GENERAL OVERVIEW OF THE CONFIGURATIONS. INSIDE ARPEGE/ALADIN (CY32T2).

K. YESSAD
METEO-FRANCE/CNRM/GMAP/ALGO

ARPEGE, ALADIN, ALARO, HIRALD, AROME.

One code, but several models shared between different European (and also some non-European countries) :

- ARPEGE : spectral global model for METEO-FRANCE applications.
- IFS : spectral global model for ECMWF applications.
- ALADIN : spectral limited area model (mesh-size often around 10 km).
- ALARO : cf. ALADIN but for some ALADIN partners, (mesh-size around 5-7 km).
- AROME : non-hydrostatic spectral limited area model for METEO-FRANCE applications (mesh-size 2.5 km) ; planned for operations in 2008.

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AVAILABLE RANGES OF CONFIGURATIONS.

The IFS/ARPEGE-ALADIN has different configurations (variable **NCONF** of **NAMCT0**, between 1 and 999) which can do for example hydrostatic forecasts, data assimilation, sensitivity studies. The following ranges of configurations are :

- 0- 99 : 3-D integration job.
- 100-199 : variational job.
- 200-299 : horizontal 2-D integration job.
- 300-349 : KALMAN filter (currently not used).
- 350-399 : predictability model (currently not used).
- 400-499 : test of the adjoint.
- 500-599 : test of the tangent linear model.
- 600-699 : eigenvalue/vector solvers.
- 700-799 : optimal interpolation.
- 800-899 : sensitivity experiments.
- 900-999 : miscellaneous other configurations.

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AVAILABLE CONFIGURATIONS (1-899).

- 1 : 3-D integration job (hydrostatic or NH).
- 131 : incremental 4-D VAR/3-D VAR (3-D VAR only for ALADIN).
- 201 : 2D shallow-water model (ARPEGE only, currently bugged).
- 202 : 2D vorticity equation model (ARPEGE only, currently bugged).
- 401 : test of adjoint with 3-D HYD model.
- 421 : test of adjoint with 2D shallow-water model (ARP).
- 422 : test of adjoint with 2D vorticity equation model (ARP).
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- 912 : computes rotation matrices for spectral space (ARPEGE only).
- 923 : initialisation of climatologic files (ARPEGE and ALADIN).
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Systems of equations :

- Thin layer (HYD) primitive equations (LNHDYN=F, LVERCOR=F).
- Deep layer (HYD) primitive equations (LNHDYN=F, LVERCOR=T).
- Thin layer (NH) non-hydrostatic equations (LNHDYN=T, LVERCOR=F), two additional prognostic variables linked to pressure departure and vertical divergence.

Remarks :

- The AD and TL codes are not used.
- ARPEGE : uses the projects ARP, TFL, XRD.
- ALADIN : uses the projects ARP, ALD, TAL, XRD.
- AROME : uses the projects ARP, ALD, TAL, XRD, MPA, MSE.

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CONFIGURATION 1 : ORGANIGRAMME.

Setup :

MASTER − > CNT0 − > CNT1 − >

- * SU1YOM (setup of level 1)
- * CNT2 − >
  - SU2YOM (setup of level 2)
  - CNT3 − >
    - * CSTA − > SUINIF (reads the initial files)
    - * SU3YOM (setup of level 3)
    - * CNT4 − > some setup routines of level 4 and STEPO − > (see below)

CONFIGURATION 1 : ORGANIGRAMME.

STEPO = management of one timestep :

- Inverse transforms + compute horizontal derivatives [(E)TRANSINVH].
- Grid-point calculations [GP_MODEL] (explicit dynamics, physics).
- Coupling (ALADIN only) [ECOUPL1].
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- Same type of architecture as for configuration 1, with obsolescent features.
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Tangent linear (TL) model.

Systems of equations :

- Assuming that the direct model computes the evolution of X :

$$\frac{dX}{dt} = f(X)$$

  the TL code computes the evolution of the small perturbation δX as :

$$\frac{d[\delta X]}{dt} = f^{'}(X)[\delta X]$$

- If the direct code is non linear, needs to have a specific tangent linear code (example : the TL code of routine STEPO is in routine STEPOTL). The architecture of the TL code generally looks like the architecture of the direct code.
- The TL model needs a preliminary direct model integration to provide the trajectory (compute $f^{'}(X)$).

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CONFIGURATIONS 501, 521, 522 : Test of the TL 3D model.

What does the configuration 501 ?

- computes the ratio

$$R = [Y_{t=T} - X_{t=T}]/[C[\delta X]_{t=T}]$$

  for different values of C, and prints it for a subset of spectral wavenumbers ($Y(t)$ is the forecast from the perturbed initial state $X_{t=0} + C[\delta X]_{t=0}$).
- this ratio must remain close to 1 (if not, the TL is not the TL of the direct code).

What do the configurations 521 and 522 (ARPEGE only) ?

