Modelling Antarctic Flows

CNRS_Coriolis
CNRS_Coriolis_06ICEBOX

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Heading

Infrastructure	CNRS_Coriolis		
Project	Modelling Antarctic Flows		
Campaign	06ICEBOX		
Title	CNRS_Coriolis_06ICEBOX		
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Date Campaign Start	01/04/2007	**Date Campaign End**	01/04/2007
Date Final Completion			

Contents:

1. Scientific aim and background:

The dynamics of density-driven flows on sloping topography has been the object of a significant amount of recent study through laboratory experiments, numerical models and field observations. Under some circumstances such flows break up into eddies, inducing strong motion in overlying water, while the viscous draining part of the flow can produce "roll-waves". The basic features and important parameters for these flows are now established, at least in broad terms.

This type of flow occurs in the seas around Antarctica, contributing to the formation of the deepest water masses of the world's oceans and thus important in the global thermohaline circulation. An extra complication in the Antarctic environment is the presence of ice shelves. These impose an upper boundary that is rather different from the usual free surface, and can result in sharp changes in water column depth. The purpose of this study is to investigate some of the basic types of flow including the effects of a modelled ice shelf. These will extend and compliment smaller scale laboratory work and numerical models, and help with our interpretation of data collected around Antarctica.

The flow in the Ronne-Filchner Ice Shelf cavity has been the subject of numerical experiments, though these are not yet of sufficient resolution to represent the eddies and other instabilities that we know are present (e.g. from mooring records as well as from laboratory experiments of related flows). Thus an important outcome of these experiments will be flow measurements that can be used to assess the reliability of existing and future numerical models of the Antarctic region. This information will be disseminated for general use by ice-shelf modellers, and Prof Holland will configure his existing numerical model to mimic the laboratory experiments to allow direct comparisons.

While we know, at least in broad terms, the main parameter values that appear to control the generation of eddies and roll waves in dense flows on slopes in open water, we do not know how these flows are affected by ice shelves. The amount of HSSW that penetrates beneath an ice shelf, and the eddy activity this generates, is very important in the formation of Ice Shelf Water and eventually the deep water masses that this contributes to. As a result of the experiments at Grenoble, we would expect to identify the main parameters and parameters regimes that describe the interaction of dense flows with ice shelves.

2. User-Project Achievements and difficulties encountered:

3. Highlights important research results:

4. Publications, reports from the project:

5. Description:

5.1. Description:

Dense source:. Surface source, similar to what is currently used to fill the tank (sponge arrangement with hoses that we were showed).

50x50 cm, floats on surface. Fill with brine which then drizzles down into the water. Rigid frame, sponge bottom.

Fresh source:. Distributed source. Seepeage hose placed underneath the big ice-shelf for distributed fresh source. 4 fresh-water sources joined to 2x1m long pieces of seepage hose, to obtain even flow rate in the whole ice-shelf. Attached underneath the ice-shelves. Try out maximum flow rate (up to 10 l/s).

Flow rate of freshwater source varies (in control run) between 1000 and 1100 litre/hour.

5.2. Definition of the coordinate systems used:

The x axis is along the upper edge of the slope, with origin at the middle of the ice shelf (basin). The y axis is pointing toward the upward slope direction, with origin at the slope edge.

The z axis is vertical upward, with origin at the tank bottom

5.3. Instruments used:

Flowmeters:

Conductivity probes:

C5 probe located at northwest corner (at outflow), located 4 cm from north wall and 4 cm from west wall.

C4 probe located at northeast corner, 44 cm from north wall and 14 cm from east wall.

