30th EWGLAM and 15th SRNWP meetings

6th -9th October 2008

Madrid, SPAIN

TIGGE-LAM:

Multi-model short-range probabilistic forecasting – scientific objectives and practical possibilities

Tiziana Paccagnella

ARPA-SIM

Italy

Ensemble Prediction

- **Ensemble prediction is based on the knowledge of the chaotic behaviour of the atmosphere and on the awareness of the limitation (errors, approximations) in our Forecasting Systems (analysis/assimilation & models).**

  These limitations induce uncertainty in our forecasts.

- **Ensemble prediction is aimed to quantify this uncertainty by producing a sample of alternative/possible future atmospheric states obtained by mimic our possible errors.**

- **Uncertainty derives from errors both in the analysed initial conditions (analysis errors) and in the forecast evolution (model errors).**

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Ensemble Prediction

- **Deterministic thinking**
  - To obtain EPS products which are better than deterministic products (e.g. 500 hPa ensemble mean)
  - To obtain a forecast of the forecast skill

- **Probabilistic thinking**
  - To have alternative evolution scenarios
  - To have probabilities associated to the occurrence of events

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Ensemble Prediction

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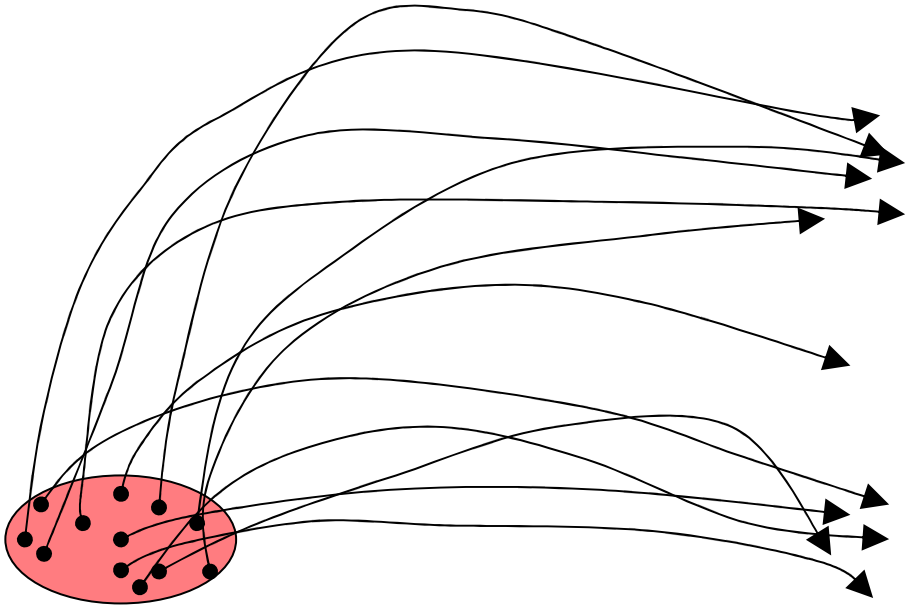
Ensemble System Characteristics



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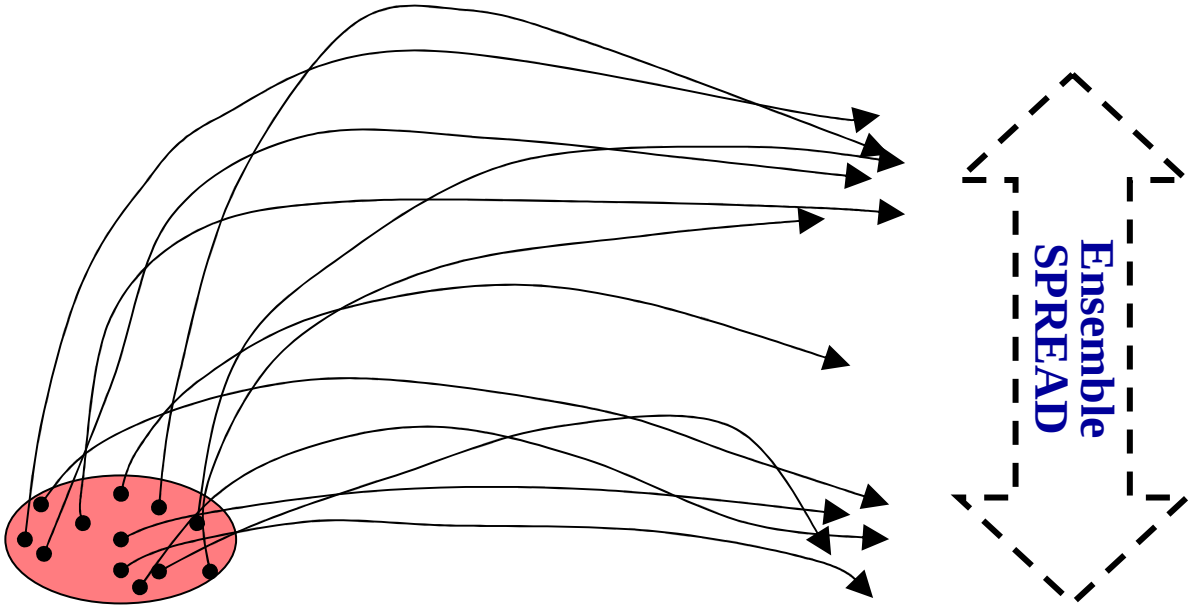
Ensemble System Characteristics



Ensemble spread

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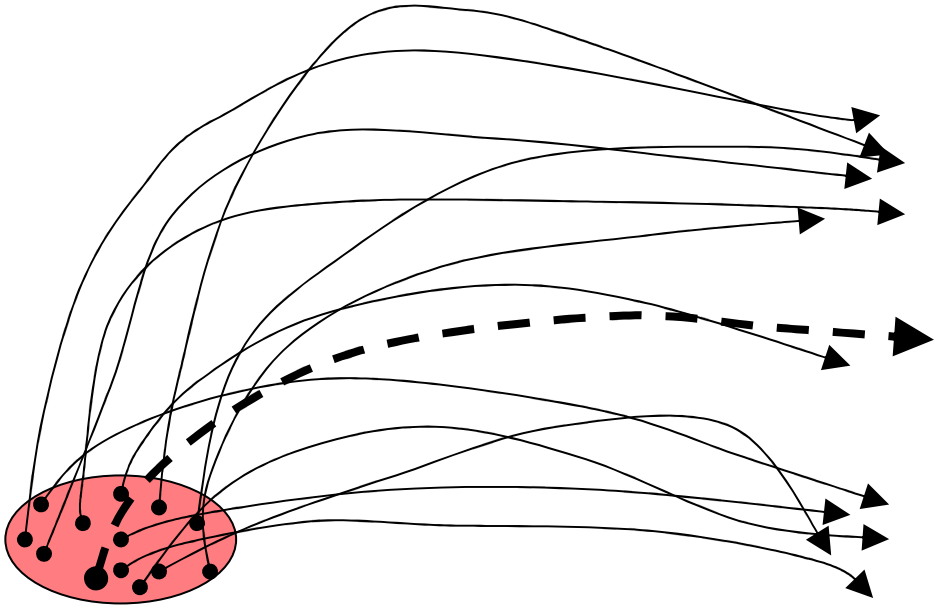
Ensemble System Characteristics



Ensemble Mean

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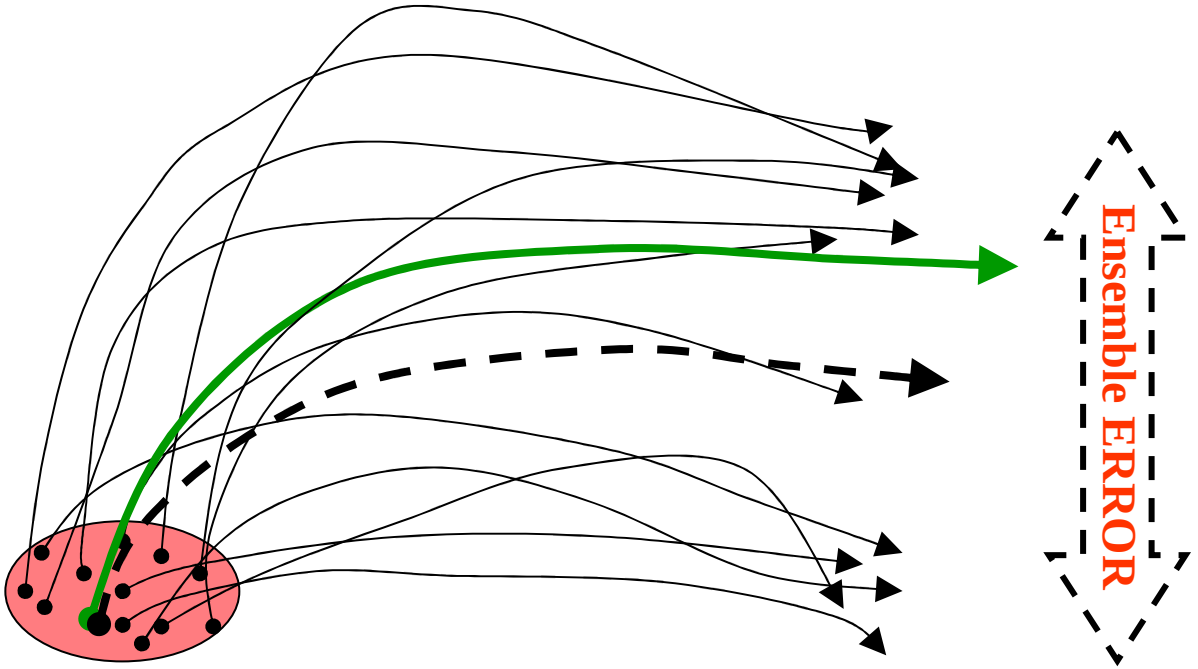
Ensemble System Characteristics



Ensemble error

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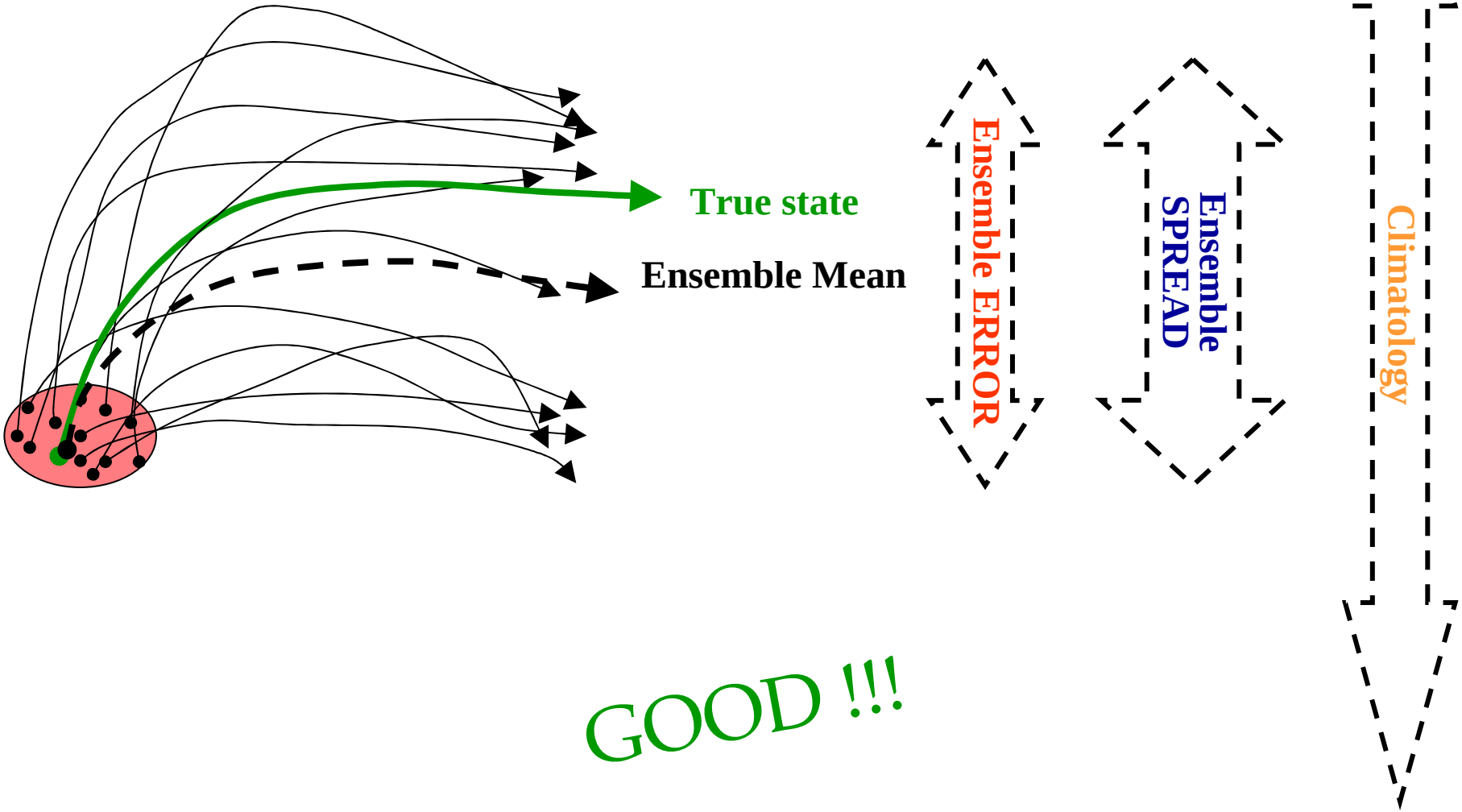

GOOD !!!

