Single Precision IFS

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ECMWF

Single precision at ECMWF

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  - More optimal way of using computing resources - higher precision used only where unavoidable.
  - Target is to achieve better computing performance through memory access reduction without compromising the model skill.
  - Testing tool (potential to identify precision sensitive or bad codes).

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- Handed over to ECMWF (2014)
  - Early EPS tests with single precision OpenIFS under prepIFS.
  - Implemented to full IFS CY41R2 allowing both precisions with the unique code (Wam, Nemo, ...).
  - More code protection & additional scientific issues (VFE, SW radiation, PBL height & mass flux, surface scheme), technical development (Dr.Hook) $\Rightarrow$ safe performance up to T_L399 guaranteed.
  - Explored in EPS (uncoupled T_L399) - additional technical complexity (mixed DP & SP jobs), more fixes (stochastic physics).
  - Recognized as serious activity for an operational implementation & new staff position (2016)
  - Seamless compilation of SP libraries (CY43R1).
  - *SP option available under prepIFS for FC & EPS experiments (CY45R1).*

Single precision crash course

- Compiling with new CPP directive "SINGLE" and no automatic real promotions like: *-fdefault-real-8 ...*
  Note: the CPP directive only affects *xrd/module/parkind1.F90* where it redefines the **JPRB** parameter.
- Additional kind created **JPRD** for those parameters which should stay always as **REAL=8**:
  system calls (USER_CLOCK), binary files handling, calls to exclusively DP libraries...
- **Once the executable is compiled the precision is fully determined.**

Compliant coding with single precision

- Avoid hard coded thresholds or constants:

  ZEPS = 1.E-14_JPRB, **IF (ZLBDA(JROF,JLEV) $<$ 1.0E120_JPRB) THEN**

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  DLOG $\rightarrow$ **LOG, DCOS** $\rightarrow$ **COS, DATAN** $\rightarrow$ **ATAN, ...**
- Stay with your computation close to 1.
  arp/setup/sucst.F90 & surf/module/suscst_mod.F90:
  RSIGMA=2.0_JPRB * RPI5 * RKBOL**4 /(15._JPRB* RCLUM**2 * RHPLA**3)**
  replaced by:
  RSIGMA=2.0_JPRB * RPI5 * (RKBOL/RHPLA)**3 * RKBOL/(15._JPRB* RCLUM**2)**

New code to accommodate single precision

- Interface routines to MPI (**MPL_SEND_REAL4_SCALAR,...**)
- Reintroduced interface to both single and double precision Blas/Lapack routines

```
IF (JPRB == JPRD) THEN
  CALL DGEMM(...
ELSE
  CALL SGEMM(...
ENDIF
```

- Interface to binary profiles in radiation
- Interface to ODB and Nemo (so far exclusively double precision)

All tests based on **JPRB==JPRD** check.

Scientific issues

- Enhanced security for variables outside ($\pm 2^{-126} \approx 1.1755E-38$, $\pm 2^{127} \approx 1.7014E+38$):

  ZEPSILON = 100._JPRB * EPSILON(ZEPSILON)

