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Downscaling techniques and tools

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World Meteorological Organization
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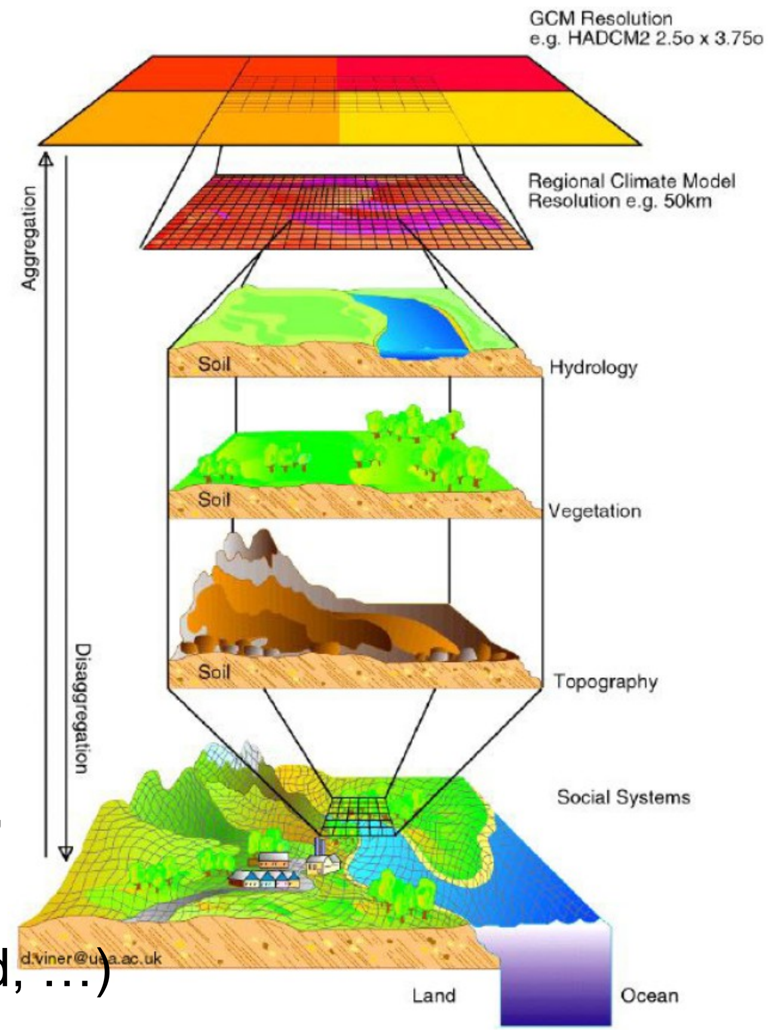
The Downscaling problem

- **Relevant Scales**
  - Mesh of the GCM ~ 100 to 200 km,
    3 month averaged information
    (or month by month)
  - Scales of applications ~ 1m to 10 km,
    Day, 10 days, month,

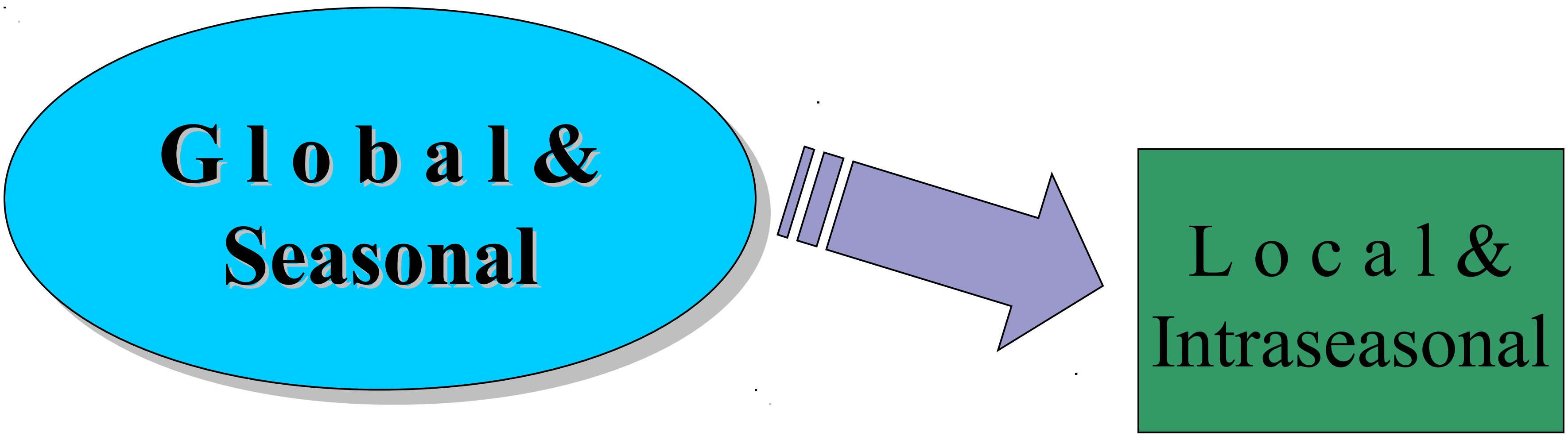
  - Climate parameters (RR, Tn, Tx,
    Number of days …),
  - Parameters from the application
    domain (Agriculture, Water resources,
    Health, …),
  - Climate parameters (RR, Tn, Tx, Wind, …)