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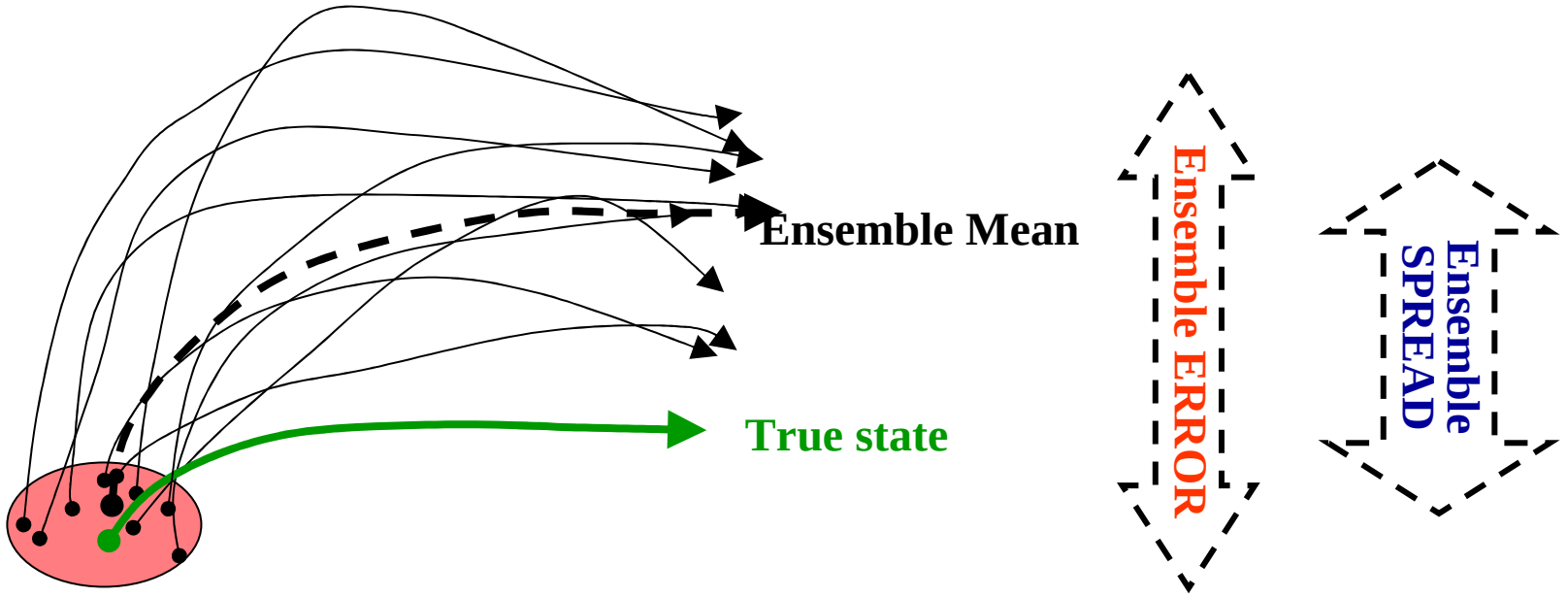

BAD !!!

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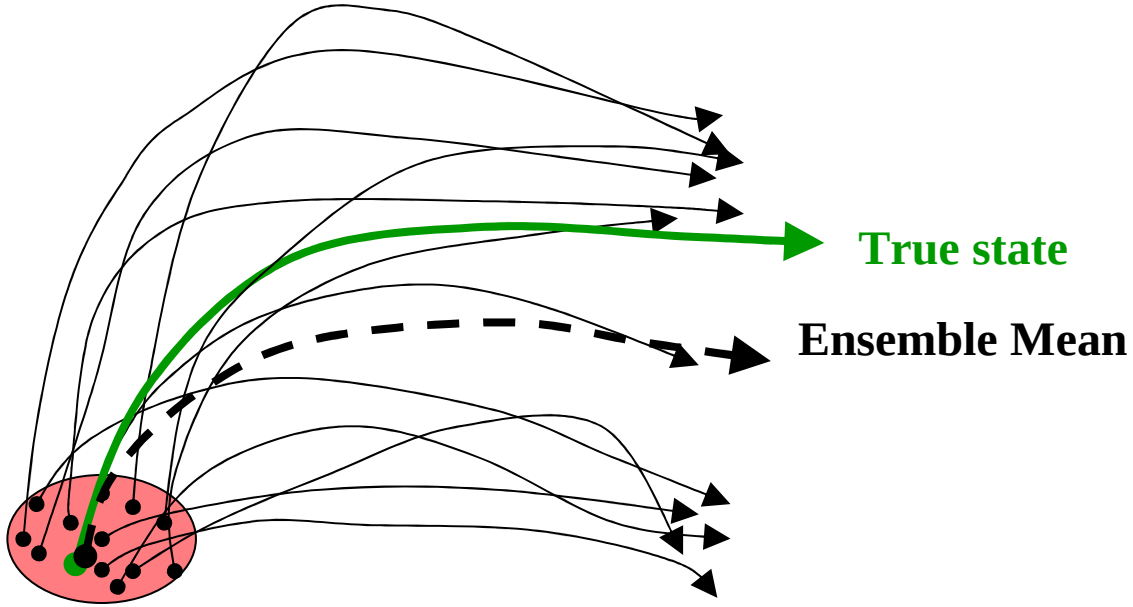
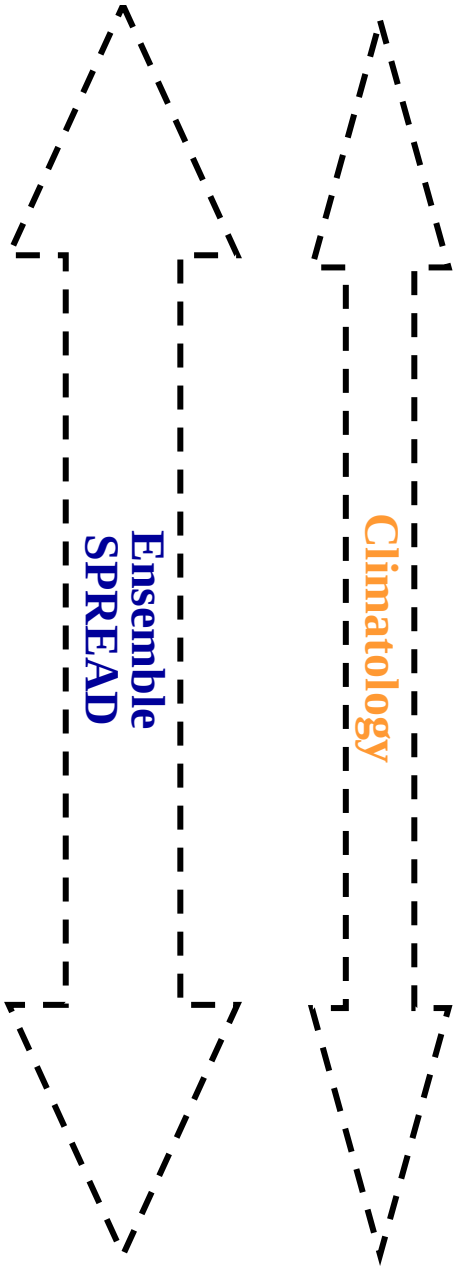


BAD !!!



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Model Errors

Accounting for uncertainties in Numerical forecast

Analysis Errors

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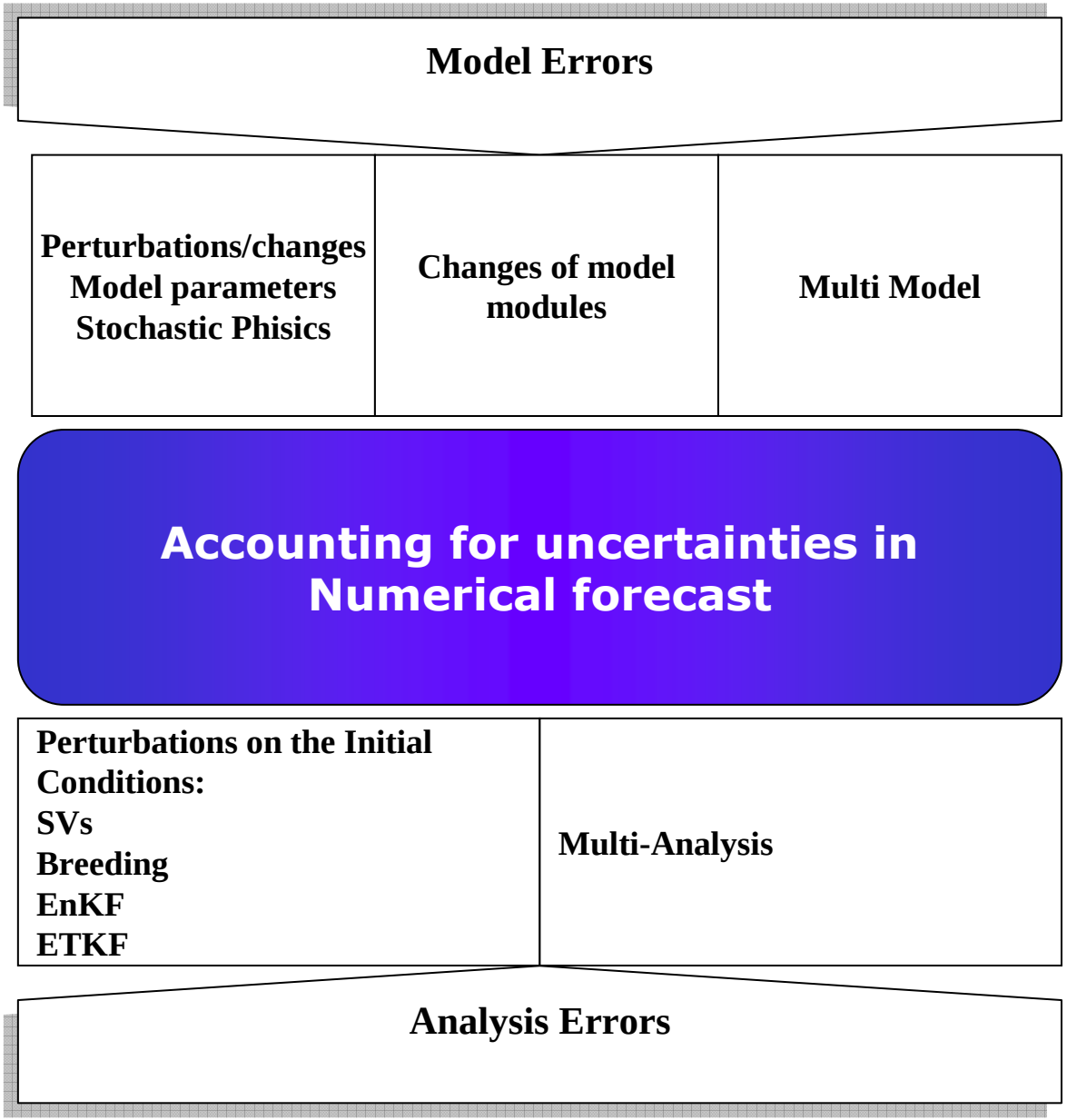

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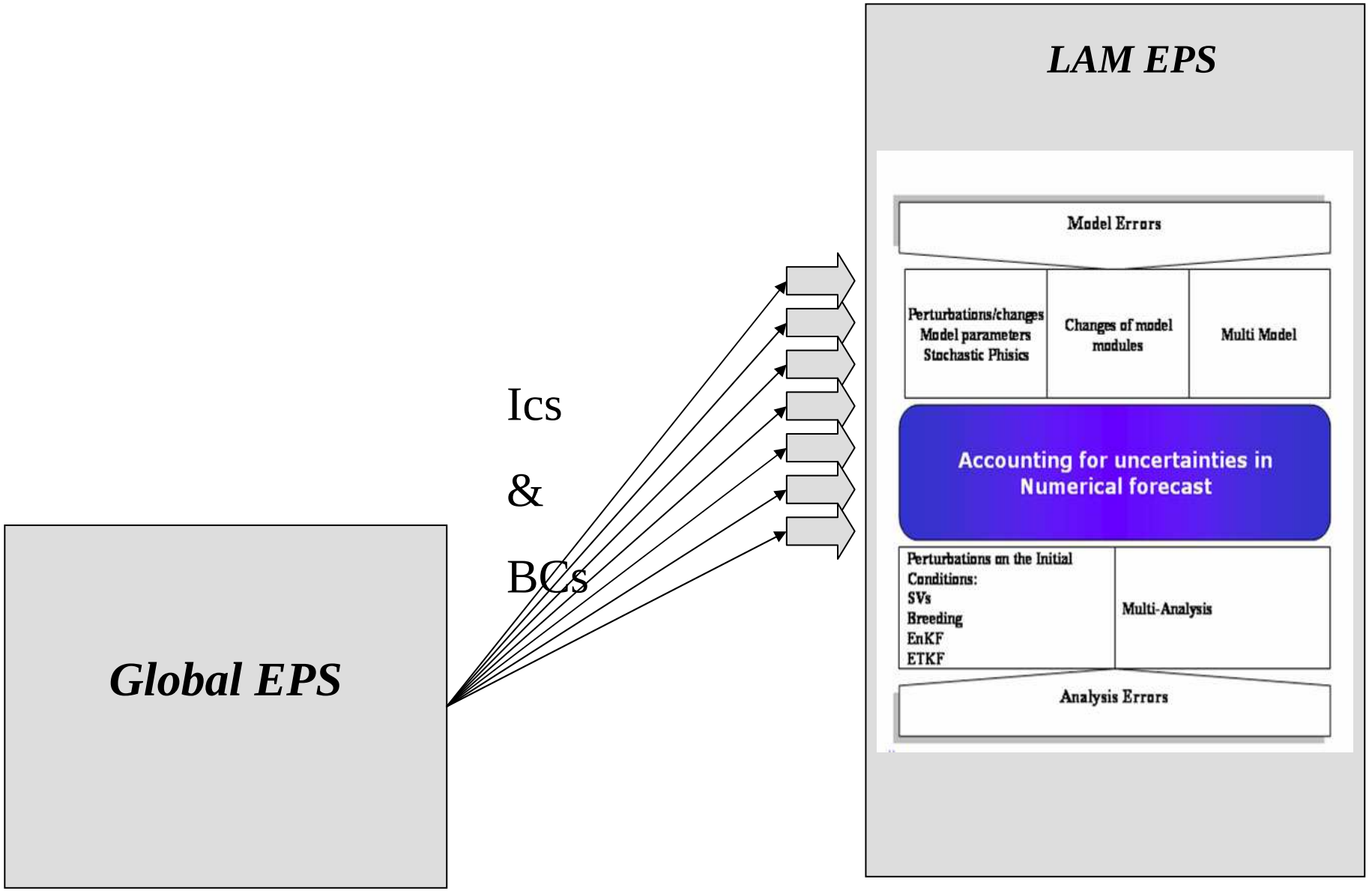

