Weather multi-model and multi-analysis ensemble forecasting on the Grid

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www.see-grid-sci.eu

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Overview

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- Scientific context – Problem definition
- Application gridification
  - Requirements
  - Architecture
  - Current implementation
- Sample results
- Issues and problems
- Future Work

Application Problem Description

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- Lorenz in 1963 discovered that the **atmosphere**, like any **unstable dynamic system** has :

  *"a **finite limit of predictability** even if the model is perfect and even if the initial conditions are known almost perfectly"*.

- In addition it is known that neither the **models** nor the **initial conditions** are perfect
- Problem: deterministic forecasts have limited predictability that relates to the chaotic behaviour of the atmosphere
- Solution: base the final forecast not only on the predictions of one model (deterministic forecast) but on an **ensemble** of weather model outputs

Mult-model/analysis Ensemble

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MULTI-ANALYSIS ENSEMBLE

based on perturbing the initial conditions provided to individual models, in order to generate inter-forecast variability depending on a realistic spectrum of initial errors

One forecast model "driven" by various initial conditions

MULTI-MODEL ENSEMBLE

based on the use of multiple models that run with the same initial conditions, sampling thus the uncertainty in the models

Many forecast models "driven" by the same initial conditions

Regional scale ensemble forecasting system

- In the context of SEE-GRID-SCI project we are developing a **RE**gional scale Multi-model, Multi-analysis **E**nsemble **F**orecasting system (**REFS**)
- The application exploits the grid infrastructure in South Eastern Europe region.
- This system comprises of four different weather prediction models (multi-model system).
  - **BOLAM**, **MM5**, **NCEP/Eta** and **NCEP/NMM**
  - The models run for the same region (South-East Europe) many times, each initialized with different initial conditions (multi-analysis) → Production of a multitude of forecasts

REFS Goals

Serial code

MPICH enabled

- Run [redacted], [redacted] models on the Grid to perform Ensemble weather forecasting
  - Combine final results to generate a “super-ensemble” forecast
- Develop a generic weather model execution framework
  - Use the same code-base for all four models
  - Support for deterministic forecasting
  - Easily adopt to various other forecast models for the same workflow

Generic workflow

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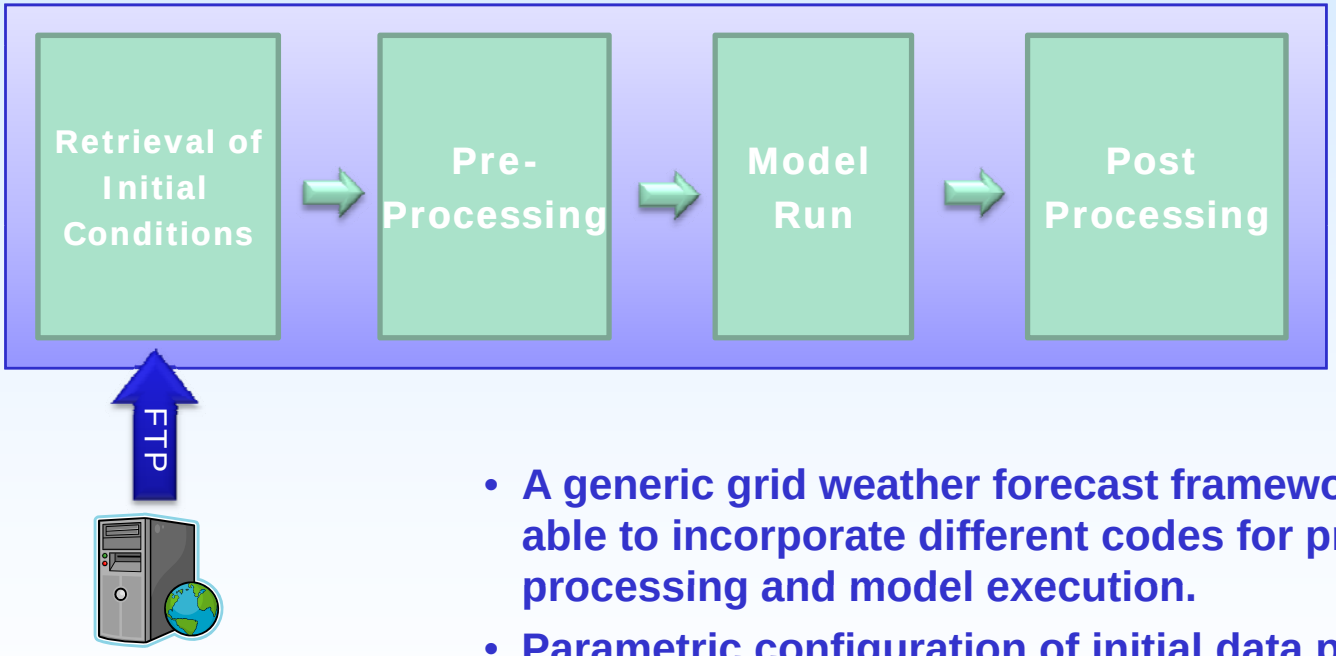
Weather models follow a specific workflow of execution



