

# Numerical study of the November 2004 deep Mediterranean cyclone

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## Overview

- Introduction
- Synoptic overview
- Numerical experiments
  - cyclogenesis in the lee of Atlas
  - deepening over the Mediterranean Sea and resulting Bura wind analysis
- Conclusions

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## Introduction

- 12-15 November 2004 - MEDEX selected case
- deep and severe impact Mediterranean cyclone
- strong winds and floods-causing heavy precipitation exceeding 200 mm/24h in South Italy
- Bura wind gusts reaching 60 m/s along the Eastern Adriatic Coast in Croatia

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## Numerical study: model description

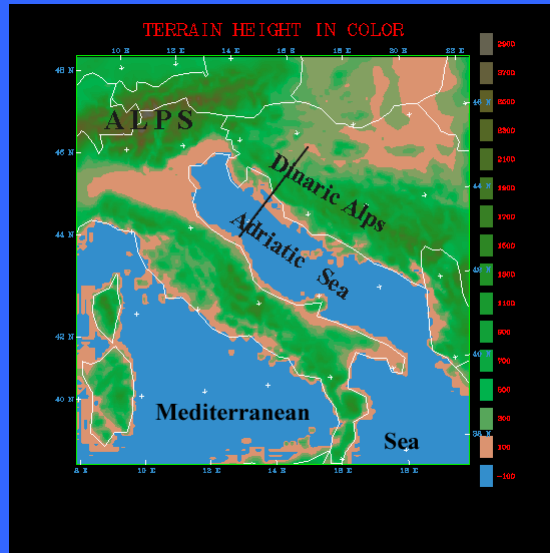
- PSU/NCAR mesoscale model (MM5)
- initial and boundary conditions provided from NCEP Final Analysis
- mesoscale data assimilation
- two two-way nested domains at
  - 21 km (cyclogenesis in the lee of Atlas Mountains)
  - 7 km resolution (Bura wind)

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## Numerical study: model domains

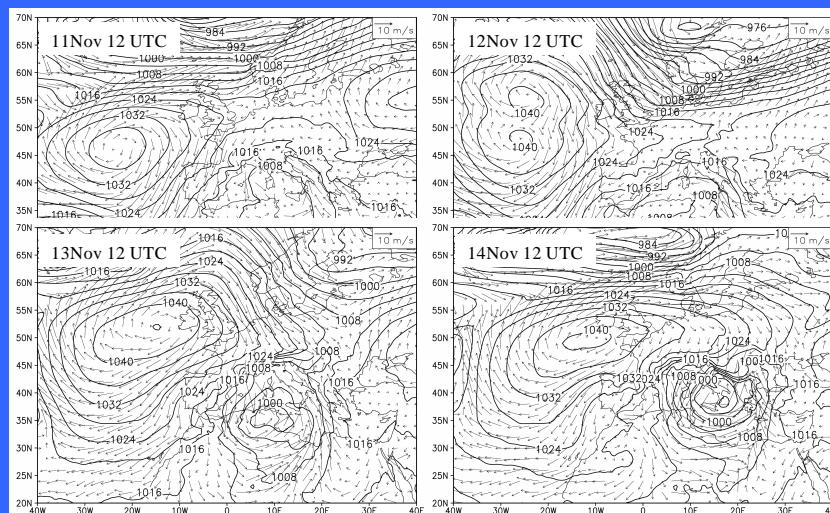


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## Synoptic overview: Observational data - surface



