SENSITIVITY OF WRF MODEL TO SIMULATE GRAVITY WAVES

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UNIVERSITAT DE BARCELONA

13TH ANNUAL WRF USERS' WORKSHOP

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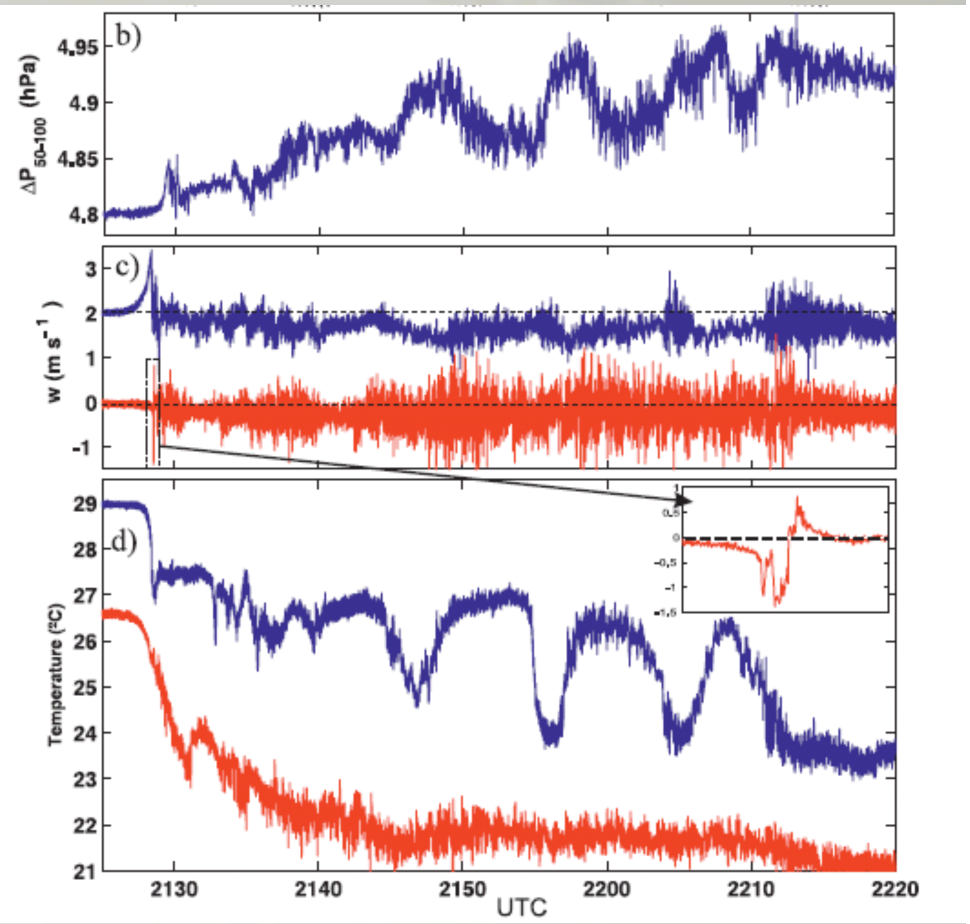
Motivation

- Observational study of internal gravity waves (IGWs) generated at the top of a drainage flow (gravity current)
- Tower measurements SABLES 2006 campaign
- Oscillations in pressure, vertical velocity and temperature



CIBA tower 19.6 m

CIBA tower 96.6 m

From Viana *et al.* 2010

Objectives

- Study the capability of the WRF model to capture the gravity waves
- Analyze the sensitivity of two planetary boundary layer (PBLs) schemes → MYJ and YSU
- Understand the origin of the IGWs
- Analyze the characteristics of the gravity waves generated by the gravity current applying wavelet transform to WRF model data

Overview

1. Introduction
2. Model setup
3. PBL and surface layer description
4. Results
   I. Description of the studied night
   II. Model experiments evaluation
   III. Overview on mesoscale fields
   IV. Oscillation features
5. Conclusions

Introduction

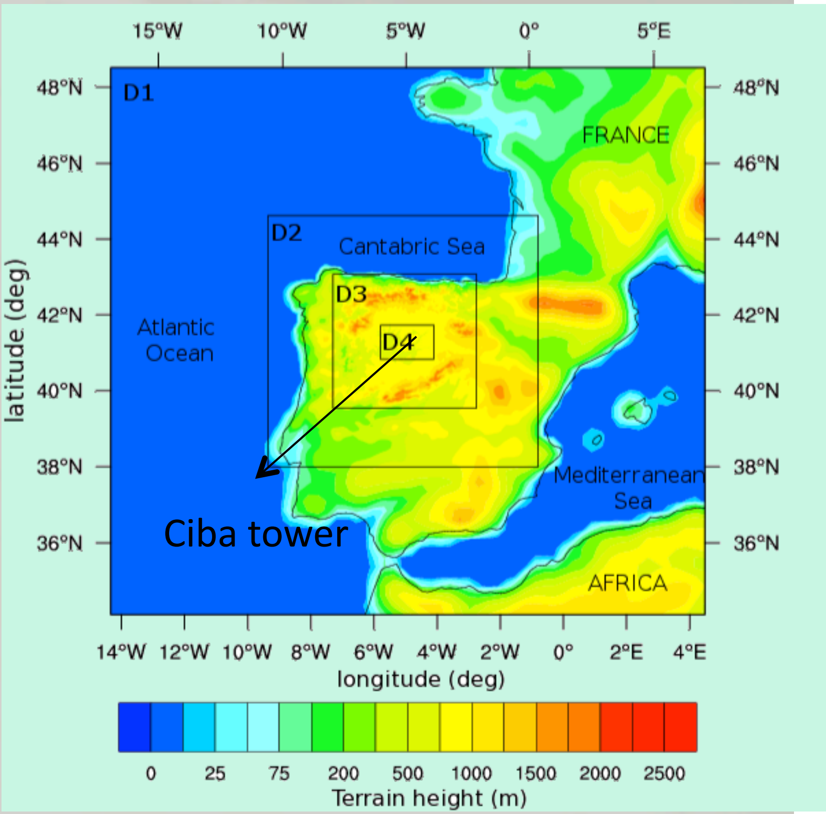
- Gravity or density currents are flows created by differences in the density of two adjacent fluids.
- They can be originated by cold fronts, sea-breeze fronts, squalls, etc.
- Irruption of these flows may result in vertical displacement of air parcels from their equilibrium position → source of IGWs
- IGWs can transport energy and momentum, and can be a source of turbulence
- Mesoscale models are useful to study mesoscale disturbances

Model setup

- WRF-ARW v3.1.1
- 3 domains 2-way nesting → 4th domain 1-way nesting
- 27 – 9 – 3 – 1 km
- 48 sigma vertical levels → 20 levels within first 250 m

	Domain 1	Domain 2	Domain 3	Domain 4
Horizontal grid	27 km	9 km	3 km	1 km
Dimensions (x, y, z)	65, 60, 48	88, 82, 48	139, 130, 48	154, 100, 48
Ini. & bound cond.	NCEP CFSR 0.5°×0.5° every 6h			WRF domain (D3)
Simulated period	22-06-2006 to 24-06-2006			Night 22-23

2 experiments



- Common physics

Radiation	Dudhia scheme for short wave radiation RRTM for long wave radiation
Land surface	NOAH Land-Surface Model (4 subsoil layers)
Microphysics	New Thompson et al. scheme
Convection	Grell 3D scheme

