Can the compiler make the difference ?

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Reasons for this talk

- **ECMWF** said that in IFS benchmark, the **Cray compiler** was the best performing one
- **Intel** is used to saying that its **Intel compiler** is the best performing one in benchmarks in general
- **HIRLAM** reported that for AROME, **Gfortran compiler** is better performing than the **Cray compiler**

... Who is right ???

A unique opportunity

- ECMWF has got a Cray computer with both 3 compilers installed :
  - **Cray**
  - **Intel**
  - **Gfortran**

- Cycle 41 has been ported on Cray by ECMWF

There is a unique opportunity to make the comparison of compilers from the point of view of operational forcasting, not from the point of view of vendors benchmarks

Plan

- Conditions of the comparisons
- Results on cycle 41
- Explanations on the differences of performances
  - What is happening
  - What to do
- New results after optimizations (cycle 41T1+)
- Conclusion

Background conditions for a fair comparison

- Make sure the scientific results are valid with respect to a reference set of spectral norms (like for vendors benchmarks)
- Make sure the scientific results are bitwise repeatable and reproducible
- Same MPI library : MPI Cray 6.3.1, compiled for each compiler
- Same MPI driver : mpiauto, by Ph. Marguinaud (*)
- Scientific library : OpenBLAS for Intel and GNU compilers, Cray SCI library for Cray(**)
- No use of a Cray paging module for the Cray compiler
- No hyperthreading
- Same striping (=4) for the file system Lustre

(*) mpiauto performs as well, or better (with hyperthreading on Intel) than aprun
(**) I was too lazy to recompile OpenBlas for Cray, but the impact is neutral)

Selection of compiler versions and options

- **Use the most recent versions of compilers :**
  - **Cray 8.2.7**
  - **Intel 15.0**
  - **GCC 4.9**
- **(Try to) use equal and optimal compiler options :**
  - **Cray** (*) : -hflex_mp=conservative -hadd_paren -hfp1
  - **Intel** (**) : -align array64byte -fp-model source -ftz -O2 -xAVX -finline-functions -finline-limit=500
  - **Gfortran** : -fstack-arrays -O2 -ftree-vectorize

    with -ffast-math at link time

(*) Reference : ECMWF
(**) Reference : Météo-France

Applications tested

- **AROME forecast :**
  - 1.3 km L90 H12
  - + I/O server (3 nodes)
  - + post-processing on-line
  - + reduced coupling frequency (for commodity, mostly)
  - 200 nodes for the model part : 400 tasks x 12 threads

Troubleshooting with Lustre

- The file system Lustre at ECMWF is not reliable for small files, it makes non-repeatable elapse time (5 % to 10% difference from one run to another)
- => several developpments to reduce this issue with small files :
  - No output listing
  - ifs.stat file, atcp file, DDH files & IO-server xml files written out to specific directories on NFS
  - pp-server control files read from a specific directory on NFS
- => Elapse time is now reliable +/- 2 %
- Still there are sporadic issues of repeatable elapse time due to the file system (whatever the size of the file is)
  - Solution : rerun ...

AND THE WINNER OF THE COMPARISON IS ...

