Better monitoring, modelling, understanding and forecasting the long-term water cycle over the Mediterranean basin: extreme, variability and trend.
Motivations (a complexe system)

Complexity, couplings, multi-scale temporal variability, spatial scale-interaction, different closure possibilities
Motivations (from IPCC-AR4)

Simulated long-term Mediterranean water cycle changes

- CMIP3 C20C simulations and A1B 21st century projections, a 14 model ensemble
- 6-yrs means of anomalies relative to 1950-2000

Some basic questions...

Q1: has this been observed?
Q2: do we understand it?
Q3: what impacts did it have?
Q4: can we simulate it?
Q5: what are the uncertainties?
Q6: what impacts will it have?
Q7: would we be able to detect it early-on?

Mariotti et al. 2008
### Observations

<table>
<thead>
<tr>
<th>Observations</th>
<th>Mean over the period</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERA40 (1958-2001)</td>
<td>1.06 mm/day</td>
</tr>
<tr>
<td>ERAI (1989-2008)</td>
<td>1.07 mm/day</td>
</tr>
<tr>
<td>HOAPS (1988-2005)</td>
<td>0.70 mm/day</td>
</tr>
<tr>
<td>GPCP (1979-2008)</td>
<td>1.63 mm/day</td>
</tr>
<tr>
<td>CMAP (1979-2007)</td>
<td>1.28 mm/day</td>
</tr>
<tr>
<td>ENSEMBLES RCMs</td>
<td>[1.0 – 1.7] mm/day</td>
</tr>
</tbody>
</table>

**Sanchez-Gomez et al. 2010; Dubois et al. 2010**

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**HyMeX**

**Motivations (from Observations)**

### Rain over the sea

#### Models

#### Radars

#### In-situ observations

**How to solve the spatial and temporal coverage problems?**

**Satellite products**

*WG1 - Water budget of the Mediterranean Sea*
WG1-SQ1: What are the long-term mean values of the Mediterranean Sea Water Budget (MSWB) components and associated uncertainties?

- characterize MSWB mean components: river, evaporation and precipitation over the sea, strait monitoring, atmosphere water divergence
- use the different closure hypotheses
- quantify and (when possible) reduce uncertainties by direct in-situ or remote measurements or by indirect methods associating observations and modelling.
- improve our modelling capability to simulate MSWB components

→ Major key-issues: Evaporation and precipitation over the sea, Assess the fluxes at the boundaries (Gibraltar Strait, Dardanelles Strait, Moisture atmospheric transport), Measure all the straits together, Underground water, River inputs
→ Reducing uncertainties, inconsistency
→ Cross-validation using different methods for a given term
→ Regionalization of the water budget at sub-basin scale
WG1-SQ2: What is the variability of the MSWB at seasonal, interannual and decadal time-scales?

- improve our understanding of the processes (water mass formation, Gibraltar Strait transport, other straits, ocean mixed layer dynamics, air-sea interaction, Mediterranean cyclones, local winds, extreme precipitations) governing the MSWB and its variability
- improve our capability to simulate the main characteristics of the Mediterranean water cycle and its variability
- improve our capability to monitor the changing MSWB

Major issues: lack of long-term suitable dataset
Find the way of quantifying the variability of the main components and deep waters properties (observation-modelling merged approach, regional reanalysis)
→ **WG1-SQ3: What are the impact of the spatially and/or temporally localized intense events on the MSWB?**

- the main objectives are to measure, simulate and understand the impact of the intense events on the variability of the MSWB
- process study
- selection of good case study
- use of a hierarchy of models
- links with WG2, WG3, WG4 and WG5

→ *Lack of good observations, need for the HyMeX EOP/SOP*
→ *Scale interactions*
→ *Influence of intense events, intense air-sea interactions*
→ *Non-linearities: localized water mass formation and long-term ocean feedback, soil moisture feedback, rapid shift*
WG1-SQ4: How will the MSWB evolve under future-climate conditions along the 21st century?