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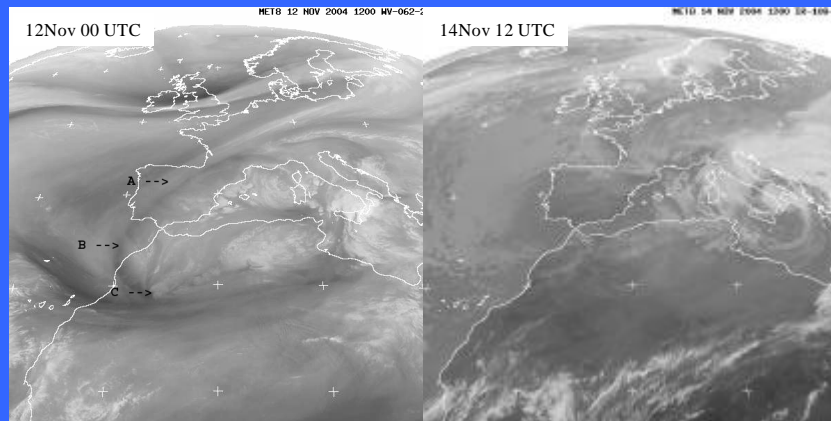
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## Synoptic overview: Observational data - upper-levels

- VW imagery

- IR imagery



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## Cyclogenesis in the lee of Atlas: METHOD

- Factor Separation method (Stein and Alpert, 1993)

$$- F_i = f_i - f_0 \quad (1)$$

$$- F_{ij} = f_{ij} - (f_i + f_j) + f_0 \quad (2)$$

$$- F_{ijk} = f_{ijk} - (f_{ij} + f_{ik} + f_{jk}) + (f_i + f_j + f_k) - f_0 \quad (3)$$

- chosen factors:

- Atlas orography
- surface sensible heat flux
- upper-level dynamical factors

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# Cyclogenesis in the lee of Atlas: METHOD

- ErPV perturbation

The figure consists of two contour plots. The left plot shows a horizontal cross-section of the ErPV perturbation, with latitude on the y-axis (21N to 54N) and longitude on the x-axis (15W to 25E). Contours are labeled 40, 80, and 120. The right plot shows a vertical cross-section, with longitude on the x-axis (15W to 25E) and pressure on the y-axis (100 to 1000). Contours are labeled -40, -80, and -120. Both plots include a color scale bar at the bottom ranging from 1 to 6.

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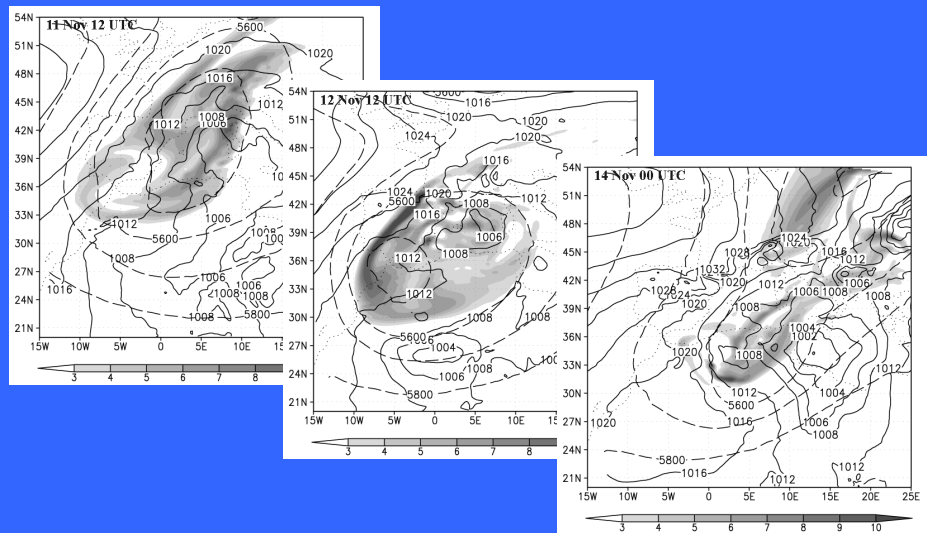
# Control run

The figure displays three maps of the Mediterranean region, showing the control run of a storm system. The maps are labeled with dates and times: 11 Nov 12 UTC, 12 Nov 12 UTC, and 14 Nov 00 UTC. Each map shows pressure contours (1002, 1006, 1010, 1012, 1016, 1020, 1024, 1028, 1032) and wind vectors. The maps are overlaid on a grid of latitude (21N to 54N) and longitude (15W to 25E). A scale bar at the bottom of each map indicates distances from 3 to 8 units. The storm system is shown moving from the west towards the east, with a significant low-pressure center developing over the Mediterranean Sea.

