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WORKSHOP ON ATMOSPHERIC LIMITED AREA MODELLING
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"Dynamical Adaptation"

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Please note: These are preliminary notes intended for internal distribution only.

Short lecture Notes on the lecture Dynamical Adaptation

JF Geleyn

* Restrictive definition of adaptation : LAM use is not adaptation

* Distinction between statistical and dynamical adaptation ; some ideas about the cycle of data in Numerical Weather Prediction

* Potential advantages of dynamical adaptation : - possibility to incorporate (but how?) more resolution / more physics
  - free choice of "target locations"

* 3 examples of dynamical adaptation
  * steady linear 3-D model with highly parameterized physics for local orographical effect in particular situations ; difficulty to assess the potential of this new approach
  * 1-D high resolution, sophisticated physics model coupled to L.S. forcing ; somewhat disappointing results, the coupling and the initialization are not in full grip.
  * retuning of the near-surface part of the model, taken out to be rerun in stand-alone mode ; instance of using the adjoint technique for optimisation (some definition of the adjoint technique and its difference with optimal control given here) ; early development stage but some promising results

* Conclusion : no single strategy ; operational usefulness still to be proven.

WHAT IS ADAPTATION ?

THE USE OF A MODEL, DRIVEN BY THE FORECAST THAT ONE WISHES TO ADAPT, ABLE TO DESCRIBE MORE SCALES OF MOTION AND/OR MORE PHYSICAL PHENOMENA THAN THE STARTING FORECAST ....

(IN THIS VERY BROAD SENSE L.A.M. USE IS ALSO ADAPTATION. SO WE SHALL ADD A MORE RESTRICTIVE CONDITION)

... AND AT A LOW COMPUTATIONAL COST, PROVIDED IT IS ONLY DONE AT PREVIOUSLY SELECTED LOCATIONS

DIFFERENT KINDS OF ADAPTATION TECHNIQUES

TATISTICAL : Regression } × { M.O.S.
Discrimination } × { P.P.

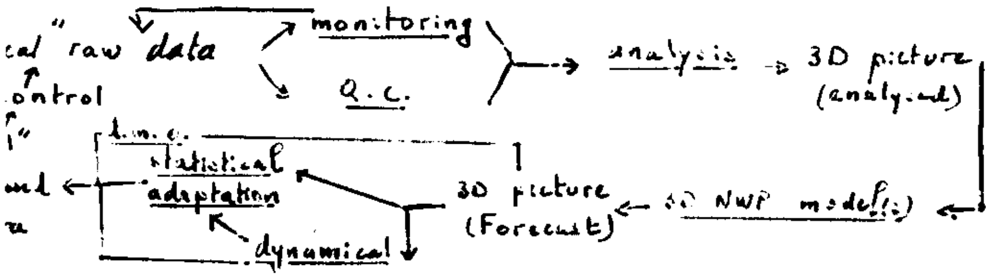
Kalman Filter

etc……

YNAMICAL 3D } models × { more vert. resolution
2D } models × { more horiz. resolution
1D } models × { more (or better tuned) physics

In the case of statistical adaptation the only constraint is that the input be produced homogeneously.

Thus, in principle, the ideal "chain" of data processing is.



WHAT ARE ADVANTAGES OF DYNAMICAL ADAPTATION (FROM THE THEORETICAL POINT OF VIEW)

A) More resolution / physics (see above)

B) At the chosen location(s), possibility of direct "tuning" against raw data of the kind one wishes to directly Forecast. But….

, as for statistical adaptation, results on learning File always > results on trial File

Basic question : how much > ?

3 examples of dynamical adaptation

* linear high resolution 3D non-hydrostatic model (Källen, MISU, Stockholm)
  ↳ cloud and wind fields

* 1D vertical column sophisticated model (CAILLOU) (Musson-Genon, DMN, Paris)
  ↳ Fog, near surface inversion !

