Global convection-permitting modelling at ECMWF

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ECMWF

1. IFS: hydrostatic regime
2. IFS: non-hydrostatic regime on the small planet
3. IFS: convection-permitting simulations on the real planet

Outline

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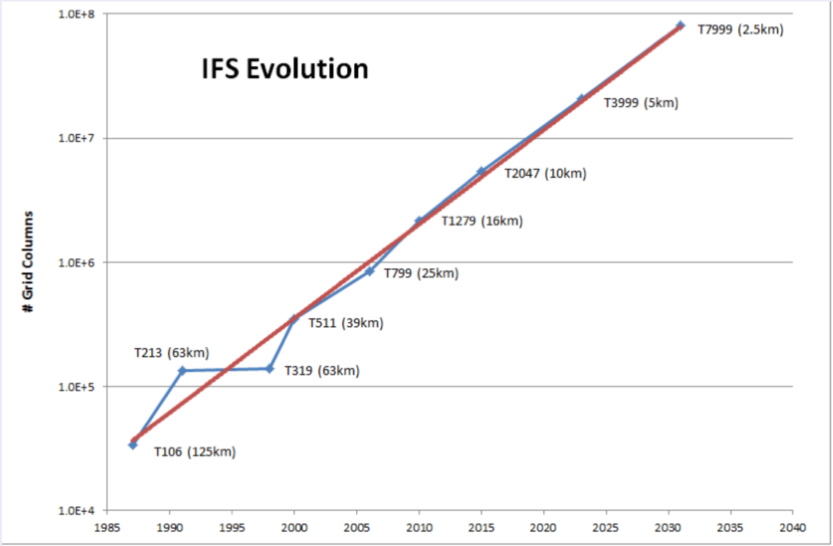
The operationnal model at ECMWF



IFS dynamical cores

- semi-Lagrangian on a reduced Gaussian grid
- spectral semi-implicit
- hybrid (hydrostatic) pressure/terrain following coordinate
- physics package tuned for the current resolutions (hydrostatic regime)

Hydrostatic or NH-Compressible

Laprise (1992), Bubnova et al. (1995), Bénard et al. (1995), Wedi et al. (2009)

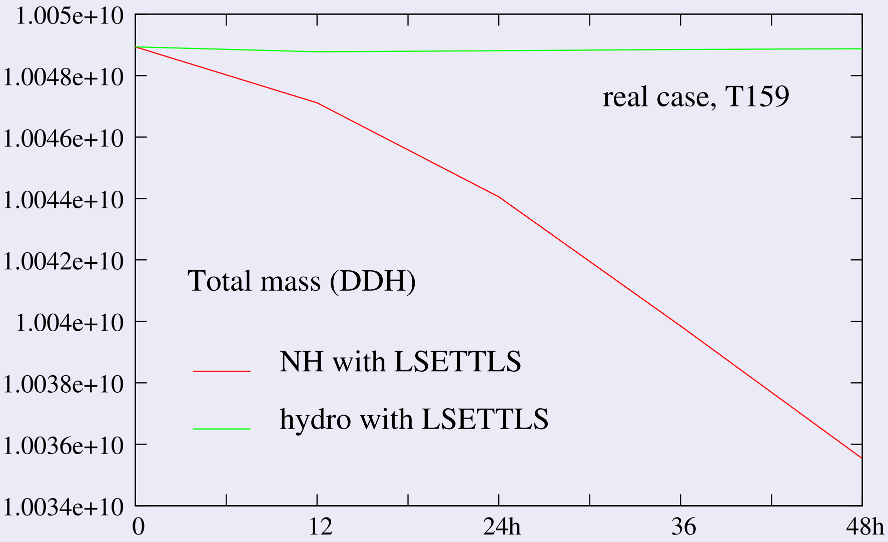
- u/v (or vor/div), T, q_x, π_s + $p - \pi$ + $(\Delta w + X)$
- finite element/finite difference in the vertical
- enthalpy/internal energy equation
- very robust/Iterative Centred Implicit scheme needed for stability ⇒ **double cost!**

What's the problem with NH-IFS without ICI scheme?

Why Arome runs (operationally from 2008) without ICI scheme but the global IFS needs it (global at "low" resolution, long range forecast, long time step)?

