Environment
Canada

Scale separation in verification measures

B. Casati Recherche en Prévision Numérique (RPN)

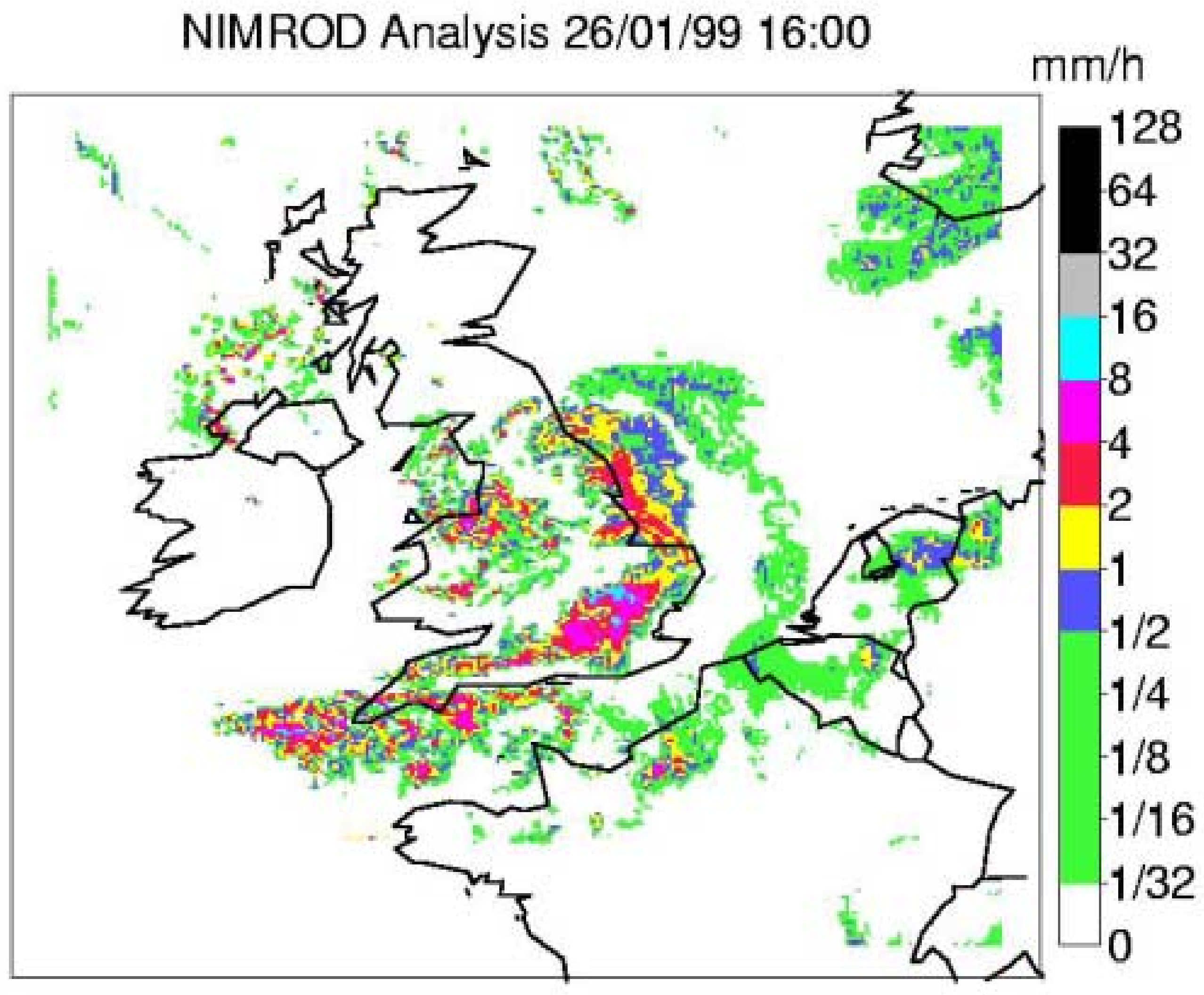
Talk outline:

- Motivations
- Review of some of the key approaches
  1. Briggs and Levine (1997)
  2. Casati et al. (2004)
  3. Denis et al. (2003), De Elia et al. (2001)
  4. Zepeda-Arce et al. (2000), Harris et al. (2001), Tustison et al. (2003)
- Discussion

Motivations

1. Different scale phenomena, different physics, different aspects of the model

2. Compare different spatial scale resolutions



Briggs and Levine (1997)

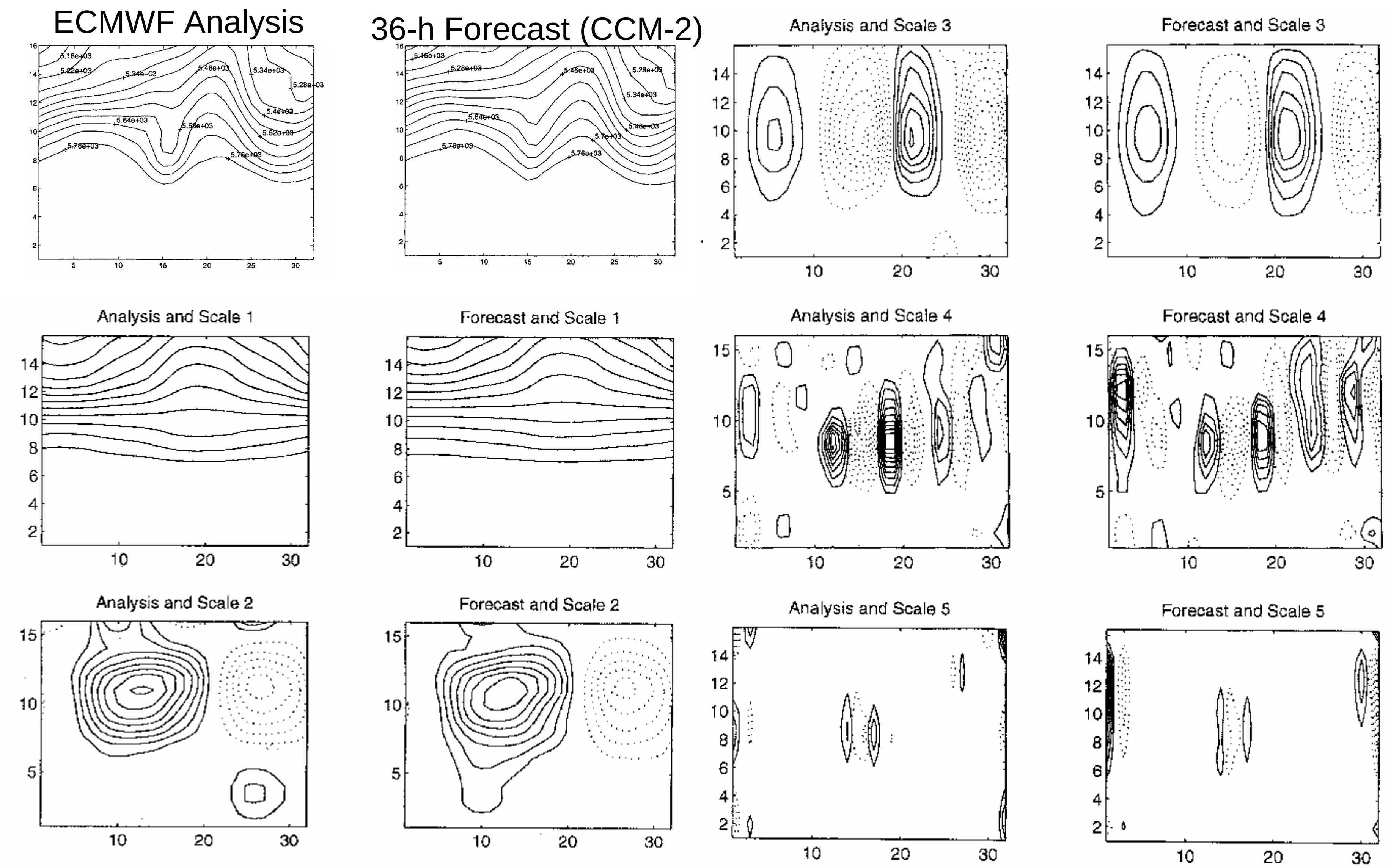
“*Wavelets and field forecast verification*”

Mon. Wea. Rev., vol. **125**, pp. 1329-1341

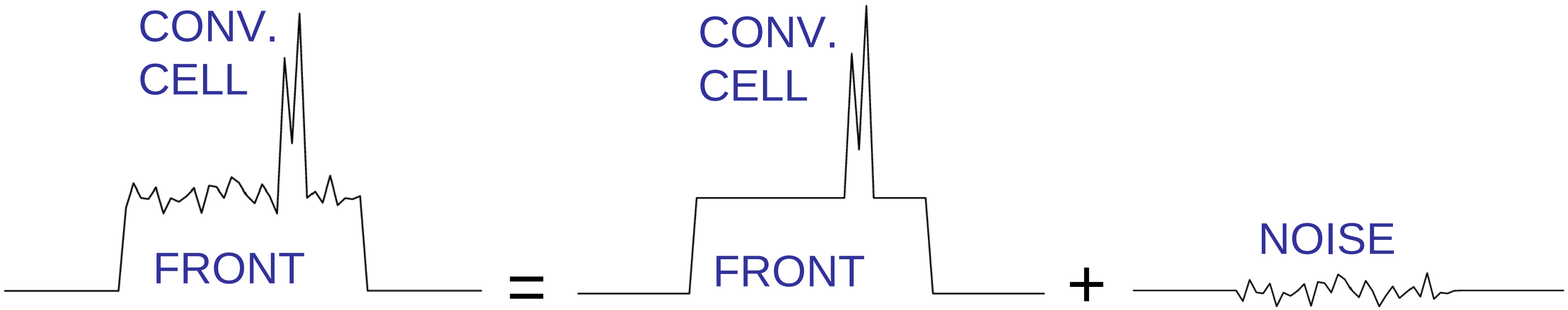
Verification of different spatial scale components obtained from a 2D wavelet decomposition of the forecast and analysis field

1. 2D discrete wavelet decomposition of the forecast and analysis fields
2. Noise removal by wavelet coefficient thresholding
3. Reconstruction of each spatial scale component.
4. Verification of each spatial scale component by:
   - RMSE, corr. coeff., energy (variance) ratio
     - % MSE, % corr. coeff. (wavelet components orthogonality)