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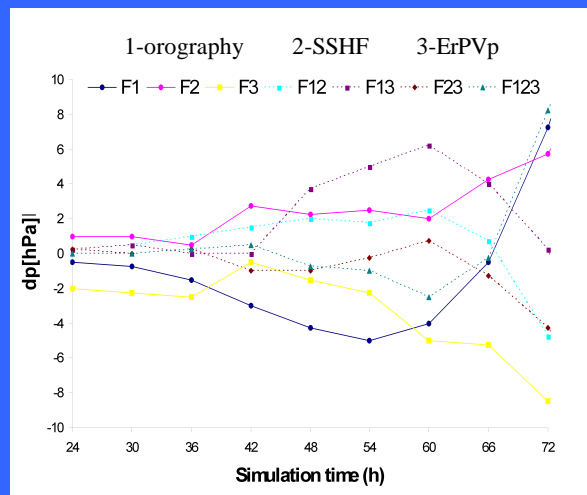
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## Cyclogenesis in the lee of Atlas: RESULTS Factor Separation

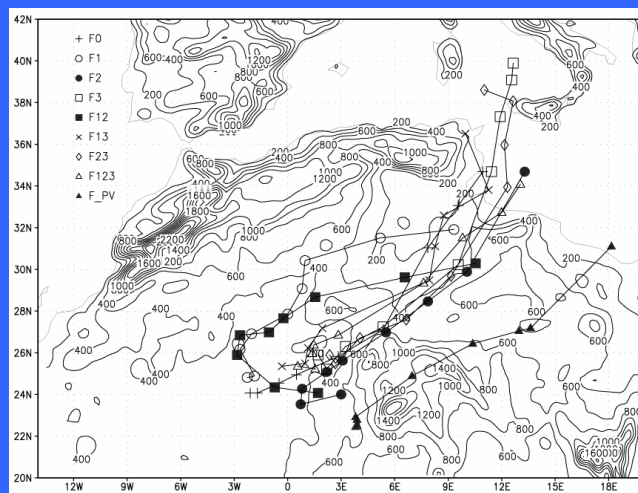


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## Cyclogenesis in the lee of Atlas: RESULTS Simulation paths



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## Phase 2: Cyclone deepening and Bura wind



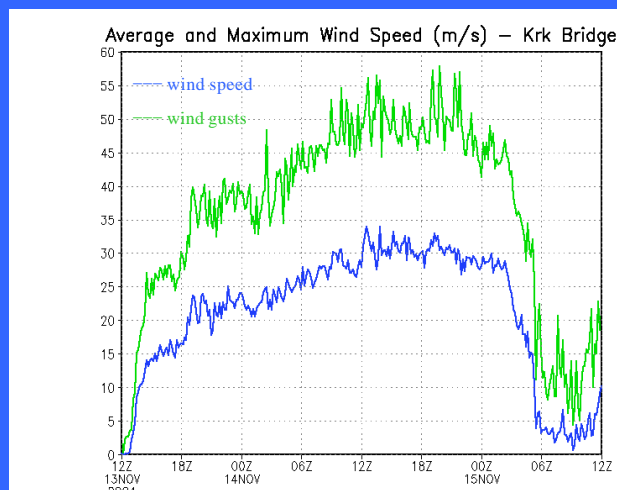
- what is the sensitivity of Bura wind to cyclone intensity and pressure distribution (large-scale pressure pattern)?