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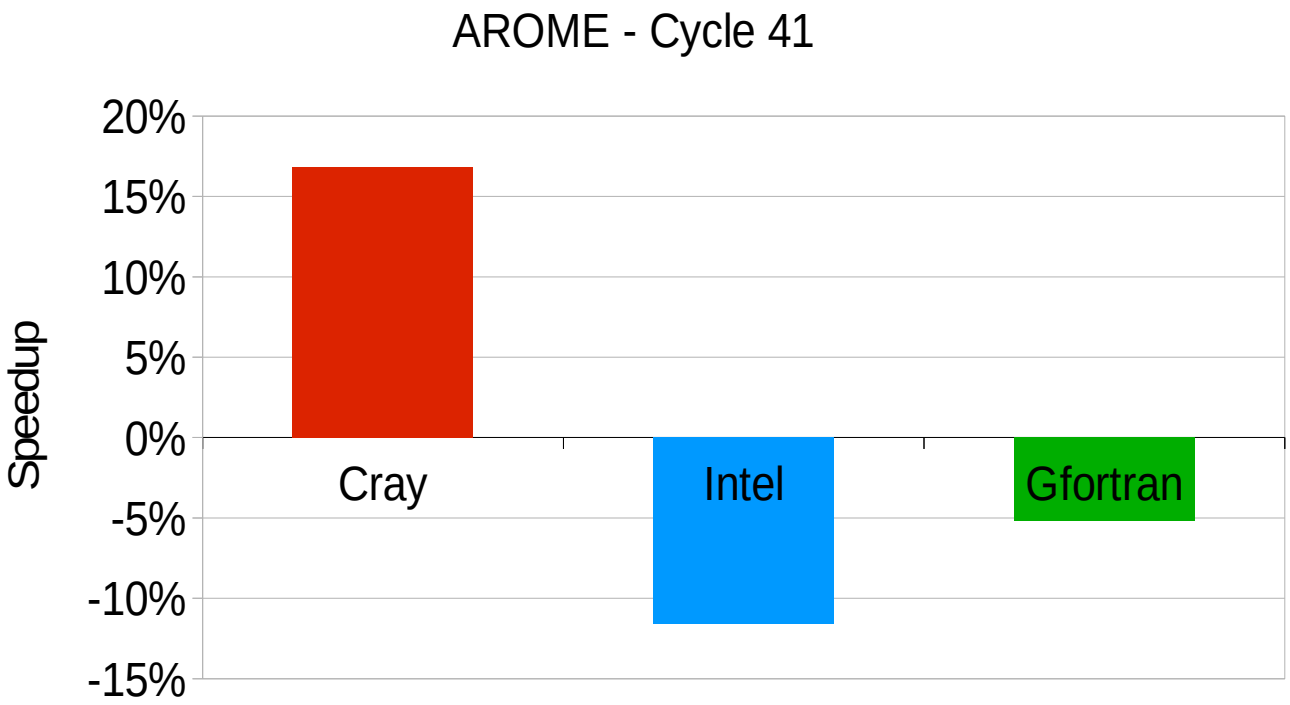
Comparisons on AROME cycle 41

Relative performance of compilers (relatively to the mean performance of them)



Cray is almost 30 % **faster** than **Intel**

Gfortran is 7 % **faster** than **Intel**

Explanation n° 1

- **Array syntax formulations (*) :**
  - **Cray** can make loop fusion on that statements
  - **Gfortran** doesn't make loop fusion on that statements
  - **Intel** hardly make loop fusion on that statements (even not really with -O3)

- **What to do :**
  - Rewrite and use the good old fortran 77 syntax !
    Indeed : array syntax can hardly make good re-use of the memory cache
  - It will even benefits a bit to Cray

(*) coding style >> (A) :,:)=B(:,:)*C(:,:) -D(:,:)/Z(:,:)

Explanation n° 2

- **Memory allocation :**
  - **Cray** uses a compiler built-in tcmalloc (thread-caching malloc)
    - Faster for allocations/deallocations cycles in parallel regions
  - **Gfortran** and **Intel** use malloc
    - Poor performance difficult to diagnose because the allocation takes place only when the memory is « touched »

- **What to do :**
  - Replace allocations/deallocations cycles by one of these :
    - Automatic arrays
    - Unique allocation
    - Deallocate/reallocate only if size has increased (or changed)

Explanation n° 3

- **Vectorization skillness (*) and efficiency *(**)* :**
  - **Cray** is skillful and efficient
  - **Gfortran** is skillful but less efficient
  - **Intel** is efficient but looks less skillful
  - Each compiler may decide to vectorize or not, on different criteria
- **What to do :**
  - Report vectorization failures to Vendors
  - Try to help the compilers with directives
    (mainly « !DEC$ IVDEP » and
    « !DEC$ VECTOR ALWAYS » for Intel)
  - If a compiler is faster than the other, try to guess how it does it

