
2 hours

Results



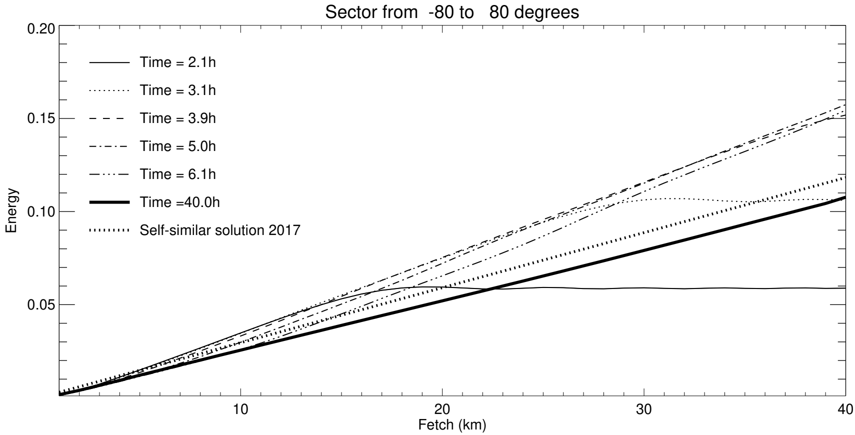
40 hours

Results

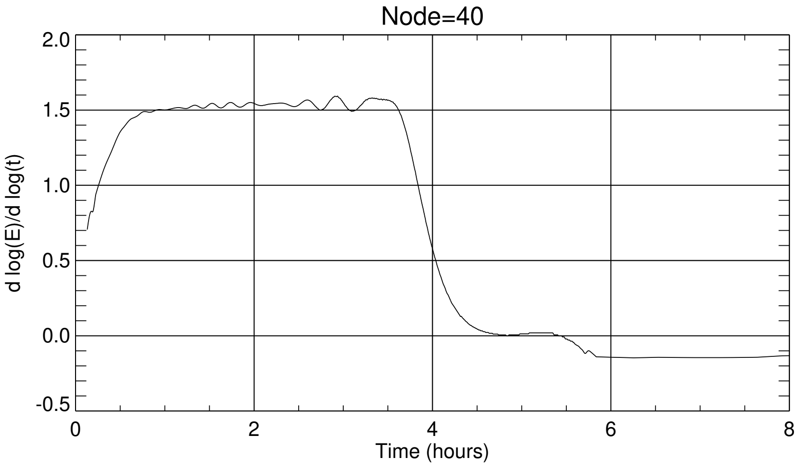


40 hours

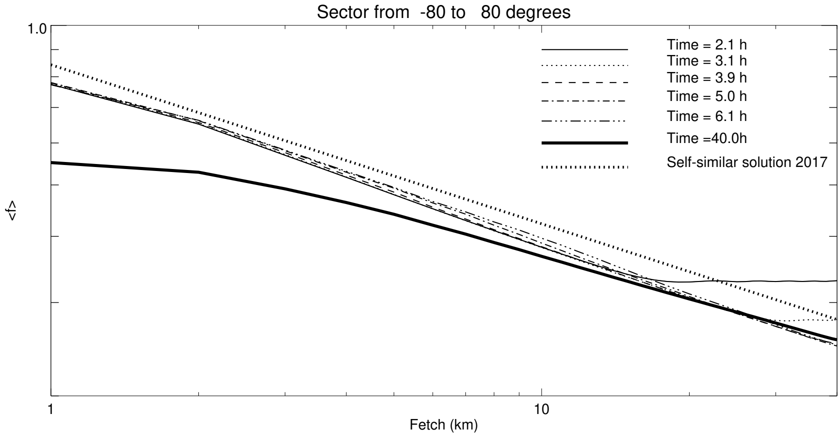
Results


Sector from -80 to 80 degrees
0.20
0.15
0.10
0.05
Energy
10
20
30
40
Fetch (km)
Time = 2.1h
Time = 3.1h
Time = 3.9h
Time = 5.0h
Time = 6.1h
Time =40.0h
Self-similar solution 2017