- A generic grid weather forecast framework should be able to incorporate different codes for pre/post-processing and model execution.
- Parametric configuration of initial data preparation
- Parametric execution based on Grid infrastructure capavbilities
- Customisation of execution steps

REFS Requirements

- Hide the Grid from end-users
  - Apply a regular “command-line” look’n’feel
  - Give the impression of local execution
- Re-use existing code base
  - Simplify existing procedures and improve execution times
- Utilize high-level tools that facilitate better quality code and overcome low-level interactions with the Grid
  - Use **Python** to replace various parts of the existing scripting code-base
  - Exploit the **GANGA framework** for job management and monitoring
- Satisfy specific technical restrictions
  - Usage of commercial compiler not available in grid sites
  - Time-bounded job execution

Utilised Grid Services

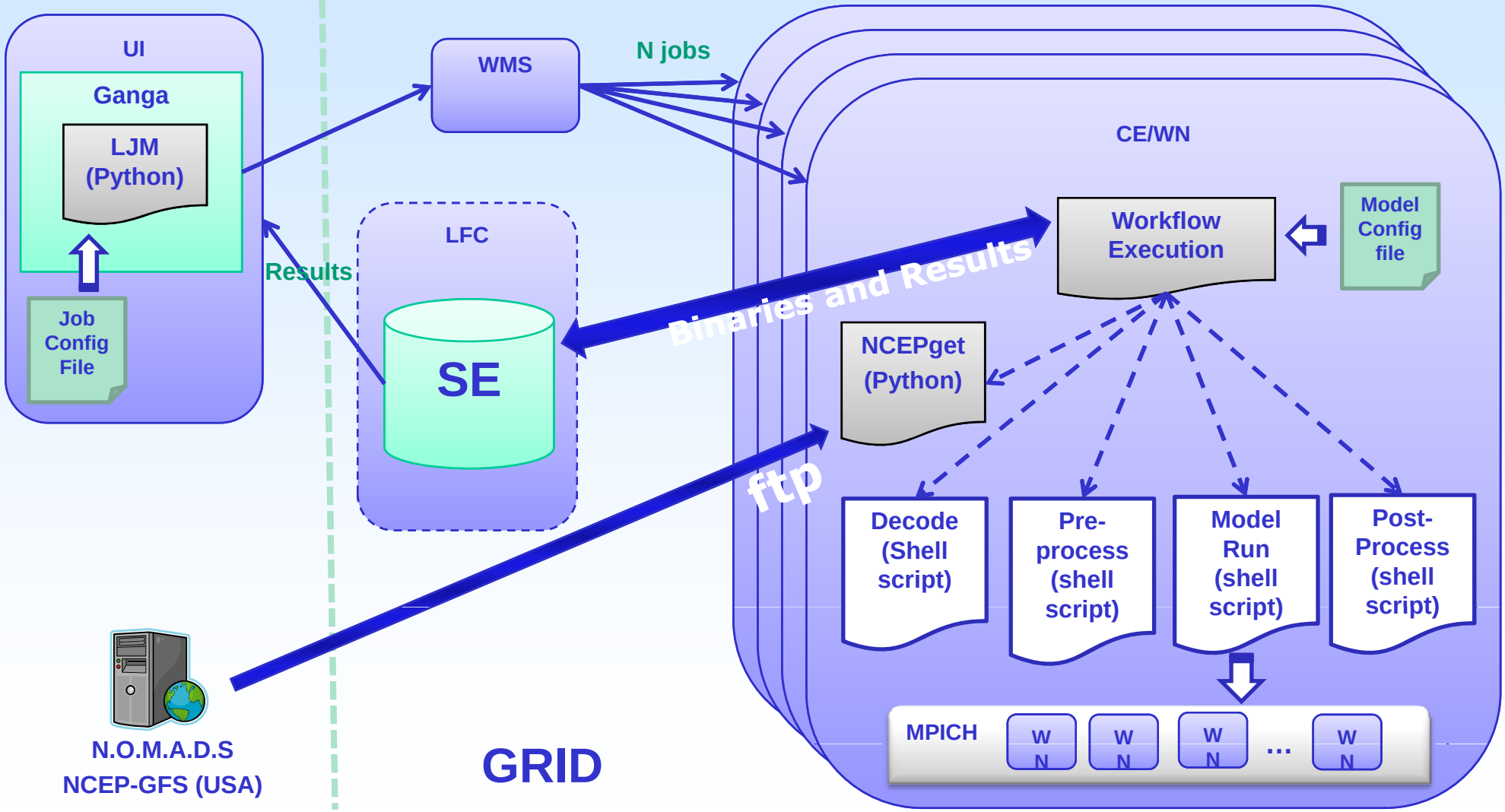
- **gLite**
  - WMS, CE – Job management
  - LFC, SE – Data management and storage
  - MPICH 1.2.7 on gLite sites