- Different PBL and surface layer schemes

	PBL	Surface layer
Exp. 1 YSU	**Yonsei University scheme**	**MM5 similarity**
Exp. 2 MYJ	**Mellor-Yamada Janjic**	**Eta surface layer**

PBL description

- Exp. 1 Yonsei University scheme (YSU) (Hong *et al*, 2006)
  - First order scheme, non-local closure turbulence, with a counter-gradient term
  - MRF modification
  - It considers the nonlocal fluxes implicitly through a parameterized nonlocal term

- Exp. 2 Mellor-Yamada-Janjic scheme (MYJ) (Janjic, 1990; 1996; 2002)
  - 1.5-order (level 2.5), local turbulence closure model of Mellor and Yamada (1982)
  - It determines eddy-diffusion coefficients from prognostically calculated turbulent kinetic energy (TKE)

Surface layer

Calculates surface exchange coefficients to compute sensible, latent and momentum fluxes

It provides the lower boundary condition for the vertical transport in PBL scheme → important for temperature and moisture

- Exp. 1 Similarity theory (MM5)
  - Coupled with YSU PBL scheme
  - Momentum, heat and moisture exchange coefficients from stability functions from Paulson (1970), Dyer and Hicks (1970) and Webb (1970). Convective velocity from Beljaars (1994)
- Exp. 2 Similarity theory (ETA)
  - Coupled with MYJ PBL scheme
  - Based on similarity theory (Monin and Obukhov, 1954)
  - Includes parameterizations of viscous sub-layer

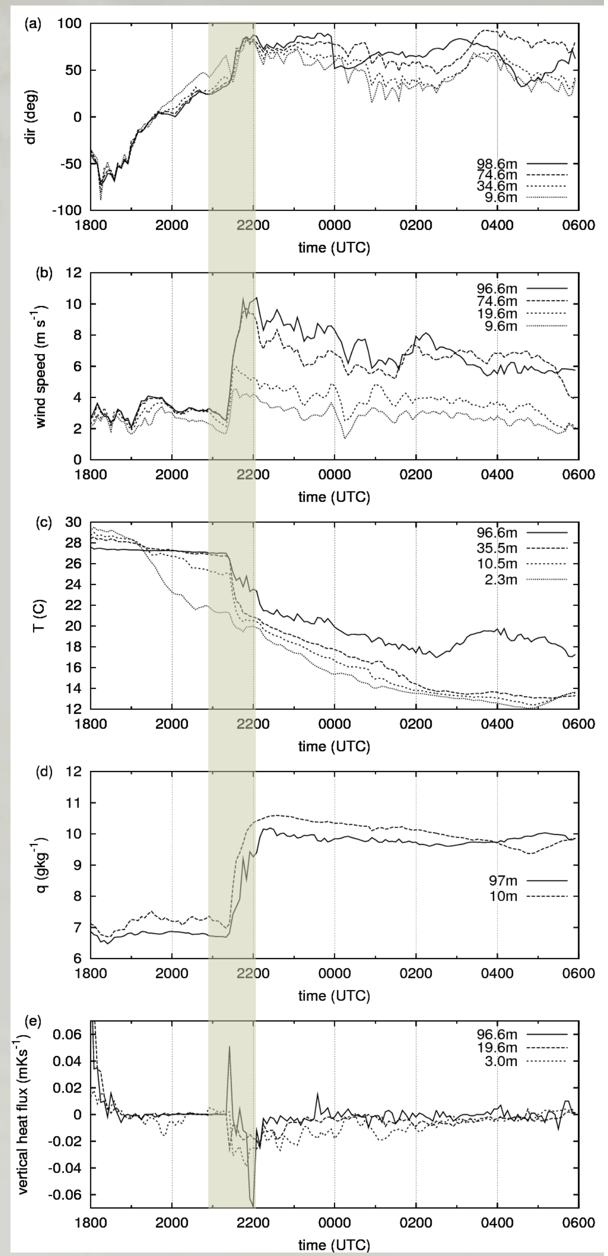
Results

- Overview of the studied night
- Overview on mesoscale fields
- Model experiments evaluation
  - Vertical structure of the density current
- Oscillations features

Description of the night case

- SABLES 2006 campaign
- Night 22-23 June 2006, high pressure area, weak horizontal pressure gradient
- Values recorded at different levels of the mast show weak NW wind and a shift at 2130 UTC, sudden intrusion of an eastern current of moderate speed.
- Temperature drops and thermal inversion is reduced
- Specific humidity rises with the current arrival
- Vertical heat flux reveals displacement of parcels due to the outbreak