for downstream operation of Users' models



The Downscaling problem

- **Seasonal predictability and associated scales ⇒ usefull information for the user (scale adaptation)**



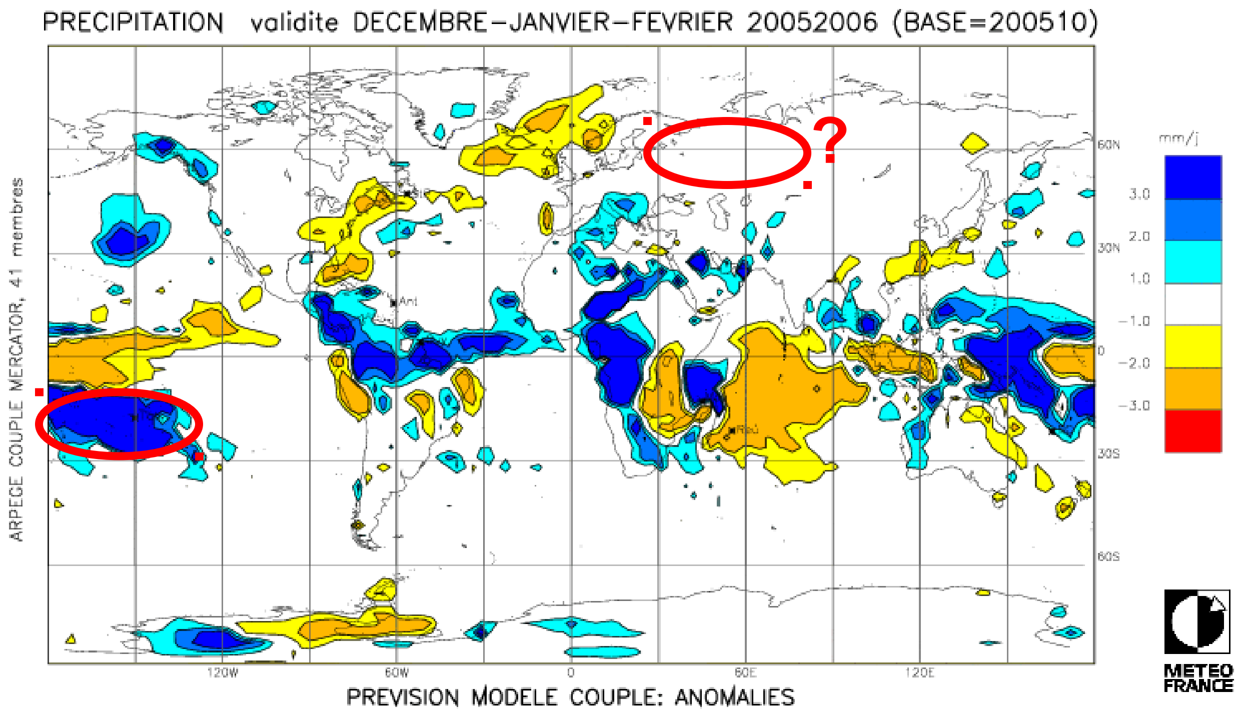
- **key questions**
  - Until which scales one can expect to downscale the large scale information ?
  - How to get the best compromise between the limits of seasonal predictability and the needs for applications ?

