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*Spatiotemporal **MVL** Analysis of EPS: Application to DEMETER multi-model Seasonal Predictions*

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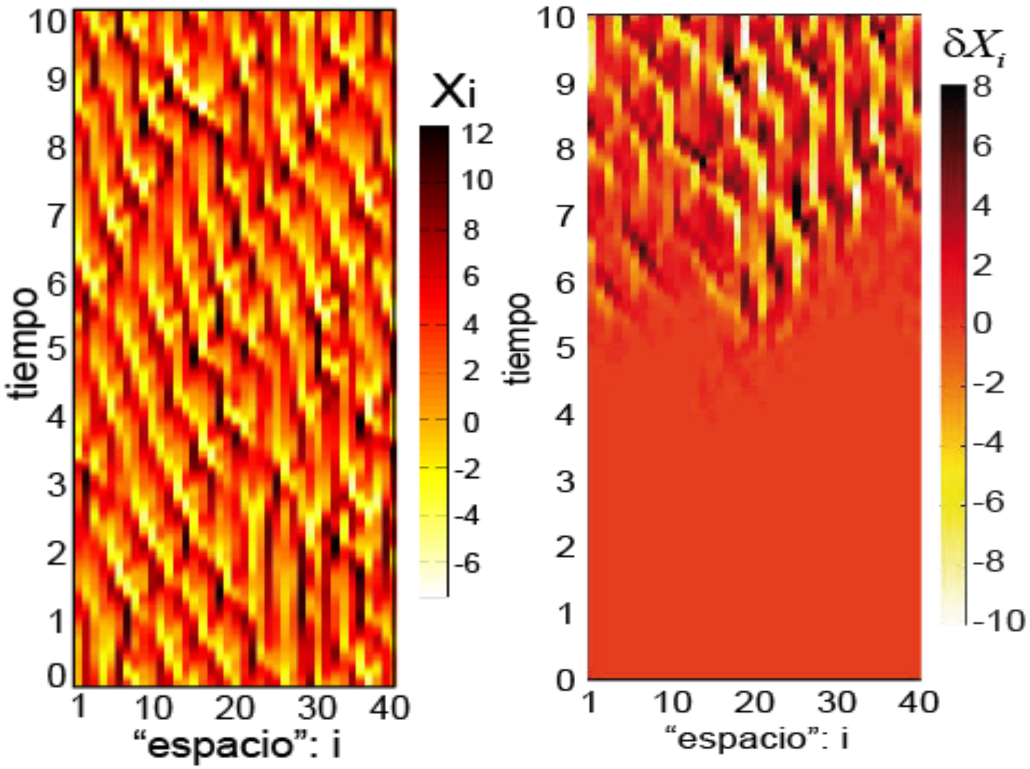
ECODYC10. Max Plack Institute Physics Complex Systems. Dresden, 25-29/1/2010

TOY Models (Physics)

Lorenz96

$$\frac{dx_i}{dt} = -x_{i-1}(x_{i-2} - x_{i+1}) - x_i + F,$$

$$i = 1, \ldots, L,$$



OPERATIONAL Models (Physics + Engineering)

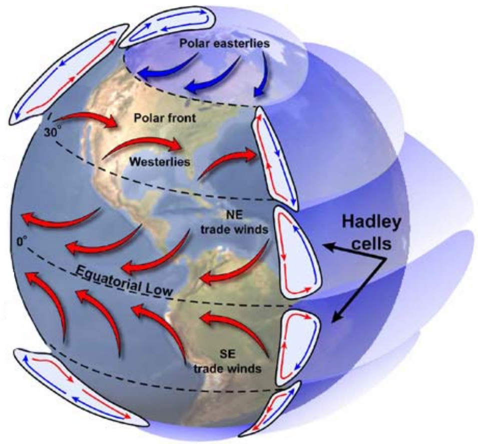
$$\frac{dv}{dt} = -\alpha\nabla p - \nabla\phi + F - 2\Omega \times v$$

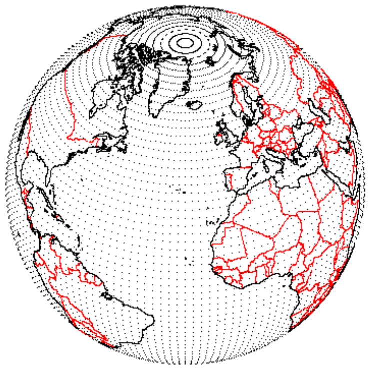
$$\frac{\partial\rho}{\partial t} = -\nabla\cdot(\rho v)$$

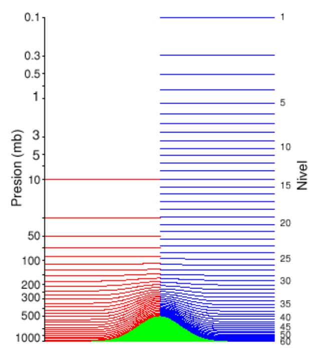
$$p\alpha = RT$$

$$Q = C_p\frac{dT}{dt} - \alpha\frac{dp}{dt}$$

$$\frac{\partial\rho q}{\partial t} = -\nabla\cdot(\rho v q) + \rho(E - C)$$







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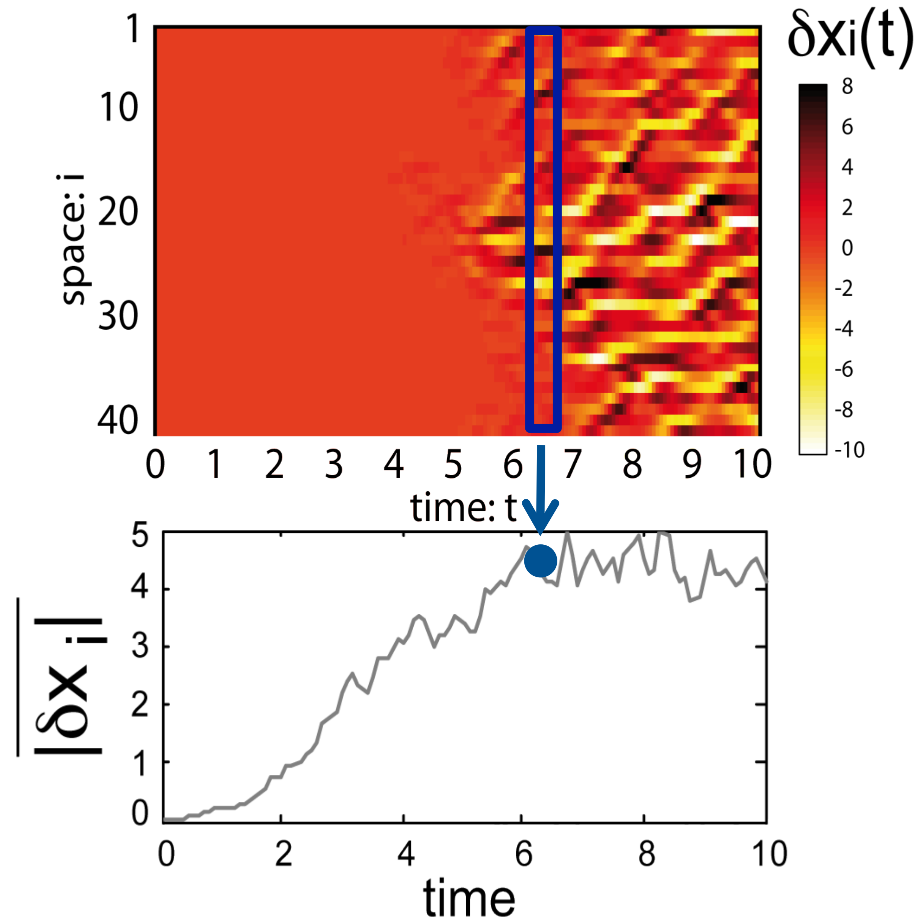
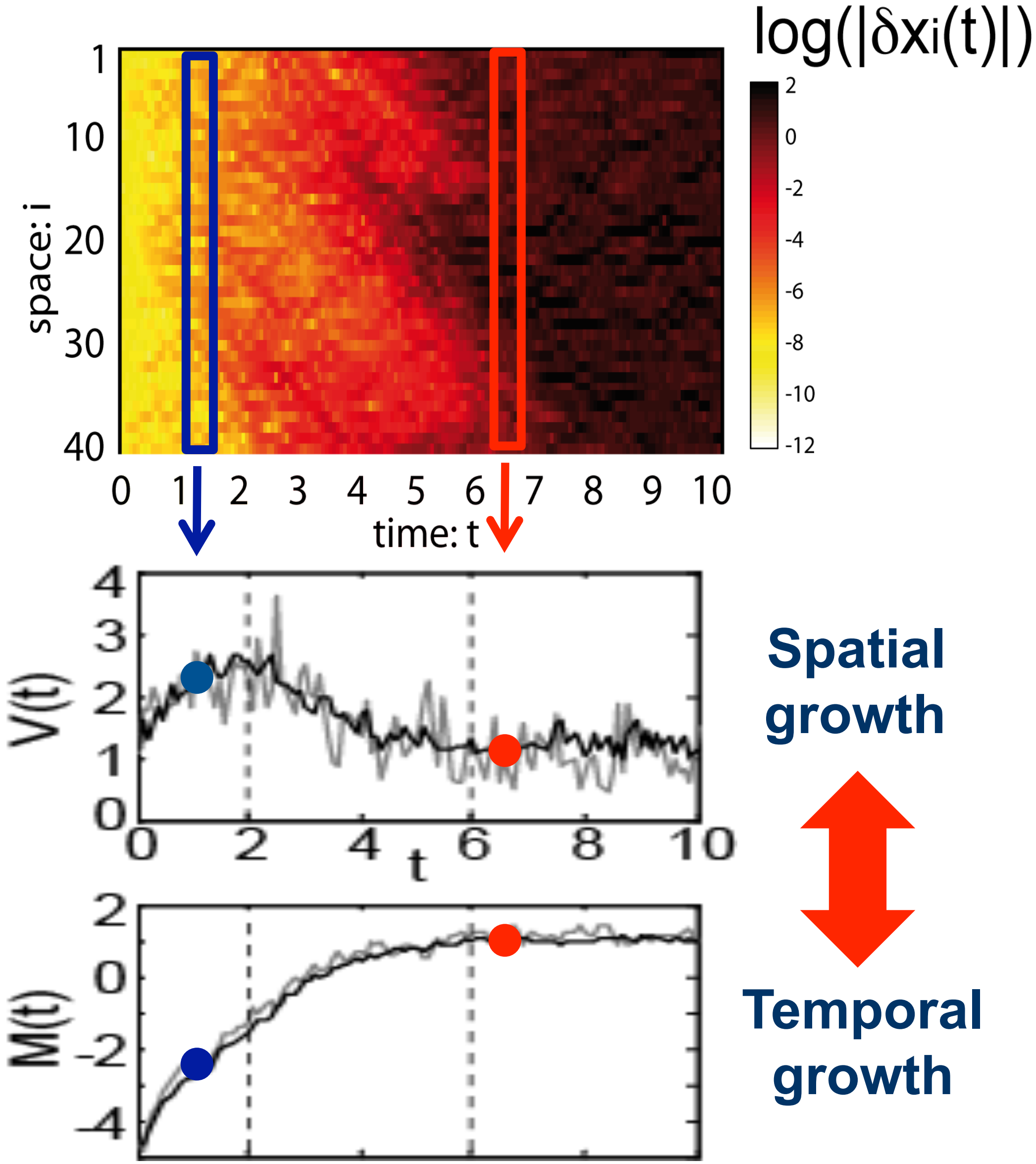
- ***Going back to theory:***
  - ***Extension to two-scale systems (Lorenz96)***

