Coupled modelling at ECMWF: Waves, Ocean and Chemistry.

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Overview

- Our atmospheric model is IFS (Integrated Forecasting System).
- Different models coupled to the IFS at ECMWF:
  - Chemical tracer models for the GEMS project (and followup).
  - Wave model (WAM).
  - Ocean models:
    - Present operational system with HOPE.
    - Research system using NEMO for future.
- Plans for each of these coupled model system.
- Ideas for OASIS developments.
- Question to the audience: How many different couplers does ECMWF at present use in either operations or research?

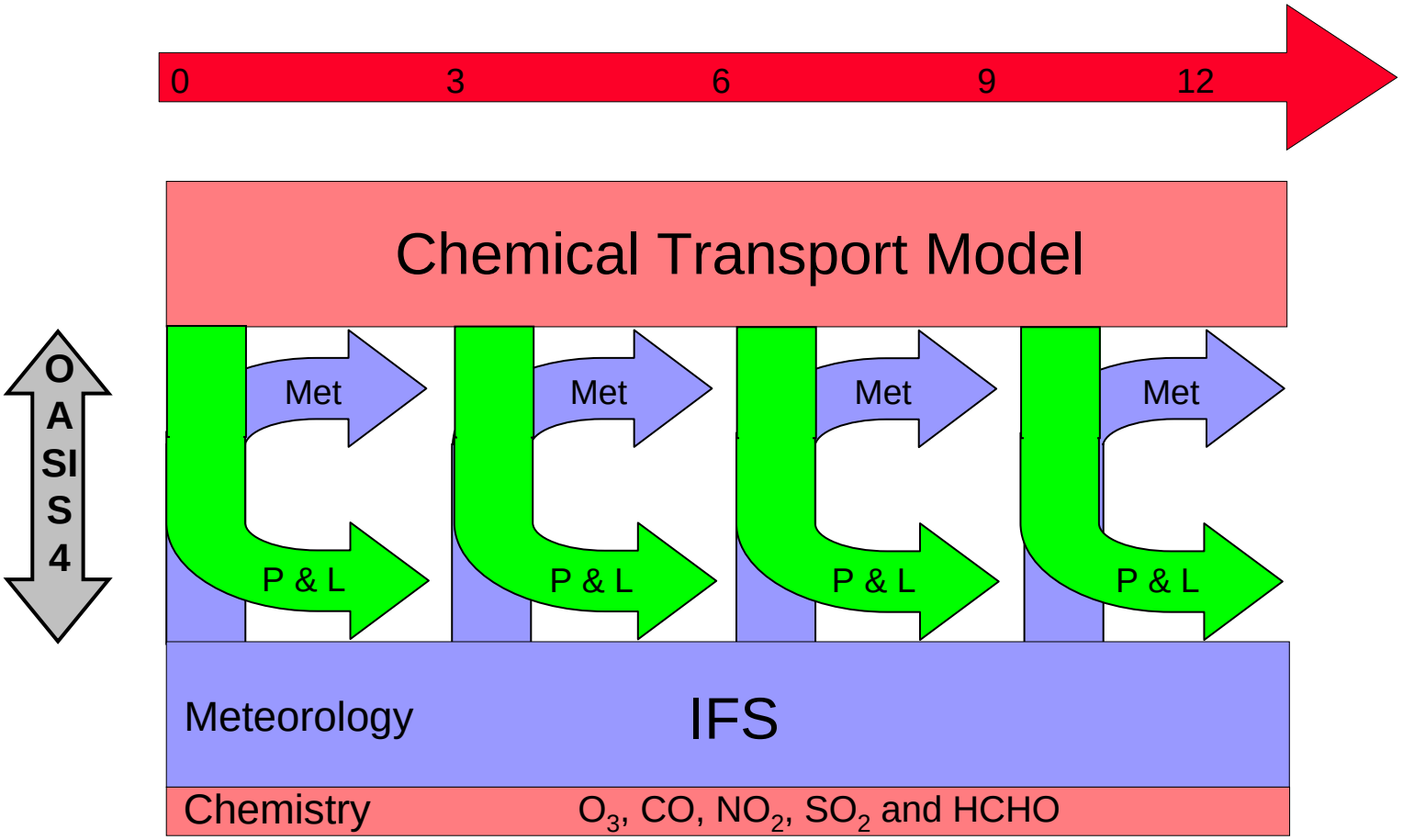
Modelling and Assimilation (satellite obs.) of atmospheric composition in GEMS