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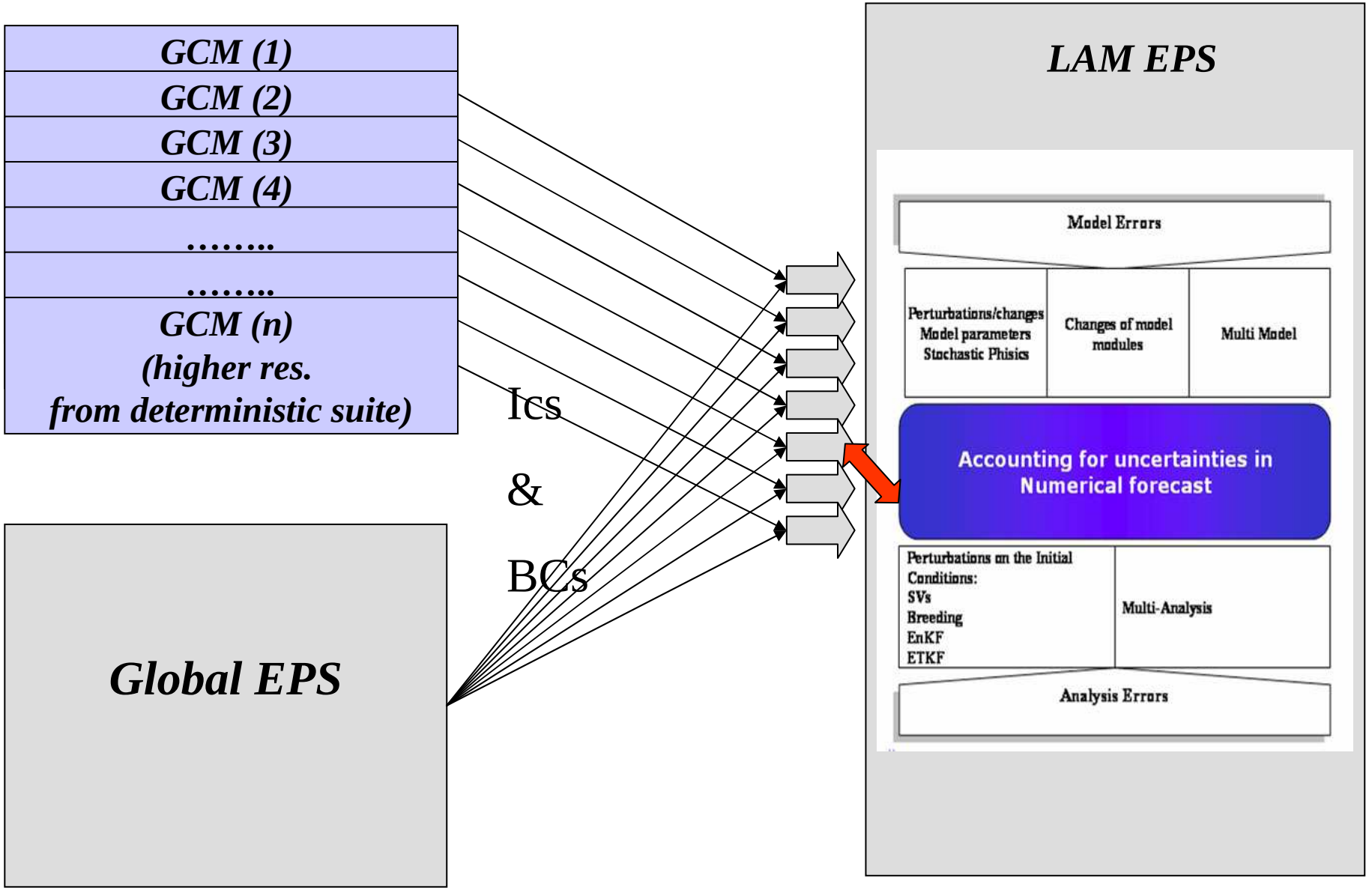

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- **Intuitively, a practical and efficient way to account for our possible errors is to initialize models with**
  - analyses obtained by independent systems (MA)
  - and to use different forecast models (MM)

- **Quality and efficiency come from: the same quality but different genetics**

- **This approach requires a lot of interoperability among the different systems**

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Multi-Model

Nowadays the concept of multi-model must be articulated:

Global EPS

- Multi Model
- MultiModel &Multi Analysis (MumMa)
- Grand Ensemble

LAM Systems

- Multi Model
- Multi Model ICs&BCs
- Grand Ensemble
- Grand Ensemble ICs & BCs

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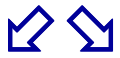
Some work has been done in the last ten years to assess the advantage of a Multi-Model Ensemble-Grand Ensemble approaches but a systematic and comprehensive evaluation requires an extensive cooperation



Science Operations

TIGGE

The THORPEX Interactive Grand Global Ensemble

Status in September 2008

Philippe Bougeault, ECMWF
Zoltan Toth, NCEP
(Co-chairs of the GIFS-TIGGE WG)

Recent research results based on TIGGE

Acknowledgments to

Young-Youn Park, KMA

Renate Hagedorn, ECMWF

Florian Pappenberger, ECMWF

Richard Swinbank et al., UK Met Office

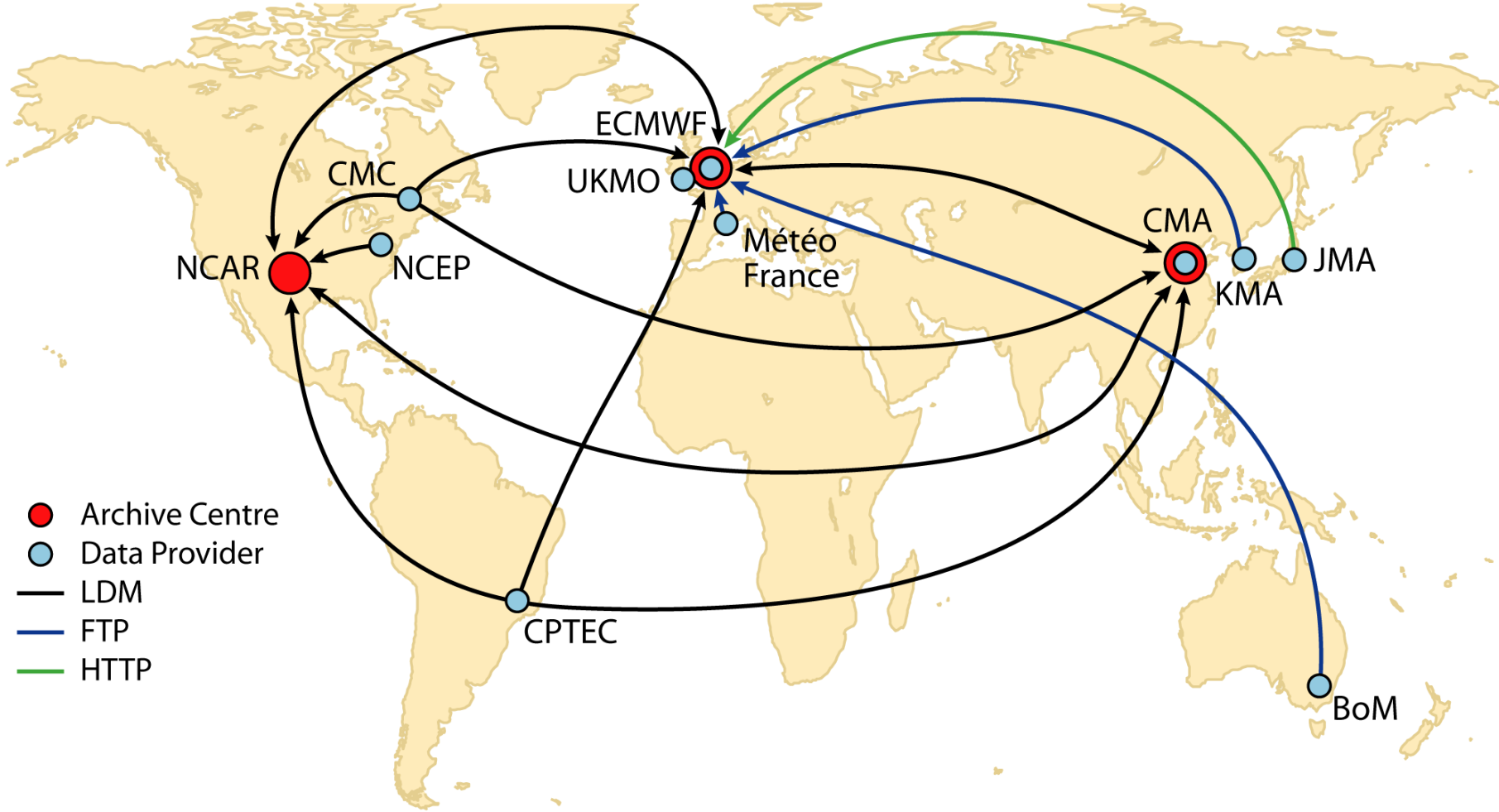
Courtesy of P. Bougeault and Z. Toth

TIGGE objectives (agreed in March 2005)

- **Enhance international collaboration on ensemble prediction for severe weather**
  - **Collaboration between operational centres and universities**
- **Develop theory and practice of multi-model ensembles**
- **Examine the feasibility of interactive ensembles responding dynamically to changing uncertainty**
- **Develop the concept of a Global Interactive Forecasting System (GIFS)**

Courtesy of P. Bougeault and Z. Toth

TIGGE data exchanges (6 to 30h after real time)



Courtesy of P. Bougeault and Z. Toth

ECMWF

TIGGE Database contents by provider

	BOM	CMA	CMC	CPTEC	ECMWF	JMA	KMA	MF	NCEP	UKMO
Standard Fields (Out of 73)	**55**	**60**	**56**	**55**	**70**	**61**	**46**	**62**	**59**	**70**
Ensemble Members	**33**	**15**	**21**	**15**	**51**	**51**	**17**	**11**	**21**	**24**
Forecast Length (Day)	**10**	**10**	**16**	**15**	**15**	**9**	**10**	**3**	**16**	**15**
Forecast cycles per Day	**2**	**2**	**2**	**2**	**2**	**1**	**2**	**1**	**4**	**2**

(As of May 1, 2008)

Courtesy of P. Bougeault and Z. Toth

ECMWF

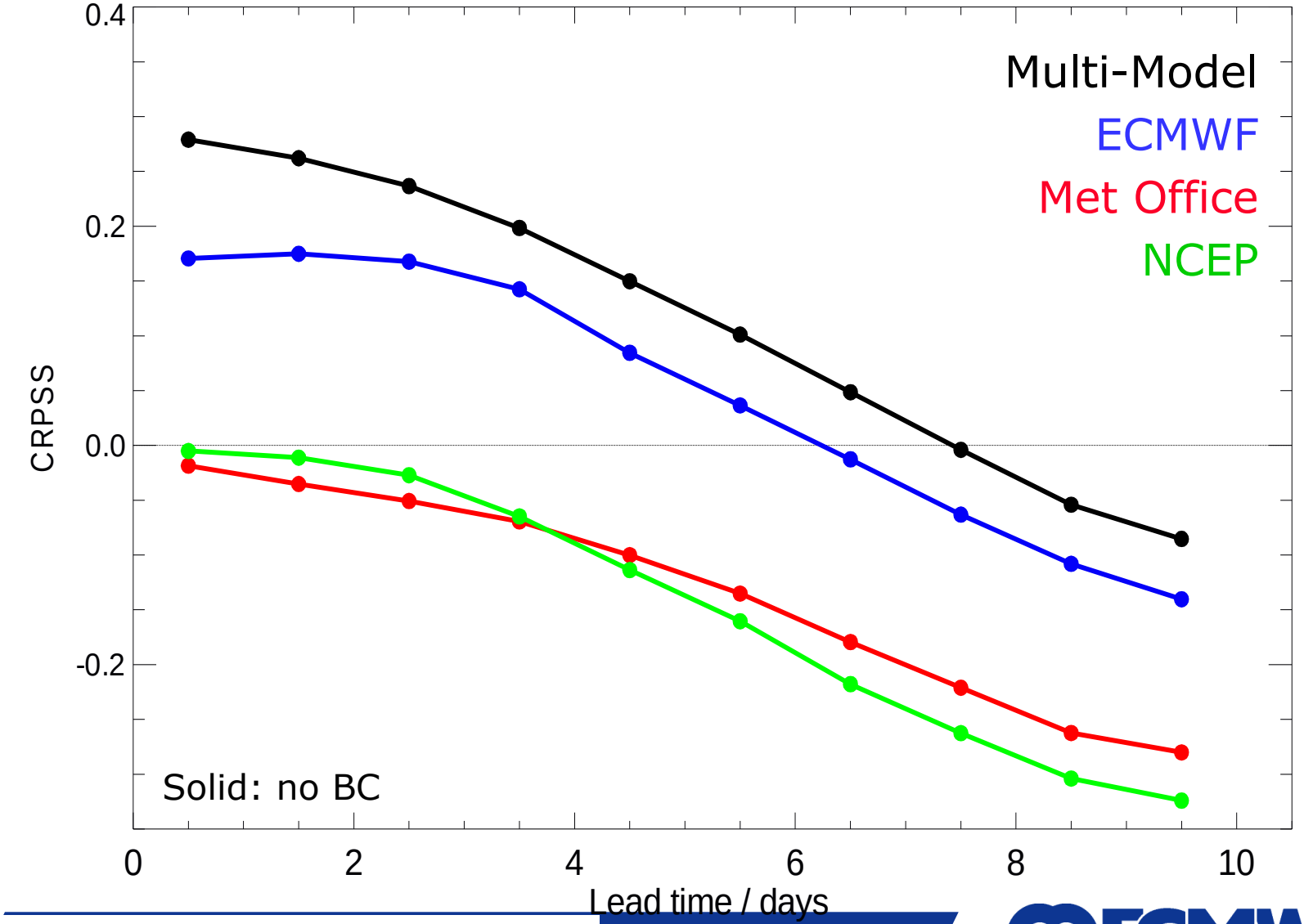
Upper air variables (preliminary conclusions from last year talk, broadly confirmed by more recent studies)

- **Significant differences in quality between the systems**
  - Up to 3 days differences in probabilistic forecast skill
  - Agreement between spread and skill is the most variable aspect and has a strong impact on probabilistic skill scores
  - In the Tropics the spread is underestimated by almost all systems
- **Impact of the verification analysis**
  - Relatively little impact in the extra-Tropics (as long as the analysis comes from one of the best systems)
  - Large impact in the Tropics (and difficult to decide which is the best analysis)
- **Skill of multi-model system versus single-model systems**
  - Only marginal improvement in the extra-Tropics
  - Significant improvement in the Tropics (subject to significant bias corrections)

Courtesy of P. Bougeault and Z. Toth

Verification of T2m against observations

T-2m, 250 European stations
2008060100 – 2008073000 (60 cases)