CIBA tower data

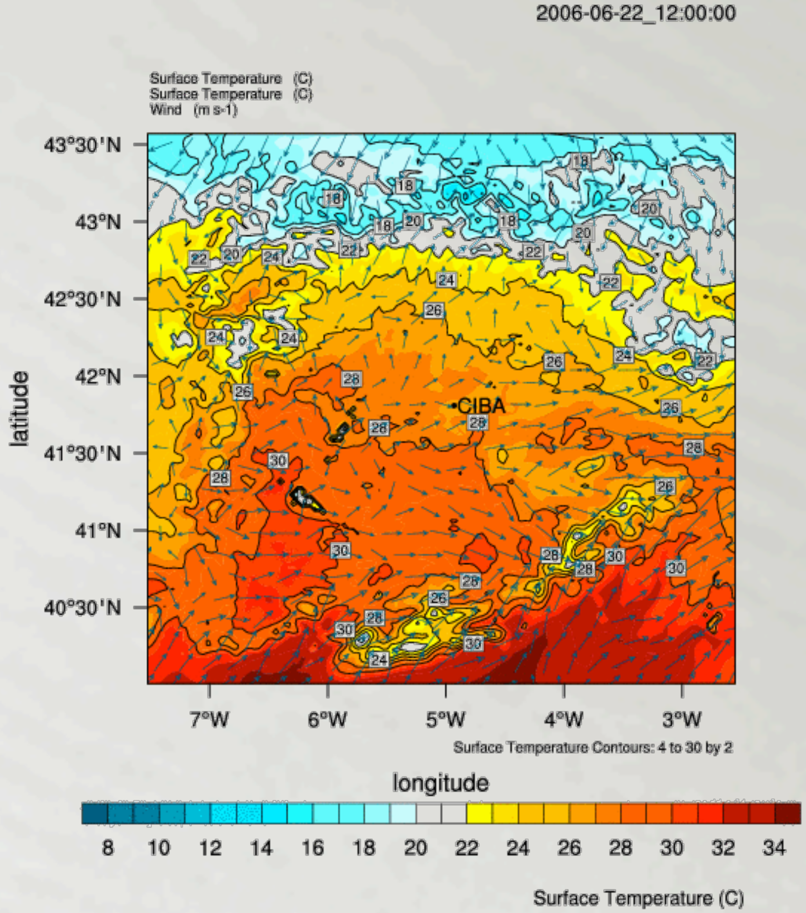


Mesoscale overwiew

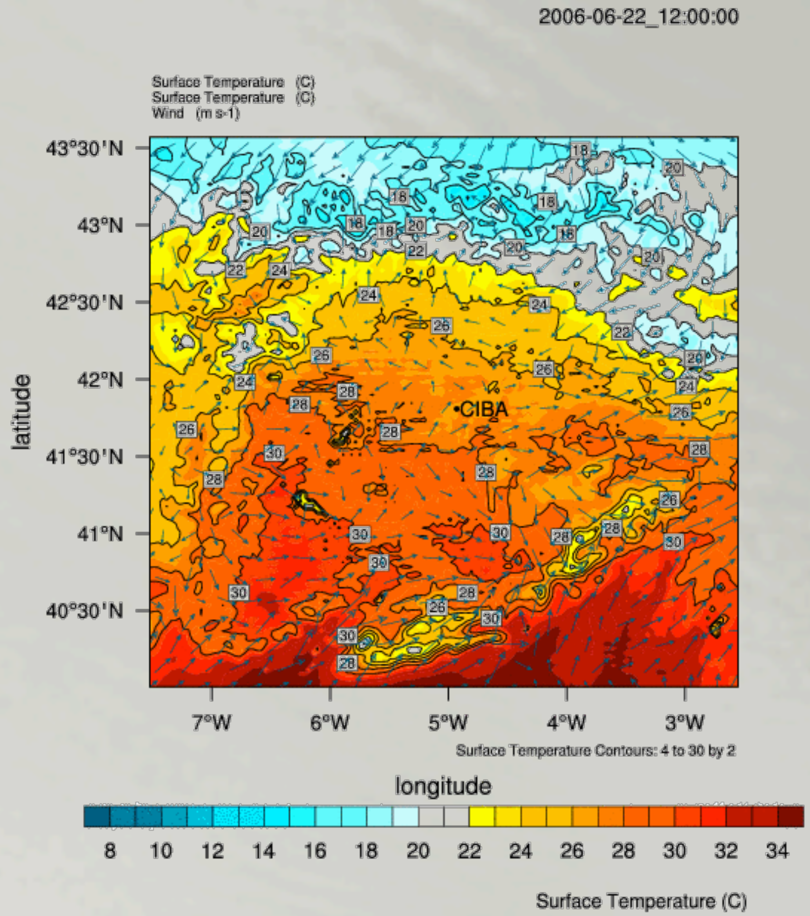
Domain 3 (3km grid)