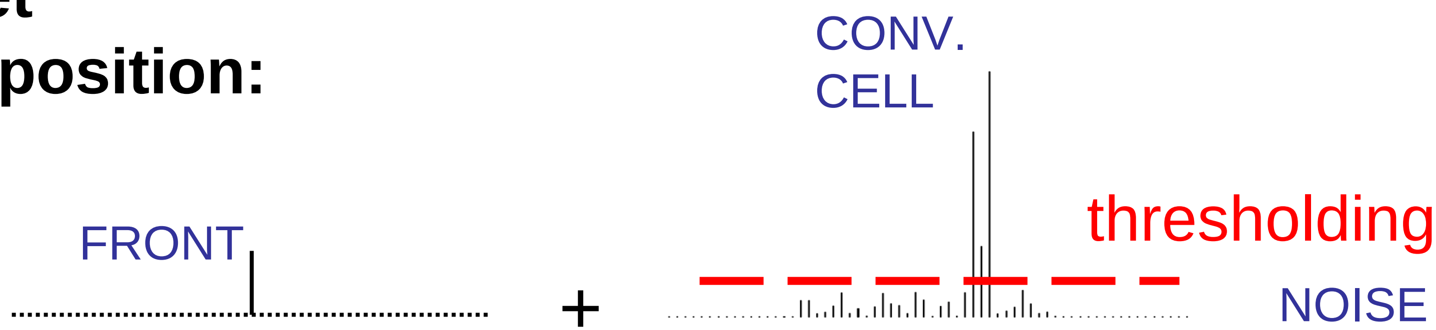
500 mb geop. Height, 9 Dec 1992, 12:00 UTC, over N. America



De-noising preserving extremes



Wavelet decomposition:



large scale coefficients

small scale coefficients

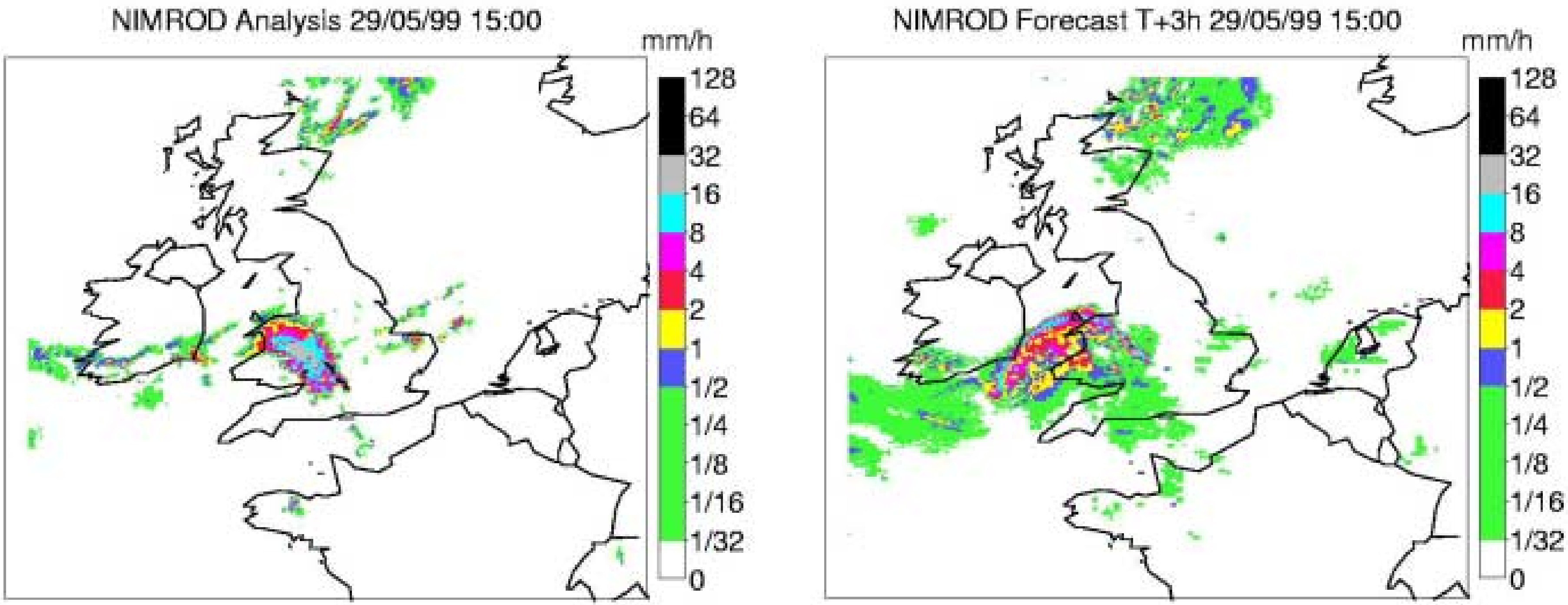
Summary

	FILTER	SCORE	PLUS
BL97	Wav. ⊕	Cont	De-noising + peaks

Casati, Ross, Stephenson (2004)

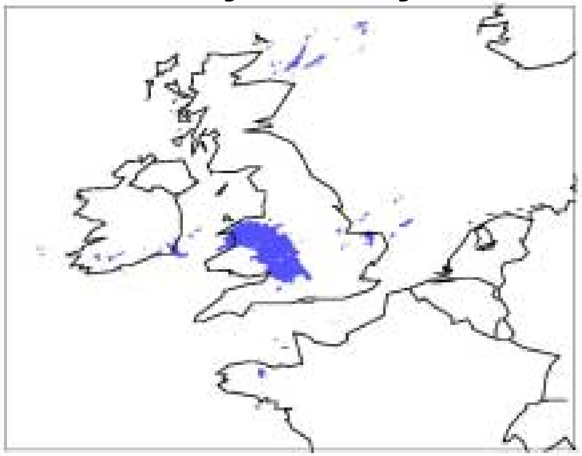
”*A new intensity-scale approach for the verification of spatial precipitation forecasts*” Met. App., vol. **11**, pp. 141-154

Evaluate the forecast skill as a function of the **precipitation intensity** and the **spatial scale** of the error

