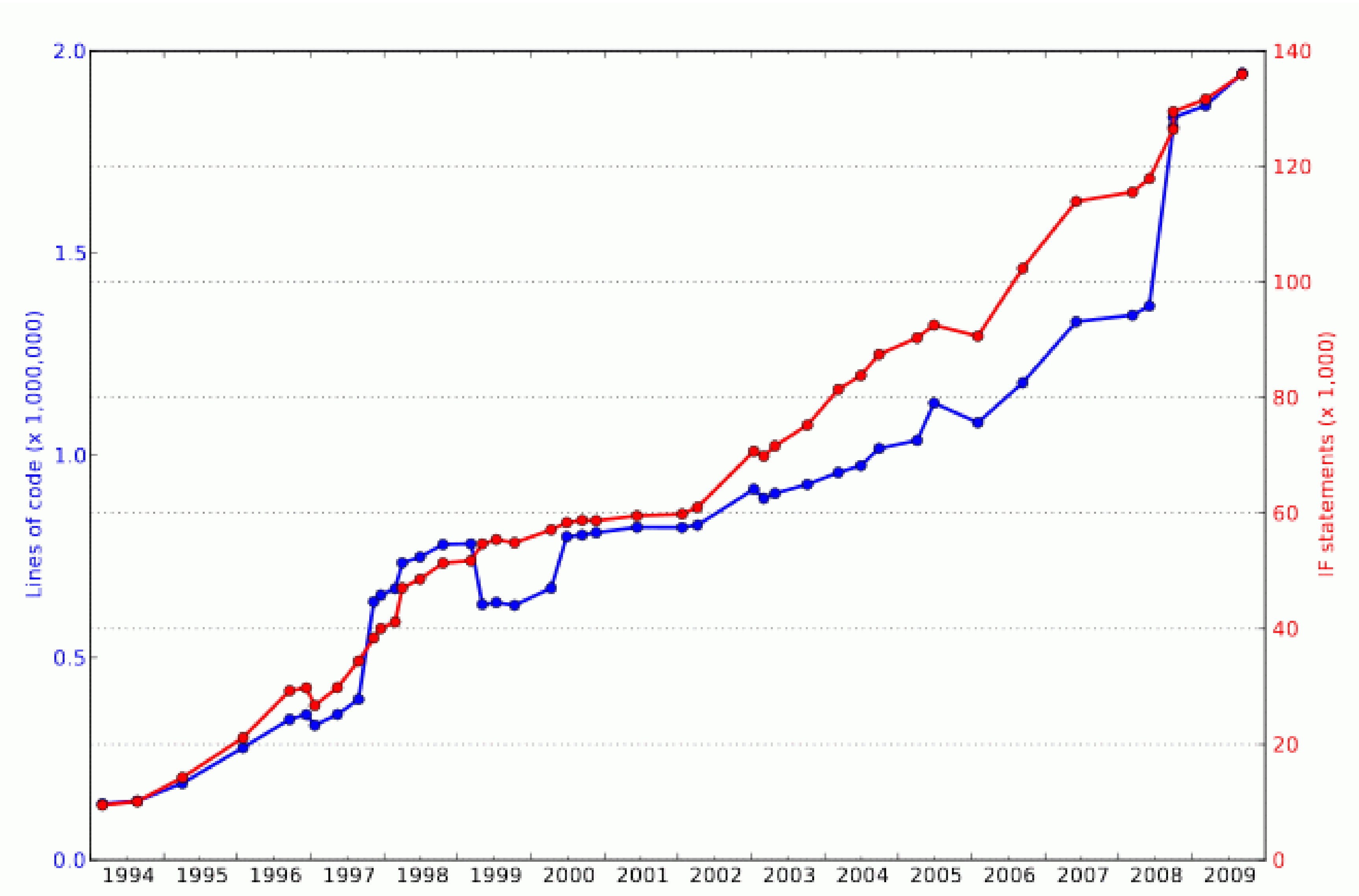
OOPS: Object Oriented Prediction System

The evolution of the IFS code in the coming 2-3 years

Why to re-arrange the IFS code ?