* Surface balance model with retuned parameters (MUSCLA) (Marois, DMN, Paris)
  ↳ automatic "SYNOP": T_{2m} q_{2m} $\vec{u}_{10m}$

90-07-18

On the simulation of meso-γ-scale cloud and wind fields

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Abstract

We have utilized a linear flow model to investigate mesoscale flow over variable orography and roughness. The model equations are solved with a combined spectral and shooting technique. In addition to wind, temperature and pressure perturbations the mesoscale variability of the humidity field is also computed. From the humidity field mesoscale variations of cloudiness is diagnosed. Comparisons are made with some observations and a simulation with a more complex, nonlinear, time dependent model.

Papers used for the examples

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Forecasting in the Vertical with a Local Dynamical Interpretation Method

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(Manuscript received 10 November 1987, in final form 4 May 1988)

ABSTRACT

A one-dimensional (1-D) planetary boundary-layer model, including a complete set of simple physical parameterizations, has been used since July 1986 to predict daily soundings at Trappes in the suburbs of Paris. This model is coupled to the French operational spectral hemispheric model, representing the large-scale atmospheric environment by means of horizontal gradients and vertical velocity in the advective terms, and geostrophic wind. The study of the statistical scores (mean absolute error and mean error) for 220 cases during the year 1986–87 provides good accuracy for the 12-h forecast (as compared to fine mesh modeling and statistical interpretation methods) but exhibits a loss of accuracy for periods longer than 12 h. Improvement in the results through adjustment of some of the model parameters with the help of a file containing 22 test situations appreciably reduces the mean absolute error; this method would thus be useful for local forecasts of sensitive weather elements. Further improvement could be obtained by coupling this 1-D model with a three-dimensional, fine mesh model and by refining cloudy turbulence and soil evaporation schemes.

1. Introduction

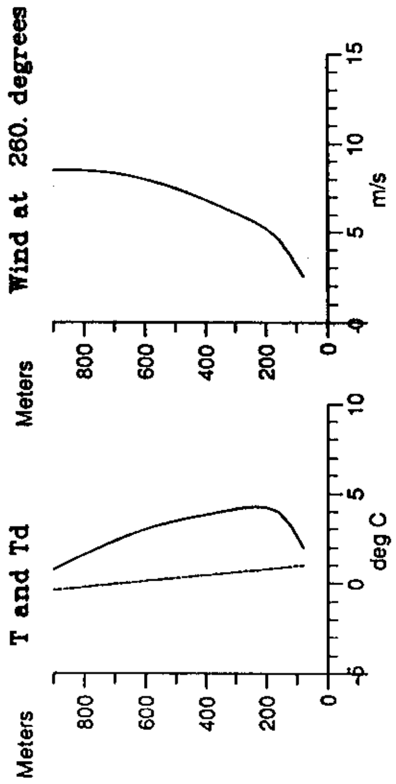
Over the last few years, numerical prediction techniques have resulted in a considerable improvement in weather forecasting. This first became evident in the beginning of the 1970s in synoptic scale prediction, model that gives the atmospheric large-scale environment in advective terms (Burk and Thompson 1982; Musson-Genon 1983).

For operational use, this boundary-layer model must include a complete set of physical parameterizations (turbulent diffusive transport, advection, solar and

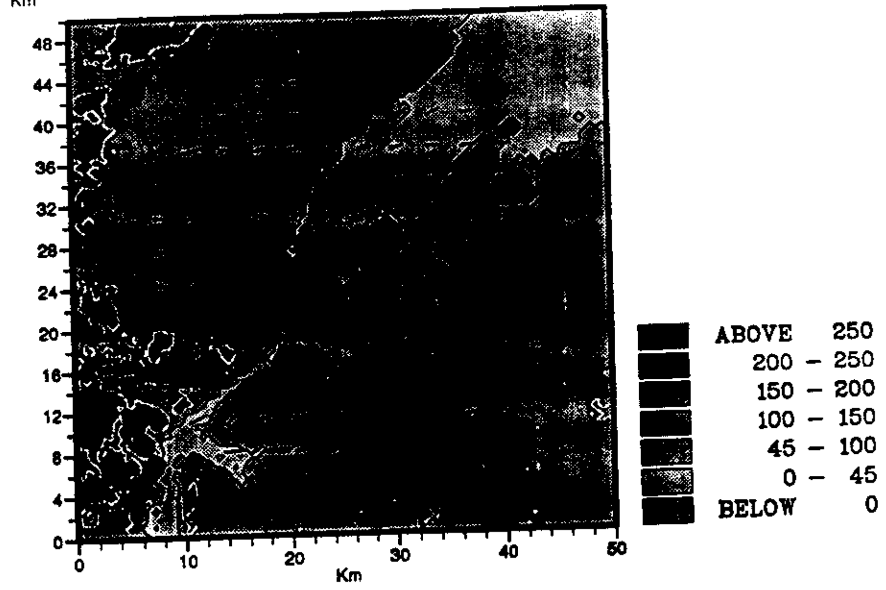
Steady linear solution (linearization around the large scale Forecast) Forced by local topographic Features : hills, lakes, shore lines ...