Courtesy of P. Bougeault and Z. Toth

ECMWF

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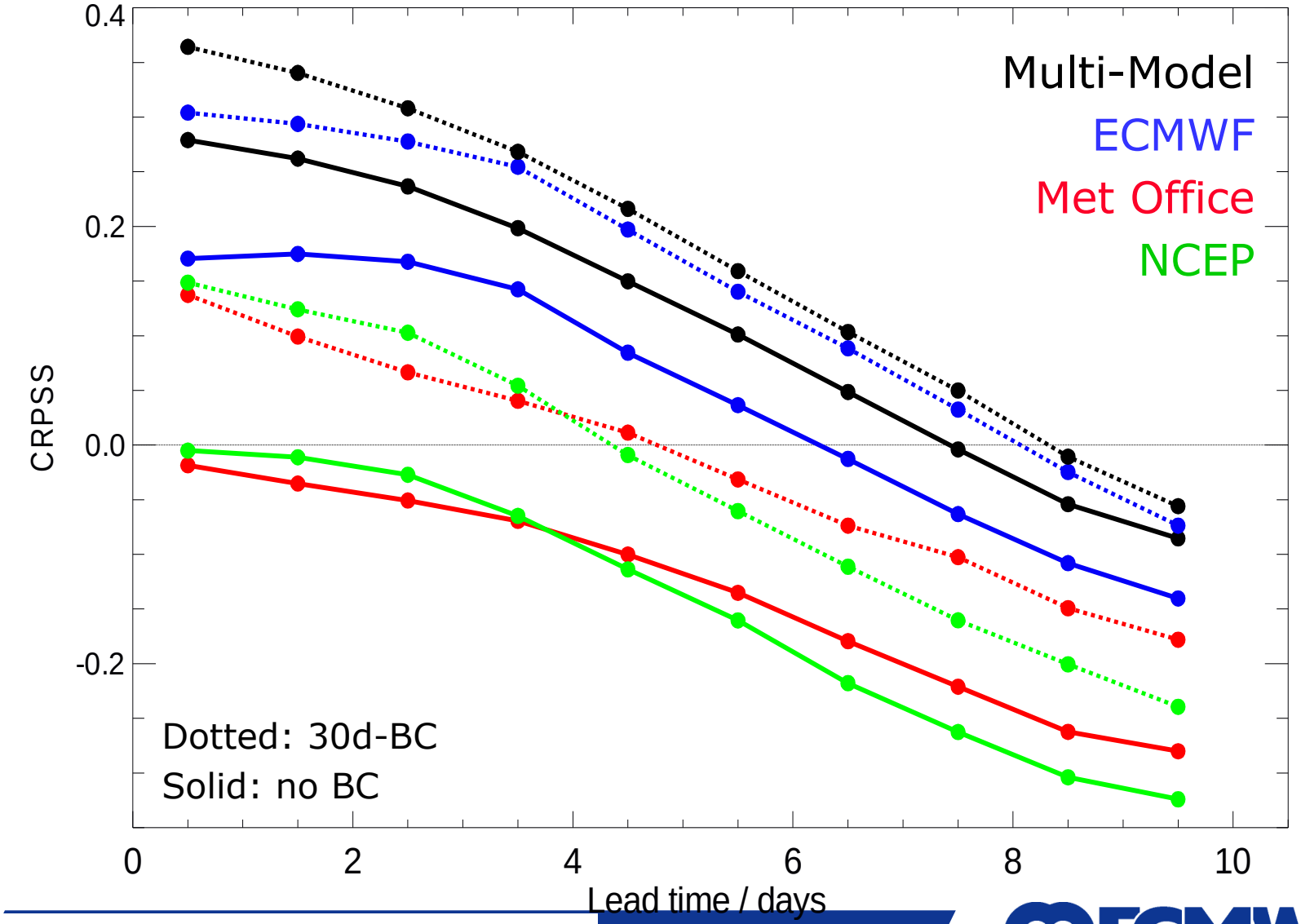


Courtesy of P. Bougeault and Z. Toth

ECMWF

Preliminary conclusions for T2m (very tentative!)

- **Results are sensitive to the choice of verifying analysis**
- **Generally speaking, MM is better than any single model**
- **Generally speaking, MM superiority comes from ECMWF, and ECMWF alone is better than any MM without ECMWF**
- **Calibration using recent forecasts reduces the superiority of the MM but does not change the above conclusions**
- **Calibration using a special set of re-forecasts may offset completely the superiority of the MM (?)**
- **The superiority of the MM may also be challenged if uncertainty in soil moisture is added in the single systems**

Courtesy of P. Bougeault and Z. Toth

TECHNICAL MEM

548

TIGGE: preliminary results on comparing and combining ensembles

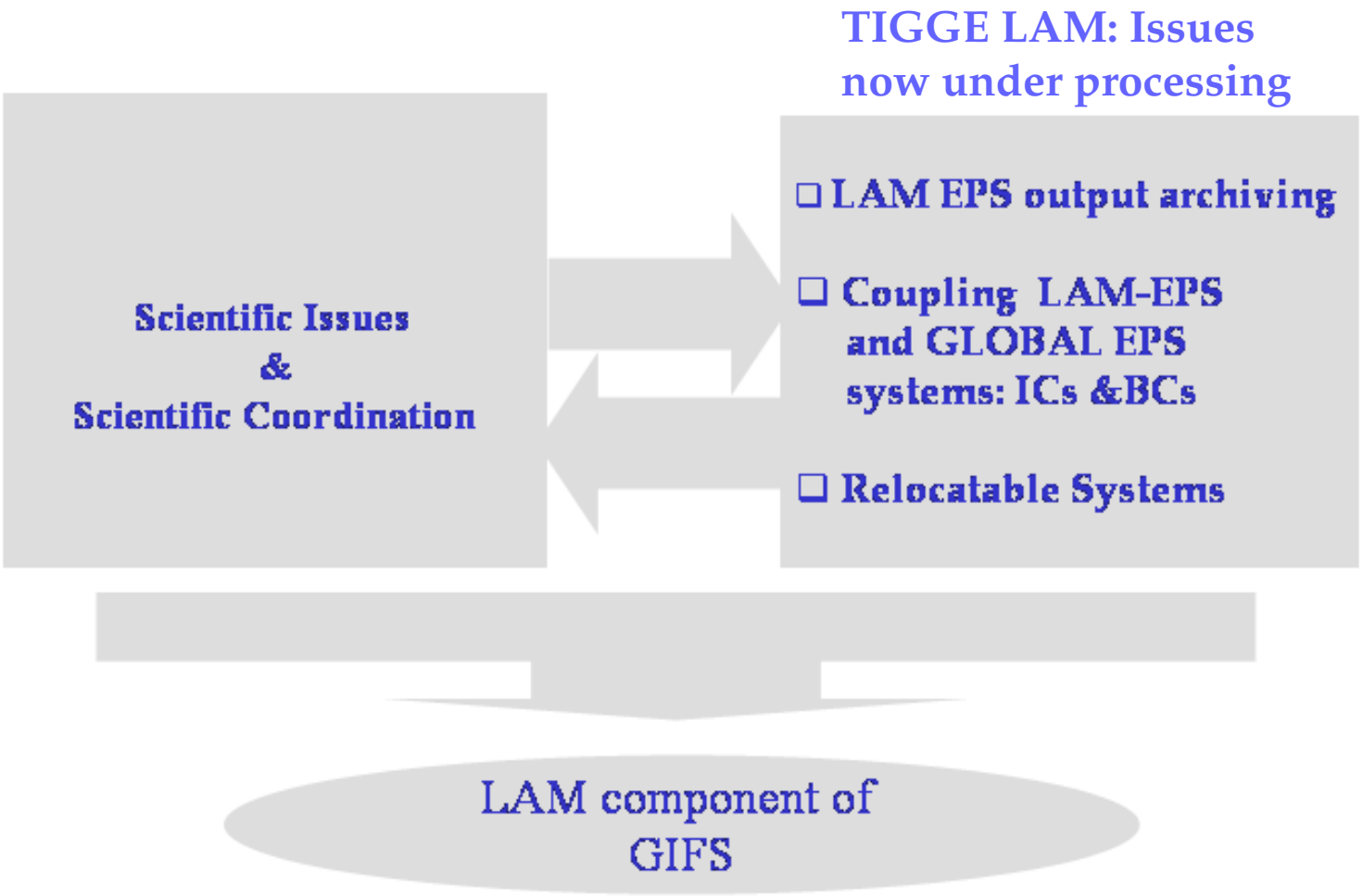
Young-Youn Park[1], Roberto Buizza and Martin Leutbecher

Research Department

Additional work

- Confirm results on longer time series, with more observations
- Examine other weather parameters
  - Rainfall, 10m wind, clouds, etc….
- Examine impact of multi-model on applications (end-to-end forecast systems)
  - Obvious example is with ensemble hydrological forecasts forced by TIGGE, and initial results are supporting superiority of MM
- Use TIGGE MM as a benchmark to improve single-model systems
  - Real scientific progress would be to encapsulate all aspects of uncertainty in a single, optimal system: TIGGE can help us to locate and repair the deficiencies of existing operational EPSs

LAM EPS & TIGGE LAM



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LAM EPS System	Institute - Consortium	Contact person	e-mail
Europe			
MOGREPS	UK Met Office - UK	Ken Mylne	ken.mylne@metoffice.com
INM SREPS	INM - Spain HIRLAM	Jose Antonio Garcia Moya	png@inm.es
SRNWP PEPS	DWD – Germany SRNWP	Michael Denhard,	Michael.Denhard@dwd.de
COSMO LEPS	ARPA-SIM – Italy COSMO	Andrea Montani	amontani@arpa.emr.it
NORLAMEPS	Met.NO	Inger-Lise Frogner Trygve Aspelien	trygve.aspelien@met.no
ALADIN LAEF	ZAMG / Austria	Yong Wang	wang@zamg.ac.at
OMSZ ALADIN EPS	Hungary	Edit Hagel	hagel.e@met.hu
United States			
NCEP-SREF	NCEP	Jun Du	Jun.Du@noaa.gov
China			
CMA-WRF LEPS	CMA/China	Jiandong Gong	gongjd@cma.gov.cn
Japan			
JMA MRI EPS	MRI/Japan	Kazuo Saito	ksaito@mri-jma.go.jp

TIGGE LAM EPS systems "registered" by sending Spreadsheet information file

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LAM EPS System	Institute -Consortium	Contact person
Europe		
COSMO DE EPS	**DWD – Germany SRNWP**	**Susan Theis**
GLAMEPS	DNMI/Univ Oslo –Norway HIRLAM ALADIN	Trond Iversen
	Czech	Richard Mladek
	Croatia	Stjepan Ivatek-Sahdan
PEARCE	Meteo-France / France	Jean Nicolau
DMI - HIRLAM	DMI	Xiao Hua Yang
United States		
UWME	Univ Washington	Clifford Mass
	NSSL in Oklahoma	David Stensrud
EnKF	Univ Washington	Greg Hakim
Canada		
CMC LAM EPS	MS / Canada	Martin Charron
Korea:		
	Korean Met Admin.	Hee Sang Lee

LAM EPS systems "not yet registered"

Something is also growing up in Brazil.

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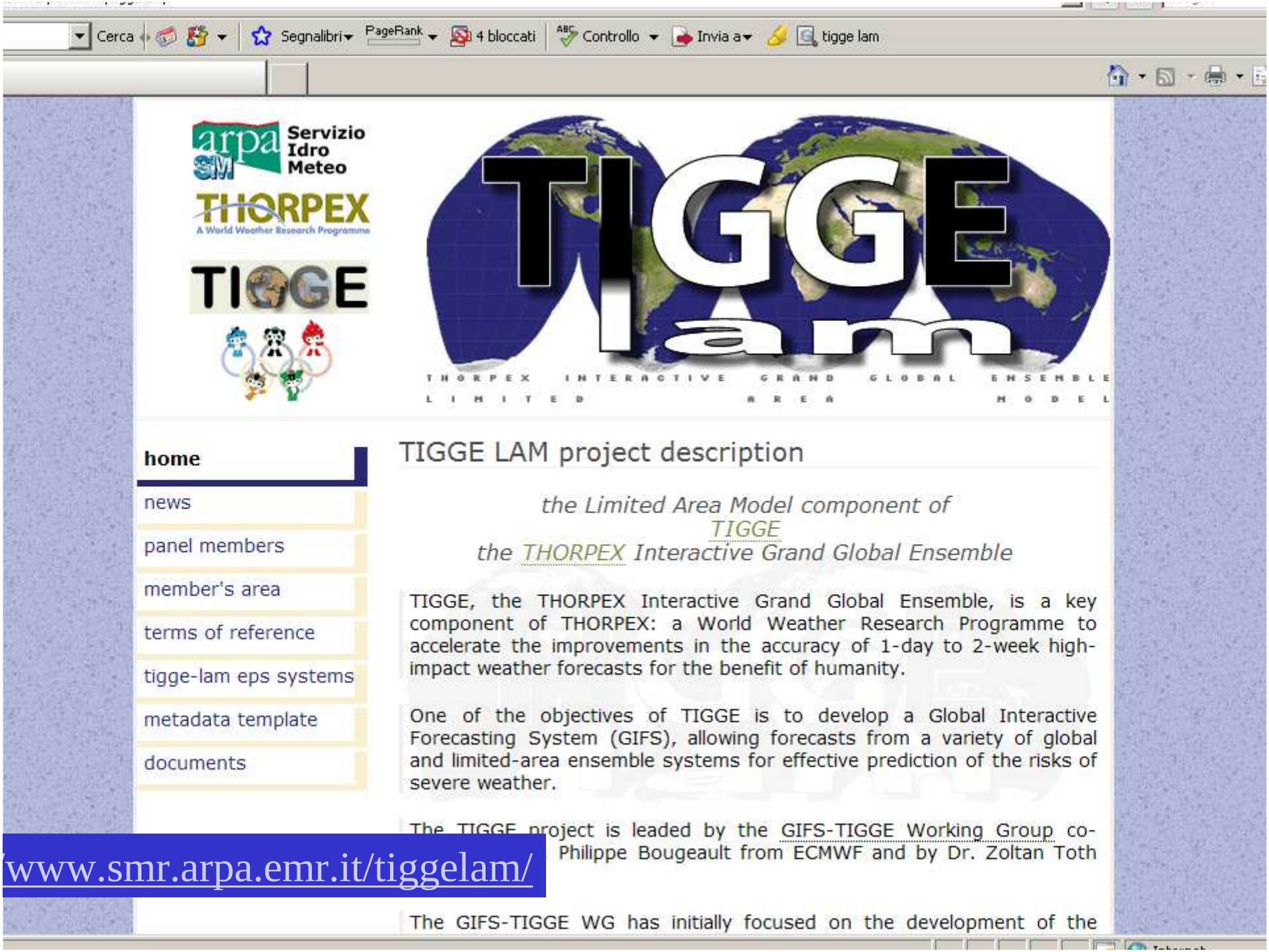

www.smr.arpa.emr.it/tiggelam/

Scientific issues

- *Initial conditions perturbations.*
  - *Breeding*
  - *EnKF,*
  - *ETKF*
  - *SVs*
- *Model perturbations*
  - *Multi-physics*
  - *Stochastic physics*
- *MultiModel / MultiBoundaries / MultiAnalysis*
- *Hybrid systems: high res deterministic combined with lower res. Ensemble*
- *Ensemble size*
- *Calibration & Reforecast*
- *Verification*
- *Use of LAM EPS products : downstream applications.*