The Downscaling bases

- **The main goals of the downscaling is**
  - To take into acount mean local effects of the large scale forcing
  - To adapt the seasonal forcasting information to the relevant scale for the user (at least to get better resolution generally needed both in space and time)
- **The downscaling should**
  - Reflect the mean effect of sub-grid processes forced by large scale conditions
  - Take into account physical processes at the « local » scales
  - Bring more than a simple interpolation
- **The downscaling brings**
  - some artificial increase in the resolution
  - uncertainty which must be evaluated
  - Information which is part of the ensemble/probabilistic forecast

The Downscaling

- **Large Scale Forcing**
  - One have chance to succeed **If and Only If** the smaller scales are significantly forced by the Large Scale signal.



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The Downscaling bases

- **Impact of the large scale forcing at « local » scales**
  - Methods to assess this impact
    - Composite analysis,
    - CCA, SVD,
    - Clustering
    - …
  - Diagnosis related to Downscaling
    - Space gradients, …
    - Homogeneous zones, …
  - Description of « local » signal and associated database
    - Data quality and homogeneity on the hindcast period,
    - Network density,
    - Gridded dataset
    - Spatialization (***be carefull with GIS !***)

Methods of Downscaling

State of the Climate system (ocean-atmosphere + Cryopshere-Biosphere)

