Future directions in convective parameterization

- What has a NWP to do ?

  - Provide best possible short-range Forecast (not too difficult with a good Analysis System)
  - Provide best possible Medium-range Forecast (4-10 days): but this supposes not only good Analysis system but also a very good model system that has to get both right the short term and the climate
  - Further: Ensemble system Forecast, coupled Wave model (10 m winds), Seasonal Prediction System

Future directions in convective parameterization

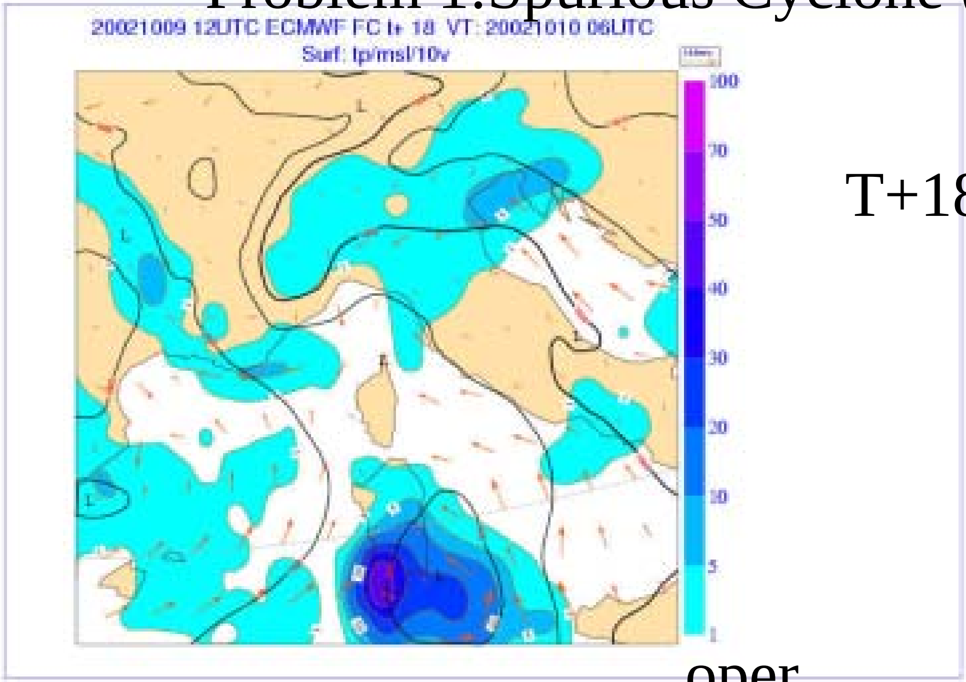
- What has a convection parameterization to do ?
    - Tropics – moisture transport, rainfall, radiative/convective equilibrium, Convective Momentum transport
    - Midlatitude summertime storms – “American Problem”
    - Stabilisation of the model, provide adequate deepening of midlatitude and tropical depressions – avoid “over-deepening”
    - Shallow transport inluding CM – trade winds

- The scheme has to run globally for each situation

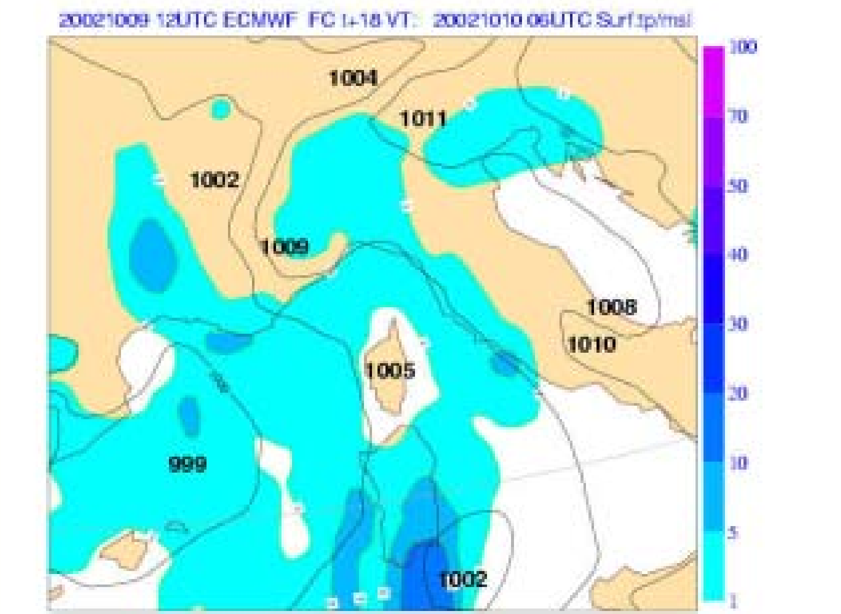
  at all resolutions (T95 (200 km)– T511 (40 km) and future T799 (25 km) > it must be stable, minimize the biases inherent in each parameterization, and usable in Analysis Cycle -> the TL and Adjoin versions can be devloped, or a “simplified physics” relatively close to nonlinear physics can be developed.

DIFFICULT TO SEE DEVELOPMENT SEPARATE FROM CLOUD SCHEME: CONVECTIVE OR STRATIFORM PRECIPITATION ?