Cameras:

two camaras are used simulataneously, covering the same field

cam A is used without the filter for PIV

cam B is used with the filter for LIF

Name, type and description	
Name of Instrument:	**AccuRange 200 Displacement Sensor**

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Quantity measured:	Bed Surface Elevation
Basis of measurement:	Laser Triangulation
General description:	Contained within submersible unit. When connected to a traverse it can measure bed surface microtopography. This can not be achieved during testing, only in either static flow conditions or unsubmerged sections of the flume, or before and after testing. Height Resolution: 15 µm Spatial Resolution: 50 µm
Range, accuracy &calibration	
Range of measurement:	50 mm
Accuracy of measurement:	+/- 0.2%
How often it should be calibrated:	Once in intial stage of measurement
Calibration procedure:	Calibrate signal to distance between sensor and target
Installation, power and data	
Power supply/supplies required:	240V
Type of connector:	sub 9 pin connector to PC serial port
Details of data acquisition system:	PC
Dimensions	

	<table><tr><td>Length (mm):</td><td>70</td></tr><tr><td>Width (mm):</td><td>60</td></tr><tr><td>Height (mm):</td><td>20</td></tr><tr><td>Weight (kg):</td><td>-</td></tr></table>***Table 5.3.2*** ***Table 5.3.1***
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5.4. Definition of time origin and instrument synchronisation:

6. Definition and notation of the experimental parameters:

6.1. Fixed parameters:

Geometric parameters:

RhoDenseFlow: density of the dense flow introduced at the tiop: close to 1004.5 kg/m3 (checked for each experiment)

RhoFreshFlow: density of the fresh flow injected at the bottom: close to 1000 kg/m3 (checked for each experiment)

6.2. Variable independent parameters:

Notation	Name	Unit	Definition	Remarks
D_1	DenseFlowRate	l/mn	volume flow rate of the dense water	
D_2	FreshFlowRate	l/hour	volume flow rate of the fresh water introduced at the bottom	
T	RotationPeriod	s	Period of rotation of the platform	
	Geometry			New Cell

Table 6.2.1

Additional parameters, checked for each experiment, are DrainLevel

DomainLevel
RhoDenseFlow: density of the dense flow (close to the fixed value 1004.5 kg/m3)
RhoFreshFlow: density of the fresh flow (close to the fixed value 1000 kg/m3)
TempDenseFlow: temperature of the dense flow
TempFreshFlow: temperature of the fresh flow
DyeFlowRate: flow rate of the dye marking the fresh flow

6.3. Derived parameters and relevant non-dimensional numbers:

Notation	Name	Unit	Definition	Remarks

Table 6.3.1

7. Description of the experimental campaign, list of experiments:

Name-dir	Date	StartTime	DrainLevel	DomainLevel	RotationPeriod	RhoDense Flow	TempDense Flow	**DenseFlow Rate**	RhoFresh Flow	TempFresh Flow	**FreshFlow Rate**	DyeFlow Rate	**Geometry**	Remarks
			Cm	Cm	**S**	Kg/m^3	Deg C	**l/min**		Deg C	**l/hour**	pump setting		
Calib_cam_01-12	1-Dec-06					0.00						0.0		Geometric calibration of the two cameras
Test_rhodamine	12-Jan-06		60	??	**60**			**10.00**			**00**			Only salt water for test dye (during spin-down)
BOX01	5-Dec-06		60	??	**60**	1004.2	19.6	**20.03**	??	13.0 (guess)	**1200**	30.0	**Control**	too much rhodamine in water - laser absorbed before reaching

														domain
BOX02	6-Dec-06		60	??	**60**	1004.7	17.0	**??**	??	??	**??**	??	**Control**	too many bubbles and also a leak (probably big)
BOX03	7-Dec-06		58	35	**no rotation**	1004.5	17.3	**20.00**	999.4	19.1	**1250**	1.0	**Control**	major leak inferred from rhodamine found in world ocean. Very few bubbles because used static freshwater source
BOX04	9-Dec-06	11:30	58.4	34.8	**no rotation**	1004.3	19.6	**20.54**	1000.3	15.1	**1200**	1.0	**Control**	used 15cm mousehole sill from now on. No leak. Laser failed (camera connecti