- Exploit existing IFS data assimilation capability without direct integration of chemistry, deposition, emission injection integration
- Build OASIS4 coupled system that relies on existing CTM
- Candidate CTM:
  - MOZART
  - TM5
  - MOCAGE (10 day test run)
- Applications (see http://gems.ecmwf.int)
  - 2003-2007 global re-analysis of CO and O3
  - NRT forecast since 2007 with and without assimilation
  - Test for SO2, HCHO and NOx

GEMS coupled system IFS-CTM

- IFS (reduced Gaussian grid) to CTM (lat-lon):
  - Up to 8 3D-grid-point meteorological fields (u,v,T,q, convective mass fluxes)
  - Up to 20 2D-grid-point surface fields
  - Un-gridded spectral fields (TM5 only)
- CTM to IFS:
  - 18 3D-grid-point fields of concentrations, production and loss rate of NOx, O3, SO2, O3 and HCHO
- No vertical interpolation by OASIS4 (… too difficult for out-of-the-box software ?)
- Exchange frequency one hour
- Experiments are sequence of many short 12/15/24 h runs

Coupled IFS-CTM reactive-gas forecasting system



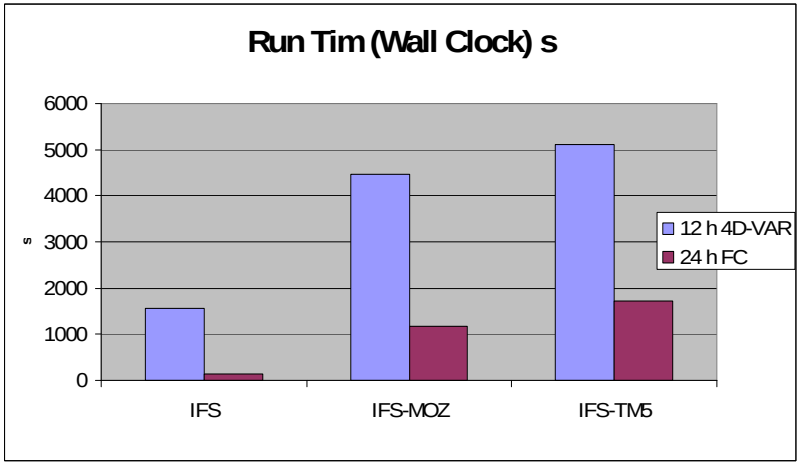
3 CTMs: MOCAGE, MOZART and TM5

MOZART chosen for main production runs

Run Time Performance

•Coupled system is scientifically sound but it is less efficient than a fully integrated C-IFS would be.

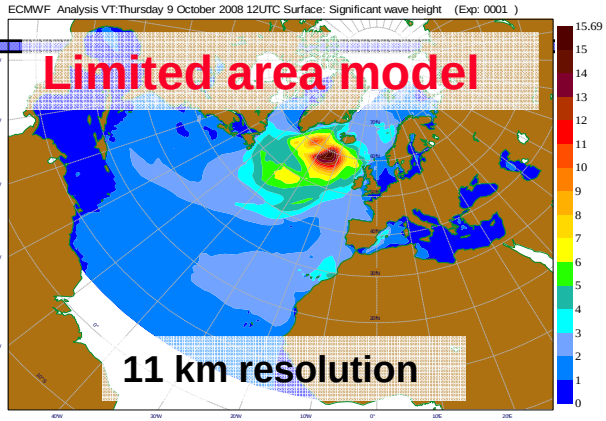
- CTM are very much slower than IFS and do not scale so well
- Coupling overhead (initialisation 6%/3% per 12/24 h run)
- C-IFS would have no duplication of transport in CTM and IFS and could benefit from IFS sophisticated parallelisation
- Long term plan to fully integrate Chemistry in IFS but operational production will be based on coupled system in the next years (MACC)

