Impact of Forcing/Coupling on Atmospheric and Oceanic Forecasts

herve.giordani@meteo.fr

GAME/CNRM (Météo-France/CNRS), Toulouse, France
Oceanic state in atmospheric models: SST

Tropical cyclones (Emanuel, 2005)

Middle latitude Storms (Doyle et Warner 1993; Giordani & Planton 2001; Ren et al., 2004; Pullen et al., 2006)

MABL circulations induced by oceanic fronts (Hyodae Seo, 2005; Giordani & Planton 1998)

Heavy precipitating events in the Mediterranean basin (Millan et al., 1995; Romero et al., 1997; Pastor et al., 2001; Homar et al., 2003)

Sensitivity of Mesoscale Convective Systems to:
- SST
- Surface flux parameterization
- Coupled ocean mixed-layer model (heat content)

Sensitivity of the Mixed-Layer to:
- surface heat & mass fluxes
CATCH-FASTEX- IOP15

SST Reanalysis

ECMWF SST Analysis
Longitude: $-43.59^\circ W$

Giordani et al., 2001
SEMAPHORE Experiment, 1993
Eymard et al., 1995

Giordani et al., 1997
Aude Case

Flash flood in the **AUDE** department **12-13 November 1999**

MCS quasi-stationary; 551 mm in 24h;
More than 30 deceases.

*(Ducrocq et al. 2003)*

**AUDE**: Radar reflectivity (dBz)
Flash flood in the **GARD department 8-9 September 2002**
MCS quasi-stationnary; 691 mm in 24h;
24 deceases
*(Delrieu et al. 2005)*
Hérault Case

**Rhone flood, December 2003**
(HÉRAULT department, 3 December 2003)
Quasi stationary frontal system; 198 mm in en 24h;
7 deceases
(Hontarrède et al. 2004)

**HERAULT : Swell in Banyuls and sea level in Port-Vendres**
METHODOLOGY

Radiative Fluxes

Heat Flux

wind

Precipitation

Floods

Atmospheric response to the SST

Atmospheric and Oceanic responses to the surface flux parameterization

OA Coupled Simulations

ATMOSPHERE

CONVECTION

ML Dynamics

HEAT FLUX

Radiative Fluxes

wind

Precipitation

Floods

- Atmospheric response to the SST

- Atmospheric and Oceanic responses to the surface flux parameterization

- OA Coupled Simulations
Atmospheric Model

Atmospheric Model: MESO-NH (Lafore et al. 1998)

Mesoscale Non-Hydrostatic Model

Turbulence scheme: Cuxart et al. (2000)
Radiative scheme: RTTM (Mlawer et al. 1997)

Grid Nesting:

Large domain $\Delta x = 9.5\text{km}$
$\Rightarrow$ parameterized convection
(Kain et Fritsch 1990; Bechtold et al. 2001)

Small domain $\Delta x = 2.4\text{km}$
$\Rightarrow$ explicit convection

Initialisation with ARPEGE analyses.
Oceanic Model

*Oceanic Model : Column mixed-layer model (Gaspar et al. 1990)*

pronostic variables : Turbulent Kinetic Energy (TKE), T, S, u, v.

*Adapted to the bathymetry*

Initialisation with climatologies

or MERCATOR analyses
The Mesoscale OA Coupled Model

*MESO-NH model*
*(Lafore et al., 1998)*

*SURFEX (surface scheme)*

*1D oceanic model*
*(Gaspar et al., 1990)*
The Mesoscale OA Coupled Model

**Stress** $(\tau_u, \tau_v)$

**Convection**

**Vertical Mixing**

**Surface Scheme** SURFEX

**Atmosphere** ATMOSPHERE

**Soil**

**Ocean**

**Bathymetry**

**SST**

**H**

**LE**

**Fsol**

**Fir**

**Mesoscale OA Coupled Model**

**1D Oceanic Model** (Gaspar et al., 1990)

**Meso-NH Model** (Lafore et al., 1998)
The Mesoscale OA Coupled Model

Experiences:

<table>
<thead>
<tr>
<th></th>
<th>MESO-NH</th>
<th>SURFEX</th>
<th>1D OCEANIC MODEL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Oceanic Forcing</td>
<td>Flux Parameterisation</td>
<td>Atmospheric Forcing</td>
</tr>
<tr>
<td>Control Simulation</td>
<td>Forced Mode (initial SST)</td>
<td>COARE 3.0 +gustiness + corrections $H_p$, $\tau_p$</td>
<td>Presribed Fluxes</td>
</tr>
<tr>
<td>Coupled Simulation</td>
<td>Interactive Coupling (Simulated SST)</td>
<td>COARE 3.0 +gustiness + corrections $H_p$, $\tau_p$</td>
<td>Interactive Fluxes</td>
</tr>
</tbody>
</table>

![Diagram of coupled model](image-url)
MCS Sensitivity to the SST

GARD: 24h-accumulated precipitation

Lebeaupin et al., 2006
MCS Sensitivity to the SST

HERAULT: 24h-accumulated precipitation

SST=16.5°C
ARP
max=343 mm
ARP+3
max=452 mm

SST=16.2°C
Hte-Res
max=331 mm
ARP-3
max=291 mm

ΔR=−12 mm

Lebeaupin et al., 2006
MCS Sensitivity to the Surface Flux Parameterization

AUDE: Heat flux (W/m²) and surface wind (m/s) with ORI, ECUME and COARE3.0 on Nov. 13 1999 06 UTC

Latent Heat Flux LE decreased by 150 to 200 W/m² under the LLJ (≈ 30 m/s)

Louis, 1979
Weill et al., 2003
Fairall et al., 2003
Lebeaupin et al., 2006
MCS Sensitivity to the Surface Flux parameterization

Aude : differences in the 18h-accumulated precipitation (mm)
Forced Oceanic Simulation: Aude

LE and surface (10 m) wind

$\Delta$SST

$\Delta$MLD

AUDE: SST & MLD differences between the final (18 h simulation) and the initial state.
Forced Oceanic Simulation: Aude

AUDE: 18h-accumulated precipitation

AUDE: SST & MLD differences between the final (18h simulation) and the initial state

ΔSST

ΔMLD

LE and surface (10 m) wind

18h-PRECIP
Forced Oceanic Simulation: Hérault

Impact of Heavy Precipitation on the Mixed-Layer

HERAULT:
Simulated MLD (m) after 24h
Forced Oceanic Simulation: Hérault

Impact of Heavy Precipitation on the Mixed-Layer

HERAULT: Simulated MLD (m) after 24h

HERAULT: 24h-accumulated precipitation

Internal Mixed-Layer

h'
Forced oceanic Simulation: Hérault

Impact of the forcing frequency on the Mixed-Layer response
Coupled OA Model

Comparison Forced/Coupled Model

GARD: 24 h-Accumulated precipitation

$\Delta R = -24$ mm

max = 332 mm  

max = 308 mm
Coupled OA Model

Comparison Forced/Coupled Model

GARD: Surface Fluxes Evolution

GARD: Evolution of the averaged SST and SSS
Synthesis

- The spatial averaged SST is a relevant parameter for MCS forecasts. The LLJ plays the role of an integrator of the SST small scale structures.

- Great dispersion in the surface flux (parameterization) > impact on the precipitation similar as a change of 1 °C in SST.

- The coupling attenuates the oceanic and atmospheric responses. The coupling decreases the accumulated precipitation similarly as a decrease of ~1 °C in SST.

- The oceanic mixed-layer response to high-resolution atmospheric forcing.
  - LLJs > flux > Mixed-Layer cooling and deepening.
  - Precipitation > fresh internal boundary layers > collapse the mixing.
  - Strong sensitivity to the surface forcing frequency.
  - Wind-stress > strong currents which contributes to enhance floods.
Major Issues

Key points for coupled OA models

• Usefulness of high resolution SST fields?
• What are the best surface fluxes for a coupled system?
• What is the optimal coupling frequency?
• What mixing parameterizations (diffusion/convection) for the ocean?
• …
What Surface Fluxes for Ocean Models?

POMME Experiment, 2001
Mémery et al., 2005

Caniaux et al., 2005
Giordani et al., 2005
Applications

An Intermediate Coupled Model. What for?

• High resolution processes studies: tropical cyclones, African monsoon (AMMA-EGEE), coastal breezes/fog, SST front, gust wind (mistral, tramontane), ...

• Towards an operational simplified coupled OA system: Ocean Mixed-Layer coupled to AROME. Good strategy?

SST and mixed-layer heat content more realistic and coherent with the atmosphere evolution. Sequential initialization with the MERCATOR analyses.

• Mesoscale operational applications: full 3D coupled OA model?