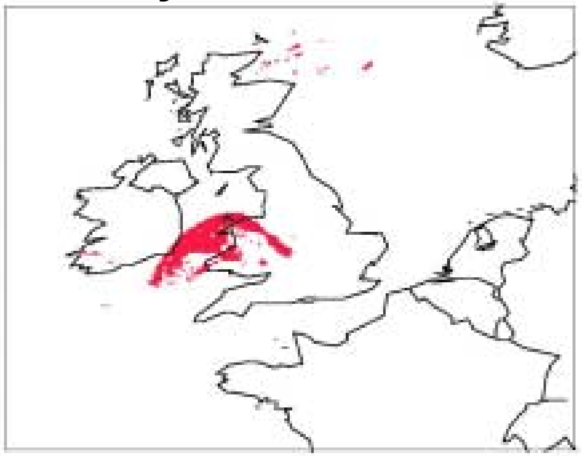


Threshold $\rightarrow$ Binary Images

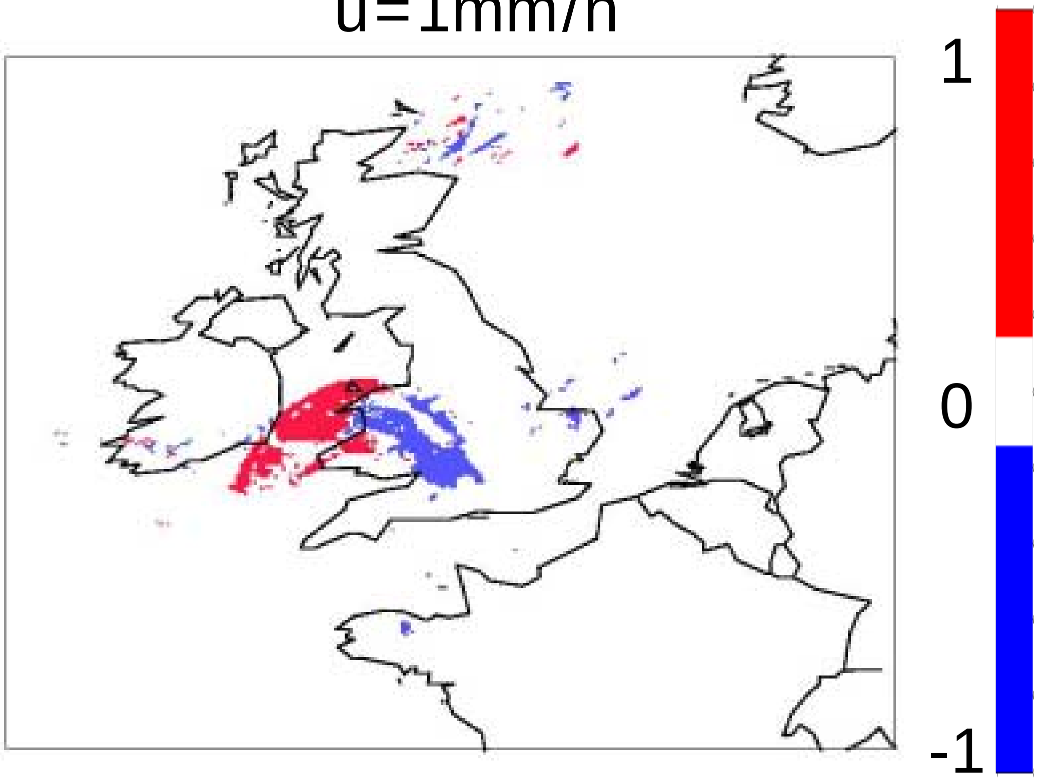
Binary Analysis



Binary Rec.Forecast

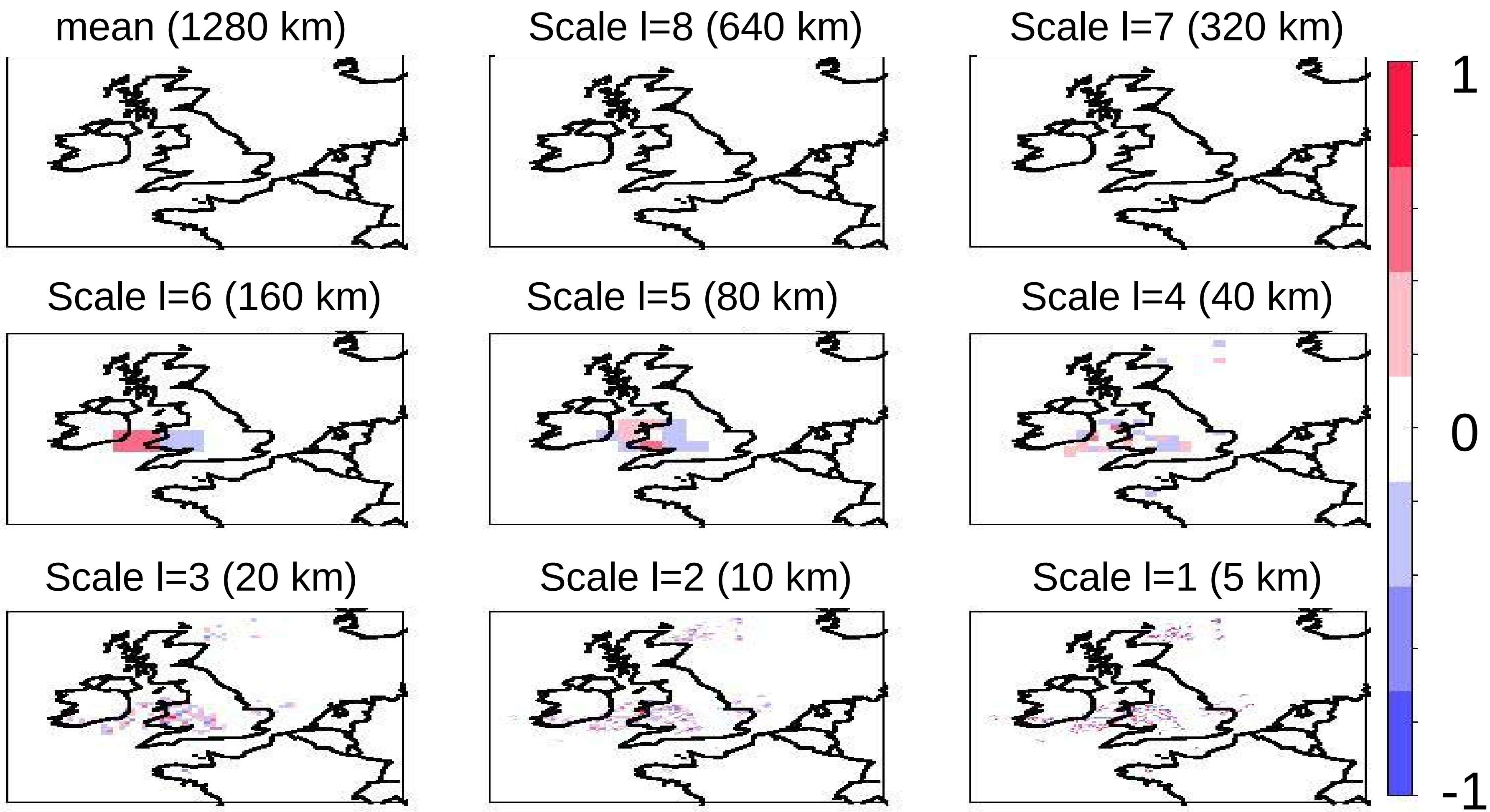


Binary Error Image
u=1mm/h



$$E_u = I_{Y'>u} - I_{X>u}$$

Scale → Wavelet decomposition of the binary error $E_u = \sum_{l=1}^{L} E_{u,l}$



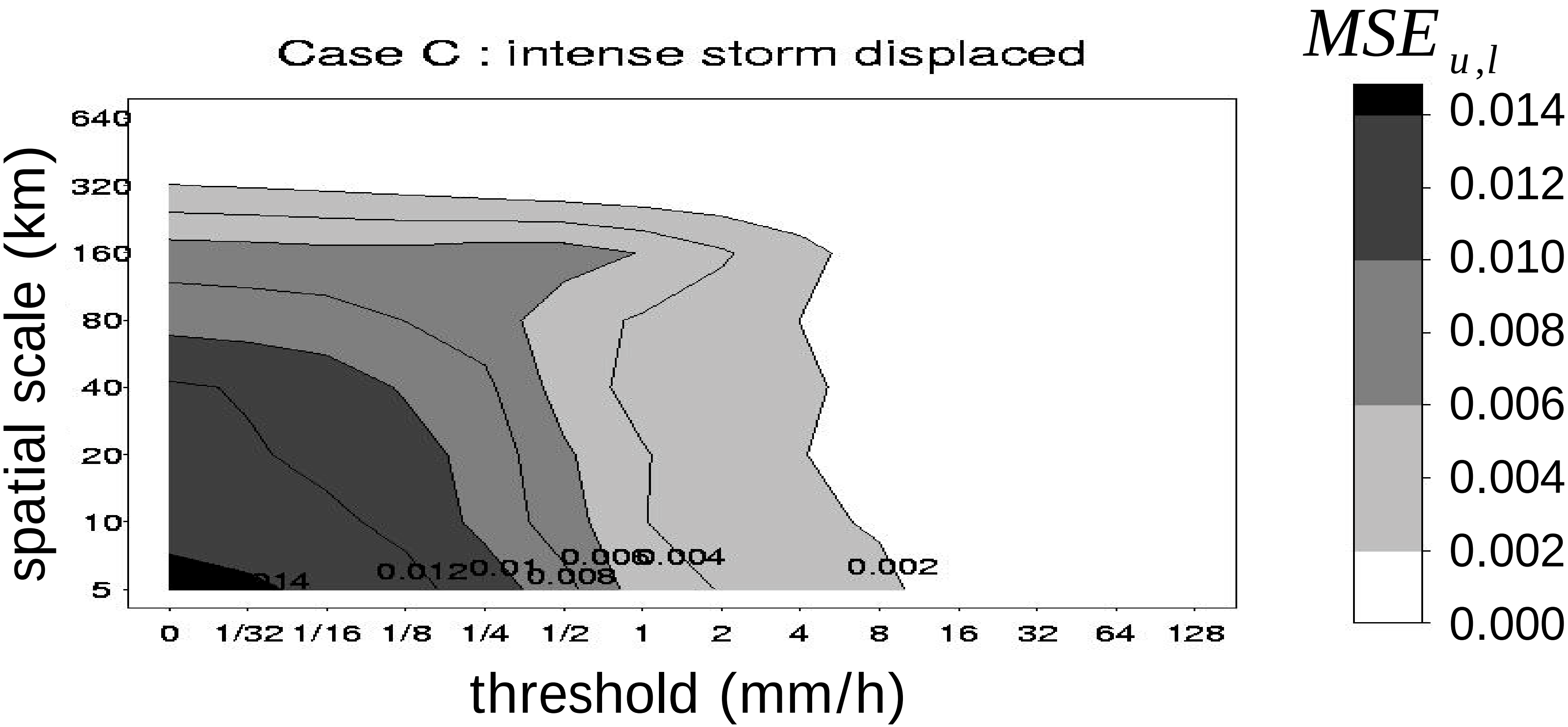
Intensity-scale MSE decomposition

$$E_u = \sum_{l=1}^{L} E_{u,l}$$

Wavelet decomposition of Binary Error Image

$$MSE_u = \sum_{l=1}^{L} MSE_{u,l}$$

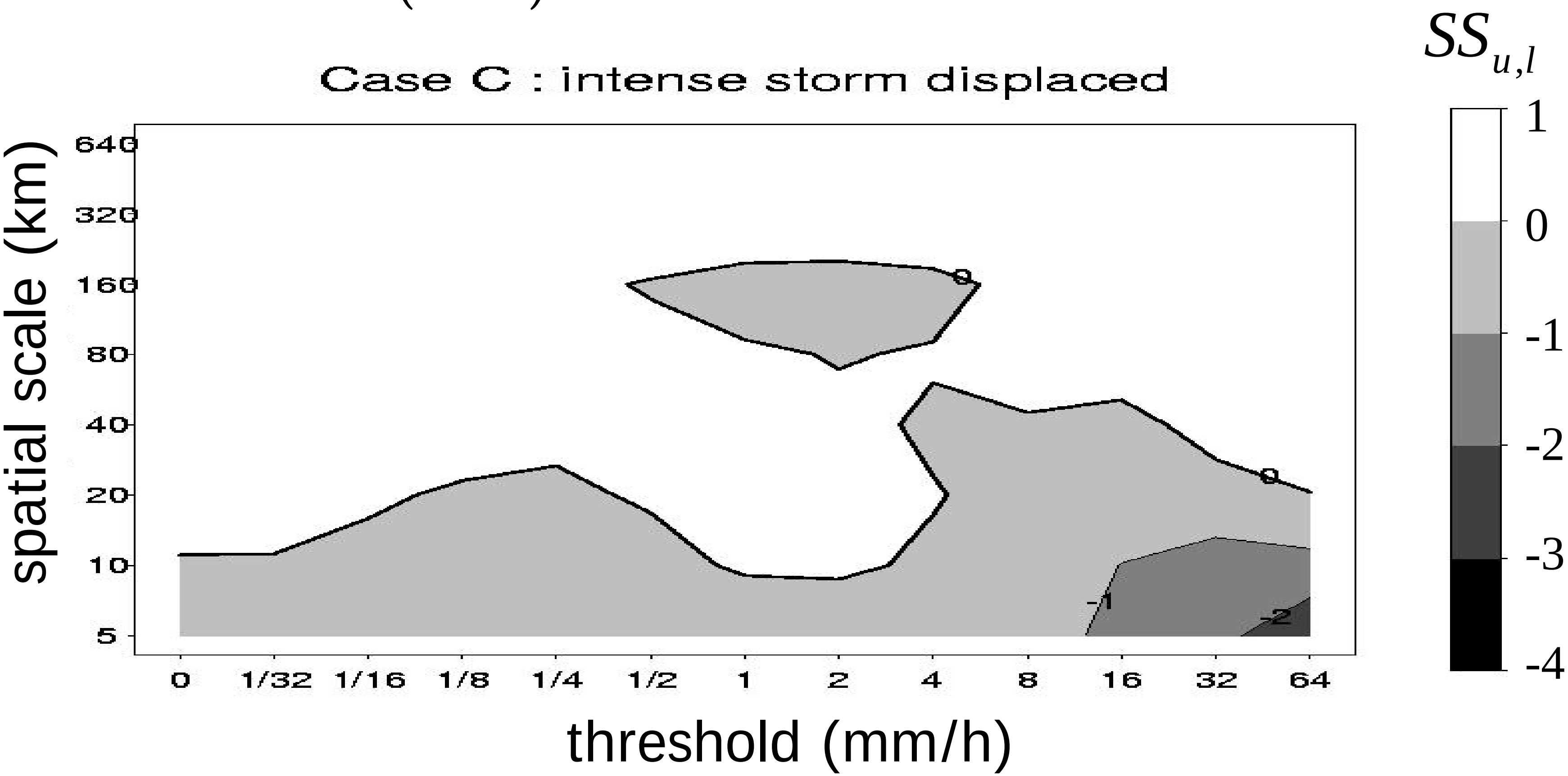
Wavelets orthogonality MSE additive properties