Basic hypothesis : both the Forcing and the answer have no significant short period important Fluctuations

Local information : orography
"highly parametrized" surface Friction
with varying roughness
(differential heating From surface)



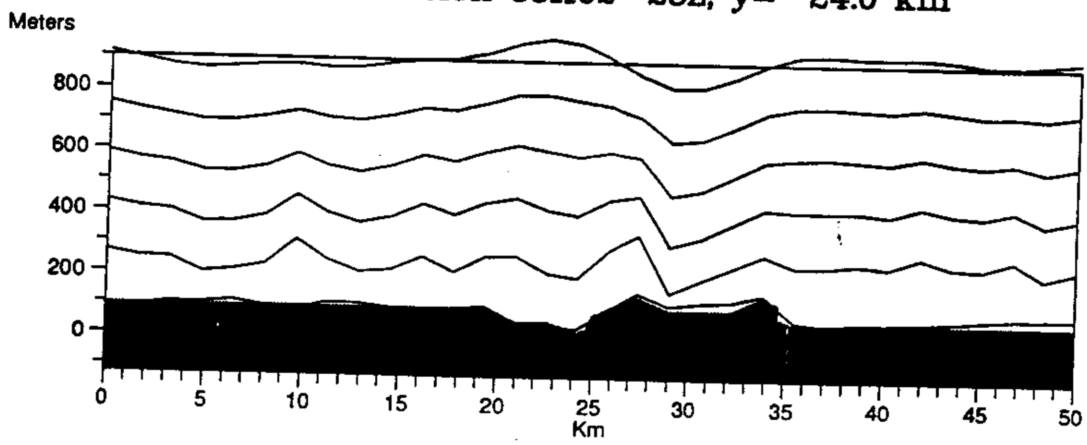
Fields at 119. meters, 831102 23Z



Basic state wind 3.7 m/s

9

Cross-section 831102 23Z, y= 24.0 km



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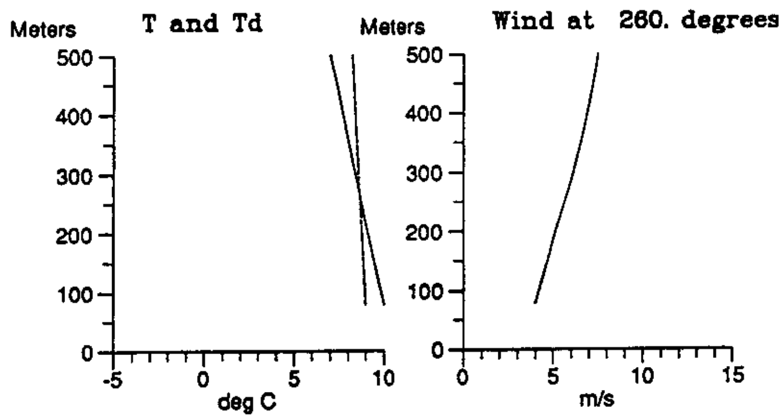
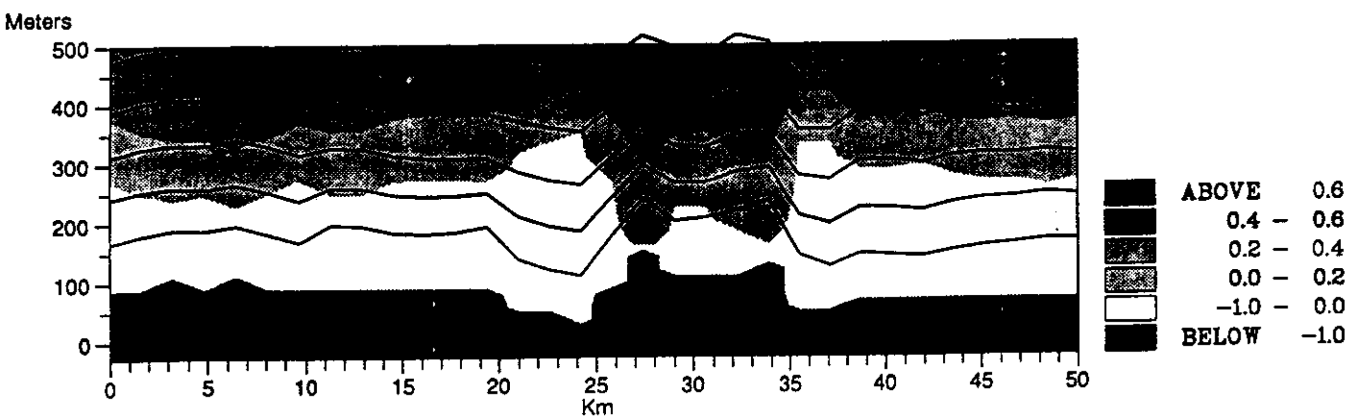
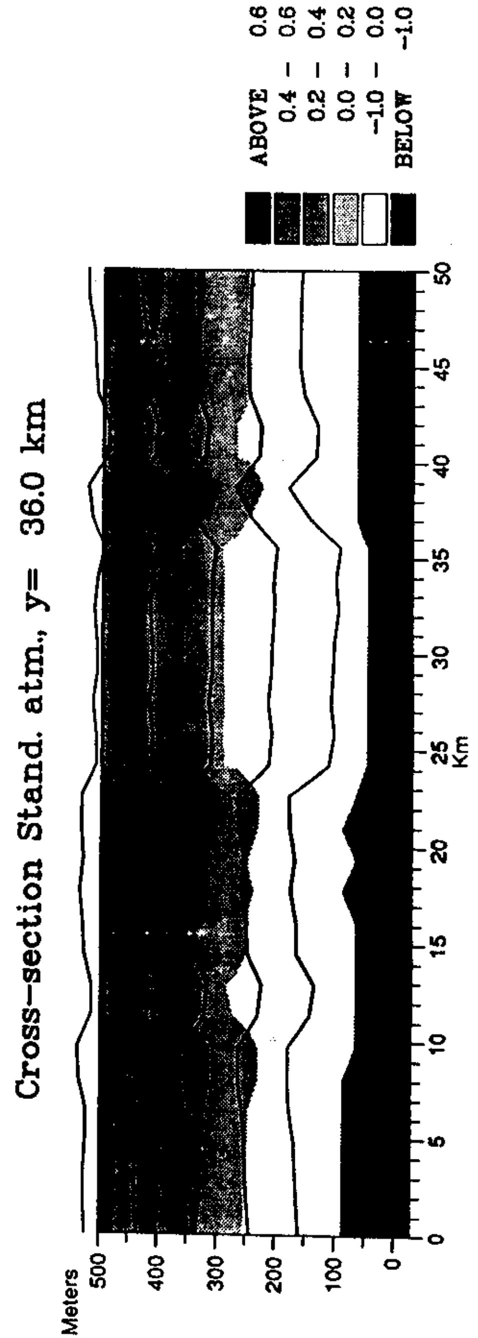


Cross-section Stand. atm., y= 24.0 km





CAILLOU : One dimensional high resolution, sophisticated physics, coupled with L.S. Forcing

58 vertical levels (bottom one at 10 m
32 underneath 1500 m!)

prognostic liquid water

Turbulent Kinetic Equation For the vertical diFFusion

complete Kessler's scheme For L.S. precipitation (no convection of course)

Smooth transition to the upper layer Forcing of the coupling model

Force-restore method For the soil

Sophisticated radiation scheme

Main problem = coupling

W U_g V_g from L.S. integration

(not the most stable of all output paramete

$-\vec{v}\,\nabla \begin{cases} q \\ \vec{v} \\ T\ldots \end{cases}$

which $\vec{v}$? model
or coupling model

Starting (and verifying) point :

an actual sounding = i.e. ≠ from the analysis at the considered grid point of the large scale model

Paradox : The "better" the coupling model the worse the coupling

(scale mixing ?)