														on) after 1:20, probes failed after 2:00
BOX05	11-Dec-06	11:20	58.4	34.8	**no rotation**	1004.7	17.9	**20.30**	1000.6	13.3	**1200**	1.0	**Control**	introduced bleach or something when trying to add particles at grounding line
BOX06	11-Dec-06	16:49	59.5	32.4	**60**	1004.7	17.9	**20.05**	1000.6	13.3	**1200**	1.0	**Control**	added automatic particle-adding at grounding line. Laser died.
BOX07	12-Dec-06	12:30	59.5	32.4	**60**	1004.6	18.7	**10.04**	1000.7	13.4	**1800**	0.5	**Control**	flushed the dense system beforehand. Was unnecessary.

BOX08	12-Dec-06	16:45	59.5	32.4	**60**	1004.6	18.7	**30.63**	1000.7	13.4	**600**	0.5	**Control**	no spin-up; just ran straight from BOX07
BOX09	13-Dec-06	11:00	59.5	32.4	**60**	1004.6	14.6	**20.00**	1000.9	13.9	**1200**	0.5	**Control**	2 hour spin-up of control case just observing a new level (approx 3.8cm above cont. shelf) To look at eddies - BOX09_2 is second hour.
BOX10	13-Dec-06	15:00	59.5	32.4	**60**	1004.6	14.6	**19.93**	1000.9	13.9	**1300**	0.5	**9cm grounding line, 22.5cm ice front**	cavity 'pinches' at grounding line
BOX11	14-	10:25	59.5	32.4	**60**			**20.30**			**1300**	0.5	**30cm**	ice shelf

	Dec-06												**grounding line, 15cm ice front**	is flat
BOX12	14-Dec-06		59.5	32.4	**60**							0.5	**??cm grounding line, ??cm ice front**	ice shelf raised until virtually no ice front
BOX13	15-Dec-06		59.5	32.4	**60**							0.5	**??cm grounding line, ??cm ice front**	ice shelf raised until virtually no ice front

Table 7.1: list of experiments

8. Data processing:

8.1-Geometric calibration:

A calibration method is used (Tsai model) taking into account the depth dependency (changing distance to the camera) and quadratic deformation of the objective**.** Reference images have been recorded in

06ICEBOX/0_CAMERA_CALIBRATION/cal_cam_BOX01_0112.

The reference images show a target plate with a set of perpendicular lines 10 cm apart, positioned horizontally at the level of the top of the slope. The raw calibration has been made using Acquix with an imposed objective lens 33 mm (true focal 25 * 1.33 index of refraction of water). Then it has been manually corrected to take into account that the plateau supporting the target was is at z=25 cm(upper plateau), not 0. (change z->-z), Tz->Tz-r9*25, same for Tx and Ty. Final adjustments (1 %) have been done with the experiment BOX06, to get a good fit with the box sides. The resulting precision on wall position is better than 1cm at any height.

The calibration parameters for each camera have been copied to the corresponding xml files (ImaDoc/GeometryCalib) for all the experiments. They are automatically used when the 'phys' option is set on the uvmat interface.

The first 16 vertical positions of the laser sheet have been directly measured in the steady regime at the end of experiments, see

0_CAMERA_CALIBRATION/laser_level_height.xls.

These has been fitted and extrapolated by the Matlab function linspace(51.8,15.5,23), providing an equal spacing of all levels. The distance to the measured positions is always less than 1.5 cm. These positions are written as in the xml files of image series.

These positions and box geometry are also given in the function

0_MATLAB_WORK/contour_box.m

which creates the box contours (xml files 'section' (in phys coordinates) and image masks for each z level and each camera (the geometric parameters have to be set at the beginning of the function).

pix/cm (approximation)

camB: 4.53 along x

4.54 along y

note on box geometry: the east wall is well perpendicular to the slope break (it is aligned with the y axis). The west wall is parallel to the east one until y= 51.7. Threre is a step there and an angle outward to allow space for the mouse hole in the back.