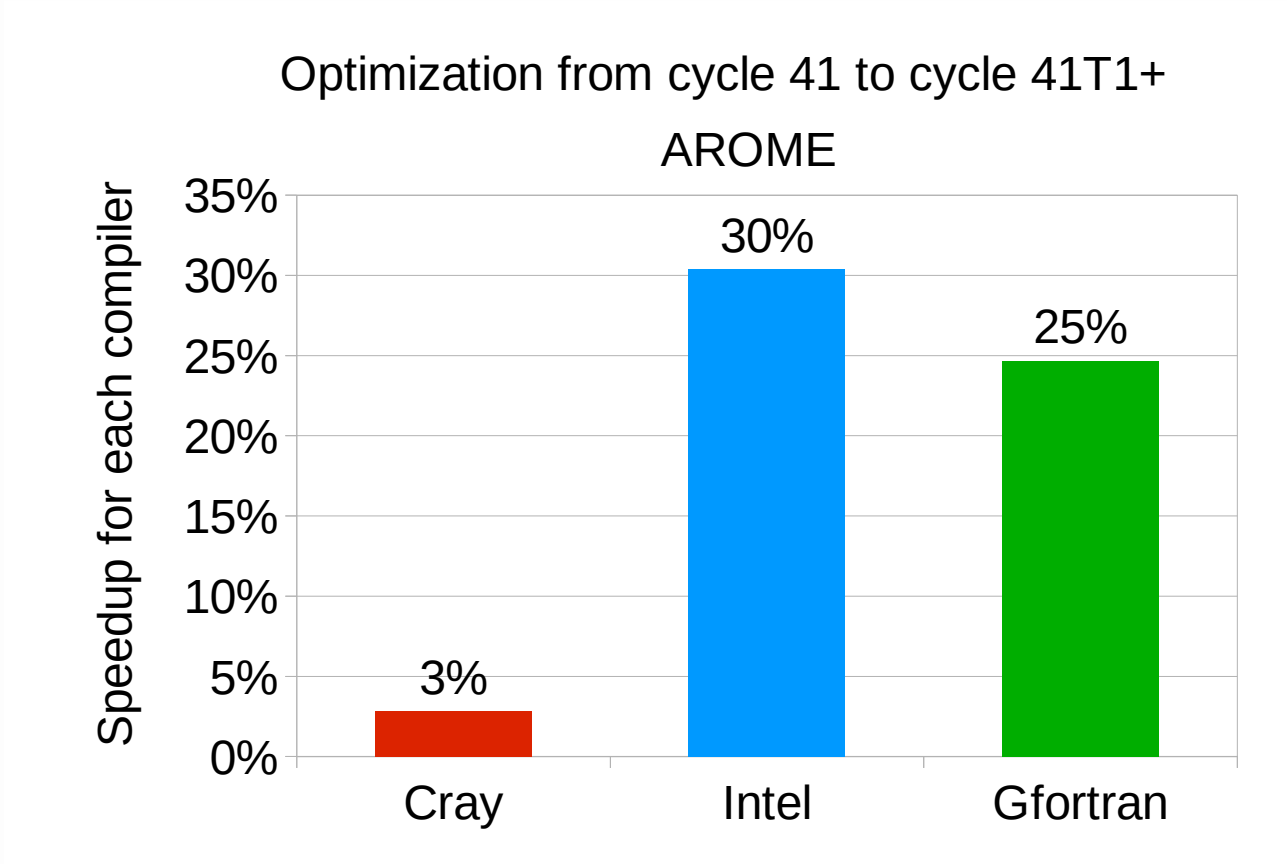
(*) ability to vectorize a given loop
(**) efficiency of the vectorization

Benefits of optimizations

- **Removal of an allocation/deallocation cycle :**
  - ≥ 200 %
- **Vectorization of a loop :**
  - from 20 % to 300 %, depending on :
    - occurrence of array syntax
    - occurrence of deferred-shape dummy arrays
- **Replacement of array syntax by a f77-style loop :**
  - 10-15 % at least
  - Should increase with the number of lines

Impact of such optimizations

Performance of cycle 41T1+(*) against cycle 41 for each compiler :