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Scientific cooperation

TIGGE

& TIGGE LAM

- SRNWP
  - Interoperability
  - EurEPS
  - Verification

- **WMO**
  - JGV Joint Working Group on Verification
  - WG/Mesoscale Weather Forecasting
  - SERA

Methodologies

Test periods (SWFDP,FDP,RDP)

Observations

- **NAEFS**

- **WMO**
  - EPS Expert Team on Ensemble Prediction Systems
  - PDP WG Predictability and Dynamical Processes Working Group
  - MEDEX Mediterranean Experiment on "Cyclones that produce high impact weather in the Mediterranean"

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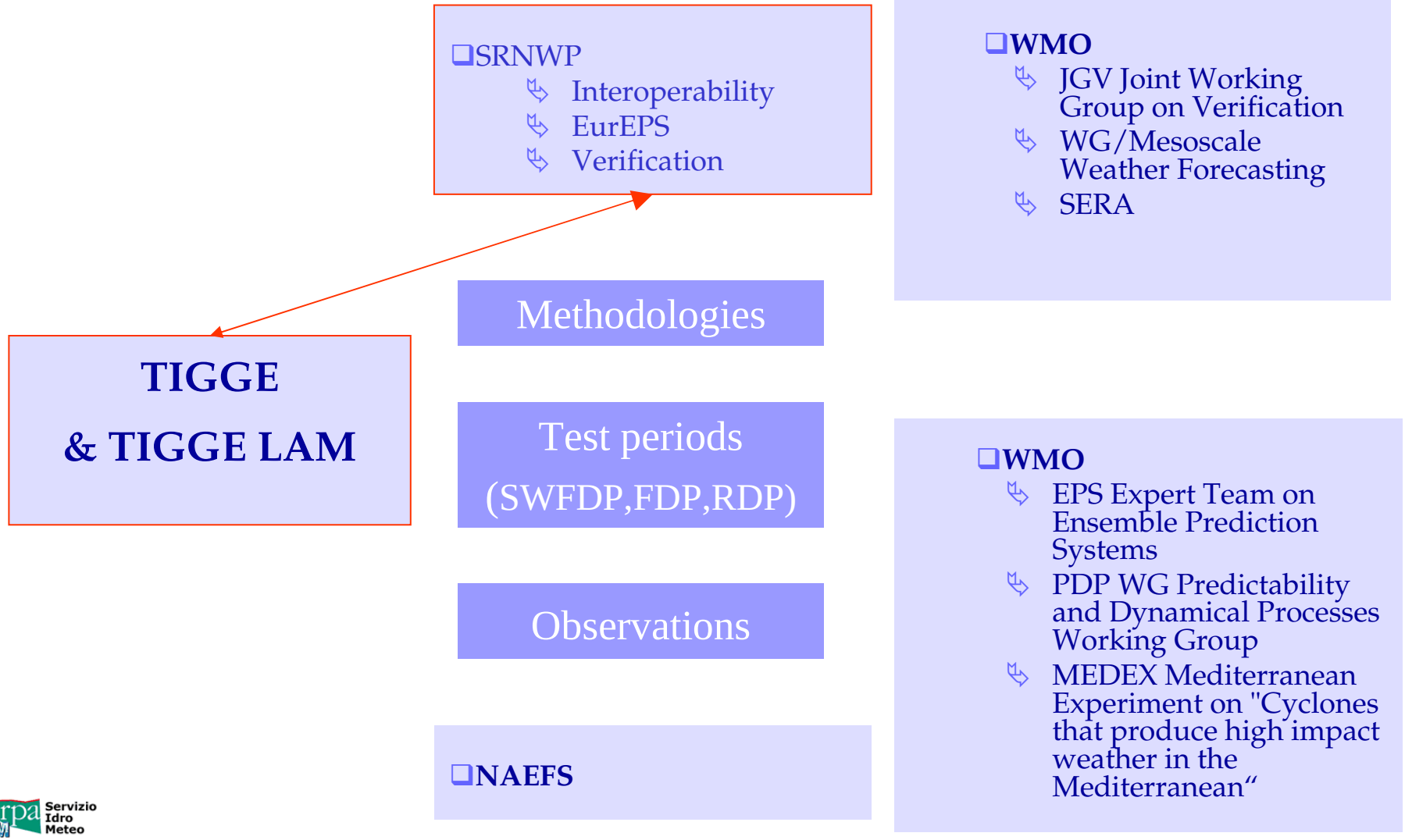
Scientific cooperation



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Scientific Issues
&
Scientific Coordination

- **LAM EPS output archiving**
- **Coupling LAM-EPS and GLOBAL EPS systems: ICs &BCs**
- **Relocatable Systems**

LAM component of GIFS

TIGGE LAM Output Parameters Archiving 1st phase

- *Initial conditions perturbations.*
  - *Breeding*
  - *EnKF,*
  - *ETKF*
  - *SVs*
- *Model perturbations*
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- *Hybrid systems: high res deterministic combined with lower res. Ensemble*
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- *Verification*
- *Use of LAM EPS products : downstream applications.*

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LAM EPS SYSTEMS

		"Relatively" simple to be Implemented At least in the simplest configurations			A lot of Interoperability Work			Hard both from the scientific and implementation aspects	
		Downscaling of Global EPS	Multi Physics	Perturbed Physics	Multimodel	Downscaling of different Global EPS	Downsc. of diff. det. models (incl. analyses)	Perturbed analyses	Multi Analyses
ZAMG AUSTRIA	ALADIN-LAEF	1.00							
CMA	CMA-WRF LEPS	1.00							
OMSZ ALADIN	ALADIN EPS	1.00							
JMA	MRI MESO EPS	1.00						1.00	
ARPA-SIM / COSMO	COSMO LEPS	1.00	1.00						
MET.NO	LAMEPS NORLAMEPS	1.00							
INM / HIRLAM	INM SREPS				1.00		1.00		
ARPA-SIM / COSMO	COSMO SREPS			1.00			1.00		
NCEP	SREF							1.00	
HIRLAM-AL-LACE	GLAMEPS	1.00	1.00		1.00				
UKMO	MOGREPS	1.00		1.00				1.00	
DWD/SRNWP	SRNWP PEPS								
PEARCE		1.00							
HMS	HMS LAMEPS					1.00			
	ECMWF/ALADIN LAMEPS	1.00							
WeatherSA	SASAWS								1.00
SAR	MUSE				1.00		1.00		

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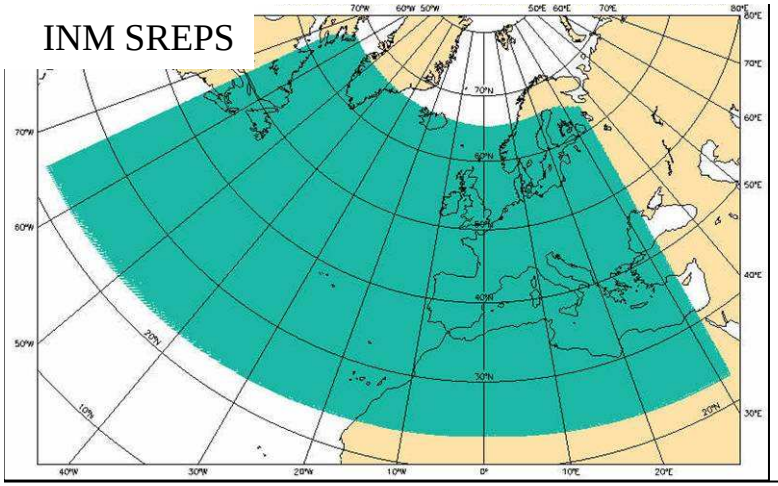
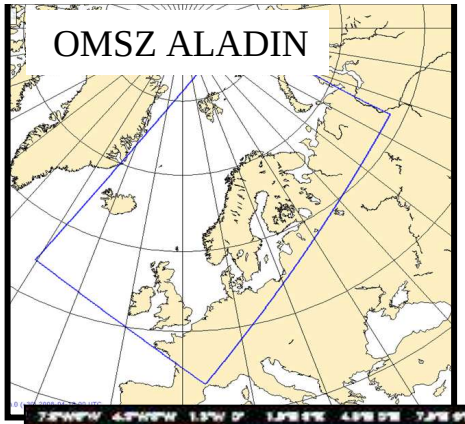
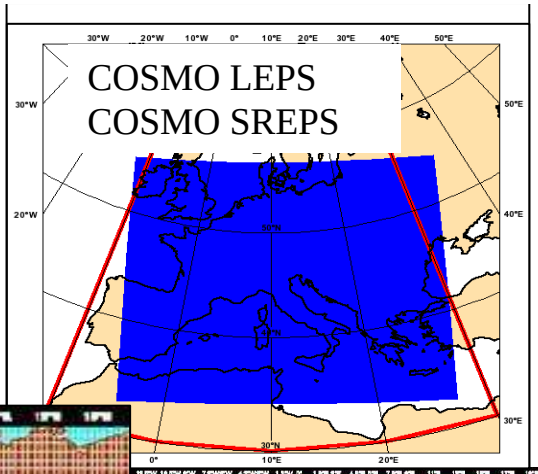
INM SREPS



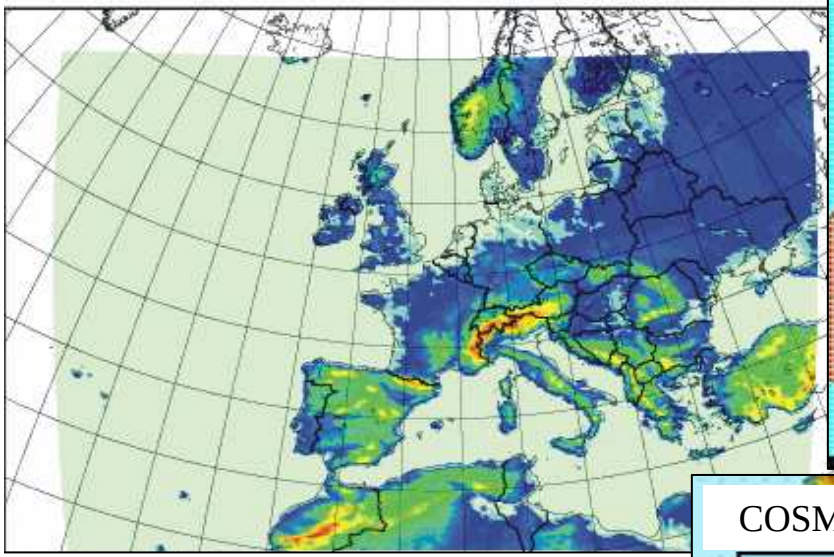
OMSZ ALADIN



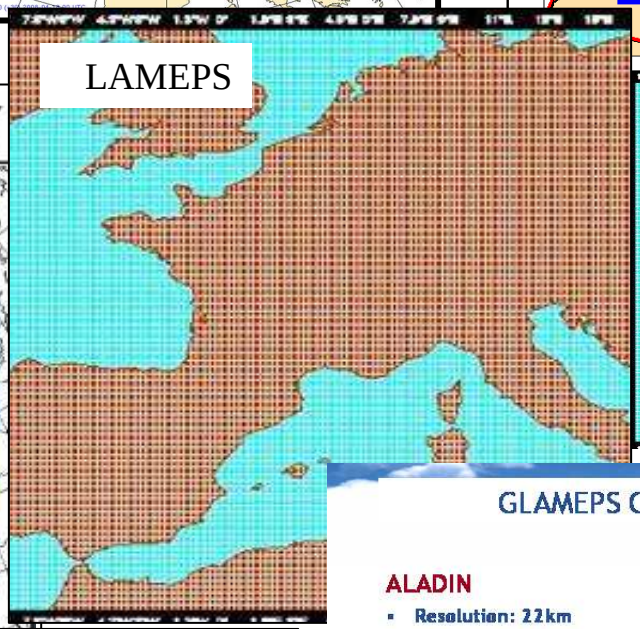
COSMO LEPS
COSMO SREPS



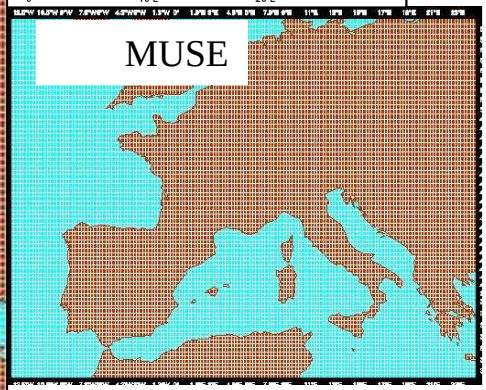
LAEF Domain & Topography



LAMEPS

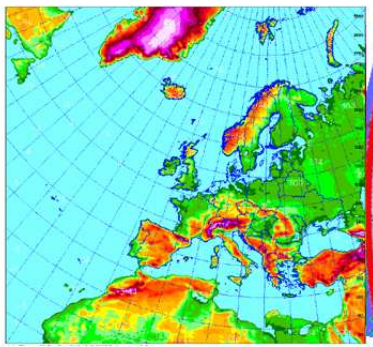


MUSE

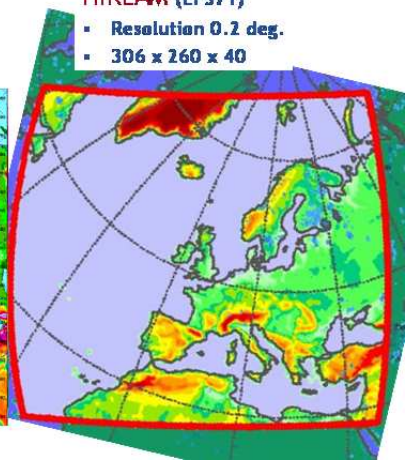


GLAMEPS Common Domain

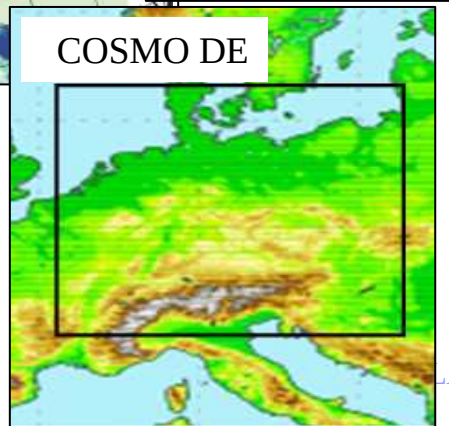
ALADIN
- Resolution: 22km
- 320 x 300 x 37



