ALADIN documentation for I-SRNWP: model fields and related aspects

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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.

Contents

1 Model fields description

Through "HISTORICAL" files or "ICMSH" (standing for **I**n-**C**ore **M**odel **S**pectral **H**ybrid) 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', sufix 'GEOPOTENTIEL'; arbitrary level;

- Surface pressure : prefix 'SURF', sufix '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 diagostic 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 lenght 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	Heat flux due to turbulence	J/m^2	cfu
SURF	CFU.Q.TURBUL	Flow of steam from a turbulence	J/m^2	cfu
SURF	CHAL.DS.SOL	Heat flux in soil	J/m^2	cfu
SURF	EAU DANS SOL	Percolation flux in soil	kg/m^2	cfu
SURF	EVAPOTRANSPI	Evapotranspiration flux	kg/m^2	cfu
SURF	FLUX DE GEL		kg/m^2	cfu
SURF	FONTE NEIGE	Flow of melting snow	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	Zonal component gust	m/s	xfu
CLS	V.RAF.MOD.XFU	Meridian component gust	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	Minimum relative humidity at 2 metres	-	xfu
CLS	MAXI.HUMI.REL	Maximum relative humidity at 2 metres	-	xfu
CLP	MIHAUT.MOD.XFU	Height of the planetary boundary layer	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	Flux of water evaporation	$kg/m^2 * s$	xfu
SURF	XFONTE NEIGE	Flux of melting snow	$kg/m^2 * s$	xfu
SURF	XRUISS.INTE	interception soil layer runoff	kg/m^2	xfu
SURF	XRUISSELLEME	Surface soil runoff	$kg/m^2 * s$	xfu
SURF	XTRANSPIRATI	Transpiration	$kg/m^2 * s$	xfu
PROF	XRUISSELLEME	Deep soil runoff	$kg/m^2 * s$	xfu

2   Introduction

ARPEGE/IFS is a spectral global model. One part of computation is done in spectral space (semi-implicit scheme, horizontal diffusion scheme for model integration), the other part in grid-point space on a grid defined by a Gaussian quadrature. So, it is necessary to perform spectral transforms from spectral space to grid-point space or vice-versa. For a global spectral model, spectral transforms are a combination of a Legendre transform and Fourier transform.

More informations about transformations from spectral to grid point space and vice-versa will be found in annex 1 and annex 2.

ALADIN is a limited area version of ARPEGE and it is also a spectral model. Its horizontal domain covers only a limited area, so the fields are bi-periodicised to be able to match with a spectral representation.
The vertical coordinate is the same as the one in ARPEGE. ALADIN needs to be forced by a global model which has to provide lateral boundary conditions, the lateral forcing is done according to a Davies relaxation. (Davies, 1976) When using ALADIN with a domain which is not too big, the horizontal grid is a quasi-regular grid (the mappin factor m has only weak variations and remains close to 1).

2.1   The η 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 η. 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($\eta = 0$) = Π_{top} and B($\eta = 1$) = 0 at the top of the model.

3 The content of the GRIB files

The **GRIB2** files content:
 INPUT fields:

- the analyse fields from the global model ARPEGE (Gaussian grid, stretching factor=2.4)

- the coupling fields for ALADIN and AROME models (Lambert grid)

Here after is the list of the parameters on ARPEGE model:

- skin Temperature (K)
- bottom layer soil temperature (K)
- u-component of wind $(m\ s^{-1})$ on 60 hybrid levels
- v-component of wind $(m\ s^{-1})$ on 60 hybrid levels
- q - specific humidity on 60 hybrid levels
- t - temperature (K) on 60 hybrid levels
- sp - surface Pressure (Pa)
- mterh - model Terrain Height (m)
- sr - surface roughness (m)
- lsm - land Sea Mask
- al - albedo
- veg - vegetation

The same parameters are also included in ALADIN model, the difference is that here there is an extra field called pres - pressure on model levels.
 Here is the list of the fields on AROME model:

- skin Temperature (K)
- bottom layer soil temperature (K)
- sd - snow depth water equivalent
- sr - surface roughness (m)
- al - albedo
- lsm - land Sea Mask
- veg - vegetation
- u-component of wind $(m\ s^{-1})$ on 41 hybrid levels
- v-component of wind $(m\ s^{-1})$ on 41 hybrid levels
- q - specific humidity on 41 hybrid levels
- t - temperature (K) on 41 hybrid levels
- snmr - snow mixing ratio on 41 hybrid levels
- rwmr - rain mixing ratio on 41 hybrid levels
- grle - graupel (snow pellets) on 41 hybrid levels
- tke - turbulent Kinetic Energy on 41 hybrid levels
- pres - pressure (Pa) on 41 hybrid levels

- sp - surface pressure (Pa)
- mterh - model Terrain Height (m)

OUTPUT fields postprocessed in native grid and pressure levels:

- the global model ARPEGE;
- ALADIN and AROME models;

These are the fields on ARPEGE model:

- skt - skin Temperature (K)
- botom layer soil temperature (K)
- sd - snow depth water equivalent
- hpbl - planetary boundary layer height (m)
- lsm - land sea mask
- tcc - total cloud cover
- hcc - high cloud cover
- mcc - medium cloud cover
- total column water $(kg\ m^{-2})$
- mconv - Horizontal moisture convergence $(kg\ kg^{-1}\ s^{-1})$
- u-component of wind $(m\ s^{-1})$ on pressure levels 1,2,3,5,7,10,20,30,50,70,100,150,200,250, 300,400,500,600,700,800,850,900,925,1000
- v-component of wind $(m\ s^{-1})$ on pressure levels 1,2,3,5,7,10,20,30,50,70,100,150,200,250, 300,400,500,600,700,800,850,900,925,1000
- gh -geopotential height on pressure levels 1,2,3,5,7,10,20,30,50,70,100,150,200,250, 300,400,500,600,700,800,850,900,925,1000
- r -relative humidity on pressure levels 1,2,3,5,7,10,20,30,50,70,100,150,200,250, 300,400,500,600,700,800,850,900,925,1000
- epot - pseudo-adiabatic potential temperature or equivalent potential temperature on pressure levels
  200,250,300,400,500,600,700,800,850,900,925,1000
- pv - potential vorticity on pressure levels 50,70,100,150, 200,250,300,400,500,600,700,800,850,900,925,1000
- w - vertical velocity $(m\ s^{-1})$ on pressure levels 1,2,3,5,7,10,20,30,50,70,100,150, 200,250,300,400,500,600,700,800,850,900,925,1000
- d - divergence s^{-1} on pressure levels 200,250,300,400,500,600,700,800,850,900,925,1000
- sp - surface pressure (Pa)
- msl - mean sea level pressure (Pa)
- 10m - u-component of wind $(m\ s^{-1})$
- 10m - v-component of wind $(m\ s^{-1})$
- 2m - 2t - 2 metre temperature (K)
- 2m - r - relative humidity
- u-component of wind $(m\ s^{-1})$ on potential vorticity surface 1500,2000,700
- v-component of wind $(m\ s^{-1})$ on potential vorticity surface 1500,2000,700

- gh - geopotential height (gpm) on potential vorticity surface 1500,2000,700

- pt - potential temperature (K) on potential vorticity surface 1500,2000,700

For ALADIN model, add to the list above the following fields:

- 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 ($W\ m^{-2}$)

- net long wave radiation flux ($W\ m^{-2}$)

- latent heat net flux ($W\ m^{-2}$)

- evaporation ($kg\ m^{-2}$)

- sensible heat net flux ($W\ m^{-2}$)

- high cloud cover

- medium cloud cover

- low cloud cover

- convective available potential energy ($J\ kg^{-1}$)

- total column water ($kg\ m^{-2}$)

For AROME model, the list of the fields is almost the same with the one in ALADIN model (the difference consists on pressure levels)

The parameter 2m Visibility is not available in ARPEGE, ALADIN or AROME model.