Large Scale Information

Statistical models

User's models

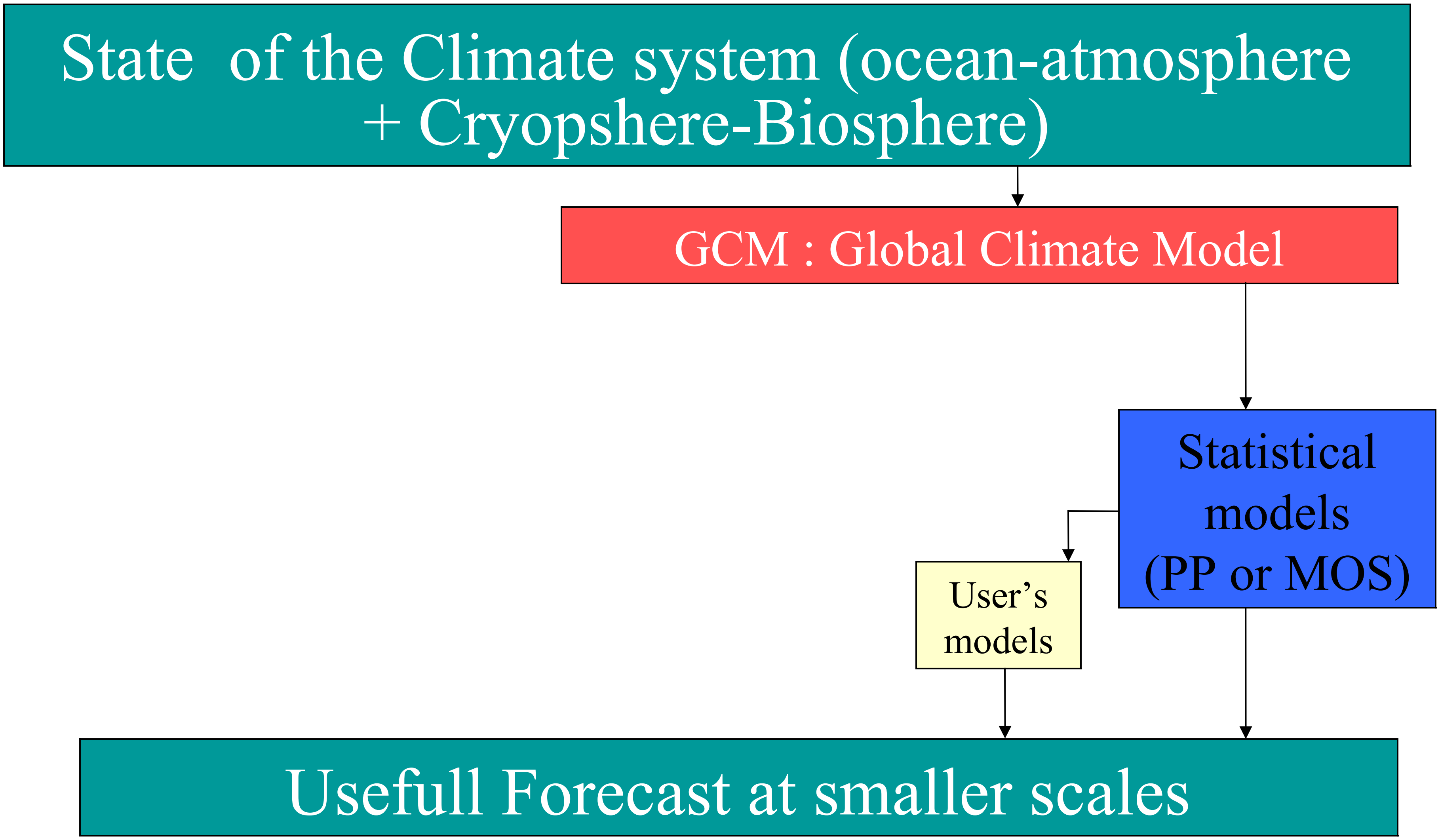
Usefull Forecast at smaller scales

Downscaling Methods

- **Purely Statistical methods**
  - Analysis of Large Scale Conditions (e.g. SST, SOI, …)
  - Asumption : LSC have a slow evolution and a significant influence on the « local » climate,
  - Statistical tools (mostly linear) including AR models and analogs
  - Common approach in RCOFs

+ low computing cost,
+ easy to implement operationally,
- Possible artificial scores,
- Weak representation of interactions within the climate system
- Difficult to use with complex relationship
- Need regular recalibration (multidecadal variability, Climate Change)

Downscaling Methods



Downscaling Methods

- **Dynamical / Statistical methods (Hybrid)**
  - Forecasted Large Scale Conditions (from GCM)
  - Asumption : LSC which have a significant influence on the « local » climate are « well » represented in the GCM
  - Perfect Prog (PP) or Model Output Statistics (MOS)

\+ Reasonable computing cost for the downscaling,

\+ Complexity of the climate system represented in the LSC (GCM)

\+ Potential predictors physically based (and numerous)

\+ Uncertainty sampling (ensemble forecast, multi-model, …)

\+ Quite easy to implement operationally (GCM ouput access ?)