8.2-PIV: (camA)

First remove the fixed backgound with 'sub_background' fct on the **whole time series (indices i and j)**(path Papillon/data/civbin/UVMAT.joel/usr_fct). This yields a new image folder ..._b. The background is obtained by sorting a sliding subseries of images. We have compared the result from 21 and 15 images for BOX06. The PIV fields are better with 21 images, so we chose this parameter value.

Missing files:

BOX07/PIV/06ICEBOX_camA_xx_1.png missing bexond xx=478

BOX09/steady/box09_2_camA_447_1.png replaced by a copy of camA_447_2.png

BOX09/ONSET/box09_2_camA_499_3.png replaced by a copy of cama_4997_2.png

8.3-LIF(camB):

a) Get a reference image series with no laser, to get the <u>offset</u> image: Io

0_CAMERA_CALIBRATION/dark_offset_1112

(repeat at ...

dark=222 (PIV)

dark=237 (LIF)

these offset values are substracted to all images at the first step of processing.

b) Sensitivity of the lens:

we illuminate a cylinder with dye and move the camera. The figure shows the value versus distance to the image center (normalized by the image half-width). No significant variation within 5%.

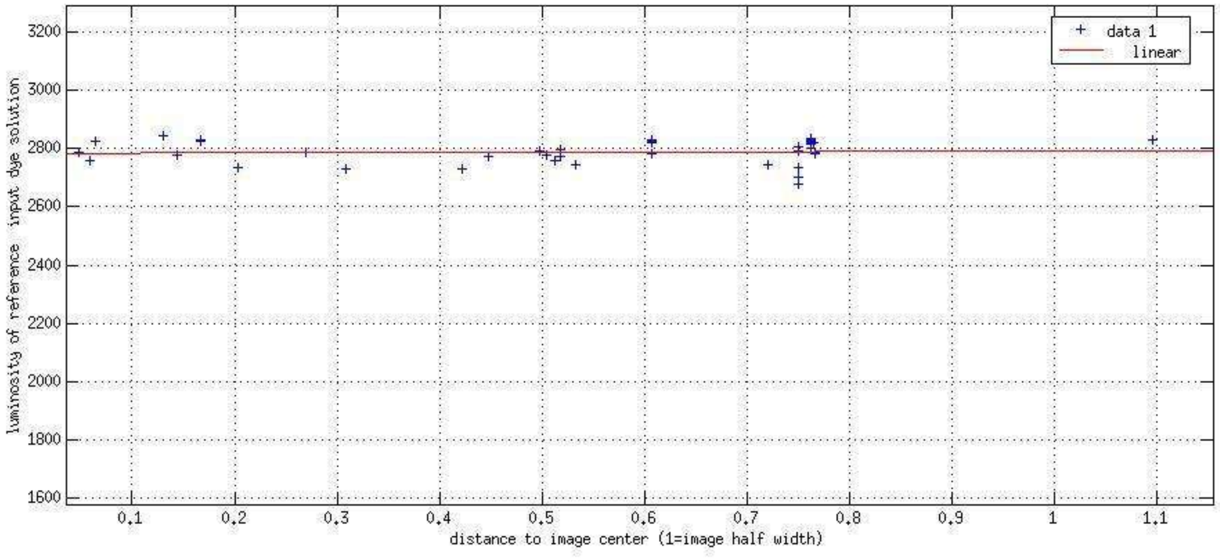

Figure 8.1

c) Reference laser luminosity and absobsion:

We first transform the coordinates into polar, with center at x=-515, y=-175, corresponding to the origin of the laser light (obtained by prolongating observed rays in physical coordinates).

We then determine the luminosity at x=-95 (slose to the illuminated edge), versus the azimuth (average in a band of 20 pixels), using the reference image with uniform concentration.

d) Absorbsion law:

$(d/dr)(rI) = -gc\, rI$

where r is the radius from laser source,I the laser light flux, c the dye concentration.

the LIF luminosity is given by

$A = a\, c\, I$

With the reference image c=1 everywhere, we get:

$(d/dr)(rA) = -g\, r\, A$

we determine g from the reference images (taking a linear fit to log(rA) along radius.

