OOPS as a common framework for Research and Operations

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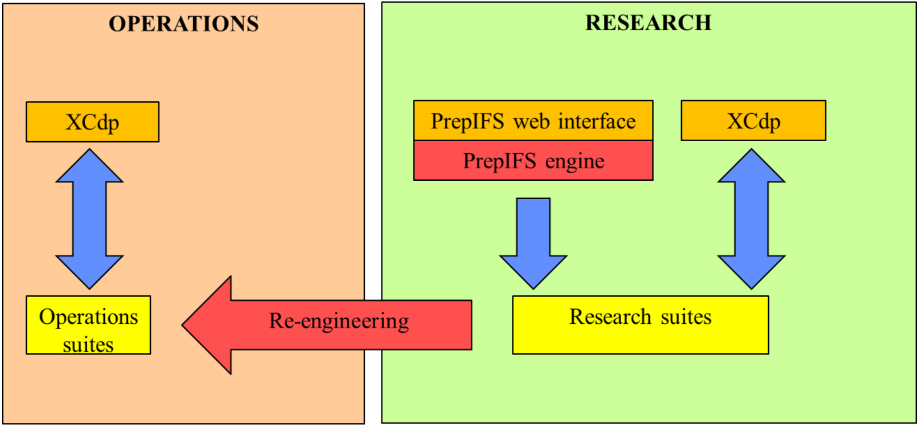
Introduction

- Forecasting systems are becoming better but more and more complex:
  - Single analysis and single forecast,
  - Ensemble forecasts,
  - Flow dependent background errors from Ensemble Data Assimilation.
- Transition between Research and Operations is currently based on common SMS/ecFlow framework
  - Research suites are generated by PrepIFS as part of an experiment
  - Research experiments are re-engineered into (e-) suites for Operations
  - Transition is getting more complex and time consuming with increased complexity of suites
- Complexity will keep increasing in the future:
  - Long overlapping 4D-Var windows,
  - Hybrid data assimilation (EDA and DA coupled two-ways),
  - Coupled ocean-atmosphere models...

From Research to Operations



The OOPS Project

- The complexity of the IFS code is more and more difficult to manage.
- New scientific and technical (scalability) developments require a more flexible data assimilation system.
- We have started re-factoring the IFS into the Object-Oriented Prediction System (OOPS).
- The scripts and suite definitions will be affected:
  - The outer loop of 4D-Var will be moved inside the C++ layer,
  - The Fortran `namalists` will have to be replaced, at least partially, by more flexible technology (XML, JSON).
- The suite definitions and scripts define the application at the highest level.
  - We should think of them as part of the "system".

OOPS Suites and Scripts

- Like the Fortran code, the suite definitions and scripts have become more and more difficult to maintain and develop.

- Three levels are mixed together in the suite definitions and scripts:
  - The model (IFS, NEMO...), although the top level of OOPS is generic,
  - The "scientifc" description of the cycling,
  - The workflow "technical" specificity (SMS or ecflow).

- The three levels could be, and should be, isolated from each other.

Example: Analysis and forecast cycling

```
dassim = oops4dvar(userConfig)
Bmatrix = mars.retrieve(Bconfig)

for date in daterange(fcycle, lcycle, step):
  obs = mars.retrieve(date, obsConf)
  background = mars.retrieve( fc(date-step, step) )

  an = dassim.run(obs, background, Bmatrix)

  fc = forecast.run(an)

  mars.archive(an)
  mars.archive(fc)
```

- The cycling is independent of the model.

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- The cycling is independent of the model.
- **B** can be flow dependent.

Example: Analysis and forecast cycling

```
# Initializations not shown...
for date in daterange(fcycle, lcycle, step):
  edate = date-step
  for member in EDA:
    edaobs = perturb(obs)
    edabg = mars.retrieve( edafc[member](edate-step, step) )
    edafc[member] = dacycle.run(edaobs, edabg, Bmatrix, config)

  Bmatrix = Covariance.estimate( edafc )

  obs = mars.retrieve(date, obsConf)
  background = mars.retrieve( fc(date-step, step) )
  dacycle.run(obs, background, Bmatrix, daConfig)
```

- The cycling is independent of the model.
- **B** can be flow dependent.
- **B** can be computed on the fly by an EDA system.

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- The cycling is independent of the model.
- **B** can be flow dependent.
- **B** can be computed on the fly by an EDA system.
- On its own, the cycling algorithm is relatively easy to describe.

Abstracting the workflow

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```

- On its own, the cycling algorithm is relatively easy to describe.
- And there is enough information to generate all the triggers!
- Why are we writing them by hand?
  - We are duplicating information.
  - It is difficult to maintain and modify.
  - The risk of bugs is increased.

Prototype: PyOOPS

- A prototype has been implemented in python to test the approach.
- The system is organised around tasks whose input and outputs are metadata objects.
- The metadata objects are also used by the workflow to generate the triggers.

```
class ForecastModel(Task):

  def constructor(self):
    self.add_input('init')
    self.add_output('fc')
    self.add_variable('length')
    self.add_variable('steps')

  def execute(self):
    analysis = self.input('init')
    forecast = MetaData( type = 'fc',
                         date = analysis.valid_time,
                         steps = self.variable('steps'),
                         window_end = analysis.window_end )

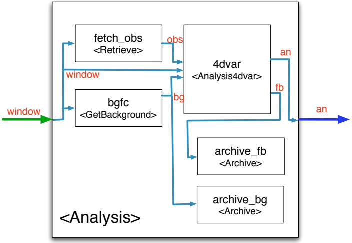
    """ code here that configures and executes the model """

    self.set_output('fc', forecast )
```

Prototype: 4D-Var Analysis Cycle

Tasks are used as building blocks to compose complex structures

Analysis example




```
class Analysis(CompositeTask):

  def constructor(self):
    self.add_input('window')
    self.add_output('an')

    self.fetch_obs
= self.add_task( Retrieve('fetch_obs') )
    self.bgfc
= self.add_task( GetBackground('bgfc') )
    self.an4dvar
= self.add_task( Analysis4dvar('4dvar') )
    self.archive_bg = self.add_task( Archive('archive_bg') )
    self.archive_fb = self.add_task( Archive('archive_fb') )

  def compose(self):
    window = self.input('window')

    bg = self.bgfc(window=window)
    obs = self.fetchobs(window=window)
    (an,fb) = self.an4dvar(bg=bg, obs=obs, window=window)
    self.archive_bg(data=bg)
    self.archive_fb(data=fb)

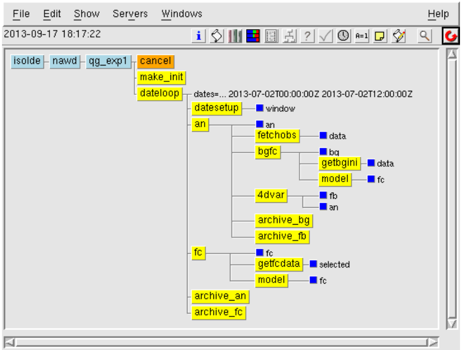
    self.set_output('an', an)

...

datesetup = DateSetup('datesetup')
analysis = Analysis('analysis')

window = datesetup(date='2013-07-02T00:00:00Z')
an = analysis(window=window)
```

Prototype with QG toy-model and ecFlow




```
class Analysis(CompositeTask):

  def compose(self):
    window = self.input('window')

    bg = self.bgfc(window=window)
    obs = self.fetchobs(window=window)
    (an,fb) = self.an4dvar(bg=bg, obs=obs,
                           window=window)
    self.archive_bg(data=bg)
    self.archive_fb(data=fb)

    self.set_output('an', an)
```

- Note that GetBackground is a composite task as well!
- The workflow (ecFlow) is abtracted from the suite definition.
  - Should we call it ezFlow?

Abstracting the workflow

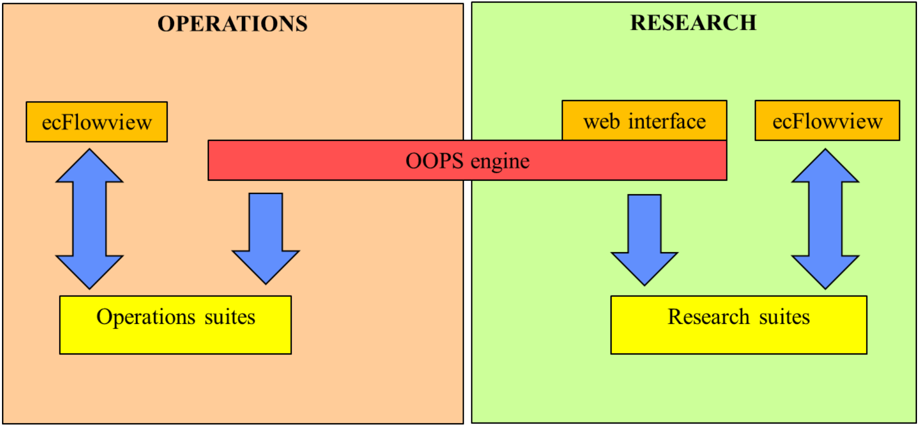
- Scientists should think as if writing any algorithm.

- Executing the (python) code generates the suite (and scripts).
  - Each component can generate a single task or a family.
  - The workflow is chosen when running the python program.
  - A simple workflow can run the tasks on the fly (toy system on a laptop).

- The workflow can be specialized for Operations to control when the observations are retrieved and the analysis cycle started.

- Everything else is the same: More can be shared between RD and OD.

Future Framework



OOPS provides a common generator for both Research and Operations suites

Summary

- The OOPS prototype is working in research mode
  - with toy models (Lorenz, QG),
  - for (simple) forecast experiments with the IFS.
- Next steps:
  - port all suites to the new framework (the bulk of the work is in identifying all the inputs and outputs of each task in the current system),
  - implement the OD mode.
- Potential:
  - for RD to express complex algorithms in a sustainable way,
  - for OD to implement these algorithm faster and with less risk of errors.