From EMERAUDE/PERIDOT projects towards ARPEGE

Jean Coiffier

(Former Scientist at CRMD)

PLAN

- NWP context at Meteo-France around 1983
- The **EMERAUDE** spectral model for synoptic forecasts
- Quality control of the EMERAUDE model
- The **PERIDOT** fine mesh Limited Area Model
- Evolution of the PERIDOT Model (domain extension)
- Quality control of the PERIDOT Model
- Emerging ideas leading to **ARPEGE** and **ALADIN** projects
- From the stones to the harmony
- References

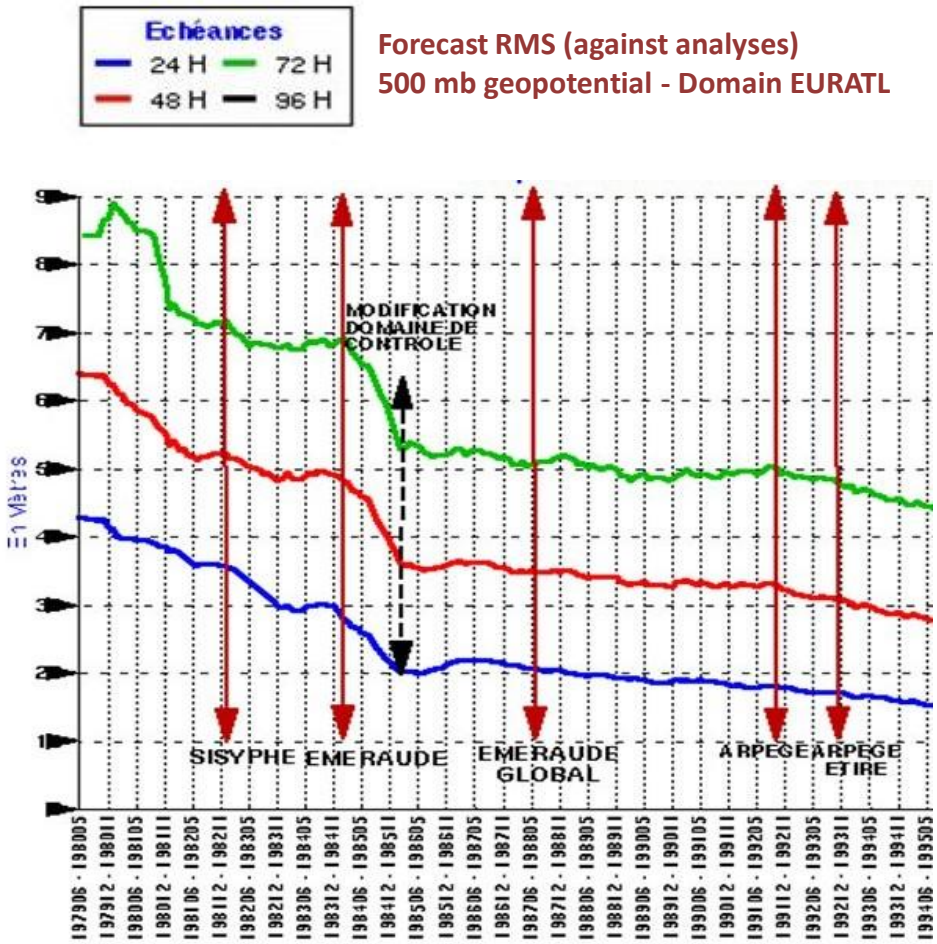
NWP context at Meteo-France around year 1983

- Lessons from AMETHYSTE and SISYPHE : Advantage to the spectral for synoptic scales in terms of accuracy and efficiency
- Availability of the Non Linear Normal Mode Initialization (NLNMI) : Allows to fully utilize wind data issued from the multivariate Optimum Interpolation SAPHIR (Système d'Analyse Presque Hémisphérique par Interpolation des Résidus).
- Availability of a new computer : The CRAY-1 at the CCVR.
- Beginning of testing EMERAUDE and PERIDOT models.
- Arrival of **Jean-François Geleyn** to the Dynamical Meteorology Research Centre (CRMD).

EMERAUDE - A spectral model for synoptic forecasts up to 3 or 4 days

- T79 spectral model (T79 # 150 km) – 15-level progressive hybrid vertical coordinate
- Domain : hémispherical and evolution towards global
- Semi implicit treatment (adaptation terms, vorticity and specific humidity by zonal wind)
- Vertical interpolation of increments (obs - guess).
- Non linear Normal Mode inititialization.
- Special treatment of the tropical belt for the hemispheric symmetrical version
- Comprehensive physical parameterizations (radiation, boundary layer and surface interactions, precipitation, convection).
- Zonal mean diagnostics

Quality control of the EMERAUDE forecasts



Forecast RMS (against analyses)
500 mb geopotential - Domain EURATL

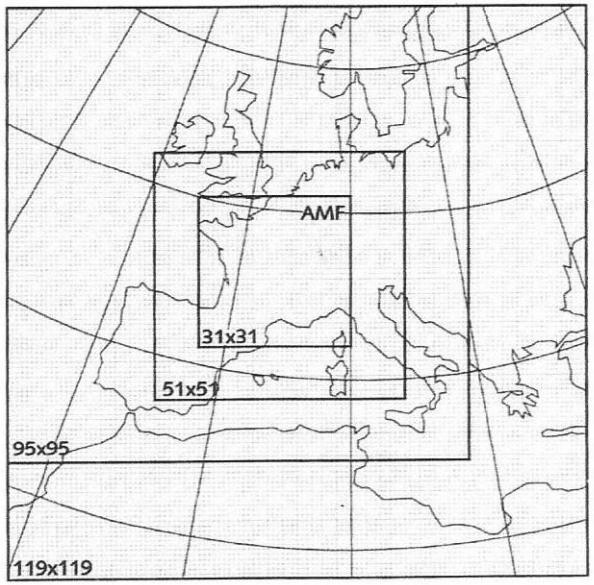
- 1984 - Testing the EMERAUDE model
- 1985 (January, 29) - EMERAUDE operational on the CRAY-1 at CCVR
- 1987 - Improvements : Taking into account the diurnal and semi-diurnal waves ; physical parameterizations
- 1987 (June) - The CRAY- 2 operational at CCVR
- 1988 (June, 29) - EMERAUDE becomes global (assimilation and model)
- 1992 (September, 29) - The unstretched ARPEGE model replaces EMERAUDE

PERIDOT (Prévision à Echéance Rapprochée Intégrant des Données Observées et Télédétectées)
A grid point limited area model over France using teledetected satellite data

- Fine mesh limited area model : staggered C-grid ; 35 km mesh size ; 15 levels
- Square domain centered over France, initially 1750 x 1750 km2
- Multivariate optimal interpolation taking into account radiances from the 19 channels of HIRS-2 and MSU of TOVS instrument aboard the NOAA satellites
- NLM Initialization over the limited area
- Continuous insertion of lateral boundary conditions from EMERAUDE outputs model every 6 hours
- Comprehensive physical parameterizations (radiation, boundary layer and surface interactions, precipitation, convection)

The successive PERIDOT developments

- 51 x 51 : Forecast area from February 1985 to June 1987
- 95 x 95 : Forecast area from June 1987 to February 1991
- 119 x 119 : Forecast area from February 1991 to October 1993



1984 - Tests and daily runs during 1984

1985 - (February, 23) the PERIDOT model becomes operational

1986 - Two runs a day (60 h at 00 UTC et 48 h at 12 UTC.

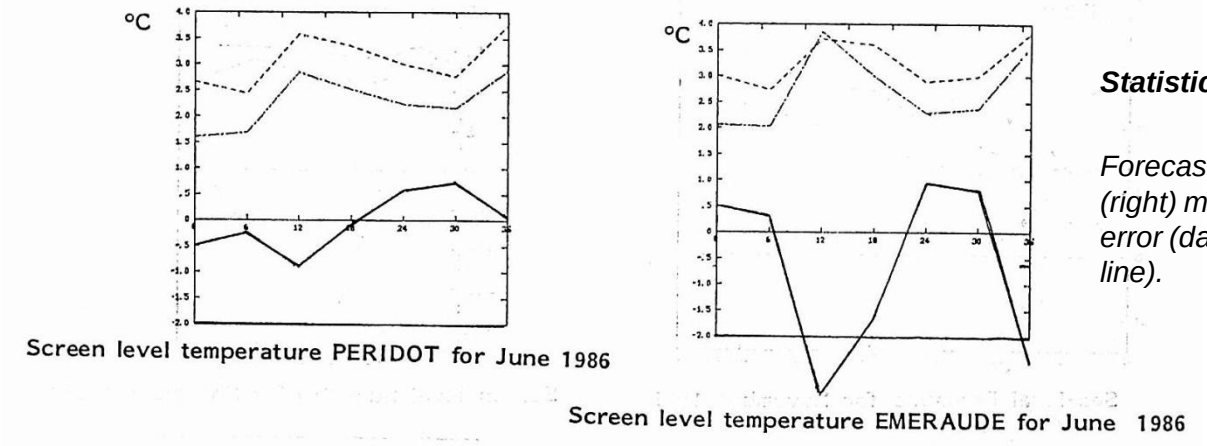
1990 - Portable PERIDOT.

1991 - Tests with 10 km mesh size (research) and 3,5 km (Super-Péridot)

1992 - Use of 3.5 km Super peridot over the Alps during Winter Albertville Olympic Games

1984-1992 – Use of Peridot in the framework of test field experiments (ALPEX, Fronts 84, PYREX)

Improvement with the PERIDOT model



Screen level temperature PERIDOT for June 1986

Screen level temperature EMERAUDE for June 1986

Statistics for the 2 m temperature , June 1986

Forecasts for fine mesh (left) and large scale (right) models. Bias (solid line), mean absolute error (dashed line), standard deviation (dotted line).

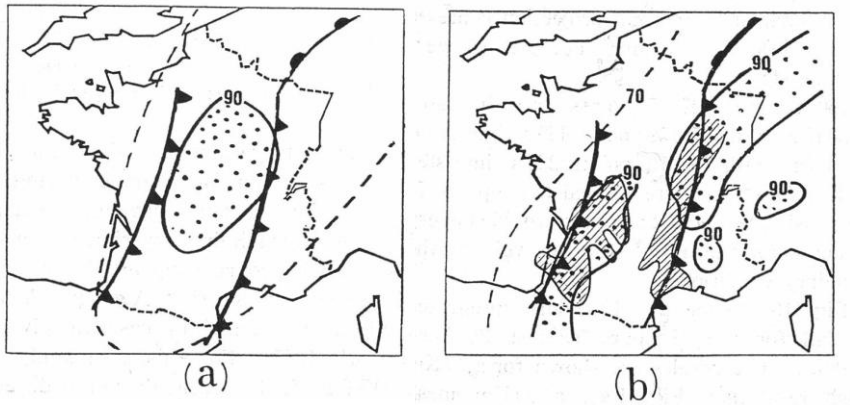
Forecasts on 7 October 1985

Large scale (a) - Fine mesh (b)

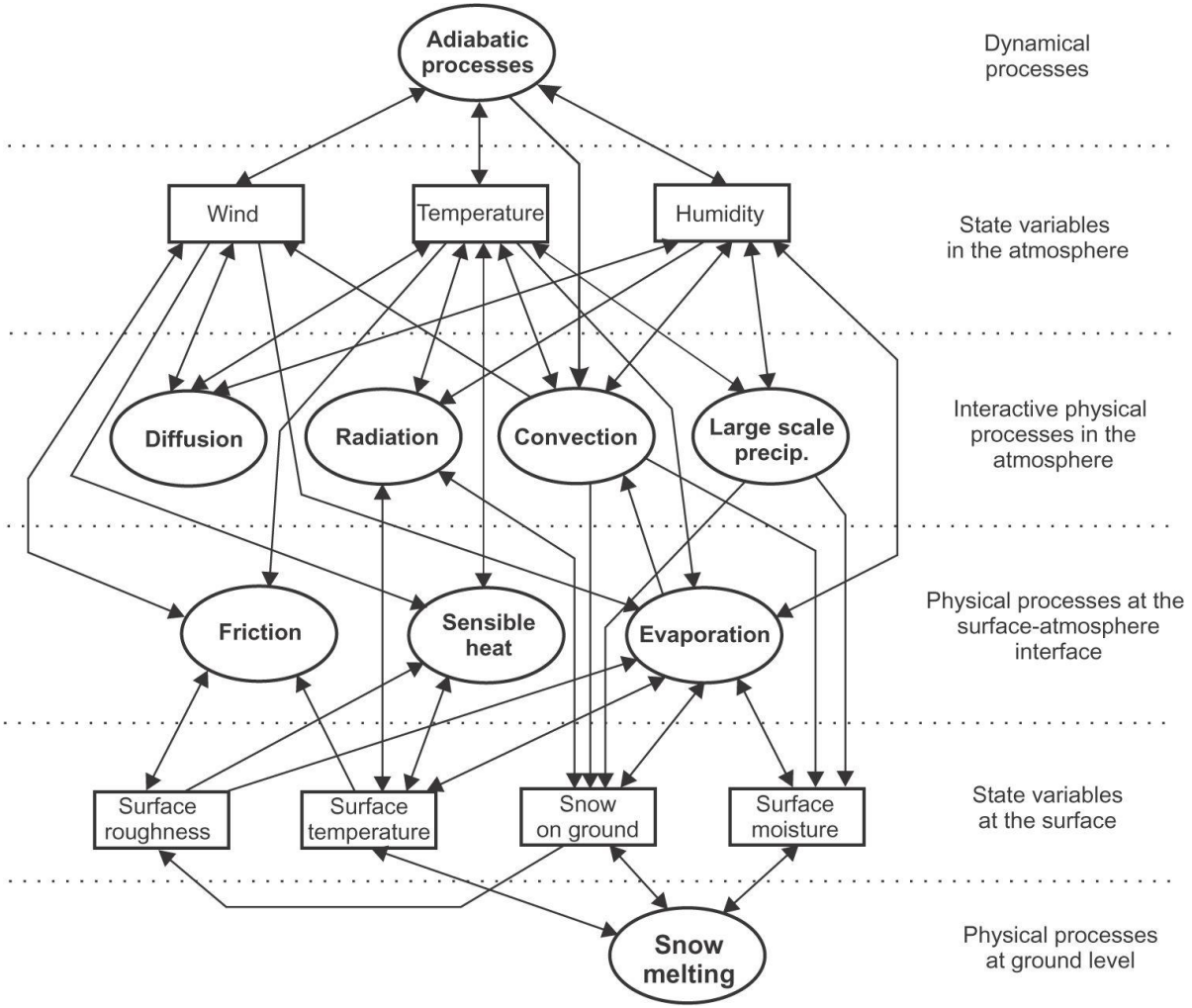
90% and above relative humidity (solid line and dotted area)

70% relative humidity (dashed line).

Radar rainfall observation (hatched area)



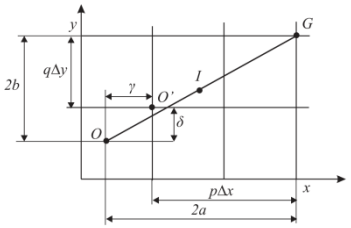
Simplified scheme showing the complexity of physical processes

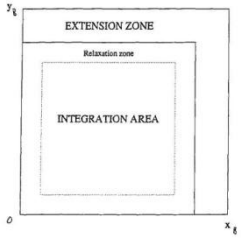


During its stay at CRMD, the work of Jean-François Geleyn has been essential in the design and improvement at various levels of the parameterization of the physical processes in the EMERAUDE and PERIDOT models.

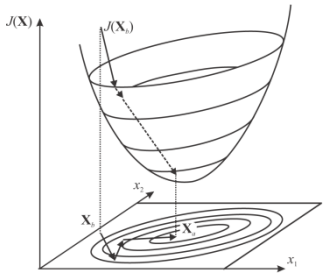
Emerging techniques in NWP

- Semi-Lagrangian treatment of the advection together with semi-implicit time integration (Robert, Yee and Ritchie, 1985)





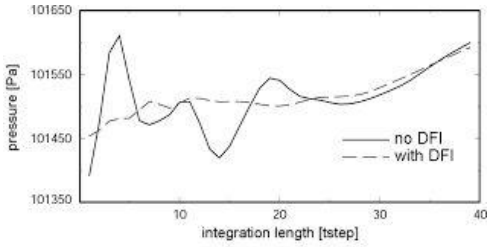
- Spectral method on limited area (Machenhauer and Haugen, 1987)



- Variational methods for analysis and data assimilation (Talagrand and Courtier, 1987)

- Variable mesh grid and spectral method as an alternative to coupled models (Geleyn and Courtier, 1988)

- Use of digital filters for initialization (Lynch and Huang, 1992)

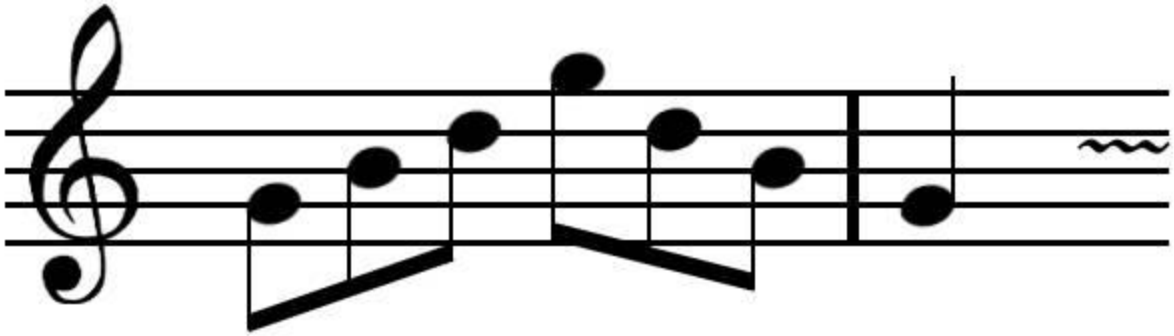


From variable mesh to ARPEGE

Large scale + Small Scale
Grande Échelle + Petite Échelle => GEPE ?

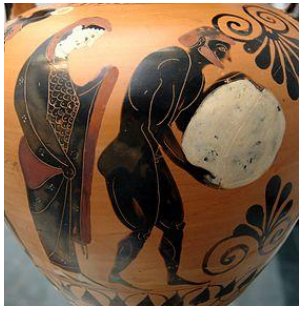
PEGE better ; by adding AR for « Action de Recherche » (Research action)

ARPEGE



From the Stones to the Harmony

Amethyste



Sisyphe

Emeraude

Peridot

Caillou (Peeble)

Météo-France is getting out the stone age

Thank you for your attention

Useful references - 1

- **EMERAUDE**

– Coiffier, J., Ernie, Y., Geleyn, J.-F., Clochard, J., Hoffman, J. and Dupont, F. (1987a). The operational hemispheric model at the French Meteorological Service. In: *Collection of Papers presented at the WMO/IUGG Symposium,* Tokyo, 4-6 Aug. 1986. Tokyo: Meteorological Society of Japan, 141-49.

– Ernie, Y., 1985: Experiments with the new french spectral model. Proceedings of the AMS Conference on Numerical Weather Prediction. Montreal. June 19 85, 486-489.

– Boulanger, M., et Coiffier, J. (1985) Détermination des modes normaux d'un modèle specral barocline en coordonnée verticale générale. Note de travail de l'EERM n° 114, février 1985.

Useful references - 2

- **PERIDOT**

– Imbard, M., Juvanon du Vachat, R., Joly, A., Durand, Y., Craplet, A., Geleyn, J.-F., Audoin, J.-M, Marie, N. and Pairin, J.-M. (1987). The PERIDOT fine-mesh numerical weather prediction system description, evaluation and experiments. In: *Collection of Papers presented at the WMO/IUGG Symposium.* Tokyo, 4-6 Aug. 1986. Tokyo: Meteorological Society of Japan, 141-49.

– Brière, S. (1982). Nonlinear normal mode initialization of a limited area model. *Mon. Wea. Rev.*, 110, 1166-88.

– Durand, Y., 1985: The use of satellite data in French high resolution analysis. *Workshop or. high resolution analysis*. ECMWF Reading UK. 89-127.

– Juvanon du Vachat, R. (1986). A general formulation of normal modes for limited-area models. Applications to initialization. *Mon. Wea. Rev.*, 114, 2478-87.

– Veyrier, Y. (1988). Prévision quantitative des précipitations. *La Houille Blanche* n° 5-6, 451-456

– Audoin, Rousseau, JdV, 1987 : Evaluation du modèle à maille fine Péridot. Comparaison avec le modèle Emeraude. *Note de travail EERM* N° 184.

Rousseau, D., Pham, H. L. and Juvanon du Vachat, R. (1995). Vingt-cinq ans de prévision numérique du temps à échelle fine (1968-1993). De l'adaptation dynamique à maille fine au modèle Péridot. *La Météorologie*, 8^{e} série, Special Issue, April 1995.

Useful references - 3

• EMERGING TECHNIQUES

– Robert, A., Yee T. L. and Ritchie, H. (1985). A semi-Lagrangian and semi-implicit numerical integration scheme for multilevel atmospheric models, *Mon. Wea. Rev.,* 113, 388-394.

– Machenhauer, B., and Haugen, J. E. (1987). Test of a spectral limited area shallow water model with time dependent lateral boundary conditions and combined normal mode semi-Lagrangian time integration schemes. In: *Proceedings of the ECMWF Workshop on Techniques for Horizontal Discretization in Numerical Prediction Models*, Reading, Nov. 1987. Reading: European Centre for Medium-range Weather Forecasts, 193-200.

– Talagrand, O. and Courtier, P. (1987). Variational assimilation of meteorological observations with the adjoint vorticity equation. I - Theory. *Quart. J. Roy. Meteor. Soc*., 113, 1311-28.

– Courtier, P. and Geleyn, J.-F. (1988). A global numerical weather prediction model with variable resolution : application to the shallow water equations. *Quart. J. Roy. Meteor. Soc*., 114, 1321-46.

– Lynch, P. and Huang, X.-Y. (1992). Initialization of the HIRLAM model using a digital filter. *Mon. Wea. Rev*., **120**, 1019-34.

– Courtier, P., Freydier, C., Geleyn, J.-F., Rabier, F., Rochas, M. (1991). The ARPEGE project at Météo-France. *Note de travail "Arpege"* n° 22, octobre 1991.