Problem 1:Spurious Cyclone (Over/Under) Developmement



T+18



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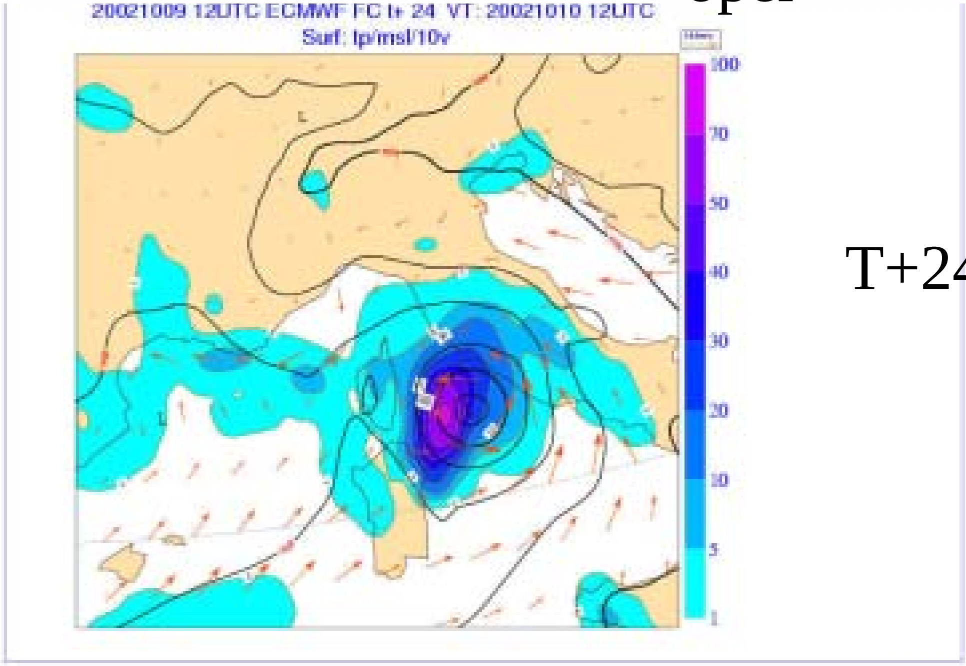
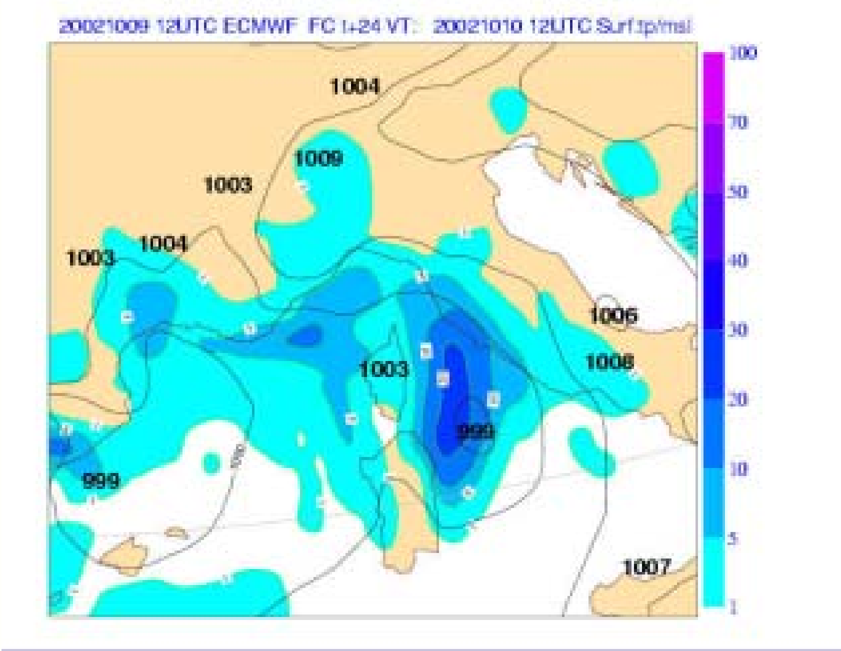


