Recent decadal changes in Mediterranean Sea water cycle

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- Mediterranean water cycle in CMIP3 simulations and projections.

- Observed 20th century Mediterranean Sea water cycle changes.

- Summary
CMIP3 model simulations (1900–2000) show a progressive decrease in rainfall and an increase in sea-surface evaporation over the Mediterranean region during the 20th century.

- Projections (A1B) show a rapid acceleration of these trends from 2020 and onwards. P–E decrease is very significant.
CMIP3 Mediterranean Water Cycle Projections

- There is a year-around projected P-E decrease over the Med Sea
- Largest decrease during the wet season (Oct-Mar)
Projected P-E changes are very significant and can potentially have important implications for future Mediterranean Sea (e.g. circulation, and sea-level through salinity changes).

**Basic Questions**

- Is there observational evidence of the GHG-forced changes suggested by the CMIP3 simulations for the 2\(^{nd}\) half of the 20\(^{th}\) century?

- Are estimated P-E changes consistent with independent estimates of Mediterranean Sea salinity changes?
Observed Med Sea E changes

- Multidecadal variations, with an overall E increase since the 1960s (2% per decade; OAFlux), larger since the mid-1970s (4% - 8% per decade).
- Observed and CMIP3 changes have similar temporal behavior, however observed changes are 1 order of magnitude larger.
Decadal changes in $E$ were primarily driven by SST changes (25%/K) via changes in the surface humidity gradient.

Multi-decadal SST variations in the Mediterranean are affected by natural decadal variability.

Link to AMO/AMV variability in the Atlantic, (Marullo et al. Pers Comm.).
Observed Med Region P changes

- Significant inter-decadal changes during 1979–2006 (e.g. the well-known precipitation decrease during the 1980s).

- Average Mediterranean Sea precipitation decreased during the period 1958–2006 (2% - 4% per decade).

- About 25% of winter precipitation variability in the Mediterranean is affected by the NAO.
**Observed Med Region E-P changes**

- Significant multi-decadal variations.
- During 1958–2006, E-P had a mean increase of 0.1 mm/d per decade (0.5 mm/d or 30% in total).
- Observed changes are one order of magnitude larger than in CMIP3.
Seasonal changes

- Most of the recent E increase occurred Sep-Mar.
- Precipitation changes are mixed.
- Most E−P increase occurred Sep-Mar driven by E changes.
Spatial changes: E

- E increased everywhere over the Mediterranean Sea (also over the Black Sea).

- Increases are greatest in the Ligurian Sea, the Adriatic and in parts of the Southeastern Mediterranean.

- Annual and Oct-Mar patterns are similar, only latter changes have larger amplitudes.

[mm/d per decade; OAFlux data; 1979–2006]
Spatial changes: P

- Annual P decreased only in the Adriatic Sea and parts of Southeastern Mediterranean.

- Negative trends during Oct-Mar, especially in Eastern Mediterranean (up to -0.3 mm/d per decade).

[mm/d per decade; GPCP data; 1979-2006]
**Spatial changes: E–P**

- Annual E–P increased everywhere in the Mediterranean Sea and most substantially in the Ligurian Sea, Adriatic Sea, and parts of Southeastern Mediterranean (up to 0.4 – 0.5 mm/d per decade).

- Oct–Mar trends have a similar pattern but rates are higher.

[mm/d per decade; OAFlux/GPCP data; 1979–2006]
E-P and salinity changes

-Rixen et al. (2005) estimated a mean Mediterranean salinity increase over the period 1950-2000 of 0.035-0.04 psu.

-A 1st order approximation of the salt conservation equation gives:

$$ \frac{DS}{Dt} \sim \frac{1}{H} (E-P)S $$

-In this approximation an E-P trend of 0-0.09 mm/d per decade over 1958-2000, would give a mean salinity change of 0-0.08 psu, consistent with estimated salinity changes.

Important role for evaporation changes, in addition to precipitation and river discharge (e.g. damming of the Nile) in Mediterranean Sea salinity variations.
Summary

- CMIP3 simulations and projections indicate a GHG-forced response in the Mediterranean resulting in a significant increase in Med. Sea water deficit.
- Observational data for 1960-2000 show an overall long-term increase in Med. Sea water deficit.
- Observed and CMIP3 simulated GHG-forced behavior are qualitatively consistent, however amplitudes differ.
- Natural decadal variability also plays an important role in determining observed variations, remains largely to be investigated.
Acknowledgments

Rong-Hua Zhang, Jin-Ho Yoon, Ning Zeng, Lisan Yu, Lucrezia Ricciardulli and Volgango Rupolo.

References