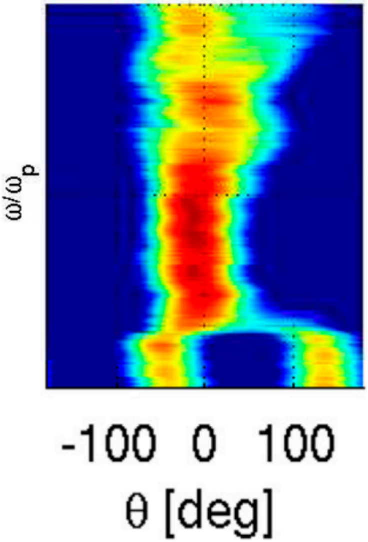
Results



Results


Sector from -80 to 80 degrees
1.0
<f>
1
10
Fetch (km)
Time = 2.1 h
Time = 3.1 h
Time = 3.9 h
Time = 5.0 h
Time = 6.1 h
Time =40.0h
Self-similar solution 2017

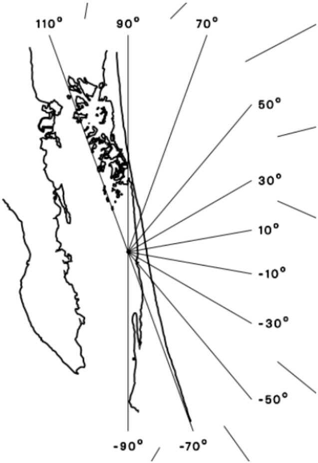
Experimental evidence

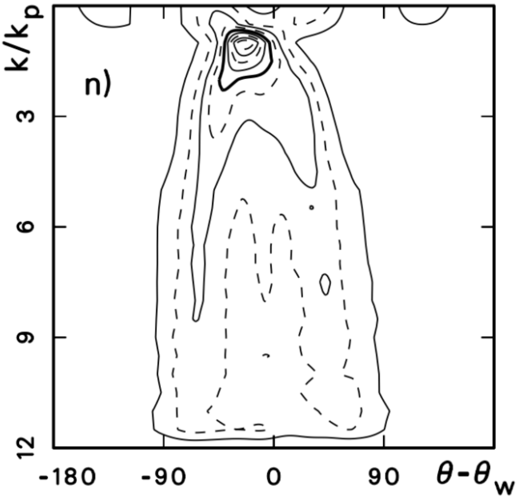


CONOCO PHILLIPS Ecofisk platform

A. Simanesew et al., 2017

Experimental evidence

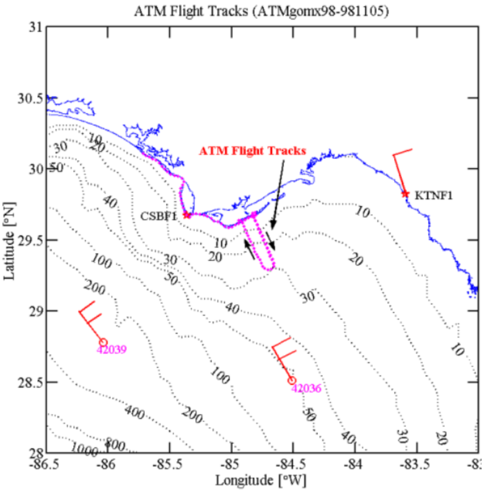


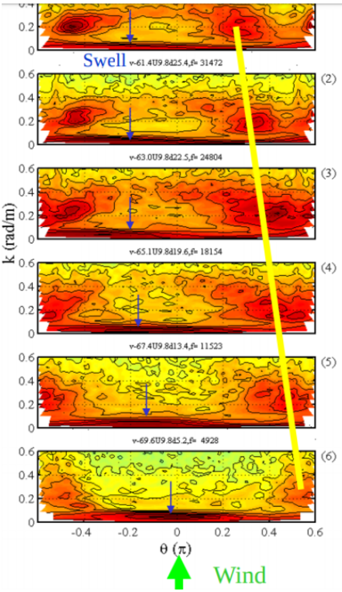


Outer Banks, Duck, NC

C. Long, D. Resio, 2008

Experimental evidence





Mexican Gulf
Paul Hwang et al, 2000

Conclusions

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

NOWA

Conclusions

1. Wave turbulence splits into 2 regimes in space and time:
   - Initial dual self-similar
   - Subsequent mix of self-similar wind sea and quazi-monochromatic waves orthogonal to the wind
2. Initial self-similar regime is self-similar threshold-like propagation
3. Subsequent regime works as Nonlinear Ocean Waves Amplifier (NOWA)
4. The system asymptotically evolves into stationary mixed state of wind sea and quasi-monochromatic waves orthogonal to the wind waves, slating at universal 15° closer to the origination shore
5. Laser-like radiation is apparently the attractor of complex nonlinear wave system
6. The obtained results are applicable to half-open ocean