- **Ganga**
  - Developed in CERN. Endorsed by EGEE RESPECT program
  - Provides a Python programming library and interpreter for object-oriented job management
  - Facilitates high-level programming abstractions for job management
  - More information: **http://ganga.web.cern.ch/ganga/**

Implementation Details

- Model sources compiled locally in UI with PGI Fortran
  - Multiple binaries produced for MM5, optimised for different number of processors (e.g. 2, 6, 12 CPUs)
- Binaries packed and stored on LFC
  - Downloaded in WNs before execution
  - Includes Terrain data
- Models are running daily as cronjobs. Notifications are send to users by email
  - Log files and statistics are kept for post-mortem analysis
  - Ganga also useful for debugging and results archiving

Software Architecture



Ensemble Forecast Execution

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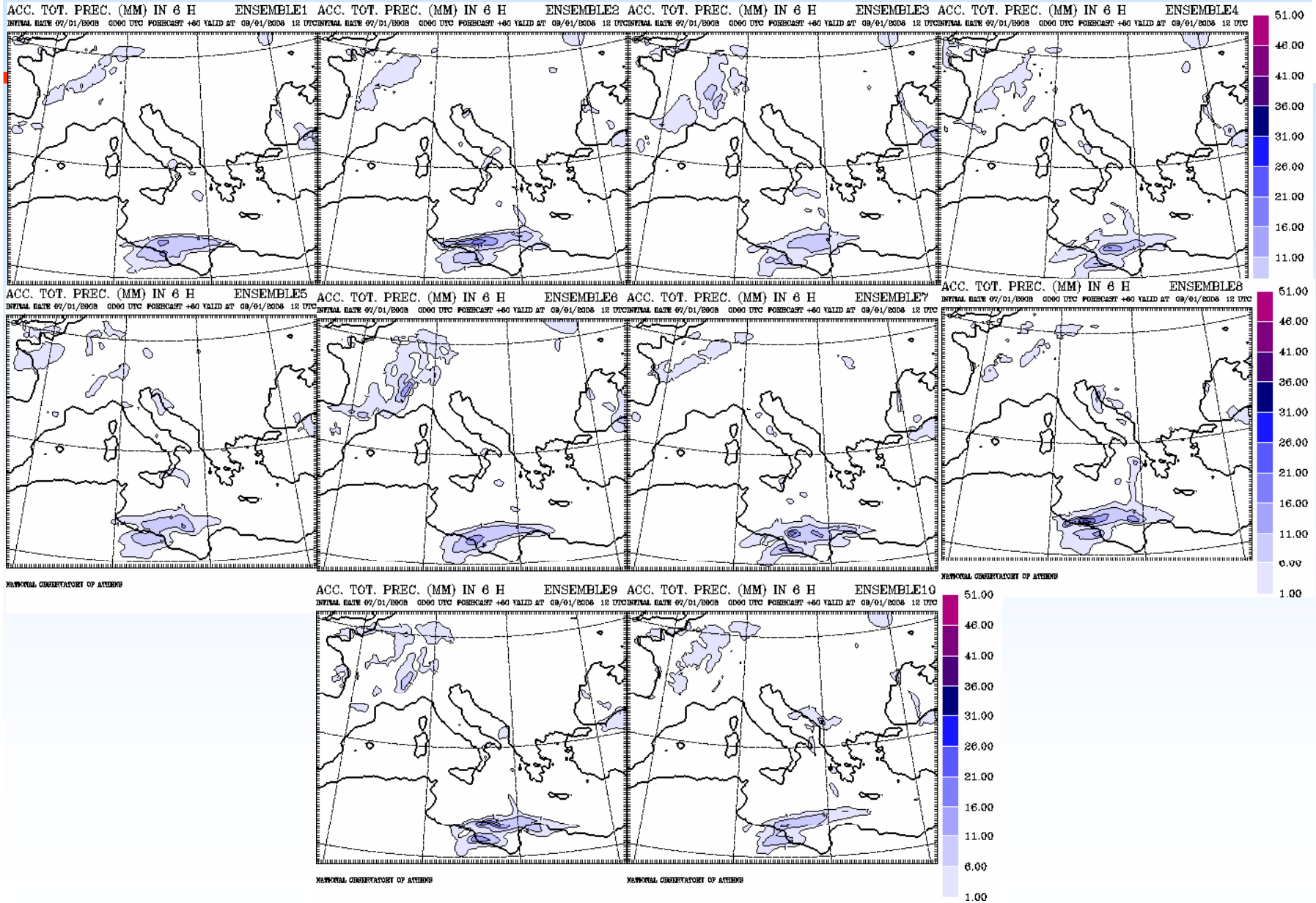
- Each member is executed as a separate job
  - 10 members in total, both for **MM5** (2-12 CPUs per member) and **BOLAM** models
  - 10 members + 1 control job for **NMM** (8 CPUs per member)
  - Each member separately downloads its initial data from NCEP servers
- Whole ensemble execution is handled by a single compound job
- Compound job definition, execution and management handled by Ganga constructs (job splitters)
- Final stage of forecast production and graphics preparation performed locally on UI

PRECIPITATION FORECASTS: BOLAM 10 members



Example of probabilistic forecasts

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From the multitude of model outputs probabilistic forecasts can be issued like:

Probability of more than:

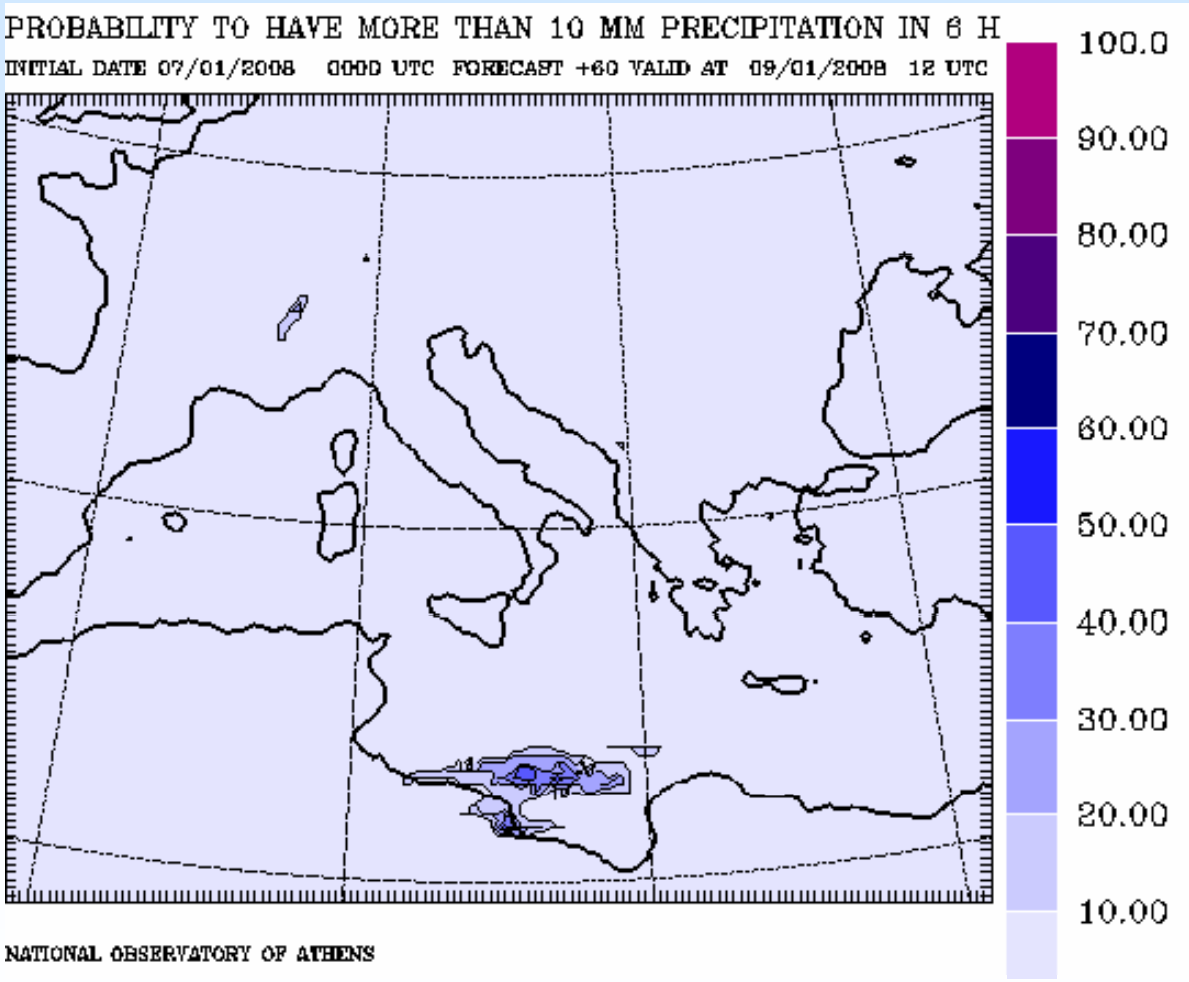
-1mm of rain

- 5 mm of rain

-10 mm of rain

Probability of exceedance of a temperature threshold

Probability of exceedance of a wind speed threshold



Problems/Pending Issues

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- Problems with initial data
  - NCEP servers sometimes down or cannot generate requested files
- Grid resources availability imbed timely execution
  - Not all members manage to complete on time
  - Some may still be in scheduled state when time expires
- Grid robustness and predictability
  - Jobs may be rescheduled while running in different sites for no apparent reason
  - Unavailability of central grid services (WMS, LFC)
- MM5 sensitive to execution environment
  - Dying processes while model in parallel section
  - MPI notoriously not well supported by grid sites (some sites “better” than others)

Initial Performance Results

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- MM5: Expected completion time: ~2hrs (including scheduling overheads) **but** large failure rate.
  - Different completion times per member depending on total processors used.
  - 12 process version takes ~40mins per member but exposes larger scheduling overhead
- BOLAM: Expected completion time for 10 members: 2,5 hrs (including scheduling overheads).
  - One member takes ~25 minutes to complete in a local cluster with optimized binary. Ensemble would take ~4 hrs locally
- NMM: Expected completion time per member ~9-10 mins minutes.

Current Status and Future Work

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- Application running in pilot phase
  - Already ported MM5, BOLAM
    - NCEP/NMM on-going
    - NCEP/Eta under way
- Planned to start “super-ensemble” runs by April
- Anticipating more resources and better support from existing once.
  - Support from EGEE Earth Science VO

More information, documentation and source code available from

http://wiki.egee-see.org/index.php/SG_Meteo_VO

Thank you

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