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:

(λ, θ) 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

(λ', θ') are the spherical coordinates
(λ_p, θ_p) are the pole coordinates

$$\cos\theta' \cos\lambda' = \cos\theta_p \sin\theta - \sin\theta_p \cos\theta \cos(\lambda - \lambda_p) \tag{1}$$

$$\cos\theta' \sin\lambda' = -\cos\theta \sin(\lambda - \lambda_p) \tag{2}$$

$$\sin\theta' = \sin\theta_p \sin\theta + \cos\theta_p \cos\theta \cos(\lambda - \lambda_p) \tag{3}$$

The inverse transformation is:

$$\cos\theta \cos(\lambda - \lambda_p) = \cos\theta_p \sin\theta' - \sin\theta_p \cos\theta' \cos\lambda' \tag{4}$$

$$\cos\theta \sin(\lambda - \lambda_p) = -\cos\theta' \sin\lambda' \tag{5}$$

$$\sin\theta = \sin\theta_p \sin\theta' + \cos\theta_p \cos\theta' \cos\lambda' \tag{6}$$

The conformal transformation
It is defined by

$$\Lambda = \lambda' \tag{7}$$

$$\sin \Theta = \frac{(1 - c^2) + (1 + c^2)\sin \theta'}{(1 + c^2) + (1 - c^2)\sin \theta'} \tag{8}$$

$$\cos \Theta = \frac{2c \cos \theta'}{(1 + c^2) + (1 - c^2)\sin \theta'} \tag{9}$$

and inverse is:

$$\lambda' = \Lambda \tag{10}$$

$$\sin \theta' = \frac{-(1 - c^2) + (1 + c^2)\sin \Theta}{(1 + c^2) - (1 - c^2)\sin \Theta} \tag{11}$$

$$\cos \theta' = \frac{2c \cos \Theta}{(1 + c^2) - (1 - c^2)\sin \Theta} \tag{12}$$

The direct transformation

The coordinates on the transformed sphere:

$$\sin \Theta = \frac{(1 - c^2) + (1 + c^2)(\sin \theta_p \sin \theta + \cos \theta_p \cos \theta \cos(\lambda - \lambda_p))}{A} \tag{13}$$

$$\cos \Theta \cos \Lambda = \frac{2c(\sin \theta \cos \theta_p - \cos \theta \sin \theta_p \cos(\lambda - \lambda_p))}{A} \tag{14}$$

$$\cos \Theta \sin \Lambda = \frac{-2c \cos \theta \sin(\lambda - \lambda_p)}{A} \tag{15}$$

with

$$A = (1 + c^2) + (1 - c^2)(\sin \theta_p \sin \theta + \cos \theta_p \cos \theta \cos(\lambda - \lambda_p)) \tag{16}$$

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

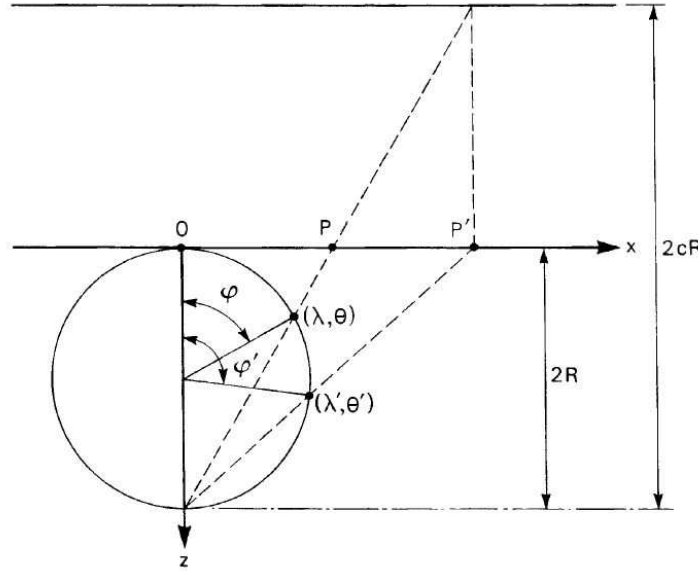$$\sin \Theta = \frac{(1 + c^2)A - 4c^2}{(1 - c^2)A} \tag{17}$$

Figure 1: The transformation associated with a magnification in the complex plane (from Courtier and Geleyn)

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4.1.1 TRACARE

Subroutine TRACARE computes geographical coordinates once given the computational sphere coordinates.
INPUT parameters:
$\sin\Theta$ - sine of the psedo-latitude on the transformed sphere;
$\sin\Lambda$ - sine of the pseudo-longitude on the transformed sphere;
$\cos\Lambda$ - cosine of the pseudo-longitude on the transformed sphere;
OUTPUT parameters:
$\sin\theta$ - sine of the real latitude;
$\sin\lambda$ - sine of the real longitude;
$\cos\lambda$ - cosine of the real longitude.

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 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 streched 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-dimenssional 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 minimizated-by default -11 points).
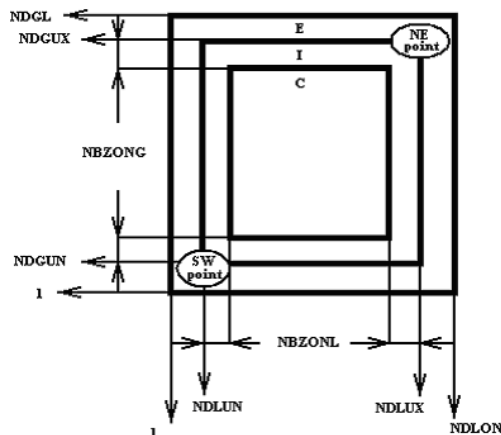

Figure 2: ALADIN domain schematic representation

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

The projections described here and available within the models are:

- Polar Stereographic Projection (SP);

- Conformal Conical Lambert projection (LCC);

- Mercator projection (M);
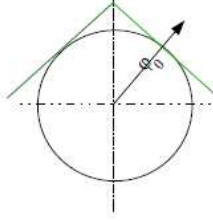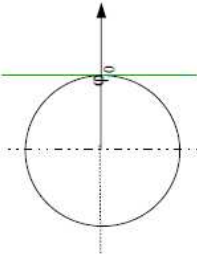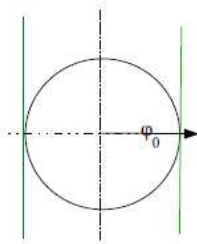
- Mercator Rotated Tilted projection (MRT)

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

Figure 3: LAM projections

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

Figure 4: formulae

Here are all the projection formulae, for tangent case, where $Kl = \sin(\varphi_0)$
The parameters that are used are:

- m is the mapping factor of the projection; it remains close to 1 if the limited area domain is not too large;

- R_{eq} is the distance of the Equator projection in polar coordinates;

- *Pole* - that defines in LCC and SP projections, the pole belonging to the projection plane. *Pole* will be chosen, according to the reference latitude φ_0, its absolute value $=1$ and will get the sign of the reference latitude whose definition domain is [-90,90] (this parameter is valueless in the Mercator projection);

- λ_0 - is the reference geographical longitude that defines the projection.

The Mercator Rotated Tilted projection

The MRT projection is only a Mercator projection (M) where by the earth has rotated from a coordinate point (λ, φ) to $(0, 0)$ this is the Rotated part of MRT. The MRT Tilted part is a second rotation along a perpendicular axis to the Poles ones and going by the coordinates $(0, 0)$. The Mercator projection is therefore made after this shift (Rotated) and rotation (Tilted) of the sphere.
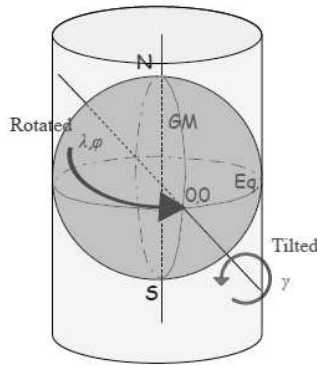The parameters describing this projection are identical as the ones for the M projection.

