

# Staying report

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The main aim of this stay, within "Interoperability Project" was to collect, possibly further extend and maintain a documentary fund which should help any NWP developer from other European consortia to understand and use pieces of the software, or model output files.

The first draft of the prepared documentation is following.

# 1 Model fields description

Through "HISTORICAL" files or "ICMSH" (standing for **In-Core Model Spectral Hybrid**) one points out the main file of raw data used as interface between programs of the suite ARPEGE/ALADIN as input to run the forecasting model.

## FIELDS IN SPECTRAL COEFICIENTS

The proposed list of "dynamical" fields needed for an adiabatic moist model is the following :

- Surface geopotential : prefix 'SPECSURF', suffix 'GEOPOTENTIEL'; arbitrary level;
- Surface pressure : prefix 'SURF', suffix 'PRESSION'
- Other upper air fields : prefix 'S', the level is counted from 1 at the "top" of the atmosphere

Suffixe	Description	Unit	Observations
TEMPERATURE	temperature	$K$	
HUMI.SPECIFI	specific humidity	$kg/kg$	
FONC.COURANT	stream function	$m^2/s$	ARPEGE file
POT.VITESSE	velocity potential	$m^2/s$	ARPEGE file
WIND.U.PHYS	"U" component of wind	$m/s$	ALADIN file
WIND.V.PHYS	"V" component of wind	$m/s$	ALADIN file

## GRIDPOINT FIELDS

Regarding gridpoints, the historical files contains climatology fields, pseudo-historical fields and diagnostic fields as instantaneous or cumulated fluxes.

Prefix	Suffix	Description	Unit	Type
SURF	PRESSION	Surface pressure	$hPa$	his
SURF	TEMPERATURE	Ground surface temperature	$K$	his
PROF	TEMPERATURE	Deep soil temperature	$K$	his
SURF	RESERV.EAU	Surface water content	$kg/m^2$	his
PROF	RESERV.EAU	Deep soil water content	$kg/m^2$	his
SURF	RESERV.GLACE	Surface ice content	$kg/m^2$	his
PROF	RESERV.GLACE	Deep soil ice content	$kg/m^2$	his
SURF	RESERV.NEIGE	Surface snow amount	$kg/m^2$	his
SURF	RESERV.INTER	Interception content	$kg/m^2$	his
SURF	EMISSIVITE	Emissivity	-	pseudo
SURF	ALBEDO	Albedo	-	pseudo
SURF	ZO.FOIS.G	dynamical roughness length times g	$J/kg$	pseudo
SURF	RES.EVAPOTRA	Resistance to evapotranspiration	$kg/m^2$	pseudo
SURF	ET.GEOPOTENT	Standard deviation	$J/kg$	clim
SURF	IND.TERREMER	Land-sea mask	-	clim
SURF	PROP.VEGETAT	Proportion of vegetation	-	clim
SPECSURF	GEOPOTEN	Surface geopotential	$J/kg$	clim
SURF	VAR.GEOP.ANI	Anisotropy of sub-scale orography	-	clim
SURF	VAR.GEOP.DIR	Angle between the direction of orography and the x-axis	$rd$	clim
SURF	IND.VEG.DOMI	Index of vegetation	-	clim
SURF	RESI.STO.MIN	Stomatal minimal resistance	$s/m$	clim
SURF	PROP.ARGILE	Proportion of clay	-	clim
SURF	PROP.SABLE	Proportion of sand	-	clim
SURF	EPAIS.SOL	Soil depth	m	clim
SURF	IND.FOLIAIRE	Leaf area index	$m^2/m^2$	clim
SURF	GZO.THERM	Thermal roughness length times g	$J/kg$	clim
SURF	PREC.EAU.CON	Convective rain	$kg/m^2$	cfu
SURF	PREC.EAU.GEC	Stratiform rain	$kg/m^2$	cfu
SURF	PREC.NEI.CON	Convective snow	$kg/m^2$	cfu
SURF	PREC.NEI.GEC	Stratiform snow	$kg/m^2$	cfu
SURF	FLU.RAY.THER	Net IR surface radiation flux	$J/m^2$	cfu
SOMM	FLU.RAY.THER	Net IR top surface radiation flux	$J/m^2$	cfu
SURF	FLU.RAY.SOLA	Net VIS surface radiation flux	$J/m^2$	cfu
SOMM	FLU.RAY.SOLA	Net VIS top surface radiation flux	$J/m^2$	cfu
SURF	FLU.MEVAP.EA	Water evaporation flux	$kg/m^2$	cfu

SURF	FLU.MSUBL.NE		$kg/m^2$	cfu
SURF	FLU.CHA.SENS	Latent heat flux	$J/m^2$	cfu
SURF	FLU.LAT.MSUB	Water evaporation latent heat	$J/m^2$	cfu
SURF	RAYT.LUNE.DE	Net radiative flux surface Moon	$J/m^2$	cfu
SURF	TIME.PREC.TO	Duration of total precipitation	$s$	cfu
SURF	TENS.TURB.ZO	Zonal component of turbulent stress	$kg/m^2$	cfu
SURF	TENS.TURB.ME	Meridian component of turbulent stress	$kg/m^2$	cfu
SURF	TENS.DMOG.ZO	Zonal gravity wave stress	$kg/m^2$	cfu
SURF	TENS.DMOG.ME	Meridian gravity wave stress	$kg/m^2$	cfu
ATMO	NEBUL.BASSE	Low cloud cover	$s$	cfu
ATMO	NEBUL.CONVEC	Convective cloud cover	$s$	cfu
ATMO	NEBUL.HAUTE	High cloud cover	$s$	cfu
ATMO	NEBUL.MOYENN	Medium hight cloud cover	$s$	cfu
PROF	FLUX DE GEL	Deep freezing flux	$kg/m^2$	cfu
PROF	RUISSELLEMEN	Deep soil runoff	$kg/m^2$	cfu
SURF	CFU.CT.TURBU		$J/m^2$	cfu
SURF	CFU.Q.TURBUL		$J/m^2$	cfu
SURF	CHAL.DS.SOL	Heat flux in soil	$J/m^2$	cfu
SURF	EAU DANS SOL		$kg/m^2$	cfu
SURF	EVAPOTRANSPI	Evapotranspiration flux	$kg/m^2$	cfu
SURF	FLUX DE GEL		$kg/m^2$	cfu
SURF	FONTE NEIGE		$kg/m^2$	cfu
SURF	RUISS.INTER	Interception soil layer runoff	$kg/m^2$	cfu
SURF	RUISSELLEMEN	Surface soil runoff	$kg/m^2$	cfu
SURF	TRANSPIRATIO	Transpiration flux	$kg/m^2$	cfu
SURF	NEBUL.TOTALE	Total cloud cover	-	xfu
SURF	NEBUL.CONVEC	Convective cloud cover	-	xfu
SURF	NEBUL.HAUTE	High cloud cover	-	xfu
SURF	NEBUL.MOYENN	Medium hight cloud cover	-	xfu
SURF	NEBUL.BASSE	Low cloud cover	-	xfu
CLS	VENT.ZONAL	10 metre U wind component	$m/s$	xfu
CLS	VENT.MERIDIEN	10 metre V wind component	$m/s$	xfu
CLS	U.RAF.MOD.XFU		$m/s$	xfu
CLS	V.RAF.MOD.XFU		$m/s$	xfu
CLS	TEMPERATURE	2 metre Temperature	$K$	xfu
CLS	HUMI.SPECIFIQ	2 metre Specific humidity	$kg/kg$	xfu
CLS	HUMI.RELATIVE	2 metre Relative humidity	-	xfu
CLS	MINI.TEMPERAT	2 metre minimum temperature	$K$	xfu
CLS	MAXI.TEMPERAT	2 metre maximum temperature	$K$	xfu
CLS	MINI.HUMI.REL		-	xfu
CLS	MAXI.HUMI.REL		-	xfu
CLP	MIHAUT.MOD.XFU		$m$	xfu
CLP	MOCON.MOD.XFU	Humidity convergence	$s^{-1}$	xfu

SURF	CAPE.MOD.XFU	CAPE	$J/kg$	xfu
SURF	XCHAL.DS.SO	Soil heat flux	$W/m^2$	xfu
SURF	XEAU.DANS SO	Water flux in soil	$kg/m^2 * s$	xfu
SURF	XEVAPOTRANSP	Evapotranspiration flux	$kg/m^2 * s$	xfu
SURF	XFLU.MEVAP.E		$kg/m^2 * s$	xfu
SURF	XFONTE NEIGE		$kg/m^2 * s$	xfu
SURF	XRUISS.INTE	interception soil layer runoff	$kg/m^2$	xfu
SURF	XRUISELLEME	Surface soil runoff	$kg/m^2 * s$	xfu
SURF	XTRANSPIRATI	Transpiration	$kg/m^2 * s$	xfu
PROF	XRUISELLEME	Deep soil runoff	$kg/m^2 * s$	xfu

## 1.1 Grid representation for the global model ARPEGE

### 1.1.1 Transformation from spectral to grid point space for a scalar field or a set of scalar fields

Transformation from spectral to grid point space needs:

- An inverse Legendre transform, for each zonal wave number  $m$ . The following quantity  $F_m(\mu)$  is computed for each latitude  $\Theta$ :

$$F_m(\mu) = \sum_{n=|m|}^{n=N_s} f(n, m) P(n, m)(\mu) \quad (1)$$

One transforms real fields, so  $F_m(\mu) = \overline{F_m(\mu)}$  and only  $F_m(\mu)$  for  $m \geq 0$

- An inverse Fourier transform, for each latitude  $\Theta$ :

$$f(\Lambda, \Theta) = \sum_{m=-N(\Theta)}^{m=N(\Theta)} F_m(\mu) \exp(im\Lambda) \quad (2)$$

One transforms real fields, so :

$$f(\Lambda, \Theta) = F_0(\mu) + 2 \sum_{m=1}^{m=N(\Theta)} [R(F_m(\mu)) \cos m\Lambda - L(F_m(\mu)) \sin(m\Lambda)] \quad (3)$$

$F_0(\mu)$  is the average of  $f$  on latitude  $\Theta$  and is real;  $N(\theta)$  is not always equal to  $N_s$  (due to the use of a reduced Gaussian grid). For latitude  $\Theta$  one obtains  $nlon(\Theta)$  grid-point values.

### 1.1.2 Transformation from grid point to spectral space

Transformation from grid point to spectral space needs:

- A direct Fourier transform, for each latitude  $\Theta$ :

$$F_m(\mu) = \frac{1}{nlon(\Theta)} \sum_{jlon=1}^{jlon=nlon(\Theta)} f(\Lambda(jlon), \Theta) \exp(-im\Lambda(jlon)) \quad (4)$$

One transforms real fields, so formula (4) becomes for non-zero  $m$ :

$$R(F_m(\mu)) = \frac{1}{nlon(\Theta)} \sum_{jlon=1}^{jlon=nlon(\Theta)} f(\Lambda(jlon), \Theta) \cos m\Lambda(jlon) \quad (5)$$

$$L(F_m(\mu)) = \frac{-1}{nlon(\Theta)} \sum_{jlon=1}^{jlon=nlon(\Theta)} f(\Lambda(jlon), \Theta) \sin m\Lambda(jlon) \quad (6)$$

Spectral expression of  $f_{sym}$  (resp.  $f_{ant}$ ) include all coefficients with even (resp. odd) value of  $m + n$ . Legendre transforms are done on  $f_{sym}$  and  $f_{ant}$  and scalar products defined by equations (1) and (9) can reduce to latitudes  $lat1$  and  $ndgnh$ .

### 1.1.3 Relationship between dimension of spectral space and grid point space for Gaussian grid

#### Quadratic grid, linear grid:

Spectral space is defined by a triangular truncation  $N_s$ . Grid point space has  $ndglg$  latitudes and a maximum number of longitudes equal to  $ndlon$ .  $ndlon$  and  $ndglg$  are always even integers: if  $ndlon$  is a multiple of 4,  $ndglg = ndlon/2$ ; if  $ndlon$  is not multiple of 4,  $ndglg = ndlon/2 + 1$ . For a quadratic Gaussian grid, there is a relationship between these parameters to avoid aliasing on quadratic terms.

- If the stretching coefficient  $c$  is equal to 1 (no stretching),  $N_s$  is the biggest integer which verify the relationship  $3 * N_s \leq (ndlon - 1)$ .
- If the stretching coefficient  $c$  is bigger than 1 (stretching),  $N_s$  is the biggest integer which verify the relationship  $3 * N_s \leq \min(2 * ndglg - 3, ndlon - 1)$ .

In a semi-Lagrangian scheme the advective quadratic terms disappear, so it is possible to use a smaller grid-point space: a linear grid. The most frequently linear grids used are the semi-linear 2.5 grid characterized by:

- If the stretching coefficient  $c$  is equal to 1 (no stretching),  $N_s$  is the biggest integer which verify the relationship  $2.5 * N_s \leq (ndlon - 1)$ .
- If the stretching coefficient  $c$  is bigger than 1 (stretching),  $N_s$  is the biggest integer which verify the relationship  $2.5 * N_s \leq \min(2 * ndglg - 3, ndlon - 1)$ .

and the linear 2.0 grid characterized by:

- If the stretching coefficient  $c$  is equal to 1 (no stretching),  $N_s$  is the biggest integer which verify the relationship  $2 * N_s \leq (ndlon - 1)$ .
- If the stretching coefficient  $c$  is bigger than 1 (stretching),  $N_s$  is the biggest integer which verify the relationship  $2 * N_s \leq \min(2 * ndglg - 3, ndlon - 1)$ .

#### Admissible dimensions:

Currently the codes of FFT (fast Fourier transforms) used allows to use integers  $ndlon$  which can write as  $2^{1+p_2} * 3^{p_3} * 5^{p_5}$ . That limits the possibility of choosing the dimensions in a discontinuous subset of truncations and dimensions for Gaussian grid.

## 2 Grid representation for LAM

### 2.1 Spectral space

We always have to bear in mind two things:

- Choice of the basic functions of the spectral representation, which is *bi-Fourier*  $(Re, Im) \cdot (Re, Im)$  in ALADIN and *spherical harmonics*  $(Re, Im)_{\text{zonal}} + L$  in ARPEGE/IFS.
- Choice of the truncation: a *triangular* one (fig. 1a) in ARPEGE/IFS with 2 real numbers defining a component and an *elliptical* one (fig. 1b) in ALADIN with 4 real numbers defining a component plus the mean wind (the 0-th component in a series), which does not exist on a sphere.

### 2.2 Grid-point space

Differences are:

1. Existence of lateral boundaries.
2. Necessity of the extension zone for biperiodizing the fields (see fig. 2).

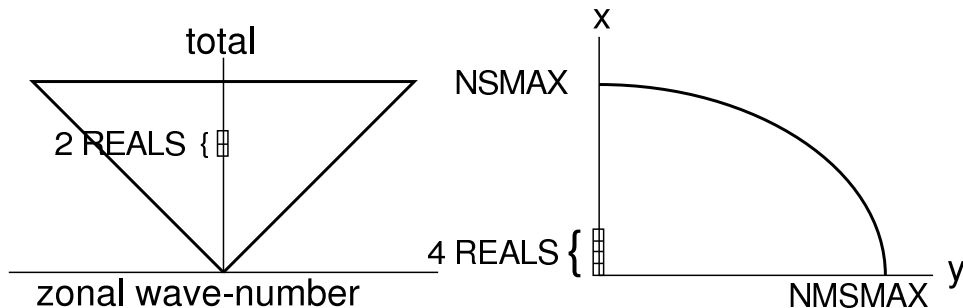


Figure 1: Schematic representation of a triangular (left) and elliptical truncation (right).

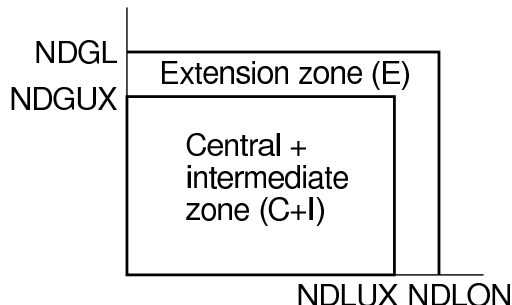


Figure 2: Schematic representation of the extension zone in ALADIN, and a few important definitions.

## 2.3 Linear grid and quadratic grid; the resolution

The difference between linear and quadratic grids lies in the number of spectral components retained in the bi-Fourier decomposition, in order to represent the physical fields, *for a given gridpoint lattice*. Consider a NDGLG regular grid, the linear grid will contain the exact number of spectral components to fully describe the original field once in spectral:

$$\text{NDGLG} = (\text{NSMAX} + 1) * 2$$

the \*2 comes from the real and imaginary parts of any spectral component, and the +1 takes into account the mean value, whose imaginary part is zero (think about the classical Fourier serie:

$$f(Y_j) = A_0 + \sum A_m \cos 2\pi m Y_j / L + B_m \sin 2\pi m Y_j / L$$

with  $\sum$  ranging from -NSMAX to +NSMAX, without the 0. A similar formula relates NDLON and NMSMAX in the X direction.

Note that the bijectivity of gridpoint and bi-Fourier fields only is guaranteed when a rectangular truncation is chosen. In an elliptic truncation, the loss of the upper-corner coefficients results in a loss of a bit of the spectral energy, especially at small scales. This phenomenon is generally called *spectral fit* (implicit to the elliptic truncation). Note furthermore that the elliptic truncation ensures isotropy, in the sense that the same number of coefficients is active in any spatial direction. However, the exact number of degrees of freedom (NDF) for the gridpoint field only is retained for a rectangular truncation. This NDF corresponds to  $2 * (\text{NSMAX}) + 1$ , the number of independent Fourier components. In gridpoint space, the NDF would be NDGLG-1, where the -1 indicates that one corner point is set once all other points are known. The quadratic grid has been long used in ALADIN in order to reduce spurious aliasing problems generated by non-linear terms in the dynamics equations. Typically, advection in the Eulerian model and the map-factor gradient terms in SL are potential sources of aliasing (also known as *spectrum backfolding*). A rude trick to avoid aliasing then consists in simply removing the trailing part of the Fourier decomposition, every time a direct transform is performed, and to ignore that part of the spectrum in spectral space computations as well. In ALADIN, the last third of the spectrum is taken away, leading to the following formula:

$$\text{NDGLG} = (\text{NSMAX} + 1) * 3$$

note here that the spectral fit is obviously stronger in the quadratic grid, and of course present

whatever truncation is chosen (rectangular or elliptic).

The *resolution* of any grid should be expressed as the mere gridpoint mesh  $\delta X$ . A *spectral resolution* does not have any specific meaning, though sometimes used simply to refer to NSMAX or the NDF. This is however improper, as the only reliable definition is to state that  $\delta X = (\text{NDGLG}-1)/L$  is the mesh size of a regular lattice of total length  $L$ .

## 2.4 The $\eta$ vertical coordinate in ARPEGE/IFS and ALADIN

The vertical representation of the meteorological fields has been made through the vertical hybrid coordinate, proceeding from the pressure as it was defined by Simmons and Burridge. Its main characteristic is that at the basis of the model it eyes the orography, but at its pick it becomes a pressure type coordinate. The vertical coordinate is inferentially defined by the following relation:

$$\Pi = A(\eta) + B(\eta)\Pi_s$$

The equation is available for the intermediate levels, but the pressure at the levels of the model can be counted from the values at the intermediate level.

The coefficients  $A$  and  $B$  only depend on  $\eta$ . This coordinate together with the vertical digitization chosen in an appropriate way provides for the conservation of the energy and the angular moment of the system. The model is vertically digitized in  $L$  layers. The scheme of the vertical digitization is based on a vertical crossed grid. The following conditions are fulfilled:

- $\eta = 1$  at the surface;
- $\eta = 0$  at the top of the model;
- $A(\eta = 1) = 0$  and  $B(\eta = 1) = 1$  at the surface;
- $A(\eta = 0) = \Pi_{top}$  and  $B(\eta = 1) = 0$  at the top of the model.

$A$  and  $B$  are given at half levels, so:

$$\Pi_{\bar{\eta}} = A_{\bar{\eta}} + B_{\bar{\eta}}$$

## 3 The content of the GRIB files

The **GRIB2** files content:

- output fields postprocessed in a regular geographical grid and pressure levels:
  - the global model ARPEGE over the domain EURO25;
  - ALADIN on domain FRANX01 (204 fields)
- input fields:
  - the analyse fields from the global model ARPEGE
  - the coupling fields for ALADIN on domain FRAN (278 fields)

Here after is the list of the fields on the domains EURO25 and FRANX01:

- Skin Temperature (K)
- Bottom layer soil temperature (K)
- Snow depth water equivalent (kg m-2)
- Convective precipitation rate (kg m-2 s-1)
- Convective snowfall rate water equivalent (kg m-2 s-1)
- Large scale precipitation rate (kg m-2 s-1)
- Convective snowfall rate (m s-1)
- Upward short-wave radiation flux (W m-2); nominal top of the atmosphere
- Upward short-wave radiation flux (W m-2); ground or water surface



- Net long wave radiation flux ( $\text{W m}^{-2}$ ); nominal top of the atmosphere
- Net long wave radiation flux ( $\text{W m}^{-2}$ ); ground or water surface
- Latent heat net flux ( $\text{W m}^{-2}$ )
- Evaporation ( $\text{kg m}^{-2}$ )
- Sensible heat net flux ( $\text{W m}^{-2}$ )
- Total cloud cover
- Convective cloud cover
- High cloud cover
- Medium cloud cover
- Low cloud cover
- Convective available potential energy ( $\text{J kg}^{-1}$ )
- Horizontal moisture convergence ( $\text{kg kg}^{-1} \text{ s}^{-1}$ )
- Planetary boundary layer height (m)
- u-component of wind ( $\text{m s}^{-1}$ ) on Pressure level 10,20,30,50,70,100,150,200,250, 300,400,500,600,700, 800,850,900,925,950,1000
- v-component of wind ( $\text{m s}^{-1}$ ) on Pressure level 10,20,30,50,70,100,150,200,250,300,400,500,600,700,800, 850,900,925,950,1000
- v-component of wind ( $\text{m s}^{-1}$ ) on Pressure level 10,20,30,50,70,100,150,200,250,300,400,500,600,700,800, 850,900,925,950,1000
- Geopotential height (gpm) on Pressure level 10,20,30,50,70,100,150,200,250,300,400,500,600,700,800, 850,900,925,950,1000
- Relative humidity on Pressure level 10,20,30,50,70,100,150,200,250,300,400,500,600,700,800, 850,900,925,950,1000
- Pseudo-adiabatic potential temperature or equivalent potential temperature (K) on Pressure level 200,250,300,400,500,600,700,800,850,900,925,950,1000
- Potential vorticity ( $\text{K m}^2 \text{ kg}^{-1} \text{ s}^{-1}$ ) on Pressure level 50,70,100,150,200,250,300,400,500,600,700,800,850, 900,925,950,1000
- Vertical velocity [pressure] ( $\text{Pa s}^{-1}$ ) on Pressure level 10,20,30,50,70,100,150,200,250,300,400,500,600,700,800, 850,900,925,950,1000
- Absolute vorticity ( $\text{s}^{-1}$ ) on Pressure level 50,70,100,150,200,250,300,400,500,600,700,800,850, 900,925,950,1000
- Relative divergence ( $\text{s}^{-1}$ ) on Pressure level 300,950
- MSL Pressure (Pa)
- TCW Total column water ( $\text{kg m}^{-2}$ )
- Surface Pressure (Pa)
- Geometric height (m) on Isothermal level t 263.15
- Geometric height (m) on Isothermal level theta'w 273.15
- 10 u-component of wind ( $\text{m s}^{-1}$ )
- 10 v-component of wind ( $\text{m s}^{-1}$ )
- 2T Temperature (K)
- SM Soil moisture ( $\text{kg m}^{-3}$ )
- MX2T6Temperature (K)
- MN2T6 Temperature (K)

- u-component of wind (gust)
- v-component of wind (gust)
- u-component of wind (m s-1) on Potential vorticity surface 1500,2000
- v-component of wind (m s-1) on Potential vorticity surface 1500, 2000
- Geopotential height (gpm) on Potential vorticity surface 1500, 2000
- Potential temperature (K) on Potential vorticity surface 1500, 2000
- Absolute vorticity (s-1) on Potential vorticity surface 1500, 2000

For more details see:

<http://www.wmo.int/pages/prog/www/WMOCodes/Operational/GRIB2/FM92-GRIB2-2008Oct.pdf>  
<http://www.wmo.int/pages/prog/www/WMOCodes/GRIB.html>

## 4 Geometry

### 4.1 Global Gaussian (ARPEGE)

Schmidt proposed a clean solution to define a global variable mesh model with local isotropic interactions. One defines a transformation from the earth to another sphere and discretizes the equations on that sphere. If the transformation is conformal (angle-preserving) then local interactions are effectively isotropic. He proposed a transformation which gives an area of concentration, and one of dilation at the antipode.

To obtain a variation of resolution on Earth, we effectuate the next transformations:

$(\lambda, \theta)$  are the the geographical coordinates of a point

#### Changing the coordinates

Geleyn has established the passing formula between one representation to another. There are two simple transformations.

#### Changing the coordinates of the pole

$(\lambda', \theta')$  are the spherical coordinates

$(\lambda_p, \theta_p)$  are the pole coordinates

$$\cos \theta' \cos \lambda' = \cos \theta_p \sin \theta - \sin \theta_p \cos \theta \cos(\lambda - \lambda_p) \quad (7)$$

$$\cos \theta' \sin \lambda' = -\cos \theta \sin(\lambda - \lambda_p) \quad (8)$$

$$\sin \theta' = \sin \theta_p \sin \theta + \cos \theta_p \cos \theta \cos(\lambda - \lambda_p) \quad (9)$$

The inverse transformation is:

$$\cos \theta \cos(\lambda - \lambda_p) = \cos \theta_p \sin \theta' - \sin \theta_p \cos \theta' \cos \lambda' \quad (10)$$

$$\cos \theta \sin(\lambda - \lambda_p) = -\cos \theta' \sin \lambda' \quad (11)$$

$$\sin \theta = \sin \theta_p \sin \theta' + \cos \theta_p \cos \theta' \cos \lambda' \quad (12)$$

#### The conformal transformation

It is defined by

$$\Lambda = \lambda' \quad (13)$$

$$\sin \Theta = \frac{(1 - c^2) + (1 + c^2) \sin \theta'}{(1 + c^2) + (1 - c^2) \sin \theta'} \quad (14)$$

$$\cos \Theta = \frac{2c \cos \theta'}{(1 + c^2) + (1 - c^2) \sin \theta'} \quad (15)$$

and inverse is:

$$\lambda' = \Lambda \quad (16)$$

$$\sin \theta' = \frac{-(1 - c^2) + (1 + c^2) \sin \Theta}{(1 + c^2) - (1 - c^2) \sin \Theta} \quad (17)$$

$$\cos \theta' = \frac{2c \cos \Theta}{(1 + c^2) - (1 - c^2) \sin \Theta} \quad (18)$$

### The direct transformation

The coordinates on the transformed sphere:

$$\sin \Theta = \frac{(1 - c^2) + (1 + c^2)(\sin \theta_p \sin \theta + \cos \theta_p \cos \theta \cos(\lambda - \lambda_p))}{A} \quad (19)$$

$$\cos \Theta \cos \Lambda = \frac{2c(\sin \theta \cos \theta_p - \cos \theta \sin \theta_p \cos(\lambda - \lambda_p))}{A} \quad (20)$$

$$\cos \Theta \sin \Lambda = \frac{-2c \cos \theta \sin(\lambda - \lambda_p)}{A} \quad (21)$$

with

$$A = (1 + c^2) + (1 - c^2)(\sin \theta_p \sin \theta + \cos \theta_p \cos \theta \cos(\lambda - \lambda_p)) \quad (22)$$

because  $c \neq 1$  the first formula is simplified by

$$\sin \Theta = \frac{(1 + c^2)A - 4c^2}{(1 - c^2)A} \quad (23)$$

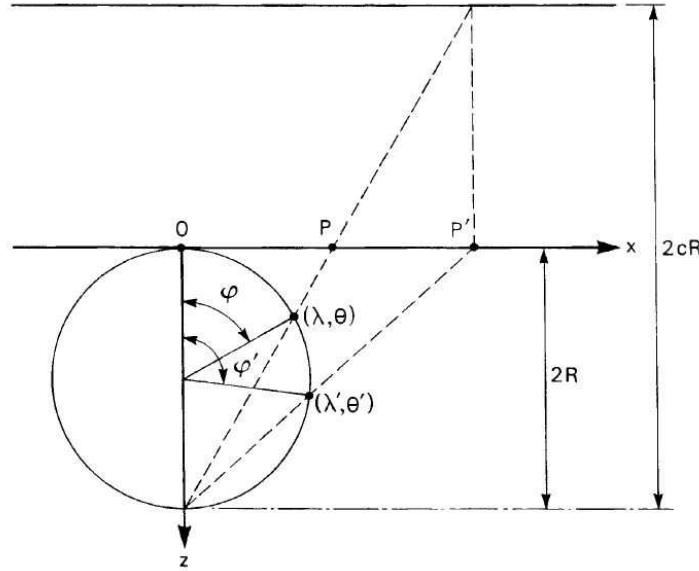


Figure 3: The transformation associated with a magnification in the complex plane (from Courtier and Geleyn)

### 4.1.1 TRACARE

Subroutine TRACARE computes geographical coordinates once given the computational sphere coordinates.

## 4.2 Geometry and projection for LAM

### 4.2.1 Projections

The ALADIN domain is defined by 2 types of parameters:

- geographical projection data - this part is defined by EGGPACK (the possibility of a tilting was not implemented in the old EGGX for the Mercator projection) library routines;
- computation array definitions

When going from the sphere to the plane projection (or from sphere to pseudo-sphere in the case of the stretched ARPEGE geometry) we introduce as map factor  $m$  locally defined by ratio mesh size in the projection mesh divided by size on the real sphere.

The model needs two-dimensional array divided in 3 regions: C zone - central zone;  
I zone - intermediate zone (by default - 8 points)  
E zone - extension zone (mathematical zone -to create the bi-periodicity of the model)

The extension zone is an artificial zone who has not meteorological information (this is the reason that this zone must be minimized-by default -11 points).

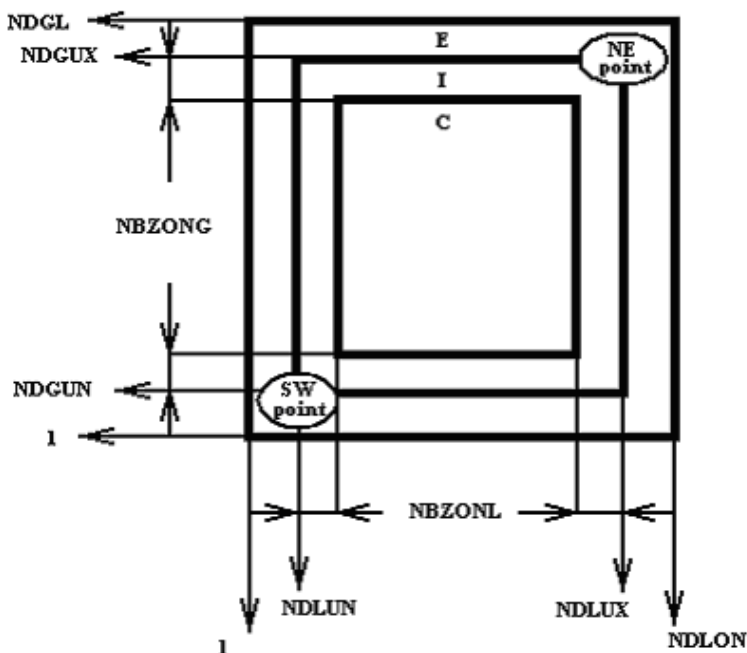


Figure 4: ALADIN domain schematic representation

NDLON - the maximum number of longitudes  
NDGL - the number of latitudes

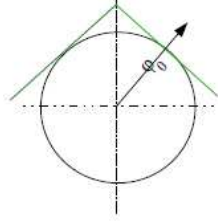
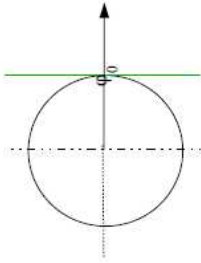
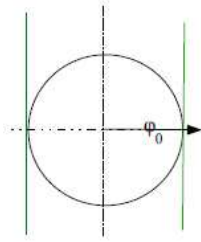
Lambert Coformal Conic	
	$Kl = Pole \cdot \sin(\varphi_0)$
Polar Stereographic	
	$Kl = 1$
Mercator	
	$Kl = 0$

Figure 5: LAM projections

Lambert Coformal Conic	Polar Stereographic	Mercator
$Kl = Pole \cdot \sin(\varphi_0)$	$Kl = Pole \cdot \sin(\varphi_0) = 1$ $\varphi_0 = \pm \frac{\pi}{2}$	$Kl = \sin(\varphi_0) = 0$ $\varphi_0 = 0$
$R_{\varphi_0} = \frac{R_T \cdot \cos(\varphi_0)^{(1-Kl)}}{Kl} \cdot (1+Kl)^{Kl}$	$R_{\varphi_0} = 2 \cdot R_T$	
$R_\varphi = R_{\varphi_0} \cdot \left[ \frac{\cos(\varphi)}{1 + Pole \cdot \sin(\varphi)} \right]^{Kl}$ $\Theta_\lambda = Kl \cdot (\lambda - \lambda_0)$	$R_\varphi = R_{\varphi_0} \cdot \left[ \frac{\cos(\varphi)}{1 + Pole \cdot \sin(\varphi)} \right]$ $\Theta_\lambda = (\lambda - \lambda_0)$	
$x = R_\varphi \cdot \sin(\Theta_\lambda)$ $y = -Pole \cdot R_\varphi \cdot \cos(\Theta_\lambda)$		$x = R_T \cdot (\lambda - \lambda_0)$ $y = -R_T \cdot \ln \left[ \tan \left( \frac{\pi}{4} + \frac{\varphi}{2} \right) \right]$
$m_\varphi = \frac{Kl \cdot R_\varphi}{R_T \cdot \cos(\varphi)}$	$m_\varphi = \frac{2}{1 + Pole \cdot \sin(\varphi)}$	$m_\varphi = \frac{1}{\cos(\varphi)}$

Figure 6: formulae

## 4.2.2 EGGPACK tool package

At the level code

- projections will be tangent to the globe; the type of projection is automatically deduced from the latitude (ELAT0) and longitude (ELON0) of the reference point of the projection;
- the (integer) dimensions of the grid-arrays are free parameters;
- the center of the LAM domain is specified (ELONC,ELATC)
- the uniform resolutions in x and y are specified
- zonal (EDELX) and meridional (EDELY) resolution
- zonal (NDLUX-NDLUN+1) and meridional (NDGUX-NDGUN+1) number of points

All the above parameters are output for the EGGPACK routine, which is returning 5 arrays:

- PGLAM(X,Y) Longitude at X,Y point;
- PGLAT(X,Y) Latitude at X,Y point;
- PGM(X,Y) Map factor at X,Y point;
- PGNORX(X,Y) sinus of angle of Grid with Geographic North at x,y point;
- PGNORY(X,Y) cosine of angle of Grid with Geographic North at x,y point;

These arrays are for C+I zone.

The use of FFT (Fast Fourier Transform) imposes the specification of the number of points over the centric domain (including the extension zone) specific values for NDLON (zonal nr) and NDGL (meridional nr)

$$\begin{aligned} \text{NDLON} &= 2^n * 3^m * 5^p, \quad (m, n, p \in \mathbf{N}, n \neq 0) \\ \text{NDGL} &= 2^i * 3^j * 5^k, \quad (i, j, k \in \mathbf{N}, i \neq 0) \end{aligned}$$

EGGPACK has eliminate the possibility of applying a rotation of a area of interest to the Equator before the projection. The possibility of a rotated:tilted Mercator geometry can be inserted in the new EGGPACK (LMRT=TRUE).

## 5 Strategy for Interoperability

Today the ALADIN model has the ability to start either from data of the global model ARPEGE (sharing the "FA" file format with it, configuration927), or from data of an ALADIN model with a larger domain (configuration ee927), or from pre-processed data of the global model IFS (so-called configuration901). This last functionality has been made possible with two computational steps, symmetrically to what should be done for making Interoperability format files :

- Conversion of a set of IFS GRIB files into an "FA" ready to run the global model ARPEGE. This converter is complex when it comes to changing field representation, or upper-air or surface parameters. But it does not interpolate any field. It is an internal configuration of the software IFS/ARPEGE/ALADIN.
- Conversion of the global ARPEGE "FA" file (or more generally : any global ARPEGE or ALADIN LAM file) into an "FA" file ALADIN. Here again this converter is actually the internal post-processing software inside ALADIN.

A few words on the context now: I-SRNWP will be organized in the frame of inter-consortia collaboration, coordinated by UK Met Office. The aim is to provide model output data from any of the consortia's models, for exchange and cross-usage in NWP applications (and downstream verification). To achieve this goal, I-SRNWP coordinates and defines the development of the required algorithms and softwares .

A first workshop has been held in Reading, Dec 1-3 2008. Besides a number of concrete actions, the main spirit of the development work has been defined, moving from the initially planned definition of a

common, "new" file format, towards a principle of "data exchange of as much as possible native model data". The justification for the shift is at two levels: avoid multiple interpolations (as would happen by passing via a common, new data format) and allow each consortium to organize the work based on its own existing experience and tools. This shift implies that each consortium must get itself into the position where it adapts its own software to the various input data, rather than to a unique format. The concept of the "adaptor" has evolved accordingly into rather a concept of "adapting the existing softwares".

In the Aladin consortium, MF and RC-LACE will coordinate the actions, sharing the responsibility of organizing and animating the development work.