MSE skill score

$$SS_u = \frac{MSE_u - MSE_{u,random}}{MSE_{u,best} - MSE_{u,random}} = 1 - \frac{MSE_u}{2\varepsilon\left(1-\varepsilon\right)}$$

$$SS_{u,l} = 1 - \frac{MSE_{u,l}}{2\varepsilon\left(1-\varepsilon\right)/L} \qquad \varepsilon = \frac{a+c}{n} = P(X > u)$$



MSE_u versus SS_u

Front slightly displaced

$$\varepsilon = 0.5$$

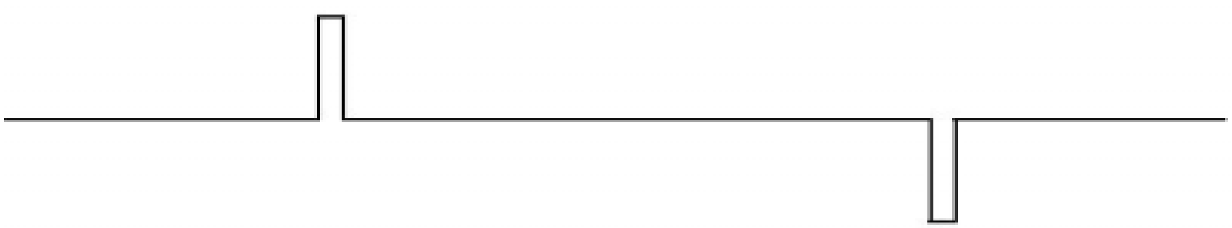
$$SS_u = 0.92$$

Shower displaced

$$\varepsilon = 0.02$$

$$SS_u = -0.02$$

Binary error

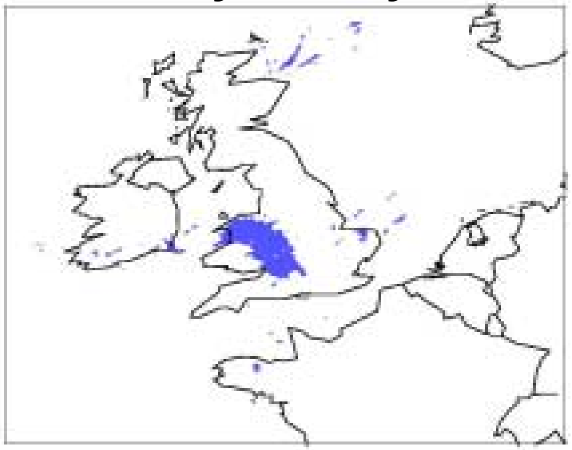


$$MSE_u = 0.04$$

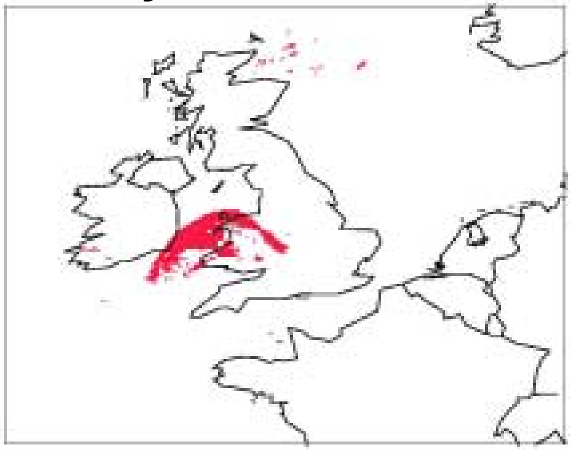
SS_u takes into account the base rate ε

Links with categorical verification

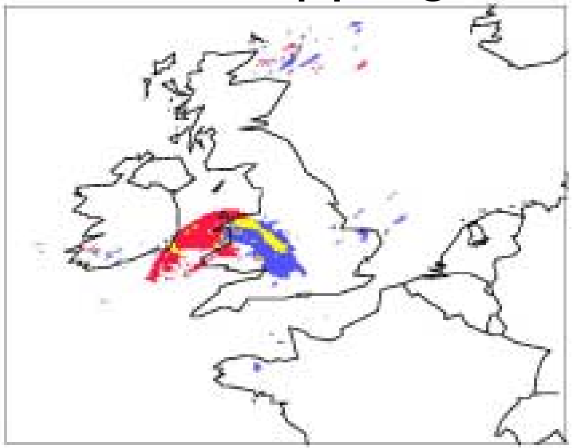
Binary Analysis



Binary Rec.Forecast



Overlapping



$$MSE_u = \frac{b+c}{n}$$

$$SS_u = HSS$$

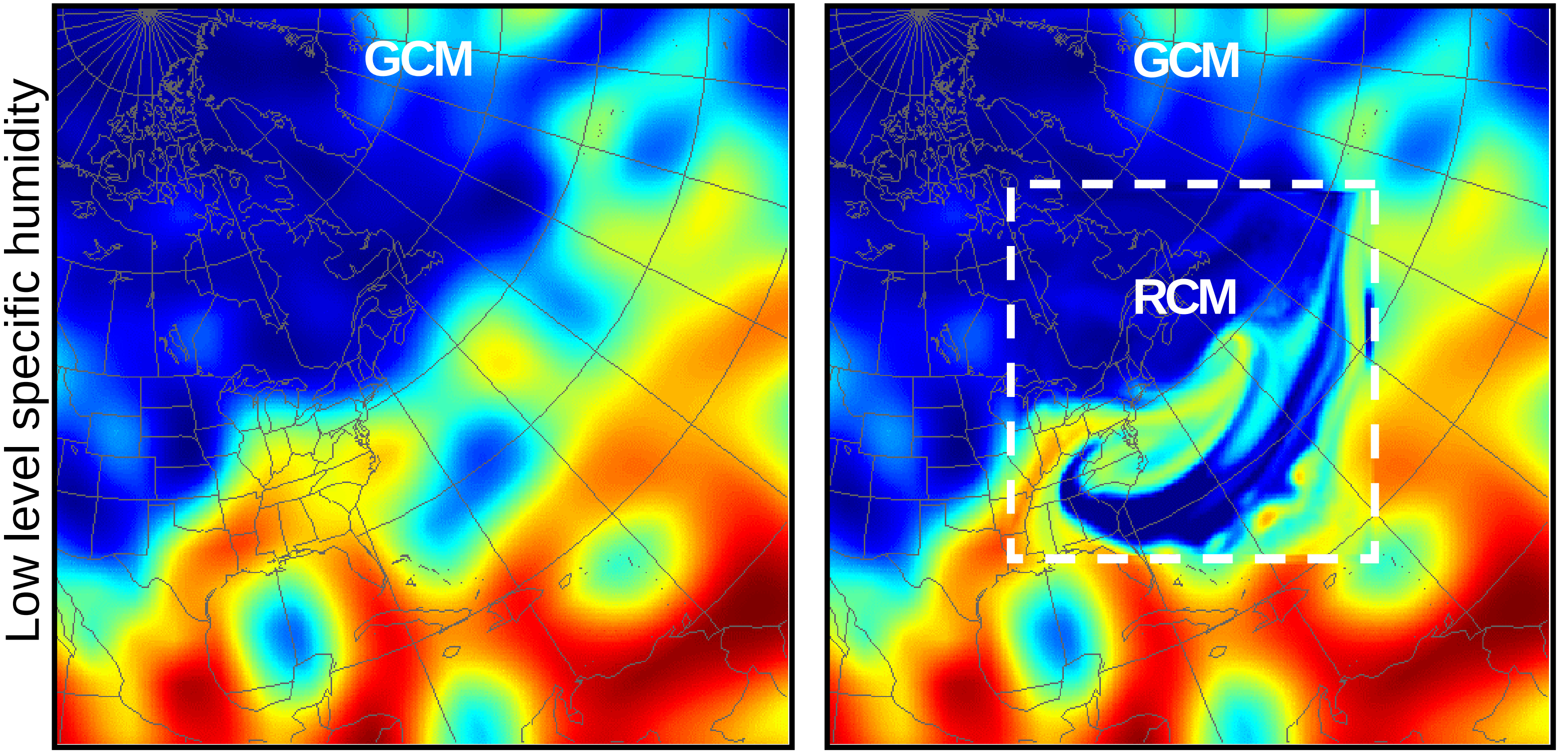
	X > u	X < u	
Y > u	Hits a	False Alarms b	a+b
Y < u	Misses c	Correct Rejections d	c+d
	a+c	b+d	a+b+c+d=n

Summary

	FILTER	SCORE	PLUS
BL97	Wav. ⊕	Cont	De-noising + peaks
CRS04	Wav. ⊕	CAT	Scale & intensity + skill measure

Denis, Laprise, Caya (2003)

"*Sensitivity of a regional climate model to the resolution of the lateral boundary conditions*", Climate Dynamics, vol. **20**, pp. 107-126



GCM (T32~600km)

RCM driven by the GCM (45km)

Aims:

- test ability of RCM to (re)generate small-scale features
- test sensitivity to different resolution lateral boundary condition

