Atmospheric Regional Reanalysis simulations, based on RAMS model, as input for crop modelling

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**Introduction**

- Numerical Weather Prediction (NWP) models have been used since late ‘70s as a major tool in atmospheric science both for research and operational purposes. Among them the Regional Atmospheric Modelling System (RAMS) represents one of the “state of the art” models available.

- The RAMS, has been used operationally at IBIMET-La.M.M.A. ([www.lamma.rete.toscana.it](http://www.lamma.rete.toscana.it)), part of the regional meteorological service of Tuscany (Italy) since 1999.

- Atmospheric initialization plays a fundamental role at both the global and regional scale where initial and boundary conditions are important all over the simulation period in order to achieve good forecasts.

- For operational forecasting purposes the general approach is to establish a reasonable choice of the initial atmosphere and soil conditions based on available datasets, retrieved from general circulation models, satellite, weather stations, etc.

- Reliability of forecasted atmospheric and soil fields decreases with the simulation time. Accordingly, such kind of datasets cannot be used extensively for non–forecasting purposes.
Global and Regional Reanalysis

- Since the NCAR/NCEP Reanalysis Project released the atmospheric global dataset, a new and powerful possibility has been available to increase the knowledge of the atmosphere dynamical behaviour

... but

- an important space – time dynamical scale gap should be covered in order to catch “regional” atmospheric behaviour.

- Due to the specific geomorphology of the Mediterranean Sea basin the low resolution Global Reanalysis datasets cannot resolve many characteristics of its dynamics. The Alps and Appennini mountains are not well represented at such resolution. So it is important to define a “downscaling technique” for catching its regional atmospheric behaviour.

- Recently a promising approach has been proposed: the so called Regional Reanalysis where the basic idea is to force regional models using “only” observed or reconstructed datasets for long lasting periods (seasons to years). The most relevant experience on this is provided by the North American Regional Reanalysis Project.
RAMS Regional Reanalysis

• We propose a dynamic downscaling strategy using RAMS model nested into the NCAR/NCEP atmospheric fields along with a weekly high resolution sea surface temperature datasets for a long period simulation run as a pilot phase for further development.

• The advantages of using such approach have become evident while these datasets are used for research and specific application purposes. In this work we present our approach for building up an atmospheric regional reanalysis dataset over the Mediterranean sea basin for agrometeorological and crop modelling purposes.
Rams Model

(... just an overview)

**Dynamical Design**: it is a regional model constructed around the full set of **nonhydrostatic, compressible equations** that atmospheric dynamics and thermodynamics, plus conservation equations for scalar quantities plus a large selection of parameterizations for turbulent diffusion, solar and terrestrial radiation, moist processes, cumulus convection, and energy exchange between the atmosphere and the surface through vegetation.

**Cloud microphysics scheme**: it is a **bulk microphysics** representation of each **hydrometeor category** provides the best compromise between accuracy and efficiency for most model applications. Physics based scheme – emphasizes individual microphysical processes rather than the statistical end result of atmospheric systems. Intended to apply universally to any atmospheric system (e.g., convective or stratiform clouds, tropical or arctic clouds, etc.).

**Surface model (Land Ecosystem Atmosphere Feedback - LEAF)**: it evaluates fluxes of energy, water vapour, and momentum between atmosphere and surface solving heat and water balance equations for multiple soil layers, multiple snow cover layers, vegetation, and canopy air. LEAF uses a mosaic approach to subdivide each surface grid cell into multiple land use types or “patches” each patch contains independent set of soil and snow cover layers, vegetation, and canopy air, or permanent water (oceans, lakes, etc.).

**Cumulus Convection Scheme**: RAMS uses a modified Kain – Fritsch cumulus scheme in order to represent convection. This modified version has a “triggering topographic mechanism” to improve convective rainfall representation over mountain areas.
Regional Reanalysis Architecture #1: RAMS Domains

- 2 nested grids (“two-way”).
- Horizon. grid spacing: 90x60 at 32 km and 186x178 at 8 km
- Vert. level spacing: 36 levels, from 100m to 1100m, top at 17km agl
Regional Reanalysis Architecture #2: Forcing Scheme