HIRLAM (EPS71)
- Resolution 0.2 deg.
- 306 x 260 x 40



COSMO DE



MOGREPS

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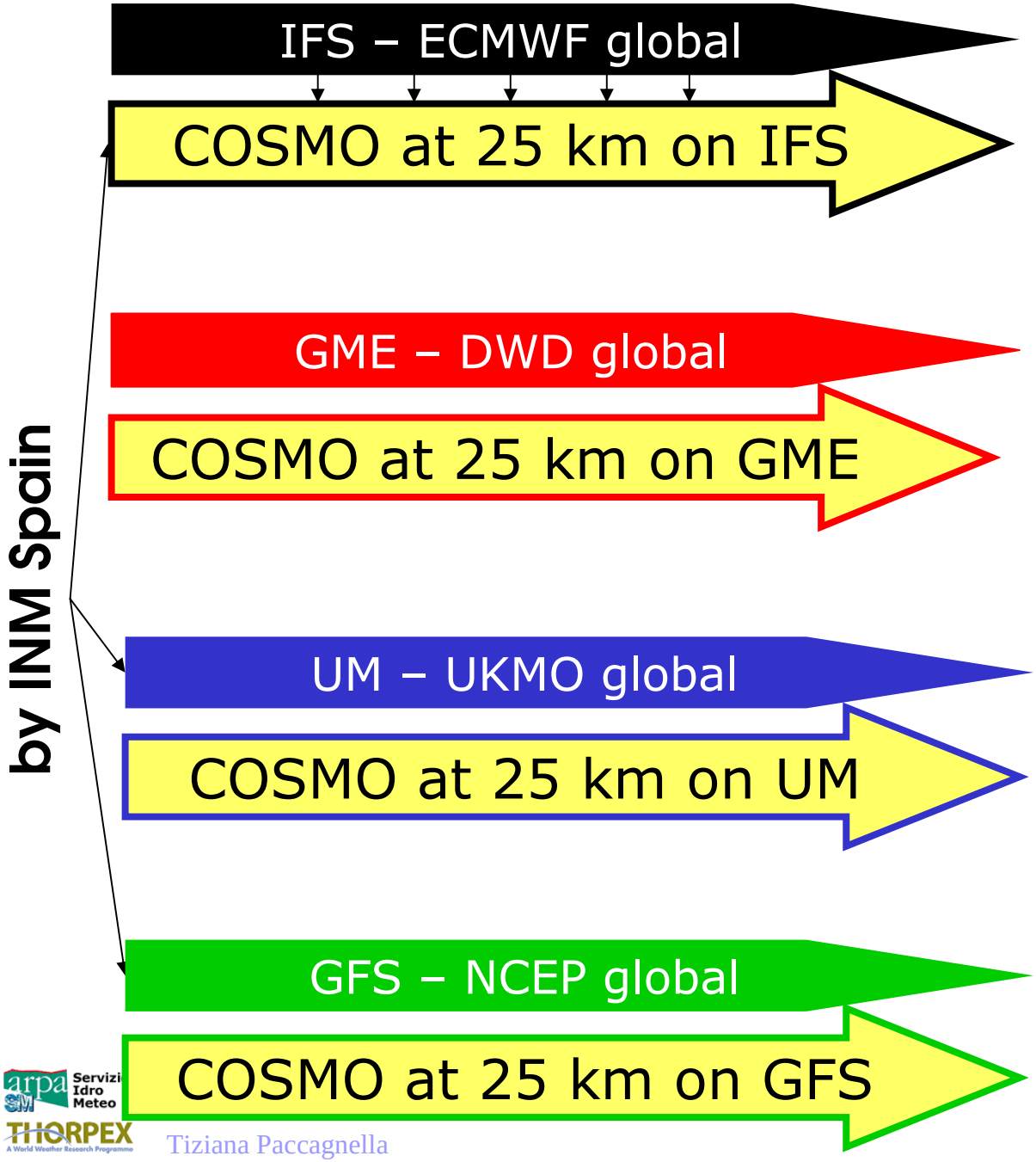

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by INM Spain

IFS – ECMWF global

COSMO at 25 km on IFS

GME – DWD global

COSMO at 25 km on GME

UM – UKMO global

COSMO at 25 km on UM

GFS – NCEP global

COSMO at 25 km on GFS

System set-up

P1: control (ope)

P2: conv. scheme (KF)

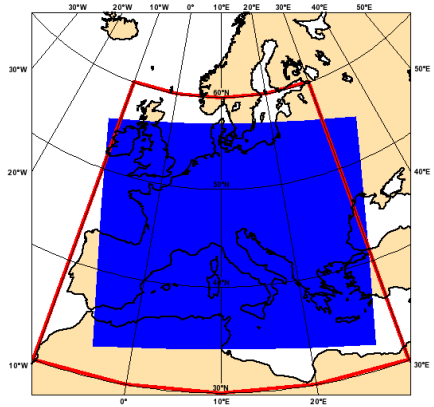
P3: tur_len=1000

P4: pat_len=10000

16 COSMO runs

10 km hor. res.

40 vertical levels



00 UTC

JJA=53 SON=54

COSMO-SREPS was running regularly during the MAP D-PHASE DOP, at 00 UTC

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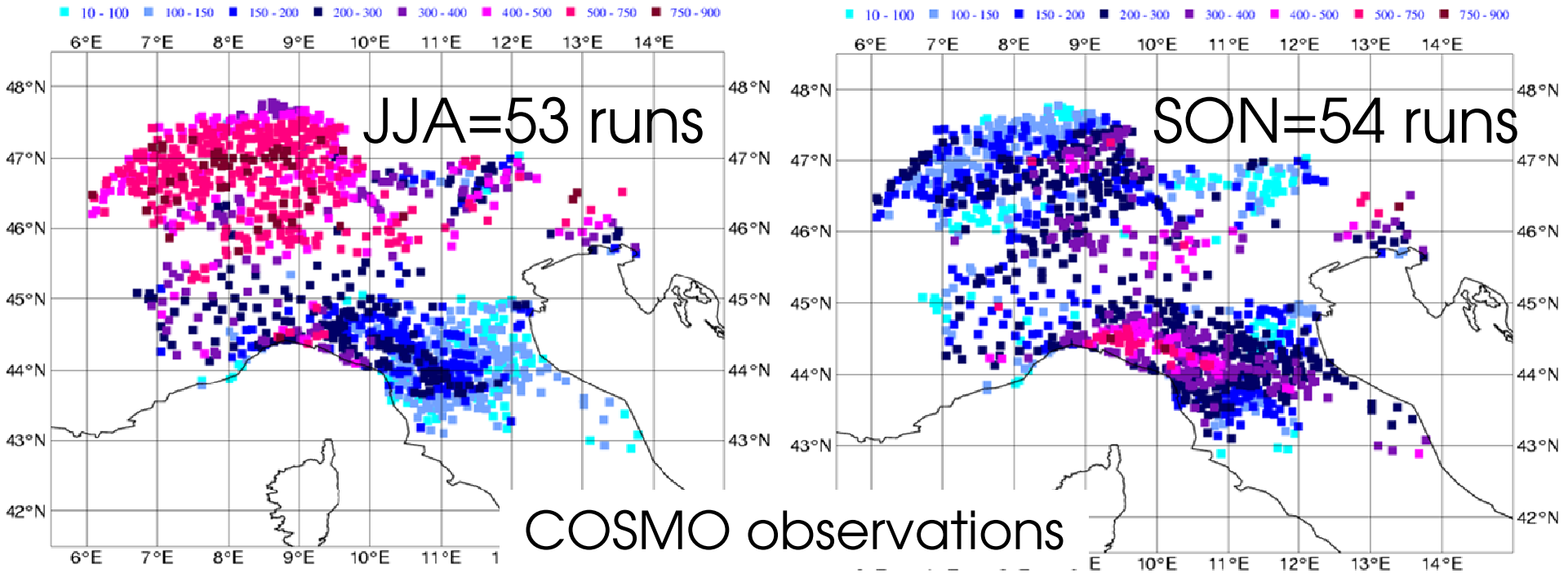
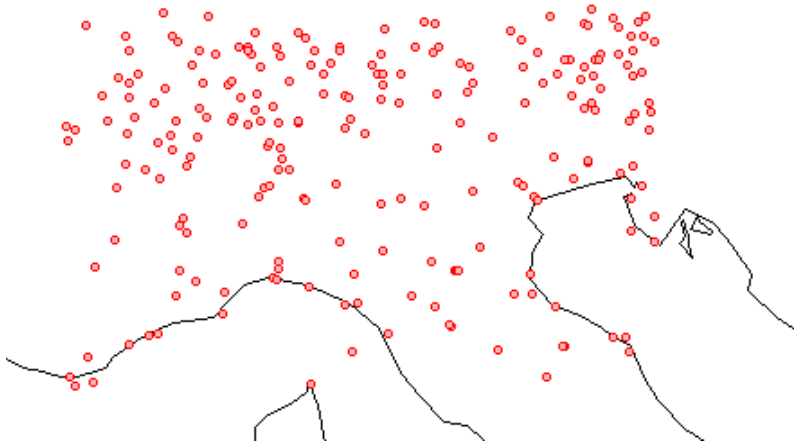
Obs. Network used by ARPA-SIM



218 synop stations on the Alpine area



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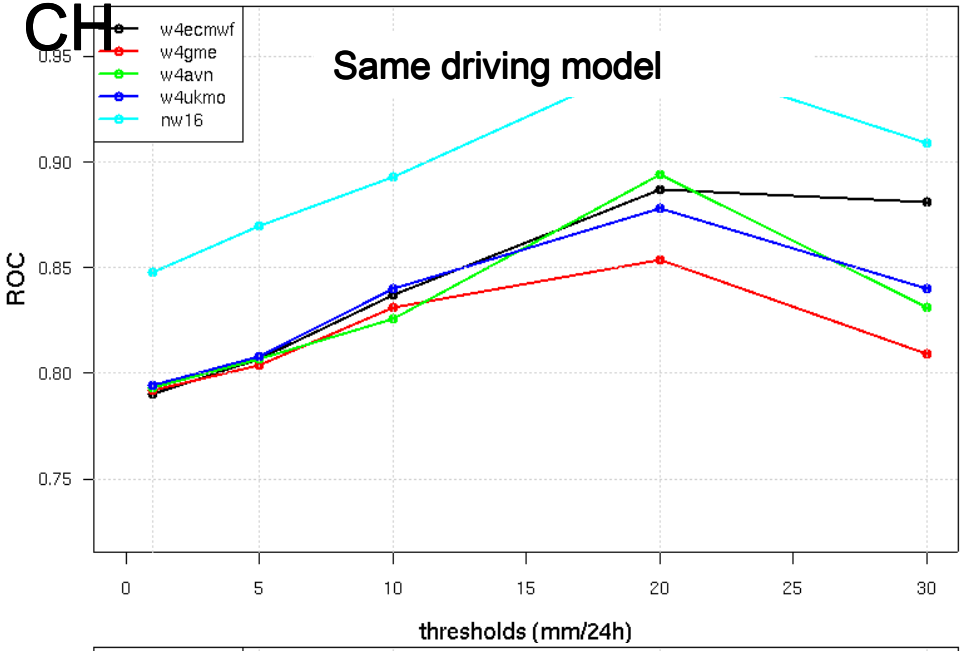
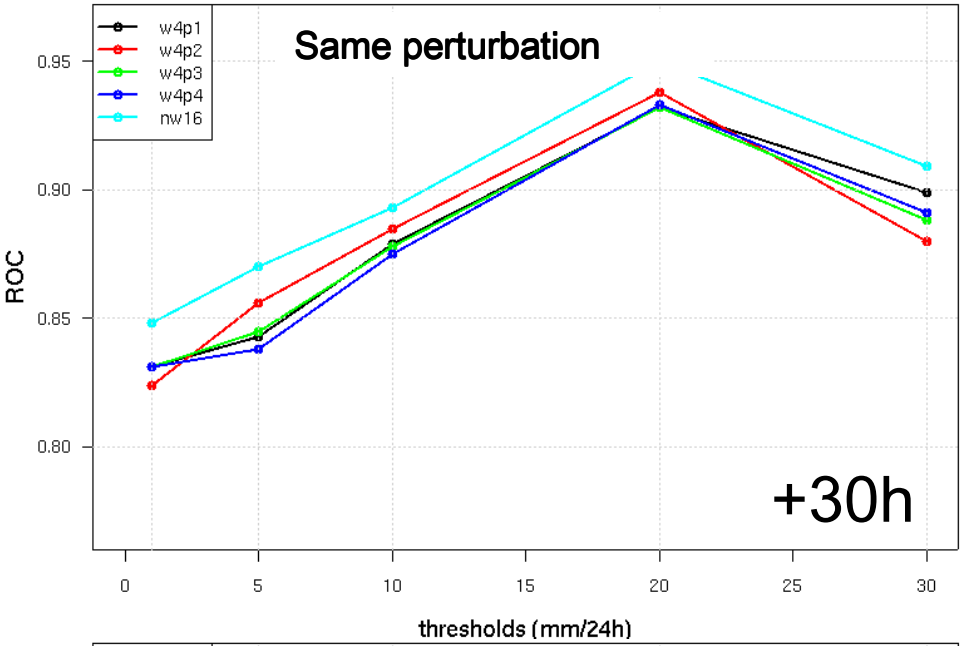
Madrid 6-8 October