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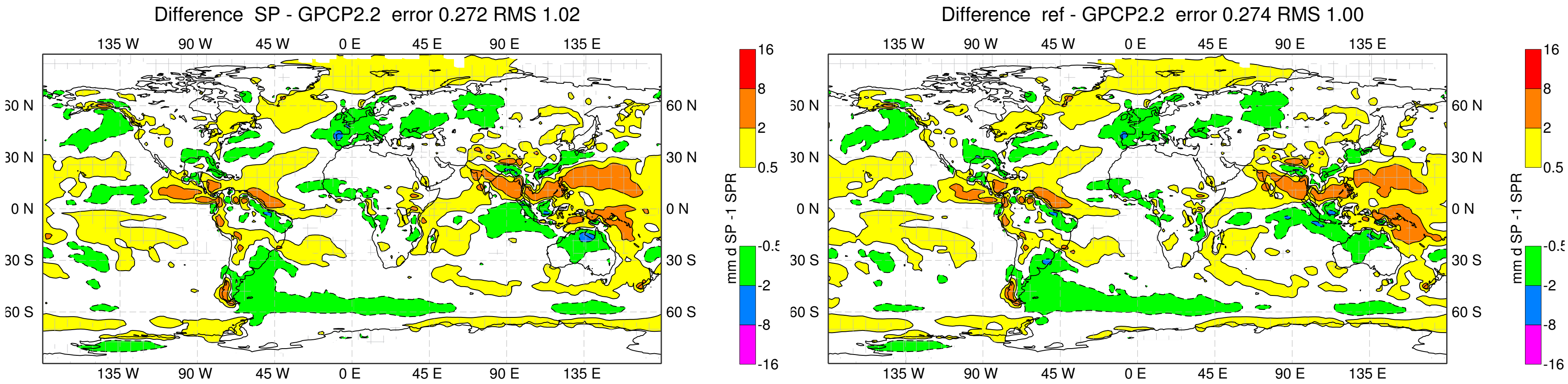
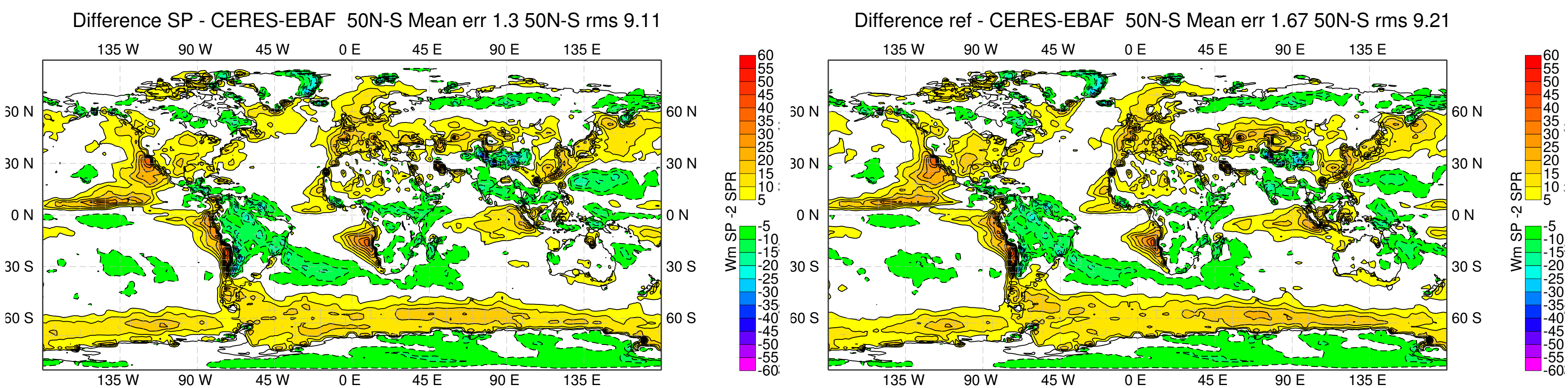
- Galerkin methods: Legendre transforms and VFE integral operator setup
- Testing tool for TL code.
- Ongoing process: identify potential and precision sensitive problems (massive data averaging, matrix inversion, quadratic equations,...) $\Rightarrow$ ideally to be rewritten in a more robust way.

Climate runs - I.