Experiment set up

RCM on large domain at high resolution → Big Brother

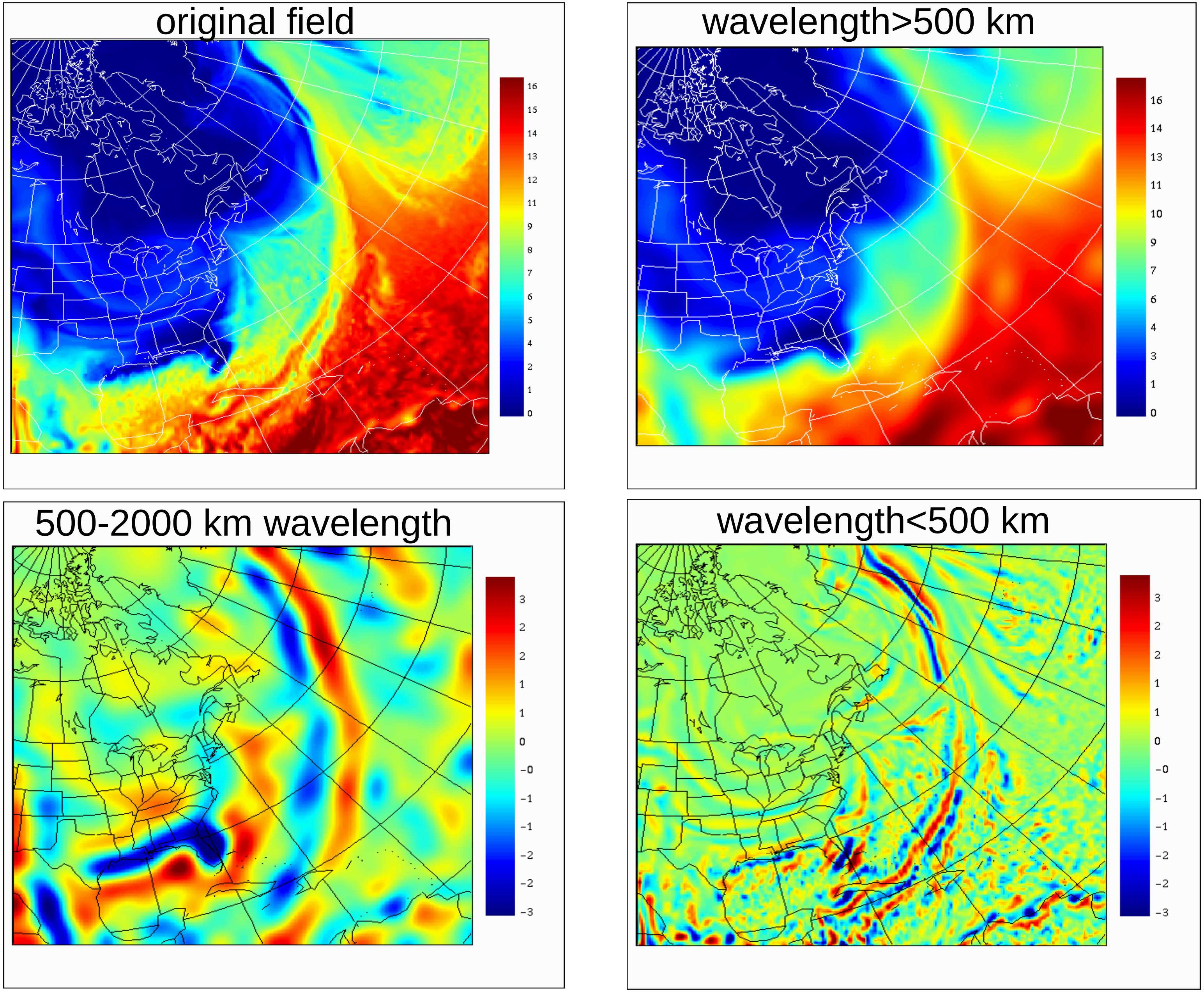
BB filtered to GCM resolution → RCM on small domain at high resolution → Little Brother

LBC at different resolution → RCM on small domain at high resolution

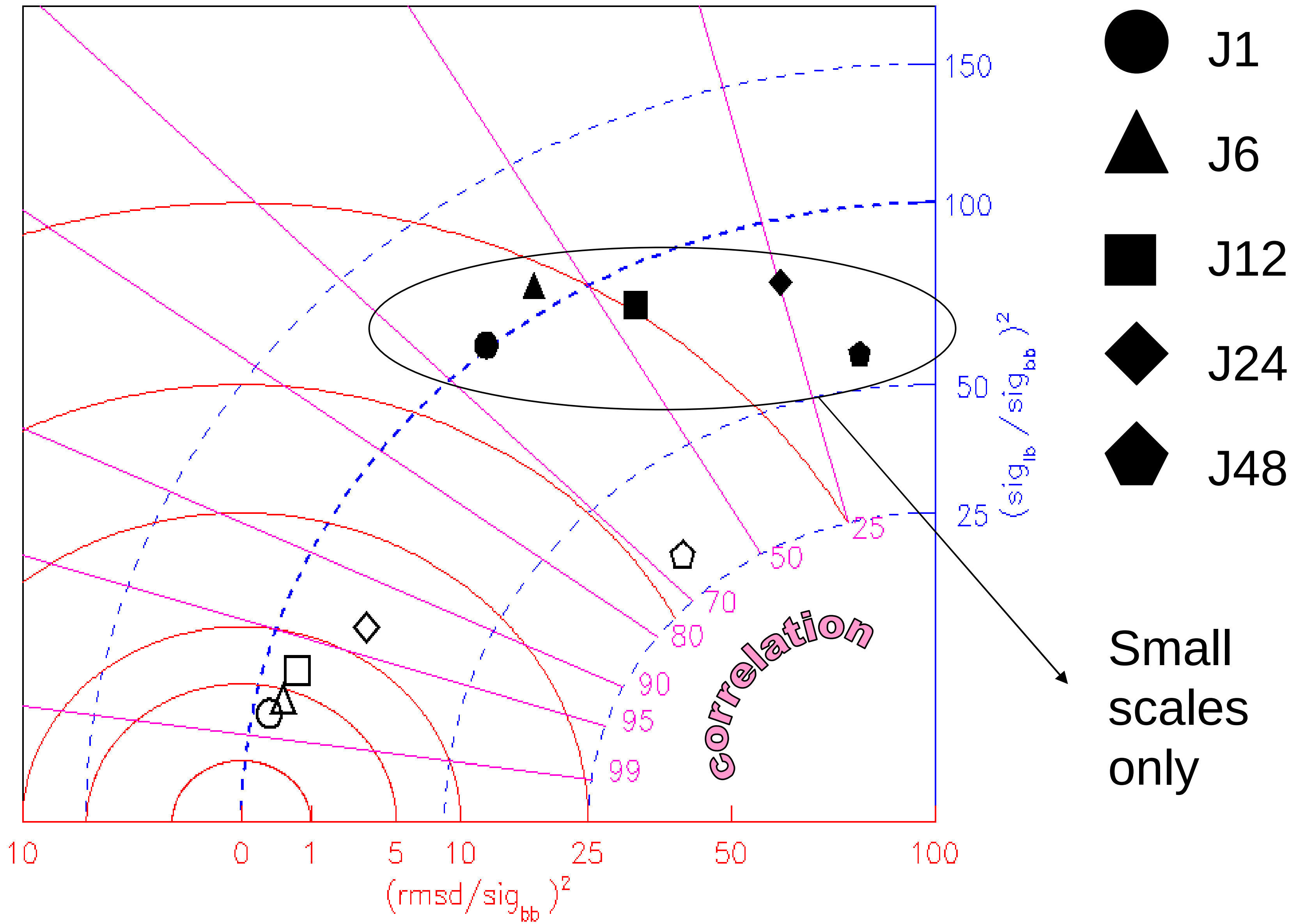
Verify Little Brother vs Big Brother

(on small domain at high resolution)