- configuration 521 : cf. 501 but for the 2D shallow-water model.
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Adjoint (AD) model.

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- Assuming that : the TL code computes the evolution of the small perturbation δX as :

$$\frac{d[\delta X]}{dt} = f^{'}(X)[\delta X]$$

the adjoint code computes :

$$\frac{d[\delta Y]}{dt} = transp[f^{'}(X)][\delta Y]$$

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- In the code, adjoint of the TL routine [SUBR]TL is generally named [SUBR]AD. The architecture of the AD code generally looks like the "inverted" architecture of the TL code, with the same trajectory code.
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- The TL code must be always coded before the AD code !

Adjoint (AD) model.

Systems of equations :

- Assuming that : the TL code computes the evolution of the small perturbation δX as :

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CONFIGURATIONS 401, 421, 422 : Test of the AD 3D model.

What does the configuration 401 ?

- runs the TL model (denoted by the matrix M), and computes

  $$S1 =< M[\delta X]_{t=0}, [\delta Y] >$$

  ($[\delta Y]$ = another perturbation).
- runs then the AD model (denoted by the matrix $transp(M)$) applied to $[\delta Y]$, and computes

  $$S2 =< [\delta X]_{t=0}, transp(M)[\delta Y] >$$
- checks that the two scalar products $S1$ and $S2$ are equal, and prints the difference (line “THE DIFFERENCE IS”) which must remain negligible compared to $S1$ (if not, the AD is not the AD of the TL code).

What do the configurations 421 and 422 (ARPEGE only) ?

- configuration 421 : cf. 401 but for the 2D shallow-water model.
- configuration 422 : cf. 401 but for the 2D vorticity equation model.

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CONFIGURATION 701 : Optimal interpolation assimilation (CANARI).

What does the configuration 701 ?

- Does an assimilation by the optimal interpolation algorithm. Solves by direct methods the linear system

  $$\delta X = (B^{-1} + H^T R^{-1} H)^{-1} H^T R^{-1} (Y - HX_g)$$

  Y=observations, X_g=guess, δX= increment to be computed.
- Does not require any TL or AD code.
- Does not require any minimizer.
- This is a purely ($\leq$3)D assimilation.
- Not well designed for some satellite data.
- Still used for surface assimilation.
- “CANARI” code, most of the specific routines involved are arp/canari/CA... routines ; the most important “hat” routines are CADAVR (interpolations at the locations of observations, arborescence calls COBS, COBSLAG, OBSV) and CAVODK (preparation and inversion of the linear system).

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CONFIGURATION 131 : Incremental 4DVAR/3DVAR/3DVAR-FGAT assimilation (hydrostatic 3D model).

What does the configuration 131 ?

- Does an assimilation by a variational algorithm. Minimizes the quadratic function :

  $$J(X) = J_b(X) + J_o(X) + J_c(X) + J_k(X)$$

  where : J_b = distance from the guess
  J_o = distance from the observations
  J_c = distance from a filtered state (generally DFI)
  J_k = distance from ARPEGE low truncation analysis (ALADIN only).
- Incremental algorithm => finds the increment $\delta X = X - X_g$ rather than X.
- The 4DVAR requires TL or AD code, but not the 3DVAR and 3DVAR-FGAT.
- 3DVAR-FGAT = 4DVAR with TL and AD operators replaced by identity.
- 3DVAR algorithm : all observations are assumed to be at the same time t_0.
- Requires a minimizer (currently CONGRAD in ARPEGE, M1QN3 in ALADIN).
- Well designed for some satellite data.
- Used for upper air data assimilation (4DVAR in ARPEGE, 3DVAR in ALADIN).
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CONFIGURATION 601 : calculation of singular vectors (hydrostatic 3D model).

What does the configuration 601 ?

- Search for an initial perturbation (or a set of orthogonal initial perturbations) which maximizes the ratio :

$$\langle [\Delta x]_{t=T}; [\Delta x]_{t=T} \rangle \,/\, \langle [\Delta x]_{t=0}; [\Delta x]_{t=0} \rangle$$

  where $[\Delta x]_{t=T}$ is the evolution by the TL model from the initial perturbation $[\Delta x]_{t=0}$.
- The orthogonal initial perturbations which are computed are called “singular vectors”.
- The main known application is the ensemble forecast.
- Conf 601 uses TL or AD code.
- The code uses the control routines CUN1, CUN2 and a Lanczos method (LANCZOS=T).
- Lanczos algorithm : approximate a full large symmetric matrix A by a small $n * n$ tri-diagonal symmetric matrix T computed after n iterations, the eigenvalues and eigenvectors of T converge towards those of A when n increases.
- There is another option which mixes the configurations 601 and 131 (put NCONF=131 and LCACDAV=T) and uses the Jacobi-Davidson algorithm (not used for operational purposes) ; the code calls the control routine CUN3.

CONFIGURATION 601 : calculation of singular vectors (hydrostatic 3D model).