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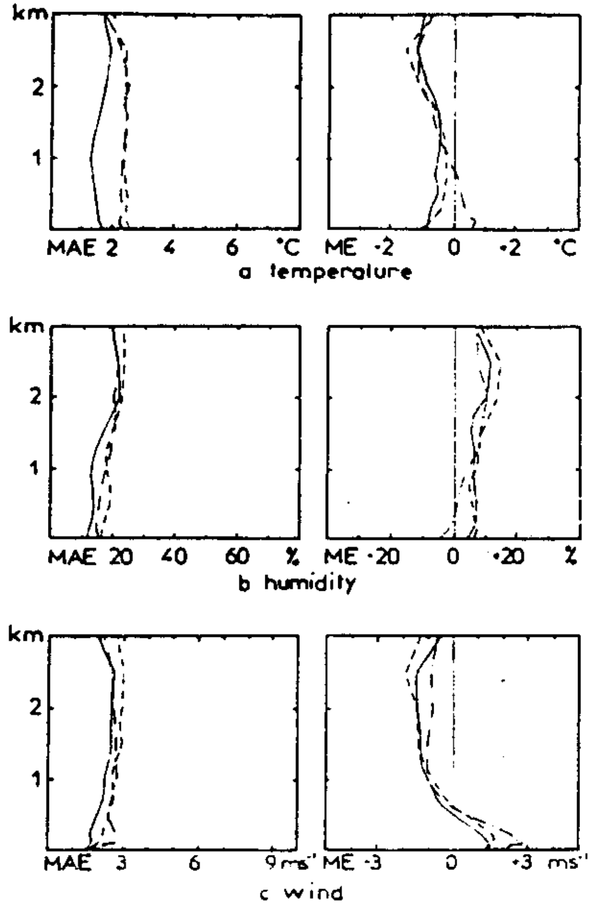

FIG. 2. The statistical scores of CAILLOU during the year 1986–87 at 12 h (solid), at 24 h (dot-dashed) and at 36 h (long-dashed): (a) temperature; (b) relative humidity; (c) wind speed.