Discrete Cosine Transform filtering of a 925-hPa specific humidity field



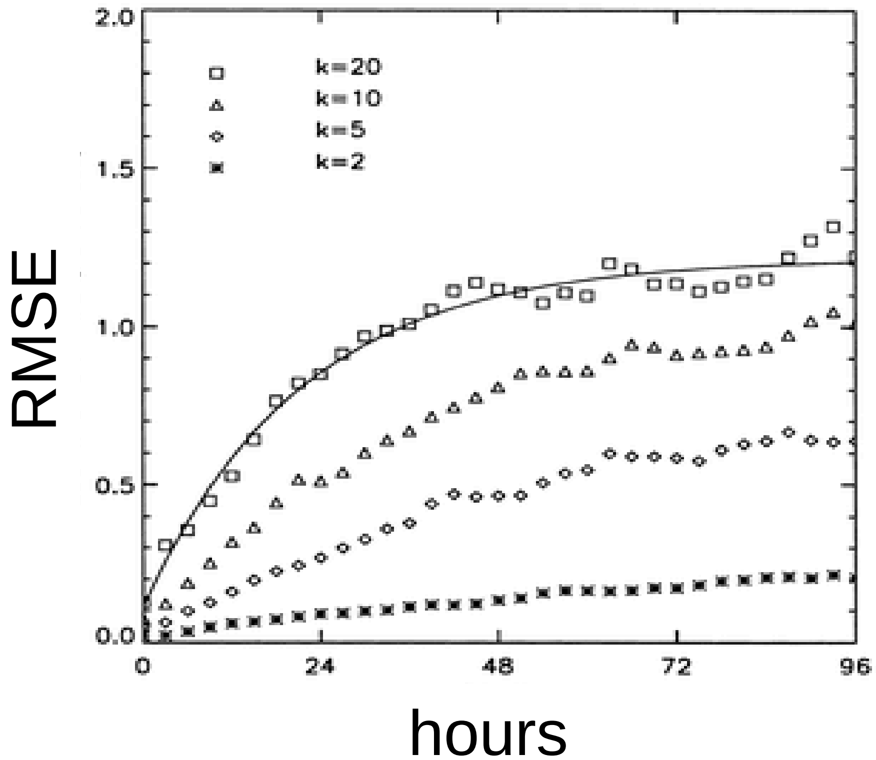
Taylor diagram for precipitation

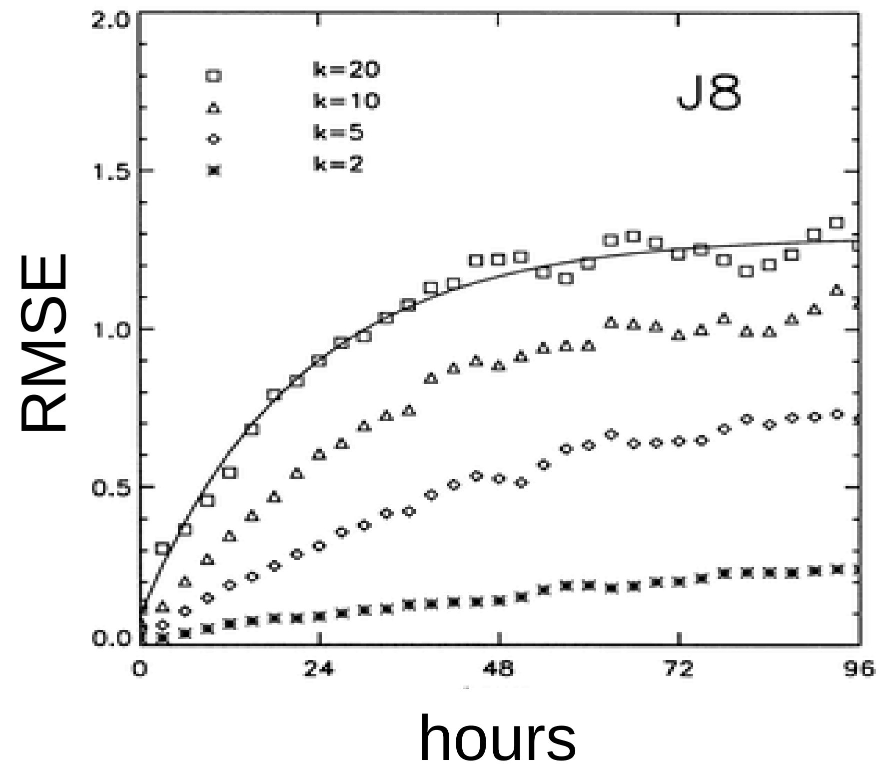


De Elia, Laprise, Denis (2001)

"Forecasting skill limits of Nested Limed Area Models: A perfect-model approach", Mon. Wea. Rev., vol. **130**, pp. 2006-2023

850-hPa vorticity fields

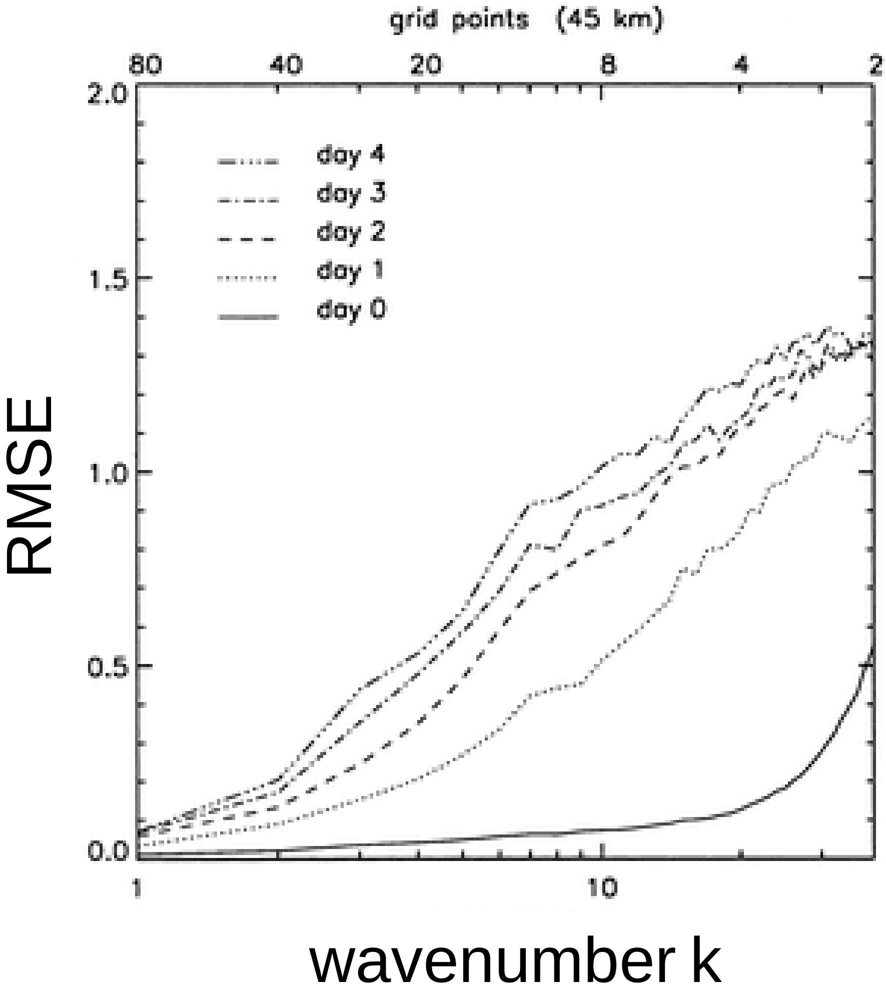




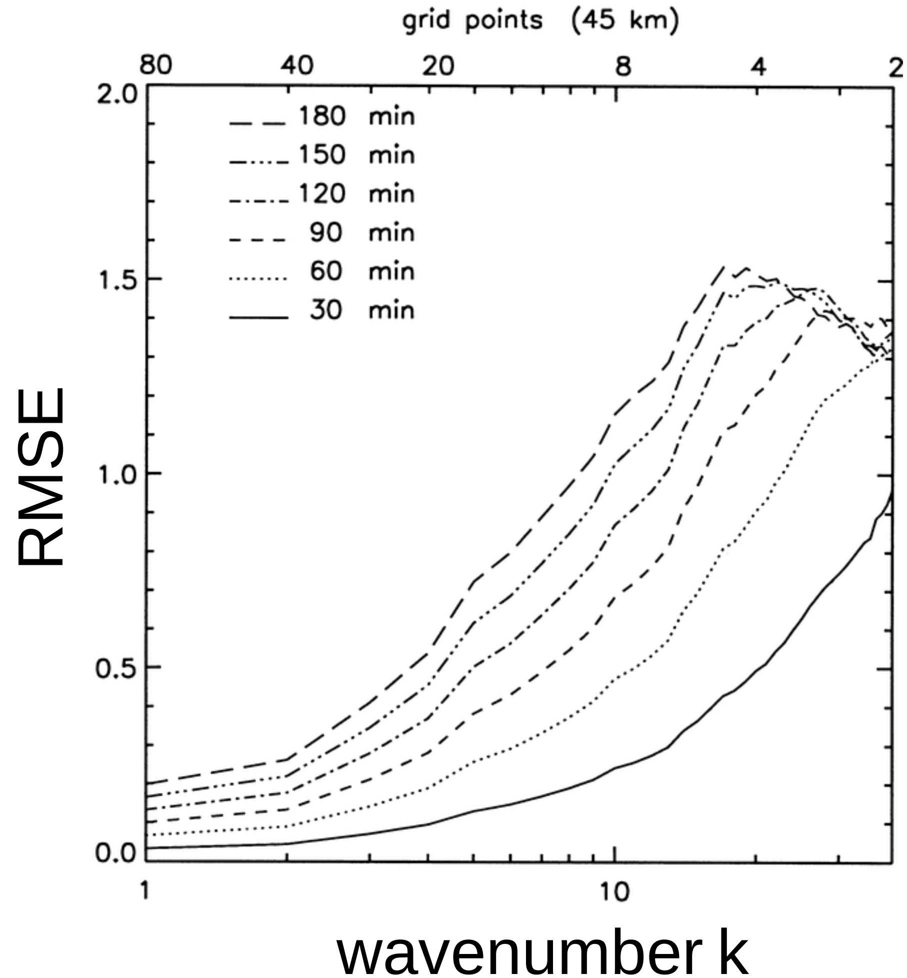
Predictability: perturbed vs control run

Filtered lateral boundary condition

850-hPa vorticity fields



Predictability: perturbed vs control run



Temporal shift of forecast

Summary

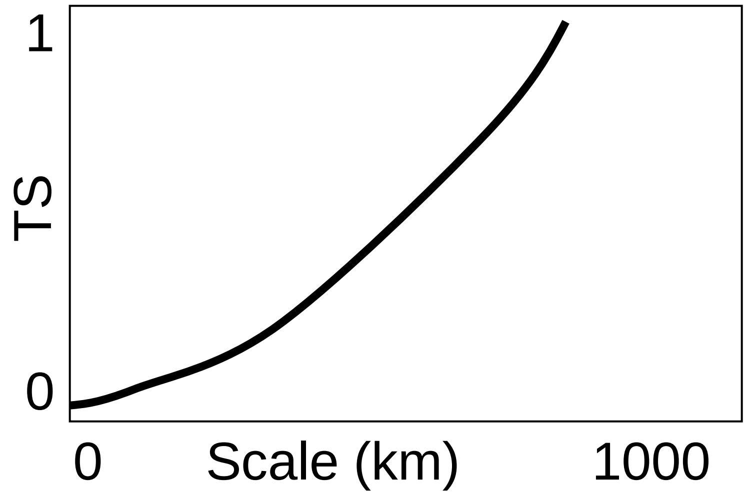
	FILTER	SCORE	PLUS
BL97	Wav. ⊕	Cont	De-noising + peaks
CRS04	Wav. ⊕	CAT	Scale & intensity + skill measure
DDeELC	Four. ⊕	Cont	Predictability + shifting

Zepeda-Arce et al. (2000)

"*Space-time rainfall organization and its role in validating quantitative precipitation forecasts*" JGR vol. **105** (D8) pp. 10,129-10,146

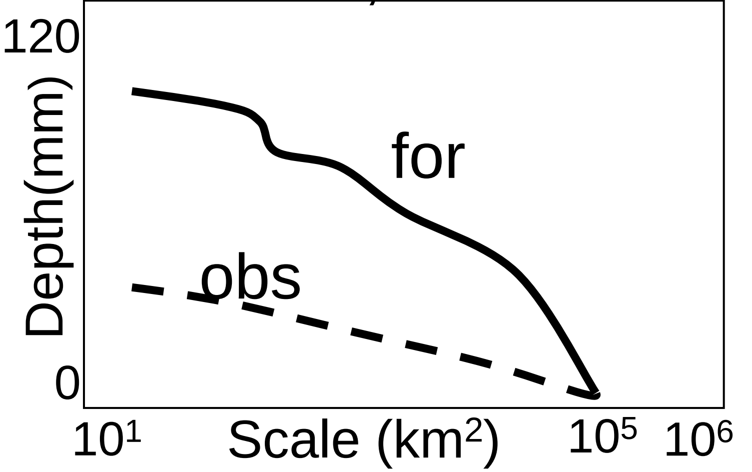
- Assess ability of reproducing multi-scale spatial structure and space-time dynamics of ppn fields
- Different scales are obtained by spatial averaging