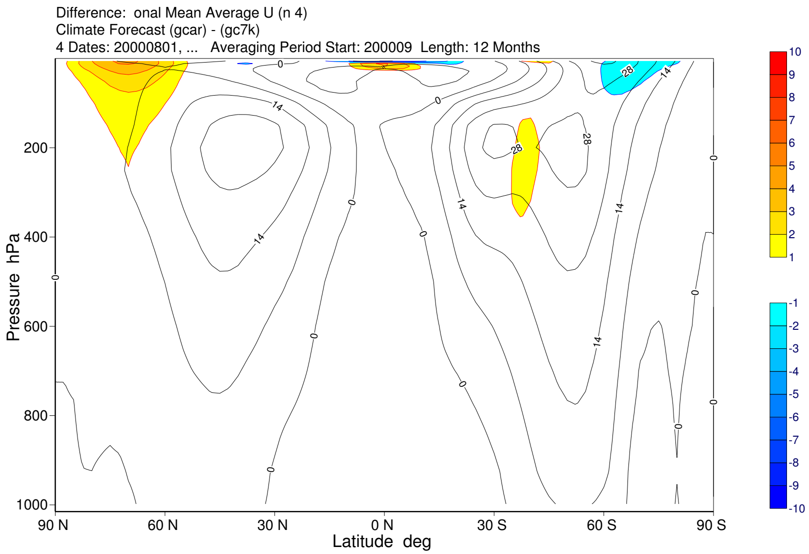


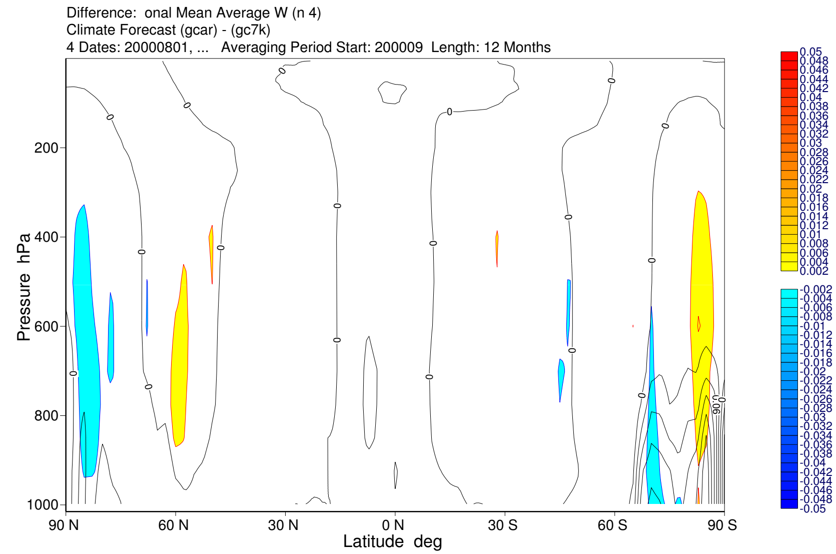
precipitation

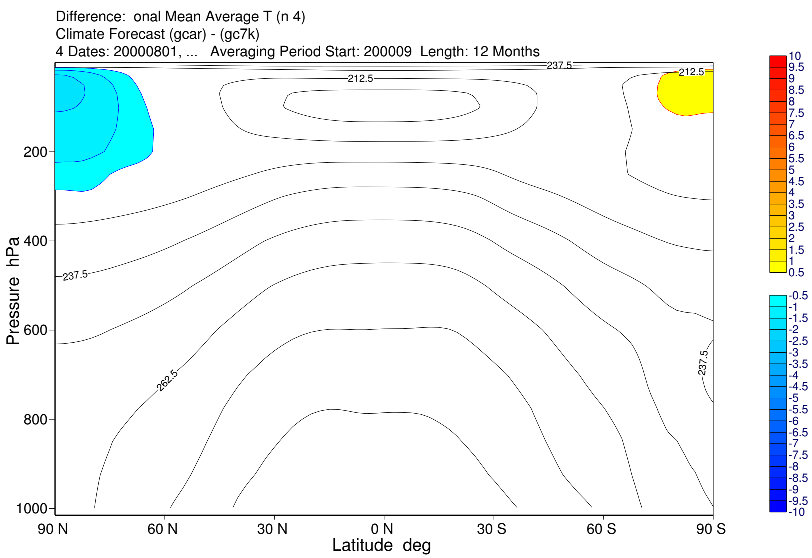


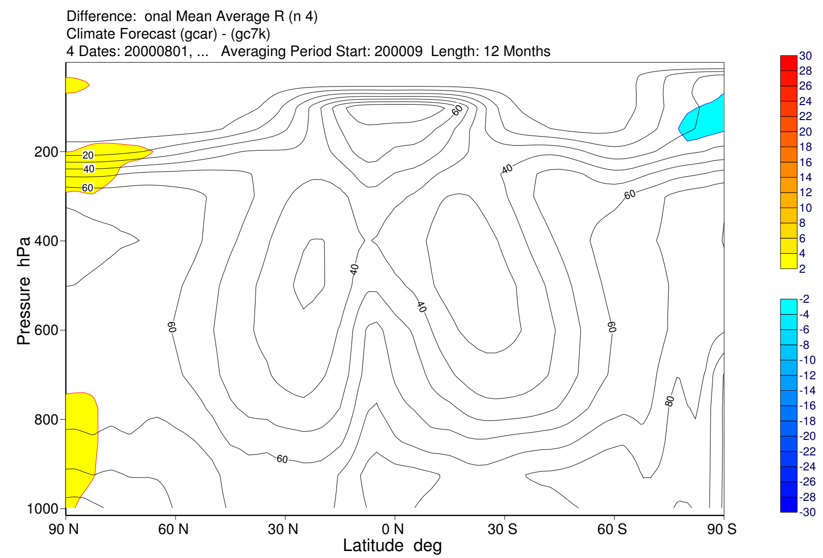
TOA sw

Climate runs - II.