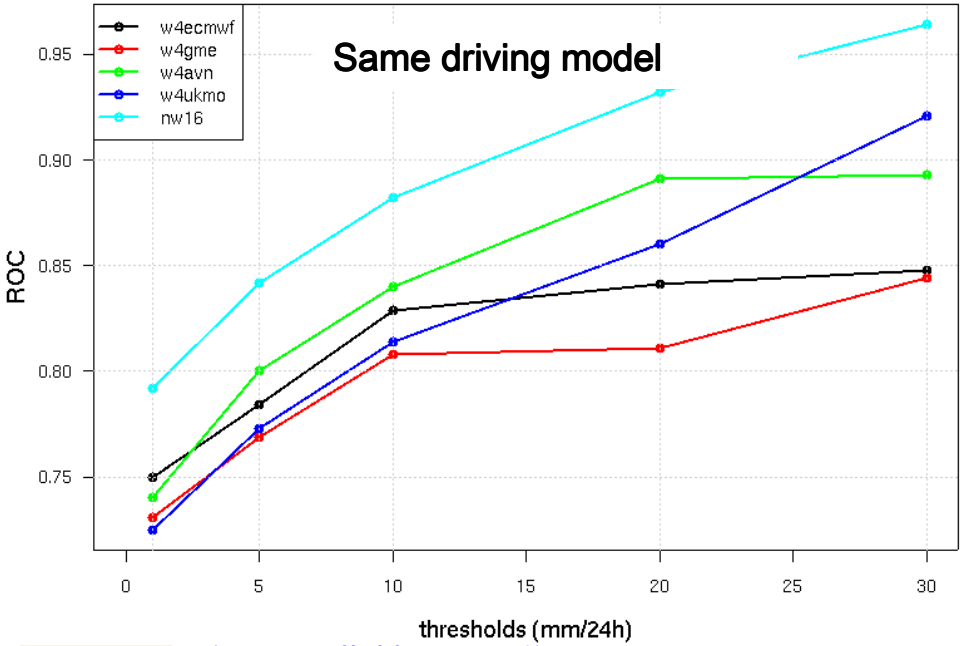
IT + CH

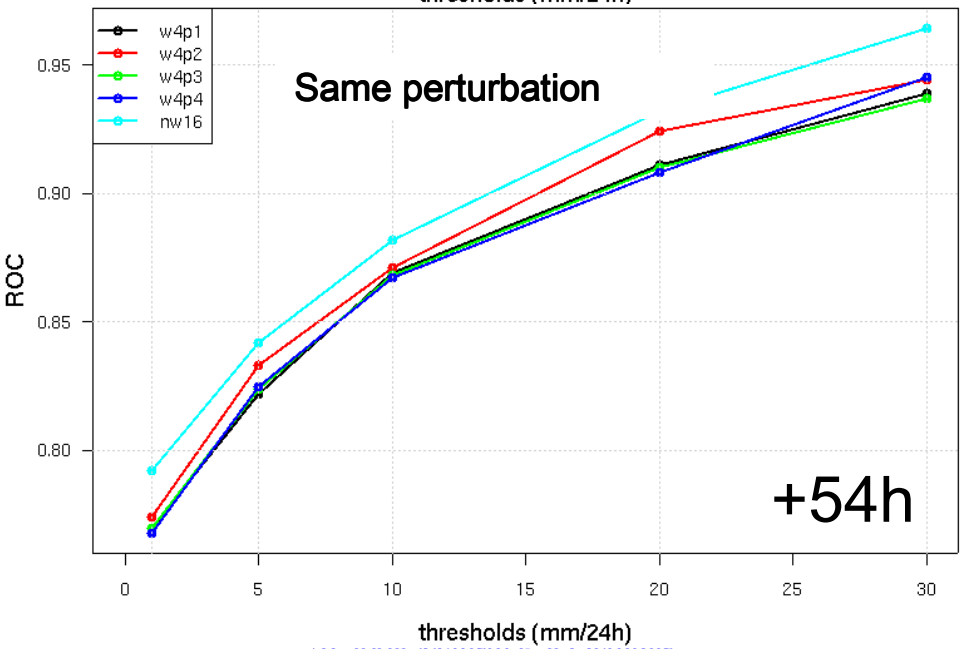
TP 24h – ave 0.5x0.5

SON07



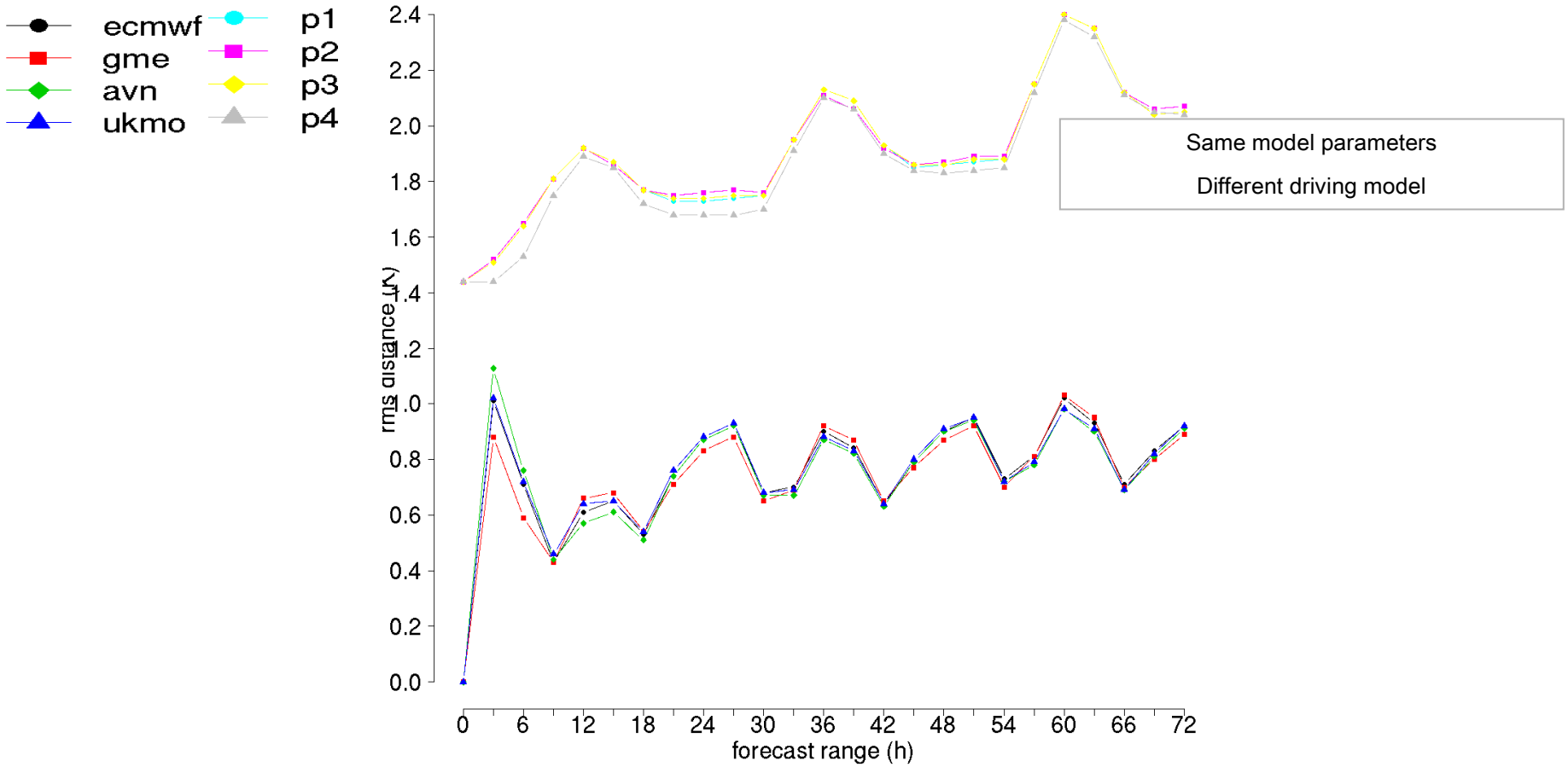






intra-group distance

JJA 2007 - 50 days



2mT Northern Italy

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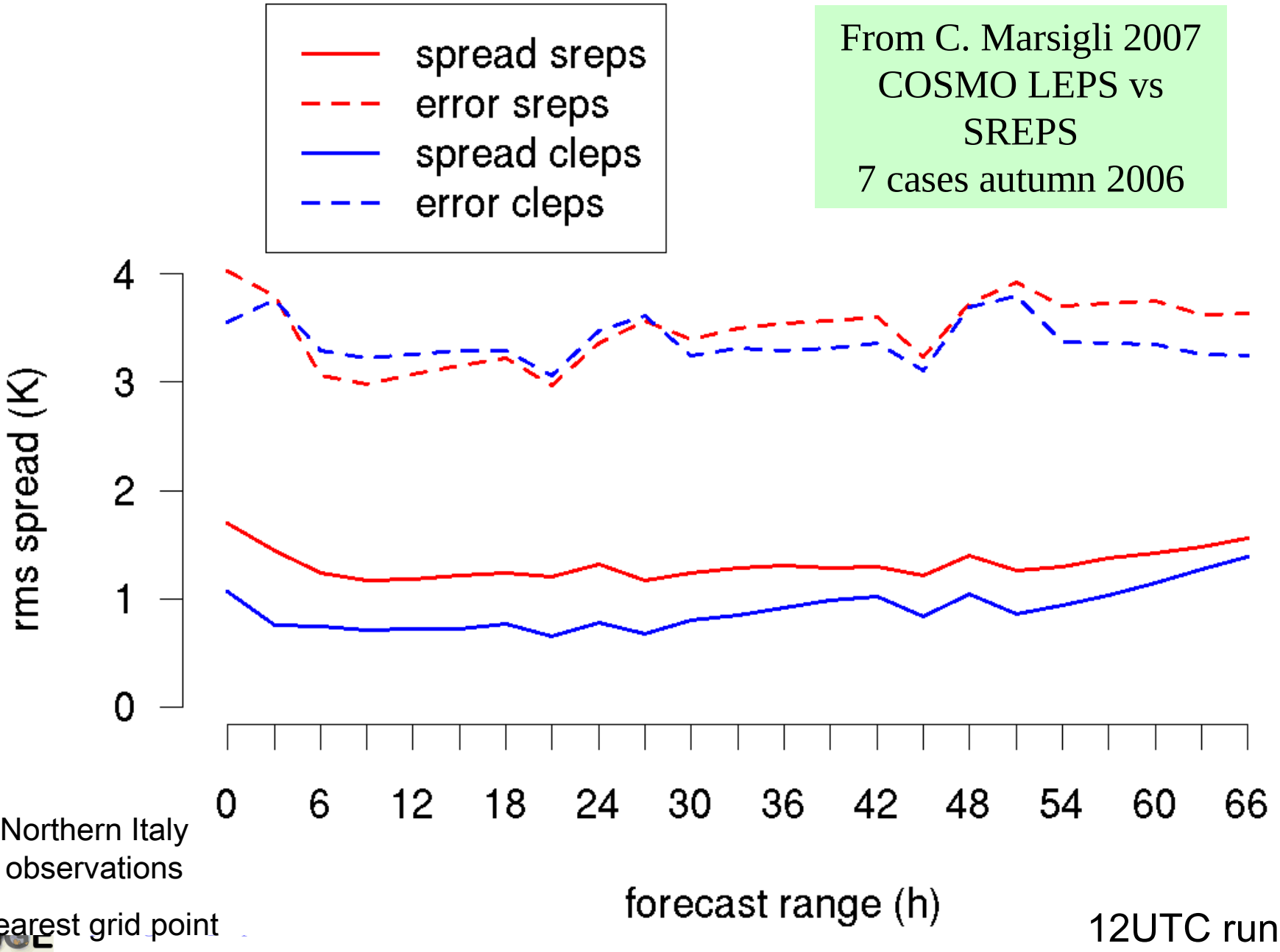
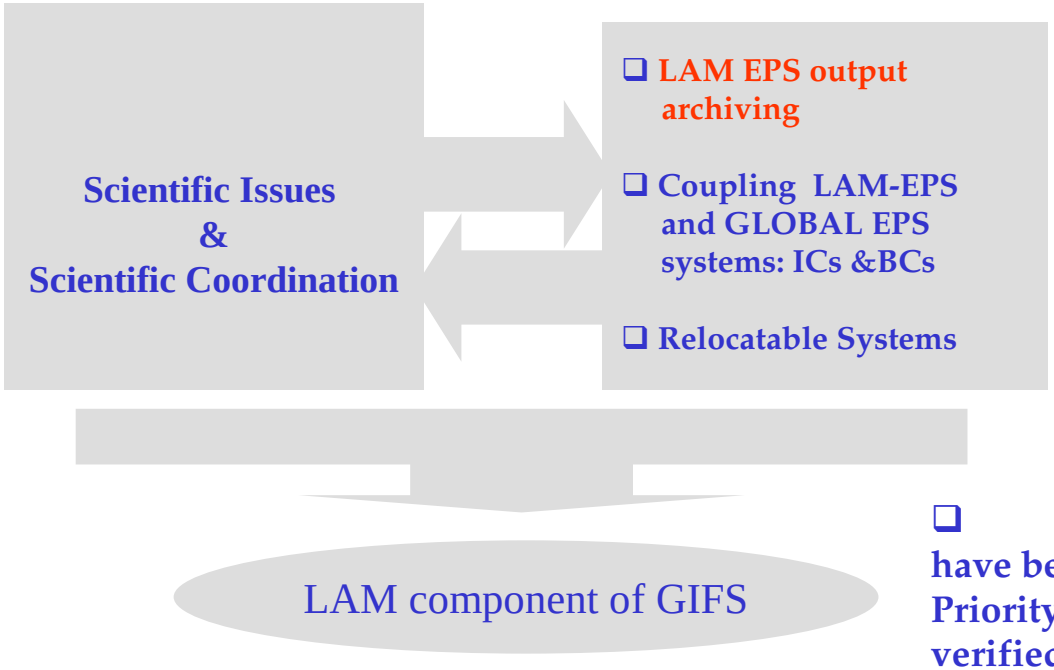
Relationship between error and spread





TIGGE LAM Output Parameters Archiving 1st phase

- Based on the TIGGE list of archived parameters, a similar list has been compiled for the TIGGE LAM systems

- Some single level parameters have been labelled as HP (High Priority) since they are the easiest to be verified and the most commonly used:
  - Mean sea level pressure
  - 10m U-velocity
  - 10m V-velocity
  - Wind Gust
  - Surface air temperature
  - Surface air dew point temperature
  - Total precipitation (liquid + frozen)
  - Large scale precipitation
  - Orography
  - Land sea mask

These parameters will be archived with highest priority

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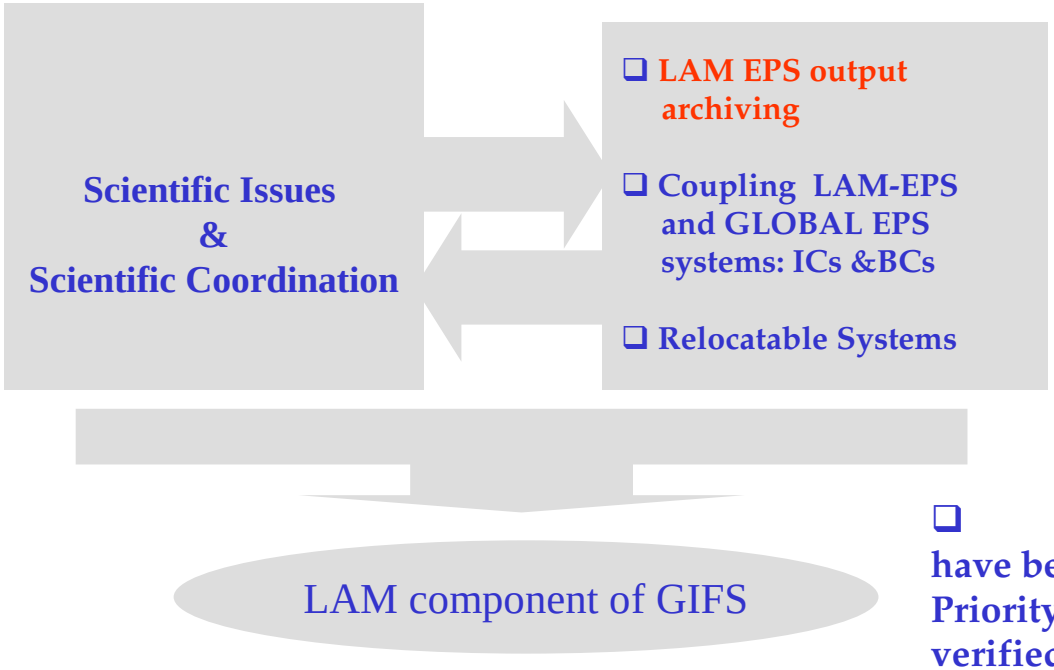

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These parameters will be archived with highest priority

- Output Fields Format
  - GRIB2
- Data policy proposal
  - The data will be made available within the same rule of TIGGE but with a delay of 24 hours.