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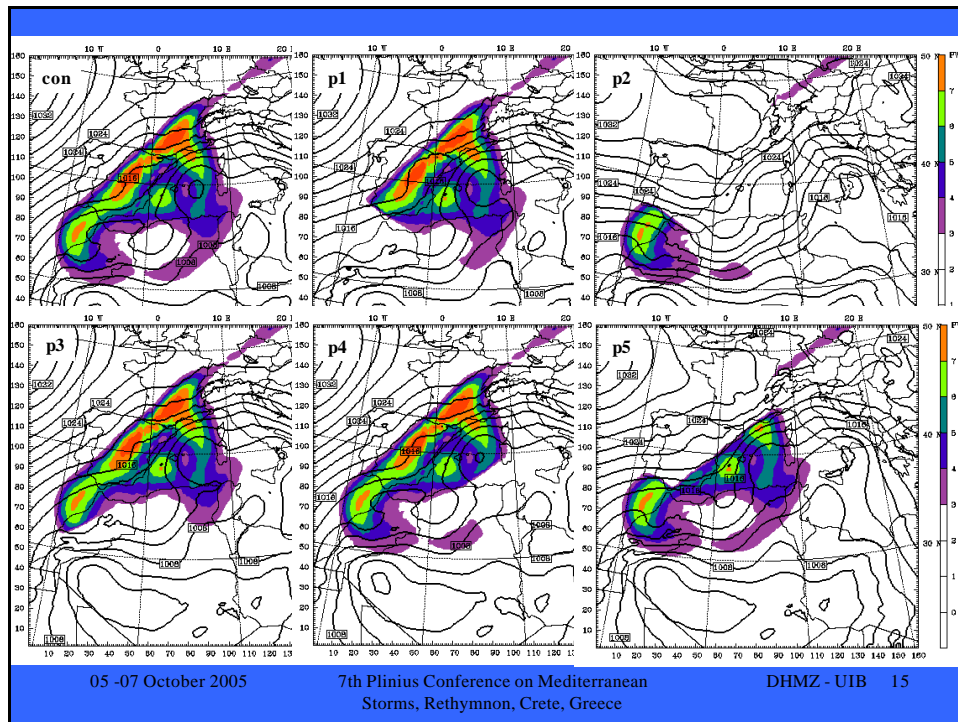
## Measurements



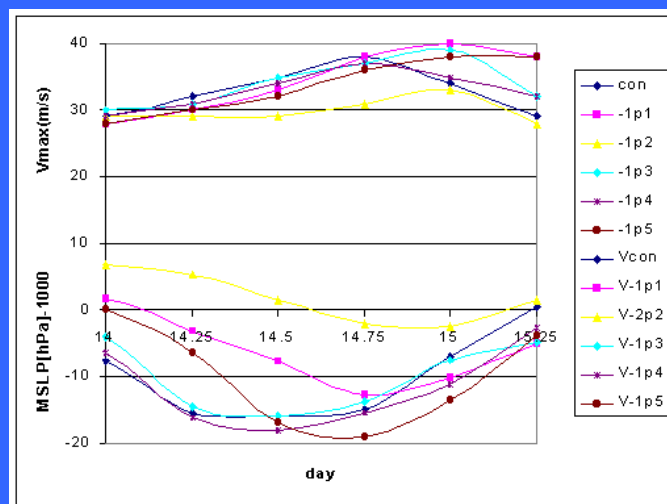
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## Numerical study: sensitivity to a cyclone intensity and pressure distribution



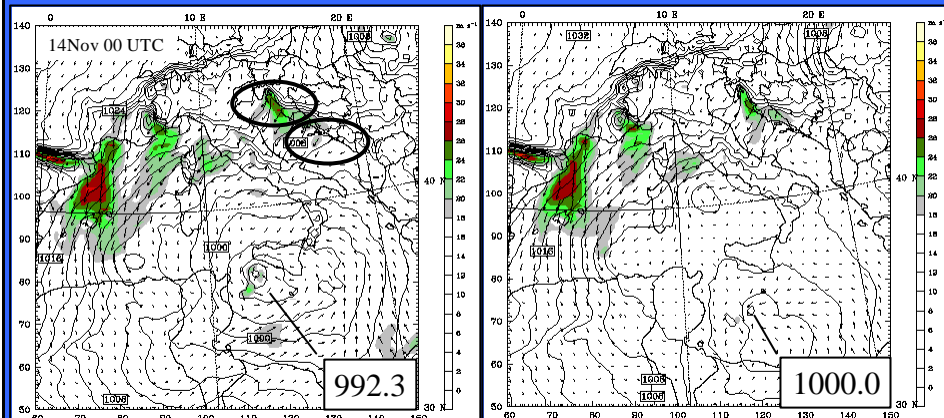
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## Sensitivity to a cyclone intensity and pressure distribution