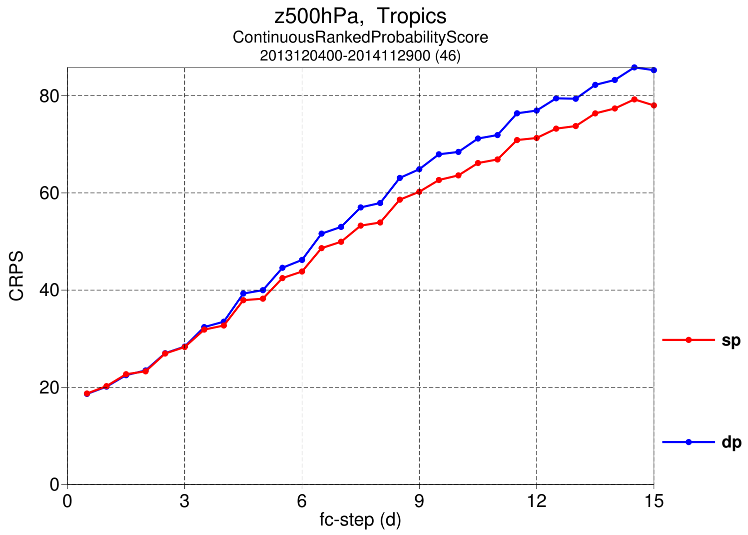


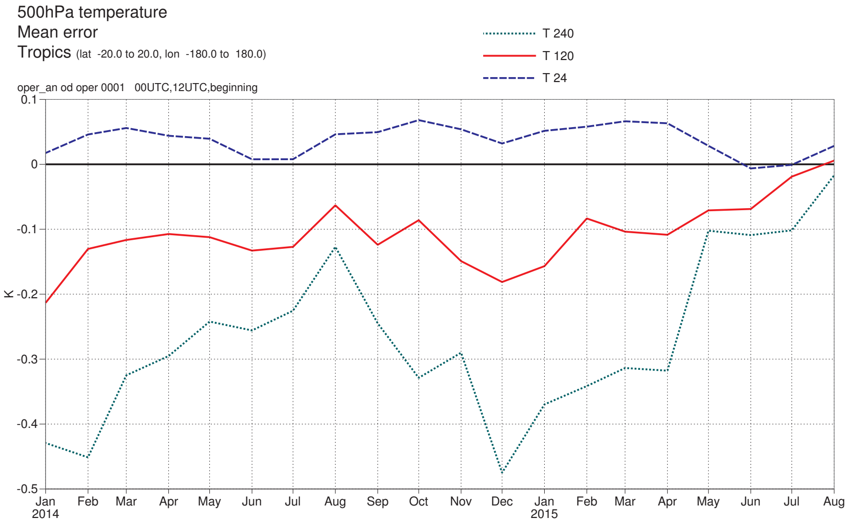






Uncoupled T399 EPS system





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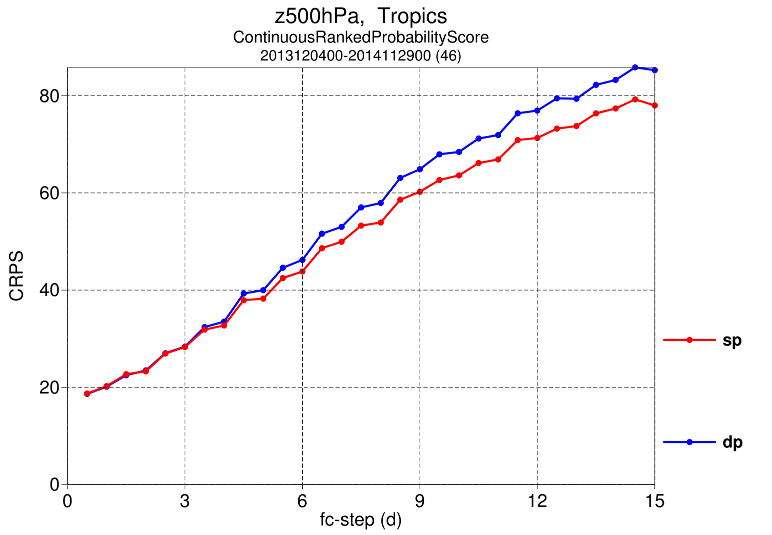
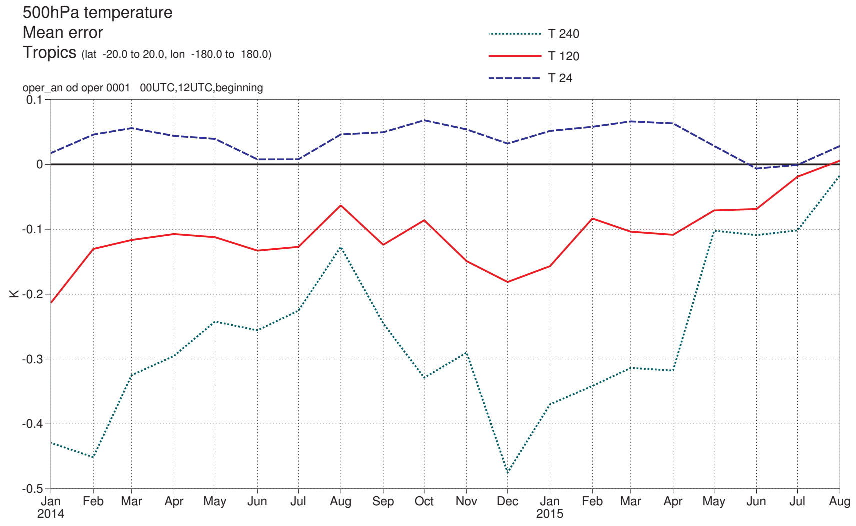
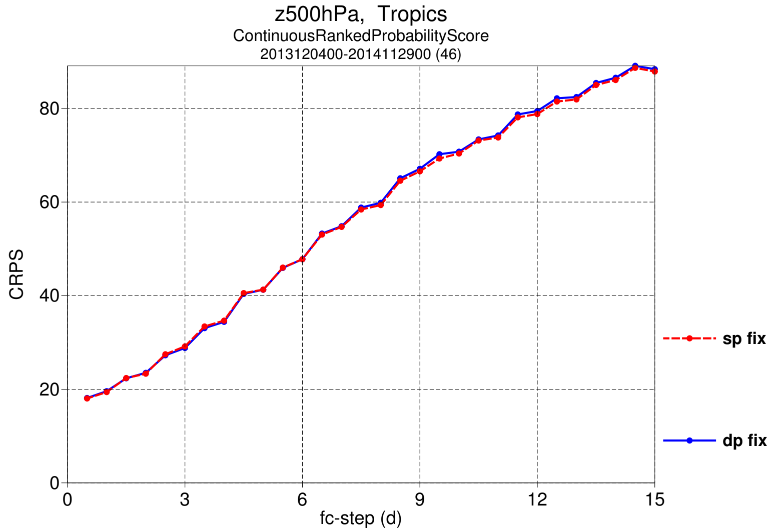
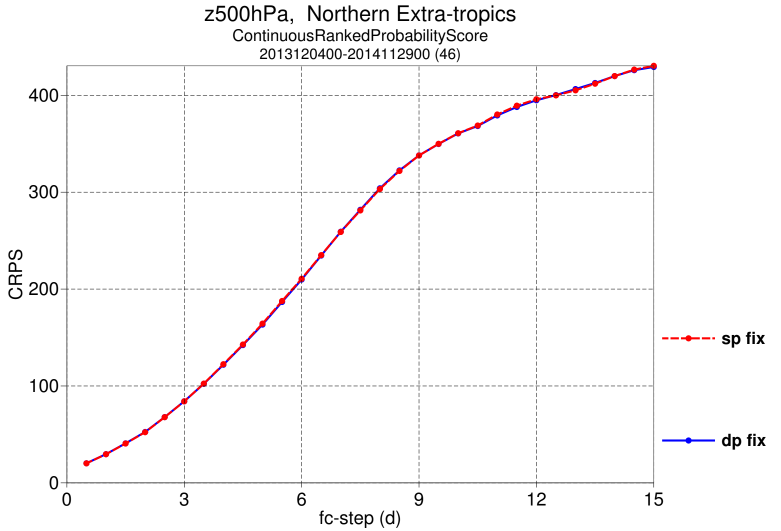