\- GCM limitations and bias,

\- Possible artificial scores and robustness problems

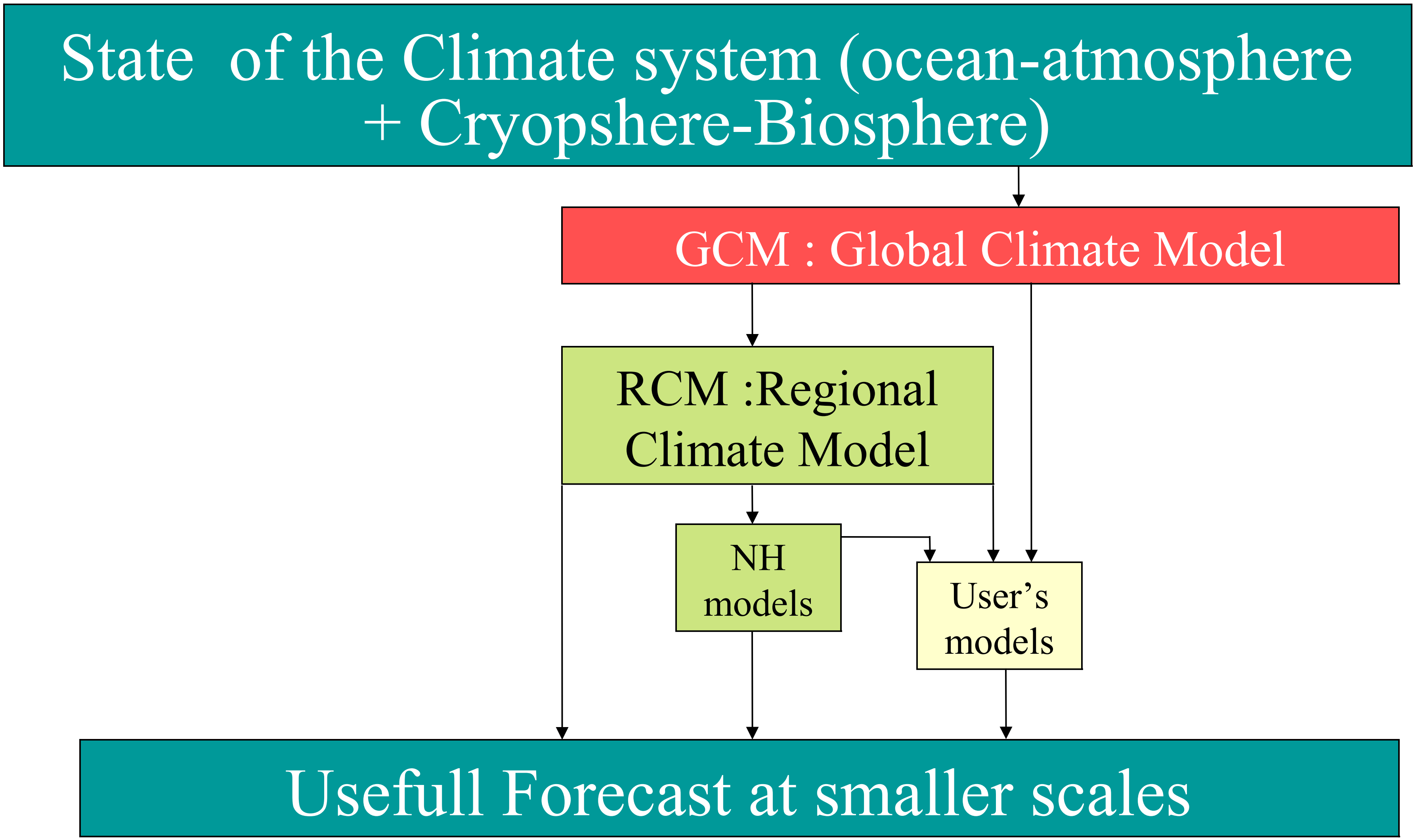
\- Symetric / Non symetric impact of large scale forcing (e.g. Niño / Niña impacts),

Methods of Downscaling

The different statistical methods

- Linear methods
  - Regression (Multiple, …)
  - Discriminant Analysis (Linear, FDA, …)
  - CCA, SVD, …
  - Modes of Variability (model vs « observed » modes),
  - …
- Non Linear methods
  - Neural networks (optimisation of the network),
  - Analogues / Anti-analogues (optimisation of the distance and choice of the number of analogues)
  - Circulation regimes / weather types (Model vs « observed »),
  - Regression trees, Logistic regression,
  - …
- Methods for Robustness evaluation
  - Overfitting
  - Multidecadal variability,
  - MOS vs PP
- ...

Downscaling Methods



Downscaling Methods

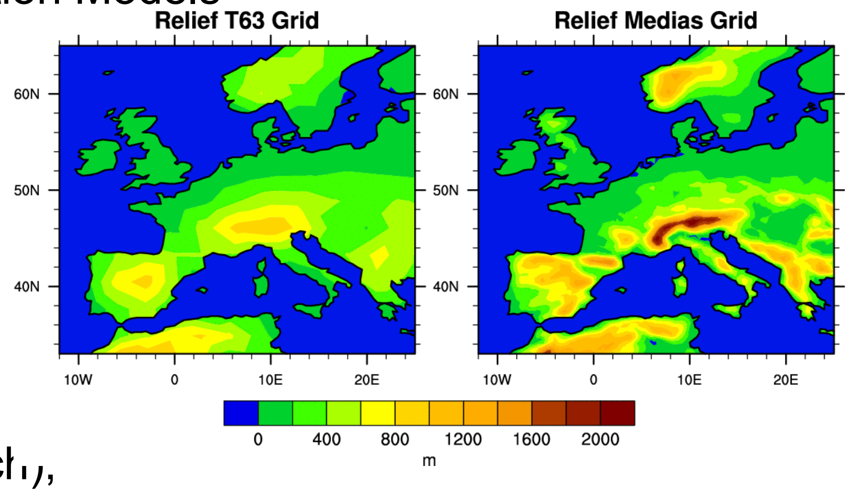
- **Dynamical methods**
  - Limited Area Model (RCM) coupled with the GCM
  - Asumption : The LSC force the « local » climate which is better represented in a LAM
  - Model Output Statistics can be added