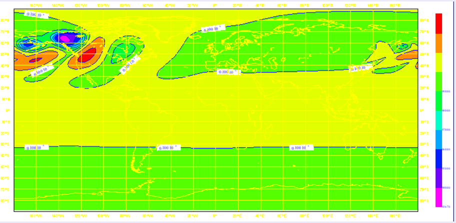
- bug?
- coupling with physics?
- Himalaya, Andes? Linear/quadratic orography/grid?
- other numerical issue(s?)?
- initial conditions?

NH-IFS without ICI scheme: Real cases in T159

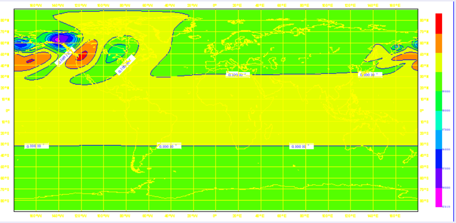


NH-IFS without ICI scheme: DCMIP baroclinic waves

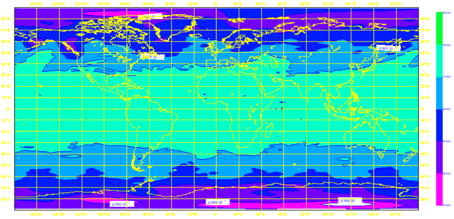
HYDRO



NH+ 1 iteration

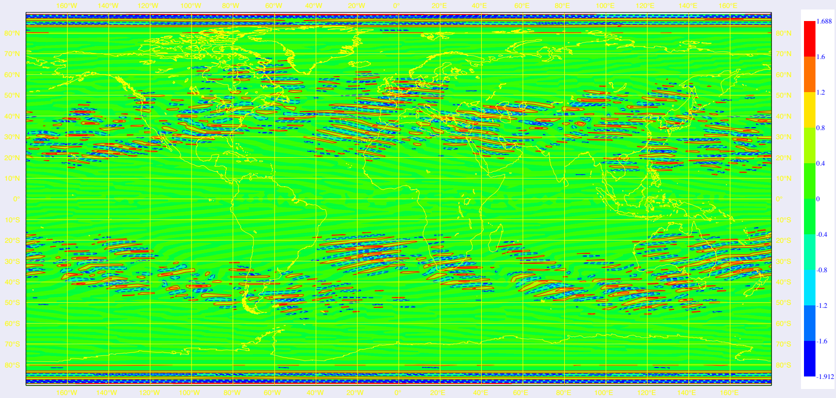


NH+extrapolation



High frequency oscillations in NH-IFS without ICI scheme

$$\psi_{(t+2\Delta t)} + \psi_{(t)} - 2\psi_{(t+\Delta t)}$$

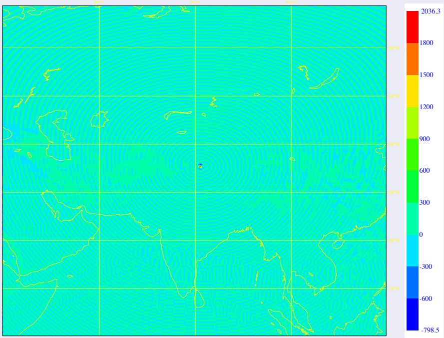


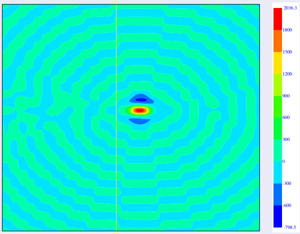
With decentring, the main high frequency oscillation is filtered (baroclinic wave, TC OK) but,

NH-IFS without ICI scheme

but, even with decentring, real cases are still unstable when resolution increases, mainly because of some “noise” in the vincinity of high mountains (usually model blows at Himalaya but similar noise has started to “build up” in the Andes, Antarctica).