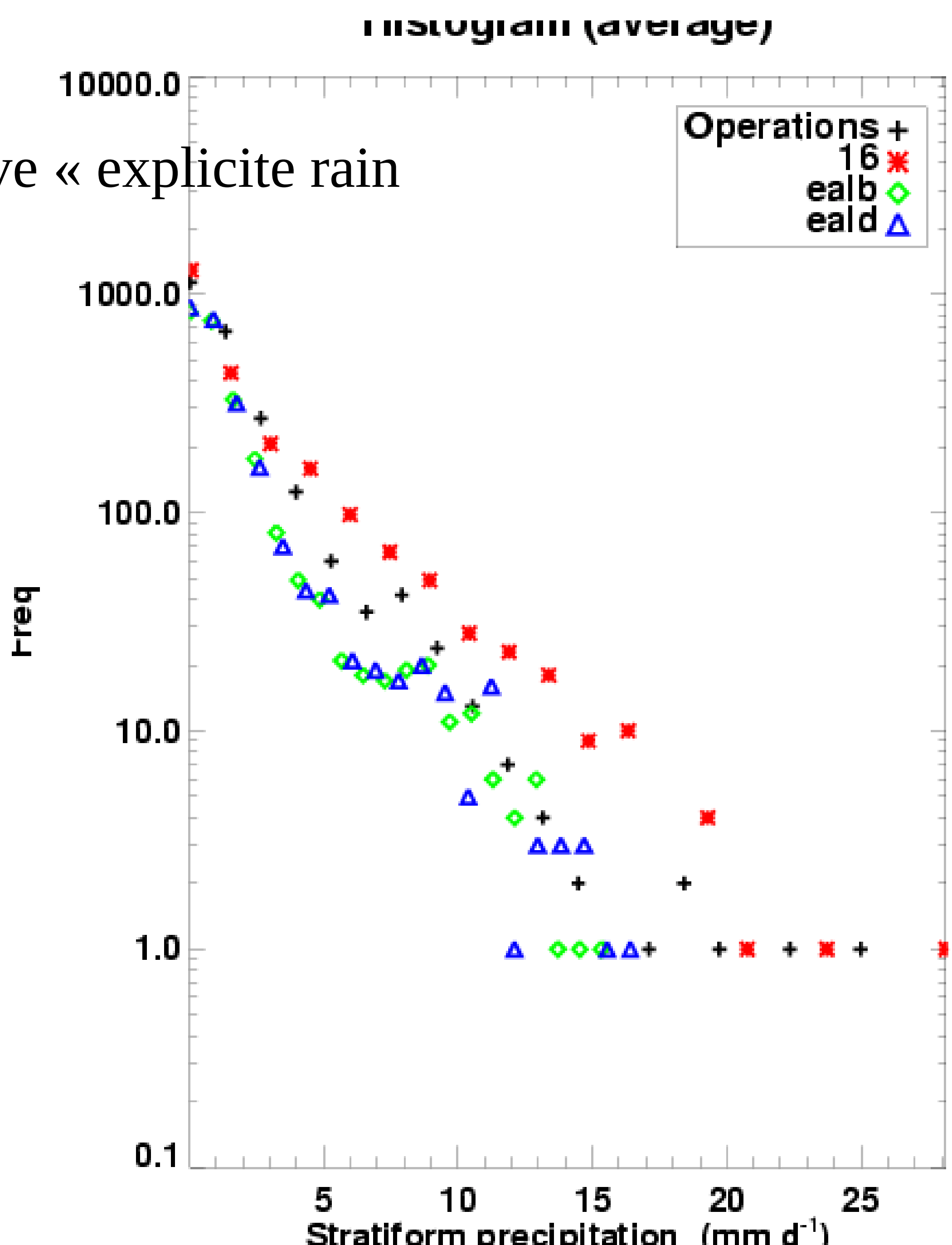
T+24



Problem 2: Excessive « explicite rain

Distribution

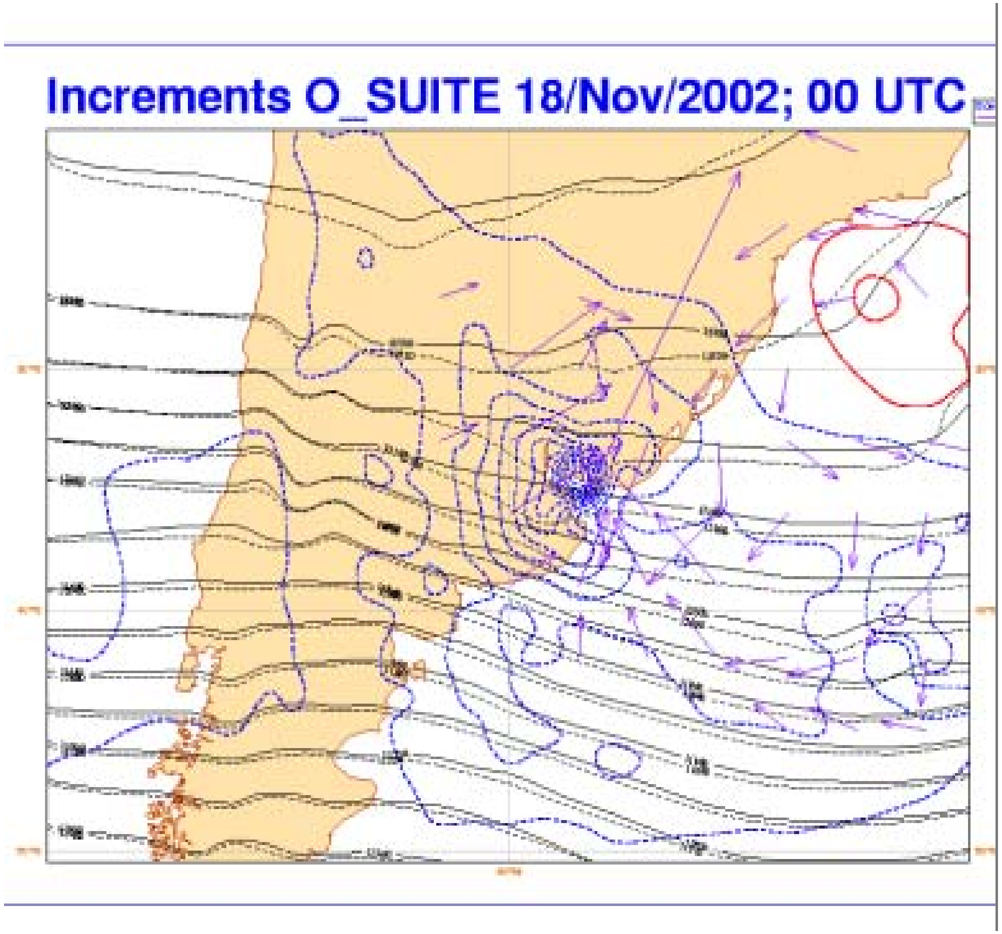
Average 20N-20S

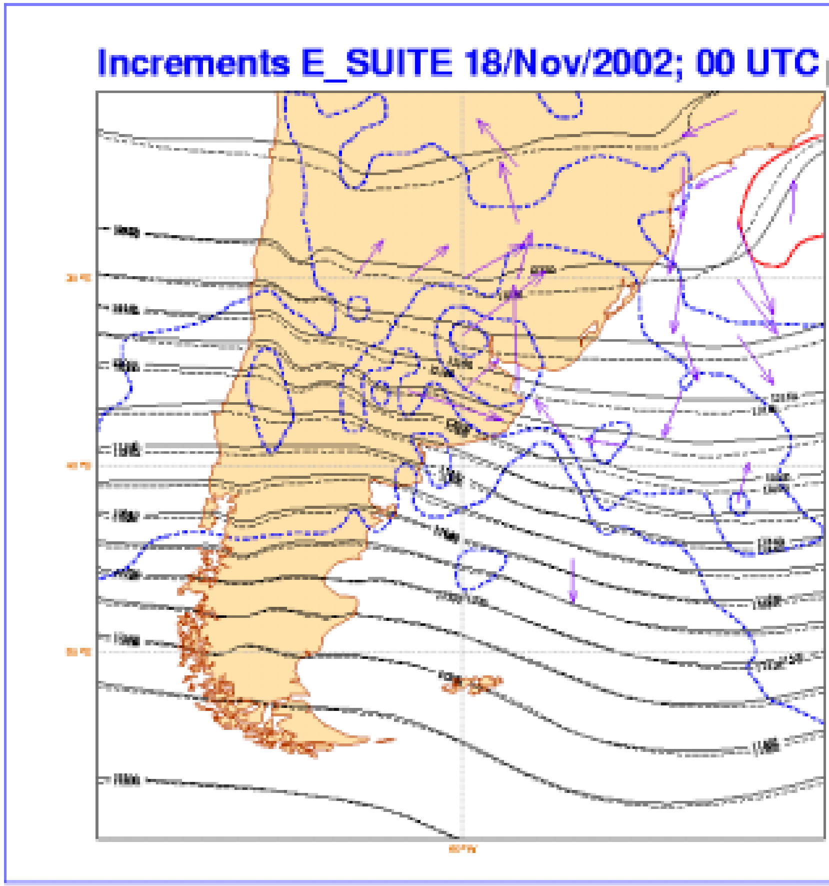


A. Tompkins

Consequence Problem 1-2:

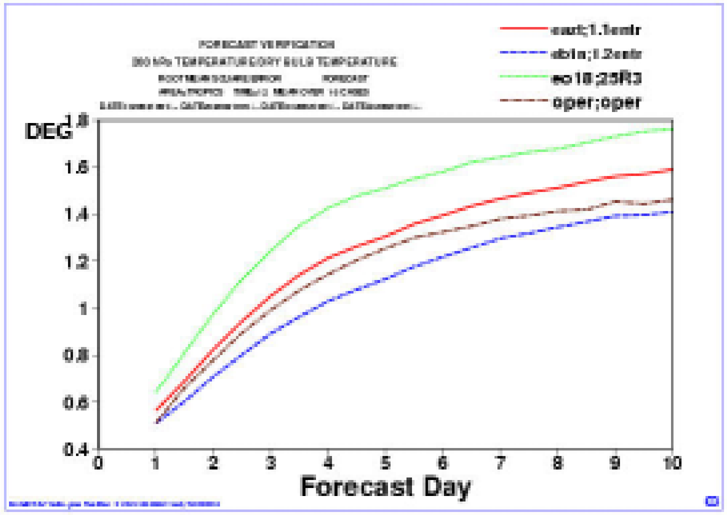
Mass (Z) and wind increments S.America Analysis – First Guess

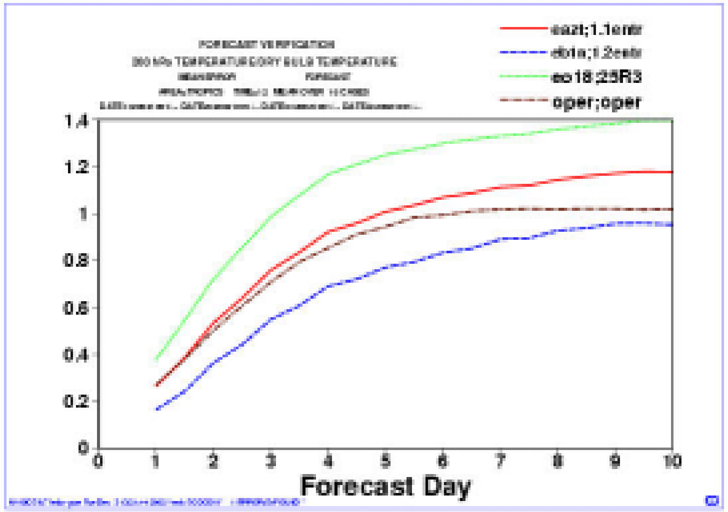


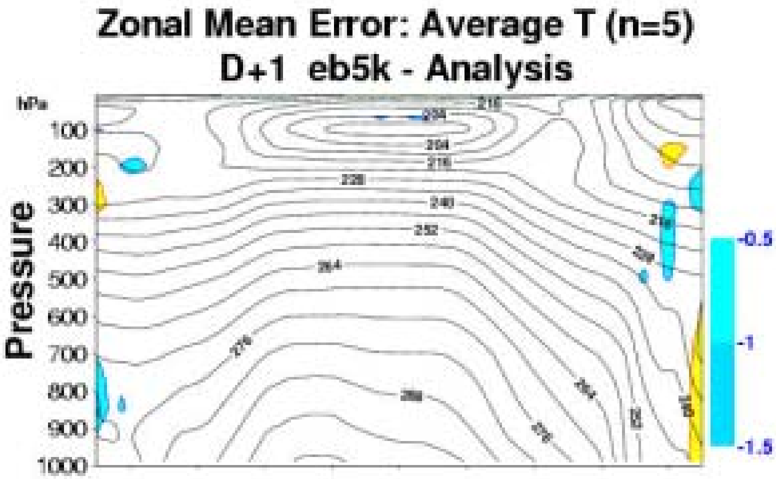


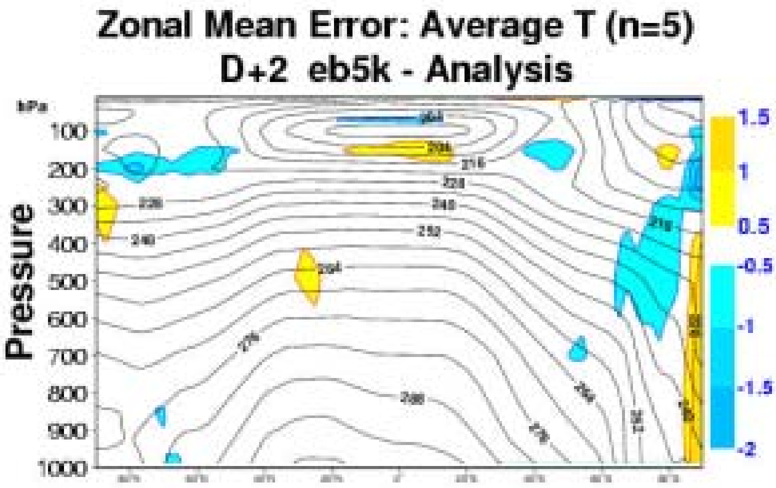
Problem 3:

Getting vertical structure right– Minimise drift « mena error growth » in medium range







