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SMR/475-8

WORKSHOP ON ATMOSPHERIC LIMITED AREA MODELLING
15 October - 3 November1990

"Large-Scale versus Meso-Scale Predictability"

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

Short lecture Notes for the lecture Large scale vs. meso-scale predictability

JF Geleyn

The lecture is oriented towards physical (including orographical) processes, given their importance at meso-scale, it completely ignores the important but largely unknown subject of predictability ⇄ data assimilation at meso-scale and it only briefly and subjectively touches the question of a priori prediction of the quality of a given forecast.

The very different behaviours of objective scores at large scale and meso-scale (rapid "saturation") should not lead to believe there is extra predictability at meso scale. Rather one should try and understand why classical large scale concepts are at fault when going to meso scale and what measures of predictability could usefully replace them.

Examples will come exclusively from the experience with the french operational NWP system: Emeraude (large scale global spectral system) and Peridot (LAM, meso scale, grid point technique).

Local details offer a potential of predictability (i.e. some local phenomena - e.g. winds near the surface forced by topographic details - can be simulated) but the question remains to be addressed whether this potential can be operationally realised (i.e. going from ability to simulate towards ability to forecast!). At least in looking at objective scores of the end of line products (including forecasters interpretation) there seem to be some real hopes it is the case.

A) Lateral boundary conditions' problem

Study of imbalances between resolved and unresolved moist processes when model's scale is changed lead to the concept of permanent spin-up at the LAM's boundaries.

This, and other dynamical problems (see A. Staniforth lecture) lead to the concept of global variable mesh modelling (→ as example one map of Mercator's representation of the ARPEGE french future system)

B) Change of scale between coupling and coupled model

Very confusing situation: slight changes can completely destroy an apparently "predictable" case or vice-versa

Thus need for "intelligent" post processing, either automatic (adaptation) or human (or mixed, in future)

C) Importance of land surface details

Orography still a problem despite undeniable progress due to its finer representation in LAMs.

Land surface processes probably as important but still in a very preliminary research phase for what concerns operational meso scale NWP application (huge data assimilation problem)

D) Time "window" for usefull extra meso-scale predictability

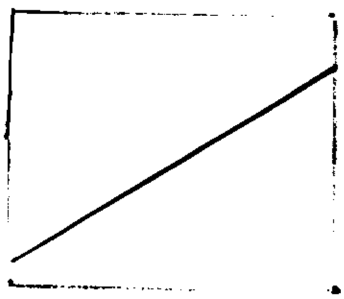
- Adaptation to local details useful (we speak only of near surface parameters)
- There is more than that in wind forecasting where we apparently make true meso scale forecasts, improving on large scale ones even in regimes with little or no orographic forcing
- less clear situation for temperature but the success of statistical adaptation with the direct model output as only predictor indicates some "hidden" meso-scale information

- Very bad situation for moisture
- Surface pressure (and geopotential heights) is a large-scale variable that should hardly be used for true meso scale forecasting.
- Results are very sensitive to the choice of physical parameterizations.

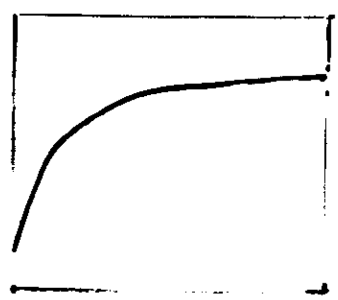
LARGE SCALE VS. MESO-SCALE PREDICTABILITY

- Importance of "physical" processes
- Lack of Knowledge on data assimilation's influence on m.s. predictability
- Is there a potential (like at l.s.) for a priori predicting the quality of a m.s. forecast?

LARGE SCALE



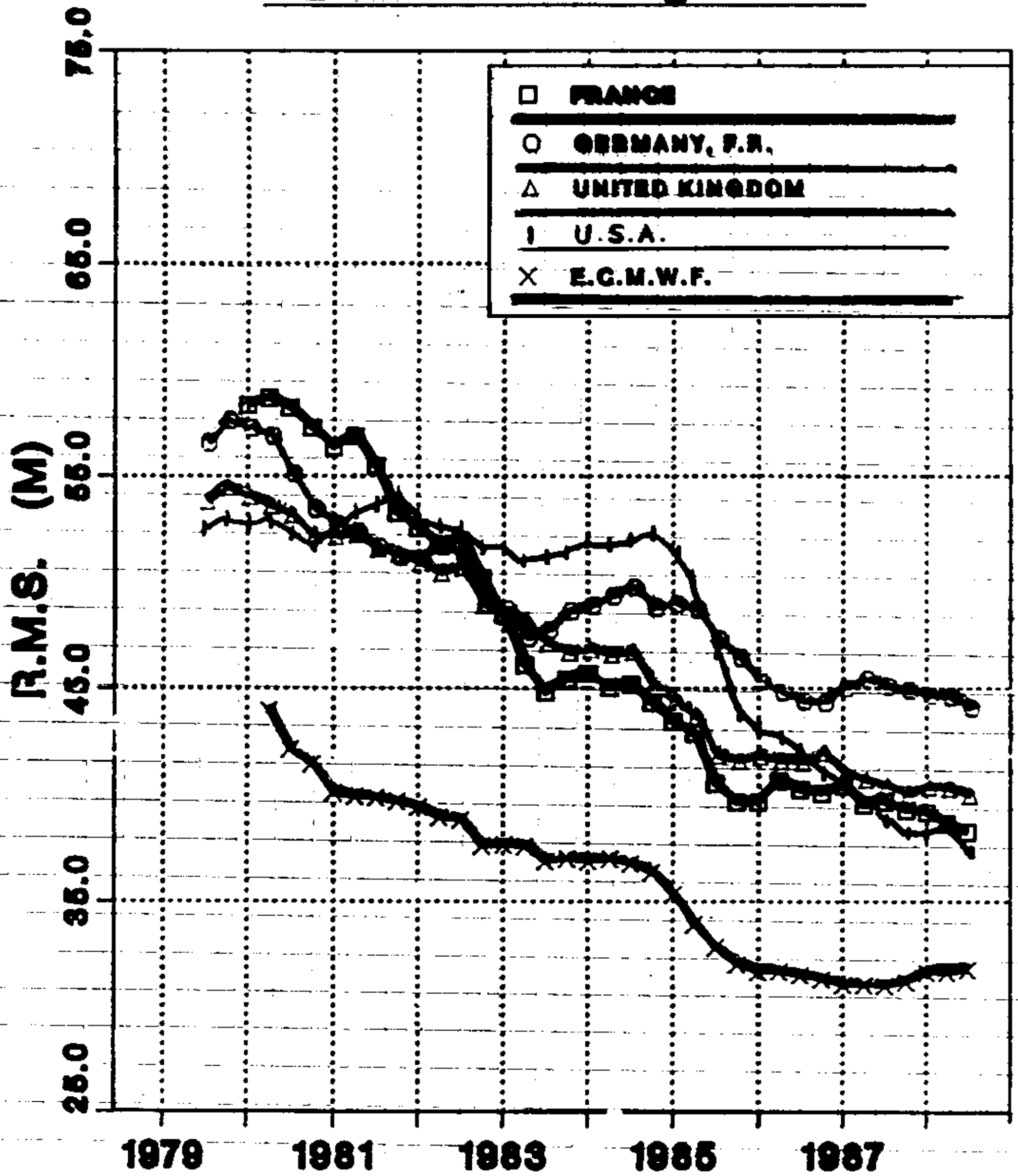
MESO-SCALE



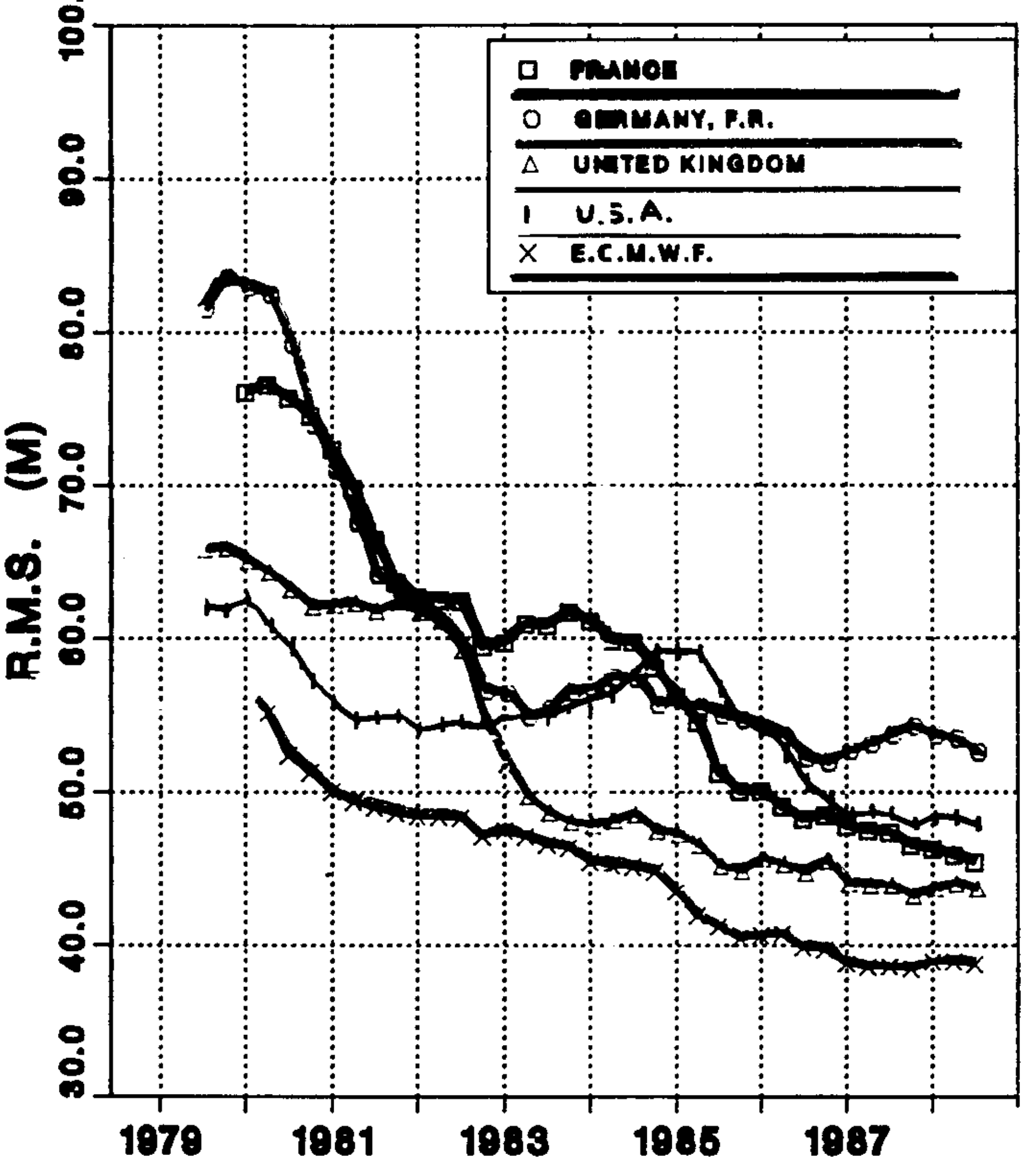
"CLASSICAL" ERROR GROTH

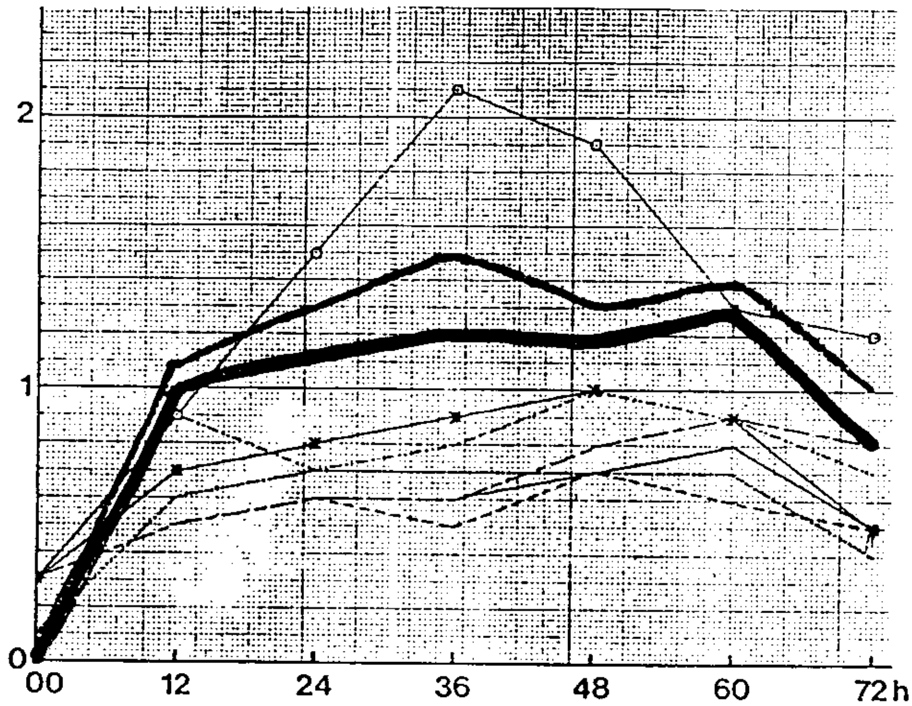
Is it linked
- to the scale?
- to the lat. boundary conditions?
- to the type of verification?
- inherent to the different atmosph. behaviours?

RMS Error of 1000 hPa Height
D + 3 Forecasts
12-Month Running Mean



RMS Error of 500 hPa Height
D + 3 Forecasts
12-Month Running Mean

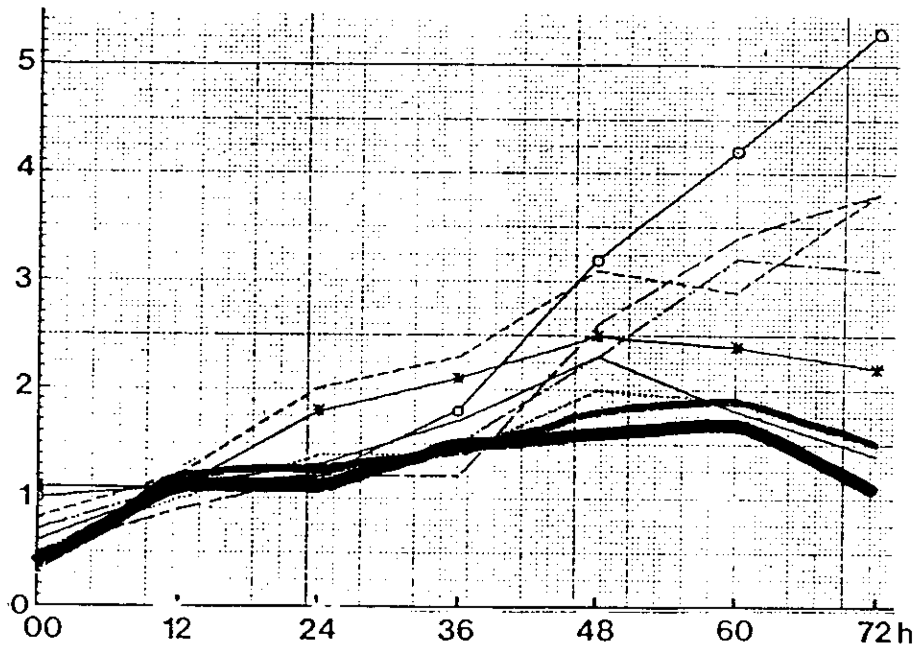




HUMIDITE (g/Kg)

500 hPa

TEMPERATURE (°C)



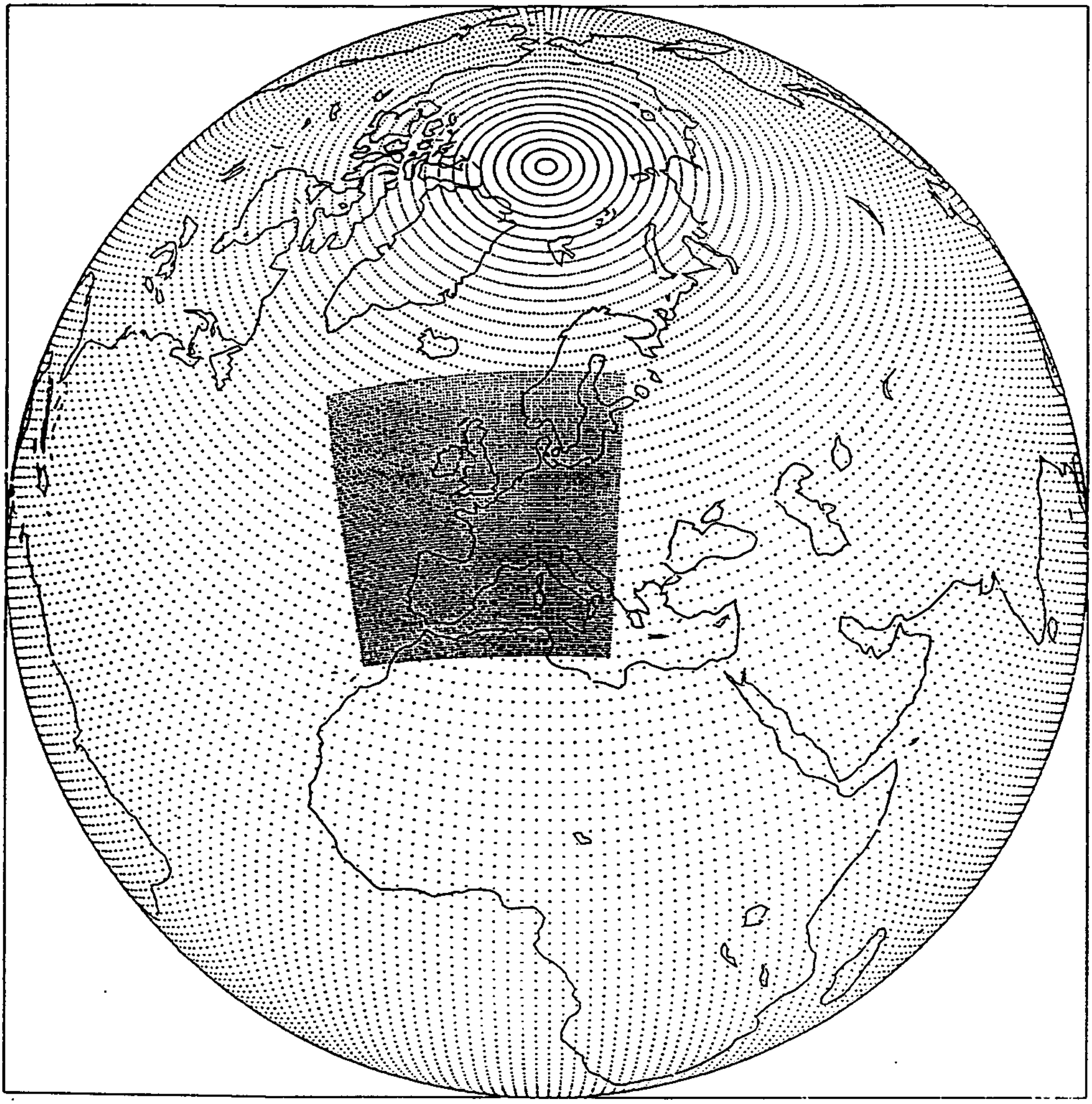
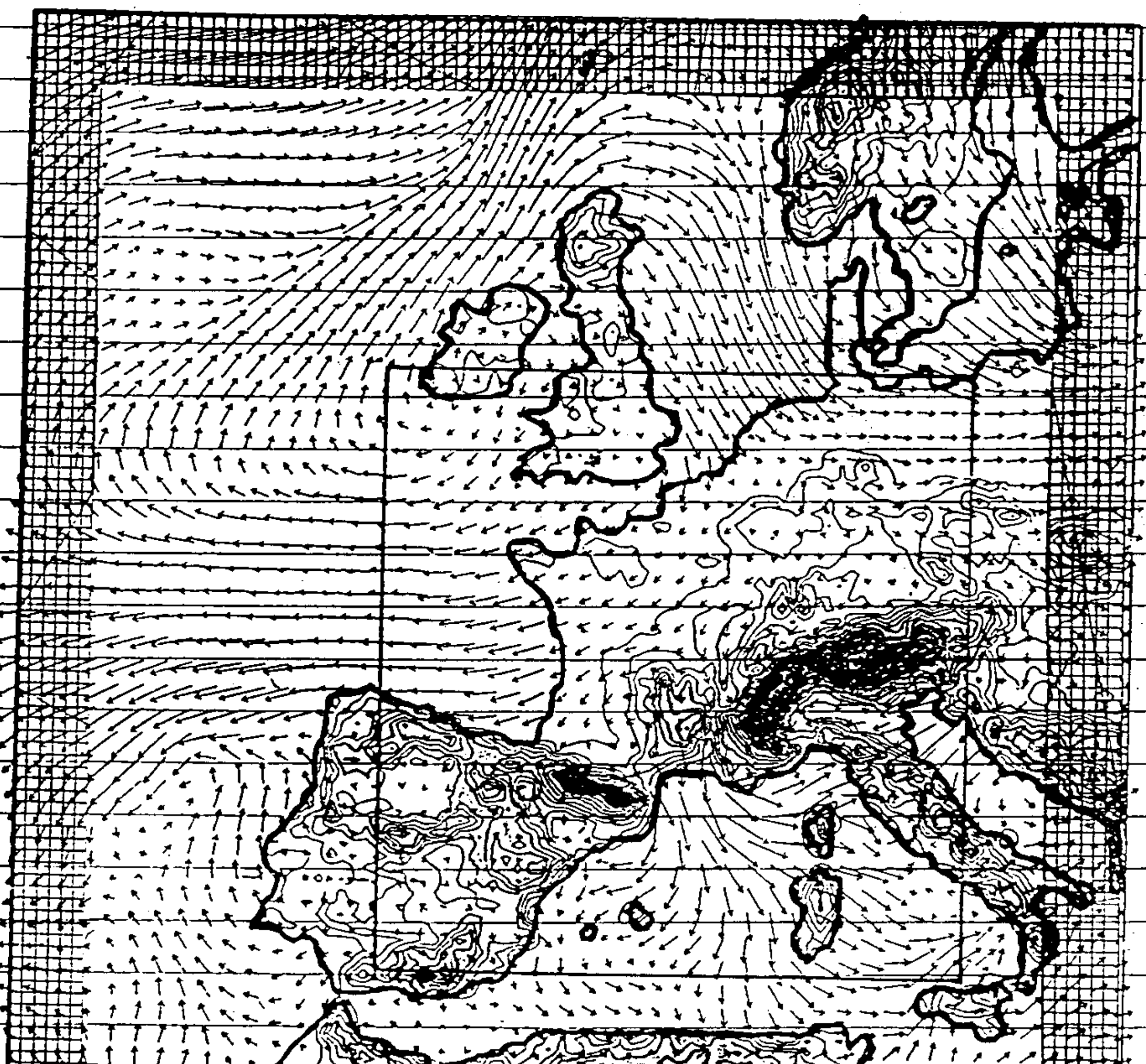


FIGURE 1 : Domaines et grilles des systèmes Emeraude (global) et Péridot.

DOMAINS FOR CURRENT AND FORTHCOMING LIMITED AREA FINE MESH MODEL (PERIDOT)

DOMAINES ACTUEL ET FUTUR DU SYSTEME DE PREVISION A MAILLE FINE (35km)

PERIDOT

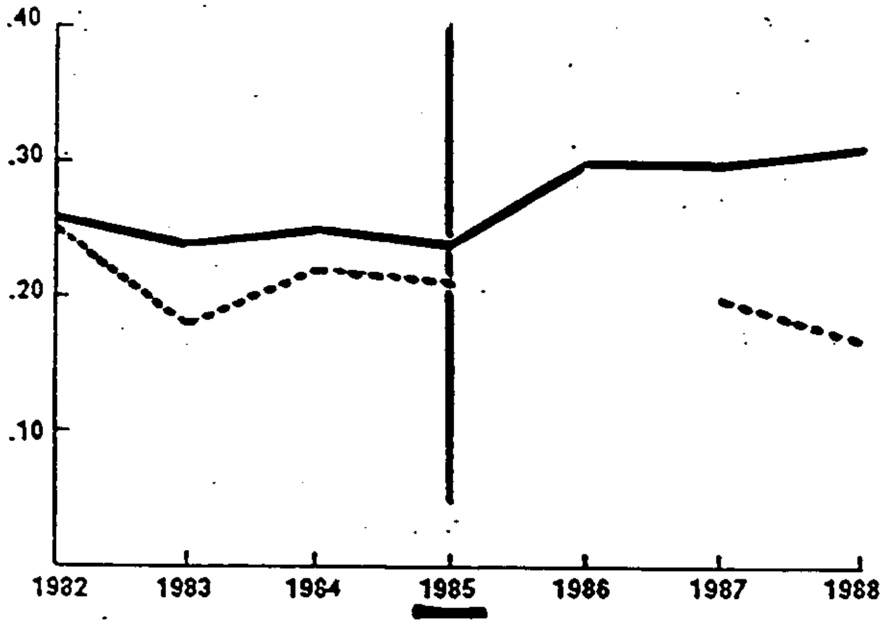


OPERATIONAL USE OF PERIDOT: IMPACT ON THE QUALITY OF THE FINAL PREDICTIONS MADE BY THE FORECASTERS

IMPROVEMENT GOT ON PERSISTENCE: $S = 1 - \frac{\text{MAE Forecaster}}{\text{MAE Persistence}}$

FOR MINIMUM TEMPERATURE FORECAST AT 2 M

TMIN AT PARIS (24 h range)



FORECASTER

E.C. STATISTICAL ADAPTATION

: FORECAST AT PARIS (IMPROVEMENT ON PERSISTENCE)

TN PERIOD	BEFORE 1982-84	/ AFTER 1986-88	PERIDOT
M.E.	.04	.05	
M.A.E.	1.88	1.81	
R.M.S.E.	2.41	2.28	- 0.13°C
St. De.	2.41	2.28	
S	.25	.30	+0.05

IMPROVEMENT

Definitions

* "Physical processes" includes not only classical parametrized processes (e.g. Radiation, Turbulent vertical mixing, Condensation/Evaporation, Convection, Surface exchanges) but also all orographic effects, since the limit between explicitely resolved and parameterized orog. effects is even more arbitrary at meso-scale than at large scale

* "Predictability" is to be understood in the operational sense (i.e. no analysed large scale LBCs) or in the pre-operational sense for research experiments (= potential future operational configuration)

* "Meso-scale" = sub synoptic (for mid-latitudes) and requiring models with mesh-sizes ($\leq$ 60 Km) $\Rightarrow$ Meso-scale predictability thus refers either to the improvement against large scale models' performances or to the capacity to forecast sub-synoptic details $\Rightarrow$ ambiguity ?

QUESTION

Is the influence of LBCs limiting meso-scale predictability to an improvement in the treatment of synoptic features, or not?

PROBLEM

The difficulty is neither in "internal" specific meso-scale developments nor in ill-posed LBCs

but

in contradictions between the "internal" and "external" evolutions for the scales that the model can handle

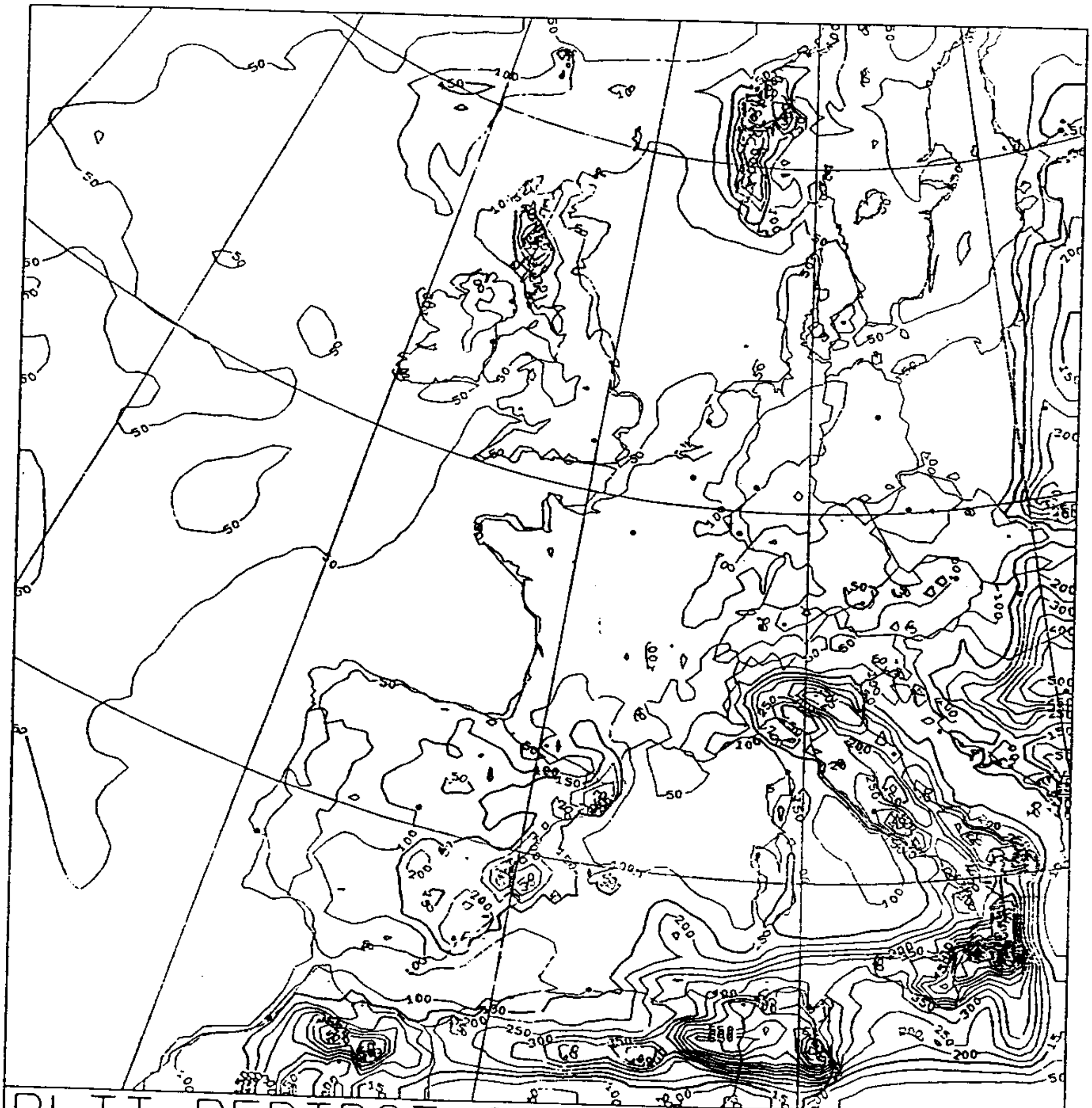
WHAT TO DO?

in the short term : ensure maximum consistency between internal and external "physical" forcings (this includes a problem of scale dependency of this forcing)

in the long term : get rid of "one way LBCs"

⇒ 2 way nesting

⇒ variable mesh



PLTI PERIDOT 06-18

Study of the too strong mesh size dependency of irreversible processes

K. YESSAD

1st result The problem does not come from internal model weaknesses (they can at most amplify it) but from the effect of lateral boundary conditions

2nd result This LBC problem is mainly linked with the coupling of the humidity field (and not with wave dynamical problems or divergence/vorticity inadequate coupling)

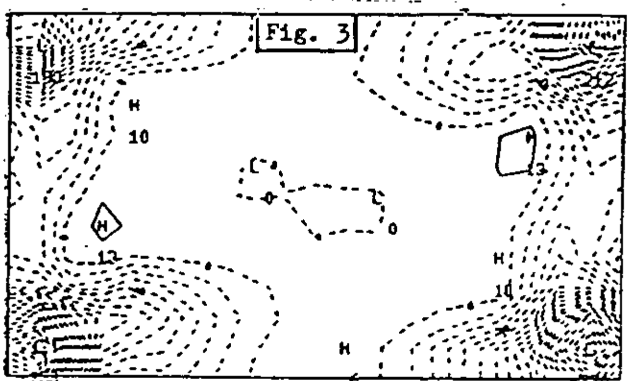
These two (surprising) results lead to a concept of "PERMANENT SPIN-UP" originating in the lateral boundary coupling zone but with effects reaching far inside the limited area domain.

Thus we have developped a bi-periodic version of PERIDOT and performed both conventional experiments coupled with externally imposed LBC, and bi-periodic experiments without coupling (and with coupling following Machenhauer and Haugen, 1988) from the same initial conditions.

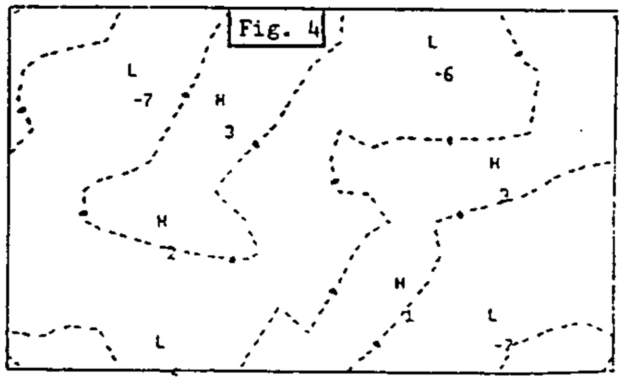
First experiments were made for an idealized situation: the initial conditions are given by a resting standard atmosphere on a sea with bi-sinusoïdal SST. The grid-size dependency is found important in a conventional experiment with coupling when the LBC are the same as the initial conditions (fig. 3) and is very small in a bi-periodic experiment without coupling (fig. 4) and a conventional experiment with coupling when the LBC come from the bi-periodic experiment forecasts (fig. 5). This means that the coupling technique (Davies, 1976) is irrelevant, but that the inconsistencies between the LBC and the coupled fields contribute appreciably to the grid-size dependency of I and J.

Fig. 3,4 and 5: FLUX DIAGNOSTICS ON IDEALIZED SITUATIONS.

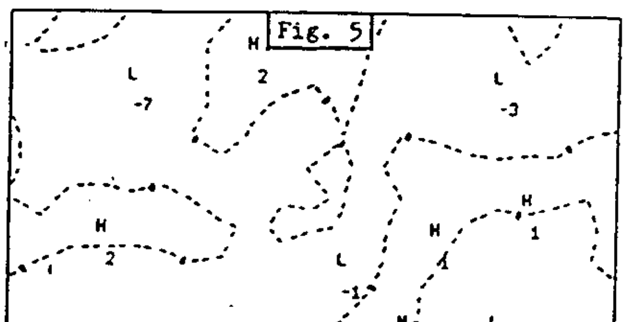
Maps of differences between the theoretical invariants J. at 160 km and 40 km grid resolution: $J_{40}-J_{160}$.
Initial conditions: Resting standard atmosphere on a sea with bi-sinusoidal SST.
Fig 3: Conventional experiment with coupling. Lateral boundary conditions are the same as initial conditions.
Fig 4: Bi-periodic experiment without coupling.
Fig 5: Conventional experiment with coupling: Lateral boundary conditions are the forecasts coming from the bi-periodic experiment.
Mass-flux type convection scheme.
Range: 60h. Averaging time: 11h30. Level: σ=0.782.
Ploting interval: 0.0001 Pa/s.



(A) Coupled with Fixed LBC



(B) Free bi-periodic



(C) Coupled with LBC From (B)

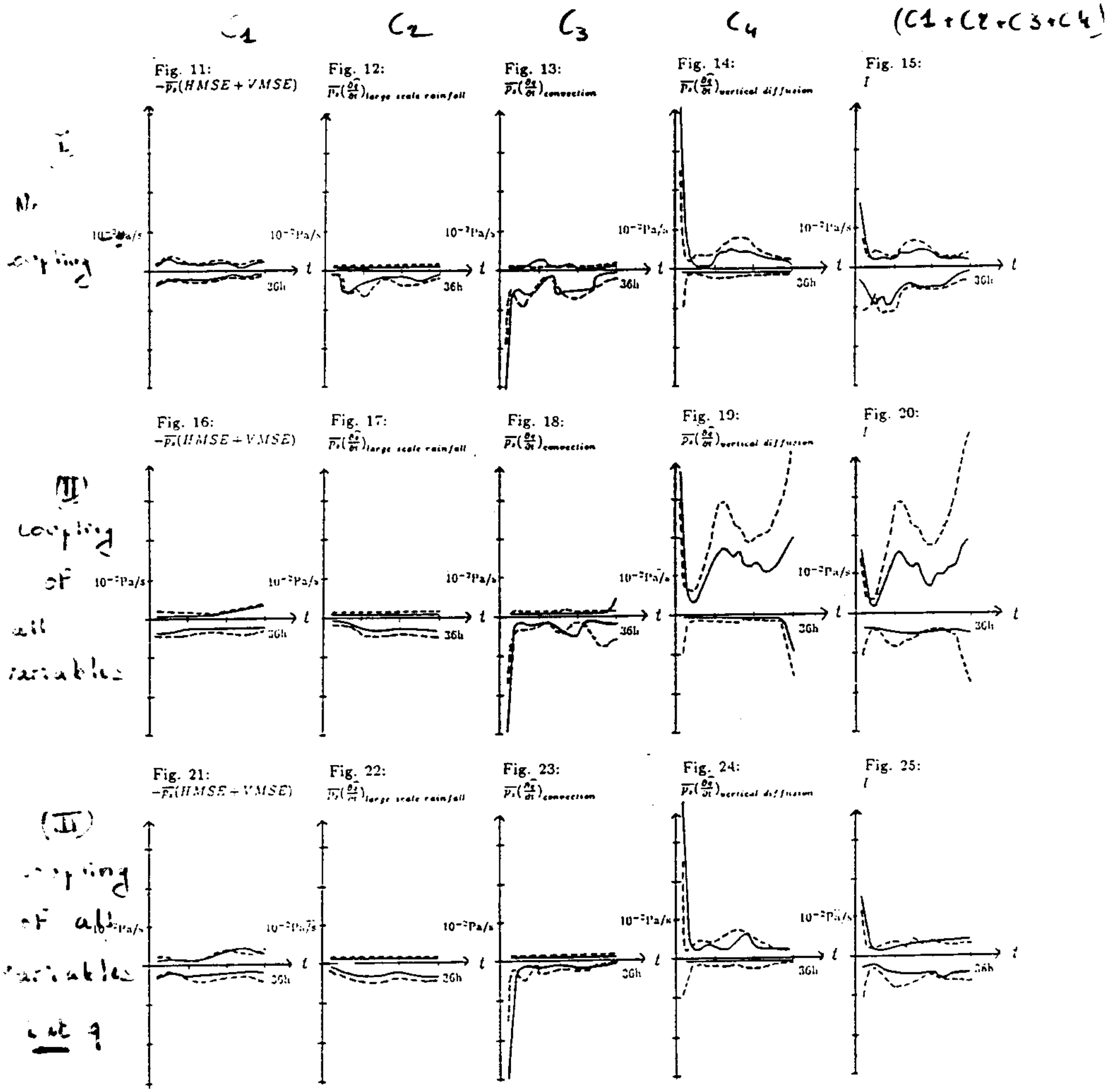


Fig 11 to 25: BI-PERIODIC RUNS ON THE BI-PERIODICIZED NCAR FIELDS: TEMPORAL EVOLUTION BETWEEN THE RANGES 0h AND 36h OF THE EXTREMA OF THE CONTRIBUTIONS OF THE THEORETICAL INVARIANTS . FLUX DIVERGENCES DIAGNOSTICS ON q.

Small forecast domain. Initial conditions: 22/04/1981 00Z.

Δx=160 km: ——— ; Δx=80 km: - - - - .

Fig. 11 to 15: No coupling.

Fig. 16 to 20: Coupling on all variables.

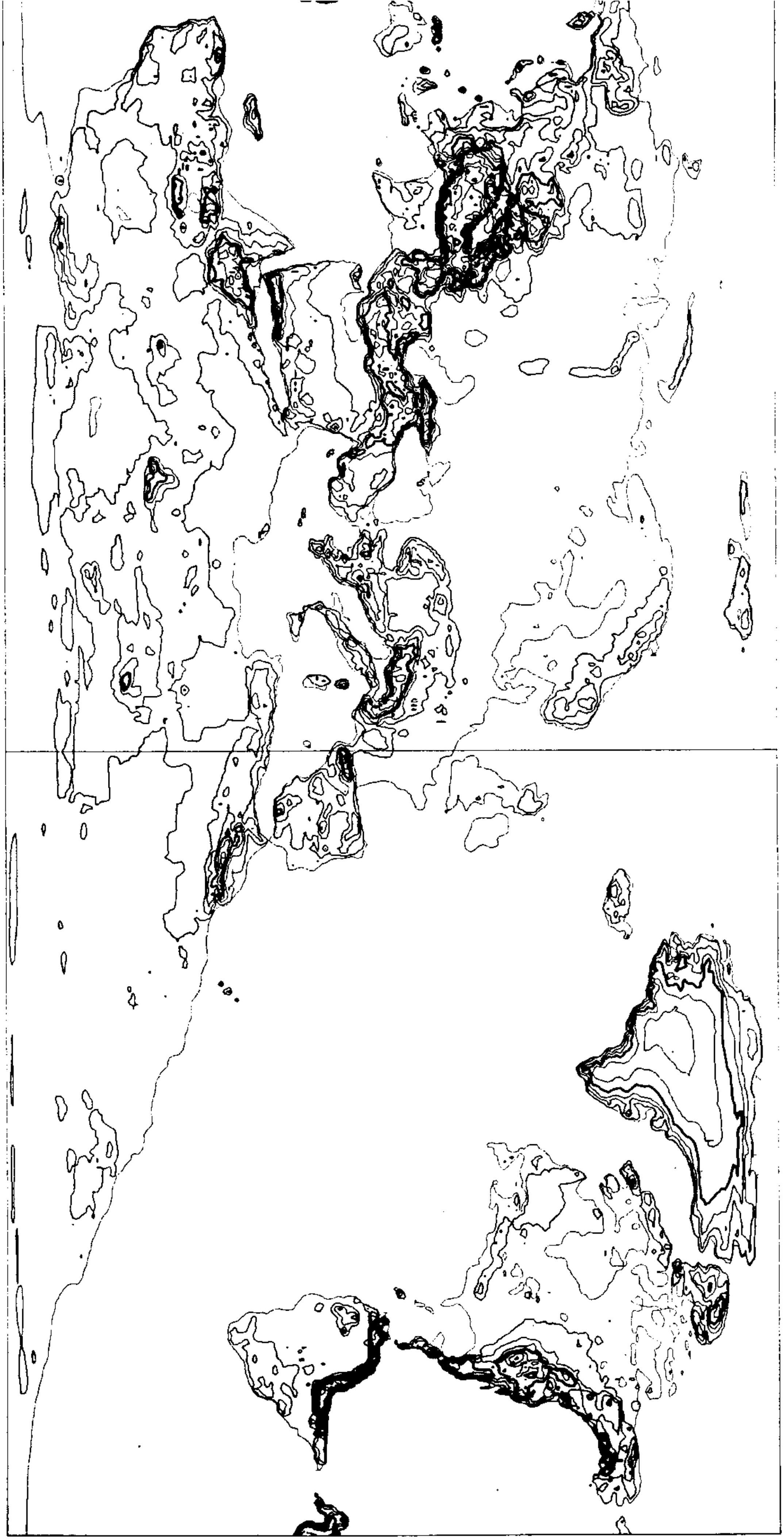
Fig. 21 to 25: Coupling on T, U, V, $ln(p_s)$. No coupling on q.

Level number 8 (σ=0.749).

Mass-flux type convection scheme (Bougeault, 1985).

→ PERMANENT ... CONCEPT

Still a convective parameterization problem left for ARPEGE



QUESTION

Is the amount of new information created by an increase in horizontal resolution improving meso-scale predictability or just confusing the issue?

PROBLEM

All scales of motions that can be treated are necessary to the most coherent picture possible of the atmospheric evolution

but

some of these scales are "predictable" and some aren't, thus the problem is one of post processing (evolving with the state of the art though)

WHAT TO DO?

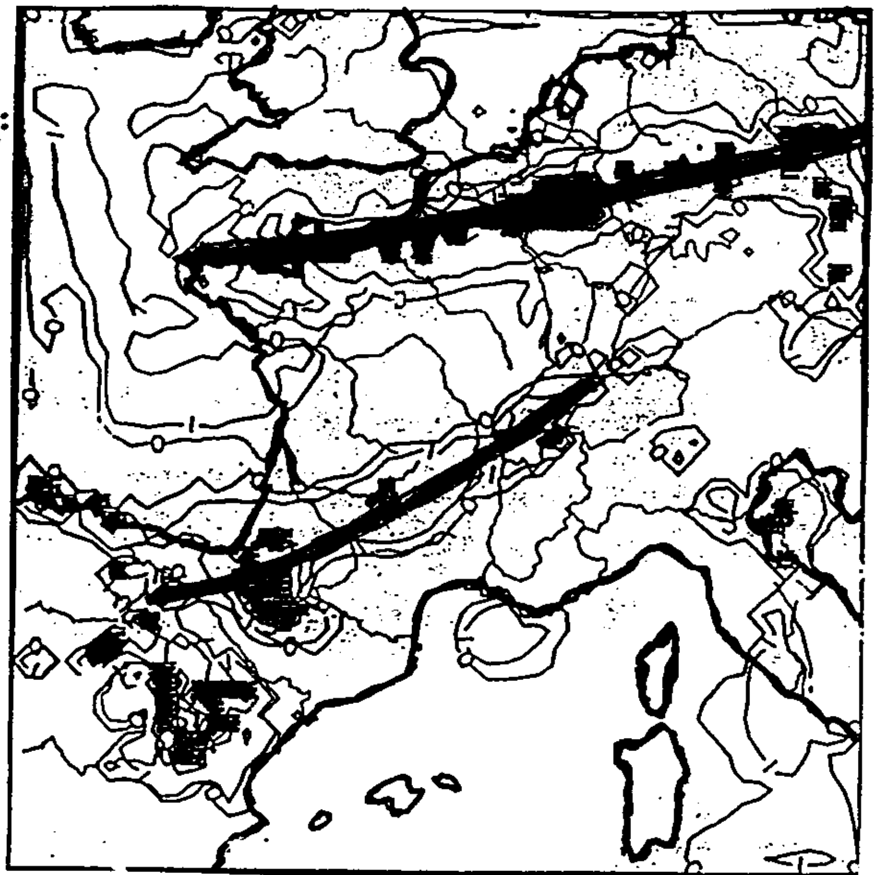
in the short term : have an all-round strategy for the extraction of useful information

* statistical adap.
* dynamical adap.
* use of higher level model information in post-p

in the long term : look for scale independent, all-purpose parameterization schemes

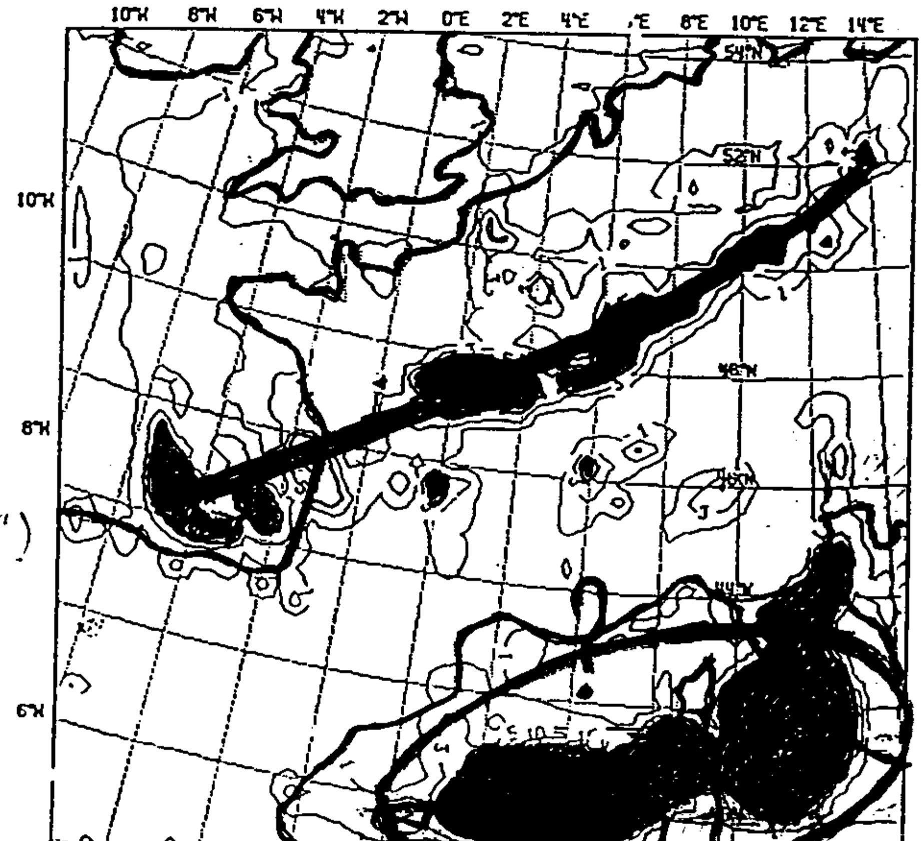
Identical Forecasts but For boundary conditions:

Preoperational Emeraude T42 (nearly the same "physics")

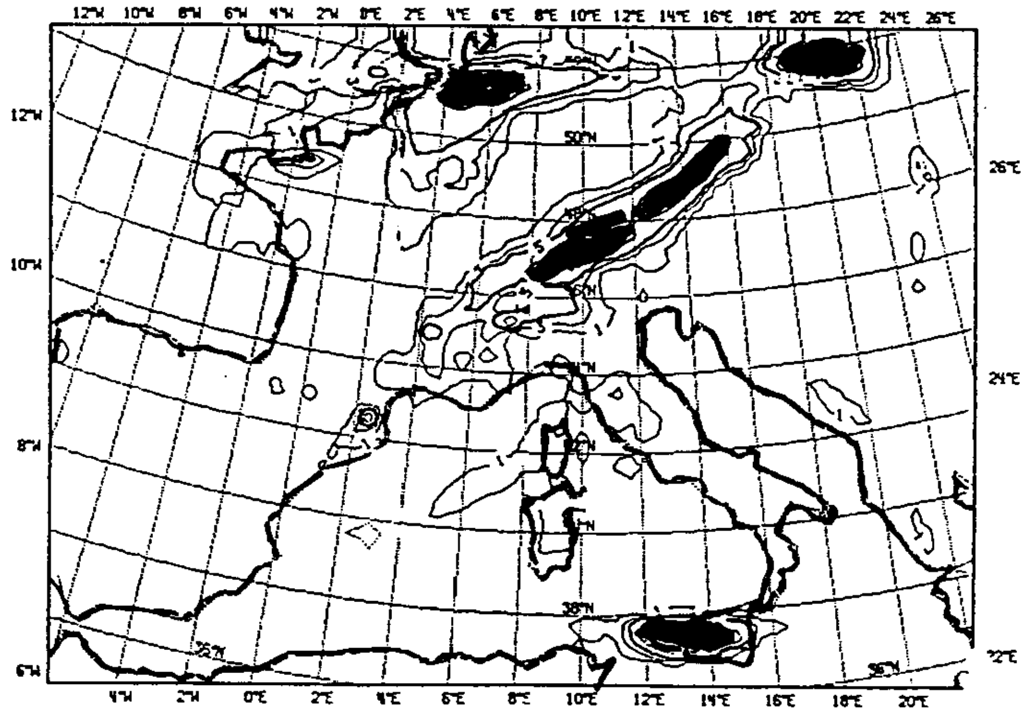


PERICOT 5/ 9/84 6TU ECH. 30 EX. 84807

ECMWF T63 (ECMWF "physics" ≠ PERIDOT "physics")



PLUIE TOTALE (MM)



72 hour Forecast From July 10th 1994 00Z
12 h accumulated rainFall

Munich hail storm

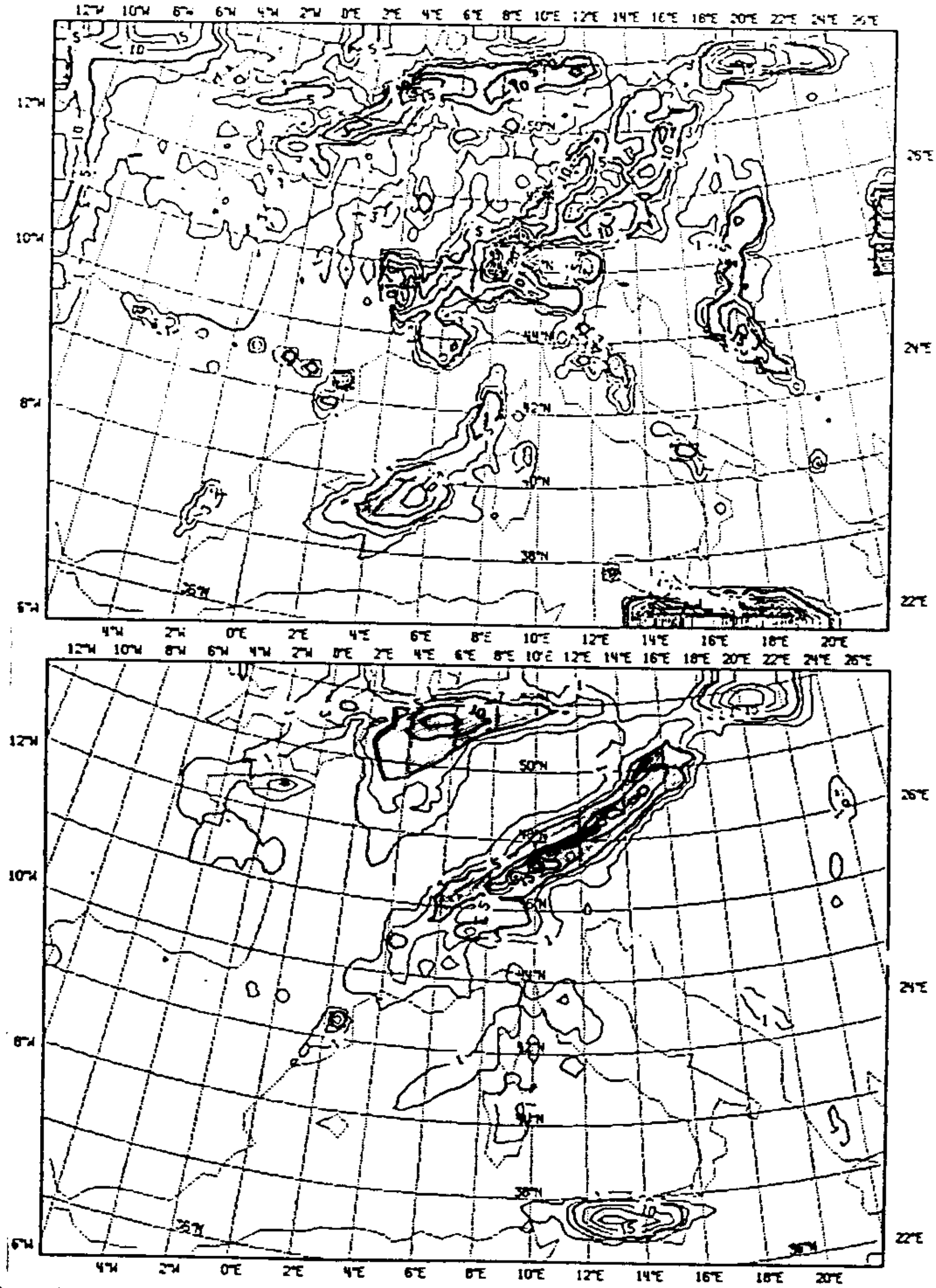
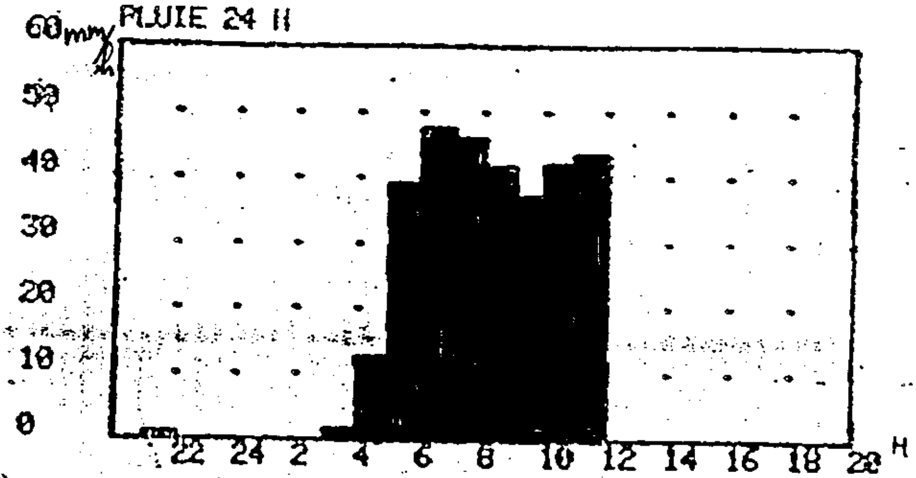


Figure 2 : Total rainfall accumulated between 60 and 72 hours of a Peridot simulation (ECMWF analysed lateral boundary conditions) starting from 10/7/84 00Z. Units mm. Isolines 1, 3, 5 (reinforced) 10, 15... .35 km mesh. Domain enlarged to 55x79 points. Top:B-scheme. Bottom:G-scheme.

TABLE 1 : Mean RMS errors of geostrophic wind (in m/s) on an ensemble of 6 forecasts scattered through the FGGE year for the domain North of 30°N.

	1000 hPa				500 hPa			
	Day 1	Day 2	Day 3	Day 4	Day 1	Day 2	Day 3	Day 4
B Scheme	6.1	7.7	8.9	10.1	4.9	7.4	9.8	11.8
G Scheme	6.3	7.9	9.0	10.1	5.0	7.6	10.2	12.0



GARD Cumul des précipitations du 2 au 3 octobre 1988

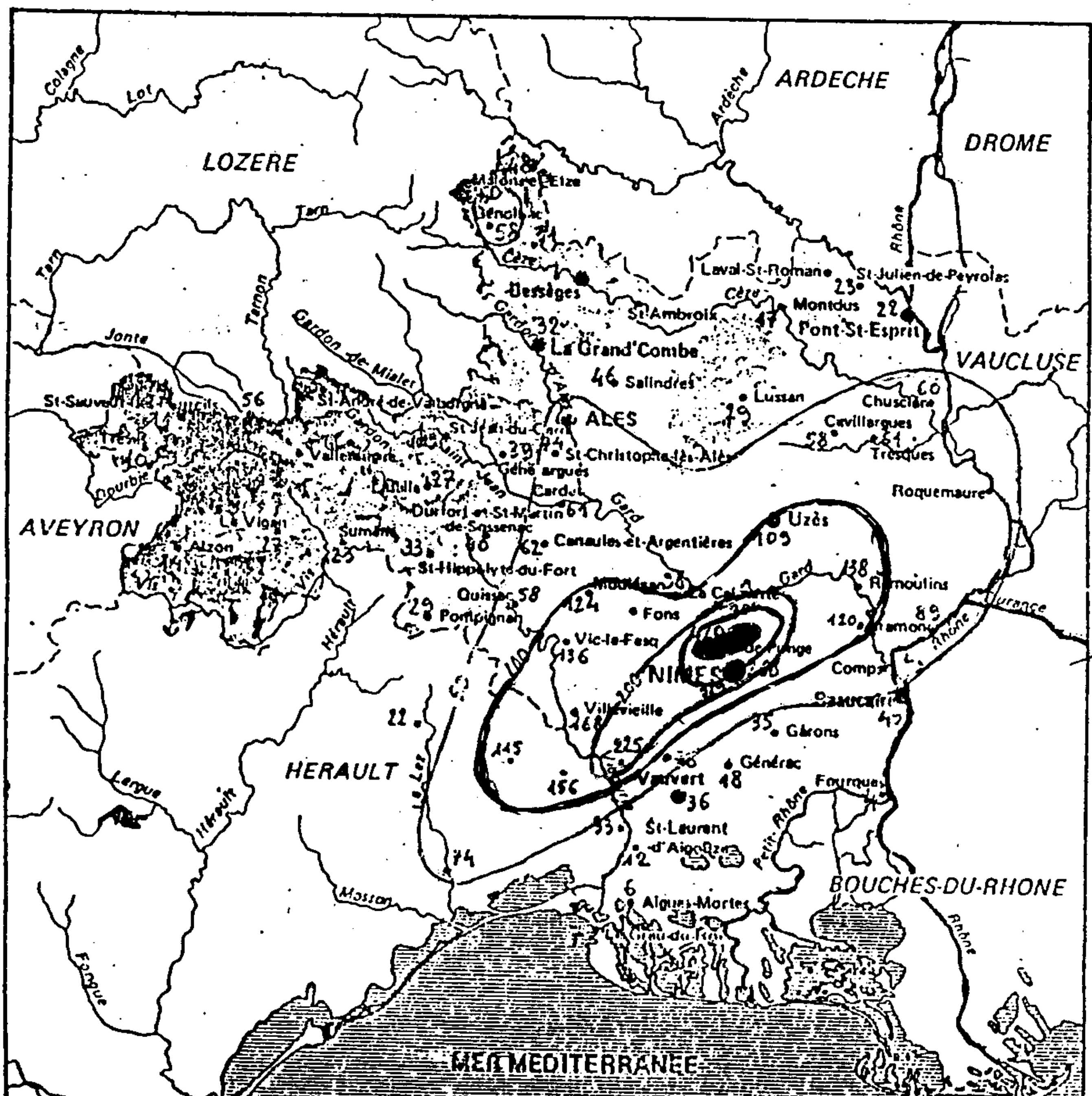


Fig 2

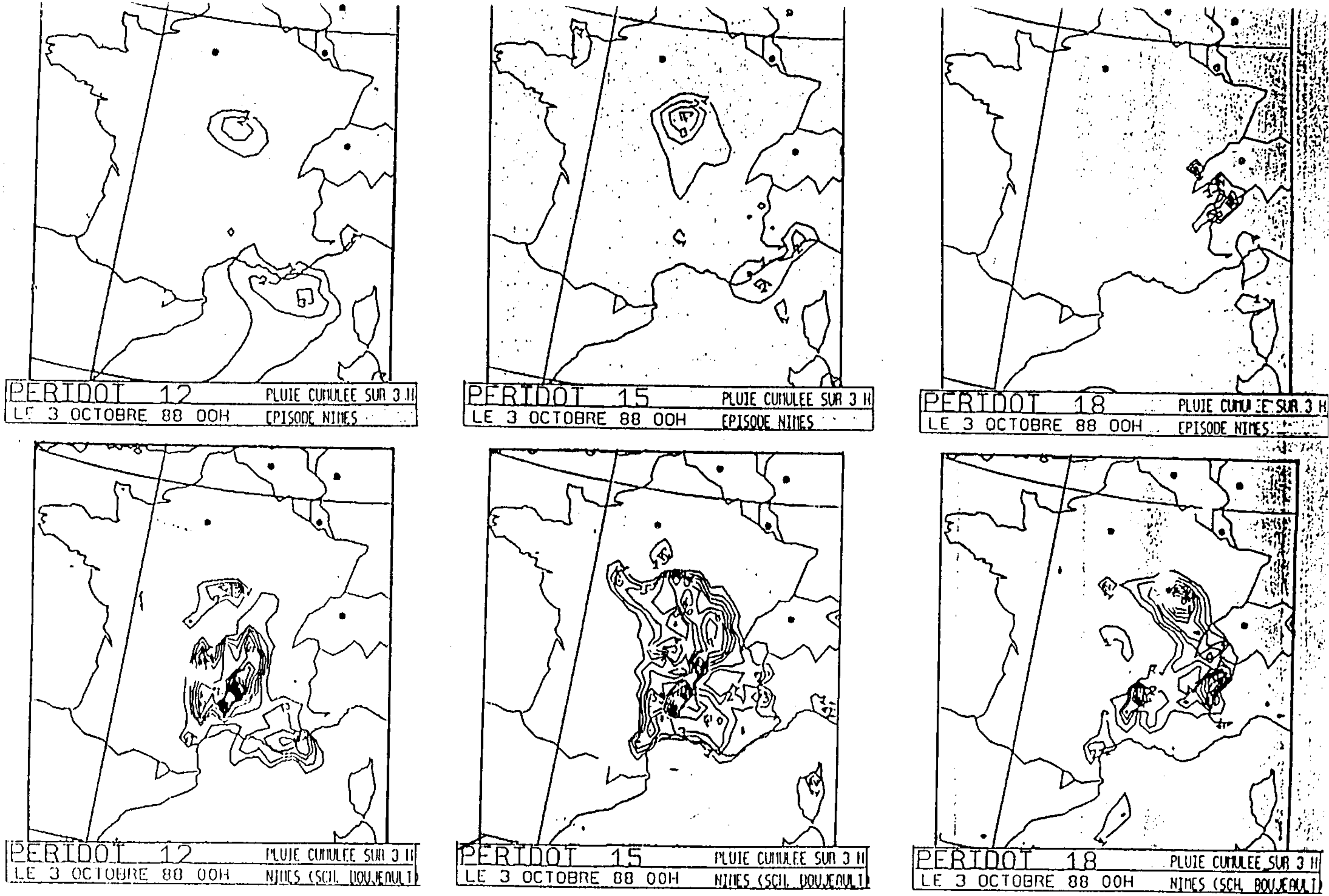
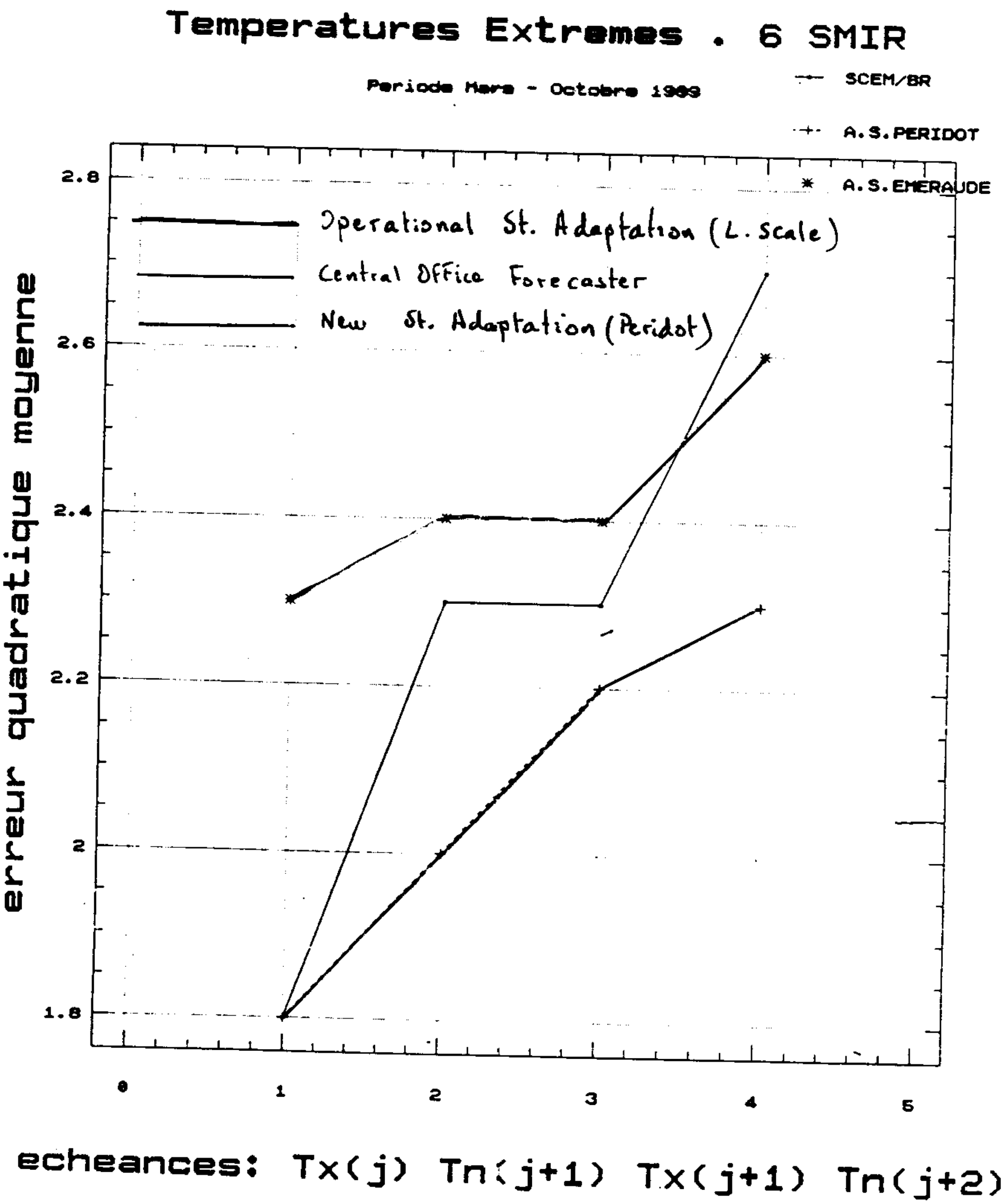

PERIDOT 12
PLUIE CUMULEE SUR 3 H
LE 3 OCTOBRE 88 00H
EPISODE NIMES
PERIDOT 15
PLUIE CUMULEE SUR 3 H
LE 3 OCTOBRE 88 00H
EPISODE NIMES
PERIDOT 18
PLUIE CUMULEE SUR 3 H
LE 3 OCTOBRE 88 00H
EPISODE NIMES
PERIDOT 12
PLUIE CUMULEE SUR 3 H
LE 3 OCTOBRE 88 00H
NIMES (SCH. BOUGEAULT)
PERIDOT 15
PLUIE CUMULEE SUR 3 H
LE 3 OCTOBRE 88 00H
NIMES (SCH. BOUGEAULT)
PERIDOT 18
PLUIE CUMULEE SUR 3 H
LE 3 OCTOBRE 88 00H
NIMES (SCH. BOUGEAULT)

fig. 3.3.13. (b)

COURBE N°5



Temperatures Extremes . 6 SMIR
Periode Mars - Octobre 1989
SCEM/BR
A.S.PERIDOT
A.S.EMERAUDE
Operational St. Adaptation (L. Scale)
Central Office Forecaster
New St. Adaptation (Peridot)
erreur quadratique moyenne
2.8
2.6
2.4
2.2
2
1.8
0
1
2
3
4
5
echeances: Tx(j) Tn(j+1) Tx(j+1) Tn(j+2)

QUESTION

Are land/sea surface model-induced circulations adding more to meso-scale predictability than a static adaptation of large-scale results ?

PROBLEM

Apparently it depends much on the "client" :
the answer might change with parameters
and
individual cases might be in contradiction with statistical averages.

WHAT TO DO ?

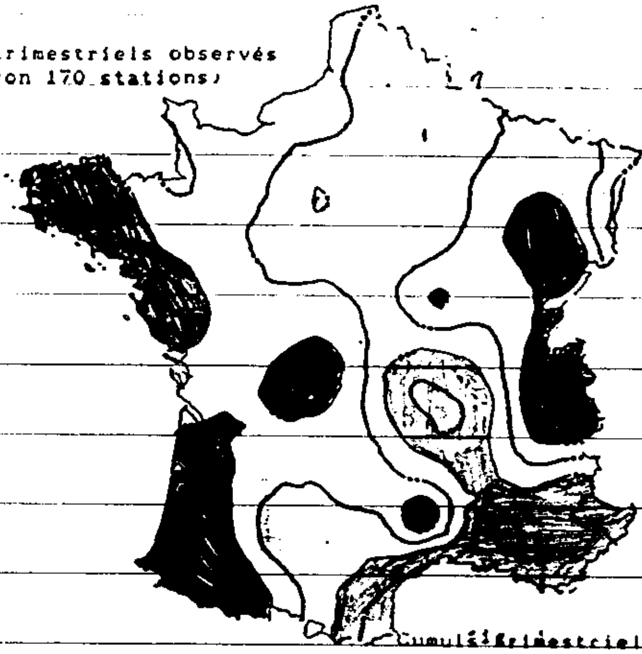
in the short term : diversify the verification strategy to help assessing the confidence level on a "parameter to parameter", "case to case" basis.

in the long term : look for more coherence between explicitely resolved and parametrized surface effects (start first by qualifying the difficulty of that task ⇒ PYREX)

PRECIPITATIONS
Cumuls trimestriels observés et prévus (1er trimestre 1988)

Cumuls trimestriels observés
(environ 170 stations)

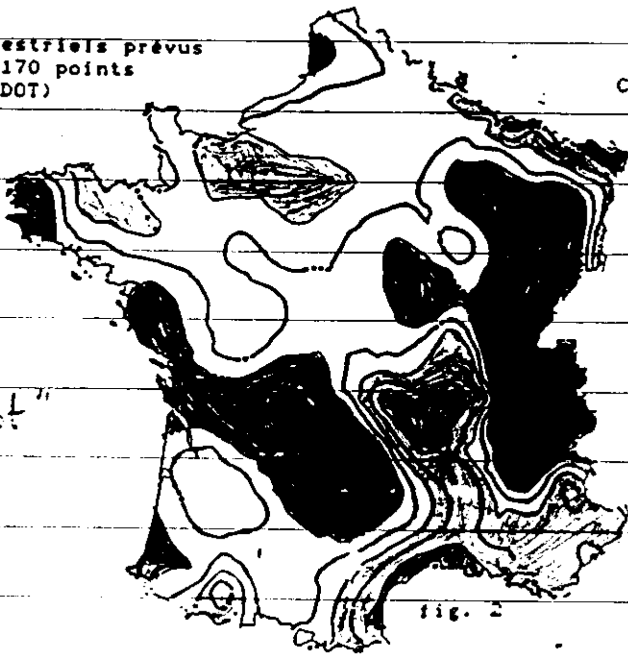
< 100 mm
< 200 mm
250 mm
> 300 mm
> 400 mm
> 600 mm



synop stations' observations

PRECIPITATIONS
Cumuls trimestriels observés et prévus (1er trimestr

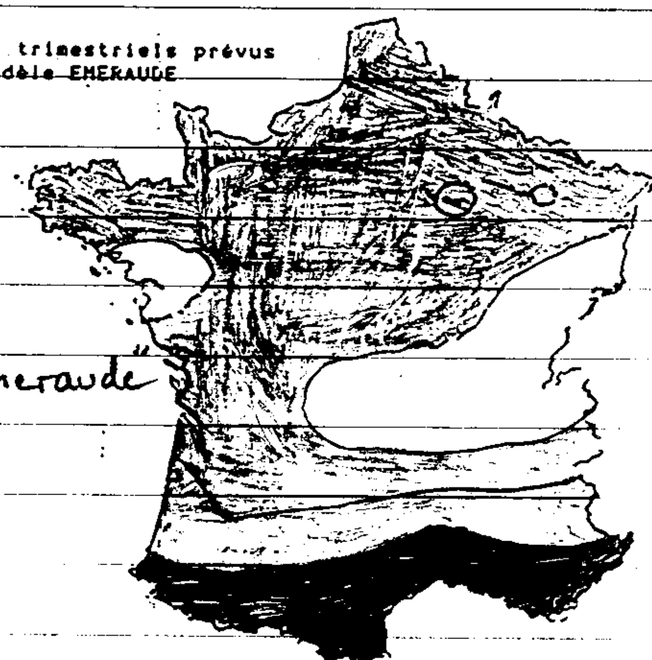
ls trimestriels prévus
nviron 170 points
PERIDOT)



ridot"

fig. 2

Cumuls trimestriels prévus
Modèle EMERAUDE

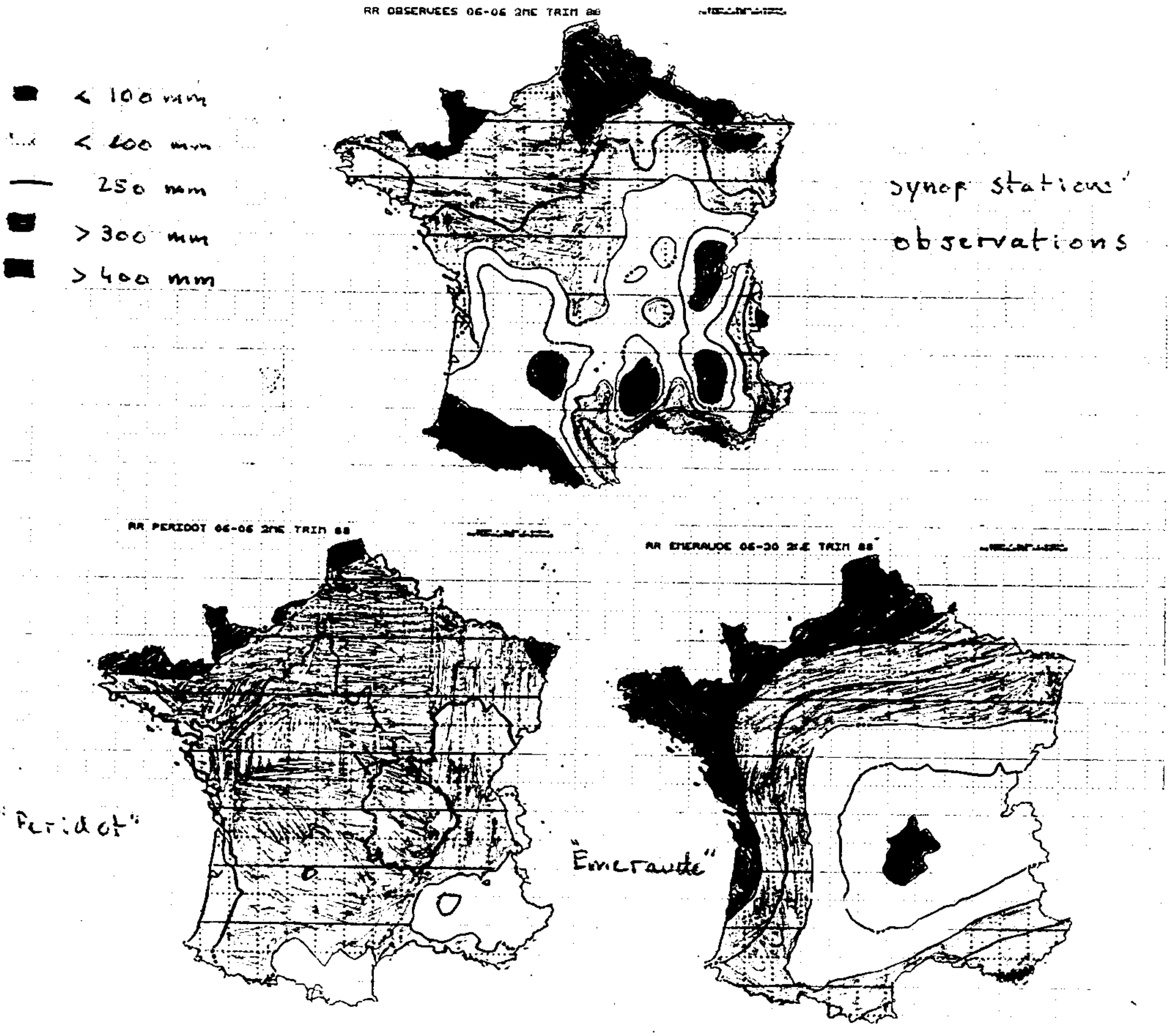


"Emeraude"

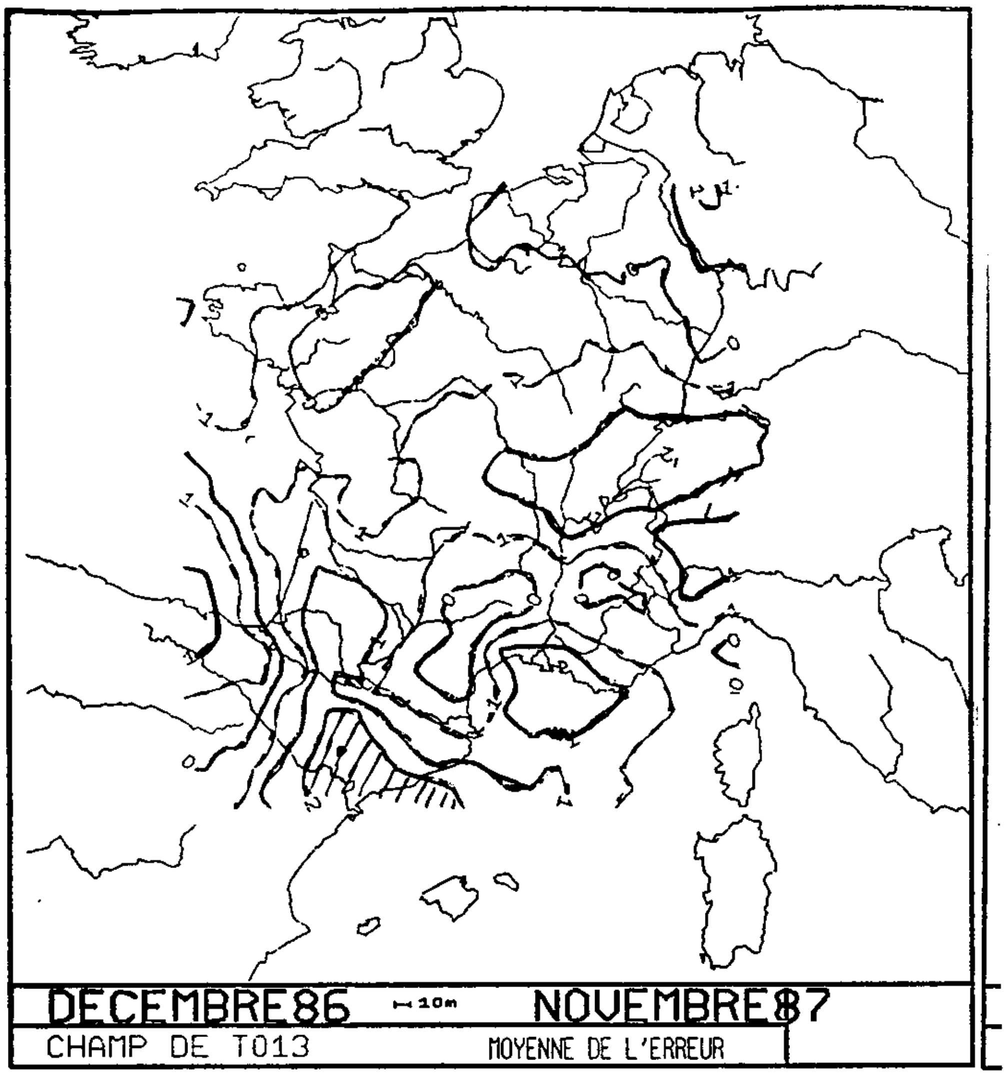
fig. 3

988 JAN.-FEB.-MAR. accumulated rainfall

(For the models 6h-30h range from 00 UTC)



1988 APR. MAY. JUN. accumulated rainFall
(For the models 6-30h range From 00 UTC)



σ = 0.971 T^ure

24 h. Forecast − analysis

1 year mean

00 UTC data

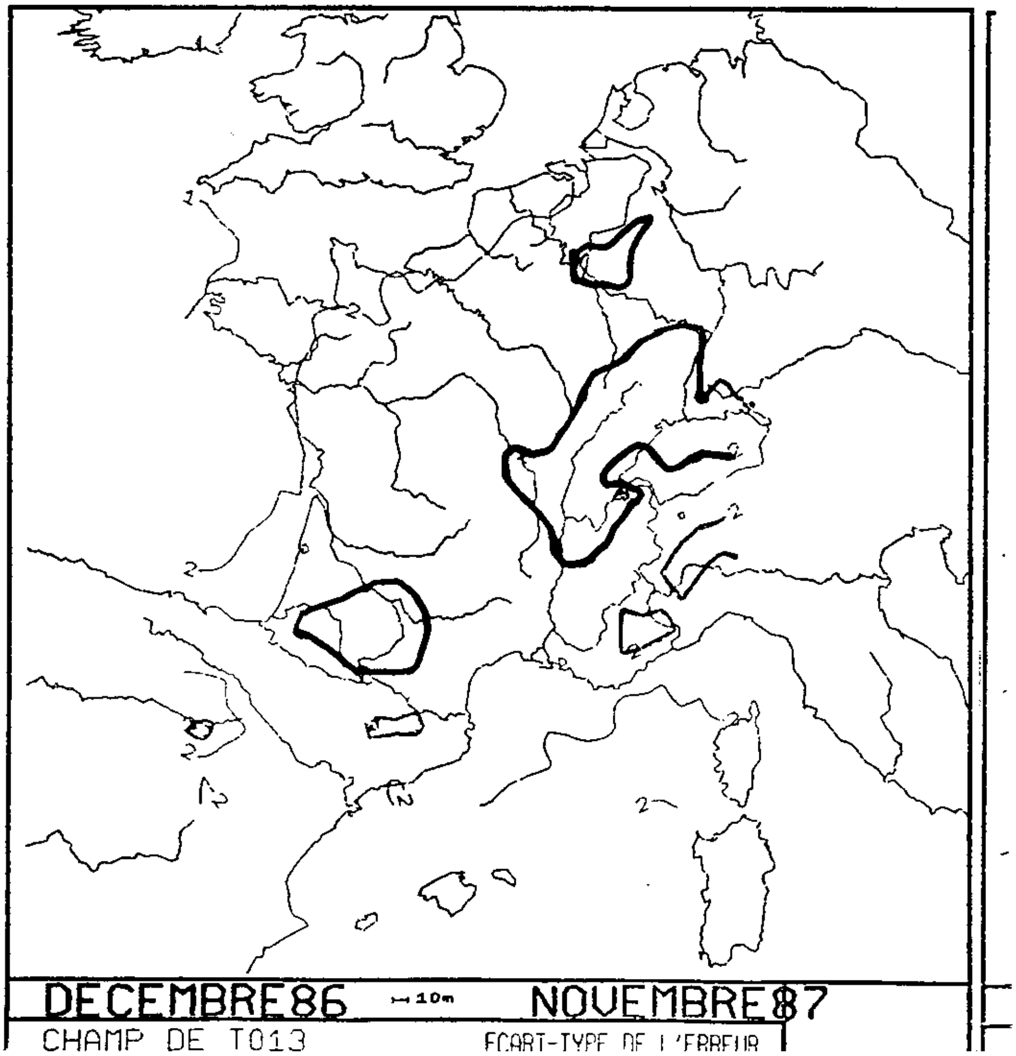
//// + 1.5 °K

+ 1° K

0

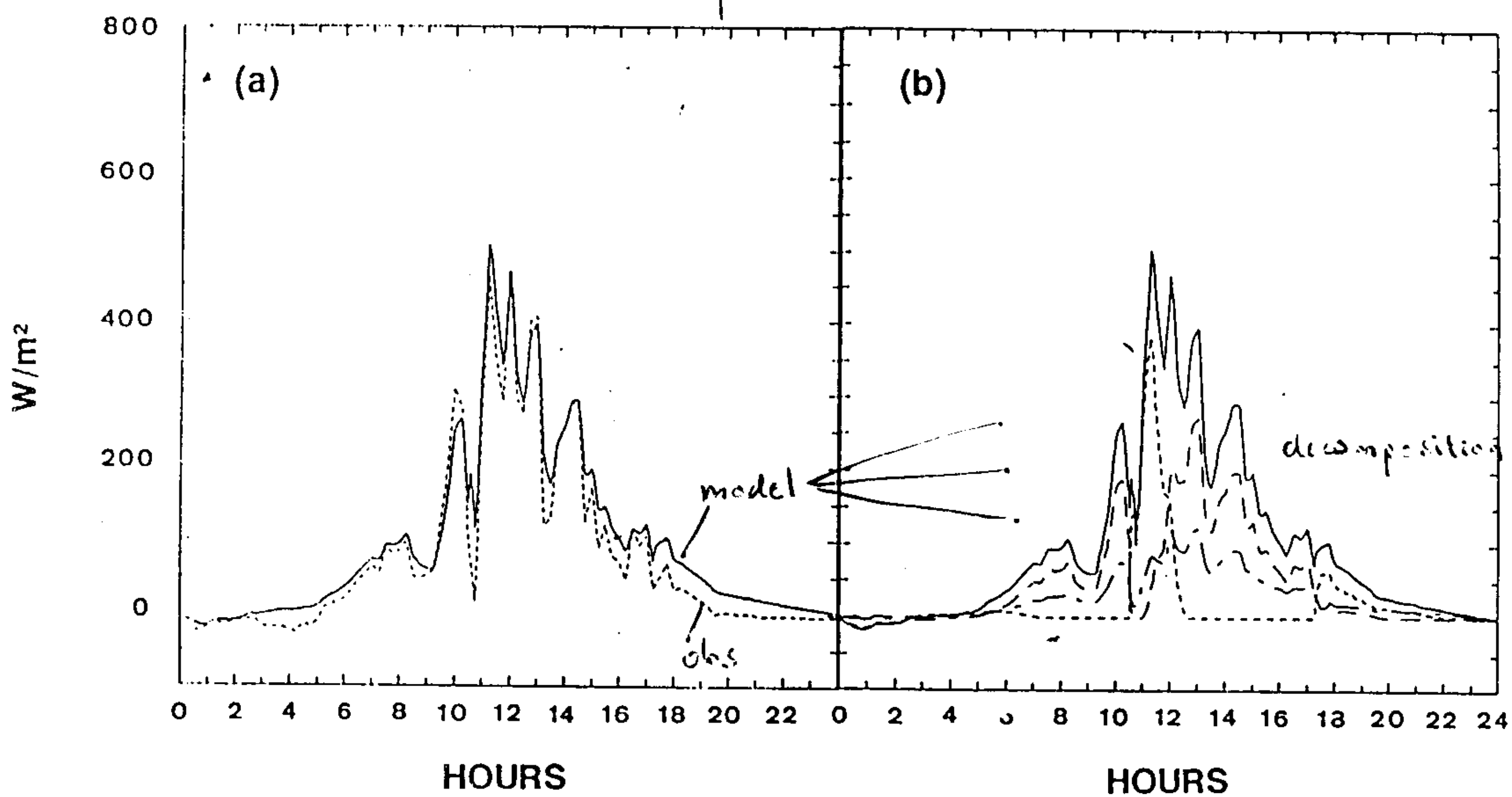
−1° K

in bias



Corresponding standart deviation

—— > 2°K



MAHFOUF et JACQUEMIN

données
HAPEX-MOBILHY

Figure 15

QUESTION

Is there scope for an accurate prediction of sub-synoptic features between the model "spin-up" time and their inherent loss of predictability?

PROBLEM

We are almost certainly ill-tuning our parameterization for meso-scale modelling due to the lack of "true" meso-scale predictable cases,

but,

in turn, we don't know if that matters much or not!

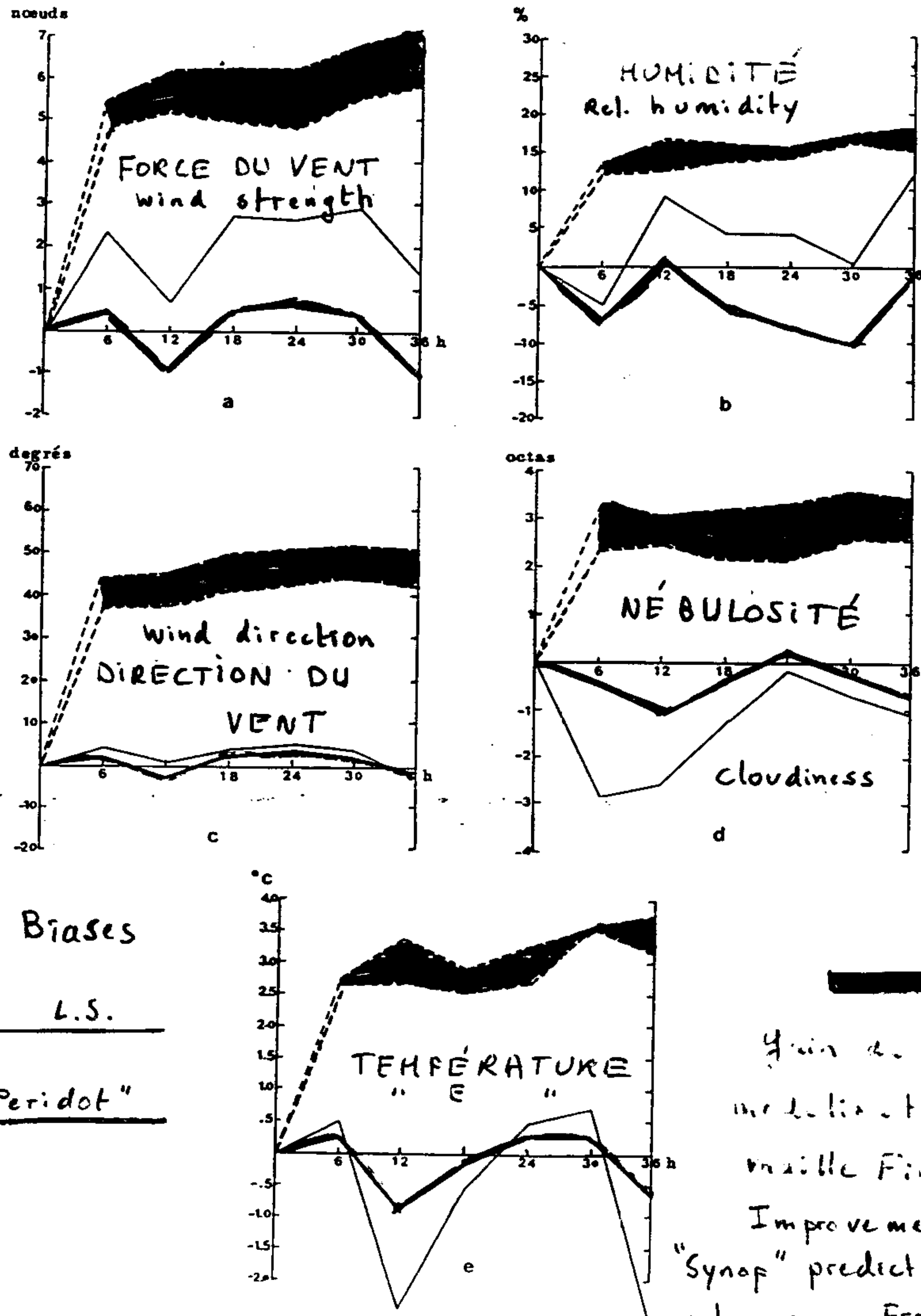
WHAT TO DO

in the short term : build "process-oriented" diagnostics: energetics, identification of "systematic errors", ...

in the long-term : have a true diabatic initialization (i.e. including the moisture variable interactively); this problem is not implicitely solved by 4-D data assimilation!

FIGURE 4 : Comparaison pour le mois de Novembre 1986 des prévisions EMERAUDE et PERIDOT vérifiées toutes deux par rapport aux observations au sol du réseau français entre 0 et 36 heures de 6 heures en 6 heures.

(Légende page suivante)



Biases

L.S.

"Peridot"

maille Fine

Improvement in std. dev. "Synop" predicted values, when going from the coupling model to "Peridot".