1. TS on different scales



2. **D**epth-**A**rea-**D**uration curves

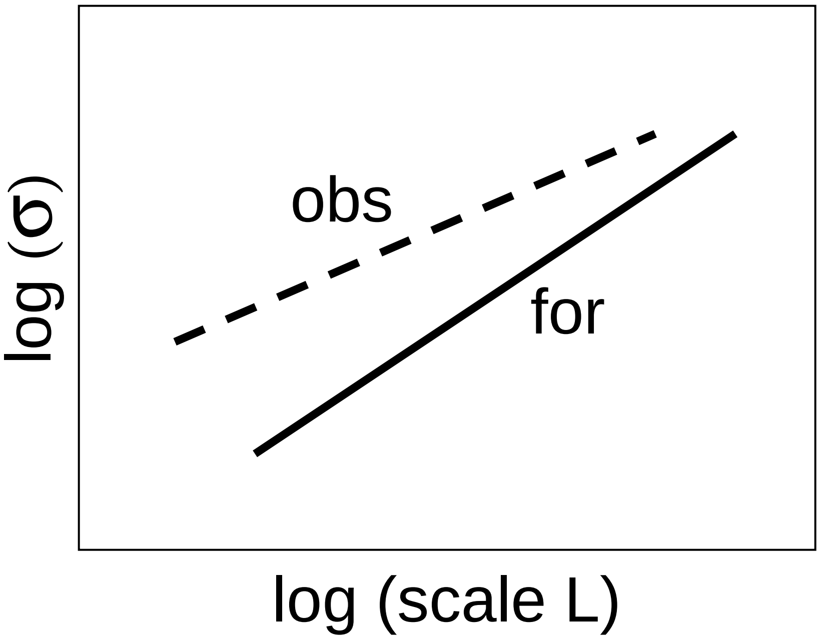
DA curve, 1h accum.



3. **Scale-to-scale variability**:

ξ_L = fluctuation on scale L

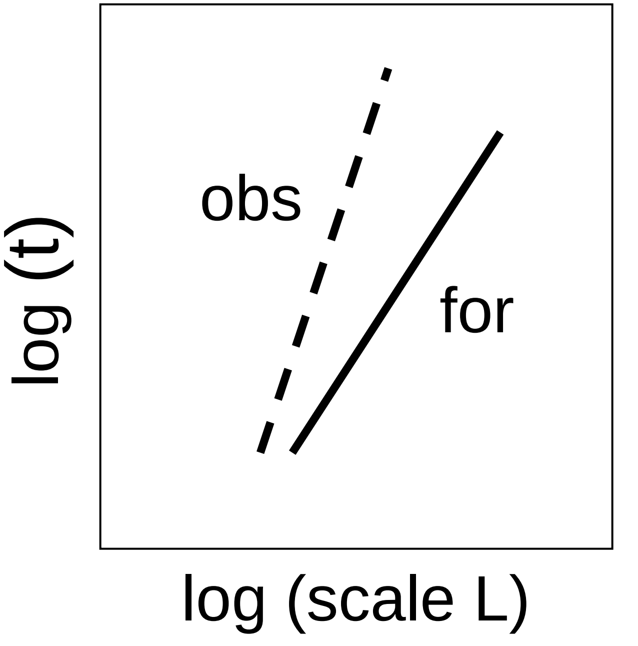
$\sigma_{\xi,L} = L^{H}$



4. **Spatio-temporal organization**:

$\Delta \ln I(t,L)$ constant,

then $t = L^{z}$

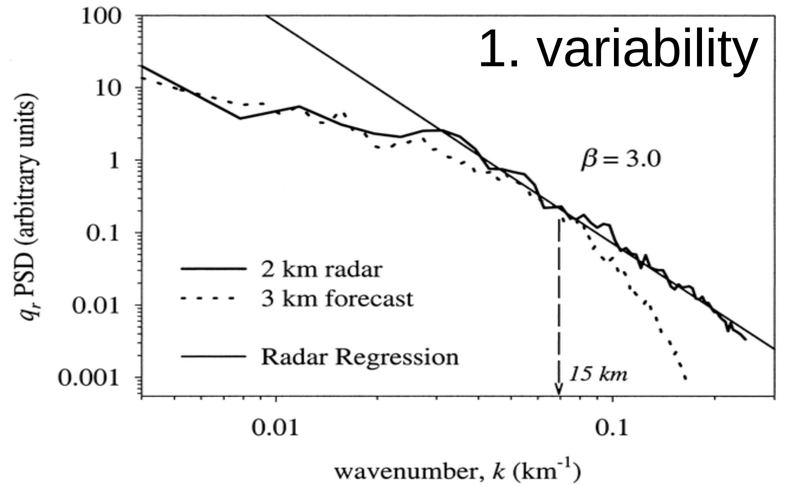


Harris et al. (2001)

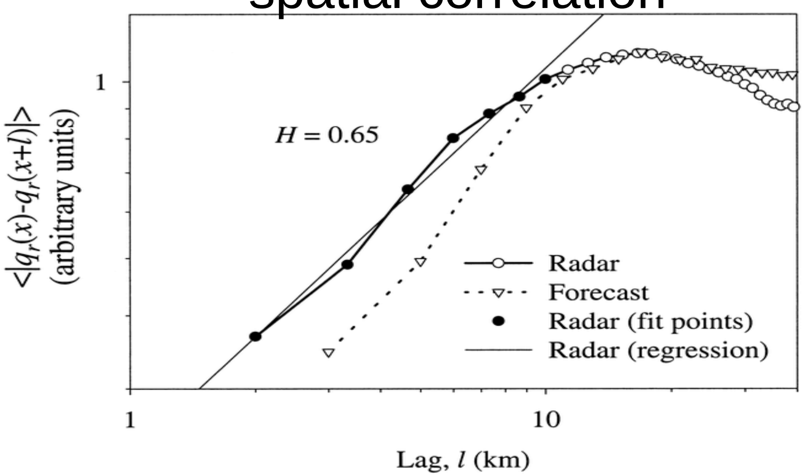
"*Multiscale statistical properties of a high-resolution precipitation forecast*" J. of Hydromet., Vol **2**, pp. 406-418

1. Fourier analysis
2. Structure function
3. Moment-scale analysis

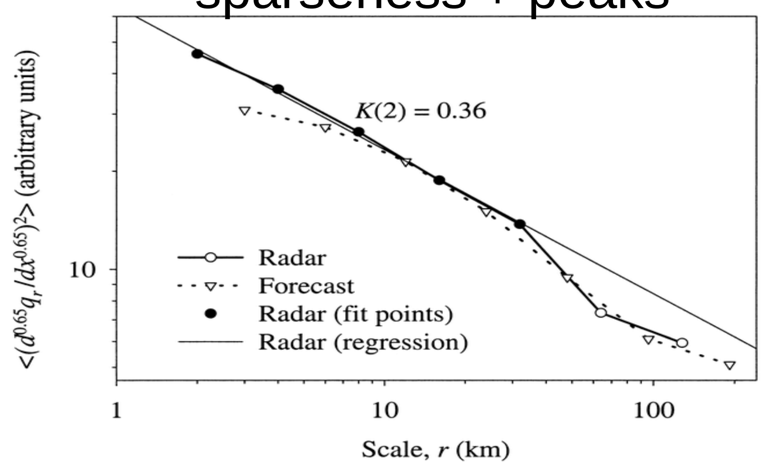
1. variability



2. Smoothness,
spatial correlation

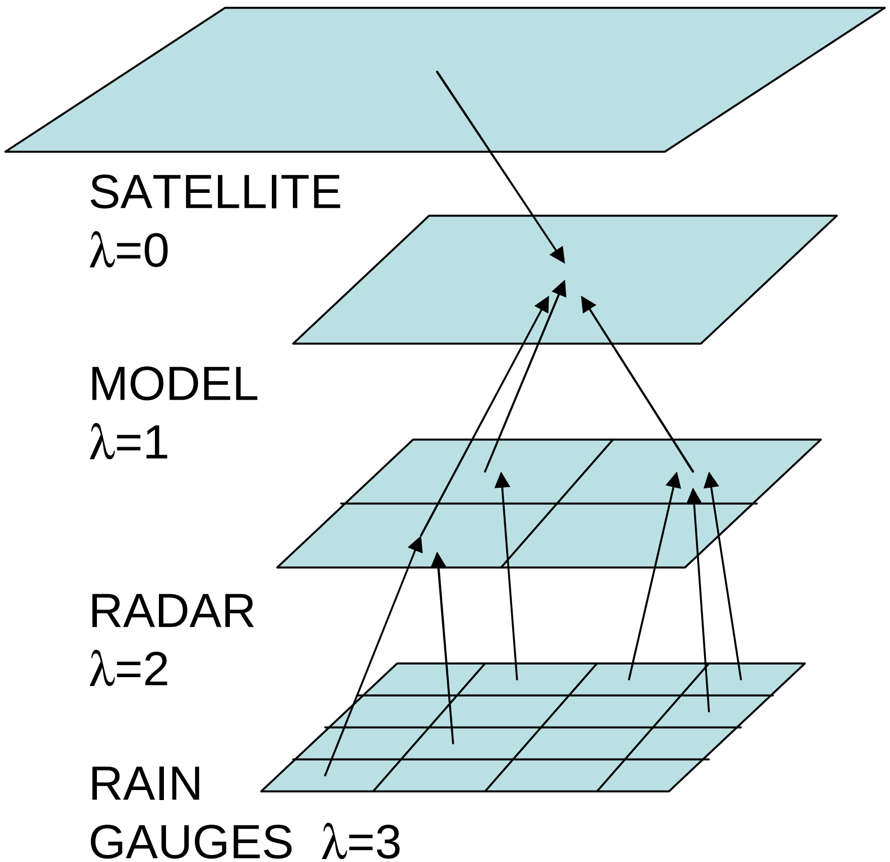


3. Intermittency
sparseness + peaks



Tustison et al. (2003)