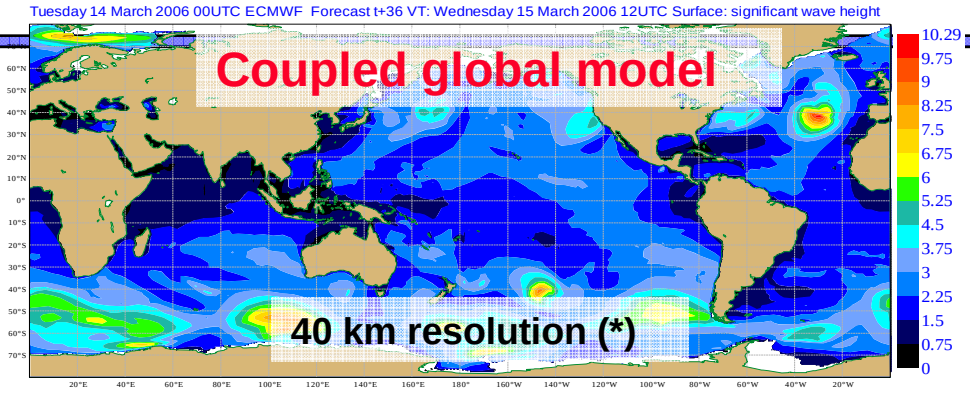


Some experiences from ECMWF-GEMS

- Good …
  - OASIS4 coupled IFS-CTM could be successfully be applied in routinely forecast and re-analysis
  - OASIS4 allowed flexibility in the choice of the coupled CTM
  - Personal support
- Not so good yet …as OASIS4 is work in progress
  - Interpolation artefacts but no good user control on interpolation method
  - Too complex control structure (smioc) and code for user debugging
  - Repetition of grid search for each field
  - Missing available sanity check on grid to grid relation

ECMWF Wave Model:



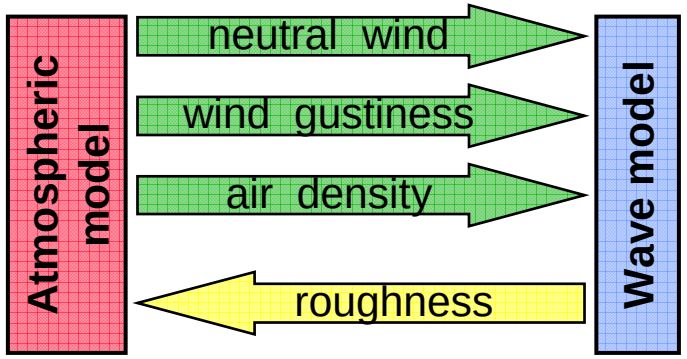


Forced by wind fields from the IFS.

In all configurations:

- **Data assimilation of ENVISAT and Jason altimeter wave heights and ENVISAT ASAR spectra.**
- **Wind vectors assimilation from ERS-2, QuikScat, Ascat**
- **Two daily forecasts.**
- **Output of integrated wave parameters and 2d wave spectra (In next operational change: the u and v component of the surface Stokes drift)**

2 –way coupled to the IFS:



Integral part of the forecasting system:

- **Deterministic (*)**
- **EPS**
- **Seasonal**
- **Re-analysis**

Technical aspects of the IFS-WAM coupling

- WAM is active for all operational forecasts done by ECMWF (medium range/monthly/seasonal).
- WAM runs on a irregular lat/lon grid with the land points removed.
- In coupled IFS-WAM mode the wave model is just a subroutine call in the IFS time stepping.
  - No external coupler used.
  - Regridding from the IFS reduced Gaussian grid to the WAM grid is done as part of this subroutine call.
  - The same number of MPI tasks and OpenMP threads are used both by IFS and WAM.
  - WAM has to scale for this to be optimal.
- A standalone version of WAM is maintained for the limited area version and testing.
- No plans to change the basic coupling procedure of WAM.

Coupling of IFS and HOPE.