Error Growth
(Primo et al. 2005, 2007)

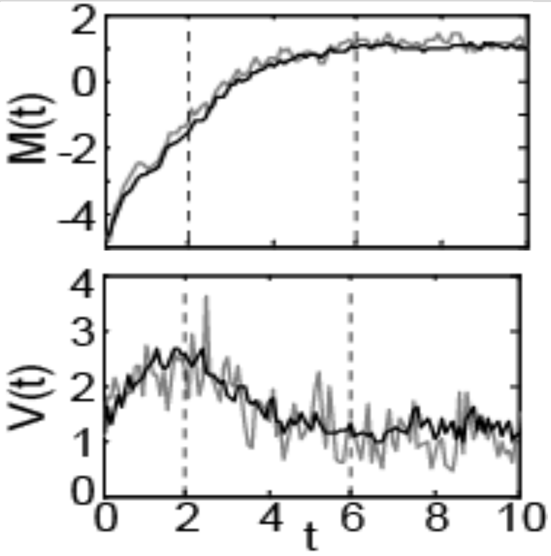
$$\delta x_i(t) = x_i^p(t) - x_i(t)$$

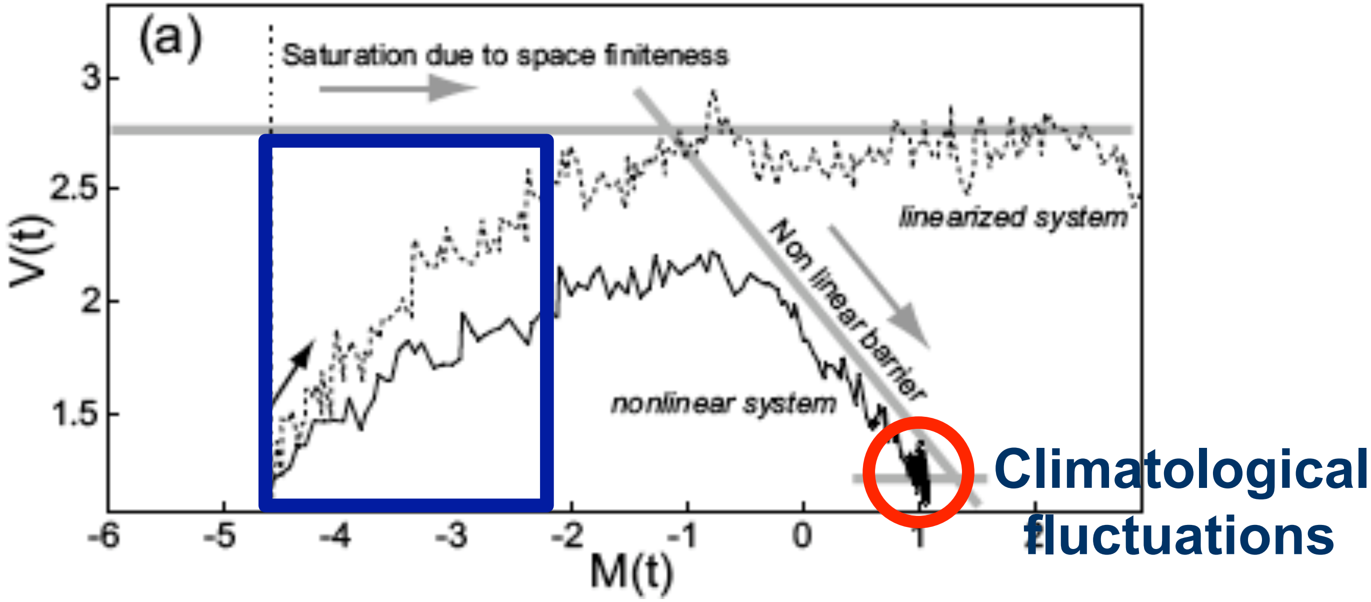
Control



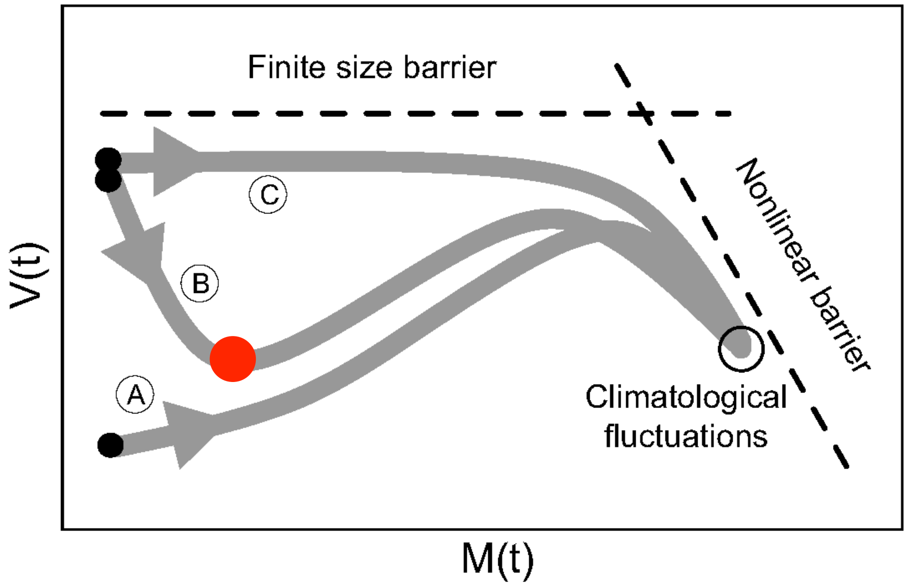


MVL Diagram





The MVL diagram provides a "fingerprint" of the system dynamics



Moreover, the initial transient is related to the initial perturbations.

A: Random and spatially uncorrelated

C: Assimilated perturbations (e.g. bred vec.)

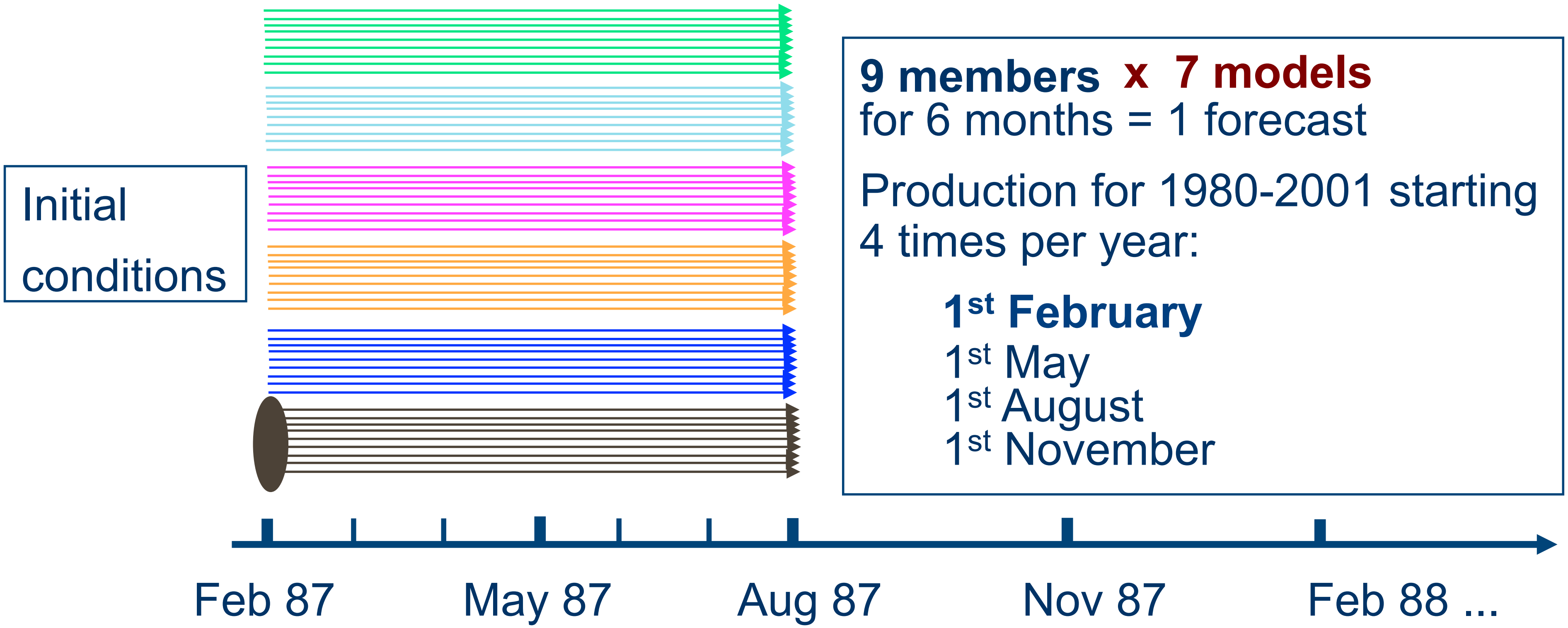
B: Spatially correlated and non-assimilated (e.g. lagged)

DEMETER Seasonal Hindcast

thanks to Francisco Doblas-Reyes

Ocean-atmosphere global circulation models running ensemble initial condition perturbations (9 members) for seasonal forecasts.

Multi-model ensemble addresses the problem of model error.



9 members x 7 models
for 6 months = 1 forecast

Production for 1980-2001 starting 4 times per year:

- **1st February**
- 1st May
- 1st August
- 1st November

DEMETER GCMs

	CERFACS	ECMWF	INGV	LODYC	Météo-France	Met Office	MPI
atmosphere component	ARPEGE	IFS	ECHAM-4	IFS	ARPEGE	HadAM3	ECHAM-5
resolution	T63 31 Levels	T95 40 Levels	T42 19 Levels	T95 40 Levels	T63 31 Levels	2.5º x 3.75º 19 Levels	T42 19 Levels
atmosphere initial conditions	ERA-40	ERA-40	coupled AMIP-type experiment	ERA-40	ERA-40	ERA-40	coupled run relaxed to observed SSTs
reference	Déqué 2001	Gregory et al. 2000	Roeckner 1996	Gregory et al. 2000	Déqué 2001	Pope et al. 2000	Roeckner 1996
ocean component	OPA 8.2	HOPE-E	OPA 8.1	OPA 8.2	OPA 8.0	GloSea OGCM, based on HadCM3	MPI-OM1
resolution	2.0º x 2.0º 31 Levels	1.4º x 0.3º-1.4º 29 Levels	2.0º x 0.5º-1.5º 31 Levels	2.0º x 2.0º 31 Levels	182 GP x 152 GP 31 Levels	1.25º x 0.3º-1.25º 40 Levels	2.5º x 0.5º-2.5º 23 Levels
ocean initial conditions	ocean analyses forced by ERA-40	ocean analyses forced by ERA-40	ocean analyses forced by ERA-40	ocean analyses forced by ERA-40	ocean analyses forced by ERA-40	ocean analyses forced by ERA-40	coupled run relaxed to observed SSTs
reference	Delecluse and Madec 1999	Wolff et al. 1997	Madec et al. 1998	Delecluse and Madec 1999	Madec et al. 1997	Gordon et al. 2000	Marsland et al. 2002
ensemble generation	windstress and SST perturbations	windstress and SST perturbations	windstress and SST perturbations	windstress and SST perturbations	windstress and SST perturbations	windstress and SST perturbations	9 different atmospheric conditions from the coupled initialization run (lagged method)

GCMs building blocks

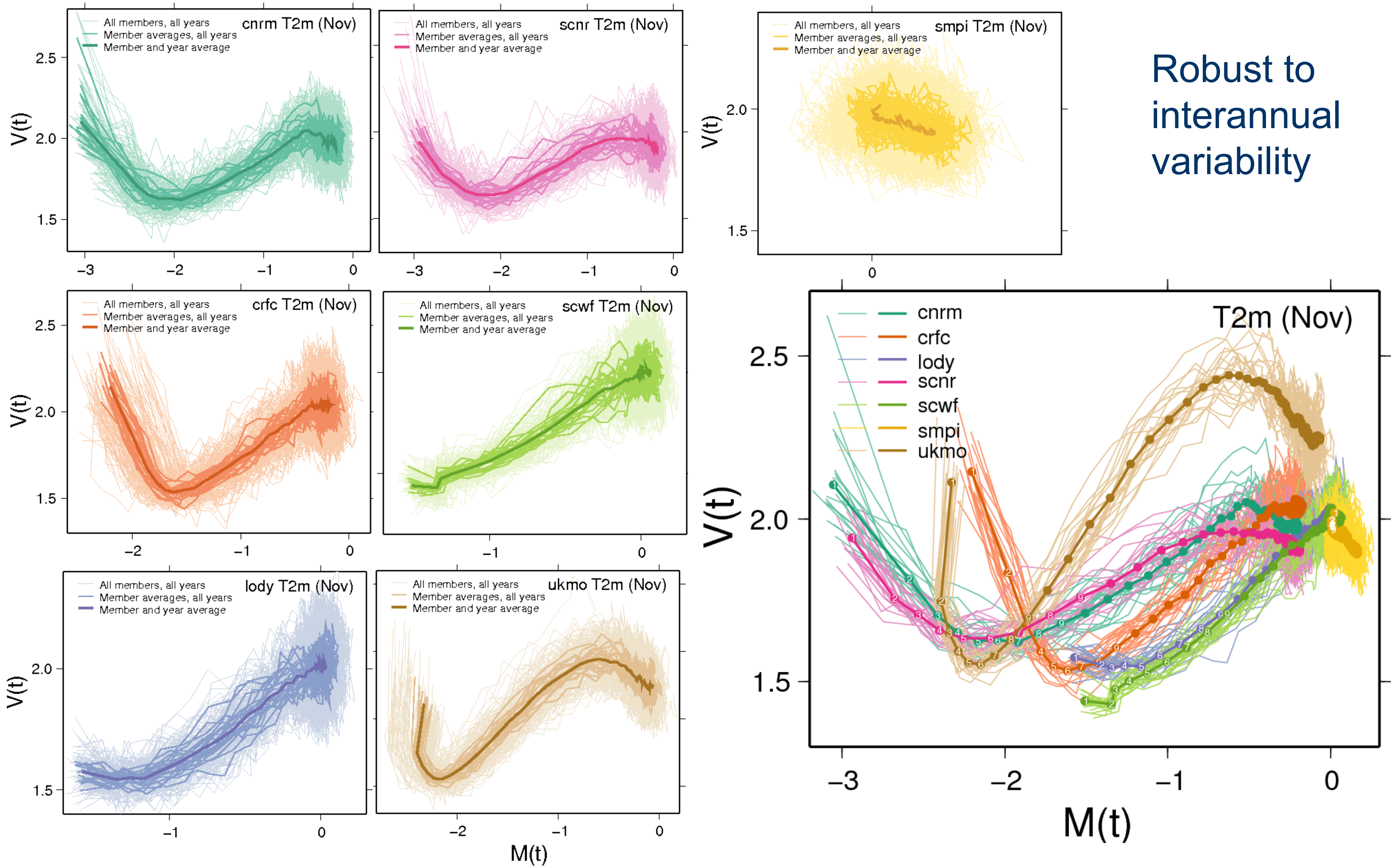
Label	Atm	Ocn	Simulation center
cnrm	A	a”	MétéoFrance
crfc	A	a	CERFACS
lody	B	a	LODYC
scnr	D’	a’	INGV
scwf	B	b	ECMWF
smpi	D	d	Max Plank Institute
ukmo	C	c	UK-MetOffice

Atmosphere models		Resolution
A	ARPEGE	T63L31
B	IFS	T95L40
C	HadAM3	2.5×3.75L19
D	ECHAM5	T42L19
D’	ECHAM4	T42L19

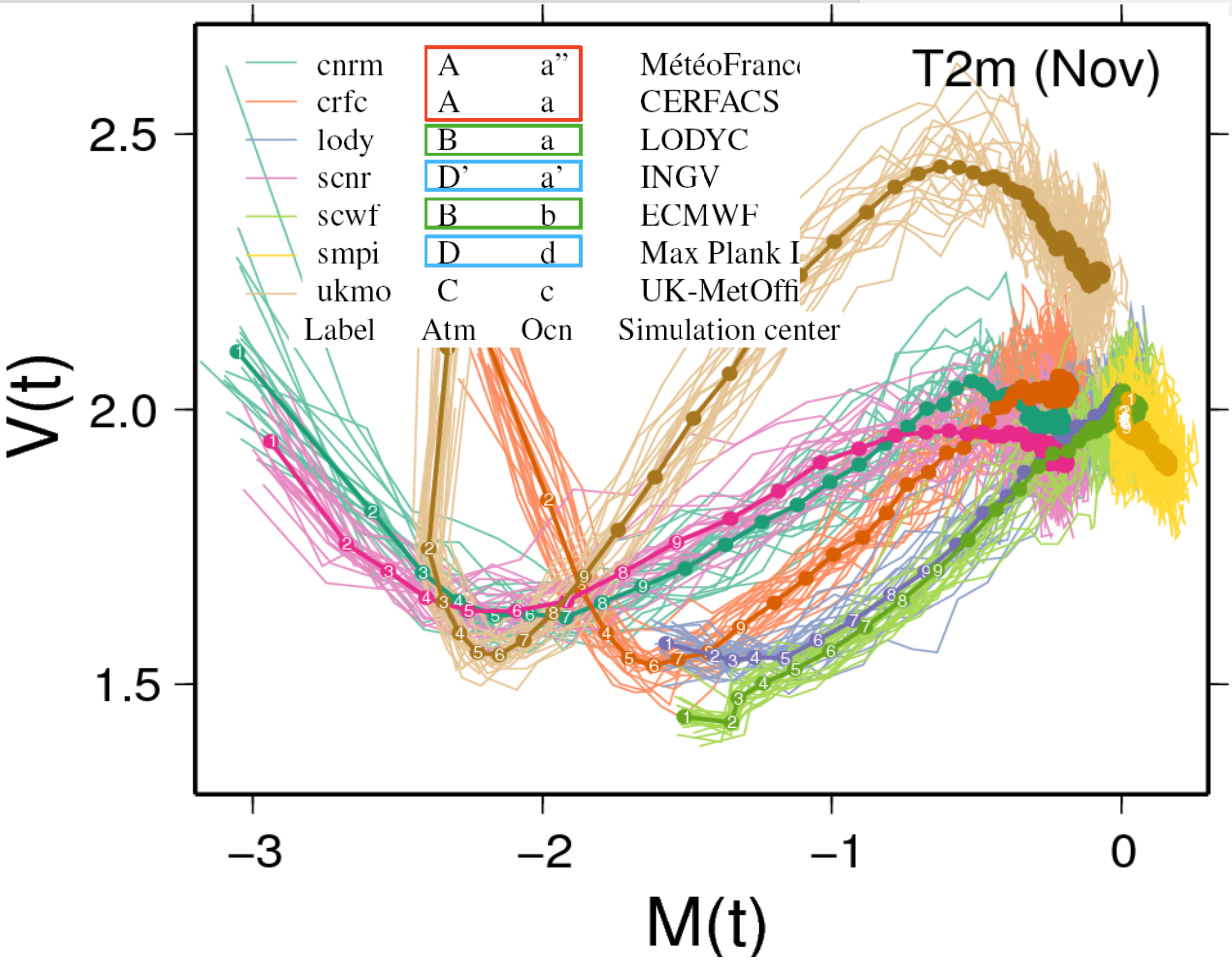
Ocean models		Resolution
a	OPA8.2	2.0×2.0L31
a’	OPA8.1	2.0×0.5-1.5L31
a”	OPA8.0	182×152L31
b	HOPE-E	1.4×0.3-1.4L29
c	GloSea	1.25×0.3-1.25L40
d	MPIOM1	2.5×0.5-2.5L23

Different models share common building blocks (atmospheric and/or oceanic components), so they cannot be considered as equiprobable representations of the model error. Thus, we need some diagnostic tool to find similarities among models dynamically.