"*Scale Recursive Estimation (SRE) for multisensor QPF verification: a preliminary assessment*" JGR vol. **108** (D8)



COARSE TO FINE

$$X(\lambda) = A(\lambda)\, X(\lambda-1) + B(\lambda)\, W(\lambda)$$
$$P_X(\lambda) = A^2(\lambda) P_X(\lambda-1) + B^2(\lambda)$$

FINE TO COARSE

$$X(\lambda-1) = F(\lambda)\, X(\lambda) + W^*(\lambda)$$
$$P_X(\lambda-1) = F^2(\lambda) P_X(\lambda) + Q(\lambda)$$

- $X(\lambda)$ = field
- $P_X(\lambda)$ = field variance
- $A(\lambda)$, $B(\lambda)$ parameters estimated by model of ppn multiscale variability structure

Summary

	FILTER	SCORE	PLUS
BL97	Wav. $\oplus$	Cont	De-noising + peaks
CRS04	Wav. $\oplus$	CAT	Scale & intensity + skill measure
DDeELC	Four. $\oplus$	Cont	Predictability + shifting
ZA++00 H++01 T++03	Wav. Four. Str. Fun. Mom. An.	Parameters related to ppn field spatio-temporal organization Focus on magnitude/variability	

Discussion

	FILTER	SCORE	PLUS
BL97	Wav. ⊕	Cont	De-noising + peaks
CRS04	Wav. ⊕	CAT	Scale & intensity + skill measure
DDeELC	Four. ⊕	Cont	Predictability + shifting
ZA++00 H++01 T++03	Wav. Four. Str. Fun. Mom. An.	Parameters related to ppn field spatio-temporal organization Focus on magnitude/variability	

Concluding remarks

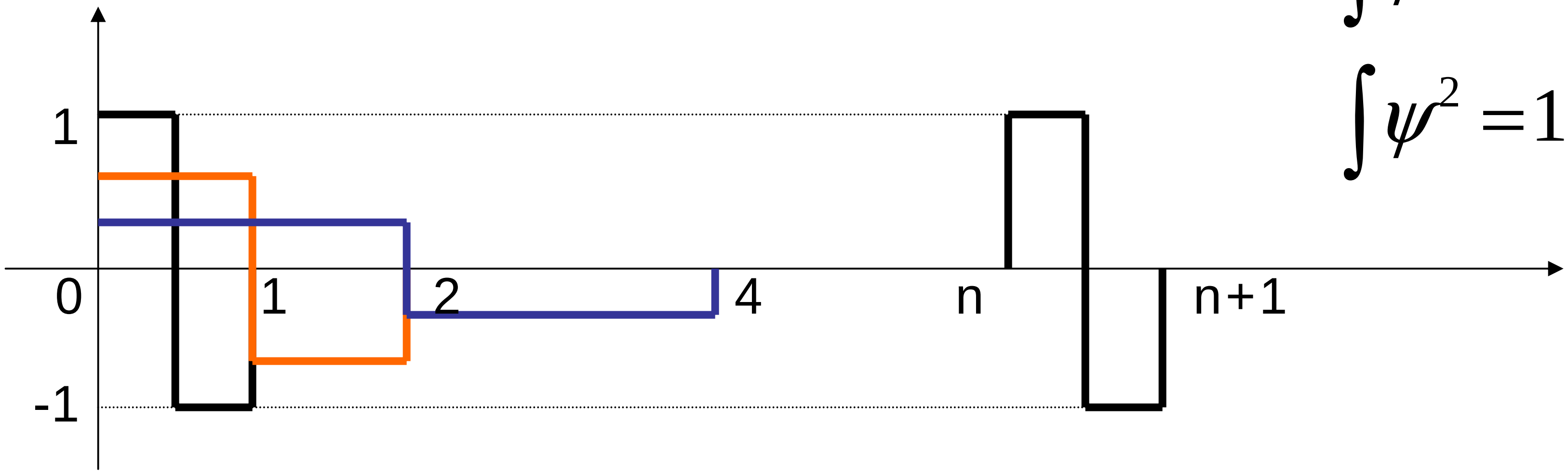
- **Wavelets** for discontinuous sparse fields, no Fourier !
- **Categorical approaches** are robust and resistant; they enable to verify for different intensities
- **De-noising preserving extremes**
- **Skill** measures; error relative to presence of features at each scale; account for **predictability** at different scales
- Error decomposition (displacement, amount) at different scales
- Error in spectral representation

Wavelets

Haar mother wavelet ψ

$$\int \psi = 0$$

$$\int \psi^2 = 1$$

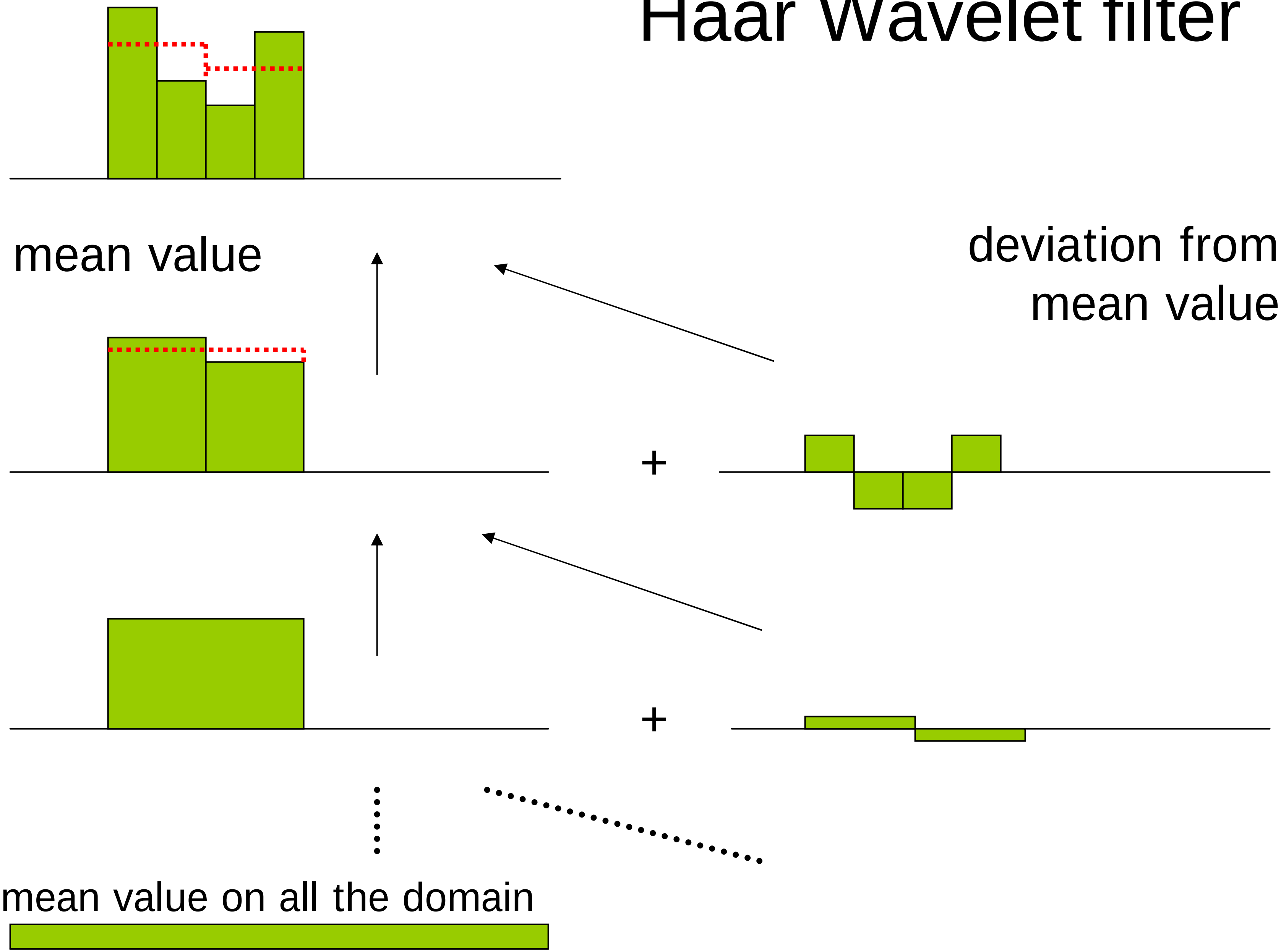


• Wavelets are locally defined real functions characterised by a **location** and a **spatial scale**.

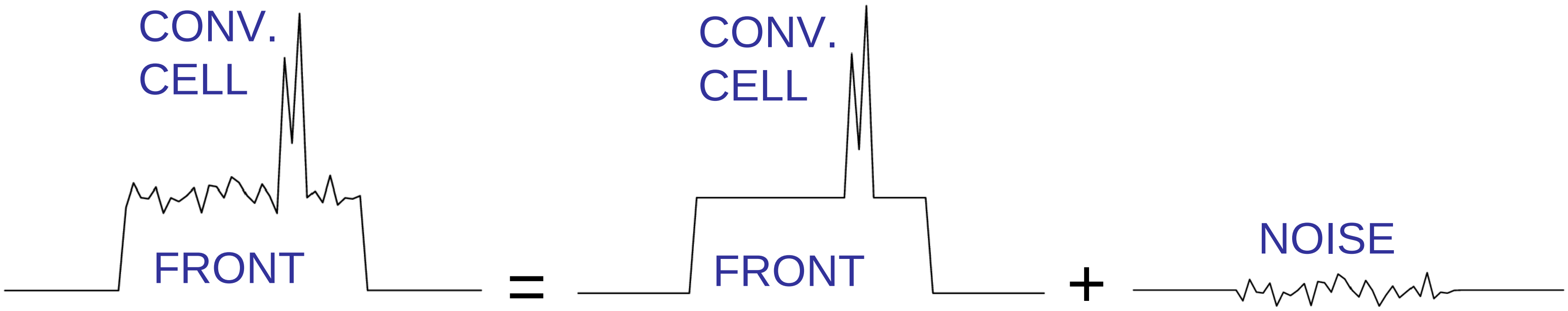
• Any real function can be expressed as a linear combination of wavelets, i.e. as a sum of components with different spatial scales.

• Wavelet transforms deal with discontinuous and sparse fields better than Fourier transforms do

Haar Wavelet filter



De-noising preserving extremes



Wavelet decomposition: