Regional Cooperation for
Limited Area Modeling in Central Europe

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A short introduction to OOPS version of 3D-Var

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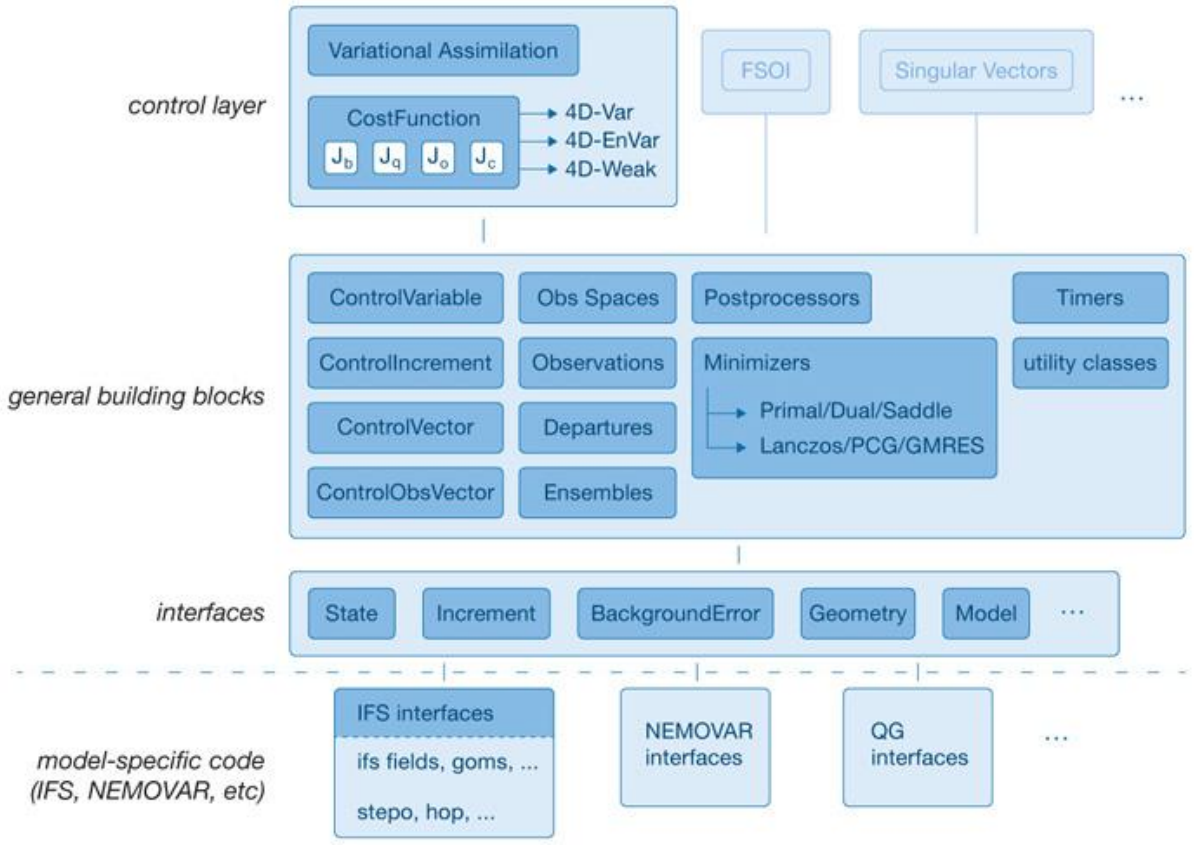
The OOPS system



Combine building blocks into an application (e.g. OOVAR)

BUILDING BLOCKS:

Exploit C++ templating mechanism

Abstract interface classes use „model“ as a template argument (at compile time) to define set of aliases to link generic classes

model specific implementation

OOPS system – code organization

- C++ code located under:
  - src/oops_src/
  - src/oopsifs
- Fortran wrappers for OOPS located in
  - src/arpifs/oops
- Entry point(s):
  - src/oopsifs/mains/ifs4dvar.cc
  - src/oopsifs/mains/ifsForecast.cc

OOPS system – main program ifs4dvar.cpp

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```
#include "ifs/IfsFortran.h"
#include "ifs/IfsTraits.h"
#include "ifs/RunIFS.h"
#include "ifs/instantiateObsErrorFactory.h"
#include "ifs/instantiateTlmFactory.h"
#include "ifs/instantiateIFSMatricesFactory.h"
#include "util/Logger.h"
#include "oops/runs/Variational.h"
#include <iostream>

using oops::Log;
using namespace::std;

int main(int argc, char ** argv) {
 ifs::mpi_init_f90();
  ifs::RunIFS run(argc, argv);
  ifs::instantiateObsErrorFactory();
  ifs::instantiateTlmFactory();
  ifs::instantiateIFSMatricesFactory();

  oops::Variational<ifs::IfsTraits> var;

  int nt = omp_get_max_threads();
  Log::info() << "Maximum number of OpenMP threads: " << nt <<
std::endl;

  int test=0;
  while ((::getenv("OOPS_TEST_DEBUG")!=0) && (test==0)) {
    sleep(1);
  }
  run.execute(var);
  return 0;
};
```

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OOPS compilation

- gmkpack, executable OOVAR
- same compiler for Fortran/C++
- eckit, fckit support libraries
  - Compilation using ecbuild – a cmake-based building system
  - compiled with MPI support

Example @belenos (based on packs by E. Arbogast, V. Vogt)
/home/gmap/mrpa/strajnarb/pack/cy46T1_oopsdev_test.IMPIIFC1805.y

Execution & namelists

- ${MPIRUN} ./OOVAR oops.json
- master configuration in oops.json:
  - provides dates, paths, file names, types of covariances and cost functions, bias correction methods etc.
- Fort.4 still read, but partly split into several topical namelists,
  - naml_bmatrix
  - naml_nonlinear_model
  - naml_oops_write_spec
  - naml_standard_geometry
  - naml_write_analysis
  - naml_linear_model
  - naml_observations_tlad
  - naml_traj_model

Oops.json config file

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```
"cost_function": {
    "window_length": "PT0H",
    "window_begin": "2019-08-18T03:00:00Z",
    "variables": "1",
    "cost_type": "3D-Var",
    "Jb": {
        "Background": {
            "state": [
                {
                    "date": "2019-08-18T03:00:00Z",
                    "term": "PT0H",
                    "ifile": "0",
                    "variables": "0",
                    "expver": "OOPS"
                }
            ],
            "ModelBias": {},
            "ObsBias": {
                "filename": "no-varbc"
            }
        },
        "Covariance": {
            "covariance": "static",
            "date": "2019-08-18T03:00:00Z",
            "namelist": "naml_bmatrix"
        },
        "ObsBiasCovariance": {
            "filename": "no-varbc"
        },
        "ModelBiasCovariance": {}
    },
```

```
"variational": {
    "iteration": [
        {
            "resolution": {
                "namelist": "naml_standard_geometry",
                "orogfile": "ICMSHOOPSINIT"
            },
            "linearmodel": {
                "version": "IfsTLM",
                "namelist": "naml_linear_model",
                "tstep": "PT1800S",
                "trajectory": {
                    "namelist": "naml_traj_model",
                    "tstep": "PT1800S"
                }
            },
            "ninner": "50",
            "gradient_norm_reduction": "0.00001"
        }
    ]
},
"minimizer": {
    "algorithm": "SQRTPLanczos"
},
```

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naml_bmatrix, naml_observations_tlad

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```
&NAMCFU
/
&NAMFPC
/
&NAMJBCODES
/
&NAMJG
  CONFIG%L3DBGERR=.TRUE.,
  CONFIG%LCLMSFCE=.TRUE.,
  CONFIG%LCORCOSU=.FALSE.,
  CONFIG%LJB_NONLINEAR_BALANCE=.FALSE.,
  CONFIG%LJB_NONLINEAR_CVHUM=.FALSE.,
  CONFIG%LJB_NONLINEAR_CVO3=.FALSE.,
  CONFIG%LJB_NONLINEAR_BALANCE_RELAX=.TRUE.,
  CONFIG%LJB_OMEGA_BALANCE_RELAX=.TRUE.,
  CONFIG%ELC=300000.,
  CONFIG%LJBBALBETA=.FALSE.,
  CONFIG%LSPFCE=.TRUE.,
  CONFIG%LSBQ_STRATOLOW=.TRUE.,
  CONFIG%LJB_OMEGA_BALANCE=.FALSE.,
  CONFIG%LRDQERR=.FALSE.,
  CONFIG%LREDNMCQ=.FALSE.,
  CONFIG%LSBLATLONG=.FALSE.,
  CONFIG%REDNMC=1.7,
/
&NAMMCUF
/
&NAMPHYDS
/
&NAMWAVELETJB
/
&NAMCOSJO
  LTC=.FALSE.,
  NOTVAR(1,1)=0,0,-1,-1,0,0,0,0,-1,-1,0,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,
  NOTVAR(1,2)=0,0,-1,-1,-1,-1,0,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,
  NOTVAR(1,3)=0,0,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,
  NOTVAR(1,4)=0,0,-1,-1,-1,-1,-1,0,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,
  NOTVAR(1,5)=0,0,-1,-1,-1,-1,0,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,0,-1,-1,-1,-1,-1,-1,-1,-1,-1,
  NOTVAR(1,6)=0,0,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,
  NOTVAR(1,7)=-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,0,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,
  NOTVAR(1,8)=-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,
  NOTVAR(1,9)=0,0,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,
  NOTVAR(1,10)=-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,
  NOTVAR(1,13)=-1,-1,-1,-1,0,-1,0,0,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,-1,0,0
&NAMDIMO
/
&NAMMKODB
/
&NAMMWAVE
/
&NAMNPROF
/
&NAMOBS
  LCAPACH=.FALSE.,
  LCACHMT=.TRUE.,
  LMKCMARPL=.FALSE.,
  L_F_SCR_WORK_TS=.FALSE.,
  LSAATOPZTD=.TRUE.,
/
&NAMSATS,
/
&NAMSCC
/
```

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OOPS sample system cy46t1 @belenos

- /home/gmap/mrpa/strajnarb/sample_3dvar_cy46t1 (prepared by Alena)
  - MASTERODB: scr_3dvar_bufr
  - OOVAR: scr_3dvar_oops_bufr
- prepares a sample bator, screening, minimization sequence on a sample CHMI domain
- Runs minimization within OOPS (binaries and namelists & help by E. Arbogast, V. Vogt, P. Brousseau)
- missing: VarBC

Minimization in cy46t1 - MASTERODB

- Congrad is the only supported minimizer
  - &NAMVAR
  - LCONGRAD = .T., // use Congrad
  - RCVGE = 0.001 // the final gradient limit where convergence is achieved
- Different behavior of outprint GREPCOST/GREPGRAD (wrong values, no outprint)
- To get the cost function:

  grep „Estimated quadratic cost“

Minimization in cy46t1 - OOPS

- OOVAR writes output to stderr and can be redirected to a file
- Jb: grep for quadratic cost function: Jb

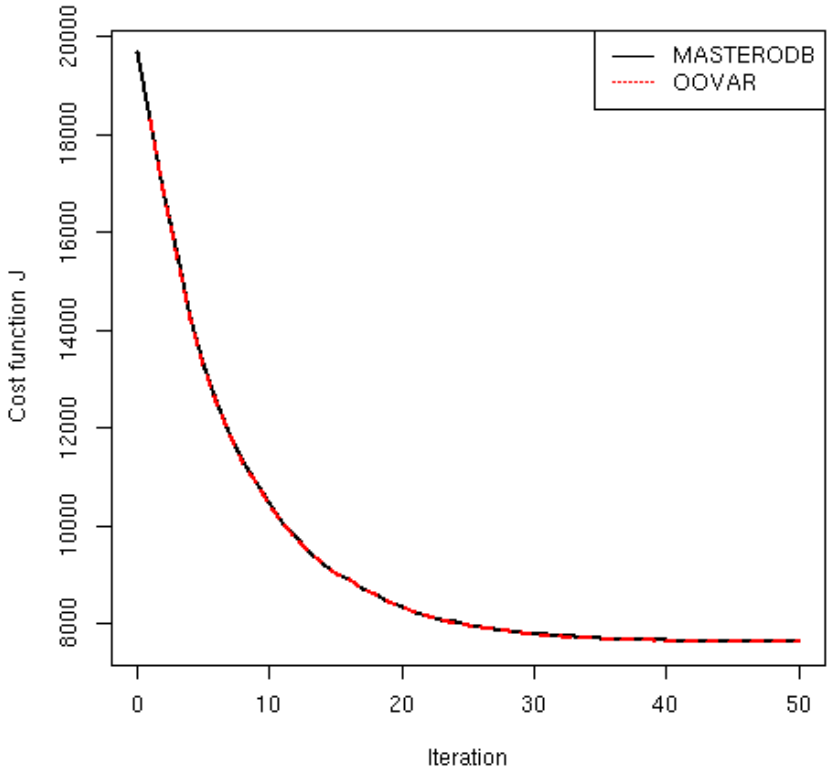
```
Quadratic cost function: Jb  ( 1) = 1.855175384541039
Quadratic cost function: Jb  ( 2) = 11.89237977546805
Quadratic cost function: Jb  ( 3) = 34.58734426451959
Quadratic cost function: Jb  ( 4) = 70.39856028354453
```

- Jo: grep for quadratic cost function: JoJc (negative , expressed as reduction from initial value!)

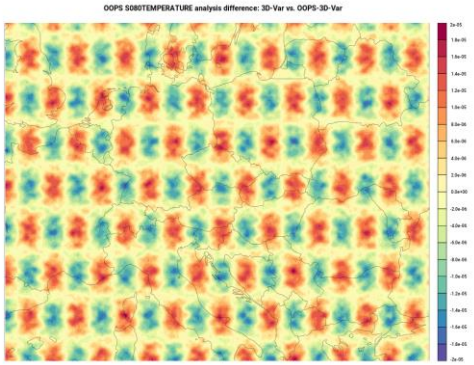
```
Quadratic cost function: JoJc( 1) = -1269.701876790282
Quadratic cost function: JoJc( 2) = -2738.282763138683
Quadratic cost function: JoJc( 3) = -4120.68322801974
Quadratic cost function: JoJc( 4) = -5380.727819272131
```

- J=Jo(iter=0) + Jb + JoJc

Cost function decrease (Congrad)



Increments



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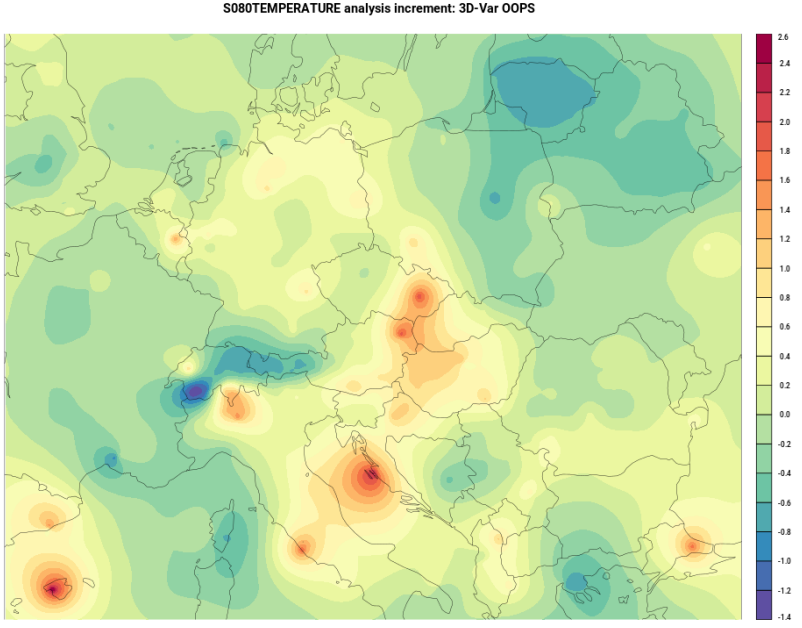
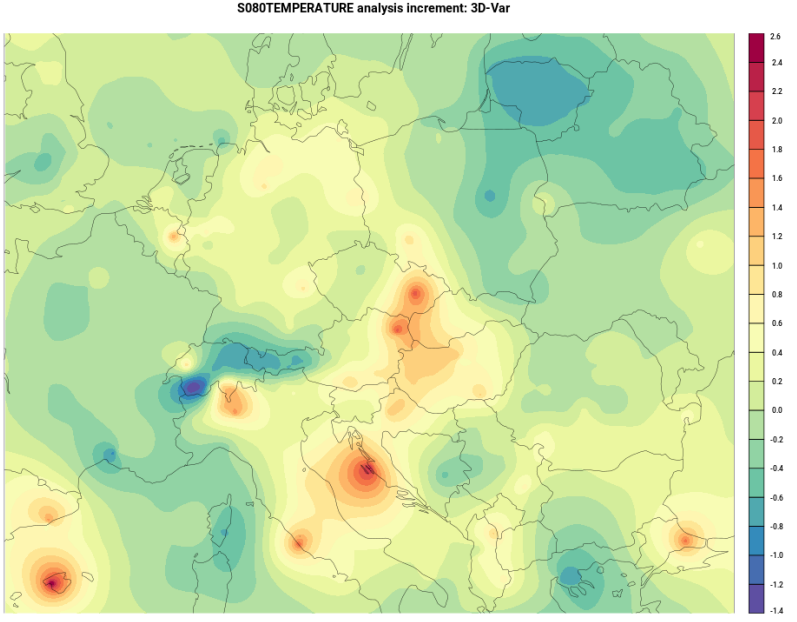
OOPS



MASTERODB



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Running/porting OOPS/OOVAR to ARSO

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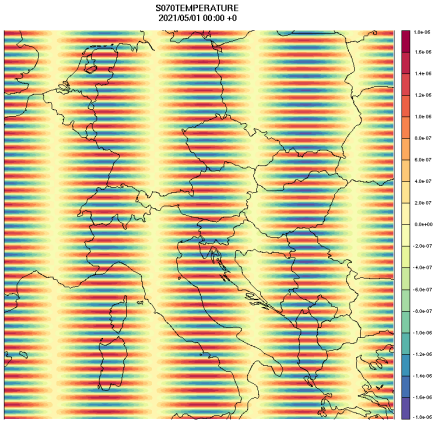
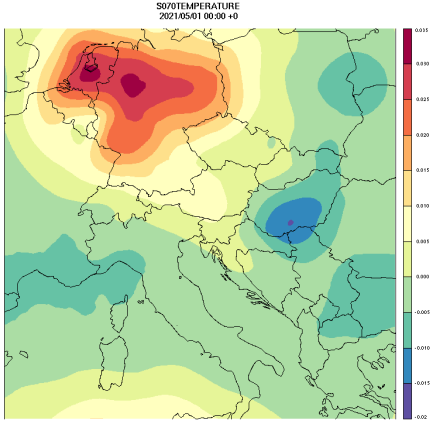
- On local ARSO HPC (SGI):
  - compiled via gmkpack and intel_fc/16.2
  - eckit (1.16.1), fckit (0.9.2)
  - Small adaptations: error_covariance_3D-mod.F90 - inconsistent use of pointer/target declarations
- Comparison done for most obstypes: synop, aircraft, temp, radiances (except Seviri) without VarBC, scatterometers
- OPERA radar refl. – non-negligible differences observed (~0.01 K, ~0.01 g/kg)
- MF bugfixes:
  - Correction of negative humidity after applying the increment
  - LREPROOPS, LNEIGE=.F.
- Small remaining difference with ALARO model and screen level observations (T2m, H2m)
- OOVAR somewhat faster (~10 %) than MASTERODB
- Not yet working with ODB_IO_METHOD=4



10^{-8} K



10^{-2} K

More info:

- More info on the sample OOPS 3D-var comparison experiment @belenos on LACE forum:

https://www.rclace.eu/forum/viewtopic.php?f=30&t=700

Next steps

- Resolve remaining issue with T2m,HU2m
- Follow next prototypes (cy48) to include screening, varBC,..
- Technically test the EnVar algorithm

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Thank you for your attention.

Acknowledgement: MF OOPS team

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