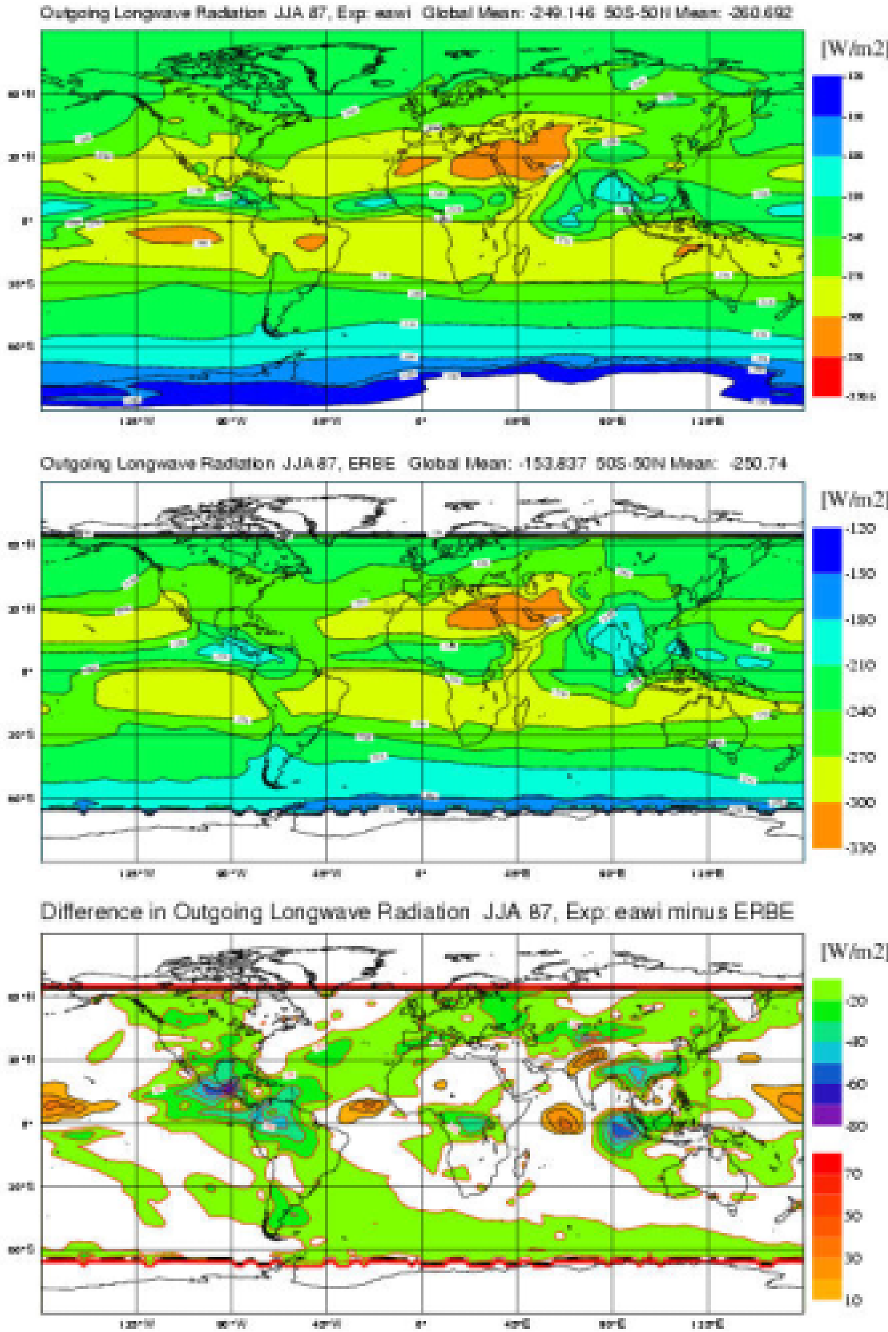


Problem 4:

Getting climate right –

Strong link to cloud scheme and poleward transport of angular momentum

OL



Possible Directions:

- Future of current (bulk/spectral) mass flux parameterizations
- “Super – Parameterizations”
- Representation by Wavelets
- Neural Networks
- Stochastic physics

(a) Future of Mass flux Parameterization

- Not yet finished, current bulk mass flux schemes are stable for long moc
time steps, relatively cheap, but limits are reached provided

  - Reasonable Trigger (diurnal cycle)
  - Improve entrainment (multiple updrafts ?)
  - Improve convective momentum transport (difficult)
  - TL and Adjoint of simplified bulk schemes are under developmen
(RPN Canada(Luc Fillon, JF Mahfouf), ECMWF (P. Lopez, M. Janiskova)

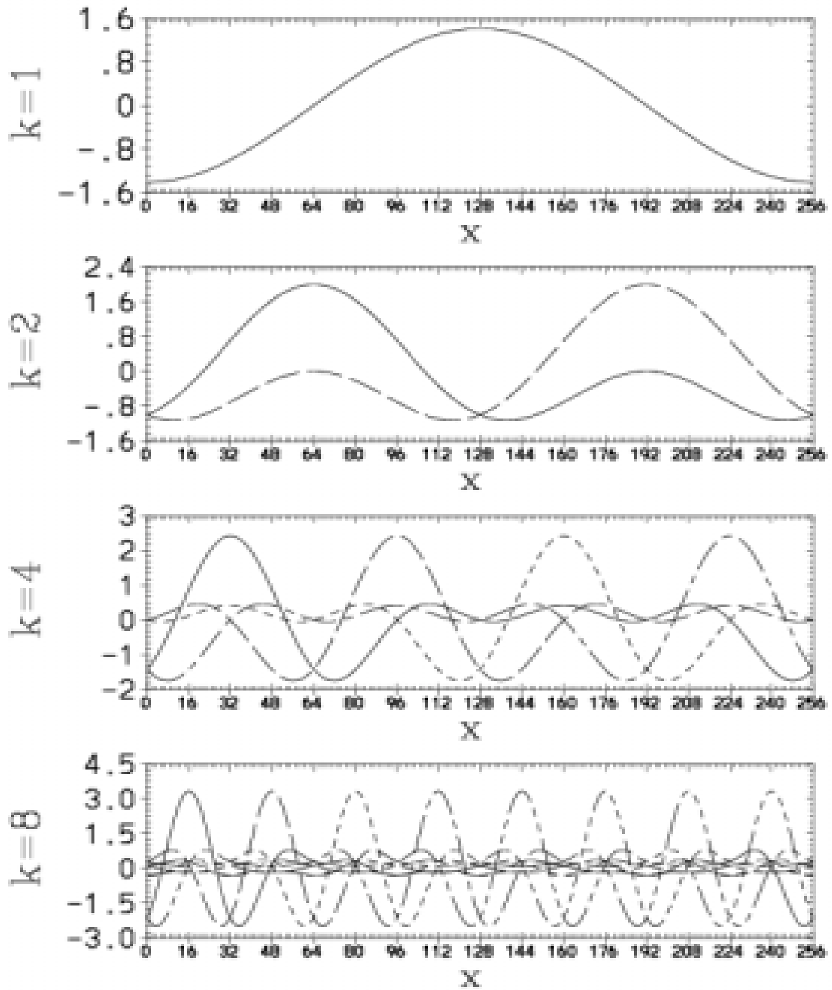
Still used by most operational Centers and GCMs and probably still for the next coming 5-10 years (more 10 than 5)

(b) Super Parameterizations – Explicit convection

- See Grabowski, Kharoutdinov and Randall
- Promissing but parameterization problem (sensitivity) is “shifted” microphysics
- Future will give the “proof” if better than classical convectio parameterizations .... “locking of precipitation – moisture loo can be controlled ? Is realistic ?