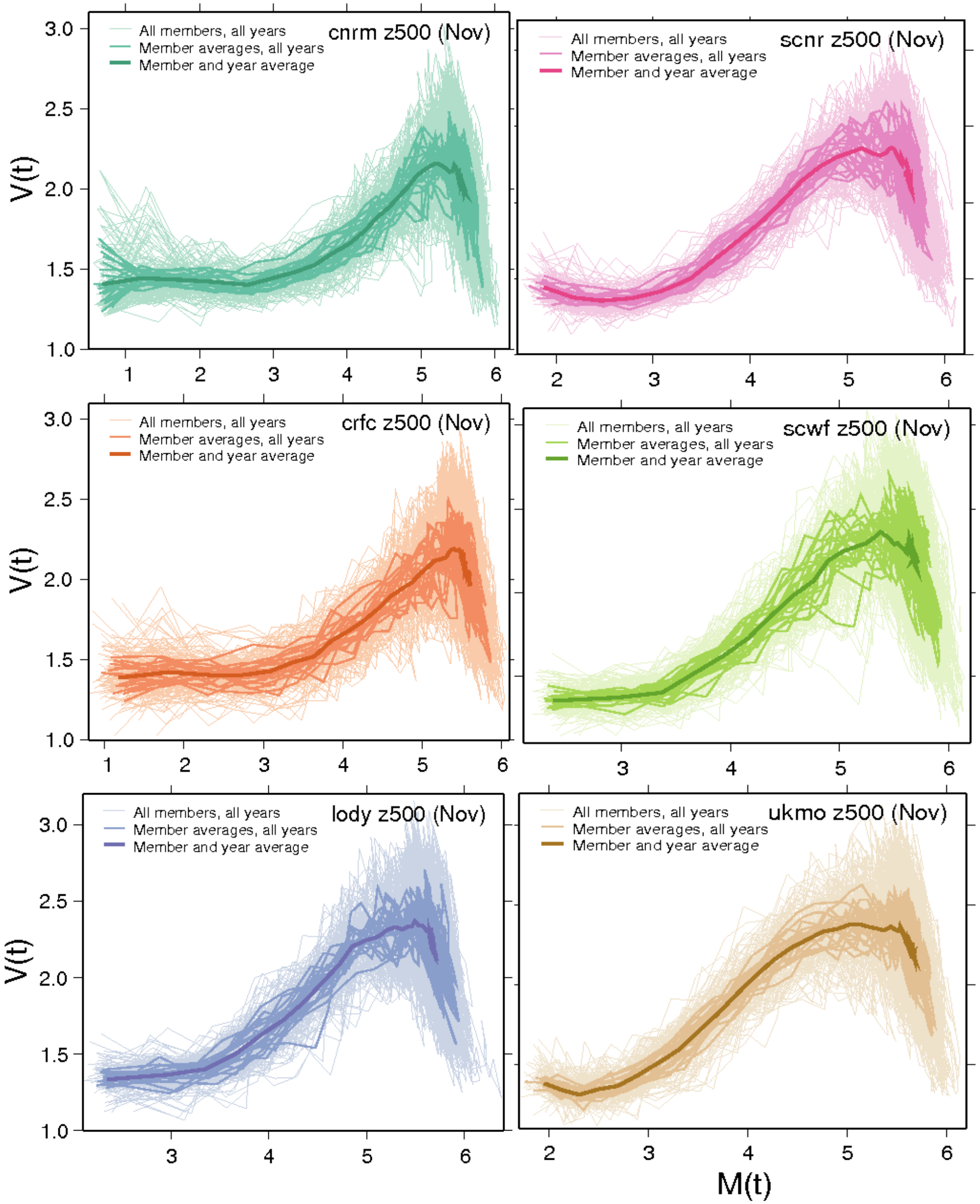
MVL for T2m

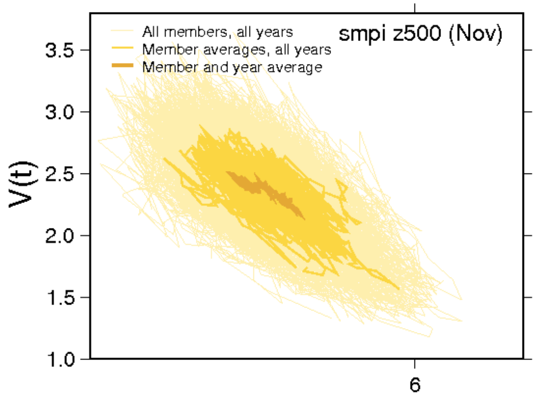


Robust to interannual variability

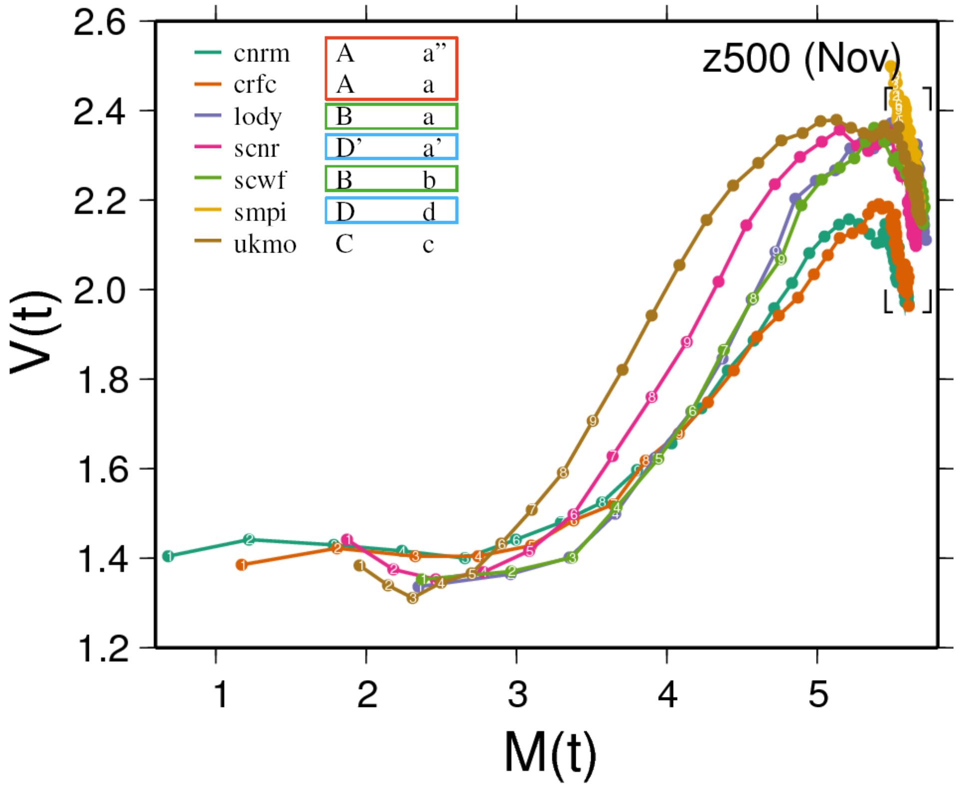

T2m (Nov)
cnrm A a” MétéoFrance
crfc A a CERFACS
lody B a LODYC
scnr D’ a’ INGV
scwf B b ECMWF
smpi D d Max Plank I
ukmo C c UK-MetOffi
Label Atm Ocn Simulation center
V(t)
2.5
2.0
1.5
M(t)
−3
−2
−1
0

MVL for z500





Robust to interannual variability



Model weighting

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A

Phil. Trans. R. Soc. A (2007) **365**, 2103–2116
doi:10.1098/rsta.2007.2070
Published online 14 June 2007

Probabilistic climate change predictions applying Bayesian model averaging

BY SEUNG-KI MIN*, DANIEL SIMONIS AND ANDREAS HENSE