- HOPE is shared memory (OpenMP) parallel only.
- HOPE and IFS are coupled using OASIS2 via files.
- IFS-OASIS2-HOPE is used for:
  - Operational seasonal forecasting (system 3).
  - As part of the EPS system:
    - Once per day (0Z) from day 10 to 15.
    - Once per week (Thursday 0Z) from day 10 to 32 for monthly forecasting.
- Fluxes from the IFS is sent to HOPE.
- SST and ice is sent from HOPE to the IFS.
- An uncoupled version of HOPE is used for an OI based assimilation system.
- Not actively developed anymore. Maintained for operations.

Coupling of IFS and NEMO.

- NEMO is going to replace HOPE for seasonal forecasting (system 4) and EPS/Monthly.
  - Other options for EPS/Monthly like a mixed layer model are being explored.
- Coupling is done with OASIS3 via MPI1.
  - Early attempts with OASIS4 were done, but at the time there were serious problems with the interpolation between the tri-polar ORCA grids and the reduced Gaussian grid of the atmosphere.
- Initially the same coupling strategy as with IFS-HOPE.
- LIM3 will probably be used in the future.
- An uncoupled version on NEMO is used for the outer loop of the new VAR based assimilation system (NEMOVAR).

Short term plans for IFS-OASIS3-NEMO.

- Operational target for the system 4 seasonal prediction system is around mid 2010. Dependencies:
  - A cycle of the IFS with good performance for seasonal forecasting.
  - NEMOVAR assimilation system operational in real time.
  - A completed set of coupled IFS-NEMO hindcasts for calibration.
  - NEMOVAR reanalysis ready for the IFS-NEMO hindcasts
- The EPS system will probably use the IFS-OASIS3-NEMO system earlier than system 4.
  - Hindcasts for a given date are done a week in advance of the nominal initial forecast time.
  - Still need ocean initial conditions both for the hindcasts and the forecasts.

Long term plans for IFS/NEMO (post S4).

- After system 4 we are planning to review the coupled IFS-NEMO system and most likely change the coupler.
  - OASIS4?
  - IFS-WAM like single executable?
    - Can we use the regridding from OASIS{3,4}?
  - Other?
- No need for easy switching of ocean model (or atmosphere model for that matter).
  - NEMO is going to be our model of choice for decades.
- Aim for long term solution.
- Internal discussions on the best strategy are ongoing.
- Efficiency and simplicity are the two main considerations.

Shortcomings of the MPMD execution model used by OASIS.

- Based on IBM AIX powerX experiences.
- Basic concepts (powerX):
  - *N* nodes with *M* chips/node with *L* cores/chip and *K* SMT threads/core.
- Running *K* MPI tasks on a core is typically not working well.
  - SMT threads are not really physical CPU's.
  - But OpenMP works nicely.
- The IBM loadleveler queuing system likes to schedule jobs such that each job requires *n* nodes, *m* tasks per node and *l* threads per task.
  - Different number of threads for different executables is possible with loadleveler, but it is quite cumbersome.
- I expect this to be a generic problem with the MPMD execution model.

OASIS developments I would like see.

- Decoupling of the grid search and the interpolation weights computation.
  - If you know your *n* nearest points on the source grid for each point of target grid the computation of the weights are easy.
  - Grid search can be expensive, but only needs to be done once with this scheme (assume that *n* is sufficient).
  - Grid search is trivial parallel, so as long as you have sufficient resources available it can be done fast.
- Support for single executable.
  - Time stepping loop managed by OASIS?
  - Time stepping loop managed by the user models with callable interpolation routines?
  - Standalone regridding?

Conclusions

- OASIS is a valuable tool for ECMWF:
  - OASIS2 has been used for operational coupled ocean-atmosphere seasonal and monthly forecasting for many years.
    - Soon this system will be retired, but it have served us well so far;-).
  - OASIS4 has been a valuable tool to get the IFS-CTM system up and running for GEMS and will be used for the operational GEMS system in the years to come.
    - Long term plans are being considered.
  - OASIS3 has been a valuable tool to get the IFS-NEMO system up and running and will be used for the operational seasonal and EPS forecast in the years to come.
    - Long term plans are being considered.
- The answer is 4 (OASIS2, OASIS3, OASIS4 and integrated IFS-WAM).