- identify the key processes controlling the future changes of the terms of the MSWB
- quantify and try to reduce the uncertainties of the future regional projections of MSWB
- identify and quantify the related impacts on the Mediterranean sea (hydrological characteristics, circulation, sea level, Mediterranean outflow waters, …)
- contribute to develop an Early Warning System of Mediterranean area changes
- Links with WG2, WG3, WG4 and WG5

→ Assessing the trends
→ Set-up indicators for an early warning system
→ Evolution of E-P-R, Water mass characteristics
→ Monitoring and understanding the response of the MTHC and Mediterranean Outflow Waters
Implementation Strategy

Interdisciplinary work, combining diverse observations and modeling, and different approaches

Objectives & Science questions

Data Rescue
In-situ
Satellite
Modelling

Success!

Some $$$ Considerations..
- Particular objectives will be funded separately
- Find the right funding organization

WG1 - Water budget of the Mediterranean Sea
Implementation Plan: proposals

Up-to-now: 37 WG1 proposals
- All on the WG1 web site
- Some are in other WGs too
- Classified in
  (i) data rescue
  (ii) in-situ observations
  (iii) remote sensing
  (iv) Modelling
  (v) Integrated analysis
- Summarized in an excel file (posted on the web site)

6 in-situ observations (atmosphere)
5 in-situ observations (ocean)
1 in-situ observations (river)
2 remote sensing (ocean, atmosphere)
5 modelling Regional Earth System Model (RESM)
2 modelling atmosphere
6 modelling ocean (Med Sea hindcast+reanalysis / local: coastal (WG4) + straits)
2 modelling river
5 analysis MSWB or air-sea flux: global, regional (Adriatic)
3 analysis Sea level
+ LOP-EOP-SOP in-situ observation proposals

Missing proposals / weak points
- regional reanalysis (ocean, atmosphere)
- long-term ocean 3D analysis
- Dardanelles Strait observations/modelling
- Adriatic modelling
- Improvement of RESM parameterizations
Principle and main tasks:
- Facilitate the access to various kinds of data (in-situ, satellite, modelling, oceanography, continental surface, hydrology, atmosphere, climate) by users from different communities. User-friendly metadatabase and database (ocean, river, atmosphere)
- Data rescue for at least river runoff datasets, meteorological observations from the countries of the South and East of the Mediterranean Sea
- Data rescue for ocean data to obtain long-term time series.
- Collect gridded analysis of atmosphere variables at the country scale (SAFRAN for France, Spain)
- Solve the issue of the Black Sea – Aegean Sea exchange fluxes
- Issue of the river discharge anthropogenic use
- Data sharing policy
**Principle and main tasks:**
- Tackle the scale problem (spatial and temporal) and bridge the gap between the in-situ campaign measurements and the regional climate models.
- Combine short-term in-situ direct measurements (precipitation over sea, evaporation, evapotranspiration, atmosphere water divergence), eulerian long-time series (1D ocean-atmosphere buoys, deep-sea mooring, strait transport, repeated CTD sections, coastal radars), with other products (observation and model reanalyses, satellite products, regional modelling).
- Sample the temporal variability using LOP observations (radars, fixed buoys and moorings, repeated CTD sections, SOO, long-term river measurements, meteorological stations, GPS).
- Inter-calibration of long-term measurements with EOP-SOP observations (research ships, network of radiosoundings, aircraft, lagrangian buoys or balloons).
- Define case study from EOP-SOP observations for the validation of the regional earth system model (or of its components) focusing on extreme events.
- Study of the scale interaction issue using the EOP-SOP obs. (impact of time or space localized events on long-term estimate of the MSWB components).
- Study the Med Sea Heat Budget as it can not be disconnected from the MSWB.
- Close sub-basin water budgets (East Med, West Med, Aegean, Adriatic, NW Med).
- Legitimate, reinforce and advice long-term monitoring system for the Mediterranean coupled climate system even after the HyMeX project.
**HyMeX**

*In-situ observation: Implementation*

Target Areas (dashed areas), hydrometeorological sites (grey boxes)

SOP for the NW Med TA. The array devoted to one RV. Potential glider transects are indicated by the green lines.