- The IFS code has reached a **very high level of complexity**. However, most configurations and **options are set up and defined globally from the highest control level down**.
- The **maintenance cost** has become very high.
- New cycles take longer and longer to create and debug.
- There is a **long, steep learning curve** for new scientists and visitors.
- It is becoming **a barrier to new scientific developments** such as long window weak constraints 4D-Var.
- Some algorithmic limitations:
  - Entities are not always independent => H^t R−1 H is one piece (jumble) of code.
  - The nonlinear model M can only be integrated once per execution => algorithms that require several calls to M can only be written at script level.

IFS growth: unfortunately, it's not an investment: It's growth of costs, not of benefits.



Modernizing the IFS

- Re-assess « modularity »:
  - Define self-sufficient entities that can be composed, that define the scope of their variables (avoid « bug-propagation ») => requires a careful understanding and definition of their interface
  - Avoid as much as possible global variables
  - Will require to widen the IFS coding rules and ***break the « setup/module/namelist » triplet paradigm***
- Information hiding and abstraction

The above leads to ***object-oriented programming***

Basics about OO-programming

- Organize the code around the data, not around the algorithms.
- The primary mechanism used by object-oriented languages to define and manipulate objects is the class
- Classes define the properties of objects, including:
  - The structure of their contents,
  - The visibility of these contents from outside the object,
  - The interface between the object and the outside world,
  - What happens when objects are created and destroyed.
- Operations, transformations on members of a class: methods

More basics about OO

- Encapsulation: content+scope of variables+interfaces (operators) put altogether
- Inheritance: allows more specific classes to be derived from more general ones. It allows sharing of code that is common to the derived classes.
- Polymorphism: refers to the ability to re-use a piece of code with arguments of different types.
- Abstraction: refers to the ability to write code that is independent of the detailed implementation of the objects it manipulates.

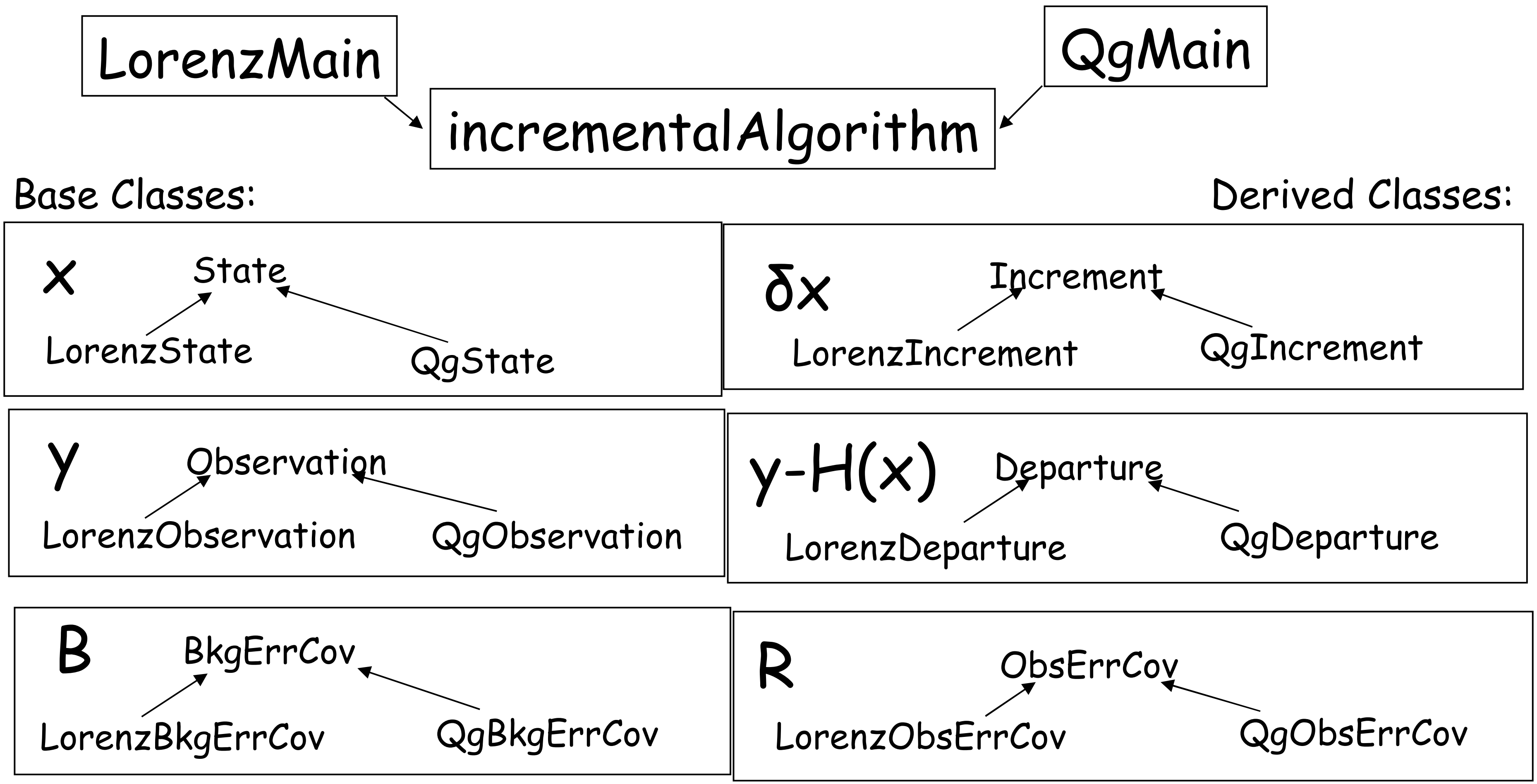
Toy OOPS

- ‘Toy’ data assimilation system to try out Object-Oriented programming for IFS

- Abstract Part
  - Code the algorithm in terms of base classes which serve to define interfaces to the data structures & functions
    - can be compiled separately

- Implementations (“Instantiation”)
  - Code Lorenz and QG models in terms of derived classes from the base classes which define data structures and functions
    - without change of abstract part

Toy OOPS implementations



Abstraction: Incremental 4D-Var

```
void incremental_4dvar( CostFunction4dvar & J,
                        ControlVariable & x,
                        Observation & y,
                        int & nouter ) {

  ChangeVariableSqrtCovar chavar(1, *J.B);
  double zj0 , zj1
  int jout;
  int ctlsize = J.B->cvecsize();
  ControlVector dx(ctlsize), gx(ctlsize),
                da(ctlsize);
  dx = 0.0;
  da = 0.0;
  Trajectory traj(J.hmop4d->get_nstep());

  for (jout=0; jout < nouter; jout ++ ) {

    Departure * ydep;
    ydep=J.get_R()->get_dep("ombg");

    Observation * yeqv;
    yeqv=y.clone("obsv");

    // Setup trajectory and departures

    ControlVariable xwork(1,x.get()[0]);
    J.get_hmop4d().nl(xwork,*yeqv,traj);
    ydep->diff(*yeqv,y);
    if (jout == 0) ydep->putdb();
    traj.set(da);
    traj.set(*ydep);
    J.settraj(traj,chavar);
    // compute inital cost and gradient
    dx = 0.0;
    J.simul(dx,gx,zj0);

    // CG Minimization
    CG(J,dx,gx,4);

    // Compute final cost and gradient
    J.simul(dx,gx,zj1);

    // Form increment and analysis
    // in physical space
    Increment * dxtmp;
    dxtmp=J.get_B()->get_inc();
    IncrementalControlVariable xinc(1,*dxtmp);
    chavar.vect2var(dx,xinc);
    *xinc.get()=*xinc.get()+*x.get();
    da = da+dx;
  }

  // Final diagnostics
  ControlVariable xwork(1,x.get()[0]);

  Observation * yeqv;
  yeqv=y.clone("obsv");
  J.get_hmop4d().nl(xwork,*yeqv,traj);
  Departure * ydep;
  ydep=J.get_R()->get_dep("oman");
  ydep->diff(*yeqv,y);
  ydep->putdb();
}
```

→IFS : a ‘F90 / C++ sandwich’

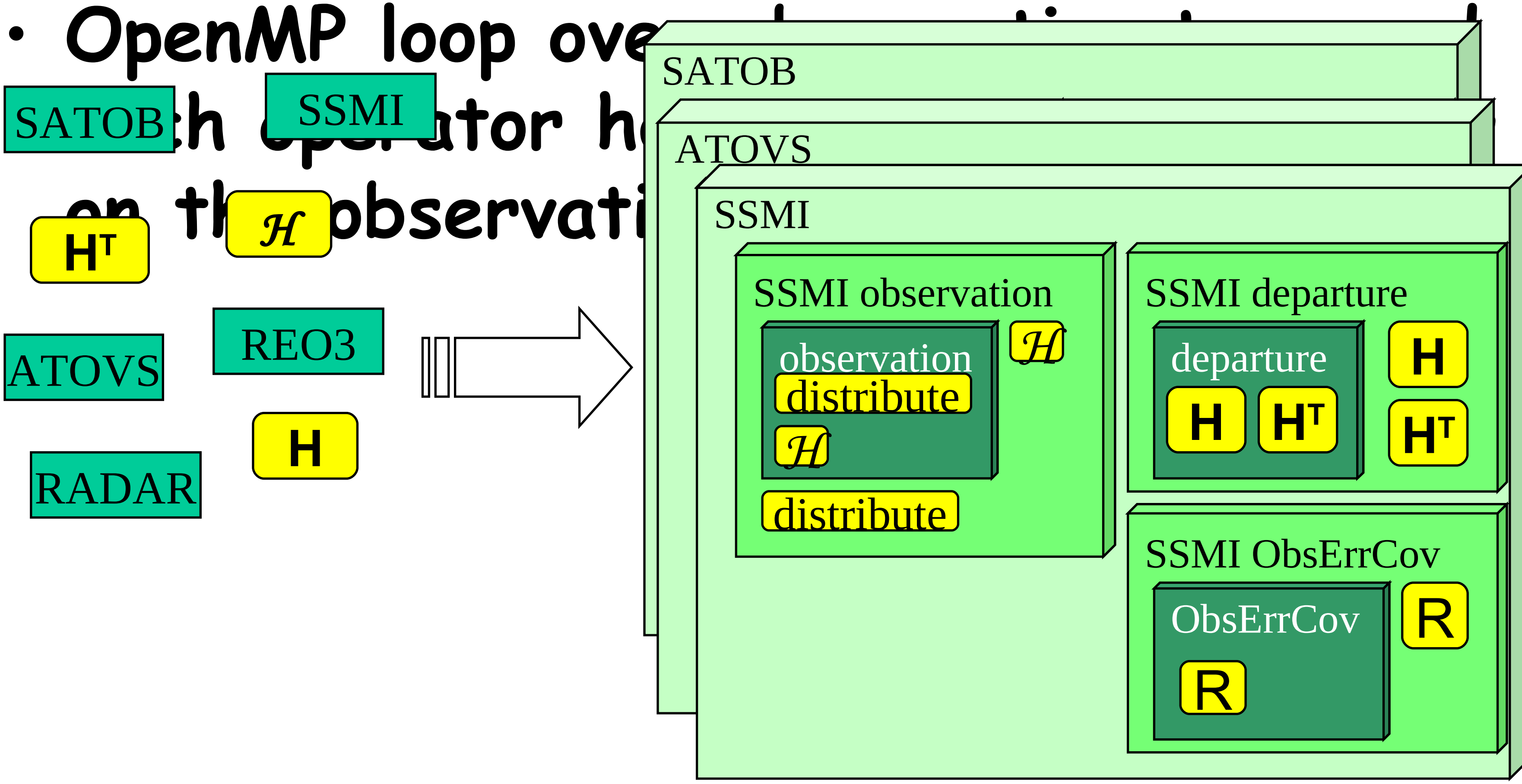
Main program: master.F90
calls mpl_init etc.

Control layer in C++ : IFS_main
Abstract part: IncrementalAlgorithm.cpp,
Stepo.cpp, Hop.cpp,
State.cpp, Increment.cpp, etc.
IFS specific: IFS_State.cpp, IFS_Increment.cpp, etc.

Computational parts in F90:
cpg.F90, callpar.F90, rttov.F90 etc.

Polymorphism

- ODB retrievals in H (hop.F90), H (hoptl.F90), H^T (hopad.F90) depend on the observation type (see ctxinitdb.F90)
- OpenMP loop ove… …ch …ator h… on th… observati…



Transition from IFS to OOPS

- The main idea is to ***keep the computational parts of the existing code and reuse them in a re-designed structure*** => this can be achieved by a top-down and bottom-up approach.
- From the top: Develop a new modern, flexible structure => ***Expand the existing toy system***.
- From the bottom: ***Move setup, namelists, data and code together***.
  – Propose new coding guidelines to that effect,
  – Everybody participates by applying it to the part of the code they know.
  – Create self-contained units of code.
- C++/F95 breaking levels: STEPO and COBS/HOP
- Put the two together: Extract self-contained parts of the IFS and plug them into OOPS => this step should be quick enough for versions not to diverge.

User considerations:

- User interface:
  - Xml files: incremental rather than full-default; no more namelists after OOPS !!!
  - Must preserve the facility to read in model parameters from a model input file (like with « FA » files; for LAM at least)
- Documentation: needs to remain at a reasonable level (clean code is « auto-documentary »)

Preliminary coding considerations:

- **At which level to split OO and standard F ?** How far should OO go into the IFS ?:
  - Start with D.A. control; assess the interior of the forecast model(s) later (NL, TL, AD) => timestep organization, externalize physics ?, phys/dyn interface, timestep 1 specificity
  - Break STEPO, make GP buffers the natural vehicle for initializing and passing model data at OO-level (spectral transforms and data become an « optional » entity within the models)
  - Later on, define grids and interpolators as Objects (both « base objects » and « instantiated objects »)
- High-level entities: ocean v/s atmospheric model, EPS and singular vector computation, EnsDA
- For « bottom-to-top » approach: write ***guidelines*** for helping developers to identify their entities

Opportunity v/s risks

- **Opportunity**:
  - Move towards a more “modern” code, sharing more concepts with other system/I.T. codes
  - Guidelines for the bottom-to-top approach will force a general and rather drastic review of the existing code (and options in the code) => some rarely used Research options may disappear !
  - Develop new configurations of the assimilation at the OO-level: NL cost function, hybrid, filters, …
  - Review of the obs operator interfacing, based on a scientific identification of the operators, while totally hiding the ODB database structuring (at the scientific level of the code)
- **Risks**:
  - Long-lasting effort that may never end in practice ?
  - Some bets are implicit: future of Fortran programming in Met’ HPC code
  - A rather tricky transition period to be organized, but the switch would be “at once” with no backward compatibility (of code) => Research developments will need to be separately adapted
  - Impact on MF and Partner’s applications: especially LAM code

Impact on MF&Harmonie applications: a first glance

- **LAM: re-organization of LELAM key**
- **MF's own 4D-VAR multi-incremental sequence:** adaptations of Arpège specifities & question of shared C++ assimilation control level
- **adaptation of Full-Pos/e927 with a well-defined interface for OOPS (2-3 possible strategies, to be further decided)** => ideally, one should be able to almost code the sequence « global forecast + e927 + LAM forecast » within one C++ piece of code
- **Keep the possibility to set up the model parameters by reading from a model input file** (923, (e)927, Arpège and LAM forecasts)
- **DFI code**: Jc-DFI but also regular D.F. initialization in global or LAM models (state vector is both input and output)
- **CANARI**
- **Other options …**

Starting efforts at MF … & partners ?

- Get familiar with OO & C++
- Implement and learn the toy
- Play with the toy
- Do your own exercise:
  - Multiple geometry, LAM versus global
  - Small ensemble
  - Extra term (« à la Jk »)
  - …
- Tutorials to come: at ECMWF (next NWP training seminar) and at MF (by EC staff, June)