We get g=0.009 +-0.001 cm-1

if I is expressed in units of the reference luminosity I_ref(Y), and A in units of the corresponding brigthness, then a=1.

The laser luminosity is then given, along each radial line:

c_0(Y)=A/A_ref(Y) .

rI=r_0 – g int(rA dr)

then c=A/I.

e) Substract part of the ref PIV image:

The final function used is LIF_series.m.

- Get reference images with the small cylinder at different positions with the rhodamine concentration of the salty source: only for test purpose
- Make a reference experiment with fresh water source cut. A uniform dye concentration should be obtained at the end

0_CAMERA_CALIBRATION/cal_rhodamine_uniform_1212

this provides the proportionality of brighness versus concentration and the decay rate due to laser absobsion.

Gain images:

We use a series of images with the same cylinder filled with dye, moving the camera to check the sensitivity dependency versus de distance to the camera axis. We first make a black image 0_CAMERA_CALIBRATION/cal_LIF/cal_LIF2_zero_camB_aver.png, average from burst 6 to 21 (burst 5 files are corrupted).

Then we substract the background to each image and get the average in a circle (radius 60 px) centered on the cylinder image.This provides a luminosity versus position in the image.

9. Organisation of data files:

- 0_DOC: miscellaneous documentation and reports
- 0_MATLAB_WORK: specific matlab functions
- 0_PHOTOS: photos of set-up
- 0_REF_FILES: files of general use (grids, calibration images)
- 0_RESULTS: processed data (time series, statistics...)
- Directory for each experiment (as named in Appendix 1), containing subdirectories:

Image series are stored as png files whose name root_i_j.png is formed the concatenation of a root name 'root' and two indices 'i' and 'j' with the separator character '_'. Information on image timing, camera setting, illumination and image calibration is provided by a xml file named root.xml in the same directory as the images.This information is specified by the xml schema 'ImaDoc ' available at the Coriolis facility.

10. Remarks about the experimental campaign, problems and things to improve:

LESSONS LEARNED – 2006

1. Mouse hole was placed at northwest. Much better location would have been northeast. Variable height of the mousehole would be good.
2. Laser should have been aligned parallel to ice shelf front so to minimize shadow effects.
3. Ability to change bottom slope would have been nice.
4. Dense source was a bucket while fresh source was a line. It would have been better to have two, long thin line sources (sponge diffusers) for both the dense and freshwater source.
5. In our experiments the ice shelf was flooded with ambient fluid. Our ice shelf was 30 cm high. An ice shelf height of 50 cm would have prevented this flooding. The precise height would be limited by the steepest slope that you would want to use.
6. The grounding line leaked. As a result we glued the grounding line wall in a fixed position. Having the entire domain enclosed in a solid (non-leaking) perimeter would be more ideal.
7. Rhodamine leaked into laser domain. Bleached seemed to clear this away.
8. More time to do experiments. Three weeks inadequate.
9. Bring ample supply of seeding particles.
10. Our freshwater source had several problems. It produced bubbles (which was mostly cured by our grounding line gap). Also, it was too cold. It would be desirable to have the freshwater source at the same temperature as the dense source. We need to ensure that our freshwater is stratifying with respect to the dense rather than mixing with it on entry.
11. Our domain was 2 m wide by 4 m long. A larger domain could be useful.
12. Our geometry was smooth. Putting canyons or ridges on the ice shelf base or sea floor could be good.
13. Out total water depth was about 58 cm. The perimeter walls of our domain were constantly on the verge of flooding. Higher side walls would be better.
14. Joins in the sidewall through which the laser illuminated our domain caused shadows. The joints should be avoided. Similar shadow problems arose with the ice shelf itself.
15. Place laser source on sidewall where freshwater is emerging. In our experiments the dense plume was on the sidewall closest to the laser and thus caused unnecessary absorption.

Window size: x
Viewport size: x