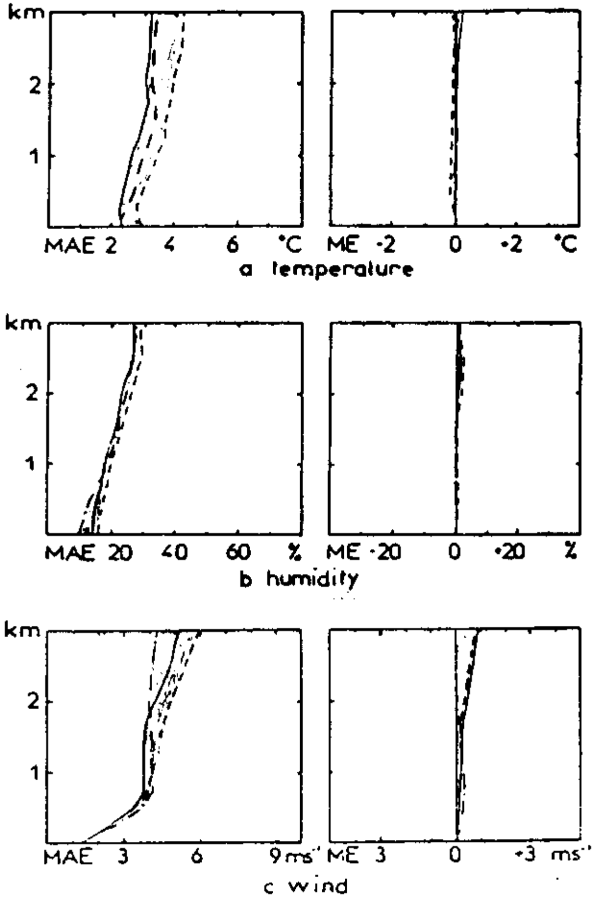

FIG. 3. The statistical scores of persistence during the year 1986–87 for $\alpha = T$ (a), H_u (b), $|V|$ (c): at 1200 UTC $\alpha = N^{-1} \sum_{1}^{N} |\alpha_{12}^{D} - \alpha_{12}^{D-1}|$ between day D and the day before $D - 1$ (solid line), at 0000 UTC $\alpha = N^{-1} \sum_{1}^{N} |\alpha_{00}^{D} - \alpha_{00}^{D-1}|$ between day D and the day before $D - 1$ (dot-dashed), at 1200 UTC $\alpha = N^{-1} \sum_{1}^{N} |\alpha_{12}^{D} - \alpha_{12}^{D-2}|$ between day D and day $D - 2$ (long-dashed).

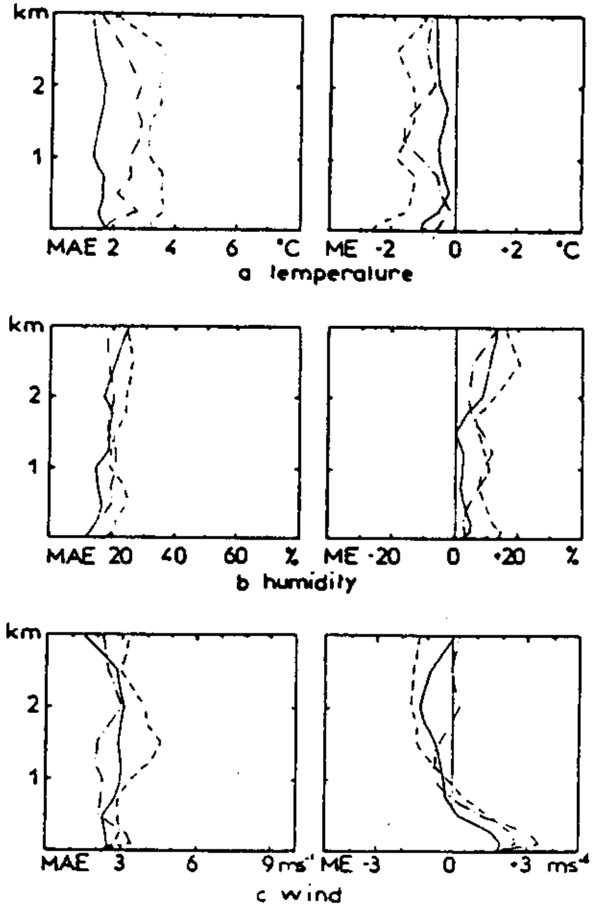

FIG. 4. The statistical scores of CAILLOU prior to adjustments for the file of test situations (symbols as in Fig. 1).