The general guidelines for work in Aladin will be the following:

- adapt 901 to GRIB2 and LAM data; insert new geometry tools for recognizing exotic grids
- develop re-gridding tools from various input grids towards Arpge/Aladin's A-grid and field staggering. A fair balance between the accuracy of re-gridding and its complexity shall be sought.
- Adapt 901 to requirements for surface fields (following the recommendations of the Surface E.T.)
- adapt headers of the Aladin's specific model file format (FA) for handling information on interoperable data; adapt accordingly the setup of 927/Fullpos (Arpge/Aladin's change of geometry software)
- collect and make available a comprehensive documentation in link with I-SRNWP needs, for use in the SRNWP community
- provide Arpge and Aladin (Alaro, Arome) GRIB2 demonstration files to other consortia
- retrieve and test other consortia's GRIB2 files for data conversion, using the extended tools described in the previous items (extended 901, 927)

## 5.1 The configuration 901

This configuration does a transformation from a GRIB file (format used at ECMWF) towards an ARPEGE file (format used at Météo France). It allows the utilisation of analyses performed at ECMWF.

### **Data retrieved from GRIB2:**

- SURFACE - grid point fields (ICMGGXXXXXINIT)
- ATMOSPHERIC - grid points fields (ICMUAXXXXINIT)  
- spectral fields (ICMSHXXXXXINIT)  
where XXXX represents the name of the experiment.

Here there is the parameter list for each type of fields (in parenthesis it is specified the grib code)

### **Surface grid-point fields**

- low vegetation cover (27)
- high vegetation cover (28)
- type of low vegetation (29)
- type of high vegetation (30)
- snow albedo (32)
- snow density (33)
- soil water layer 1 (39)
- soil water layer 2 (40)
- soil water layer 3 (41)
- soil water layer 4 (42)
- orography (129)
- soil temperature level 1 (139)

- soil temperature level 2 (170)
- soil temperature level 3 (183)
- soil temperature level 4 (236)
- snow depth (141)
- standard deviation of orography (160)
- anisotropy of sub-grid scale orography (161)
- angle of sub-grid scale orography (162)
- land/sea mask (172)
- surface roughness (173)
- albedo (174)
- soil type (43)
- soil temperature level 2 (170)
- soil temperature level 4 (236)

#### **Atmospheric grid-point fields**

- specific humidity (133, on all model levels)

#### **Atmospheric spectral fields**

- temperature on (130, all model levels)
- vorticity (138, on all model levels)
- divergence (155, on all model levels)
- $\ln P_s$  (152, on all model levels )

This list is not exhaustive.

After all the necessary parameters are obtained from *MARS*, the configuration 901 could be run. We will also need climatology data and for that we should run c923 to complete data with *ISBA* (Interaction Soil Biosphere Atmosphere) surface data. The output will be a file *ARPEGE* with the same geometry as in the GRIB input files. To change this geometry we should run the 927 configuration (*FULLPOS*).

## **5.2 Post-processing package**

### **FULL-POS:**

FULL-POS is a package allowing the post-processing of different types of variables on different types of surfaces and on different types of horizontal domains.

#### **The different post-processable types (3D) of variables are:**

- 3D dynamical variables (like temperature, specific humidity), abbreviated into DYN3D;
- 2D dynamical variables (like logarithm of surface hydrostatic pressure), abbreviated into DYN2D;
- Surface fields used in the physics (for example the surface albedo or the land-sea mask), or produced by the physics (for example the surface reservoir content of water), abbreviated into PHYSOL;
- Fields computed by the CFU (cumulated fluxes) software;
- Fields computed by the XFU (instantaneous fluxes) software;

#### **The different types of surfaces (2D) variable of post-processing are:**

- Hydrostatic pressure surfaces;



- Geopotential height surfaces;
- Hybrid coordinate model surfaces;
- Potential temperature surfaces;
- Potential vorticity surfaces.

**The different types of horizontal domains of post-processing are:**

- The whole Earth in spectral representation;
- The whole Earth in grid-point representation on a reduced or not reduced Gaussian grid;
- The whole Earth in grid-point representation on a lat-lon grid;
- An ALADIN sub-domain in spectral representation;
- An Aladin sub-domain in grid-point representation;
- A lat-lon sub-domain in grid-point representation (in this case several domains can be treated in the same job).

The main usage of FULL-POS is to obtain fields on different types of surfaces and different types of horizontal domains in order to plot them, for example the geopotential height at 500 hPa, the mean sea level pressure, the total amount of forecast rainfall. Another important application of FULL-POS is to prepare the initial file (and LBCs files in LAM case) in a different geometry (with a different horizontal geometry and also a different spacing of vertical levels). This is the configuration 927 of FULL-POS. For example, what one can do:

- make a global file of truncation  $N_{s2}$ , stretching  $c_2$ , high resolution pole of coordinates  $(\theta_{pe_2}, \lambda_{pe_2})$ , vertical hybrid coordinate defined by a pair of coefficients  $(A_2, B_2)$ , from a global file of truncation  $N_{s1}$ , stretching  $c_1$ , high resolution pole of coordinates  $(\theta_{pe_1}, \lambda_{pe_1})$ , vertical hybrid coordinate defined by a pair of coefficients  $(A_1, B_1)$  (pseudo-configuration 927 of FULL-POS);
- make an ALADIN file from a global ARPEGE file (pseudo-configuration E927 of FULL-POS);
- make an ALADIN file from an ALADIN file covering a bigger domain (pseudo-configuration EE927 of FULL-POS);
- modify an ARPEGE file with some data coming from an ALADIN file.

It is also possible to do the following applications:

- change a spectral field into its grid-point representation (or the reverse thing) in a file;
- add fields containig zeros (or some climatological data for PHYSOL surface fields) in ARPEGE or ALADIN files;
- add non-hydrostatic variables in files initially containing only hydrostatic variables, in order to be used by a non-hydrostatic model;
- remove the poles in grid-point fields in old ARPEGE files still containig poles.

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