+ Complexity of the climate system represented in the LSC and the LAM
+ Better extreme events forecasts
+ Uncertainty sampling (ensemble forecast, multi-model, …)
+ No needs of observations over the region of interest,

- Difficult to implement operationally (GCM coupling files)
- GCM limitation and bias,
- Huge computing resources
- Boundary effects
- LAM limitation and error propagation
- Risk of black box use

Downscaling Methods

- **Dynamical downscaling**
  - A lot of available RCM models
    - MM 5
    - PRECIS,
    - ALADIN
    - HIRLAM,
    - WRF, …. ,
  - Some Hight Resolution Global Circulation Models
    - Full HR GCM
    - Stretched Grid



  - Some available models (HR GCM)
    - Earth Simulator (~10 km – Research),
    - ECMWF (operational - ~80 km),
    - Arpège (T63 L31 C3.5 - ~50km - Research),

Downscaling Methods

- **Dynamical downscaling**
  - General Circulation Model
    - Quality of Mean climate and variability and assessment of GCM bias
    - Quality of the Large Scale Forecast
    - Provision of coupling files,
    - Provision of hindcast,
  - Regional Climate Model
    - Quality of Mean climate and variability and assessment of LAM bias (LAM forced by Reanalysis)
    - Reference experiment (LAM forced by GCM hindcast),
    - Evaluation of Forecast quality
    - Verification of added value to the Large Scale Forecast
    - Operational coupling,

Downscaling Methods

- **Other Points of interest :**
  - Global Circulation Models
    - Influence of resolution on the quality of the Large Scale Signal (mean climat, bias, forecast)
    - Influence of resolution on the efficiency of dynamical downscaling
    - Parametrizations
    - Coupled Climate Components
    - …
  - RCM
    - One way versus Two way nesting,
    - Relevant LAM resolution with respect to GCM resolution,
    - Choice of simulated area,
    - Parametrizations,
    - Coupled vs Uncoupled RCM,
    - Influence of large water bodies,
    - Extreme event forecasts,
    - How to cope with GCM bias ?
    - …