See Woitjek’s talk

c) Representation and Compression of convective fields with the aid of discrete Wavelets



Fourier transform and STFT using window function

$$\hat{s}(\omega) = \int s(t)\ e^{-i\omega t} dt$$

$$\hat{s}_\tau(\omega) = \int s(t)\ g(t-\tau)\ e^{-i\omega(t-\tau)} dt$$

Wavelet transform (time,scale)

$$S(\tau, a) = |a|^{-1/2} \int s(t)\ \Psi^\star\left(\frac{t-\tau}{a}\right) dt$$

$$= \ |a|^{1/2} \int \hat{s}(\omega)\ \hat{\Psi}^\star(a\omega)\ e^{i\omega\tau} d\omega$$

References: Y. Meyer (1991), S. Mallat (1989), I. Daubechies (1988)

Mass flux representation – square pulses -

$$\overline{X} = \frac{1}{N}\sum_{k=1}^{K}\sum_{i=1}^{N} X_i\ \Psi_k \Rightarrow \overline{w(z)\,X(z)} = \sum_k \tilde{a}_k \tilde{w}_k \tilde{X}_k(z)$$

Decomposition is not unique as it does not satisfy the « admissibility » condition (zero domain mean of analysing function)

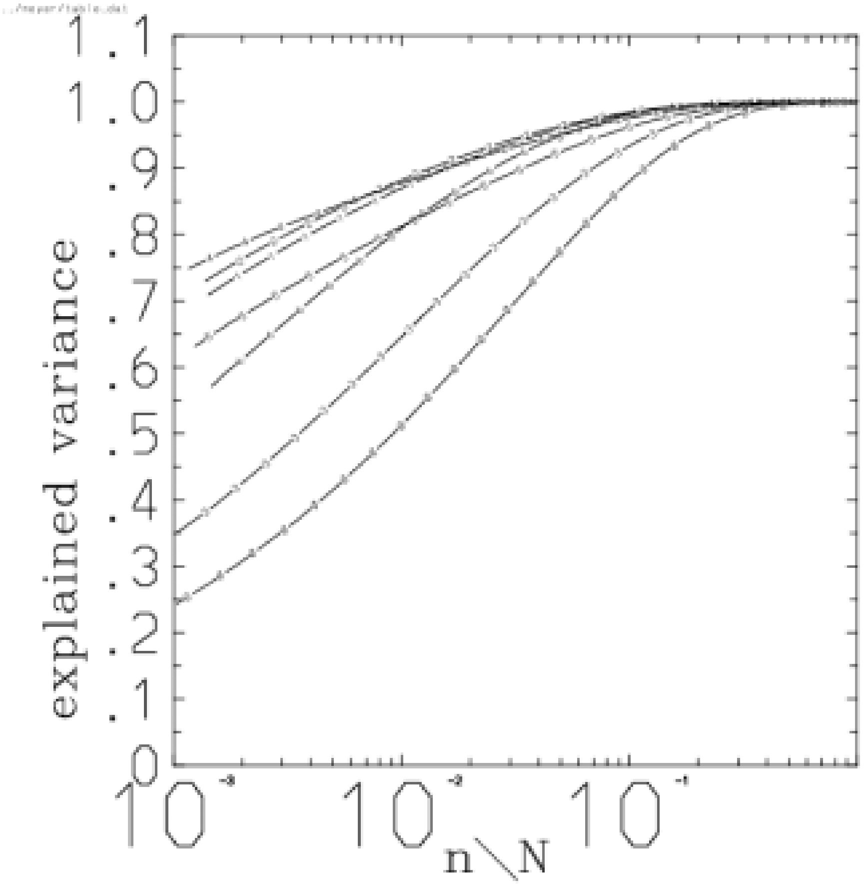
Wavelet transform (time,scale)

$$\frac{\partial X}{\partial t} = -\frac{1}{\rho}\nabla \cdot \rho \mathbf{v}\, X + F_x$$

$$\frac{\partial \widehat{X}_k}{\partial t} = \sum_{i,j}(a_{i,j,k}\widehat{u}_i + b_{i,j,k}\widehat{v}_j)\widehat{X}_k - \frac{1}{\rho}\frac{\partial}{\partial z}\rho \sum_{i,j} c_{i,j,k}\widehat{w}_i \widehat{X}$$

$$+\widehat{F}_{x,k}$$

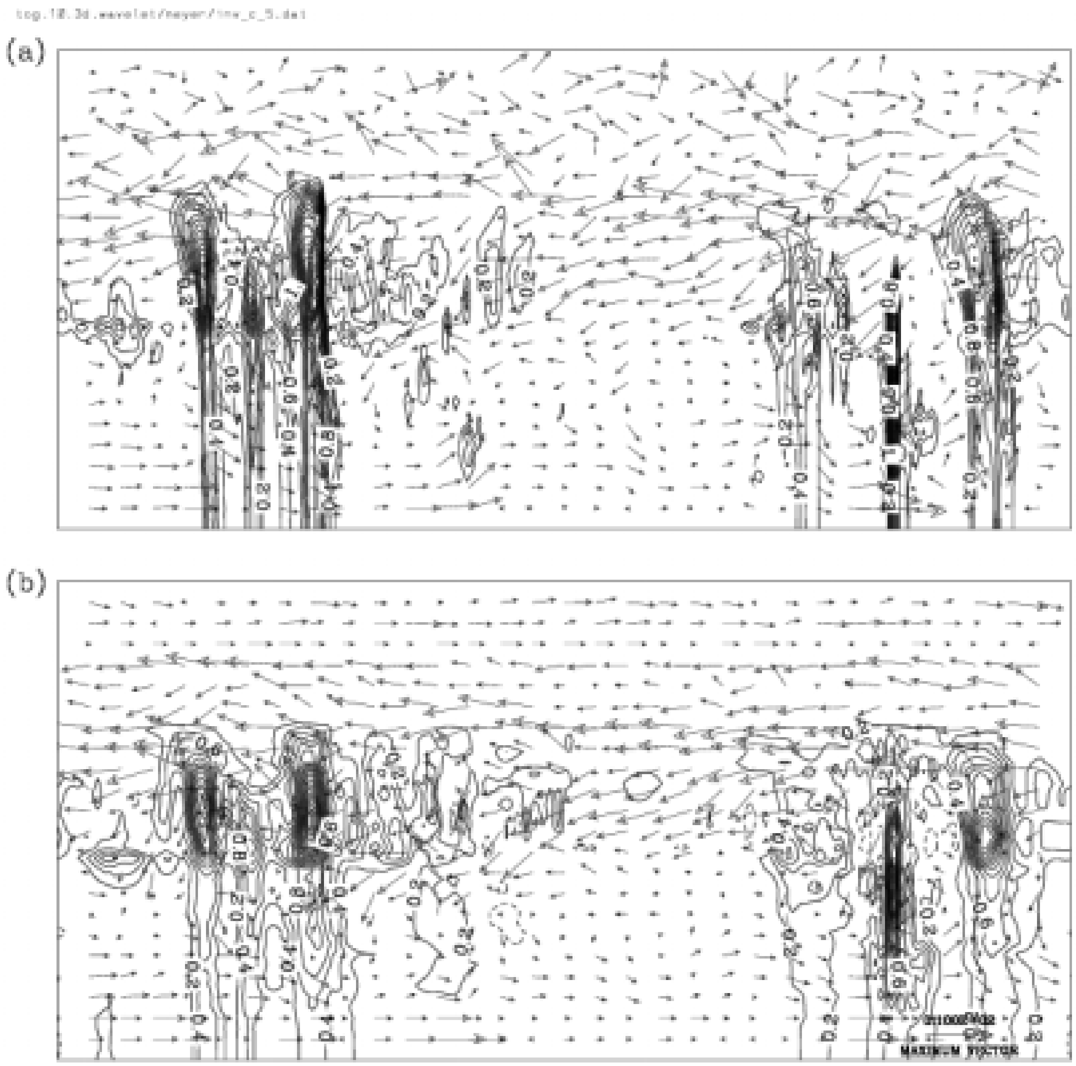
Assessment of compression using explained variance