Figure 5: The MRT projection

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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 meridianal (EDELY) resolution

- zonal (NDLUX-NDLUN+1) and meridianal (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(meridianal nr)

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

EGGPACK has eliminate the possibility of applying a rotation of a area of interest to the Equator before the projection.

A ANNEX 1

A.1 Grid representation for the global model ARPEGE

A.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 Θ:

$$F_m(\mu) = \sum_{n=|m|}^{n=N_s} f(n,m) P(n,m)(\mu) \tag{18}$$

  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 Θ:

$$f(\Lambda, \Theta) = \sum_{m=-N(\Theta)}^{m=N(\Theta)} F_m(\mu) exp(im\Lambda) \tag{19}$$

  One transforms real fields, so :

$$f(\Lambda, \Theta) = F_0(\mu) + 2 \sum_{m=1}^{m=N(\Theta)} [R(F_m(\mu)) \cos m\Lambda - L(F_m(\mu) \sin(m\Lambda)] \tag{20}$$

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

A.1.2 Transformation from grid point to spectral space

Transformation from grid point to spectral space needs:

1. A direct Fourier transform, for each latitude Θ:

$$F_m(\mu) = \frac{1}{nlon(\Theta)} \sum_{jlon=1}^{jlon=nlon(\Theta)} f(\Lambda(jlon), \Theta) exp(-im\Lambda(jlon)) \tag{21}$$

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

$$R(F_m(\mu)) = \frac{1}{nlon(\Theta)} \sum_{jlon=1}^{jlon=nlon(\Theta)} f(\Lambda(jlon), \Theta) \cos m\Lambda(jlon)) \tag{22}$$

$$L(F_m(\mu)) = \frac{-1}{nlon(\Theta)} \sum_{jlon=1}^{jlon=nlon(\Theta)} f(\Lambda(jlon), \Theta) \sin m\Lambda(jlon)) \tag{23}$$

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 $ndgnh$.

A.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 streching coefficient c is equal to 1 (no streching), N_s is the biggest integer which verify the relationship $3 * N_s \leq (ndlon - 1)$.

- If the streching coefficient c is bigger than 1 (streching), 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 gidpoint space: a linear grid. The most frequently linear grids used are the semi-linear 2.5 grid characterized by:

- If the streching coefficient c is equal to 1 (no streching), N_s is the biggest integer which verify the relationship $2.5 * N_s \leq (ndlon - 1)$.

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

- If the streching coefficient c is bigger than 1 (streching), 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.

A   ANNEX 2

A.1   Grid representation for LAM

A.2   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. 6a) in ARPEGE/IFS with 2 real numbers defining a component and an *elliptical* one (fig.6b) 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.
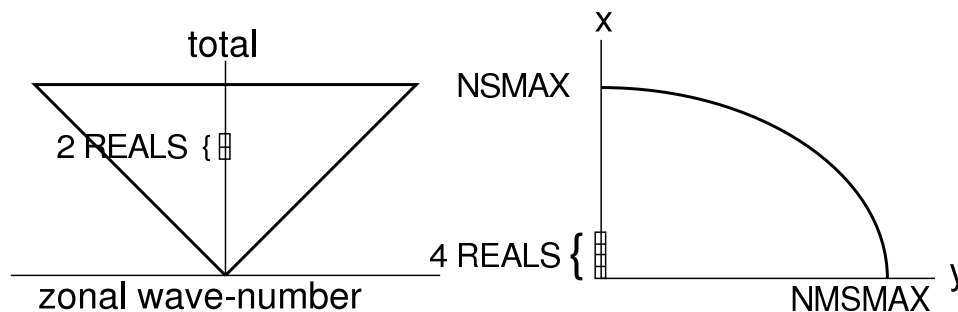
Figure 6: Schematic representation of a triangular (left) and elliptical truncation (right).

A.3   Grid-point space

Differences are:

- Existence of lateral boundaries.