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- Lanczos algorithm : approximate a full large symmetric matrix A by a small $n * n$ tri-diagonal symmetric matrix T computed after n iterations, the eigenvalues and eigenvectors of T converge towards those of A when n increases.
- There is another option which mixes the configurations 601 and 131 (put NCONF=131 and LCACDAV=T) and uses the Jacobi-Davidson algorithm (not used for operational purposes) ; the code calls the control routine CUN3.

CONFIGURATION 601 : calculation of singular vectors (hydrostatic 3D model).

What does the configuration 601 ?

- Search for an initial perturbation (or a set of orthogonal initial perturbations) which maximizes the ratio :

  $$\langle [\Delta x]_{t=T} ; [\Delta x]_{t=T} \rangle \, / \, \langle [\Delta x]_{t=0} ; [\Delta x]_{t=0} \rangle$$

  where $[\Delta x]_{t=T}$ is the evolution by the TL model from the initial perturbation $[\Delta x]_{t=0}$.
- The orthogonal initial perturbations which are computed are called “singular vectors”.
- The main known application is the ensemble forecast.
- Conf 601 uses TL or AD code.
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CONFIGURATION 801 : sensitivity studies (hydrostatic 3D model).

What does the configuration 801 ?

- Answers to one of the two following questions :
  a/ once defined a scalar cost function (preferably quadratic), what is the sensitivity of this cost function to some basic meteorological variables ? What are the basic variables which have the most impacts on this cost function ?
  b/ one does a forecast (“experiment forecast”), and uses a “reference forecast”. What is the perturbation to bring to the initial state, in order the model forecast to get the closest as possible as the “reference forecast” (the distance being measured by the above scalar cost function) ?
- The cost function can be defined globally or locally (ARP and ALD).
- Conf 801 uses the AD code, some options the TL code also.
- Answering question b/ requires a minimizer (currently M1QN3).
- The code calls the control routine CGR1.

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CONFIGURATIONS 923, 931, 932 : climatologies, SST, ice.

What does the configuration 923 ?

- Produces some surface climatologic files (ARPEGE and ALADIN).
- Currently 10 parts (top control routine INCLI[n] with n=1 to 10) ; the first part computes the orography (spectral and g.p. calculations, use of the minimizer M1QN3R) ; the other parts compute some other surface fields (grid-point calculations, horizontal interpolations from a database file).
- One file per month.
- Not used at ECMWF.

What do the configurations 931 and 932 ?

- 931 : initialisation of SST (INCLITC, ARPEGE only).
- 932 : initialisation of sea-ice (CSEAICE, ARPEGE only).
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SCREENING AND TRAJECTORY UPDATE.

These configurations are used in a 3DVAR/4DVAR suite.

Screening.

- This is a conf 1 with LSCREEN=1 (apparent configuration 2) ; additionally to a forecast :
  ∗ an observation file is read
  ∗ model data are interpolated at the observations locations (COBS+COBSLAG, OBSV)
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- This configuration must be called before the configuration 131.

Trajectory update.

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DIAGNOSTICS.

List of diagnostics.

- FULL-POS : the post-processing on different type of surfaces.
- FULL-POS 927, E927, EE927 : FULL-POS used to do changes of horizontal geometry (927 = ARPEGE-ARPEGE ; E927 = ARPEGE-ALADIN ; EE927 = ALADIN-ALADIN).
- DDH : diagnostics on horizontal domains, based on the flux-form of an equation.
- CFU : temporally cumulated fluxes computed from the physical parameterizations.
- XFU : instantaneous fluxes computed from the physical parameterizations.
- ISP or "movies" : to diagnose the "cloudiness" which can be seen by a satellite.
- ECHKEVO : diagnostic of the temporal evolution of some quantities.
- Physical tendencies diagnostics (...CHET routines).
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STRUCTURE OF A SCRIPT.

Example for a forecast, experiment code=ALAD.

- Get the initial file, copy it on ICMSHALADINIT.
- ALADIN : get the coupling files, copy them on ELSCFALADALBC[n], n=000,001,002,003, etc...
- Get the namelist, copy it on fort.4.
- Get the command line variables.
- Get the executable, copy it on MASTER.
- Execute MASTER.
- print the output listing (on the NEC, ”cat lola” and at least ”cat NODE.001_01” for the output of the main node).
- Save the output files, for example the historical files ICMSHALAD+[ech], ech=0000,0003,0006,0009, etc...

Remarks for other scripts.

- Some scripts may be more tricky (for ex. conf 131, 923).

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Example for a forecast, experiment code=ALAD.

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CONCLUSION.

- ARPEGE/ALADIN is a very tricky software (3400 routines for project ARP, 10000 for all projects).
- It allows to do a lot of things ; some configurations are obsolescent and not regularly validated.
- Requires manpower to maintain and validate it.
- Requires severe rules of coding in order to keep it understandable.

More information about these configurations.

- Start by the general documentation "ykarpbasics" (on http ://www.cnrm.meteo.fr/gmapdoc/).
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