Internal wave turbulence in attractor experiments

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Outline



Experimental setup : the lab

The lab at ENS de Lyon, or the charming atmosphere of experimental work



illustration by Hélène Bléhaut

IGW attractors

Attractors in non linear regime

Experimental setup : the tank



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Experimental setup : the tank



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Monochromatic forcing

To be more demonstrative, we used here fluorescent die to visiualize isopycnals



You can find some very nice movies here : law amplitude forcing and strong amplitude forcing (non linear effects)

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Attractors in non linear regime

Differents attractors in trapezoïdal tank

Maas et al. studied the trapezoidal geometry and summerized some results by plotting the Lyapunov exponent (caracterizing how two initially closed paralel rays separate exponentially after bouncing on the boundaries of the tank) in function of the tank geometry and the forcing frequency.

They found that all the exponents were negative or zero : attractors are generic !

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Plus, some experiments shown that attractors exist in 3D geometries.

Pillet et al., 2018



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1 monochromating forcing experiment corresponds to one dot in this plot. Next slides illustrate how one can probe a complete vertical line with one single experiment

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IGW attractors

Attractors in non linear regime

Outline

1. IGW attractors

- a. Experimental set tup
- b. <u>Study of the impulse response</u>

2. Attractors in the non linear regime

- a. Analysis of a non linear experiment
- b. Slowly increasing the forcing amplitude

3. 3D experiments conducted at LEGI

- a. The setp-up in the Coriolis facility
- b. <u>Some results</u>

Impulse response experiment

We suggested a new way of exploring this diagram : by moving very quickly (~ 1 sec) the generator plate from an initially inclined position to the vertical one, one excites all frequencies below N and gets the linear response of the tank.



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Fourier transform of velocity field

















IGW attractors

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Back to the Lyapunov diagram

We see that the data of the 4 experiments shown here indeed recover the diagramm of Maas et al.



We also recover the fact that trapezoidal geometries have broad-band spectrum. It is not the case for the rectangular tank that has a discret set of resonances (right line).

Davis et al., accepted in PRL, 2020

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Non linear attractos





IGW attractors

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The secondary waves



IGW attractors

Attractors in non linear regime

The secondary waves



IGW attractors

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Attractors in non linear regime

¹³ The secondary waves : energy density



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Attractors in non linear regime

The secondary waves : E_{k_x,k_z}



We can do two observations concerning these secondary waves :

- They are mainly on the dispersion relation : they are linear solutions
- Each of them corresponds to different wavevectors (thanks to the slope) : rich structure

Davis, PhD thesis

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Triadic resonant interaction

These secondary waves are generated via multiple triadic resonant interactions :



<u>Davis, PhD thesis</u>

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Attractors in non linear regime

Increasing amplitude experiment

We can see the transition from linear to non linear regime by increasing slowly in time the amplitude of the wave generator :



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Attractors in non linear regime

Spatial spectrum



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Attractors in non linear regime

Spatial spectrum : larger scales

Filtering a given secondary wave at different times



one can see that as it fills the tank it gets a larger typical wavelength

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Attractors in non linear regime

When one cascade stops another

Filtering the velocity field at the forcing frequency



thus it generates secondary waves with greater and greater length scales

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Attractors in non linear regime

When one cascade stops another

The maxima of energy density are located to bigger scales because of a two cascades mechanism :



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Attractors in non linear regime

Limit spectrum at high forcing



Davis et al., accepted in PRL, 2020

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Limit spectrum at high forcing



Davis et al., accepted in PRL, 2020

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3D experiments in Grenoble

conductivity probe

wave generator

+ 2 lasers + 2 cameras leading to ~30 horizontal 1 vertical PIV velocity fields

3D experimental set-up in the Coriolis facility at LEGI (Grenoble, France).

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Attractors in non linear regime



Savaro et al., in revision for PRF, 2020

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