2 m temp + wind 10m 1200-2300 UTC

YSU



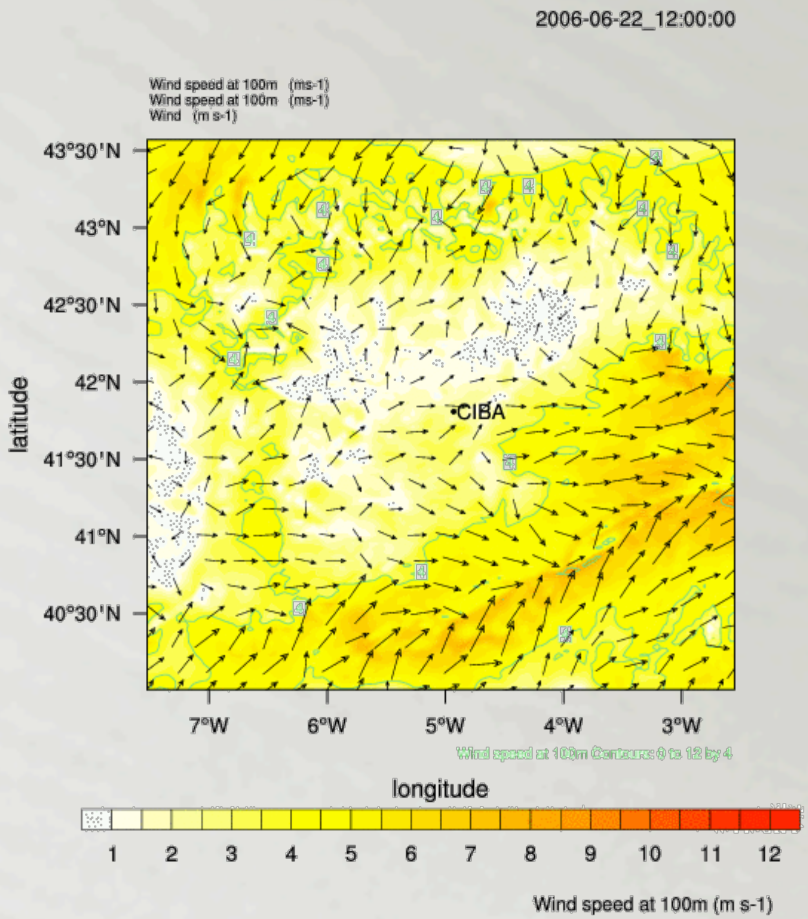
MYJ



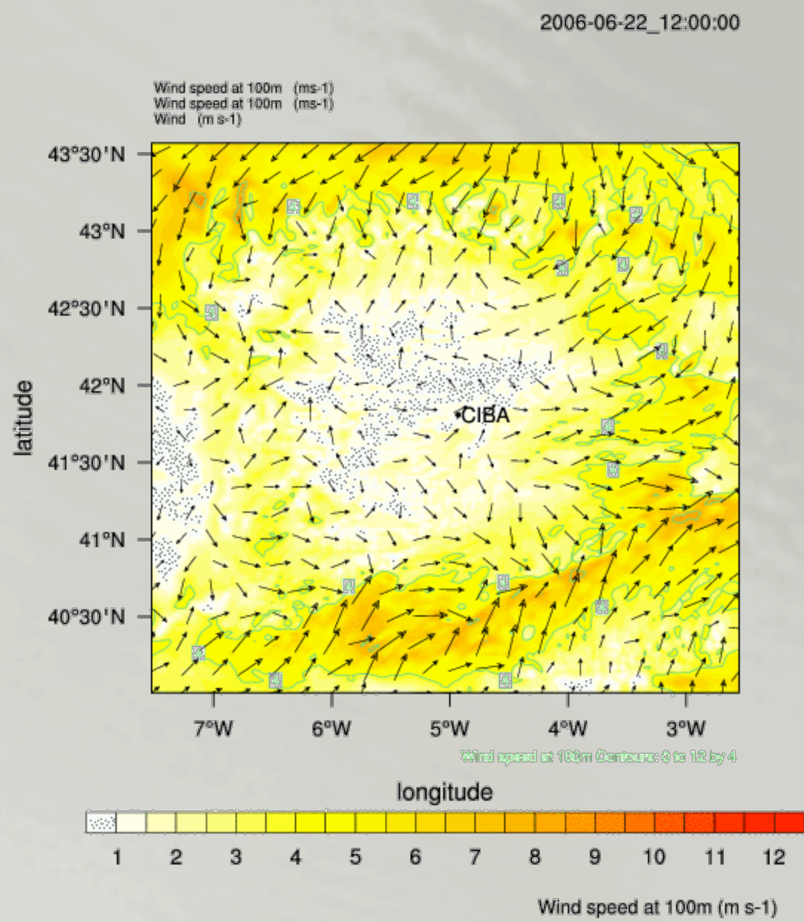
A density current coming from the NE

Wind at 100 m   1200-2300 UTC

YSU

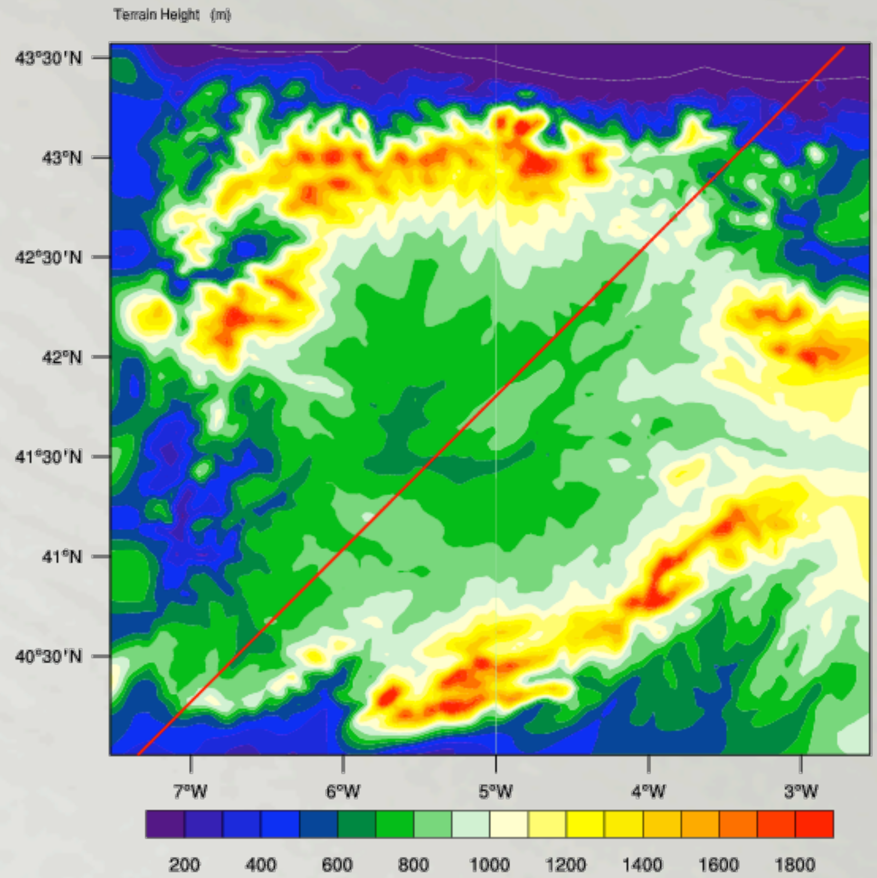


MYJ



Mesoscale overview

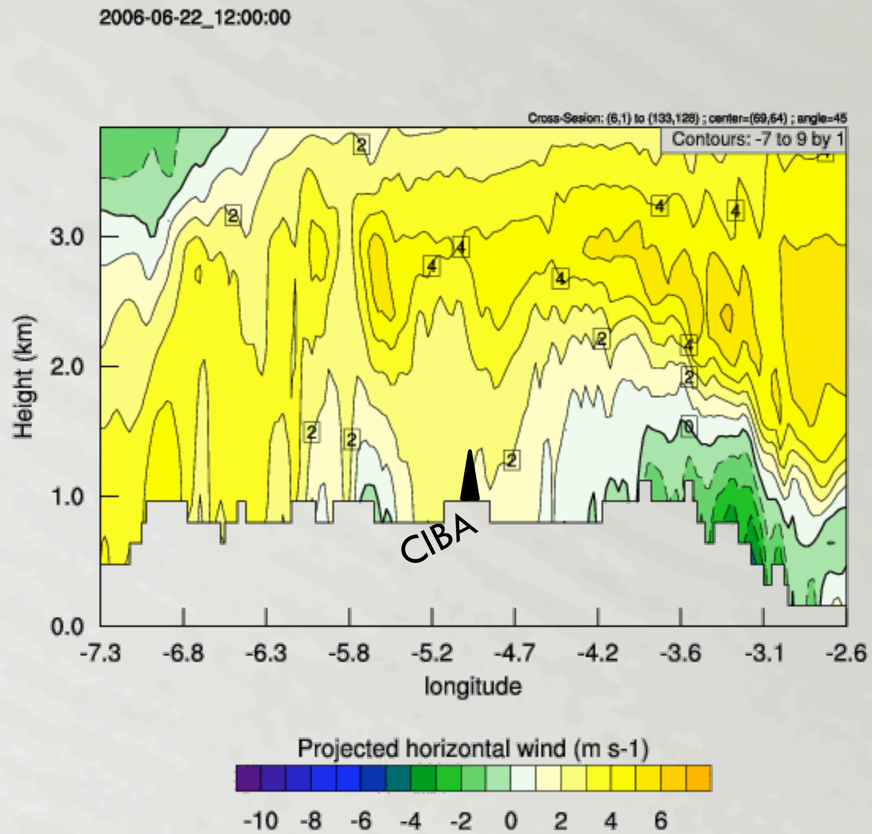
Cross section NE-SW (Domain 3)