It is a continuous run which represents a pilot phase experiment lasted from 1\textsuperscript{st} September 2003 to 1\textsuperscript{st} June 2004 using atm. forcing at 2.5° every 6 hours and SST, based on daily AVHRR data, produced at IBIMET.
Monthly mean RAMS and Global Reanalysis comparison for two different stations shows an increase of atmospheric fields reliability due to the adopted strategy. The physical schemes in RAMS guarantee a better reconstruction of atmospheric behavior on long lasting runs for seasonal purposes.
The RAMS data (using the 8 km grid) have been validated with the observed one at station sites for the whole pilot period. Then the DELPHI model has been initialized both with observed station and RAMS data, outputs have been compared.
Station 01A Comparison #1

**Daily Tmax [°C]**

**Daily Tmin [°C]**

**Daily Tot Rad [MJm⁻²]**

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Station 01A Comparison #2

**Rams vs. OBS**

Mean Wind Drift [km/day]

Daily PCP [mm/day]

Cumulated PCP [mm]

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Temperature Comparison

<table>
<thead>
<tr>
<th>R</th>
<th>Massa Marittima</th>
<th>Pitigliano</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tmax</td>
<td>0.86</td>
<td>0.87</td>
</tr>
<tr>
<td>Tmin</td>
<td>0.70</td>
<td>0.72</td>
</tr>
</tbody>
</table>

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Temperature Discrepancies Distribution

MASSA MARITTIMA (GR): distribuzione delle differenze di Tmin osservate e stimulate da RAMS

MASSA MARITTIMA (GR): distribuzione delle differenze fra Tmax osservate e stimulate da RAMS

MASSA MARITTIMA (GR): distribuzione degli errori della Tmax, Tmin e Tmedia
Seasonal Temperature Discrepancies

MASSA MARITTIMA (GR): distribuzione stagionale delle T_min

Spring

Winter

Fall
Daily Rainfall Discrepancies

MASSA MARITTIMA (GR):
andamento giornaliero della pioggia osservata e simulata da RAMS

PITIGLIANO (GR):
andamento giornaliero della pioggia osservata e simulata da RAMS

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RAMS Reanalysis for Agriculture: The DELPHI Crop Model

Regional RAMS dataset was used as input for crop modeling in order to assess the applicability of diagnostic atmospheric datasets used in combination with crop models such as DELPHI.

Model **DELPHI** originates from the **AFRC-Wheat** model that was originally developed in the UK (Porter, 1984).

It is a deterministic “durum wheat” crop simulation model that uses a series of input to calculate phenological development, leaf area and biomass growth on a daily basis.

- Assimilation is calculated as a function of *leaf area, daily mean irradiance, air temperature, water and nitrogen availability*. Total *evapotranspiration* is calculated using Penman-Monteith equations and a *soil water balance* is calculated dynamically using precipitation and irrigation data.
- Soil properties and the main characteristics of the *wheat variety* (photoperiodic and vernalization responses) is also required.
- *Allocation* is described explicitly in DELPHI using a series of empirical allometric functions and modeling the mechanistic processes involved in assimilate partitioning among the different plant organs.
- Model output include daily and final estimates of the total above and below ground *biomass* of the crop as well as *grain yield* and the fraction of *proteins* in the grains.
- The weather parameters required in input are: *maximum and minimum daily air temperature, total daily global radiation, vapor pressure deficit* (VPD) calculated at 9am, *mean daily wind speed, total daily rainfall* and *irrigation amounts*.
- The model has been **extensively calibrated and tuned for Italian conditions** since 1998 and it is currently used operationally at IBIMET.

DELPHI Results and Input Sensitivity

Phenological Phase Estimate

Biomass Estimate [q ha⁻¹]

Data Input Sensitivity Tests
CONCLUSION

• The RAMS model reveals a way to dynamically "downscale" atmospheric fields providing a good reliability, which could be enhance further, after a local calibration, with Model Output Statistics approach, neural networks, etc.
• The method could be simply implemented on a quasi – real-time framework: e.g., based on the previous day analysis fields (just 1 day lag!) over areas where a few or no obs stations were available.
• This approach can improve climatic impact studies reliability downscaling global climate models outputs for catching regional dynamics and thus their impacts.
• Could be use, once calibrated, to "play" with atmospheric sensitivities studies, e.g., wet o dry seasons and to get meteorological knowledge on areas not (well) covered by stations.

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