sented. The forecast results for 1200 UTC are very en-

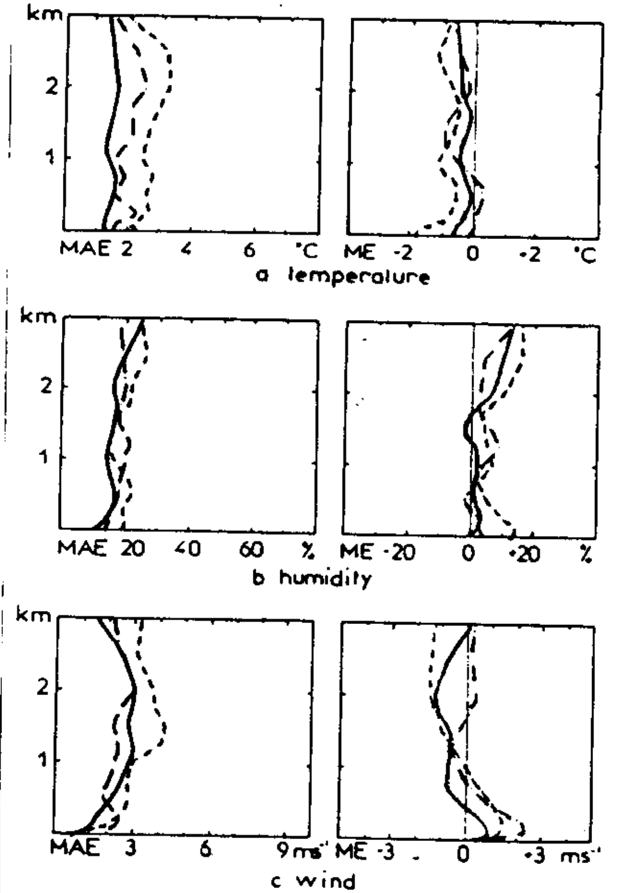

FIG. 9. The statistical scores of CAILLOU after adjustments for the file of test situations (symbols as in Fig. 1).

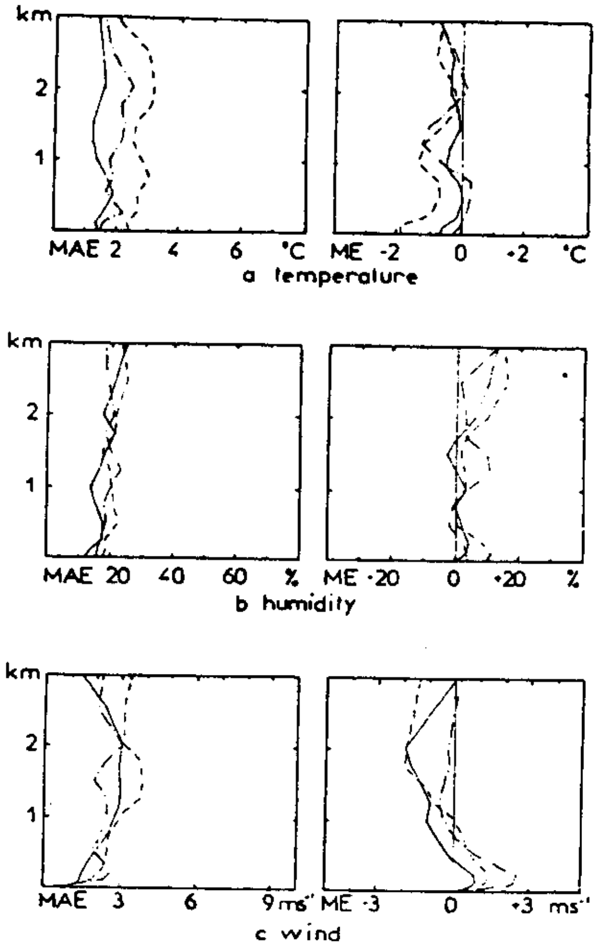

FIG. 10. The statistical scores of CAILLOU for the file of test situations with advection by means of large-scale wind (symbols as in Fig. 1).

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7.

DYNAMICAL ADAPTATION : MUSCLES project

C. Marais
L. Musson-Genon

Basic idea :

- Store T_N HU_N $\vec{u}_N$ Precip. Rad. ...
  From PERIDOT run at a given grid point
- Rerun the "soil" model with modified values of
  - Albedo
  - Emissivity
  - Heat Capacity
  - Water Capacity
  - Roughness length
- On a learning File optimise the choice of these parameters to Forecast at a given location (use of the adjoint code helps a lot)

Preliminary results

- encouraging .3 °K of RMS potential
- but what will remain
  - on test File
    and
  - when combined with statistical adaptation

??