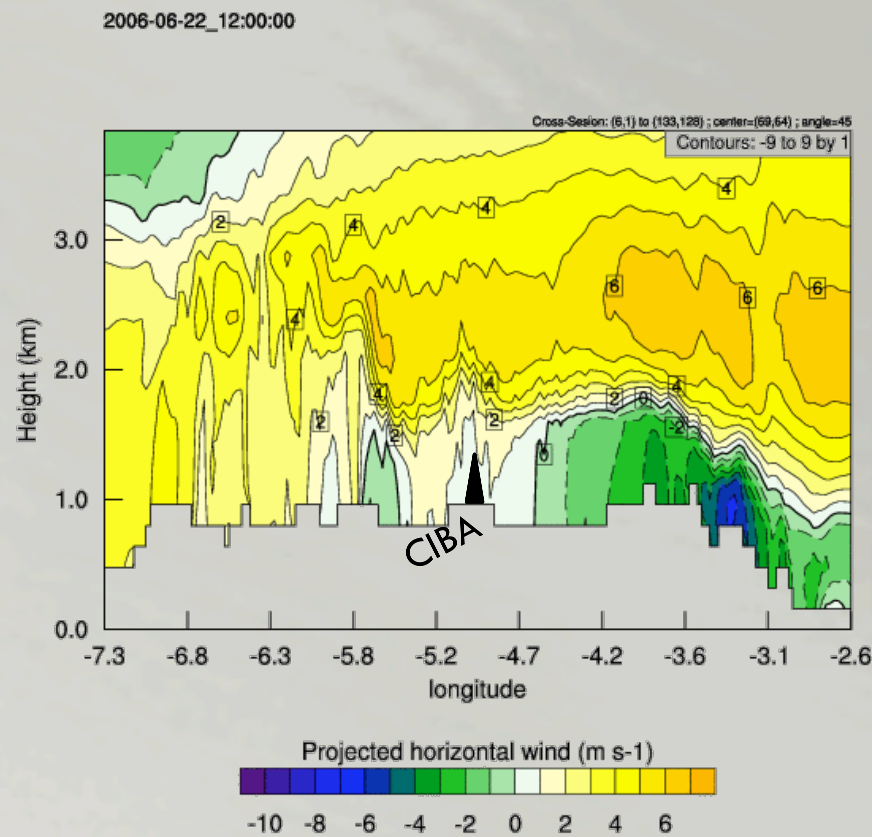
Mesoscale overview

Cross section NE-SW: Projected horizontal wind 1200-2300 UTC

YSU



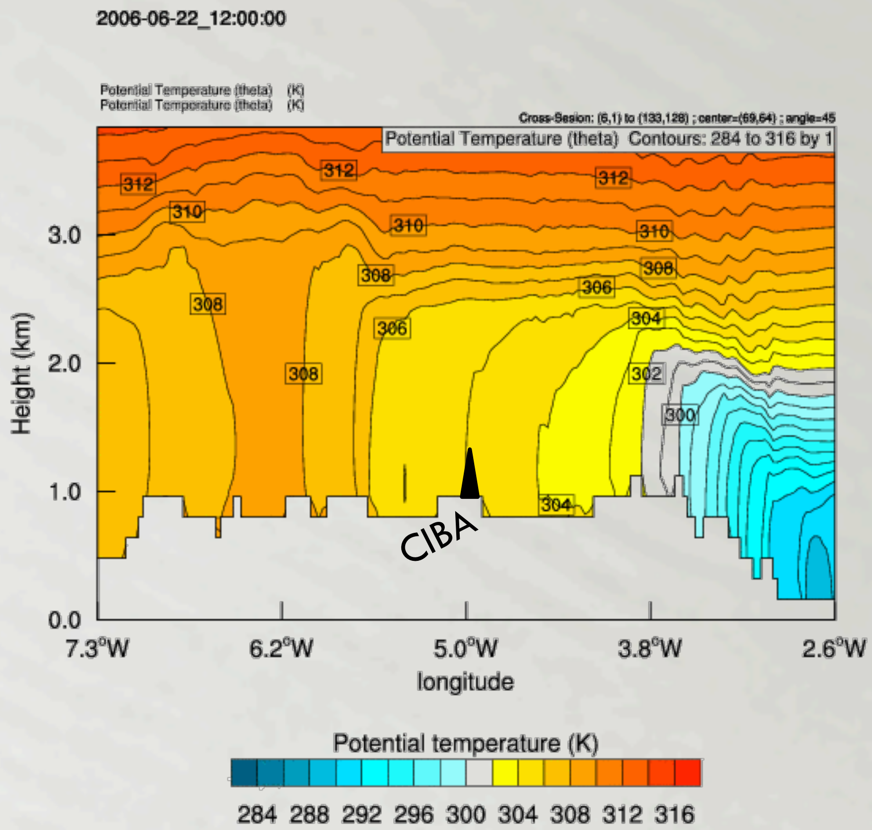
MYJ



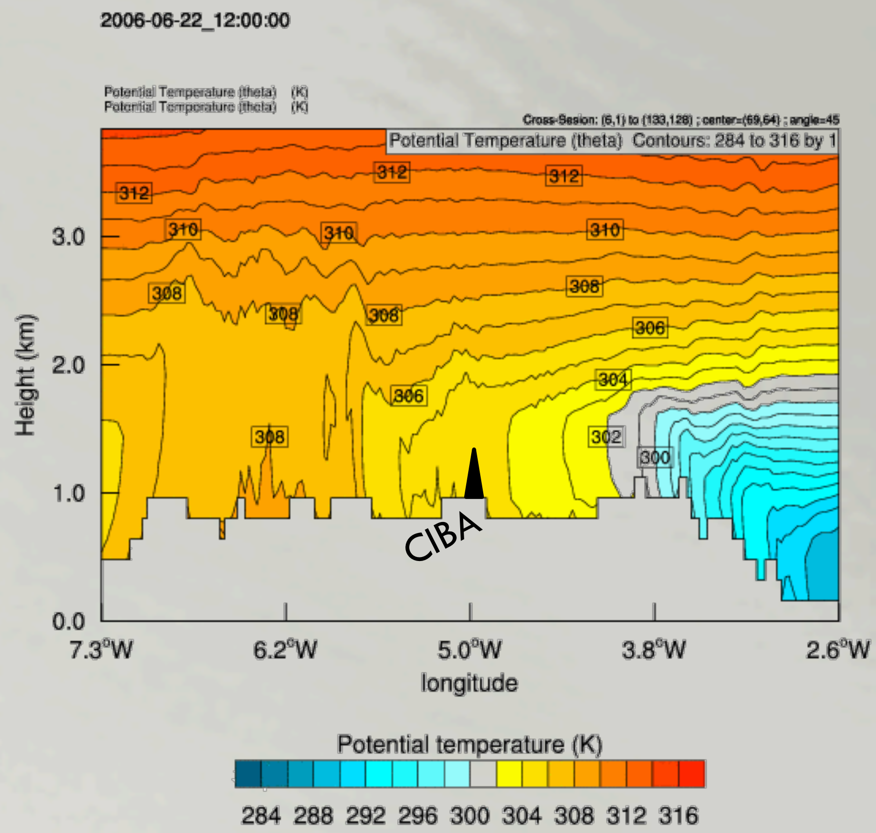
Mesoscale overview

Cross section NE-SW: Potential temperature 1200-2300 UTC

YSU



MYJ



Model experiments evaluation at CIBA site

1 km (D4) model outputs

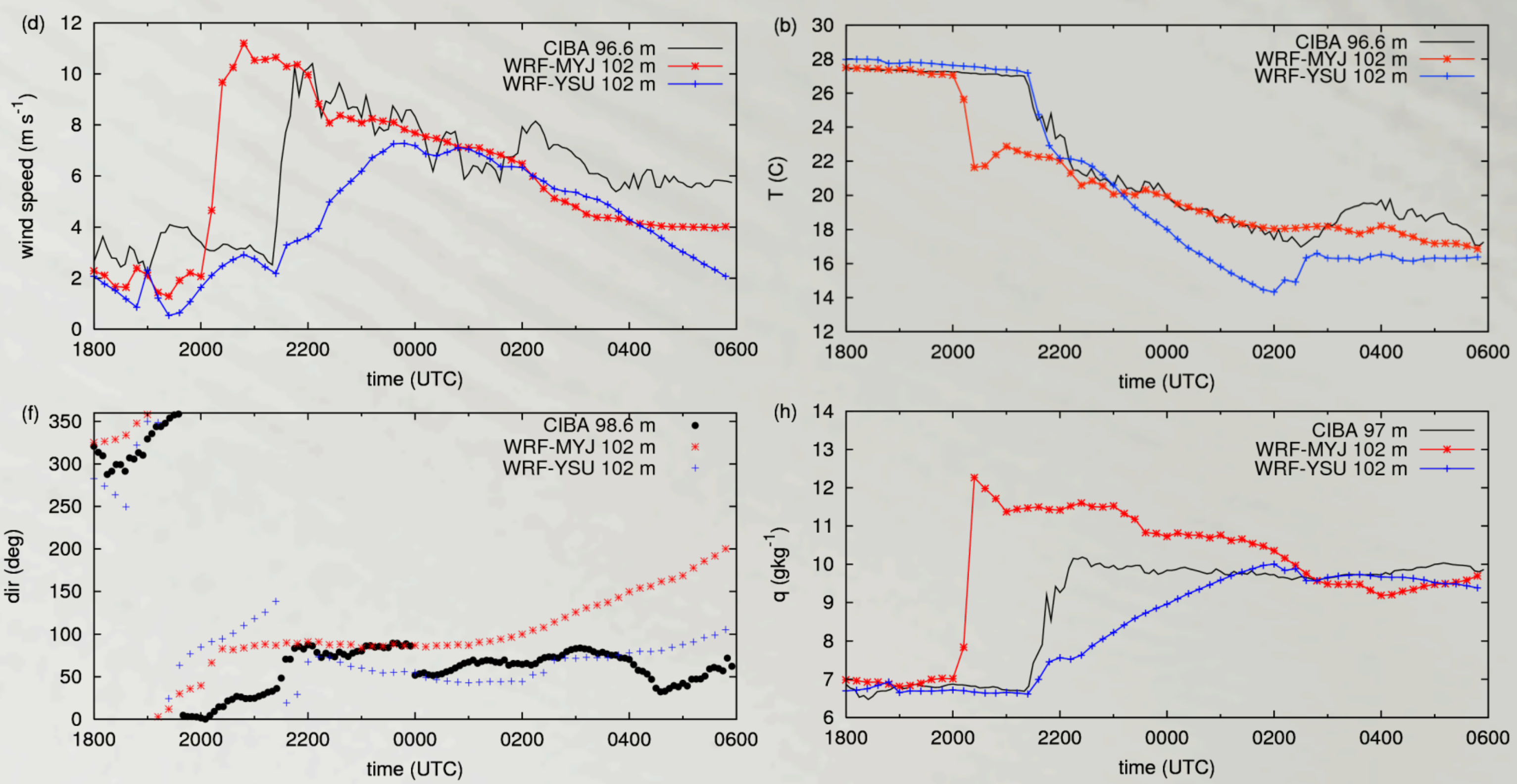
At the top of the tower (~100 m):