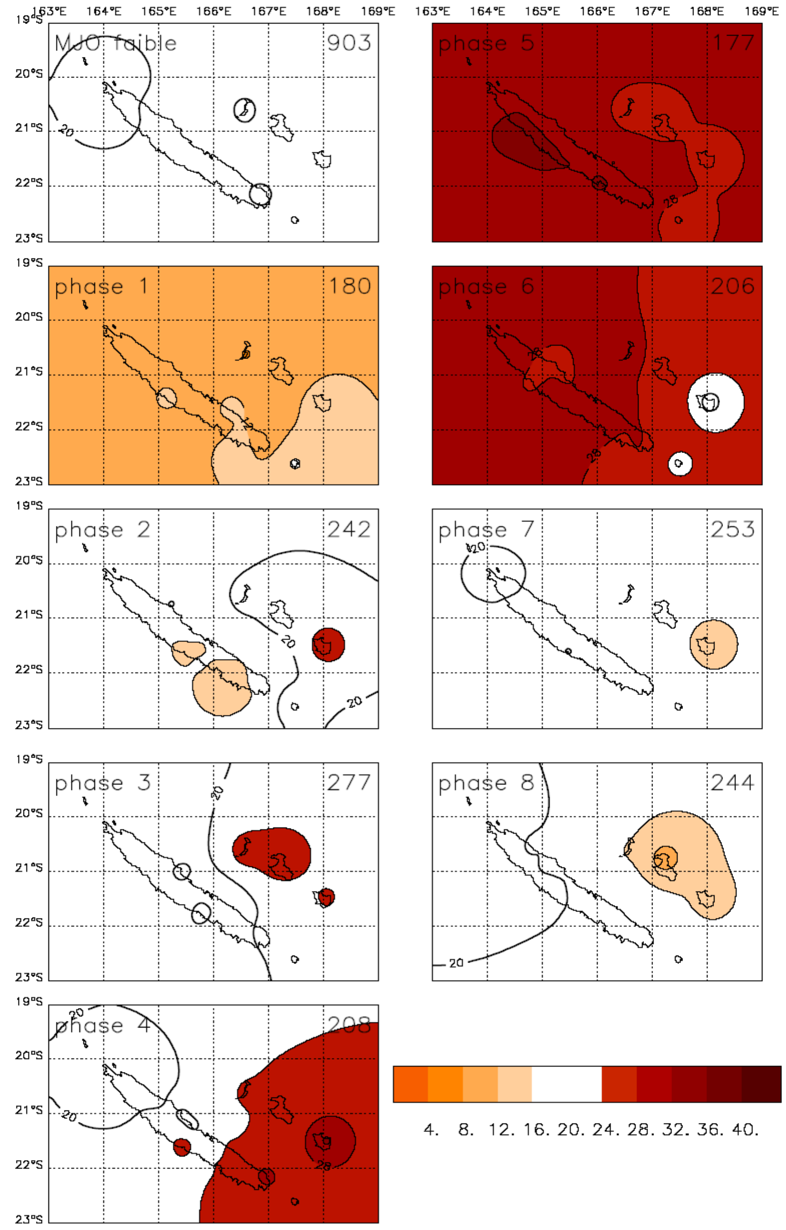
Methods of Downscaling

- **Other methods**
  - Conditional dynamical simulations (e.g. by circulation regimes / Weather types),
  - Interpolation and local corrections (e.g. vertical gradients, quantiles/quantiles corrections)
  - Weather generators,

Downscaling in time

- **Intraseasonal variability**
  - Intraseasonal evolutions
  - Intraseasonal modulations
  - Significant intraseasonal forcing of the MJO on Tn, Tx and RR

<u>Probabilities of rainfall above the upper quintile (strong rainfall) in JFM vs MJO phases (Real time MJO Multivariate Index – Wheeler & Hendon – MWR - 2004)</u>



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Conclusion

- **Sucess in downscaling depends on :**
  - The predictability over the targeted region,
  - The « local » part of the signal which is large scale forced,
  - The parameter, the targeted categories and the period ,
  - « Good » observations for calibration when needed (climate and users's domain),
  - The use of the information,

- **About downscaling models (MOS or PP) :**
  - A sufficient long period for training (notably when multidecadal variability is present),
  - Recalibration of the model on a regular basis
    - notably when one have a short training period),
    - when the GCM changes (MOS),

Conclusion

- **About downscaling models (MOS or PP) :**
  - Verification of added value brought by the model,
  - Verification of the robustness of the model,
  - Robustness seems to depend on the category (terciles more robust than quintiles),
  - The merging of information coming from different GCM can be done quite easily (but is it better than single model downscaling ?),
  - For short training period, the Perfect Prog approach seems to be quite robust (use depends probably on predictability)
  - A lot of methods can be used,
  - The « best » choice can depend on the forcing, the period and the parameter,

Conclusion

- **About Dynamical downscaling :**
  - Verification of additional value brought by the RCM,
  - Challenge for extreme events,
  - Coupled version can improve the local representation of the local climate (depends on the link between local SSTs and local climate),
  - Challenges in initial states (e.g. Snow / Ice, soil moisture, …),
  - Fine mesh analysis (especially for surface parameters)
  - Resolution / Parametrizations / …
  - Multimodels issues

Conclusion

- **About Downscaling :**
  - Tools similar for both seasonal and climate change issues,
  - Capacity building useful for both seasonal and climate change issues,
  - Seasonal forecasts first step for CC adaptation,
  - Tailoring and Downscaling quite similar activities
  - Many softwares available for statistical downscaling
  - MOS (or PP when necessary) promoted notably in the frame of RCOFs activities and WMO framework
  - Some RCMs already widely disseminated – take care with operational aspects for seasonal forecasting
  - Difference between operational forecasting suites and « resarch » mode (more suitable for CC issues)

Butterfly Effect …

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