Modelling at the RMI: the past, the present and the future

Piet Termonia

With precious help of Gaston Demarée

To be more specific ...

- The work of J. Van Isacker
- ***A historical gap?***
- The ALADIN era

… and a lesson to be learned from this

Atmospheric modeling

Laws of nature (physics)

Equations

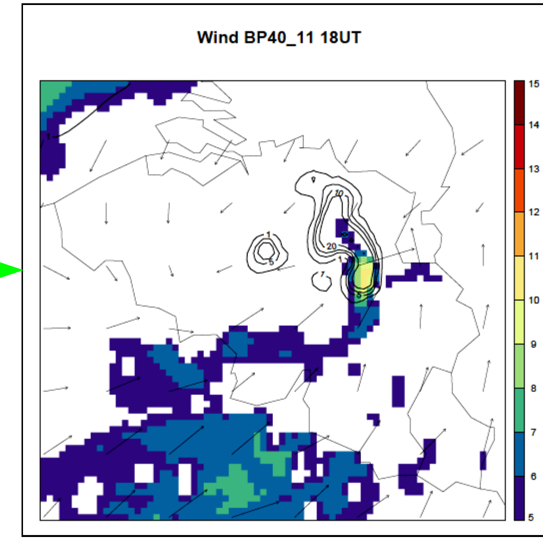
Numerics

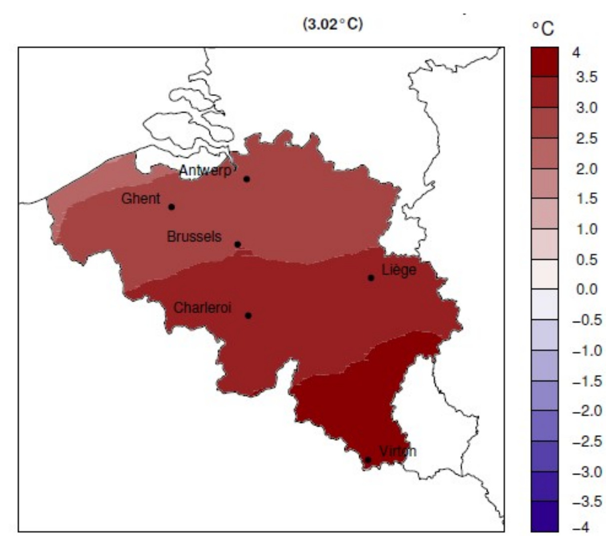
Algorithmics

Numerics

Meteorological observations

Pukkelpop warning





Climate projection

SCIENCE ***INFRASTRUCTURE*** ***APPLICATIONS***

Multidisciplinarity **Capacity**

Jacques Van Isacker

- Pioneering work on numerical weather prediction
- And on analysis of atmospheric dynamics by harmonic analysis (together with Defrise and Van Mieghem).
- Students: Jean-Pierre Stessel, Willy Struylaert
- *Unfortunately did not publish much.*

Van Isacker, second person from the right

1950, Charney, Fjörtoft, von Neuman, Tellus barotropic vorticity Eq.

11 October **1973**: signature of the convention by the member states for the creation of ECMWF in Brussels

August **1979**: first operational medium weather prediction by ECMWF

21 April **1983**: first T63 spectral model by ECMWF

1990: initiative to start of the international ALADIN consortium

Van Isacker, J. (1959) Méthode numérique de prévision du temps. Scientia (Rivista di Scienza), Annus LIII, Vol. XCIV, N. DLXVI, Series VI, p. 125-129.

Van Isacker, J. (1962) Theoretical and Experimental Research on Numerical Weather Prediction in Belgium. Proceedings of the International Symposium on Numerical Weather Prediction in Tokyo, November 7-13, 1960. Published by the Meteorological Society of Japan, March 1962, pp. 9-13.

Van Isacker, J. (1963) Le Laboratoire de Calcul numérique de l'Institut Royal Météorologique. Le mouvement scientifique en Belgique – De wetenschappelijke Beweging in België, Fédération belge des Sociétés scientifiques – Belgisch Verbond der Wetenschappelijke Verenigingen, Volume X, p. 271-276.

Van Isacker, J. & Struylaert, W. (1974) A semi-filtered, hemispherical, semi-implicit model. Global Atmospheric Research Programme (GARP), The GARP Programme on Numerical Experimentation, Report of the International Symposium on Spectral Methods in Numerical Weather Prediction, Copenhagen, 12-16 August 1974, Report No. 7, pp. 189-192.

Struylaert, W. & Van Isacker, J. (1975) Modèle atmosphérique filtré destiné à la prévision numérique du temps. In: Hommage à – Hulde aan Jacques Van Mieghem. Pour son 70e anniversaire – Voor zijn 70e verjaardag. Institut Royal Météorologique de Belgique. IRM, Publications, Série A, N° 91, p. 233-241.

Van Isacker, J. & Struylaert, W. (1977) Comparison of Semi-Implicit and Filtered Integration Schemes. Beiträge zur Physik der Atmosphäre, 50. Band, p. 177-185.

Van Isacker, J. & Struylaert, W. (1985) Numerical forecasting using Laplace transforms. Royal Meteorological Institute of Belgium, Publications Series A, Vol. 115, 31 p.

25 November 1996: signature by the RMI of the ALADIN MoU

1950, Charney, Fjörtoft, von Neuman, Tellus barotropic vorticity Eq.

Van Isacker, J. (1959) Méthode numérique de prévision du temps. Scientia (Rivista di Scienza), Annus LIII, Vol. XCIV, N. DLXVI, Series VI, p. 125-129.

Van Isacker, J. (1962) Theoretical and Experimental Research on Numerical Weather Prediction in Belgium. Proceedings of the International Symposium on Numerical Weather Prediction in Tokyo, November 7-13, 1960. Published by the Meteorological Society of Japan, March 1962, pp. 9-13.

Van Isacker, J. (1963) Le Laboratoire de Calcul numérique de l'Institut Royal Météorologique. Le mouvement scientifique en Belgique – De wetenschappelijke Beweging in België, Fédération belge des Sociétés scientifiques – Belgisch Verbond der Wetenschappelijke Verenigingen, Volume X, p. 271-276.

11 October **1973**: signature of the convention by the member states for the creation of ECMWF in Brussels

Van Isacker, J. & Struylaert, W. (1974) A semi-filtered, hemispherical, semi-implicit model. Global Atmospheric Research Programme (GARP), The GARP Programme on Numerical Experimentation, Report of the International Symposium on Spectral Methods in Numerical Weather Prediction, Copenhagen, 12-16 August 1974, Report No. 7, pp. 189-192.

Struylaert, W. & Van Isacker, J. (1975) Modèle atmosphérique filtré destiné à la prévision numérique du temps. In: Hommage à – Hulde aan Jacques Van Mieghem. Pour son 70^{e} anniversaire – Voor zijn 70^{e} verjaardag. Institut Royal Météorologique de Belgique. IRM, Publications, Série A, N° 91, p. 233-241.

Van Isacker, J. & Struylaert, W. (1977) Comparison of Semi-Implicit and Filtered Integration Schemes. Beiträge zur Physik der Atmosphäre, 50. Band, p. 177-185.

August **1979**: first operational medium weather prediction by ECMWF

21 April **1983**: first T63 spectral model by ECMWF

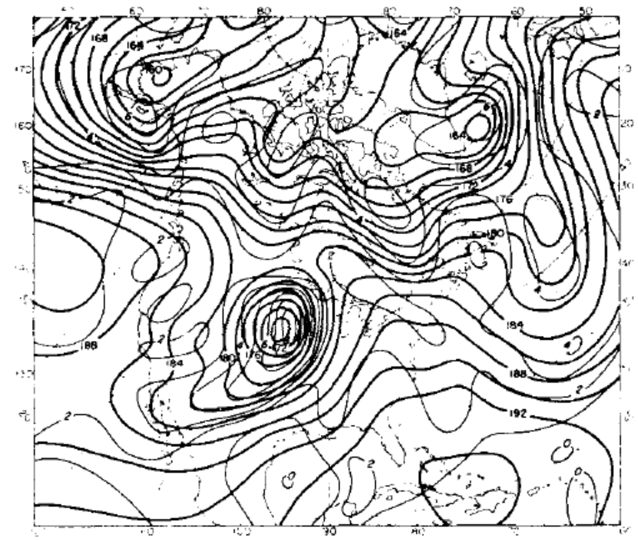
Van Isacker, J. & Struylaert, W. (1985) Numerical forecasting using Laplace transforms. Royal Meteorological Institute of Belgium, Publications Series A, Vol. 115, 31 p.

GAP

1990: initiative to start of the international ALADIN consortium

25 November **1996**: signature by the RMI of the ALADIN MoU

Charney, J. G., Fjörtoft, R. and Von Neumann, J. (**1950**) Numerical integration of the barotropic vorticity equation. *Tellus*, **2**, pp. 237–254

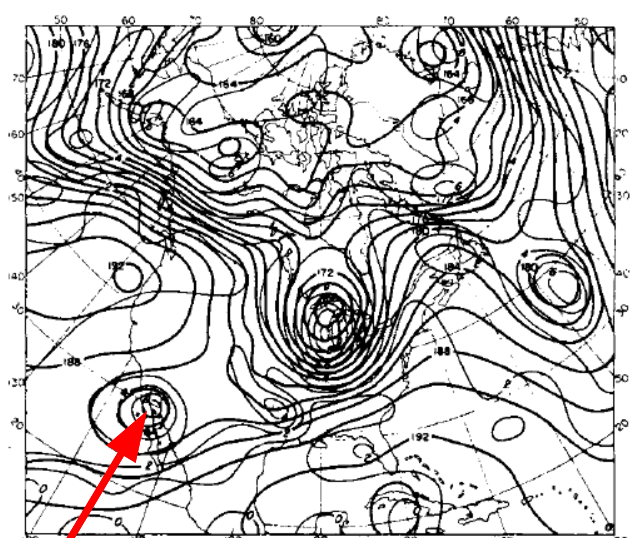


a

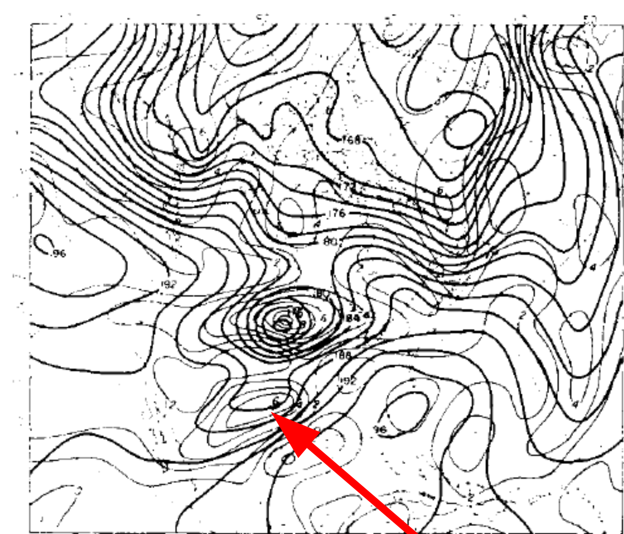
Analysis at 5-1-1949, 0300 GMT Geopotential (thick) and vorticity (thin)

24-h model evolution

Computed geopotential and vorticity at 6-1-1948, 0300 GMT



b



d

Analysis at 6-1-1949, 0300 GMT Geopotential (thick) and vorticity (thin)

1950, Charney, Fjörtoft, von Neuman, Tellus barotropic vorticity Eq.

Van Isacker, J. (1959) Méthode numérique de prévision du temps. Scientia (Rivista di Scienza), Annus LIII, Vol. XCIV, N. DLXVI, Series VI, p. 125-129.

Van Isacker, J. (1962) Theoretical and Experimental Research on Numerical Weather Prediction in Belgium. Proceedings of the International Symposium on Numerical Weather Prediction in Tokyo, November 7-13, 1960. Published by the Meteorological Society of Japan, March 1962, pp. 9-13.

Van Isacker, J. (1963) Le Laboratoire de Calcul numérique de l'Institut Royal Météorologique. Le mouvement scientifique en Belgique – De wetenschappelijke Beweging in België, Fédération belge des Sociétés scientifiques – Belgisch Verbond der Wetenschappelijke Verenigingen, Volume X, p. 271-276.

11 October **1973**: signature of the convention by the member states for the creation of ECMWF in Brussels

Van Isacker, J. & Struylaert, W. (1974) A semi-filtered, hemispherical, semi-implicit model. Global Atmospheric Research Programme (GARP), The GARP Programme on Numerical Experimentation, Report of the International Symposium on Spectral Methods in Numerical Weather Prediction, Copenhagen, 12-16 August 1974, Report No. 7, pp. 189-192.

Struylaert, W. & Van Isacker, J. (1975) Modèle atmosphérique filtré destiné à la prévision numérique du temps. In: Hommage à – Hulde aan Jacques Van Mieghem. Pour son 70e anniversaire – Voor zijn 70e verjaardag. Institut Royal Météorologique de Belgique. IRM, Publications, Série A, N° 91, p. 233-241.

Van Isacker, J. & Struylaert, W. (1977) Comparison of Semi-Implicit and Filtered Integration Schemes. Beiträge zur Physik der Atmosphäre, 50. Band, p. 177-185.

August **1979**: first operational medium weather prediction by ECMWF

Van Isacker, J. & Struylaert, W. (1985) Numerical forecasting using Laplace transforms. Royal Meteorological Institute of Belgium, Publications Series A, Vol. 115, 31 p.

21 April **1983**: first T63 spectral model by ECMWF

1990: initiative to start of the international ALADIN consortium

25 November 1996: signature by the RMI of the ALADIN MoU

Van Isacker, 1963

Depuis une dizaine d'années déjà, à l'initiative du professeur J. Van Mieghem, alors chef du Service d'aérologie, plusieurs membres du personnel scientifique de l'Institut Royal Météorologique (I.R.M.) se sont activement intéressés à l'application des méthodes numériques en météorologie, à l'aide des machines mathématiques.

Depuis novembre 1961, l'I.R.M. dispose d'un ordinateur électronique I.B.M. 7070 qui permet de résoudre automatiquement, suivant des programmes préétablis, des problèmes mathématiques extrêmement complexes que pose l'utilisation des méthodes numériques en météorologie, notamment la prévision numérique.

Depuis le début de l'année 1962, cet équipement est utilisé en priorité pour réaliser quotidiennement une prévision numérique, à 48 heures d'échéance, de la carte météorologique hémisphérique au niveau de pression de 500 millibars. Cette carte, ainsi que les cartes intermédiaires à 12, à 24 et à 36 heures d'échéance, constituent une aide précieuse dans l'élaboration finale de la prévision du temps.

Van Isacker, 1963, barotropic, non-divergent

En tenant compte de ces hypothèses, on peut réduire les équations de la dynamique atmosphérique à une seule équation aux dérivées partielles exprimant la conservation de la rotationnelle absolue η de la vitesse

$$(1) \qquad \frac{\partial \eta}{\partial t} + u \frac{\partial \eta}{\partial x} + v \frac{\partial \eta}{\partial y} = o \; ; \; \eta = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y} + f$$

u et v étant les composantes de la vitesse du vent, $f = 2\,\omega \cos \varphi$ le terme de Coriolis résultant de la rotation de la Terre.

L'hypothèse de non-divergence permet d'exprimer les composantes du vent à l'aide d'une fonction de courant ϕ liée à la pression

$$(2) \qquad u = - \frac{\partial \phi}{\partial y} \qquad v = \frac{\partial \phi}{\partial x}$$

L'équation d'évolution de la fonction ϕ est

$$(3) \qquad \frac{\partial \Delta \phi}{\partial t} + \mathrm{J}\,(\Delta \phi + f\,,\,\phi) = o$$

où Δ représente le laplacien et J le jacobien. La résolution de l'équation aux dérivées partielles (3) requiert l'exécution de plusieurs millions d'opérations arithmétiques et ne peut être réalisée qu'avec l'aide d'un puissant calculateur électronique.

Van Isacker, 1963, 48h Forecast

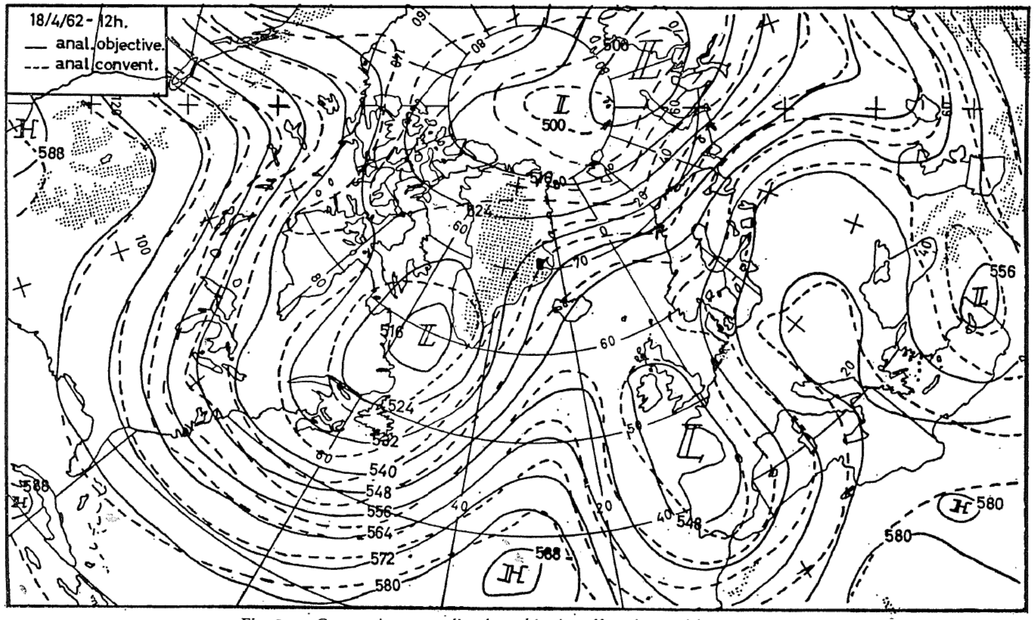


Fig. 2. — Comparaison entre l'analyse objective effectuée numériquement et l'analyse conventionnelle faite au Bureau du Temps pour le 18.4.1962.

Comparison, on 18-4-1962, 12h of

- Numerical analysis (solid line)
- Conventional forecaster's analysis in the weather office (dashed line)

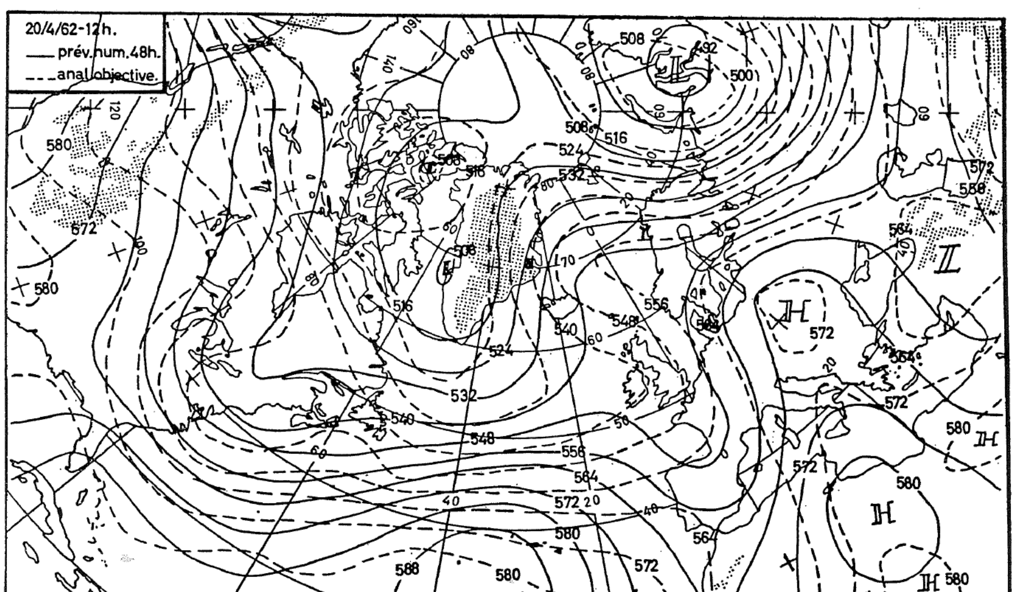


Fig. 3. — Comparaison entre la situation prévue et la situation observée du 20.4.1962.

Comparison on 20-4-1962 of

- 48-h lead time Numerical Weather Prediction (solid line)
- Numerical analysis at that moment of the situation (dashed line)

1950, Charney, Fjörtoft, von Neuman, Tellus barotropic vorticity Eq.

Van Isacker, J. (1959) Méthode numérique de prévision du temps. Scientia (Rivista di Scienza), Annus LIII, Vol. XCIV, N. DLXVI, Series VI, p. 125-129.

Van Isacker, J. (1962) Theoretical and Experimental Research on Numerical Weather Prediction in Belgium. Proceedings of the International Symposium on Numerical Weather Prediction in Tokyo, November 7-13, 1960. Published by the Meteorological Society of Japan, March 1962, pp. 9-13.

Van Isacker, J. (1963) Le Laboratoire de Calcul numérique de l'Institut Royal Météorologique. Le mouvement scientifique en Belgique – De wetenschappelijke Beweging in België, Fédération belge des Sociétés scientifiques – Belgisch Verbond der Wetenschappelijke Verenigingen, Volume X, p. 271-276.

11 October **1973**: signature of the convention by the member states for the creation of ECMWF in Brussels

Van Isacker, J. & Struylaert, W. (1974) A semi-filtered, hemispherical, semi-implicit model. Global Atmospheric Research Programme (GARP), The GARP Programme on Numerical Experimentation, Report of the International Symposium on Spectral Methods in Numerical Weather Prediction, Copenhagen, 12-16 August 1974, Report No. 7, pp. 189-192.

Struylaert, W. & Van Isacker, J. (1975) Modèle atmosphérique filtré destiné à la prévision numérique du temps. In: Hommage à – Hulde aan Jacques Van Mieghem. Pour son 70e anniversaire – Voor zijn 70e verjaardag. Institut Royal Météorologique de Belgique. IRM, Publications, Série A, N° 91, p. 233-241.

Van Isacker, J. & Struylaert, W. (1977) Comparison of Semi-Implicit and Filtered Integration Schemes. Beiträge zur Physik der Atmosphäre, 50. Band, p. 177-185.

August **1979**: first operational medium weather prediction by ECMWF

21 April **1983**: first T63 spectral model by ECMWF

Van Isacker, J. & Struylaert, W. (1985) Numerical forecasting using Laplace transforms. Royal Meteorological Institute of Belgium, Publications Series A, Vol. 115, 31 p.

1990: initiative to start of the international ALADIN consortium

25 November 1996: signature by the RMI of the ALADIN MoU

Van Isacker, J. & Struijlaert, W. (1974)

SAMENVATTING VAN DE BESCHIJVENDE VERGELIJKINGEN VAN DE ATMOSFEER.

$$\Delta\dot{\psi} - J(\eta,\psi) - R(\eta,\theta') + R(\Delta\theta,\psi') - J(\Delta\theta,\theta'') = 0 \qquad (29a)$$

$$\Delta\dot{\theta}' - \Delta\phi + \upsilon = 0 \qquad (29b)$$

$$\upsilon = -J(\eta,\theta') + R(\Delta\theta,\theta'') + R(\eta,\psi) + J(\Delta\theta,\psi') - \Delta E_k$$

$$E_k = \frac{1}{2}\left[Q(\psi,\psi) + Q(\theta',\theta') + 2J(\theta',\psi)\right]$$

$$\dot{T} = J(T,\psi) + R(T,\theta') - (T\,\Delta\theta)' + \frac{\Delta\theta}{p}\,T\,\frac{R}{c_p} \qquad (29c)$$

$$\dot{\phi}_0 = \frac{\Delta\theta_0}{p_0}\left(\frac{R}{c_p}E_{k_0} + RT_0 + \frac{R}{c_p}\phi_0\right) + J(\phi_0,\psi_0) + R(\phi_0,\theta_0') \qquad (29d)$$

Van Isacker, J. & Struijlaert, W. (1974), cont'd

- Spectral model (but with interaction coefficients explicitly computed)
- Semi-Filtering of the fast propagating gravity waves.
- Runge Kutta and semi implicit methods both tested (1977)
- 3 “vertical levels” (3 modes in pressure)
- Spectral truncation T19

Conclusion

Le modèle atmosphérique décrit précédemment est appliqué régulièrement à la prévision du temps à l'IRM.

Grâce à l'utilisation du filtrage sélectif et du schéma d'intégration semi-implicite, il a été possible de choisir un pas d'intégration de 3 heures, ce qui permet d'effectuer une prévision à 72 heures d'échéance en 4 heures sur l'ordinateur IBM 360/44 de l'IRM.

Semi-filtered semi-implicit schemes, 1977

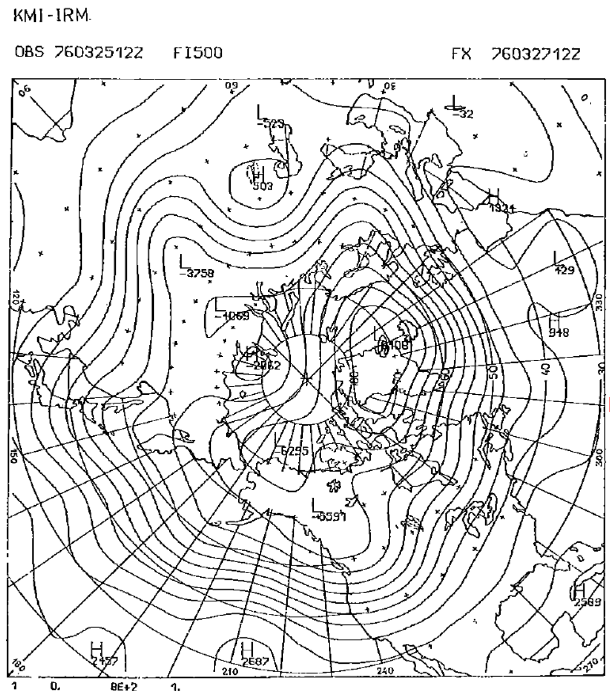


Figure 2. Predicted geopotential – primitive model – time step 1/2 hour.

Δ t · 2

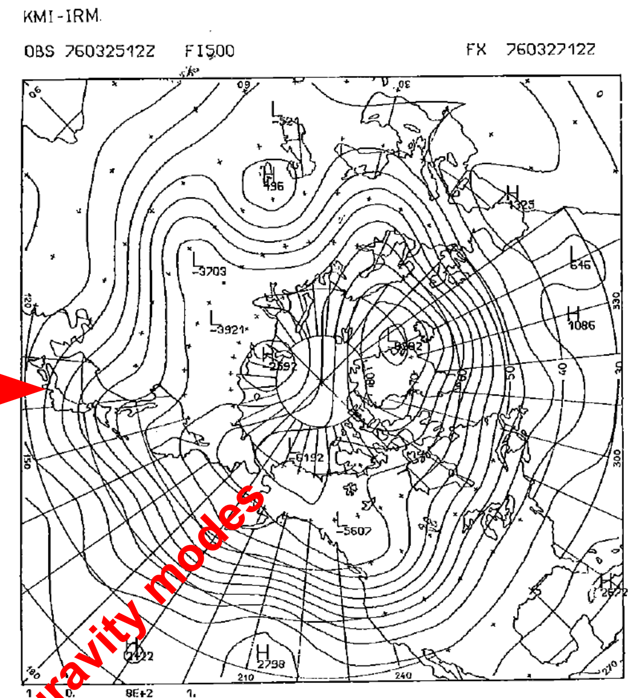


Figure 3. Predicted geopotential – primitive model – time step 1 hour.

Filtering of fast gravity modes

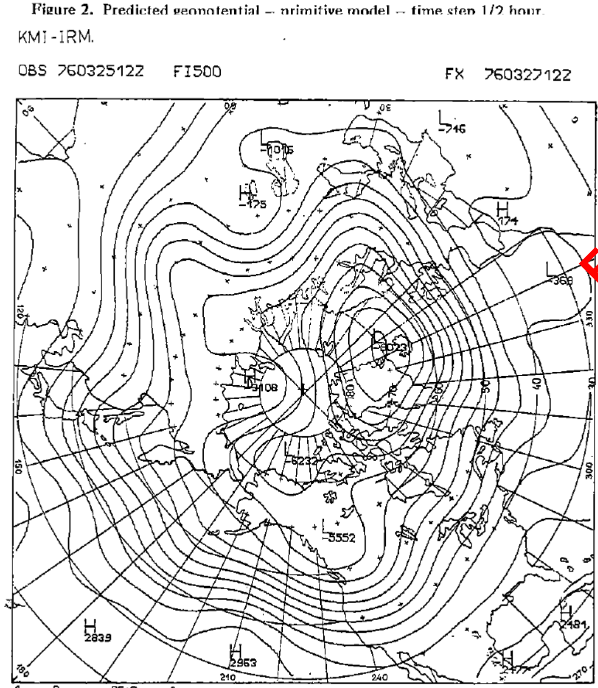


Figure 4. Predicted geopotential – filtered model – time step 2 hours.

Linear balance effect

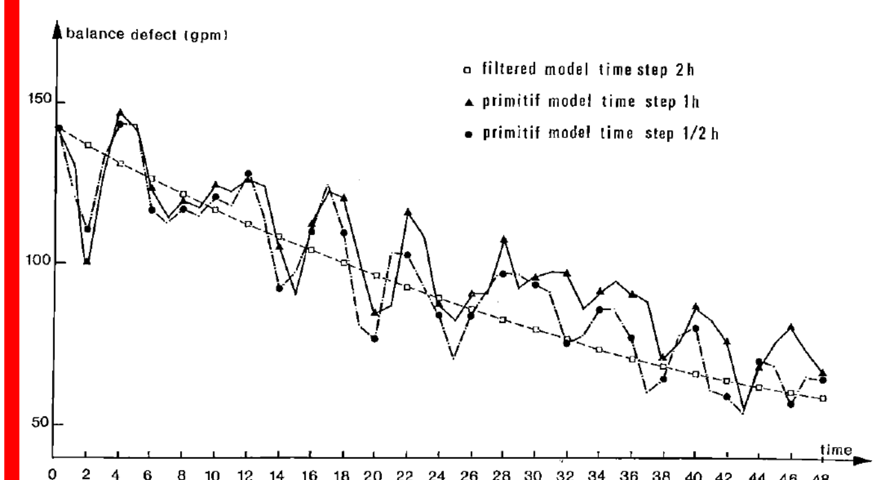


Figure 8. Evolution in time of the linear balance defect

1950, Charney, Fjörtoft, von Neuman, Tellus barotropic vorticity Eq.

Van Isacker, J. (1959) Méthode numérique de prévision du temps. Scientia (Rivista di Scienza), Annus LIII, Vol. XCIV, N. DLXVI, Series VI, p. 125-129.

Van Isacker, J. (1962) Theoretical and Experimental Research on Numerical Weather Prediction in Belgium. Proceedings of the International Symposium on Numerical Weather Prediction in Tokyo, November 7-13, 1960. Published by the Meteorological Society of Japan, March 1962, pp. 9-13.

Van Isacker, J. (1963) Le Laboratoire de Calcul numérique de l'Institut Royal Météorologique. Le mouvement scientifique en Belgique – De wetenschappelijke Beweging in België, Fédération belge des Sociétés scientifiques – Belgisch Verbond der Wetenschappelijke Verenigingen, Volume X, p. 271-276.

11 October **1973**: signature of the convention by the meber states for the creation of ECMWF in Brussels

Van Isacker, J. & Struijlaert, W. (1974) A semi-filtered, hemispherical, semi-implicit model. Global Atmospheric Research Programme (GARP), The GARP Programme on Numerical Experimentation, Report of the International Symposium on Spectral Methods in Numerical Weather Prediction, Copenhagen, 12-16 August 1974, Report No. 7, pp. 189-192.

Struylaert, W. & Van Isacker, J. (1975) Modèle atmosphérique filtré destiné à la prévision numérique du temps. In: Hommage à – Hulde aan Jacques Van Mieghem. Pour son 70e anniversaire – Voor zijn 70e verjaardag. Institut Royal Météorologique de Belgique. IRM, Publications, Série A, N° 91, p. 233-241.

Van Isacker, J. & Struylaert, W. (1977) Comparison of Semi-Implicit and Filtered Integration Schemes. Beiträge zur Physik der Atmosphäre, 50. Band, p. 177-185.

August **1979**: first operational medium weather prediction by ECMWF

Van Isacker, J. & Struylaert, W. (1985) Numerical forecasting using Laplace transforms. Royal Meteorological Institute of Belgium, Publications Series A, Vol. 115, 31 p.

Talk of Peter Lynch (?)

21 April **1983**: first T63 spectral model by ECMWF

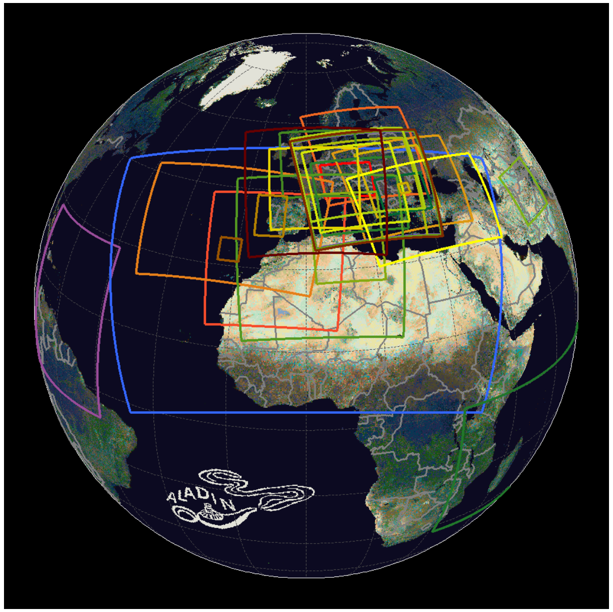
1990: start of the international ALADIN consortium

25 November 1996: signature by the RMI of the ALADIN MoU

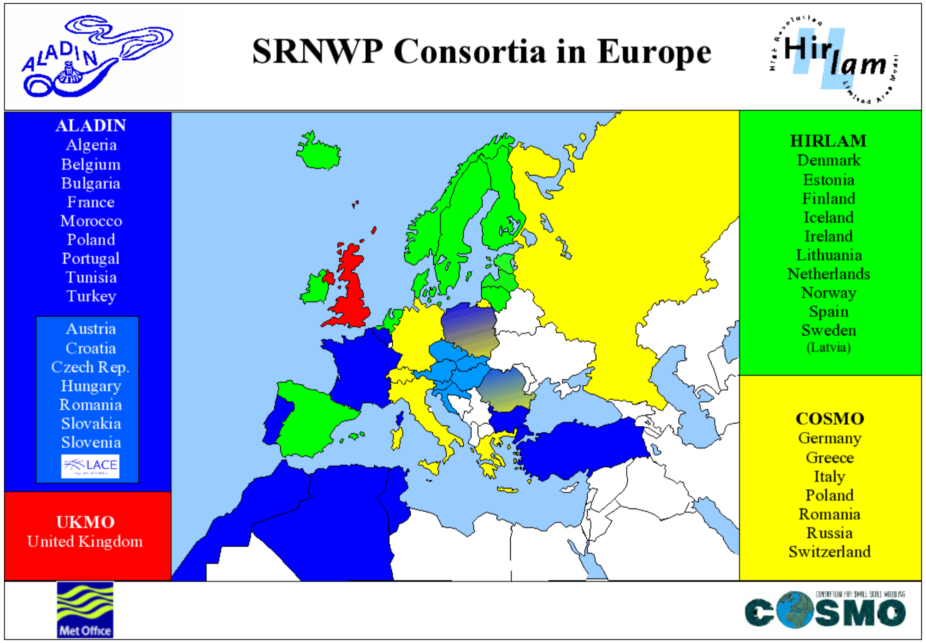
1996: H. Malcorps signs the ALADIN MoU

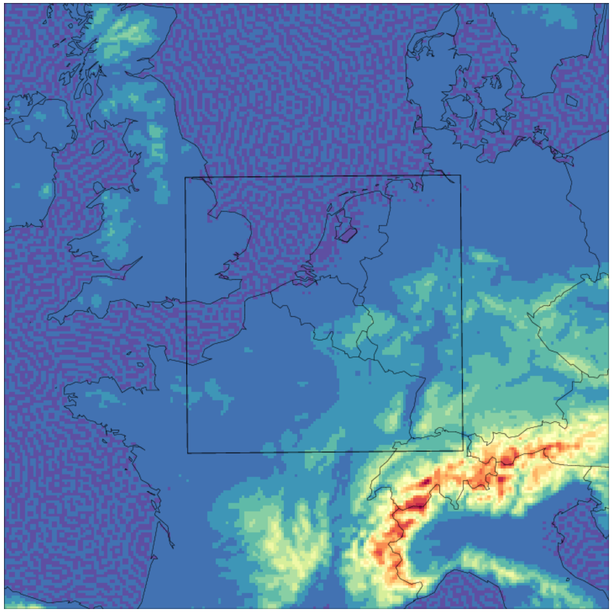
- In the nineties the RMI decided to become active in the activities of the LAM consortia. Under the impulse of A. Quinet the RMI decided to join the ALADIN consortium
- Jean-François Geleyn was the leading scientist in this consortium at that time. Luc Gerard made his PhD under supervision of J.-F. Geleyn.
- The PhD of Luc Gerard was the basis was the basis for the 3MT scheme. This scheme formed the basis for the development of the ALARO model.
- The ALADIN model is *spectral* *semi-implicit (SI)* semi-Lagrangian (SL) [Van Isacker's model was not SL, but computed the non-linear terms in spectral space] and formulated in u,v [Van Isacker's model was formulated in stream function/velocity potential].

Current status of the ALADIN consortium



- Scientific colaboration of the national meteorological services (NMSs) of 16 countries
- About 85 FTEs in man power contributions
- http://www.cnrm.meteo.fr/aladin/
- Each participating NMS runs its own model to satisfy its national needs.
- The model runs on limited-area domains





The basis (I) of the ALADIN consortium [as implemented by J.-F. Geleyn]: **TRAINING and CAPACITY BUILDING!**

Each local team should become as complete as possible, i.e. to install, run the model and to derive the local applications.

Each team is supposed to contribute to R&D.

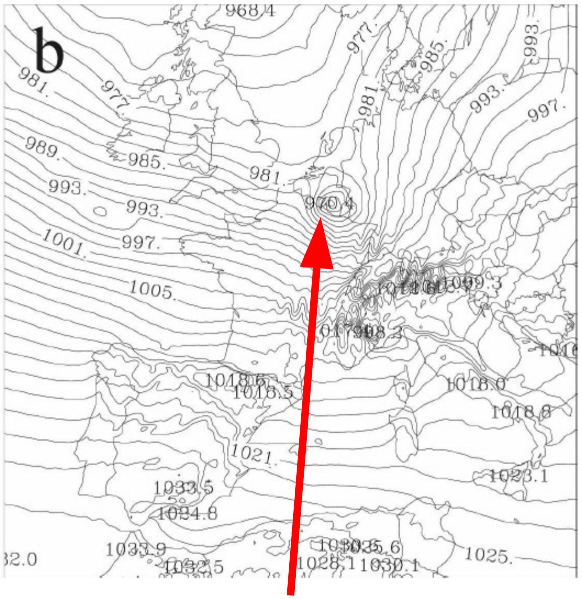
The Belgian ALADIN team: current members

< 1996	1999	2000	2006	2008	2010	2012
Luc Gerard [physics]	**Piet Termonia** [dynamics, numerics]	**Alex Deckmyn** [EPS, data assimilation, verification]	**Rafiq Hamdi** [surface, climate]	**Daan Degrauwe** [dynamics, numerics, code design]	**Steven Caluwaerts** (UGent) [dynamics]	**Rozemien De Troch** [climate]
				Geert Smet [predicatbility, EPS]		**Annelies Duerinckx** [data assimilation]
				Joris Van den Bergh [predictability, physics]		**Olivier Giot** [climate]
						Michiel Van Ginderachter [physics, validation]

The RMI back in the NWP business

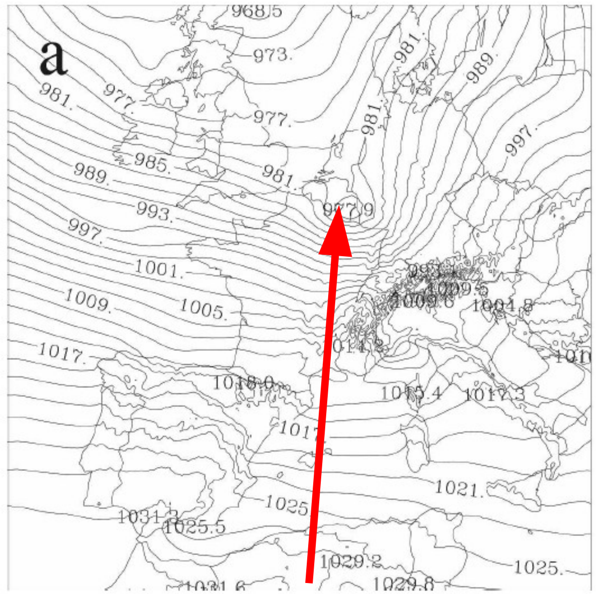
Problem of the balanced states : SSDFI, the famous French Xmass storm (26/12/1999)

Large-scale field (reference)



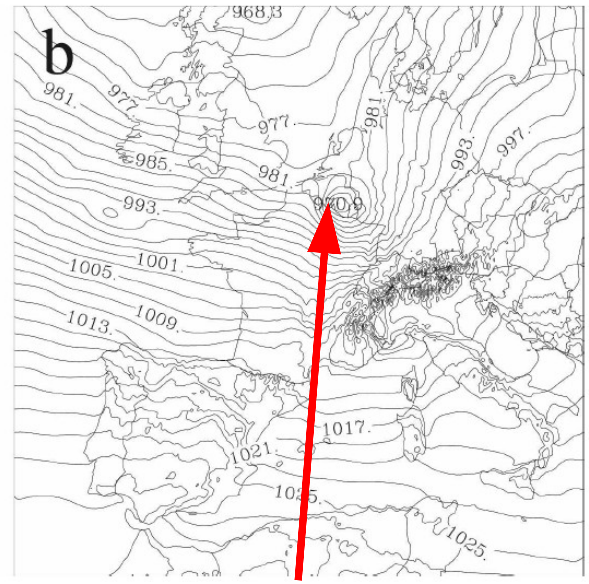
970.4 hPa

Result of DFI



977.9 hPa

Scale-selective DFI



970.9 hPa

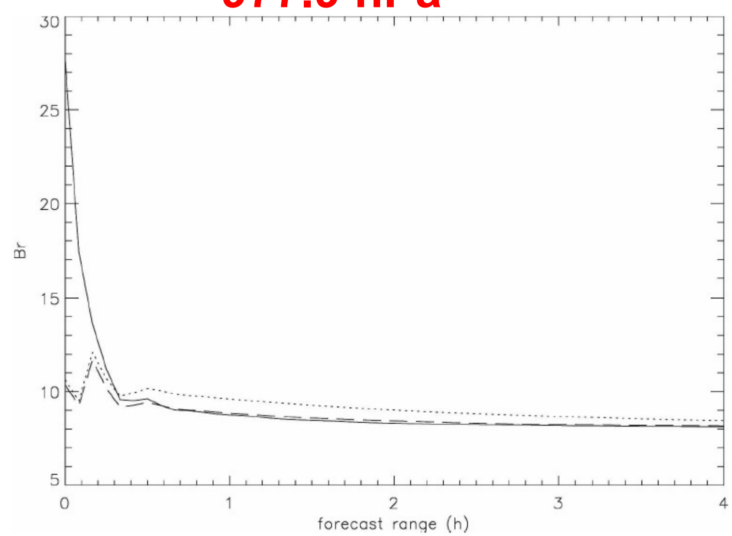


FIG. 6. Br for the uninitialized forecast (solid), initialized with DFI_{3h} (dots), and with $SSDFI_{1.5h}$ (dashed), applied on the Lothar storm at 0900 UTC.

Termonia 2008, *Mon. Wea. Rev.*

Basis (II): scientific attitude quote from Feynman but implemented by J.-F. Geleyn

"When I was at Cornell, I often talked to the people in the psychology department. One of the students told me she wanted to do an experiment that went something like this--it had been found by others that under certain circumstances, X, rats did something, A. She was curious as to whether, if she changed the circumstances to Y, they would still do A. So her proposal was to do the experiment under circumstances Y and see if they still did A.

I explained to her that it was necessary first to repeat in her laboratory the experiment of the other person--to do it under condition X to see if she could also get result A, and then change to Y and see if A changed. Then she would know the real difference was the thing she thought she had under control.

She was very delighted with this new idea, and went to her professor. And his reply was, no, you cannot do that, because the experiment has already been done and you would be wasting time."

In other words: **change what you want to test, keeping all other things equal!**

The SI SL spectral school is sometimes “criticised” [by the Explicit-Eulerian, gridpoint school], e.g

- Spectral methods will not be OK for steep slopes (cfr. High resolution)
- Semi-Lagrangian methods “filter” too much, they are not conservative.
- Stability can be obtained by higher-order Runge-Kutta.
- ….

However, no one actually tests this in 3D models!!!

Go between:

- change our code minimalistically to a local discretization
- In practice we only want to change the computation of the derivatives in the system
- If this can be done we will have an efficient tool to test some of the tenets of NWP

Horizontal discretizations (FD/FE): dispersion relations

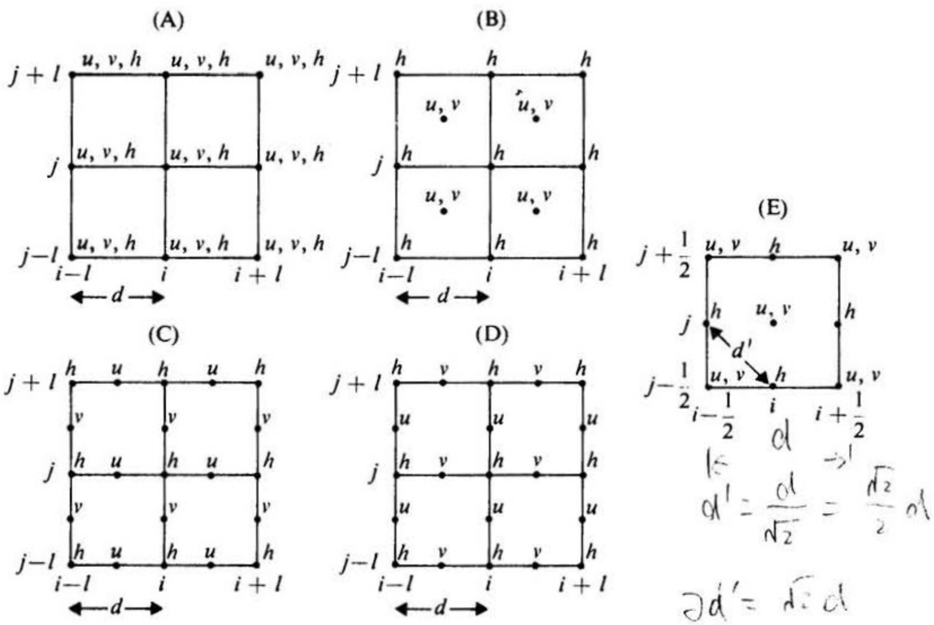
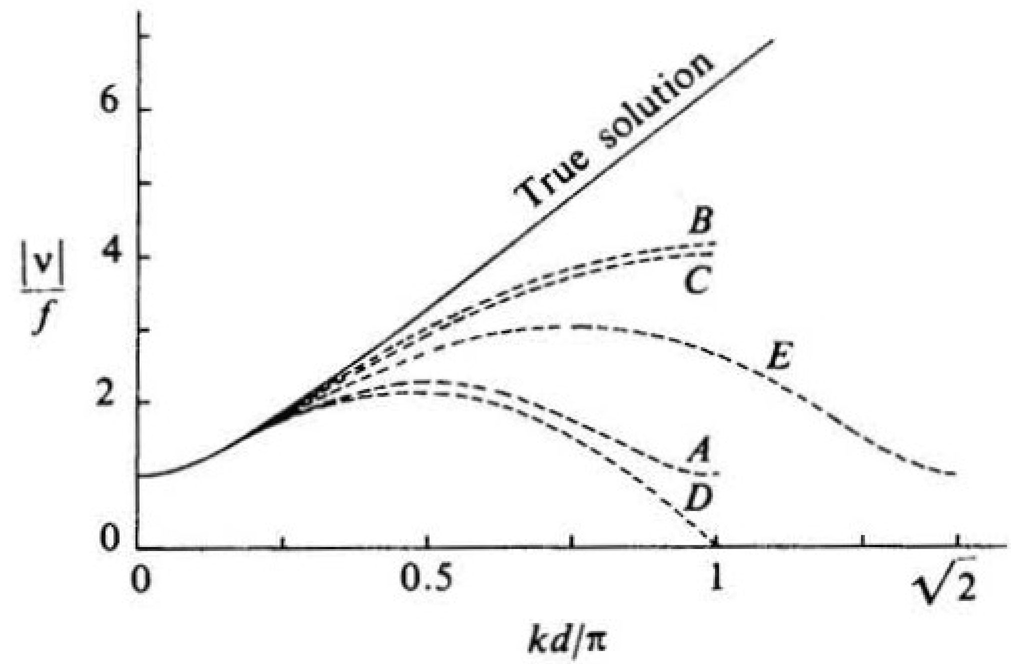


Figure 3.1 Five types of lattice considered for the finite difference solution of (3.1).



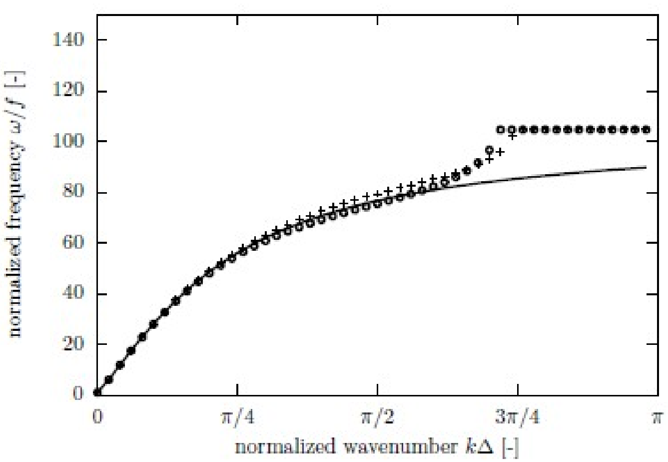
Mesinger and Arakawa, 1976

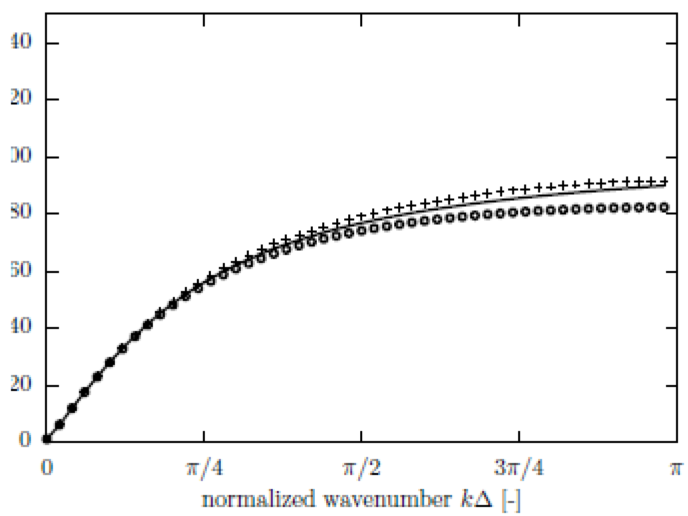
If we stay on the A grid, we have to fornulate the dynamics in terms of **vorticity and divergence** [in fact the Laplacians of Van Isacker's stream function and velocity potential]

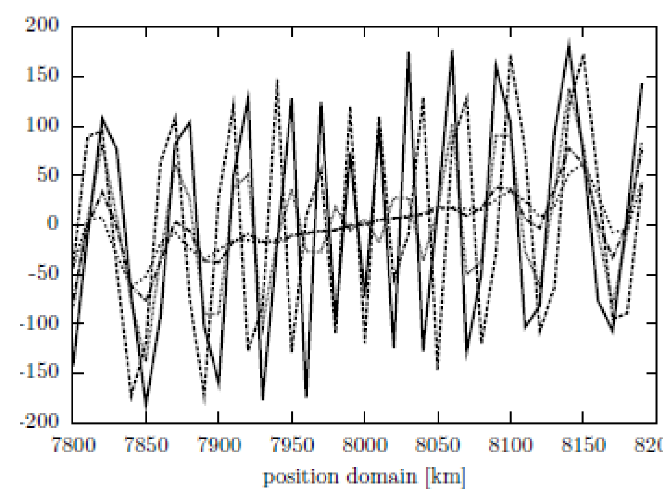
Replacing the spectral methods by Horizontal Finite elements on a Z-grid.

$$(\mathcal{I} - \frac{\Delta t}{2}\mathcal{L}^*)\mathbf{X}_A^+ = (\mathcal{I} + \frac{\Delta t}{2}\mathcal{L}^*)\mathbf{X}_D^0 + \Delta t(\mathcal{M} - \mathcal{L}^*)\tilde{\mathbf{X}} + \Delta t\mathcal{F}(\mathbf{X}^0) = \mathbf{R}$$

	ALADIN timestep organization	
1	transform the fields from spectral space to gridpoint space	
2	calculate physics in a parallel manner in the arrival points	$\mathcal{F}(\mathbf{X}_A^0)$
3	update tendencies	
4	compute SL departure points D and interpolate to D	
5	compute explicit part dynamics	$(\mathcal{I} + \frac{\Delta t}{2}\mathcal{L}^*)\mathbf{X}_D^0 + \Delta t(\mathcal{M} - \mathcal{L}^*)\tilde{\mathbf{X}}$
6	add all tendencies	$\mathbf{R}_{lam}$
7	couple and relax the LAM fields to the host model	$\mathbf{R}_{tot} = \alpha\mathbf{R}_{lam} + (1-\alpha)\mathbf{R}_{host}$
8	transform the fields from gridpoint space to spectral space	
9	solve Helmholtz problem	$\mathbf{X}_A^+ = (\mathcal{I} - \frac{\Delta t}{2}\mathcal{L}^*)^{-1}\mathbf{R}_{tot}$







Caluwaerts, Degrauwe, Termonia, Voitus, Bénard, Geleyn

1950, Charney, Fjörtoft, von Neuman, Tellus barotropic vorticity Eq.

Van Isacker, J. (1959) Méthode numérique de prévision du temps. Scientia (Rivista di Scienza), Annus LIII, Vol. XCIV, N. DLXVI, Series VI, p. 125-129.

Van Isacker, J. (1962) Theoretical and Experimental Research on Numerical Weather Prediction in Belgium. Proceedings of the International Symposium on Numerical Weather Prediction in Tokyo, November 7-13, 1960. Published by the Meteorological Society of Japan, March 1962, pp. 9-13.

Van Isacker, J. (1963) Le Laboratoire de Calcul numérique de l'Institut Royal Météorologique. Le mouvement scientifique en Belgique – De wetenschappelijke Beweging in België, Fédération belge des Sociétés scientifiques – Belgisch Verbond der Wetenschappelijke Verenigingen, Volume X, p. 271-276.

11 October **1973**: signature of the convention by the meber states for the creation of ECMWF in Brussels

Van Isacker, J. & Struijlaert, W. (1974) A semi-filtered, hemispherical, semi-implicit model. Global Atmospheric Research Programme (GARP), The GARP Programme on Numerical Experimentation, Report of the International Symposium on Spectral Methods in Numerical Weather Prediction, Copenhagen, 12-16 August 1974, Report No. 7, pp. 189-192.

Struylaert, W. & Van Isacker, J. (1975) Modèle atmosphérique filtré destiné à la prévision numérique du temps. In: Hommage à – Hulde aan Jacques Van Mieghem. Pour son 70e anniversaire – Voor zijn 70e verjaardag. Institut Royal Météorologique de Belgique. IRM, Publications, Série A, N° 91, p. 233-241.

Van Isacker, J. & Struylaert, W. (1977) Comparison of Semi-Implicit and Filtered Integration Schemes. Beiträge zur Physik der Atmosphäre, 50. Band, p. 177-185.

August **1979**: first operational medium weather prediction by ECMWF

21 April **1983**: first T63 spectral model by ECMWF

1990: start of the international ALADIN consortium

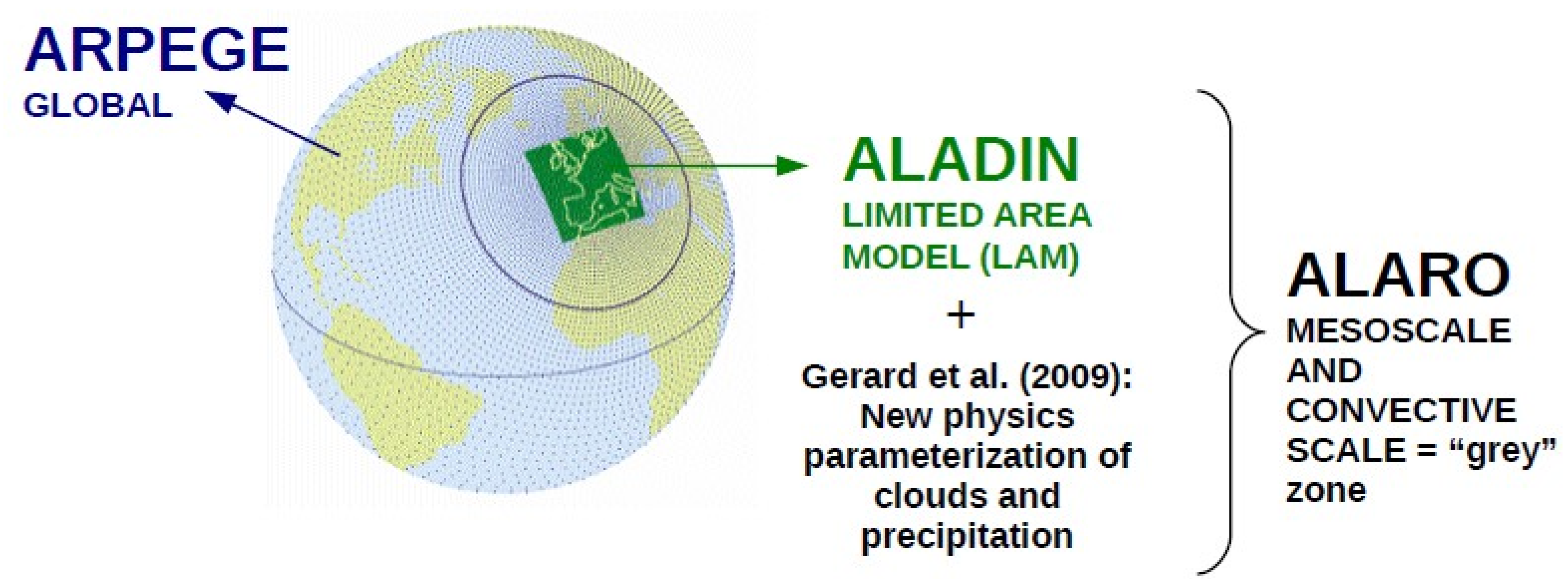
25 November 1996: signature by the RMI of the ALADIN MoU

Innovations related to modeling

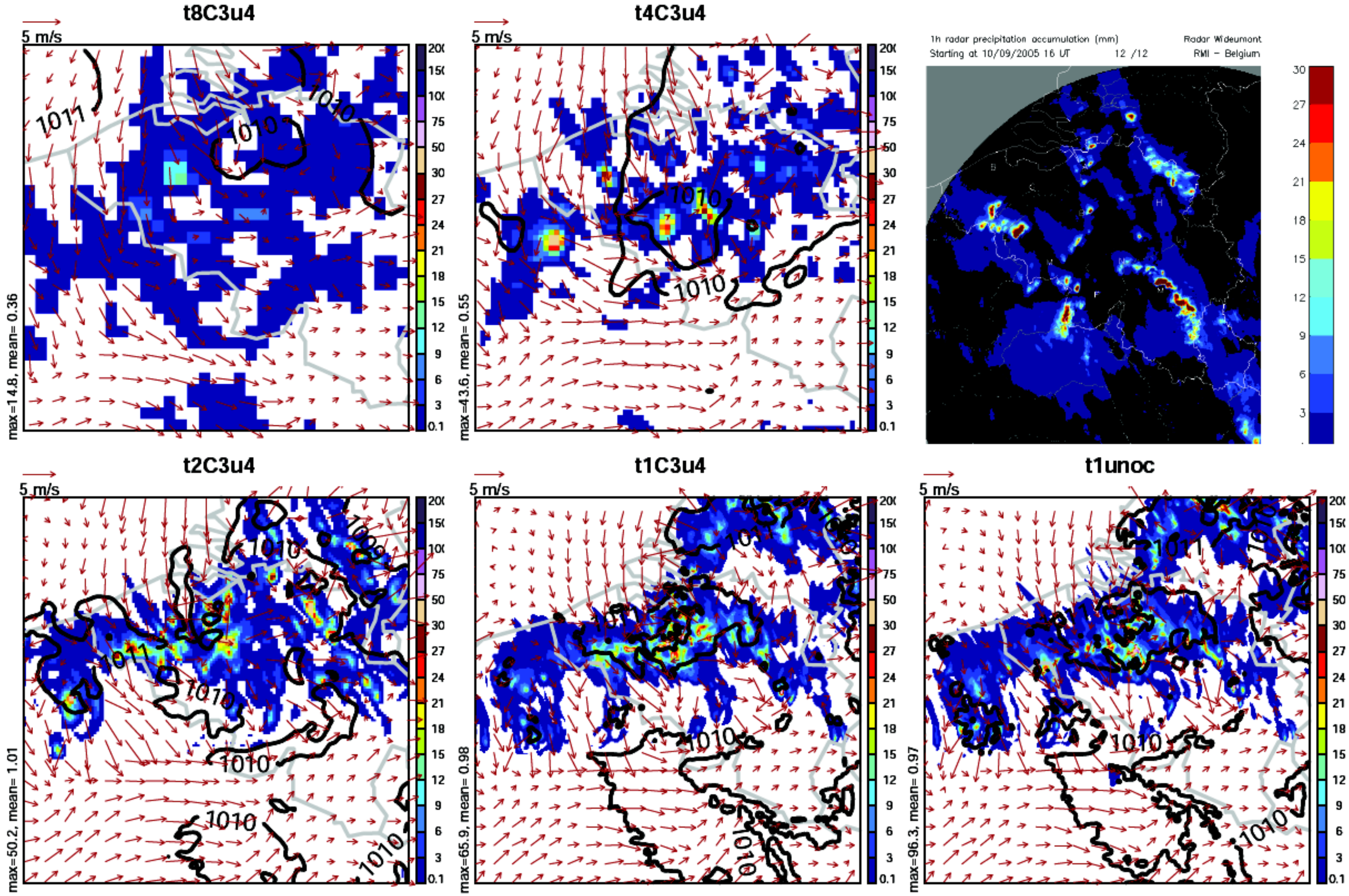
MCUF, SSDFI, LBCs, Boyd's coupling	P. Termonia, D. Degrauwe, A. Deckmyn, R. Hamdi, S. Caluwaerts
Dynamics, **horizontal FEs**	S. Caluwaerts, D. Degrauwe, P. Termonia
Code design: OOPS, physics dynamics coupling, SURFEX	D. Degrauwe, R. Hamdi, P. Termonia, G. Smet,J. Van den Bergh
3MT (and its successor CSD)	L. Gerard
Urban modeling: UHI for Brussels, see breeze propogation, run off.	R. Hamdi
Modeling of Evapotranspiration	F. Meulenberghs, N. Ghilain, A. Arboleda, J. M. Barrios
Air pollution: new transport length for air pollution	P. Termonia, A. Quinet, R. De Troch
A flux conservative physics-dynamics interface	B. Catry, D. Degrauwe, M Vanginderachter
Validation, **Pukkelpop**	M. Vanginderachter, P. De Meutter
Verifiction and statistical processing (CREV, EVMOS, …).	S. Vannitsem, B. Van Schaeybroeck, L. De Cruz, G. Smet, A. Deckmyn, P. Termonia
GLAMEPS	A. Deckmyn, G. Smet, J. Van den Bergh
Data assimialtion: EKF, STAEKF, 3Dvar	R. Hamdi, A. Duerinckx, A. Carrassi, P. Termonia
Data assimilation: wavelets for simplifyng the B matrix	A. Deckmyn
Regional climate	R. De Troch, O. Giot, R. Hamdi, P. Termonia
Early warning system for precipitation based on the SCHEME hydrological model	E. Roulin, P. Baguis, J. Van den Bergh

Deep convection (at 1-3 km resolution) : to parameterize or not to parameterize?

- Again two schools [both were followed with the ALADIN consortium]::
  - Convection is (sufficiently well) resolved at 2.5 km so that we do not need to parameterize it, and we make a discontinuous large jump in resolution from 10 km to 2.5 km. This led to the **AROME model configuration** based on the ALADIN NH dynamics with the meso-NH physics, developed in the past by Météo France.
  - Some partners of the consortium can not afford this big jump in terms of available computing resources and a second plan was made to upgrade the ALADIN physics to make it suitable to be run in what we call the gray zone (i.e. scale for between 3 and 7 km) . This led to a multiscale parameterization of deep convection, the so-called 3MT scheme. This led to the **ALARO model configuration**.



3MT: increasing the resolution in scale-aware manner.



Courtesy L. Gerard

Other diabatisms in “Streams of research”

- MT (Piriou 2007) → 3MT (Gerard *et al.* 2007) → hydrostatic ALARO-0 → NH ALARO-1 and PCMT (Piriou): **multiscale treatment of deep convection**
- **Progress on turbulent diffusion**
  - **in the stable regimes** concluded from Quasi-normal-mode-elimination techniques of Sukoriansky *et al.* (2005).
  - Cheng, Y. and Canuto,V.M. and Howard, A.M., 2002
  - EFB turbulence closure scheme, Sergej Zilitinkevich.
- Lilly (1968) → Betts (1973)→ Marquet (2011)'s new moist thermodynamical variable theta_1s → Marquet, Geleyn (2011) -> treat **shallow convection as part of the vertical diffusion**?

Jean-Francois Geleyn:
Implement the different “truths” in one single model code.

This allows for clean scientific testing

Since the **thermodynamics** is key, one needs A frame for a consistent treatment

Tellus (2007), 59A, 71–79

TELLUS

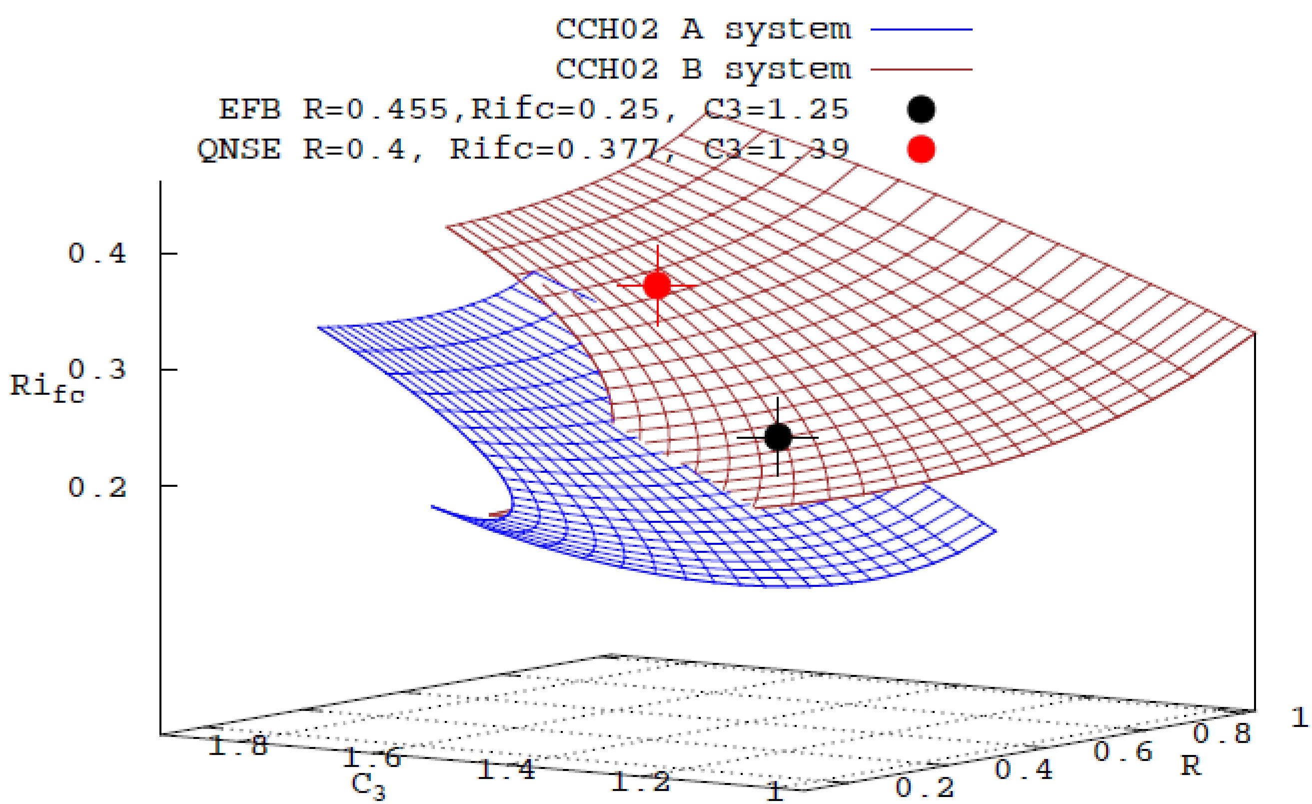
Flux-conservative thermodynamic equations in a mass-weighted framework

By B. CATRY[1]*, J.-F. GELEYN[2]†, M. TUDOR[3], P. BÉNARD[4] and A. TROJÁKOVÁ[2],
[1]*Sterrenkundig Observatorium, Ghent University, Ghent, Belgium;* [2]*Czech Hydrometeorological Institute, Prague Czech Republic;* [3]*Croatian Meteorological and Hydrological Service, Zagreb, Croatia;* [4]*Centre National de Recherches Météorologiques, Météo-France, Toulouse, France*

(Manuscript received 29 January 2006; in final form 8 September 2006)

$$c_p \frac{\partial T}{\partial t} = gL_l(T)\frac{\partial}{\partial p}(P_l' - P_l''') + gL_i(T)\frac{\partial}{\partial p}(P_i' - P_i''')$$
$$- g\left[c_l P_l + c_i P_i - \frac{c_p - c_l q_r - c_i q_s}{1 - q_r - q_s}(P_l + P_i)\right]\frac{\partial T}{\partial p} - g\frac{\partial J_s}{\partial p}$$
$$+ gT\left(c_{pd}\frac{\partial J_{q_d}}{\partial p} + c_{pv}\frac{\partial J_{q_v}}{\partial p} + c_l\frac{\partial J_{q_l}}{\partial p} + c_i\frac{\partial J_{q_i}}{\partial p}\right) - g\frac{\partial J_{\text{rad}}}{\partial p},$$

Space of parameterizations: example the TOUCANS scheme



Courtesy I. Bašták Durán

Taking care of the numerics AND the algorithmics one can implement (up to some approximations) different turbulence schemes in one software code allowing clean scientific tests.

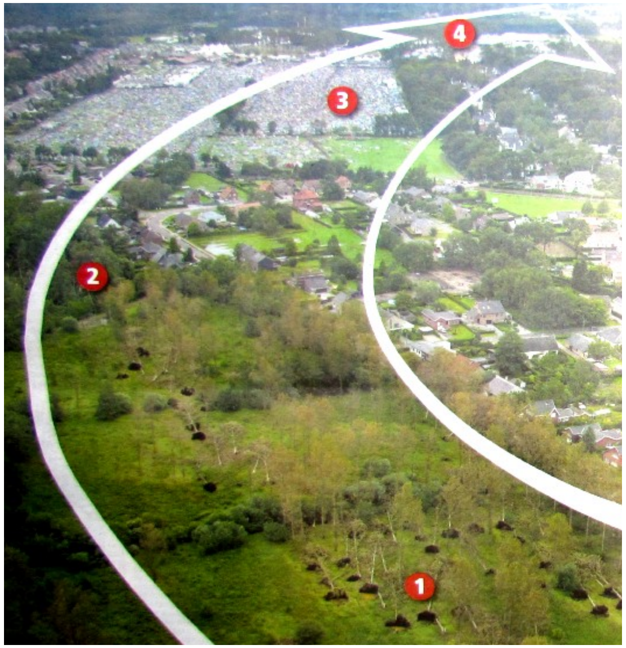
Three examples addressing national needs:

Weather alerts: Pukkelpop

Climate projections

Probabilistic forecasting (economic value)

Pukkelpop, 18 August 2011



Source: “*Het belang van Limburg*”

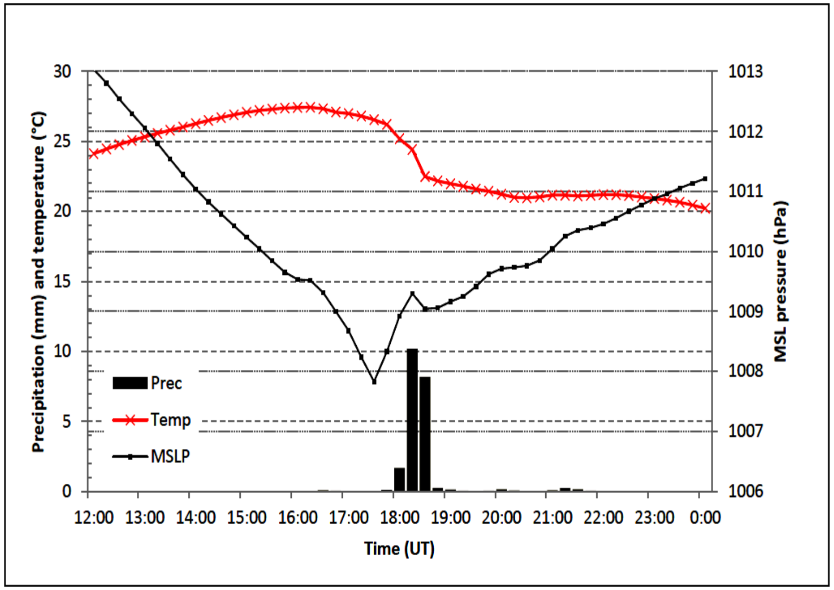
Downburst ~ 100 m

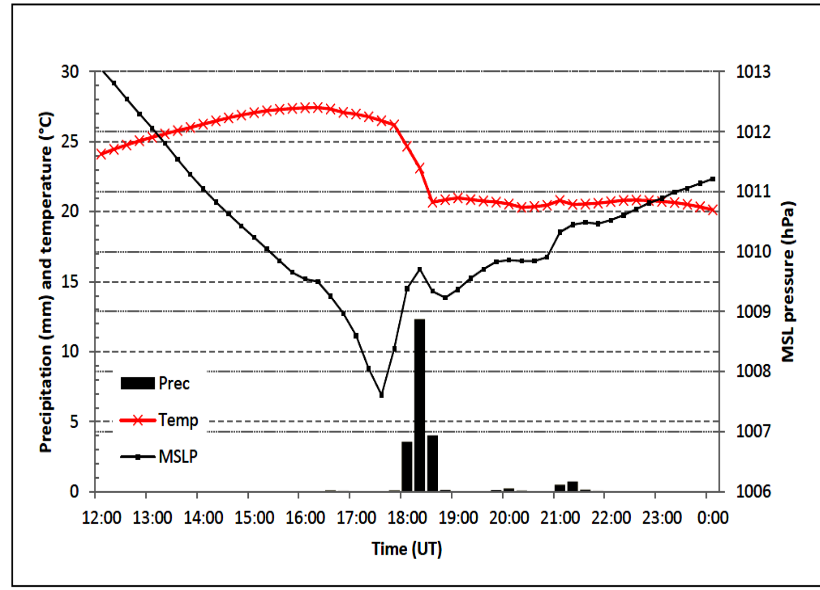
Operational NWP model RMI: 4 km

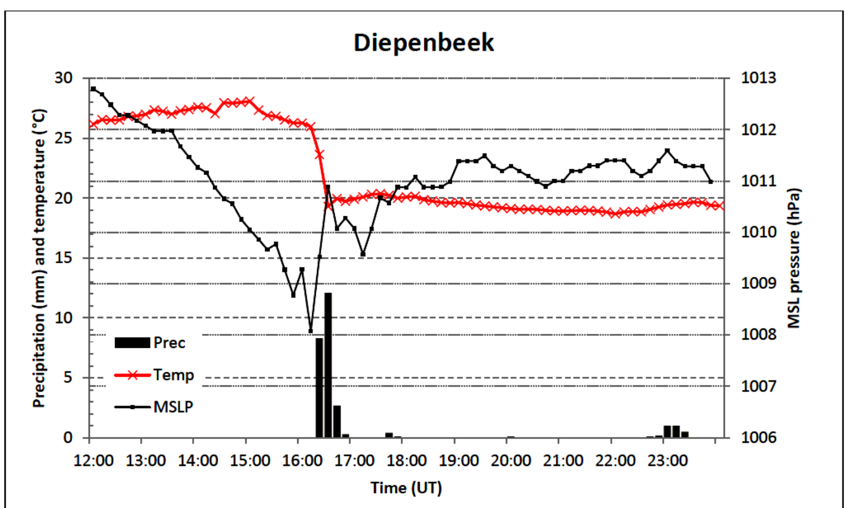
- **Predictability of Pukkelpopstorm at 4 km resolution?**
- **What is the “truth”?**

Reference run at 1 km (taken at the limit of current operational computational resources)

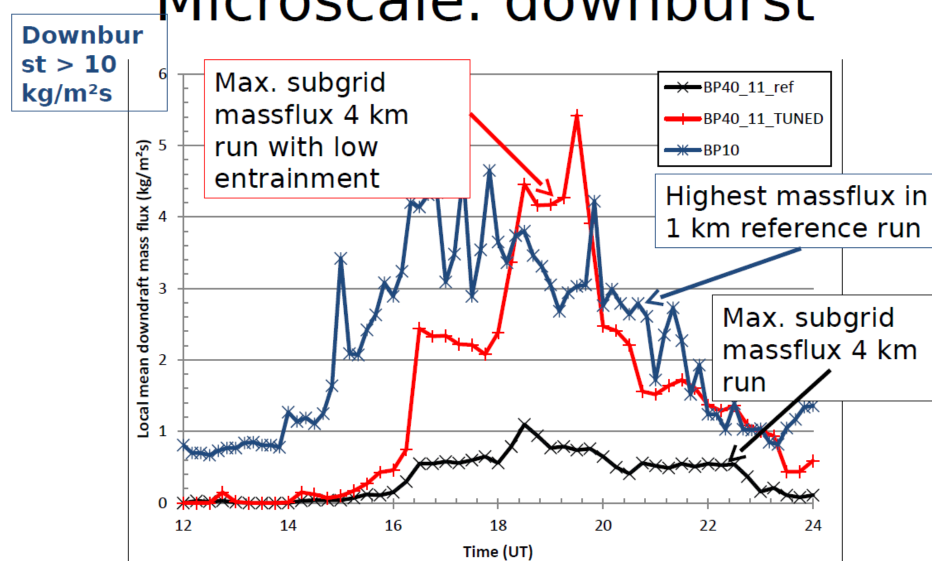
Can downdrafts of the 3MT scheme be used as "proxies", and tune them?





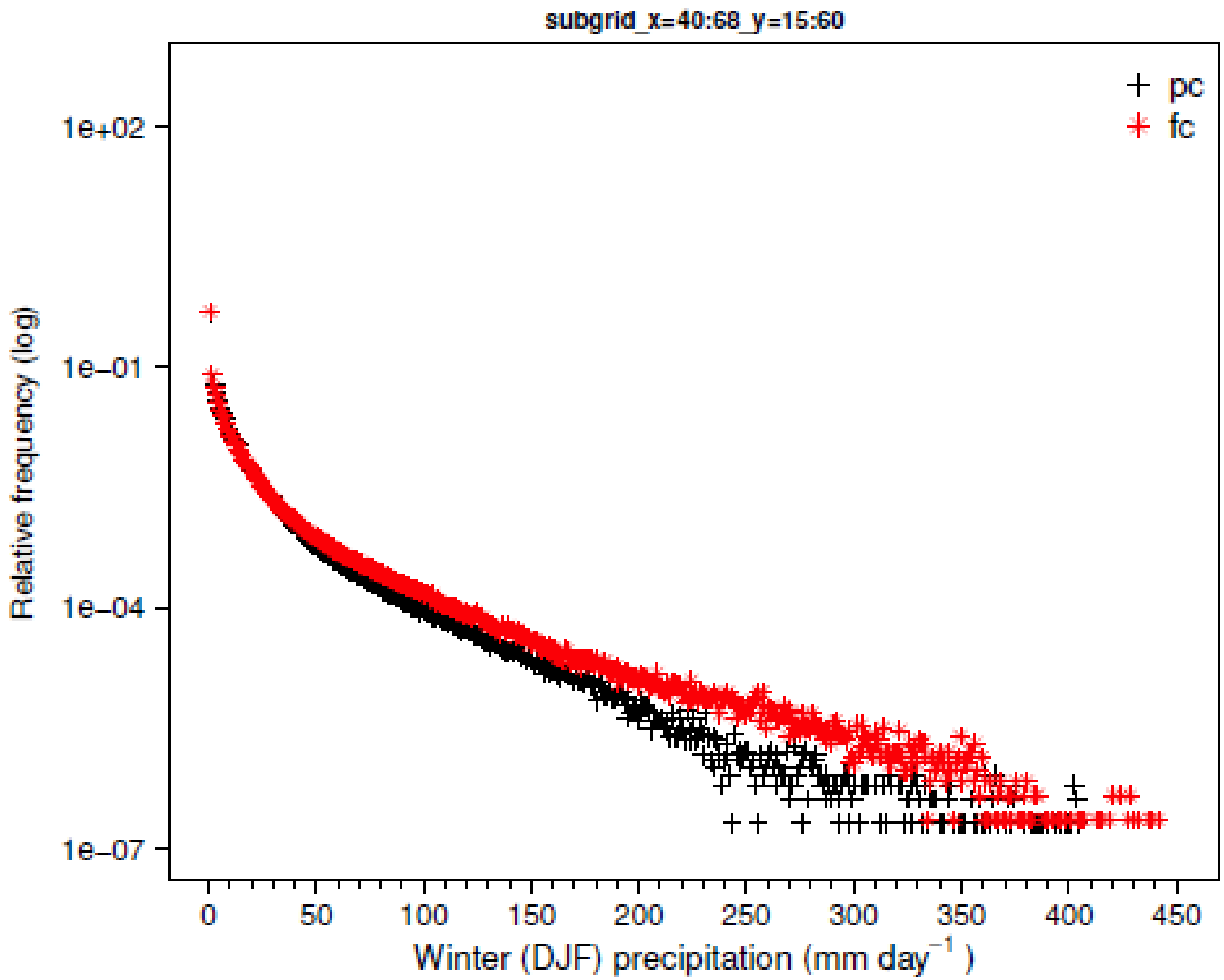


Microscale: downburst



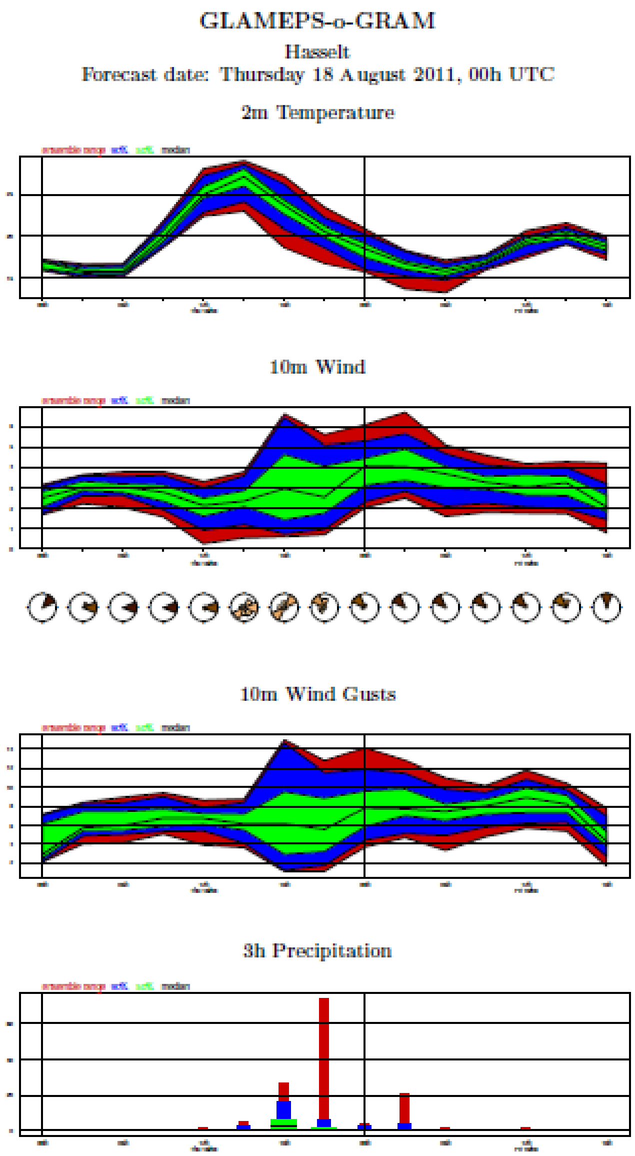
P. De Meutter, L. Gerard, G. Smet, P. Termonia

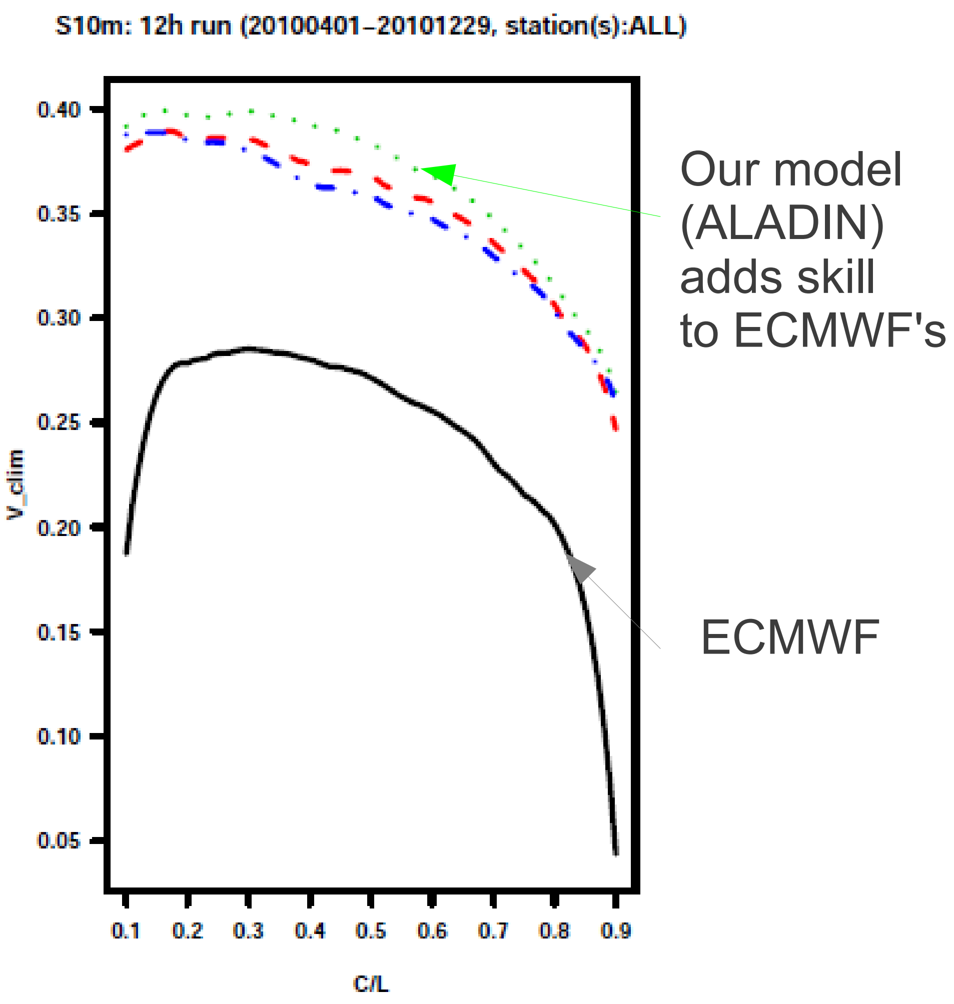
Change of precipitation between 1961-1990 and 2071-2100, driven by the A1B scenario for Belgium, computed by the ALARO model



R. De Troch, R. Hamdi, O. Giot, P. Termonia

Today we perturb the model runs to make probabilistic forecasts to make early warnings (ill. Pukkelpop run) and to increase their economic value (e.g. wind for energy production)





Smet, G., P. Termonia and A. Deckmyn, 2012: Added economic value of limited area multi-EPS weather forecasting applications *Tellus* , *A* , **64** , 18901

Synthesis

- The RMI was at the forefront of NWP from the end of the fifties to the middle of the seventies (with a logical extention into Laplace tranforms) due to the work of J. Van Isacker.
- This activity dispersed. Alledgedly ECMWF played a role in this [His model had to compete with a centre he himself advocated].
- NWP was relaunched after 1996 in Belgium, thanks to the efforts of Jean-François Geleyn.

A lesson for the future

- The exercise is to find a balance between the much needed internationalization and growing demands in terms of research capacity.
- The activities in the ALADIN consortium have proven so far, to provide a good middle ground (providing scientific innovations AND local applications)
- Key to this are, in my opinion, the two basic principles I mentioned, implemented by Jean-François Geleyn:
  - delocalized training and capacity building (not necessarily university specific);
  - algorithmic and numerical care to accomodate the “streams of research”.