- Wind speed increases
- Wind turns from north to east in both schemes
- Temperature drops 5 C
- Specific humidity rises

Observation (CIBA tower)

WRF-MYJ experiment

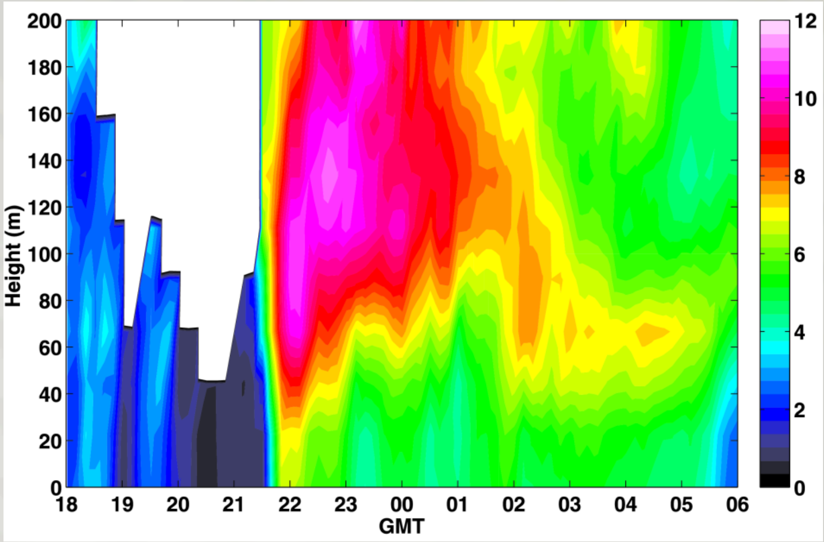
WRF-YSU experiment



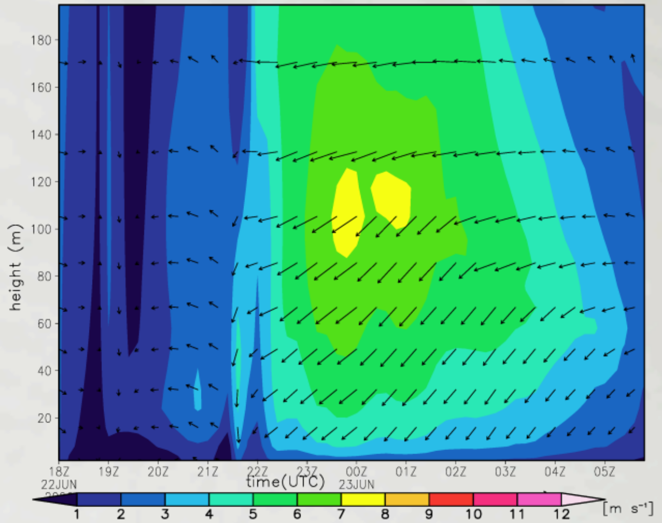
Vertical structure of the gravity current

Wind speed time-height diagram at CIBA site

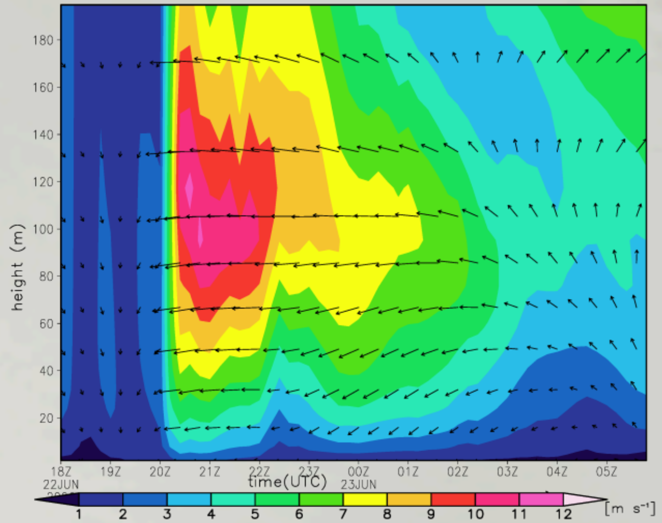
RASS-SODAR



WRF-YSU



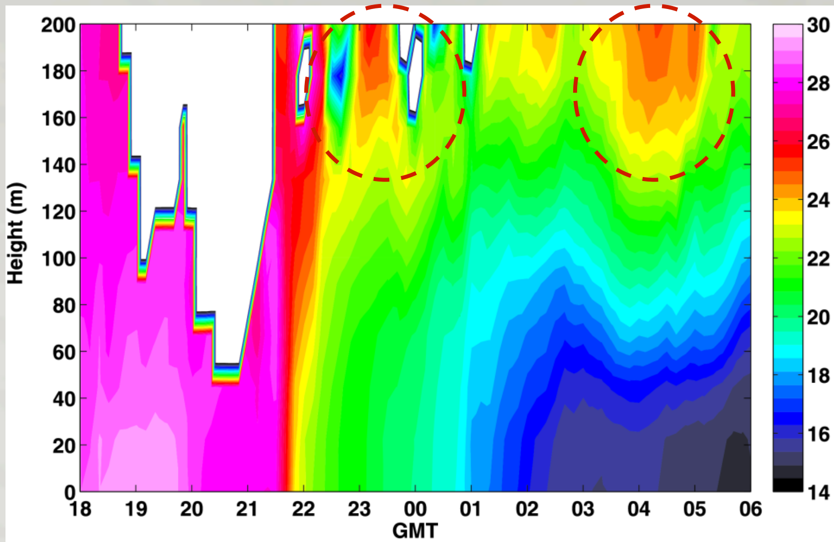
WRF-MYJ



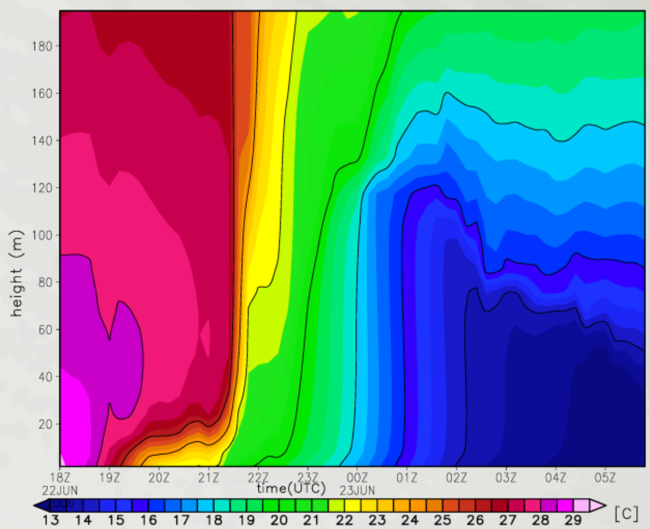
Vertical structure of the gravity current