Operational sounding network (red bullets) and its envisaged extension (magenta circles)

Operational weather radar network and its planned evolution (sea rain)

**WG1 - Water budget of the Mediterranean Sea**
In-situ observation: Implementation

moored CTDs (additional planned moorings are indicated by blue triangles).

yearly or bi-yearly CTD transects performed by gliders or vessels.

surface buoys (in black circles, areas which need to be instrumented.)

hypothetical network of ships of opportunity carrying autonomous instruments and performing XBT transects.
Principle and main tasks:
- Tackle the resolution and spatial coverage problem and the temporal homogeneity problem
- Combine the already existing low resolution and long-term products with the new short-term, higher resolution satellite products, the in-situ campaign measurements and the models.
- Review of the already existing datasets for the past decades: temporal and spatial coverage, frequency, drawbacks, homogeneity check
- New combined products specific for the Med Sea, inter-calibration
- New algorithms to extend the satellite products towards the coast line
- New products for LOP (higher resolution … all fluxes at 0.5°, Mediterranean area adapted)
- Are satellite products usable to force regional models (Atmosphere, land-surface, ocean)?
- Variables to be covered: SST, SSS (?), radiative fluxes, turbulent fluxes, surf. wind, surf. temp, surf. humidity, atmosphere water content, multi-layer cloud cover, aerosols by classes, sea and rain
- Sea level: combine tide gauges and satellites, new gravimetry measurements, high-resolution coastal products, current speed products
- Development of a new MSSH for validation and assimilation
## Satellite: Implementation

### Products / Sources / Resolution

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Temporal Coverage</th>
<th>Spatial Resolution</th>
<th>Temporal Resolution</th>
<th>Platform</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>SST</td>
<td>2007(2003)</td>
<td>1km(2km)</td>
<td>2/daily(4daily)</td>
<td>AVHRR/NOAA/METOP</td>
<td>Météo France (MF)</td>
</tr>
<tr>
<td></td>
<td>1989-2007</td>
<td>50km</td>
<td>daily</td>
<td>Pathfinder, SSMI, MODIS</td>
<td>Max Planck (MP), Academy of Athens (AA)</td>
</tr>
<tr>
<td>Radiative fluxes: shortwave, longwave</td>
<td>1984-2006</td>
<td>100km</td>
<td>3hrly</td>
<td>SSM/I</td>
<td>AA</td>
</tr>
<tr>
<td></td>
<td>2004</td>
<td>10km</td>
<td>hrly</td>
<td>MSGI/SEVIRI</td>
<td>MF</td>
</tr>
<tr>
<td>Wind speed at 10m, wind components, wind stresses</td>
<td>1989-2007</td>
<td>50km</td>
<td>daily</td>
<td>SSM/I</td>
<td>MP - AA</td>
</tr>
<tr>
<td>Air Humidity, Specific humidity, humidity difference sea surface saturation</td>
<td>1989-2007</td>
<td>50km-100km</td>
<td>daily</td>
<td>SSM/I, TOVS</td>
<td>MP - AA</td>
</tr>
<tr>
<td>Liquid water, ice water content</td>
<td>1989-2007</td>
<td>50km-100km</td>
<td>3hrly</td>
<td>SSM/I</td>
<td>MP - AA</td>
</tr>
<tr>
<td>Air temperature</td>
<td>1979-1995</td>
<td>250km</td>
<td>daily</td>
<td>MSU 2R</td>
<td>AA</td>
</tr>
<tr>
<td>Clouds</td>
<td>1984-2006</td>
<td>50-100km</td>
<td>3hrly</td>
<td>SSM/I</td>
<td>AA</td>
</tr>
<tr>
<td>Salinity</td>
<td>Launch: 2010</td>
<td>200km</td>
<td></td>
<td>Acquarius</td>
<td>AA</td>
</tr>
<tr>
<td>Aerosols: chemical, microphysical, and optical properties</td>
<td>1978-2009</td>
<td></td>
<td>daily</td>
<td>TOMS</td>
<td>AA</td>
</tr>
<tr>
<td></td>
<td>Launch: June 2009</td>
<td></td>
<td></td>
<td>GLORY</td>
<td>AA</td>
</tr>
<tr>
<td>Topography/Gravity: Sea surf height, wave height, ocean storage, ocean bottom pressure changes</td>
<td>1993-2005</td>
<td>5km</td>
<td>10 day repeat cycle</td>
<td>TOPEX/POSEIDON</td>
<td>AA</td>
</tr>
<tr>
<td></td>
<td>2002-2007</td>
<td>5km</td>
<td>10 day repeat cycle</td>
<td>JASON-1</td>
<td>AA</td>
</tr>
<tr>
<td></td>
<td>2006-ongoing</td>
<td>300km</td>
<td></td>
<td>GRACE/GOCE</td>
<td>AA</td>
</tr>
</tbody>
</table>
**Modelling: Implementation**