From 256 x 256 x 47 domain CRM run -

2 km hor.grid

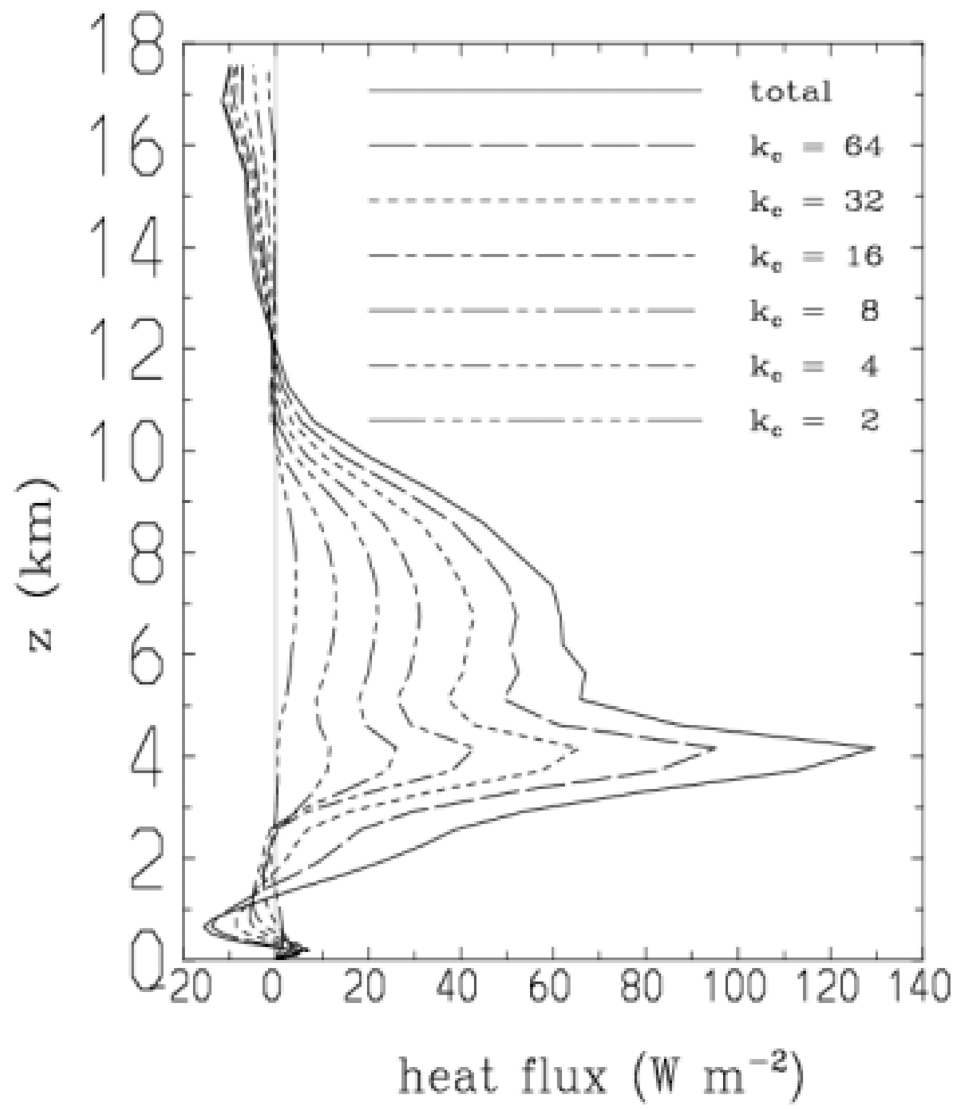
TOGA Total condensate and wind field – vertical cross sectio