Temperature time-height diagram at CIBA site

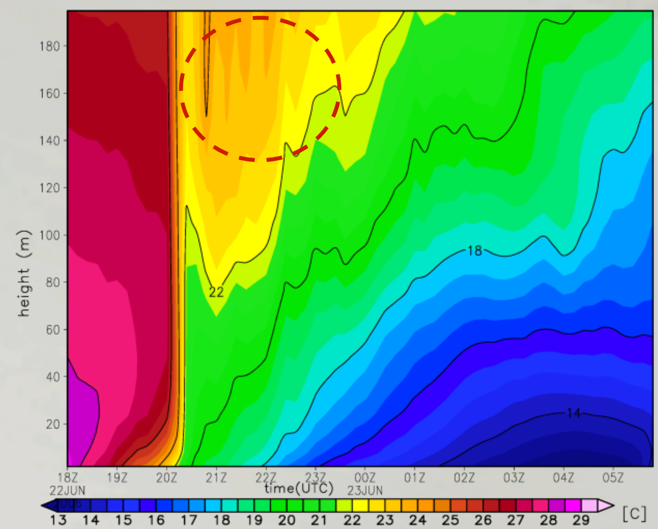
RASS-SODAR



WRF-YSU



WRF-MYJ

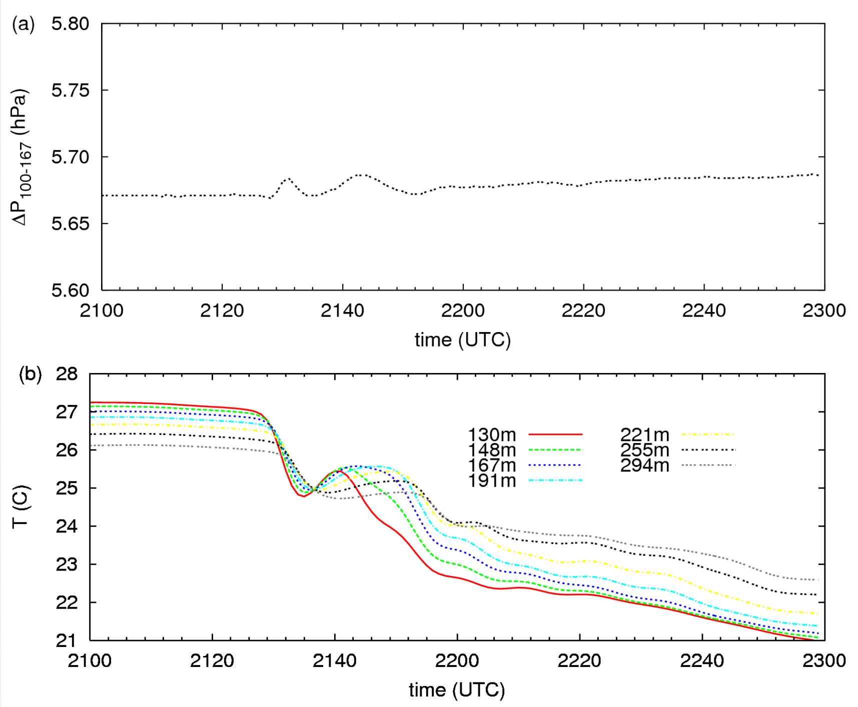


Oscillations features

Mean magnitudes → 12-minute model outputs / Spectral analysis → 1-minute model outputs