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TIGGE LAM output parameters

Meeting about TIGGE LAM archiving - Phase 1
High Priority Parameters archived at the three archiving centres ECMWF, NCAR, CMA
ECMWF - 4 Sept. 2008

Participants:

Manuel Fuentes
Baudouin Rault
Yong Wang
Michael Denhard
Antonio Garcia Moya
Trond Iversen
Ken Mylne
Tiziana Paccagnella
Andrea Montani

- It is very important to make the use of TIGGE LAM data easier for the main users (e.g hydrologists) who are not familiar with tools and methodologies to manipulate meteorological fields.

- So, the *recommended solution* for this Phase 1, archiving of the High Priority parameters at the three TIGGE Archiving Centre, is:
  - Standard geographical lat/lon grid at 0,1° resolution

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TIGGE LAM Output Parameters
Archiving
1st phase

To make the use and exchange of these fields easier, the TIGGE archiving Centres ECMWF, NCAR and CMA will support TIGGE LAM by including in the TIGGE archive also these HP parameters.

Due to the regional nature of LAMs, the outputs coming from the different systems will be archived in one of the three Centres following a Geographical/Regional competence principle

Archiving Centre	LAM EPS products	
ECMWF	MOGREPS	UK Met Office
	INM SREPS	INM - Spain HIRLAM
	SRNWP PEPS	DWD – Germany
	COSMO LEPS	ARPA-SIM – Italy
	NORLAMEPS	Met.NO
	ALADIN LAEF	ZAMG / Austria
	OMSZ ALADIN EPS	Hungary
	COSMO DE EPS	DWD – Germany
	GLAMEPS	DNMI/Univ Oslo –Norway
	EPS	Czech
	EPS	Croatia
	PEARCE	Meteo-France / France
	DMI - HIRLAM	DMI Denmark
NCAR	NCEP-SREF	NCEP
	UWME	Univ Washington
	NSSL EPS	Oklahoma
	EnKF	Univ Washington
	CMC LAM EPS	MS / Canada
CMA	CMA-WRF LEPS	CMA/China
	JMA MRI EPS	MRI/Japan
	KOREA EPS	Korean Met Admin.

TIGGE LAM Output Parameters Archiving
2nd phase

There is a general consensus about the idea to plan, for the future, a decentralized archiving systems based on Regional Centres

- **This will be harmonized with the GIFS development phase**

- **This should be coordinated at regional level in the THORPEX geography**

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Clear common interests and objectives: issues now under planning and discussion

SRNWP

EurEPS

- **A document defining a set of verification methods …..and .. a set of cases or periods for verification.**
- **A database of a range of ensemble forecasts and observations…..,**
- **A report on the benefits of a grand LAM-EPS for the prediction of high-impact weather events**
- **Definition of a European contribution to TIGGE-LAM.**

- **LAM EPS output archiving**

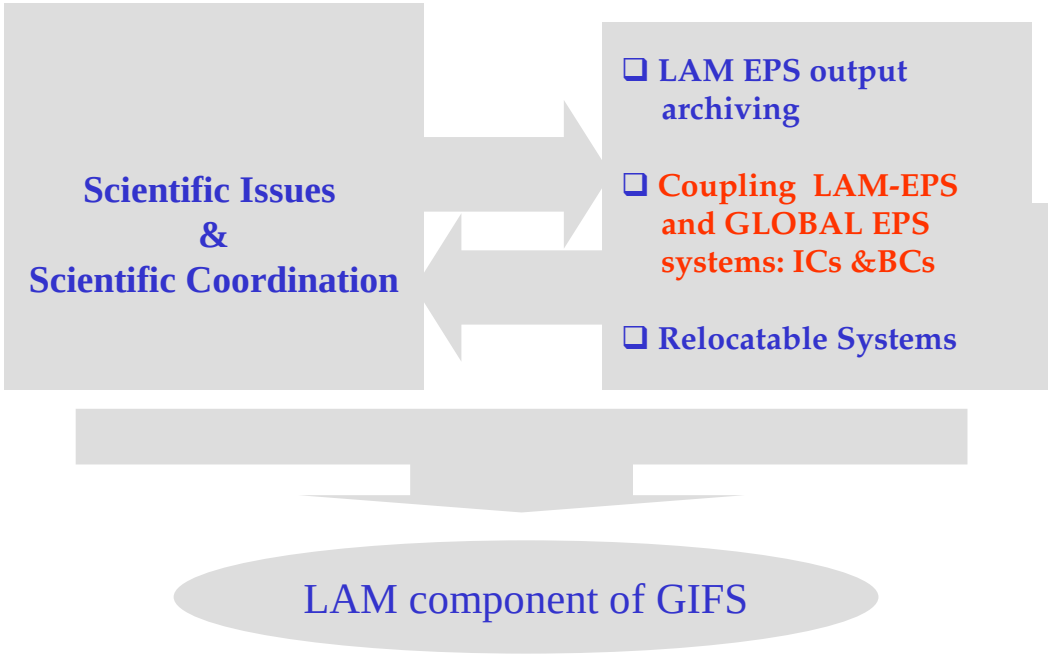
SRNWP

Verification

SRNWP

Interoperability

- **D1: A report documenting the standard output format and including a list of parameters for which the output format is to be applied. …….**
- **D2: Documentation describing the requirements and specification for the adaptor software (hereafter adaptors). ……**
- **D3: Four 2-way adaptors that transform the output from every LAM (hereafter LAM) to the standard output format and vice versa. Documentation will also be provided. …..**
- **D4: Enhancements to existing software tools that enable all LAMs to process data from the four Global Model providers. ……. ….. (*Refine the work plan for delivery of D4 ready for the start of Year 3 (September 2010)*)**



Coupling Globals and LAMs: Initial and Boundary Conditions

The concept of GIFS and of Adaptive Forecasting Systems would benefit of a good interoperability as regards the coupling between the different LAM and the different Global Models.

It is clear that this vision must deal with the many problems related to the huge amount of coordinated work to be devoted to this task as regards both technical and scientific aspects.

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Coupling Globals and LAMs: Initial and Boundary Conditions

Two options were evaluated about the possible formats to provide initial and boundary conditions:

1. **Initial and Boundary conditions provided on a standard 3D grid:**
   - on a lat-lon grid at horizontal resolutions adequate to the original model resolution;
   - on pressure levels with a number of vertical levels high enough to minimize the loss of information;
   - in terms of standard and pre-defined physical variables.

2. **Initial and Boundary conditions provided on the global models original "computational grid"**

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Coupling Globals and LAMs: Initial and Boundary Conditions

Both options present advantages and disadvantages but there is a preference for the option 2 (original model levels)

Due to the complex interoperability aspects underlying this issue, it is really important to be well phased with similar initiatives

The coupling of Global models with LAMs will be matter of cooperation and coordination with the INTEROPERABILITY project of the Short Range Numerical Weather Prediction Programme of EUMETNET (the EUropean METeorological services NETwork).

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Clear common interests and objectives: issues now under planning and discussion

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- **LAM EPS output archiving**
- **Coupling LAM-EPS and GLOBAL EPS systems: ICs &BCs**
- **Relocatable Systems**

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Coupling Globals and LAMs: Initial and Boundary Conditions Archiving

- Temporary archive of daily "real time" data.
  - These data should be stored at the producing centres for a very short time from 3 to 10 days depending on the restrictions/possibilities of each producing centre.

- Permanent archive on selected periods (e.g. during specific projects, Forecast Demonstration Projects, Research Demontration Projects, etc.etc.).
  - These data should be stored at the producing centres. Another option could be to include these archives in the overall TIGGE archive centres.

- Permanent archive for Special Cases related to severe events.
  - As above. These data should be stored at the producing centres. Another option could be to include these archives in the overall TIGGE archive centres.

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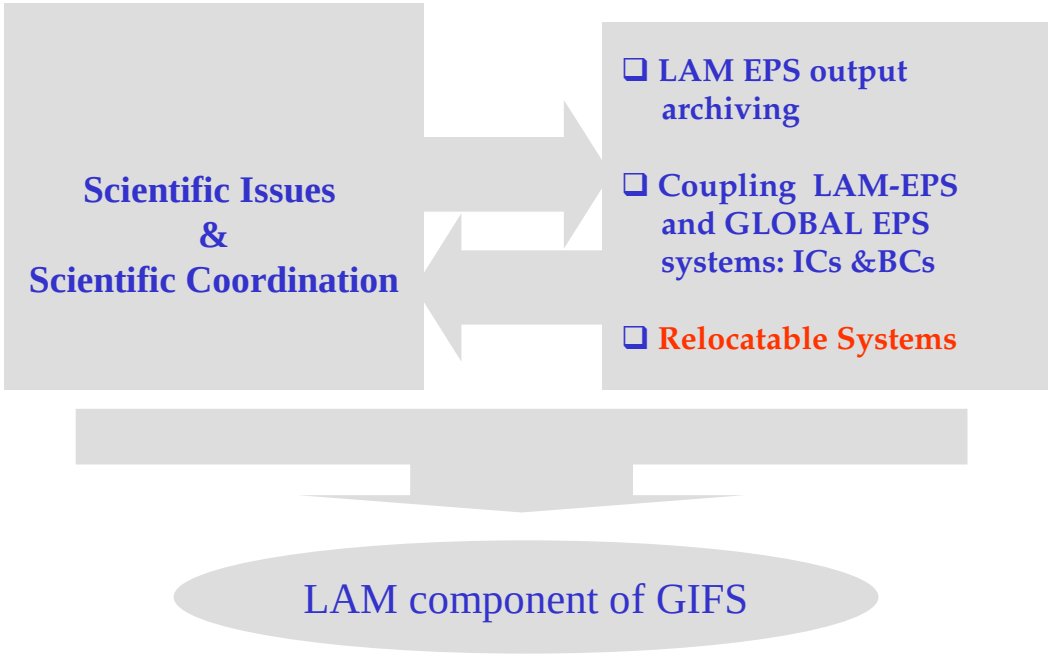

Relocatable systems

In TIGGE LAM two system components were foreseen:

- **A Fixed Component: which is formed by all the LAM EPS systems running operationally over fixed geographical domains at a suitable resolution and fulfilling all the TIGGE requirements.**

- **A Mobile/Relocatable Component which should be a real interactive component to be operated on demand with the required set-up characteristics.**

Non-homogeneous LAM EPS systems distribution

- Regions with more systems covering the same area
- Regions without LAM EPS implementations

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TIGGE LAM and GIFS

LAM ensemble is a strategic component of TIGGE and of the GIFS considering the need/ambition to optimize the forecasting system in real time.

During the Phase 2, TIGGE LAM and TIGGE should progressively merge together also considering the common general infrastructure they will be based on.

The interactive nature of GIFS will require the definition of a common methodology to asses the quality of systems to be activated on demand. This issue should be strongly coordinated with the THORPEX regional committees also to

- evaluate priorities related to geographical areas and associated severe weather phenomena
- Define the test- periods by considering the inventory of severe events and the observational data set available

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Cooperation with WMO WG MWF (chair. Jeanette Onvlee)

Cooperation with WMO WG Verification (chair. Barbara Brown)

- Test period
- Data set
- Methodologies

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TIGGE LAM and GIFS

It should be nice to present some projects to relocate some of the European systems in other regions

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1st plenary TIGGE LAM meeting

First TIGGE LAM meeting

Bologna 19-21 January 2009

Related programmes/initiatives:	Archiving TIGGE LAM products	Interoperability aspects related to ICs & BCs	Relocatable systems and GIFS	Scientific aspects and activities
SRNWP *Programmes* *Presentations* ……..				•Presentations and contributions also from •The WWRP WG on Mesoscale Weather Forecasting •The expert team on EPS •The WGNE Joint Working Group on Verification) •The Beijing RDP •……..

Concluding Remarks

- The Multi-model concept in its wider sense (more models, more ensembles, etc.) is one of the main issues to be investigated in TIGGE and in TIGGE LAM
- The necessary high level of interoperability implies a strong cooperation to facilitate the exchange of products both as regards the model systems output and the ICs/BCs files.
- Europe is the region with more initiatives in LAM Ensemble Predictions and this is a perfect situation to give very valuable contributions to TIGGE LAM
- The SRNWP Programmes are so close to TIGGE LAM that every effort must be done to ensure the maximum cooperation and sharing of resources.

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Thank you!

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TIGGE LAM PANEL
Terms of reference

The Panel should:

- **propose a possible structure of the TIGGE-LAM component.**
- **maintain the necessary liaison with already existing LAM EPS initiatives and with related new projects.**
- **encourage a coordinated approach to LAM EPS**
- **should formulate proposals to facilitate the interoperability (different LAMs driven by different GCMs) of the different modelling systems contributing to TIGGE.**
- **formulate proposals for the creation of a coordinated distributed archive of limited-area ensemble forecasts.**
- **contribute to the definition of scientific issues related to LAM EPS**
- **propose guidelines as regards LAM EPS validation, calibration and combination, in a close coordination with the GIFS-TIGGE WG.**

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