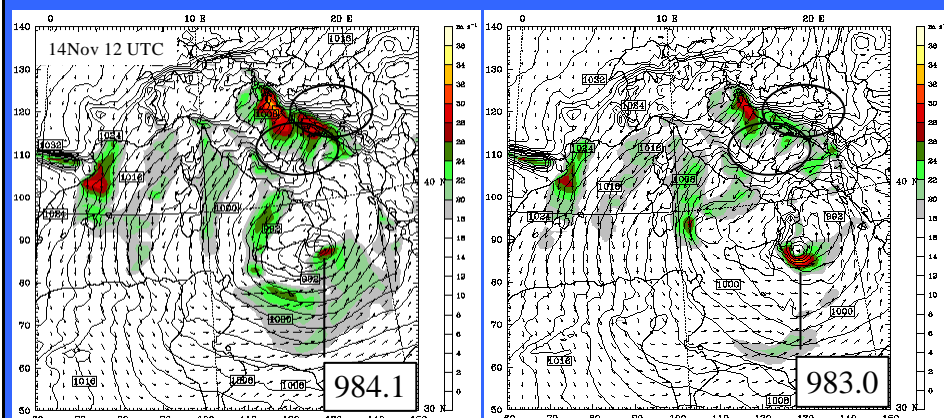


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## Sensitivity to a cyclone intensity and pressure distribution

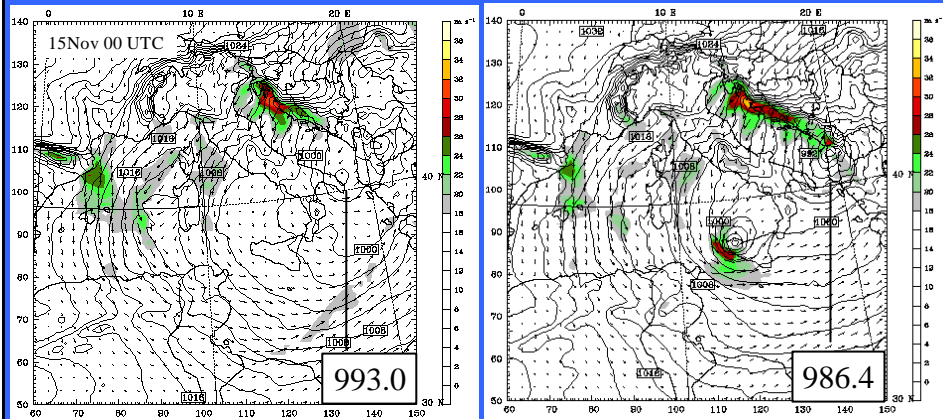


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## Sensitivity to a cyclone intensity and pressure distribution



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## Conclusions: Atlas lee cyclogenesis

- Upper-level dynamical factors and orography play the crucial cyclogenetic role
- Surface sensible heat flux has a cyclolytic afternoon contribution
- Can the two-phase lee cyclone development theory be applied to Atlas lee cyclogenesis?

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### Conclusions: Bura analysis

- Bura along the Northern Adriatic coast is primarily dominated by the upstream conditions
- The existence of a downstream low pressure system in the vicinity of Adriatic Sea is crucial for onset of Bura in Southern Adriatic
- Does Southern Adriatic Bura follow the hydraulic theory?