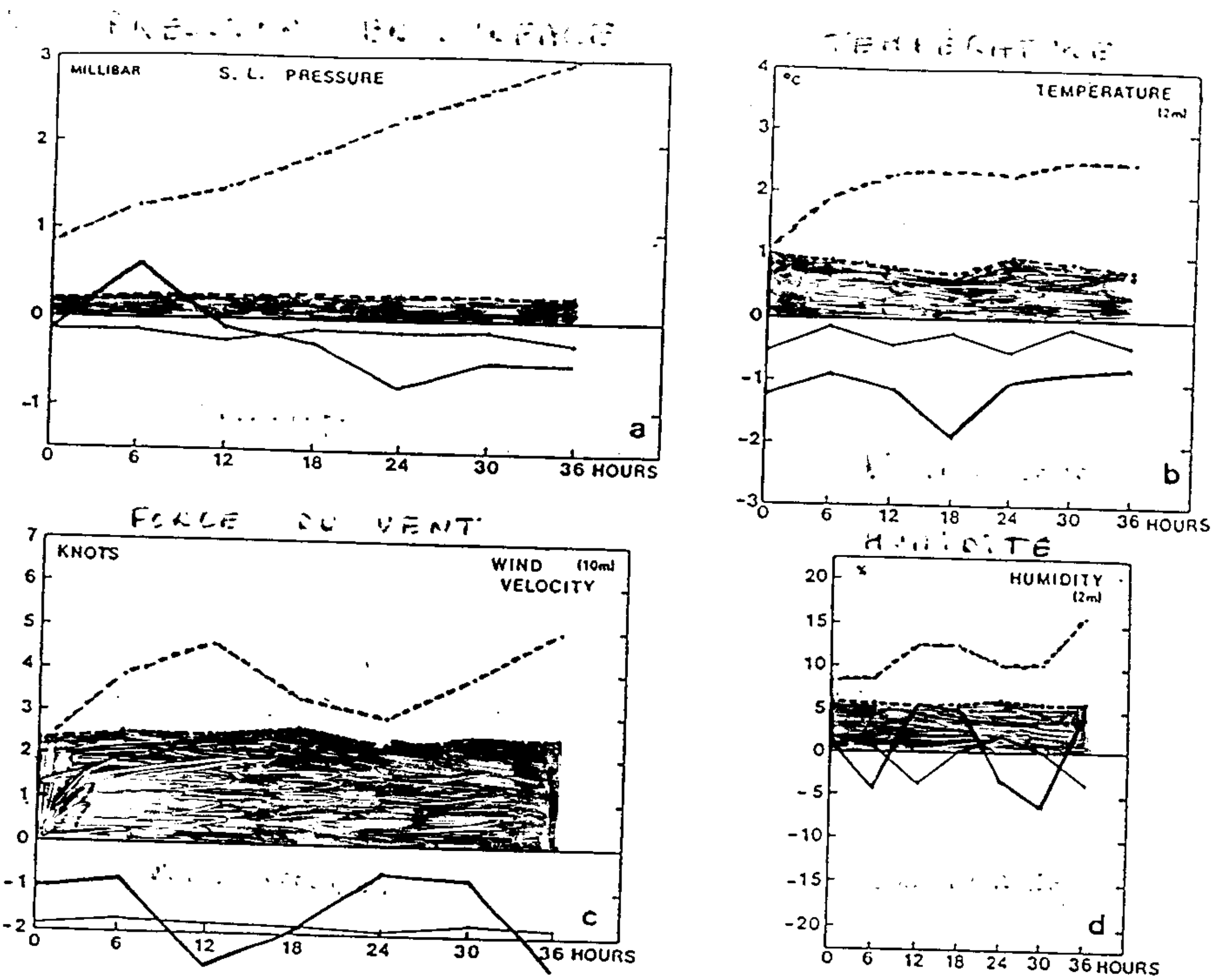


Figure 13 : "Peridot" verification at Orly for the year 1986 (thick lines) compared with the "Orly vs. Villacoublay" measure of natural variability (thin lines) . a) surface pressure ; b) 2m temperature ; c) 10m wind speed ; d) 2m relative humidity . Full lines = biases ; dashed lines = standard deviations . Forecasting range 0 to 36 hour.

SHORTER CONTRIBUTIONS

THE DISTRIBUTION OF RAINDROPS WITH SIZE

By J. S. Marshall and W. McK. Palmer[1]
McGill University, Montreal

(Manuscript received 26 January 1948)

Measurements of raindrop records on dyed filter papers were made for correlation with radar echoes (Marshall, Langille, and Palmer, 1947). These measurements have been analyzed to give the distribution of drops with size (fig. 1). The distributions are in fair agreement with those of Laws and Parsons (1943).

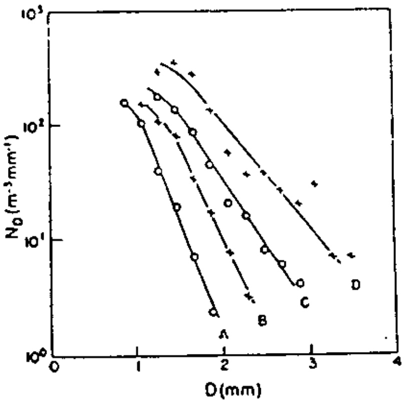


FIG. 1. Distribution of number versus diameter for raindrops recorded at Ottawa, summer 1946. Curve A is for rate of rainfall 1.0 mm hr^{-1}, curves B, C, D, for 2.8, 6.3, 23.0 mm hr^{-1}. $N_D\delta D$ is the number of drops per cubic meter, of diameter between D and $D + \delta D$ mm. Multiplication by 10^{-3} will convert N_D to the units of equation (2).

Except at small diameters, both sets of experimental observations can be fitted (fig. 2) by a general relation,

$$N_D = N_0 e^{-\Lambda D}, \qquad (1)$$

where D is the diameter, $N_D\delta D$ is the number of drops of diameter between D and $D + \delta D$ in unit volume of space, and N_0 is the value of N_D for $D = 0$.

It is found that

$$N_0 = 0.08 \text{ cm}^{-4} \qquad (2)$$

for any intensity of rainfall, and that

$$\Lambda = 41 R^{-0.21} \text{ cm}^{-1}, \qquad (3)$$

where R is the rate of rainfall in mm hr^{-1}.

For diameters less than about 1.5 mm, both sets of observations fall short of the value for N_D given by equation (1), and they disagree slightly with each other. Laws and Parsons' observations are better in this region, and tend toward a common value of N_0 for all rates of rainfall.

The mass of rain water M per unit volume of space, and the sum Z of sixth powers of drop diameters in unit volume (a radar quantity), can be calculated as functions of Λ from equation (1), and so correlated with the rate of rainfall R by equation (3). It is of interest to compare these correlations with those obtained when M, Z, and R are determined more directly from the experimental records (table 1). The deficit of small drops in the observations, as compared with equation (1), should make the observed value of M, and to a lesser extent that of Z, smaller than those derived from the equations.

TABLE 1. $M = \frac{1}{6}\pi\Sigma N_D D^3\delta D$ and $Z = \Sigma N_D D^6\delta D$ as functions of the rate of rainfall R.

Reference	M mgm m^{-3}	Z mm^6 m^{-3}
Marshall, Langille and Palmer (1947)	80 $R^{0.83}$	190 $R^{1.72}$
Revision of the above	72 $R^{0.88}$	220 $R^{1.60}$
Z/R correlation by Wexler (1947) (data of Laws and Parsons, 1943)	68 $R^{0.88}$	320 $R^{1.44}$
From equations (1) and (3)	89 $R^{0.84}$	296 $R^{1.47}$

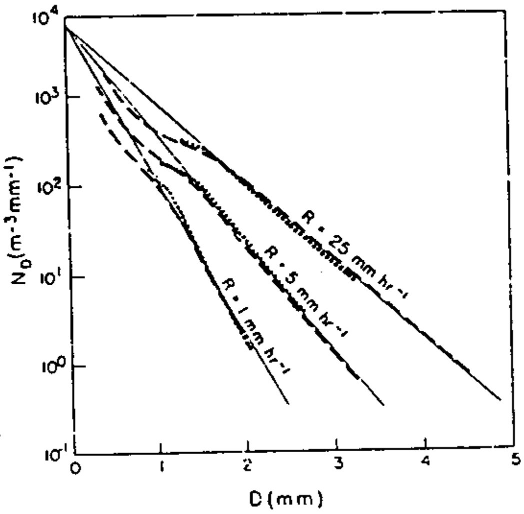


FIG. 2. Distribution function (solid straight lines) compared with results of Laws and Parsons (broken lines) and Ottawa observations (dotted lines).

[1] Holding a Bursary of the National Research Council of Canada.

The exponential distribution of equation (1) is the type that would obtain if growing drops were in continual danger of disintegrating, the likelihood of disintegration being proportional to the increment in diameter or in distance of fall through cloud. Such behavior might be explained by the random accumulation by each drop of electrical charge as more and more randomly charged cloud drops or smaller raindrops are acquired by coalescence, and the resultant disintegration of overcharged drops. Relevant calculations and experiments on coalescence are in progress.

Part of the work reported here was done during summer employment in the Radar Meteorology Section of the Defense Research Board's Radio Propagation Laboratory at Ottawa.

REFERENCES

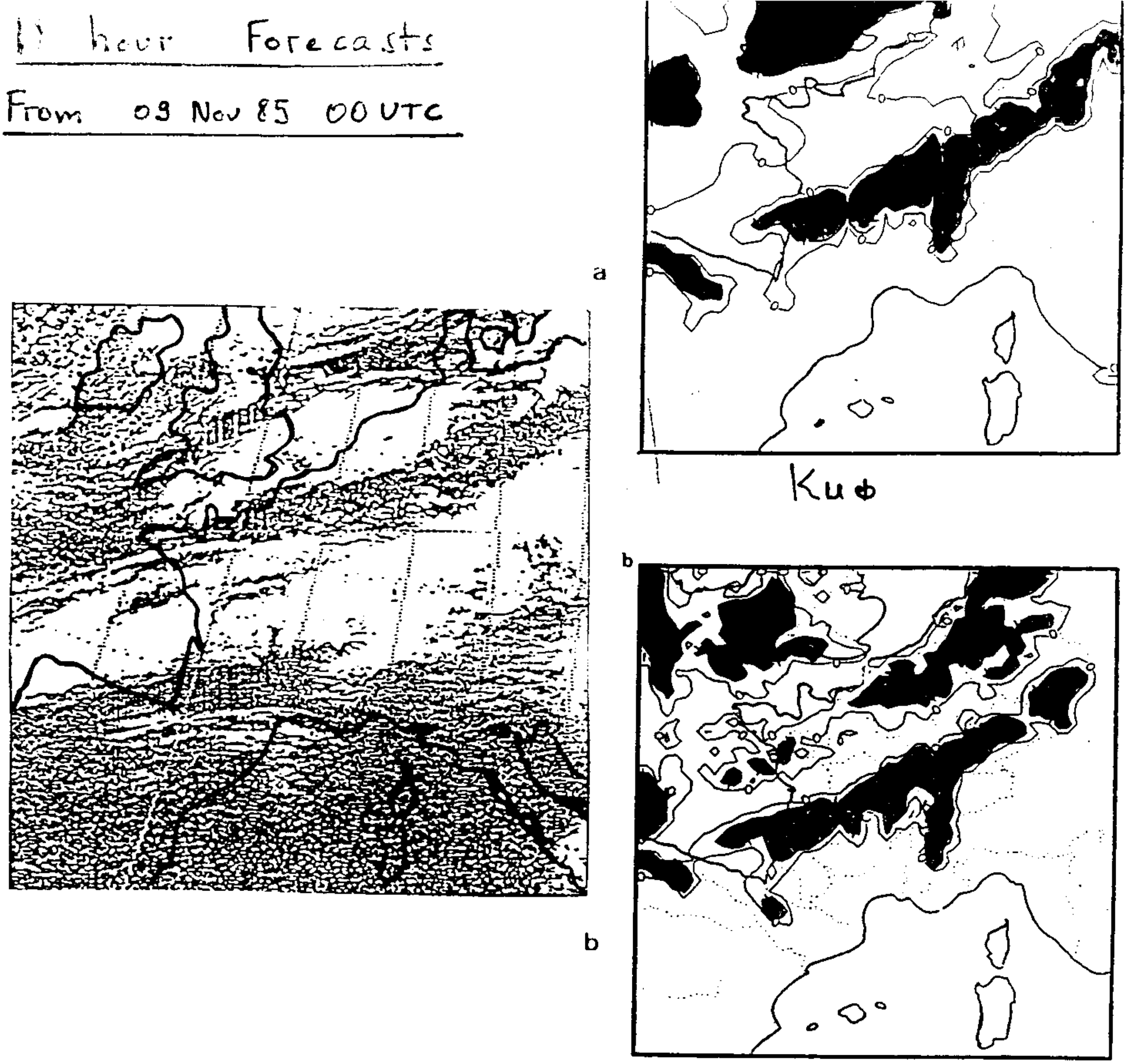
Laws, J. O., and D. A. Parsons, 1943: The relation of raindrop-size to intensity. *Trans. Amer. geophys. Union*, 24, part II, 452–460.

Marshall, J. S., R. C. Langille, and W. McK. Palmer, 1947: Measurement of rainfall by radar. *J. Meteor.*, 4, 186–192.

Wexler, R., 1947: Radar detection of a frontal storm 18 June 1946. *J. Meteor.*, 4, 38–44.

18 hour Forecasts

From 09 Nov 85 00 UTC



liquid water in the cloud added. (A.S. 1374)

shallow convection

Figure 8 : Application du nouveau schéma de convection au domaine Péridot. Cartes de précipitations pour une Prévision à 18 heures à partir du 09.11.85.

a) Ancien schéma

b) Nouveau schéma

c) Image Infrarouge A.V.H.R.R. du 09.11.85 à 18 heures

— 5 mm/h

— 1 mm/h

L = 400 Km

CONCLUSIONS

I) Meso-scale predictability <u>exists</u> but we do not have <u>yet</u> the means to assess even its limits.

II) Nevertheless simple measures (essentially of diagnostic nature) can help making the most of to-day's "l.s.m.u.m.f."

III) In the long term, a strategy of meso-scale- (and not LAM-!) oriented modelling should help clarify the issues and improve not only meso-scale forecasts (in the mean) but also their reasonable use for dissemination

IV) We might be here potentially in a better shape than for the forecast of forecast's quality at larger scales

- relevance of early check against reality (radar; satell.)
- importance of forced circulations
- more possibilities of extracting useful informations
- .....

V A specific work on NWP-oriented meso-scale parameterization schemes will probably be as useful here as that done years ago for medium-range NWP (but for quite different reasons)