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GEOPHYSICAL RESEARCH LETTERS, VOL. 30, NO. 12, 1629, doi:10.1029/2003GL017130, 2003

Probability of regional climate change based on the Reliability Ensemble Averaging (REA) method

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Abdus Salam ICTP, Trieste, Italy

L. O. Mearns
NCAR, Boulder, USA

ENSEMBLES

Project acronym: ENSEMBLES

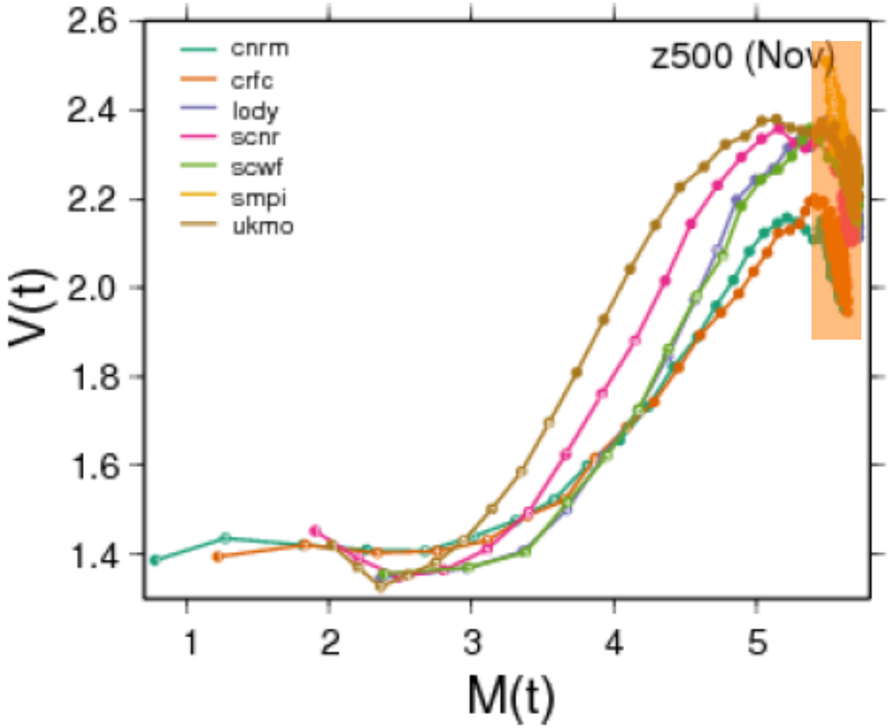
Project title: ENSEMBLE-based Predictions of Climate Changes and their Impacts

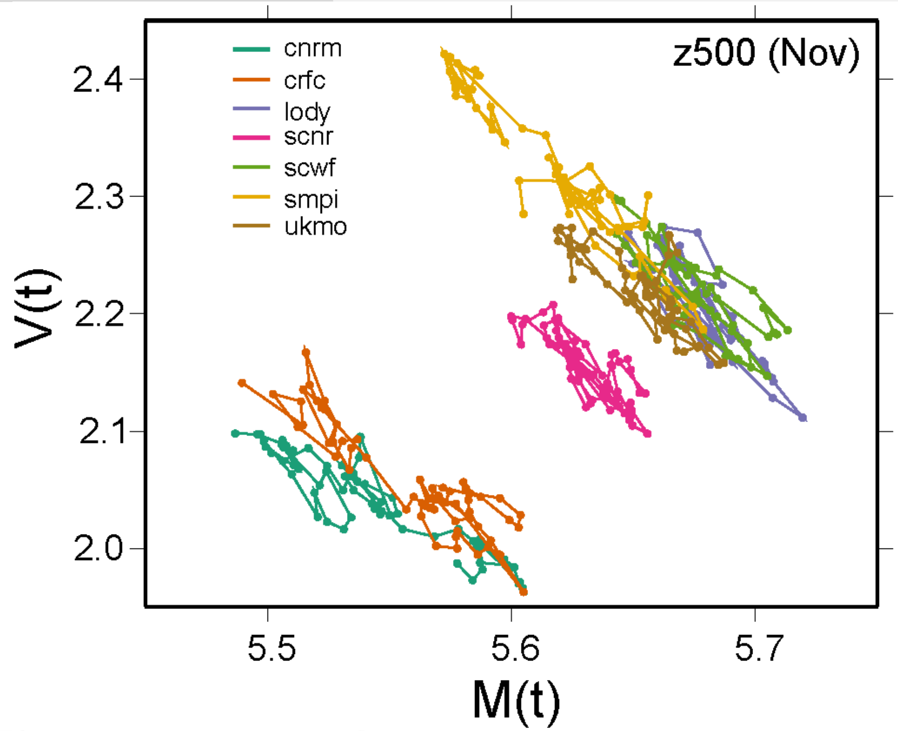
Deliverable D2B.6: Refinement of the Reliability Ensemble Averaging (REA) Framework
Actual submission date: February 2006

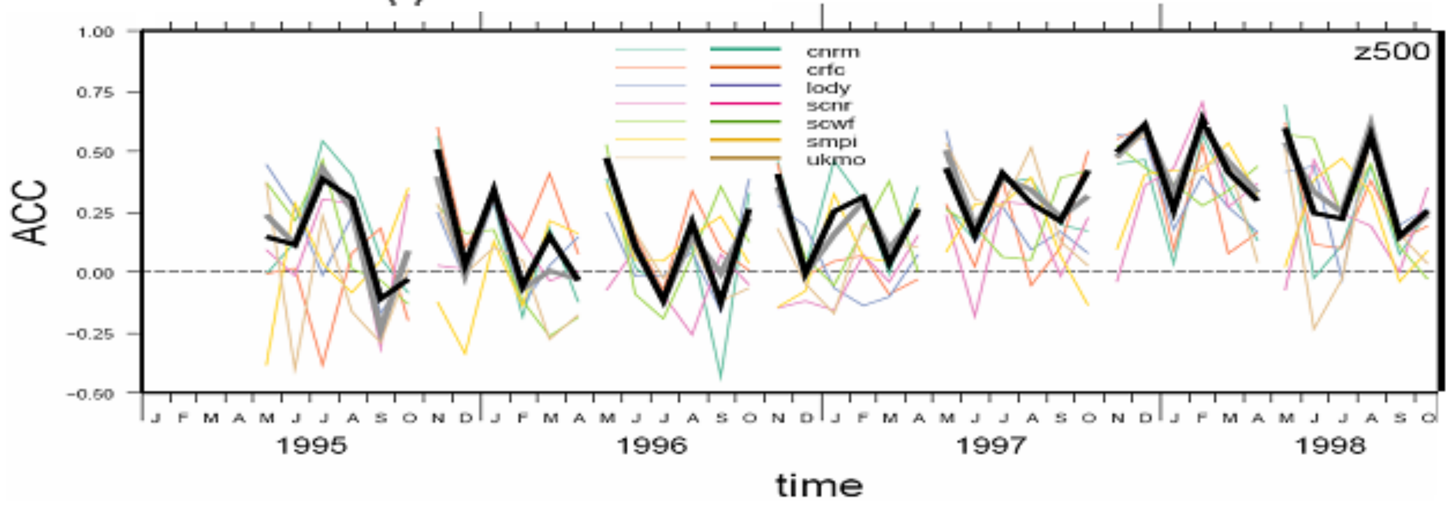
All these methods weight models according to performance.