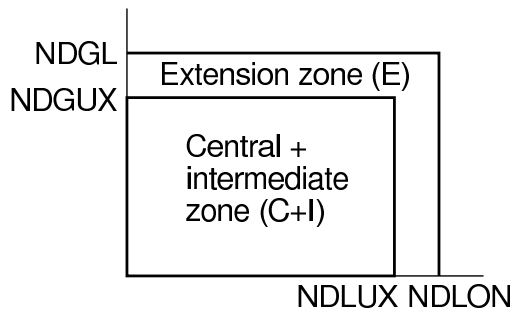- Necessity of the extension zone for biperiodizing the fields (see fig. 7).

Figure 7: Schematic representation of the extension zone in ALADIN, and a few important definitions.

A.4   Linear grid and quadratic grid for LAM; 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:

NDGLG=(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 garanteed 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 ellliptic 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*(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:

NDGLG=(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 δX. 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 δX =(NDGLG-1)/L is the mesh size of a regular lattice of total length L.

A ANNEX 3

A.1 Specifications for Interoperability in ALADIN

Today the ALADIN model has the ability to start either from data of the global model ARPEGE (sharing the "FA" file format with it, configuratione927), 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:

- 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 of ALADIN.

The aim of I-SRNWP 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 .

Let us recall some major specifications for the interoperable files, as resulting from the two specific workshops held at ECMWF (Dec. 2008, Dec. 2009):

- All interoperable files should be produced on native horizontal model grids (no more lat/lon grids). This requirement is true for both post-processing files and restart files (re-entering/model files). Note that the vertical grid shall be either pressure levels (post-processing files) or native model levels (for re-entering files), in which case the GRIB2 header eventually must be able to describe all possible solutions from the consortia (contact here is ECMWF).

- The SRNWP E.T. members for System aspects will be in charge of the preparation and future coordination for maintenance of Interoperability. The System E.T. is also responsible for the governance of the maintenance plans for the standard format and the adaptors. There should be at least one annual review of the adaptors, including a testing before the annual SRNWP meeting.

- Further details about the technical content of the standard format files can be found in the Minutes of the two workshops and the I-SRNWP technical documentation.

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 (revised strategy from February 2010):

- One preliminary aspect will be to ensure that ALADIN models can properly initialize GRIB identifiers for fields written with the GRIB_API/GRIB2 interface.

- Configuration 901 is kept unchanged, based on the version able to convert GRIB1 =¿ FA (an extension to GRIB2 is however planned for other operational purposes).

- Configuration 903: this will be a new configuration, whose monitor routine will need to be designed and coded. 903 will convert post-processing input files into post-processing output files in all-Aladin format.

- Configuration 902: this will be a new configuration, whose monitor routine will need to be designed and coded, based on the experience gained with 903. 902 will convert any interoperable input file into an all-Aladin model output file suitable for model integration. *The previously planned work on extending the FA-cadre description so that Aladin file frames can contain the identification and description of exotic grids is not needed anymore, since the equivalent facility will be included directly in the new configurations 902/3. Full-Pos/927 only will receive classical Aladin-type of data as input.*

A.2 The configuration 901

This configuration does a transformation from a GRIB file (format used at ECMWF) towards an ARPEGE file (format used at Meteo France). It allows the utilisation of analyses performed at ECMWF.
Data retrieved from GRIB2:

- SURFACE - grid point fields (ICMGGXXXXINIT)

- ATMOSPHERIC - grid points fields (ICMUAXXXXINIT)
  - spectral fields (ICMSHXXXXINIT)
  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 Ps (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 ($FULLPOS$).

A.3 Post-processing package

FULL-POS:

FULL-POS is a package allowing the post-procceing 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} , streching 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.

A   ANNEX 4

A.1   Parameters which describe the model surface

Here is the list of the input parameters requested:

- surface temperature -that can be the sea surface temperature over oceans, the sea-ice temperature over sea-ice and the soil temperature over land (K);

- soil temperatures at various depths (K);

- soil moisture contents (ice and water separately) at various depths (K);

- soil texture (classes or fractions of clay, sand, organic matter) for each of soil layer;

- soil wetness index at various depths;

- snow water equivalent (kg/m^2);

- land sea mask

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