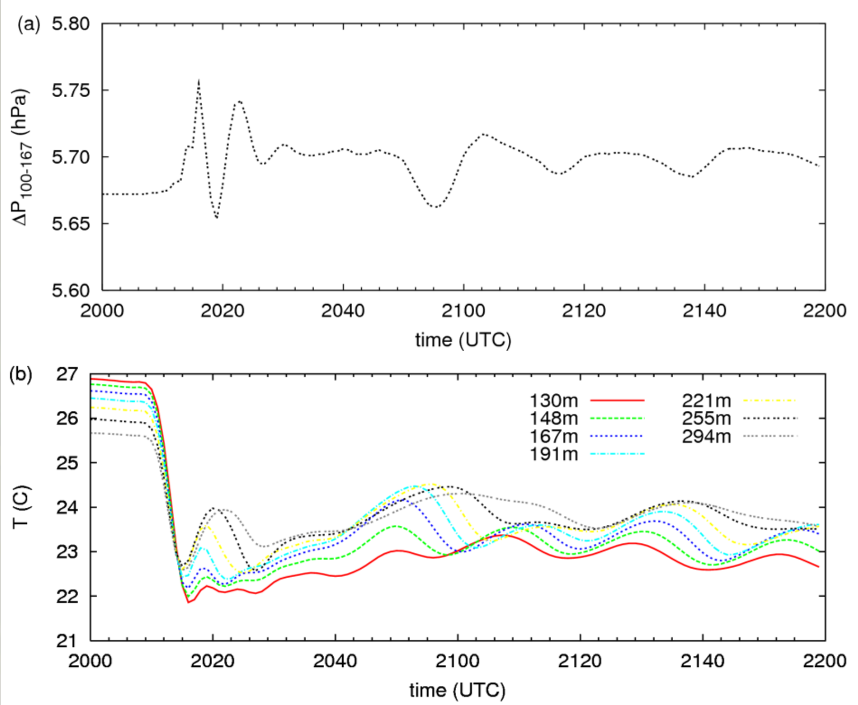
YSU scheme

No oscillations



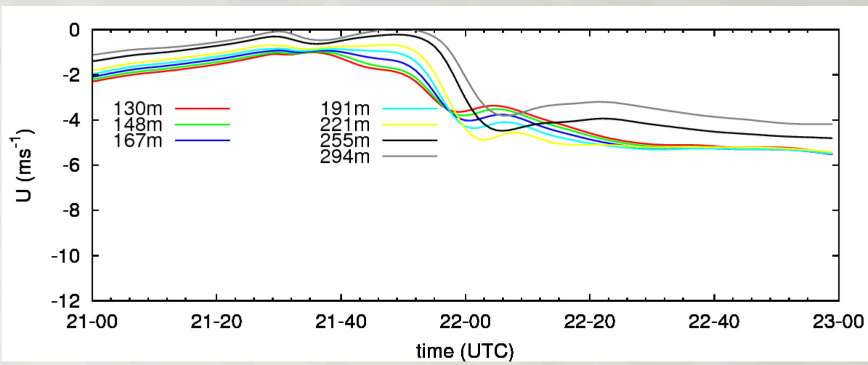
MYJ scheme

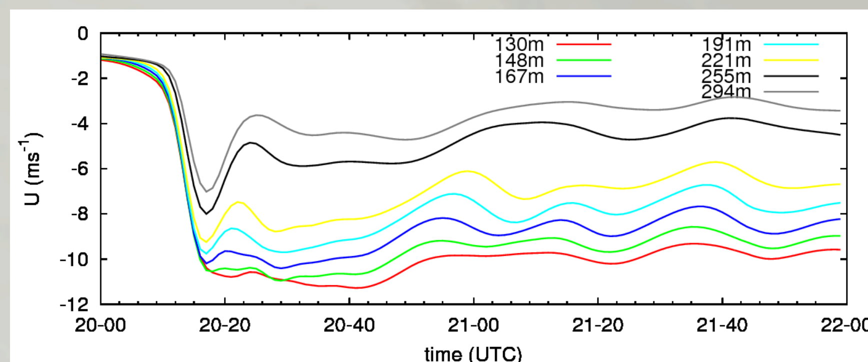
Oscillations

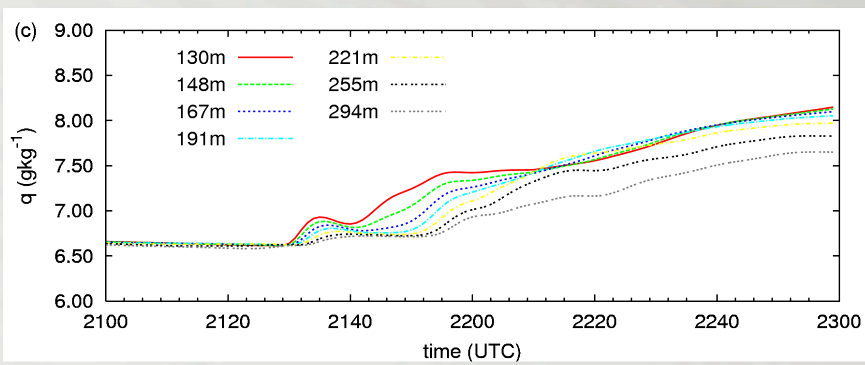


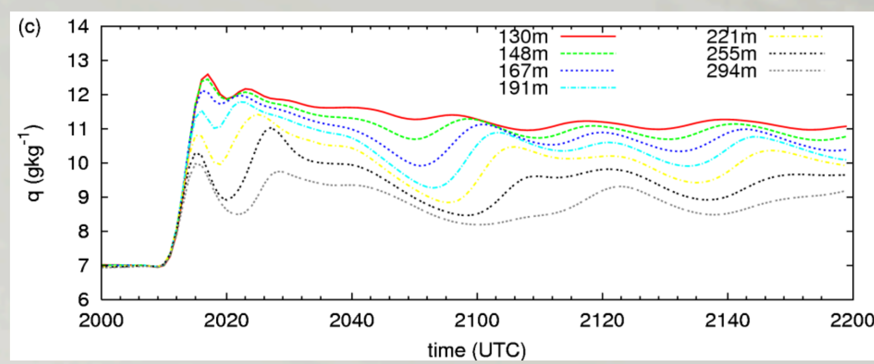
Oscillations features

YSU scheme	MYJ scheme
No oscillations	Oscillations

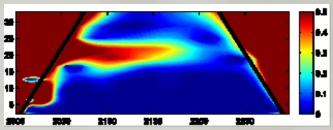








Oscillations features



Wavelet transform method (Terradellas et al., 2005) applied to 1 minute model outputs of potential temperature at 167 m

Energy wavelet density ($K^2\ s^{-1}$)
Inside the cone of influence there is a signal of ~20 minutes period.

WRF- MYJ (167 m)	Observed (Viana et al., 2010) (50-100 m)
f (outputs) = 0.016 Hz	f (data) = 2 Hz
T = 20-22 min	T = 9.2 min
c = 6-9 m s^{-1}	c = 6.2 m s^{-1}
Dir = 240-260°	Dir = 20°
λ = 8-10 km	λ = 3.5 km

- Modeled waves are seen between 130 and 300 m / Observed waves are seen below 100 m
- Higher periods and wavelengths in modeled waves

Conclusions (I)

- WRF model is a good tool to study the origin and development of a density current and the generation of IGWs
- MYJ experiment represents better the main features of the density current and is capable to detect oscillations with the entrance of the current at a given point
- YSU experiment captures the arrival of the current on time but does not reproduce the gravity waves

Conclusions (II)

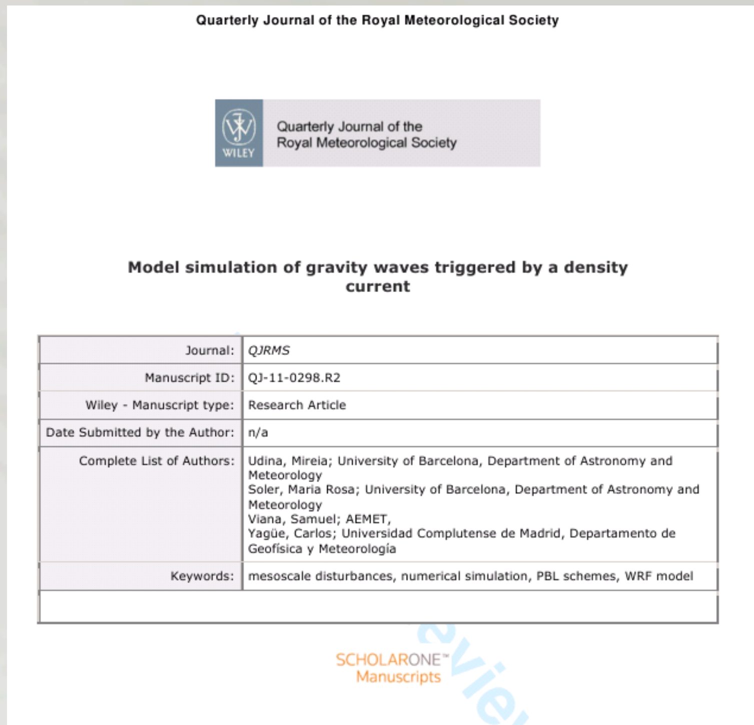
- The origin: a cold air mass coming from the Cantabric sea, modulated by the topography
- The intrusion of the density current pushes upwards the ambient air (acting as a cold front) forming a warmer layer at the top of the current where oscillations developed
- Waves in the model are produced at higher altitudes than the observed ones
- Modeled waves have longer periods and wavelengths than observed

Conclusions (III)

- Discrepancies may be due to:
  - The modelled wave may arrive as a damped and smoothed perturbation
  - Wavelet transform technique is applied to different magnitudes with different frequencies (model / observations)
  - 1 km resolution could be too coarse to solve a wave of 3.5 km

Conclusions (IV)

Results to be published in the Quarterly Journal of the Royal Meteorological Society



Quarterly Journal of the Royal Meteorological Society

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Model simulation of gravity waves triggered by a density current

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Manuscript ID:	QJ-11-0298.R2
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Date Submitted by the Author:	n/a
Complete List of Authors:	Udina, Mireia; University of Barcelona, Department of Astronomy and Meteorology Soler, Maria Rosa; University of Barcelona, Department of Astronomy and Meteorology Viana, Samuel; AEMET, Yagüe, Carlos; Universidad Complutense de Madrid, Departamento de Geofísica y Meteorología
Keywords:	mesoscale disturbances, numerical simulation, PBL schemes, WRF model

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Future work

- Understand better the influence of the surface-layer schemes coupled with PBL schemes
- Perform further studies to clarify the capacity of the models to simulate IGWs
- Increase the resolution (< 1 km)
- Perform further studies with WRF-LES

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THANK YOU !!

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