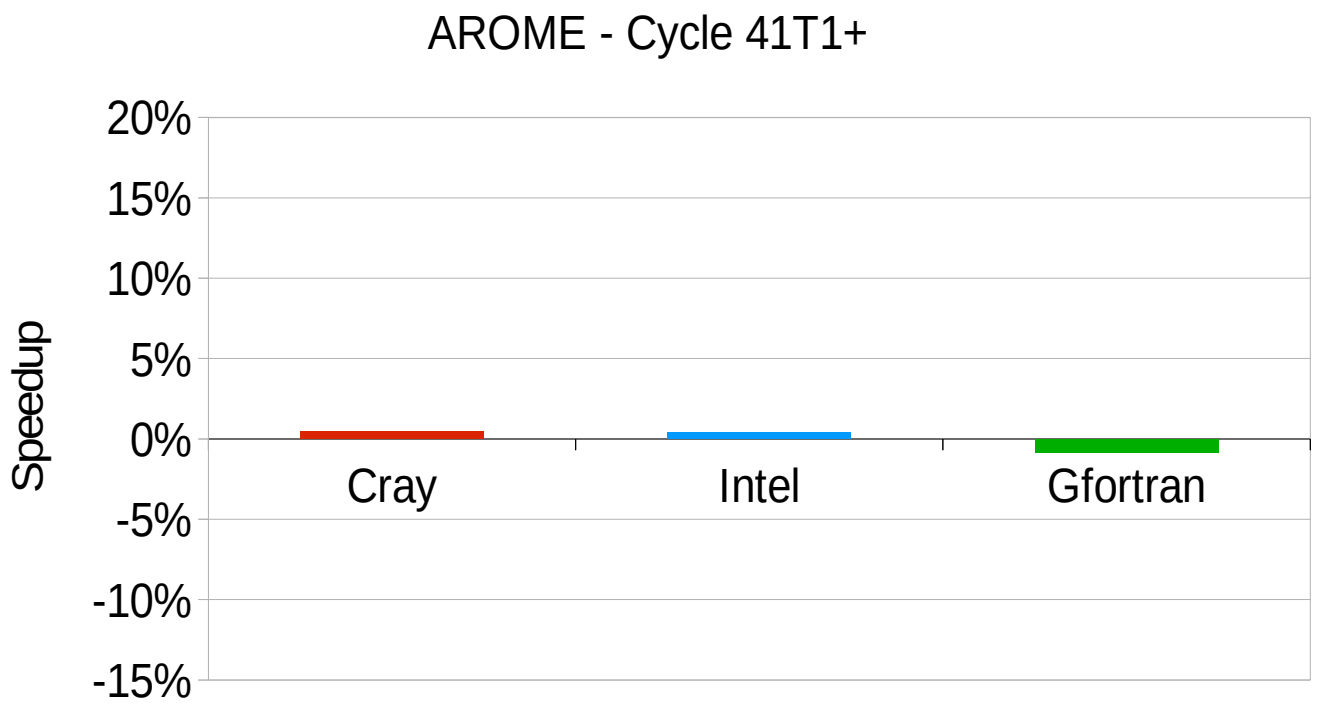


(*) Cycle 41T1 + supplementary optimizations

AND
AFTER SUCH OPTIMIZATIONS,
THE WINNER
IS ...

Comparisons on AROME cycle 41T1+(*)

Relative performance of compilers (relatively to the mean performance of them)



All 3 compilers performs at the same speed

(*) Cycle 41T1 + supplementary optimizations

Conclusions

- **Yes, the compiler can make the difference :**
  - Buy a Cray compiler if you have money
    and you don't want to worry about optimization
  - Consider the trade-off between Intel compiler licences
    + potential benefits after optimization work (with a little help from Gfortran or Cray), and just Gfortran for free

- **The comparison of compilers tells us :**
  - Where there can be room for optimizations, anyway
  - How to code in a more « competitive » way
    (or is it a more « portable » way ?)

Thank you for your attention !

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Optimization modset available
on git@merou :

khatib_CY41T1_main.01%opt1