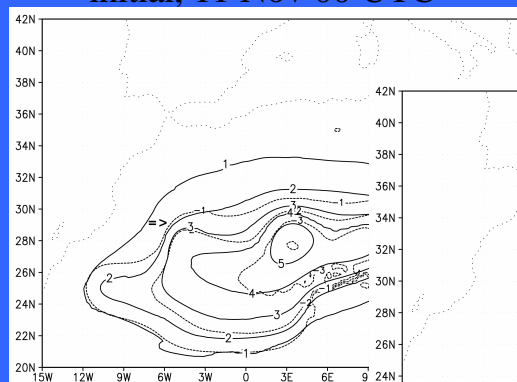
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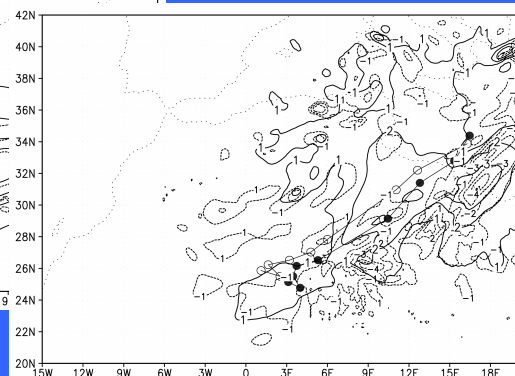
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### Cyclogenesis in the lee of Atlas: thermal anomaly sensitivity experiment

- initial, 11 Nov 00 UTC



- +24 h forecast



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## Bura

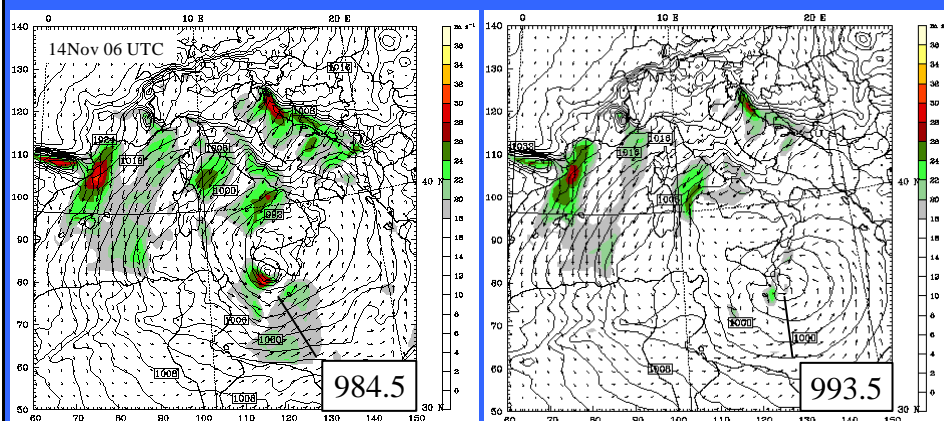
- Bura (bora) is gusty downslope wind occurring along the Eastern Adriatic coast
- develops when strong pressure gradients build up over the coastal mountain range
- qualitatively similar to hydraulic flow
- what is the sensitivity of the Bura response to macro-? (meso-?) scale pressure intensity and distribution?

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## Sensitivity to pressure intensity and distribution

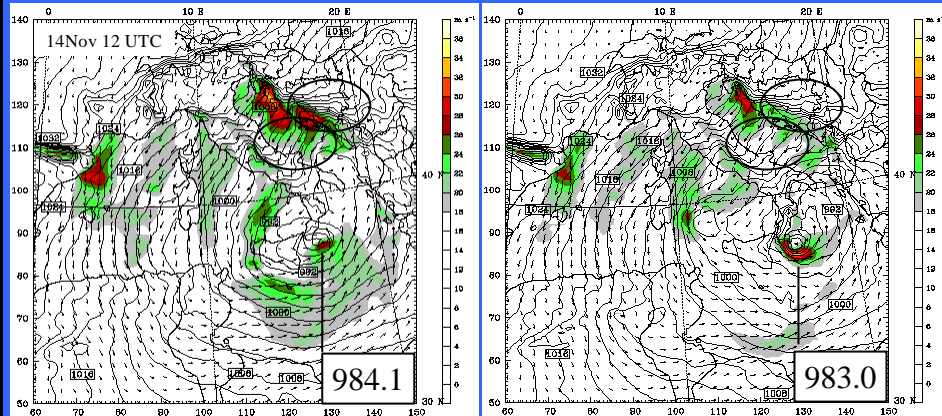


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## Sensitivity to a cyclone intensity and pressure distribution



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