Thus, if a "good" model is included several times in the ensemble, then the results will be biased towards this particular model.

Model Comparison & weighting



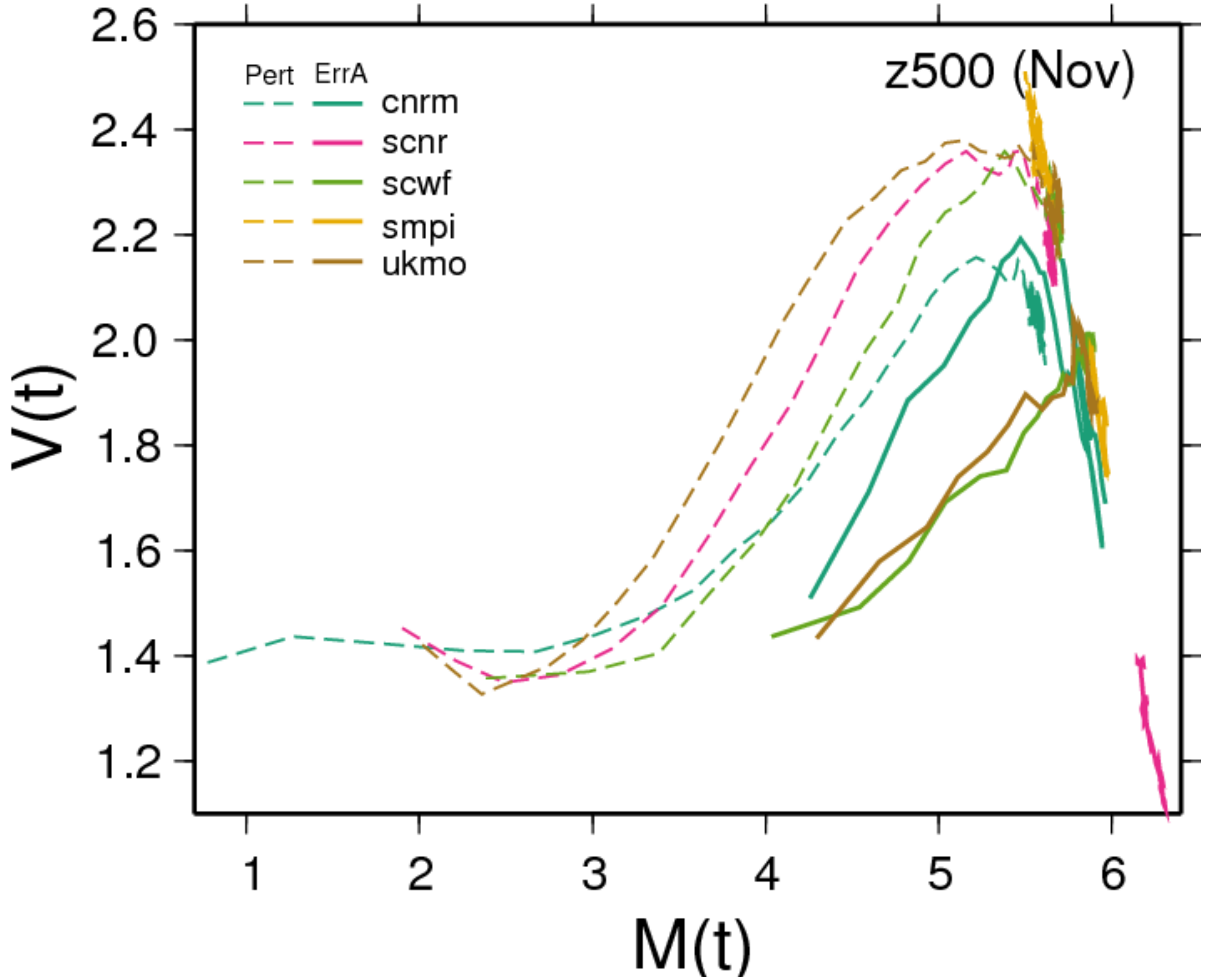




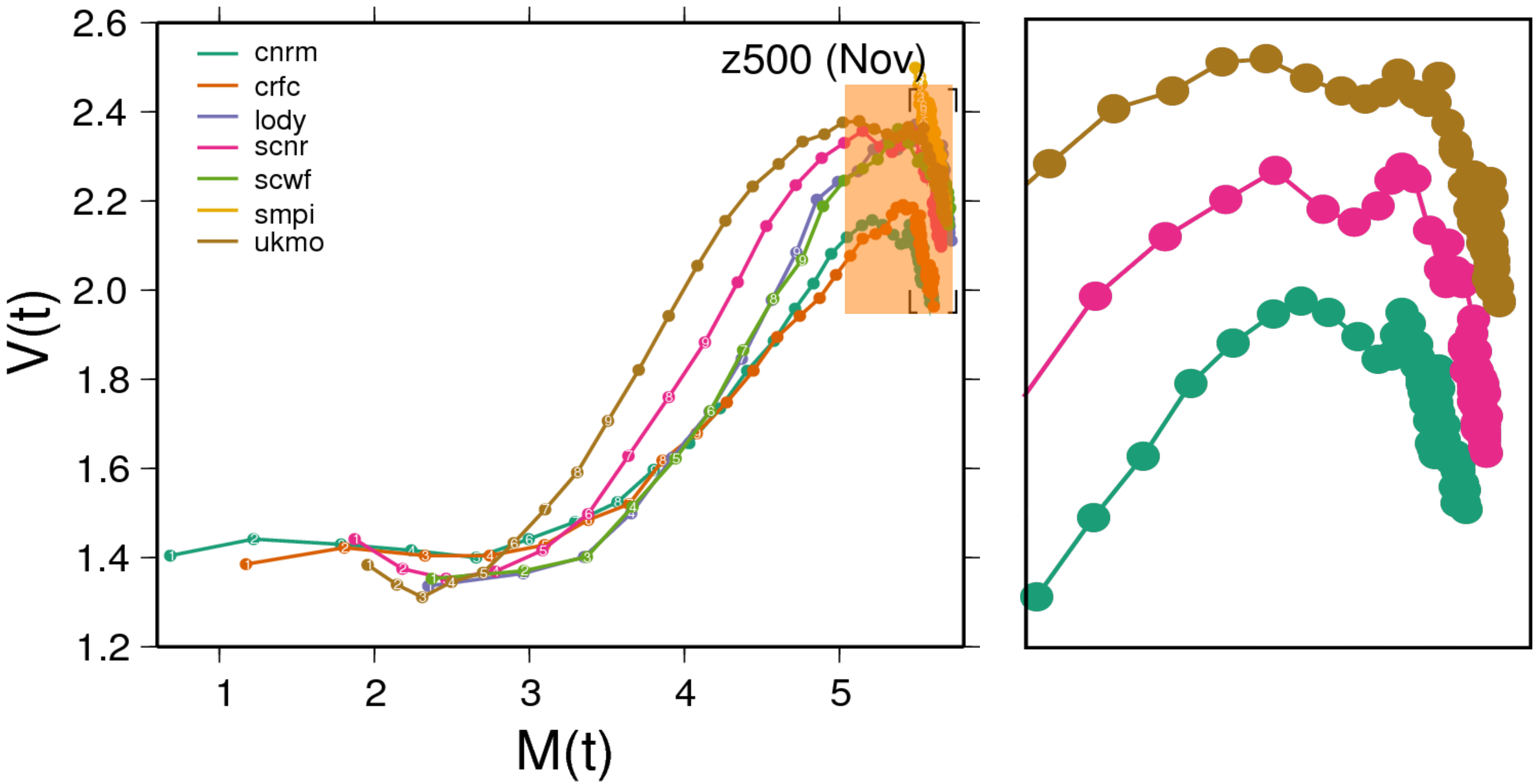
MVL control vs MVL reanalysis

$$\delta x_i(t) = x_i^p(t) - x_i(t)$$
Control

$$\delta x_i(t) = x_i^p(t) - x_i(t)$$
Reanalysis



Role of slow-fast dynamics

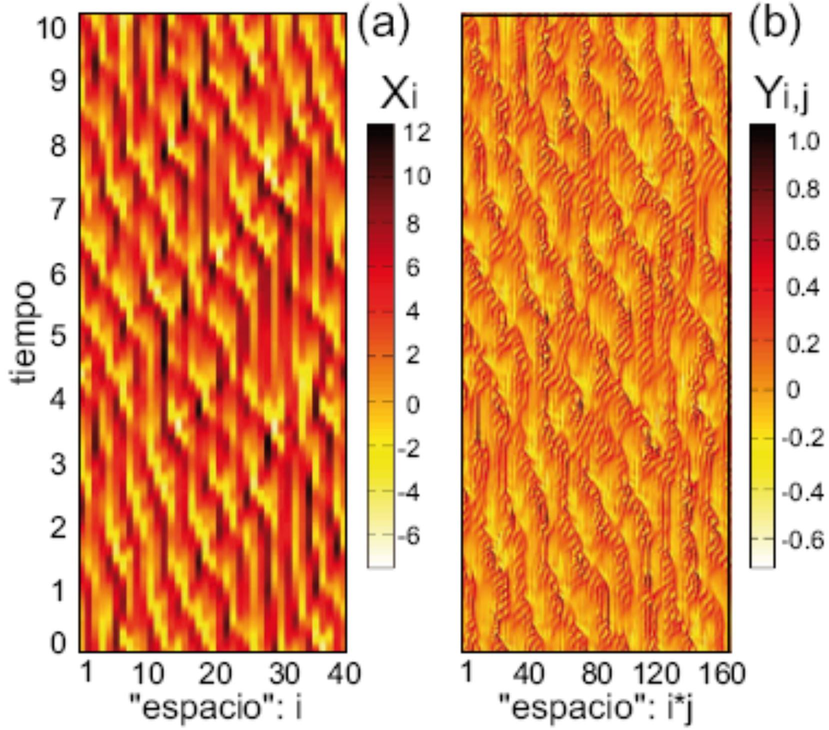


Two-Scale Lorenz96

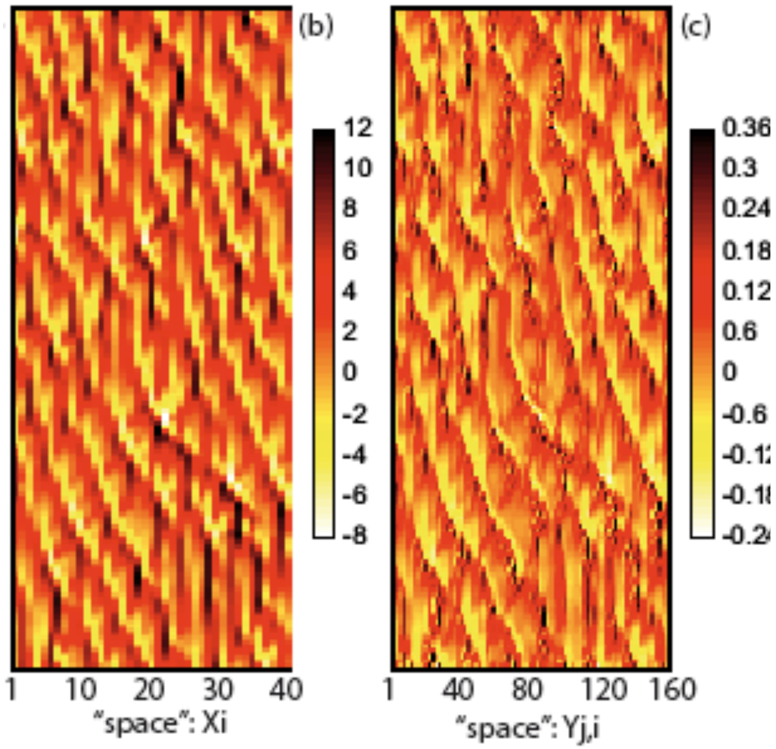
$$\frac{dx_i}{dt} = x_{i-1} \cdot (x_{i+1} - x_{i-2}) - x_i + F - \frac{hc}{b} \sum_{j=1}^{N} y_{j,i}$$

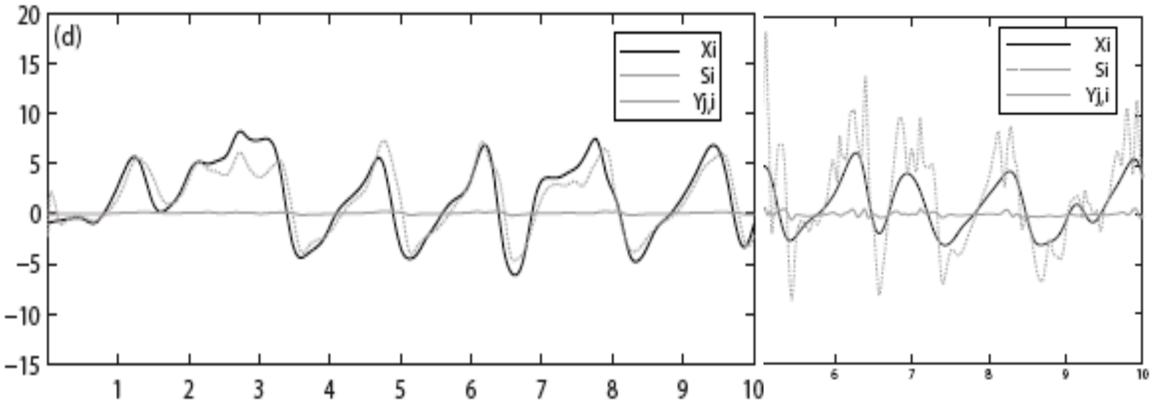
$$\frac{dy_{j,i}}{dt} = cby_{j+1,i} \cdot (y_{j-1,i} - y_{j+2,i}) - cy_{j,i} + \frac{hc}{b} x_i$$