**REGIONAL EARTH SYSTEM: Integrated Modelling Strategy**

**Principle and main tasks:**
- Promote the development of Regional Earth System Models (and of each components), of very high-resolution Regional Climate Models (7-15 km), regional reanalysis for the various components, ensemble runs.
- Combine data-rescue, in-situ observations, satellite products, very-high resolution modelling, components modelling, strait modelling to validate and improve (new parameterizations) the regional earth system models.
- Promote the use of ocean-atmosphere 1D case study, of intense event case study and of a hierarchy of models during the SOP periods and over the target areas.
- Promote coordinated inter-comparison projects (case study, common periods and forcings).
- Set-up water budget oriented diagnostics and process-oriented (or SOP-oriented) diagnostics.
- Target: the Mediterranean Sea (with its sub-basins) and its whole catchment basin (hindcast 1960-2010, LOP/EOP/SOP, 21st century).
- Perform multi-component regional climate change scenarios, regional analyse of the decadal forecasts and perform grand-ensemble scenarios.
- Provide data for the regional climate modelling needs of the WGs (database).
- Perform stream1-simulations at the beginning of HyMeX (hindcast, scenario), stream2 after the EOP/SOP and model improvement work.
- Interaction with the marine ecosystems and chemistry and aerosols Mediterranean community.

**HyMeX**
WG1 - Water budget of the Mediterranean Sea

Modelling: Implementation

1960 2010 2020 2100

Hindcast: ERA40
Hindcast: ERAInterim
LOP/EOP/SOP
IPCC-AR5 scenario

MedCORDEX domain

atmosphere
river
ocean

10 km 25 km 50 km

ERAInt
RCP4.5/8.5
ENSEMBLE runs

CORE

Med sea
AORCM
RESM
NCEP
Big Brother

Other GCMs
TIER1
TIER2
Other RCPs

Med sea

50 km
- Close links with all the other WGs on the scale-interaction issue
- Close links with all the other WGs on the trends and scenario issues
- Scientific connexion with MedCLIVAR on climate variability, sea level
- Scientific connexion with the CIESM on long-term ocean (river) monitoring
- Implementation connexion with WCRP/MedCORDEX and the coming IPCC-AR5
- Links to GEWEX
- Link with the Met services for data policy issue
- Link with FP6 and FP7 European projects: ENSEMBLES, CIRCE, SESAME, CLIM-RUN, Acidification, Ocean for tomorrow
- Links to CLIVAR/AMOC, dynamic of the Atlantic THC