MUSCLES

MODELISATION UNIDIMENSIONNELLE DU SOL ET DE LA COUCHE LIMITE EN SURFACE

σ 15 — T Q U — FORCAGE PERIDOT TOUTES LES 3H DE 0H A 36H

CALCUL DES FLUX DANS LA CLS

$$Q_0 = -a^2 . U . (\theta(z) - \theta_s) . F_\theta \left(\frac{z+z_0}{z_0}, Ri \right)$$

$$E_0 = -a^2 . U . (Q(z) - Q_s) . F_\theta \left(\frac{z+z_0}{z_0}, Ri \right)$$

avec $a = \dfrac{K_a}{\mathrm{Log}\left(\frac{z+z_0}{z_0}\right)}$

EVOLUTION DE T_s

$$\frac{\partial T_s}{\partial t} = C_{sol} . H_{at} - \frac{2\pi}{\tau_1} . (T_s - T_p)$$

avec $H_{at} = (1 - A).R_s + E . R_t - \rho_s C_p Q_0 - \rho_s L E_0 - E \sigma T_s^4$

CALCUL DE Q_s

$$Q_s = H_u . Q_{sat} + (1 - Desert) . (1 - H_u) . Q$$

avec $H_u = 0{,}5 . (1 - \cos(\pi W_s))$

T_s Q_s — R_s R_t P

SOL

RES. SUP.

$$\frac{\partial W_s}{\partial t} = \frac{1}{\frac{W_{smax}}{C_{wsol}}} . (P - \rho_s E_0) - \frac{W_s - W_p}{\tau_1}$$

RES. PROF.

$$\frac{\partial W_p}{\partial t} = [illegible] . \frac{W_s - W_p}{\tau_1}$$

T_p

ADJOINT TECHNIQUE (don't mix up the concept with that of "optimal control" - that might be done (expensively) without adjoint technique!) → 4D data minimization example

$$X \xrightarrow{\mathcal{F}} Y$$

linearisation of all steps } knowledge of the "trajectory" required

$$\frac{\partial X}{\partial \alpha} \xrightarrow{\mathcal{L}(\mathcal{F})} \frac{\partial Y}{\partial \alpha}$$

Sensitivity study : one non zero element of $\frac{\partial X}{\partial \alpha}$ *

⇒ all values of $\frac{\partial Y}{\partial \alpha}$

Adjoint calculation : the reverse

* or rather any single function of the vector X (and Y in the reverse case)

- OPTIMISATION DES SEPT CONSTANTES LOCALES

30 Cool A E Desert Warm/Cool Warm/Warm

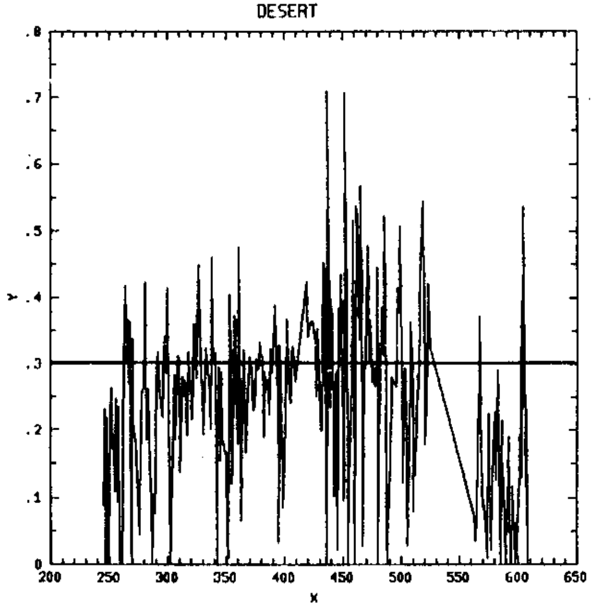
Méthode utilisée : TECHNIQUE DE L'ADJOINT POUR MINIMISER LES ERREURS DE PREVISION

Résultats obtenus sur un fichier test comportant 1 an de données

DIMINUTION DE L'ERREUR ABSOLUE MOYENNE

POUR T_{2m} : 0.22°
POUR Q_{2m} : 0.12 g/kg sur le Bourget
POUR U_{10m} : 0.08 m/s

EXEMPLE D'OPTIMISATION D'UNE CONSTANTE LOCALE ICI DESERT



- APPLICATION DE LA METHODE EN PREVISION

Détermination des constantes locales par moyenne glissante sur les jours précédents la prévision.