CRM data

Filtered ~ 1%

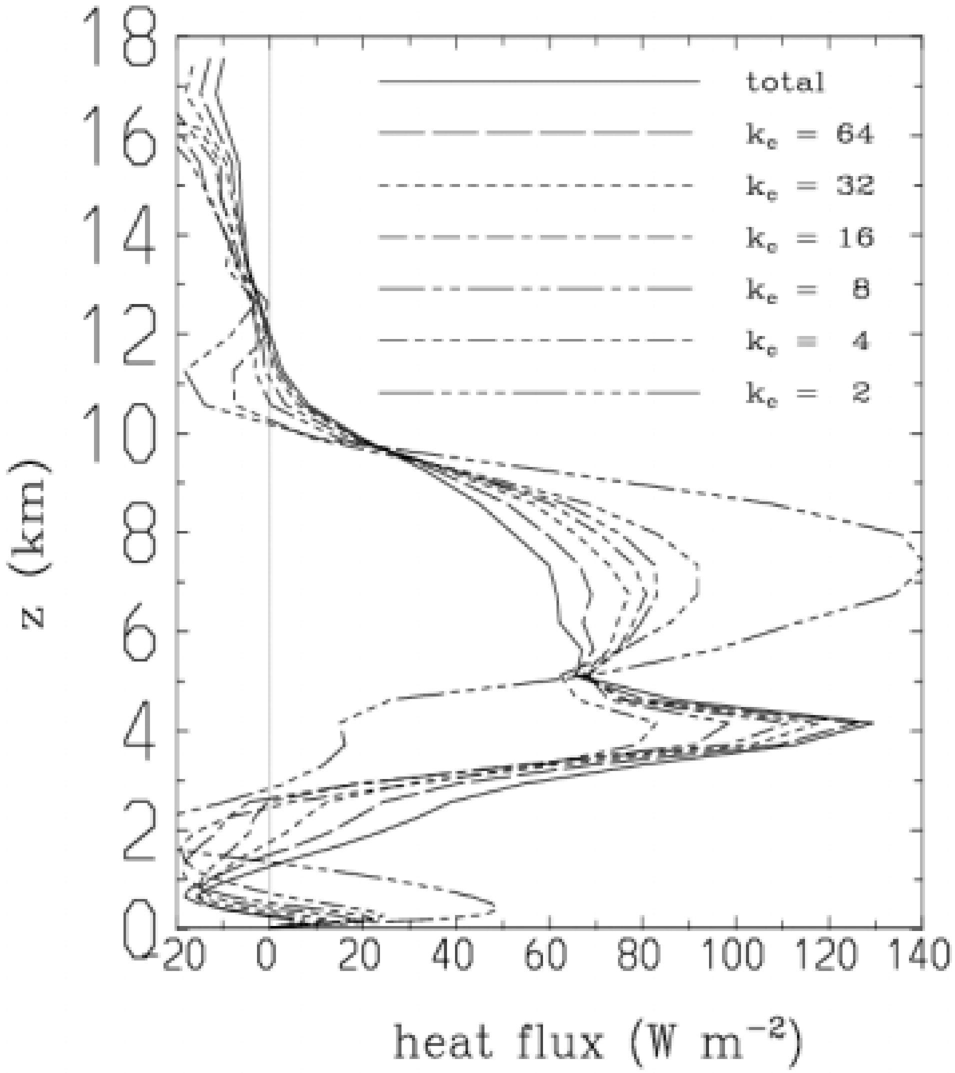
Variation of total flux with truncation/resolution - compressio



Jun-Ichi Yano

Wavelets

Renormalization of total flux



(c) Neural Networks

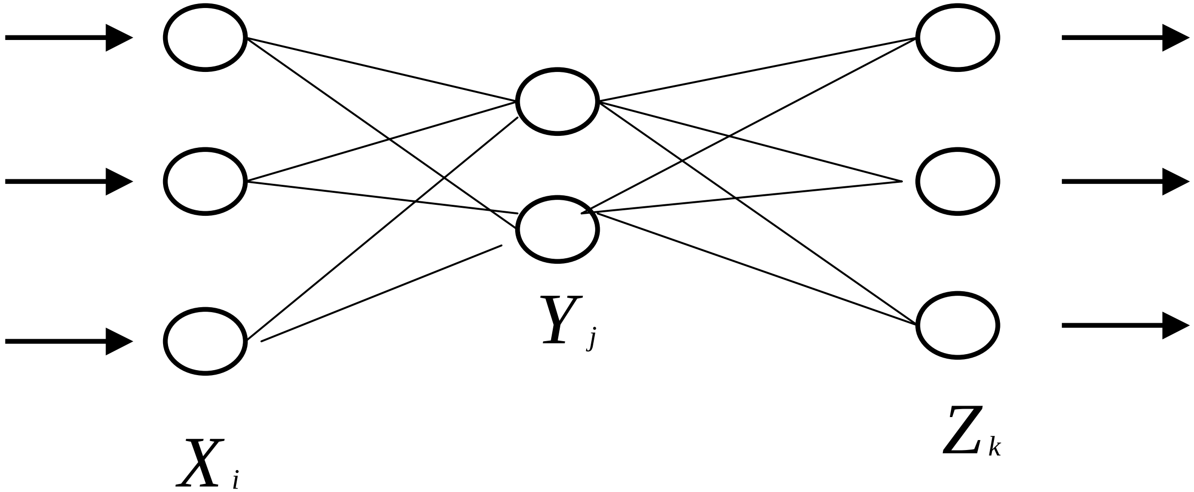
- See W. Hsieh and B. Tang (BAMS 1998) for a review of geophysic applications

- Has a biological-Psychological origin in “brain studies” 1940s, 1950s

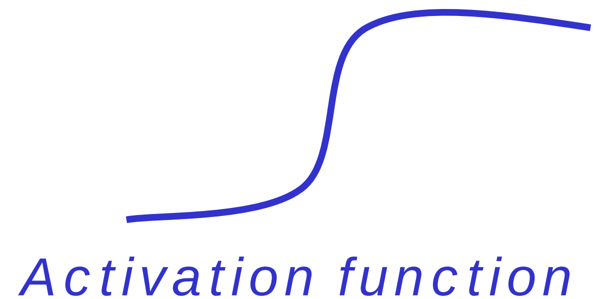
- It is an empirical method where a set of Input varibales X1, X2 etc. Is no linearly linked to a set of output variables Z1, Z2 etc.

- The NN method minimizes a Cost function and can be linked variational data assimilation

Thanks to Fréderic Chevallier and Emanuel Moreau



$$Y_j = \tanh\left(\sum_i w_{ij} x_i + b_j\right)$$



$$Z_k = \sum_j \widetilde{w}_{jk} Y_j + \widetilde{b}_k$$

Determine weights *W* and bias parameter *b*, originally by backward propagation algorithm (« adjoint ») or now by steepest descent - iteration

Application for convection parameterization:

- Train the network with defined Set of Input/Output Parameters:

  Input e.g: P, T, q, u, v

  Output: convective tendencies for T, q, u, v, massflux

- where get Input/Output from:

  mainly CRM, observations, complete with GCM

- Advantage: once trained application in model easy -> vector of weights

  no need to write Tangent linear and Adjoint

- Big work/Inconvenient: Problem is big – need a lot of Input Files

- Practical Aspect: probably best use normal Trigger function of convection scheme to activate convection, the Output tendencies from NN algorithm might still have to be "normalized" by classical CAPE closure.

Need Help+Profiles want to work together ?

Brief Summary

Gracias Javier y Lola

- There are no miracles, and progress is slow

“controlled error growth”

- Probably progress will be (hopefully) done in all 4 directions

- Does anybody has other suggestions ?

Joyeux Noel, Feliz Navidad Frohe Weihnacht, Merry Christmas, prettige Kerstdagen, Feliz Natal