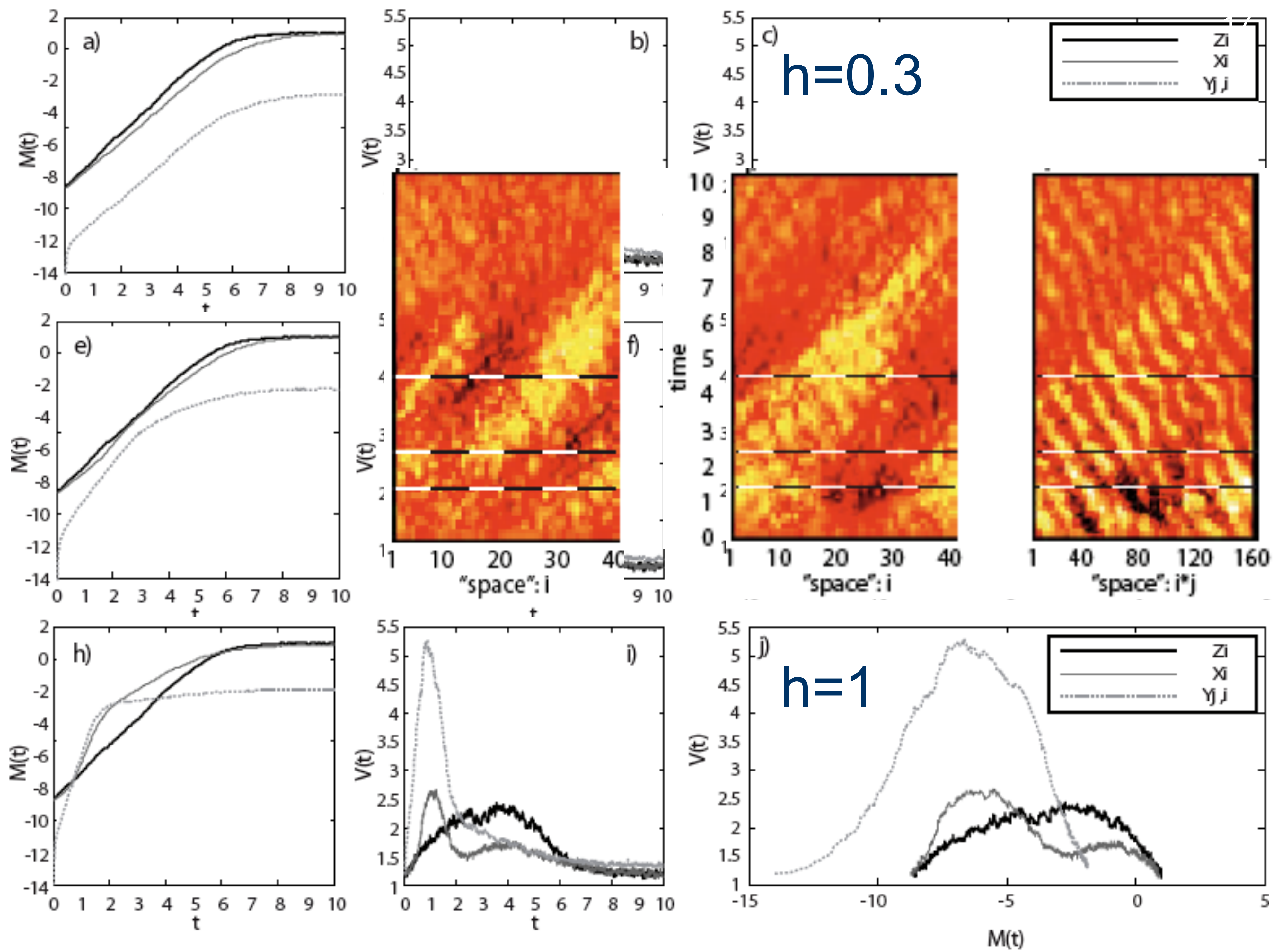
h=1



h=0.3

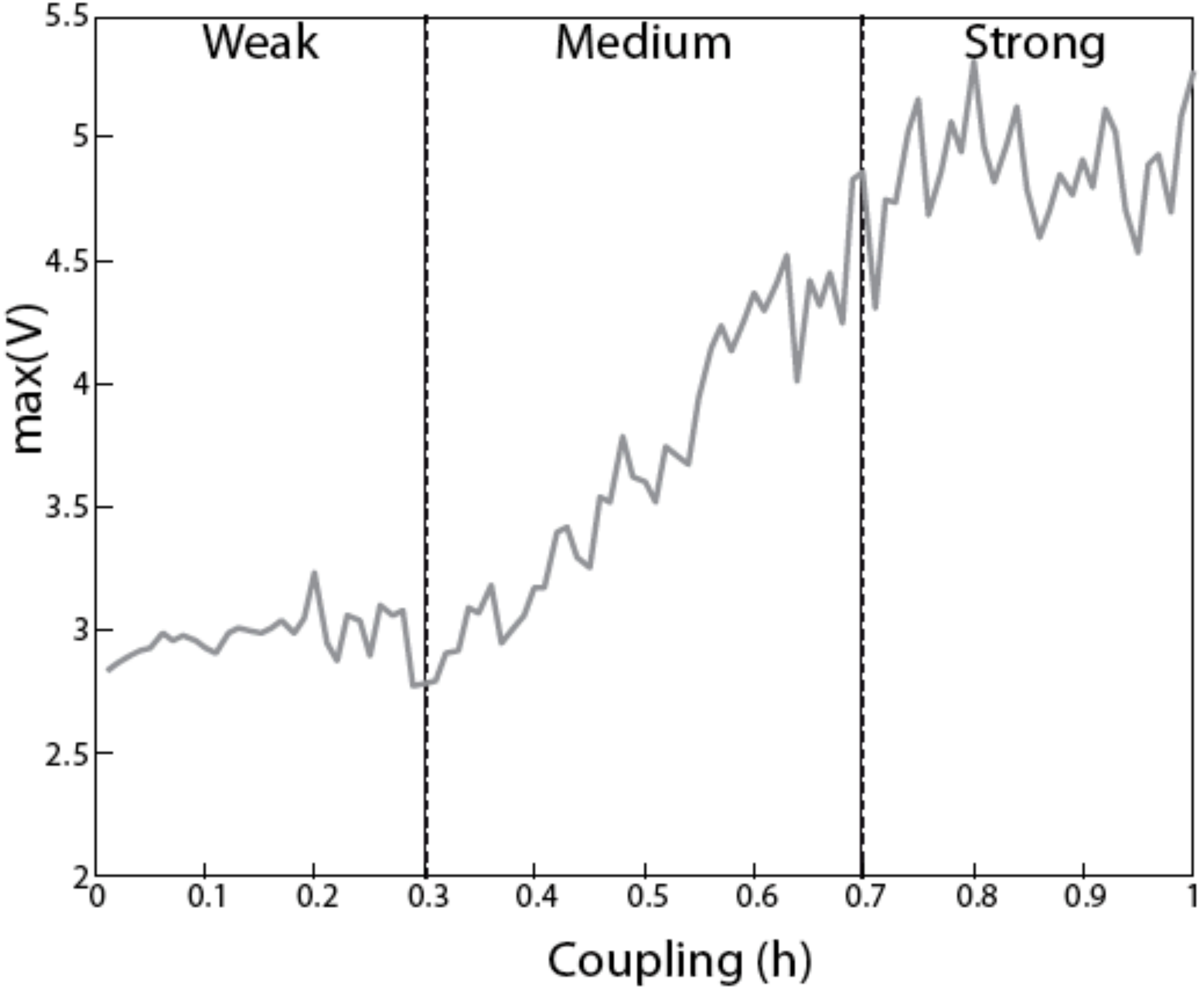






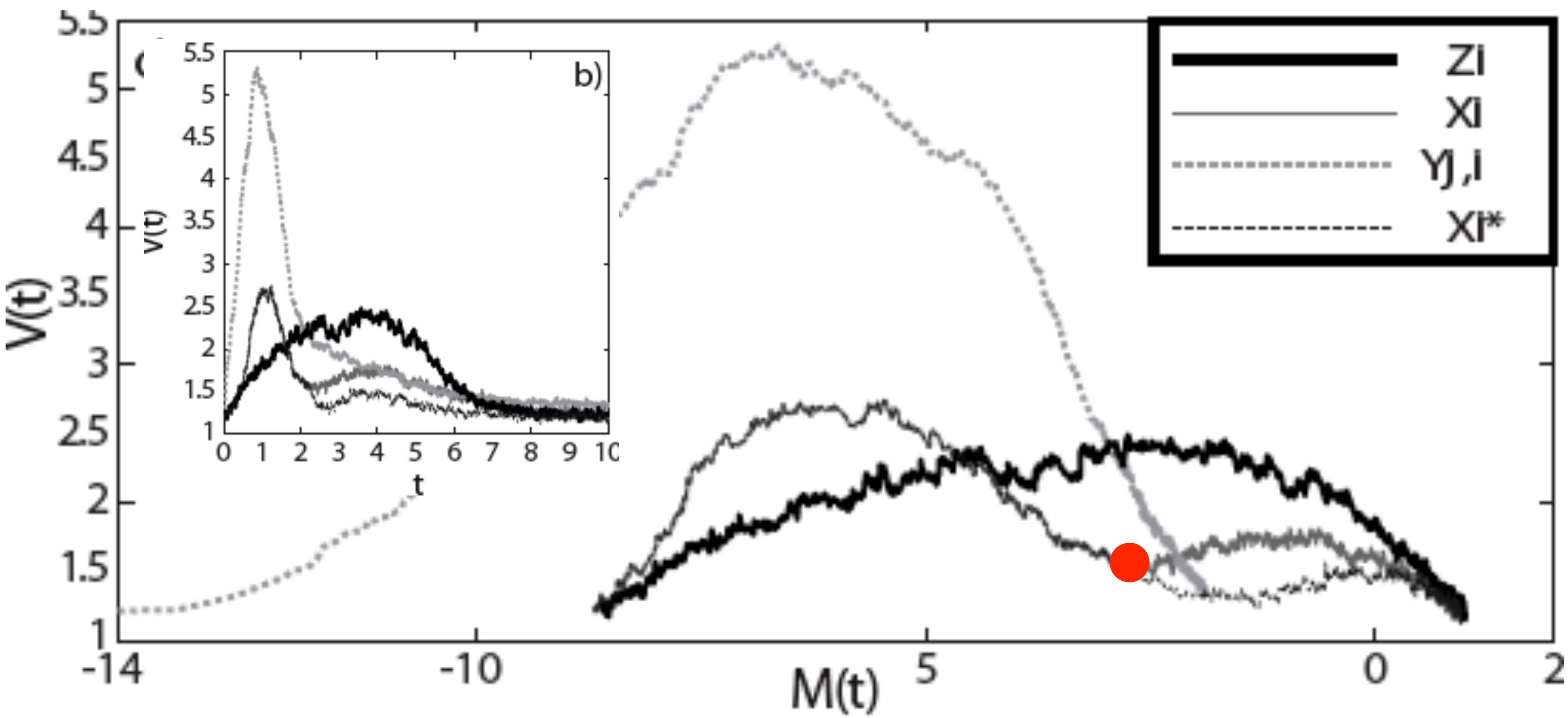
a)
b)
c)
e)
f)
h)
i)
j)
h=0.3
h=1
Zi
Xi
Yj,i
M(t)
V(t)
t
time
"space": i
"space": i*j

Sensitivity of the coupling param.



Fast variables vs Noise

The fast variables play a role in the dynamics of slow variables even after saturation. They cannot be substituted by an “effective” noise.



The MVL diagram is a powerfull diagnosis and characterization tool.

We (*operational meteorology*) can benefit from the advances in spatiotemporal nonlinear physics.

ALSO THE OTHER WAY AROUND.

More Info ...

http://www.meteo.unican.es

S. Herrera, J. Fernández, M.A. Rodríguez and J.M. Gutiérrez (2010)
Spatio-temporal Error Growth in the Multi-Scale Lorenz96 Model
Nonlinear Processes in Geophysics, submitted.

J. Fernández, C. Primo, A. S. Cofiño, J.M. Gutiérrez, M.A. Rodríguez (2009)
MVL Spatiotemporal analysis for model comparison. Application to the DEMETER Multi-model Ensemble
Climate Dynamics, 33, 233-243. DOI: 10.1007/s00382-008-0456-9

J.M. Gutiérrez, C. Primo, M.A. Rodríguez and J. Fernández (2008)
Spatiotemporal Characterization of Ensemble Prediction Systems.
The Mean-Variance of Logarithms (MVL) Diagram
Nonlinear Processes in Geophysics, 15, 109-114.