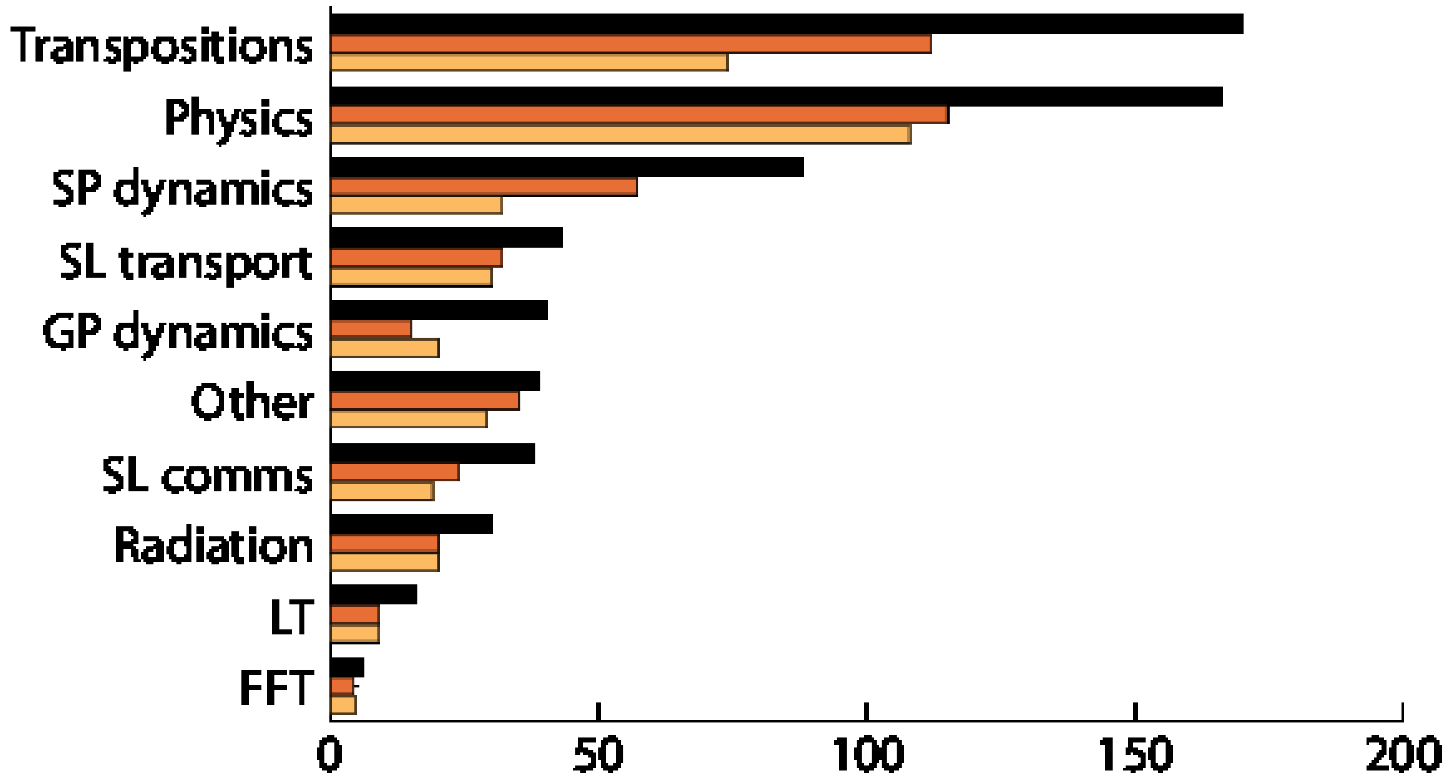






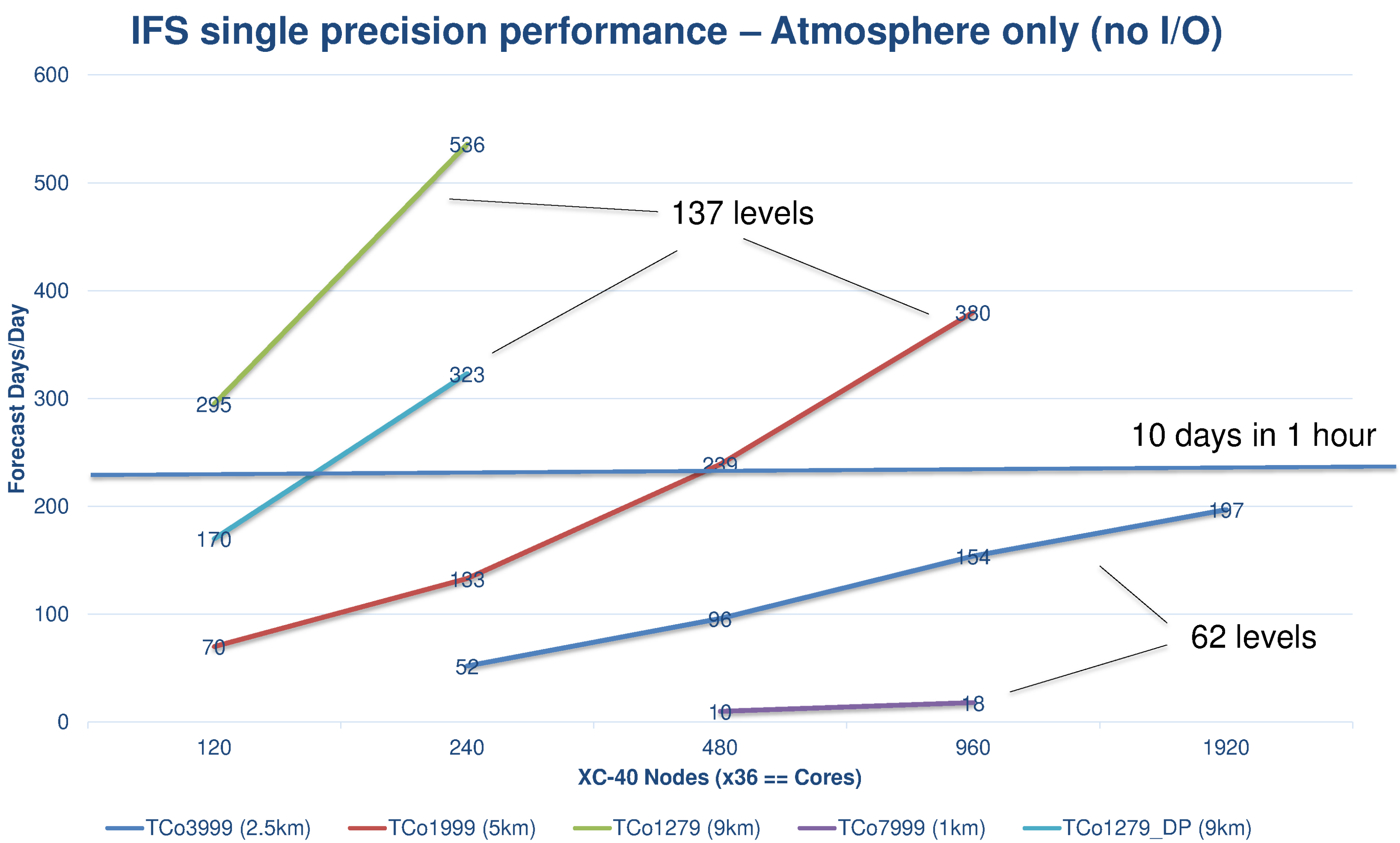
Computational cost - EPS

Single precision runs 37% faster (per standard timestep).
Optimizing cache utilization through NPROMA the gain becomes over 40% w.r.t. the double precision reference.



Cray XC30, 96 MPI x 8 OpenMP

Computational cost - atmospheric model



Single precision plans at ECMWF

- From CY45R1 single precision becomes available for RD testing.
- Extensive validation required. (Offline surface scheme already by default in SP!)
- Conservativeness issue.
- Review of TL code.
- Plan to make it default option for all FC & EPS jobs in RD.
- SP for data assimilation (i.e. mixed SP and DP code).
- Single precision Nemo.
- Investigate use of reduced precision.
- Reduced accuracy vs. more sophistication.