T511, NH+SETTLS, XIDT=0.1, $\Delta t = 900$ s





$\Delta t = 900$ s	64 h
$\Delta t = 450$ s	13 h
$\Delta t = 225$ s	3 h

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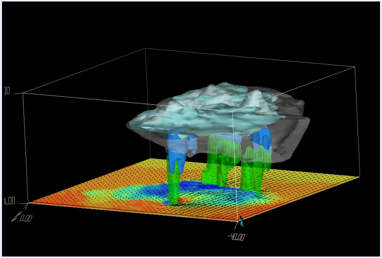
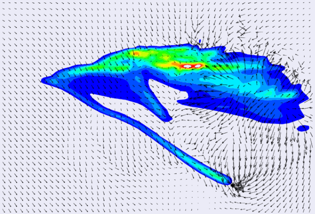
Scientific academic validations in CRM mode

Splitting storms (Weisman and Klemp, 1984) on a small planet



Accumulated precipitation

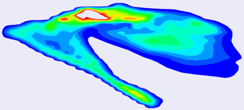


Resolved convection on a small planet

- $R_{small} = \gamma R_{real}$
- $f = 0$
- characteristic space and time scales of convection are the same on the small planet and on the real planet
- simulations on the small planet can directly be compared to LAM simulations (MesoNH, EULAG)

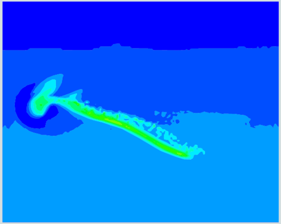
Grey zone of convection

Simulations at 6.5 km resolution without and with convection scheme

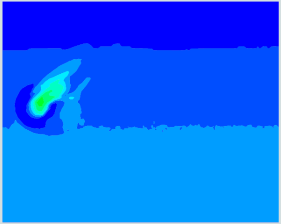


First call of cloud scheme before

convection only



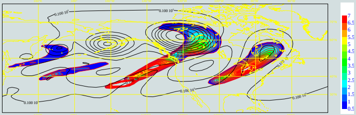
convection + cloud scheme



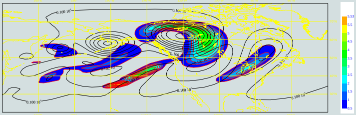
Coupling convection with large scale processes on the small planet?

Standart microphysics

After 10 real planet days

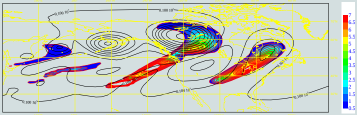


After 10 small planet days, g*1

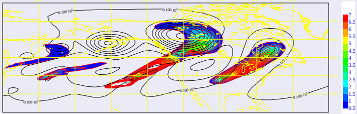


Accelerated microphysics

After 10 small planet days, g*1, $V_f * 10$



After 10 small planet days, g*10



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Real cases at convection-permitting resolutions (**N. Wedi**)

Global simulation on the real planet

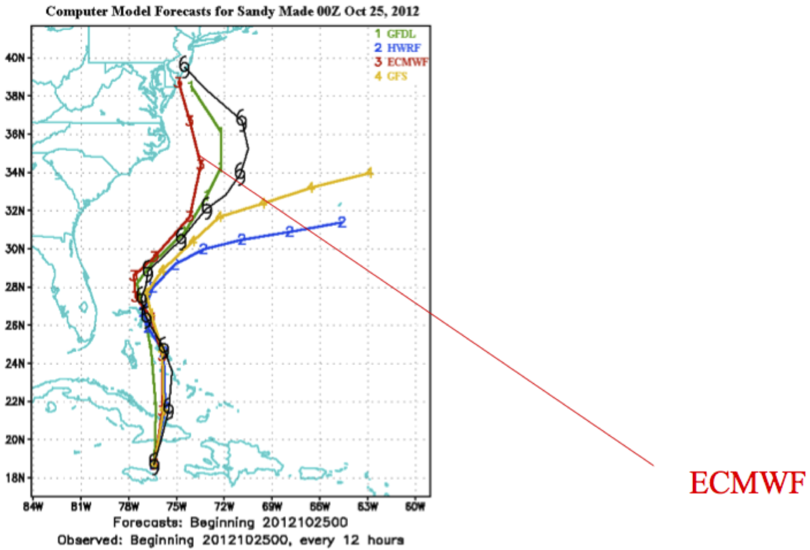
- T4000 ($\Delta x \simeq 5$ km), L91,$\Delta t = 180$ s
- T8000 ($\Delta x \simeq 2.5$ km), only L40,$\Delta t = 30$ s, only a 12 hour forecast

- very preliminary results (more for machine timing than skill)
- unique opportunity thanks to an empty (but still very unstable) "next" supercomputer
- new climate files
- no assimilation (forecasts start from operational analyses)
- **Fast Legendre Transforms** (Wedi and Hamrud, 2013)

Tropical Cyclone Sandy

NASA Earth Observatory, 28th October 2012

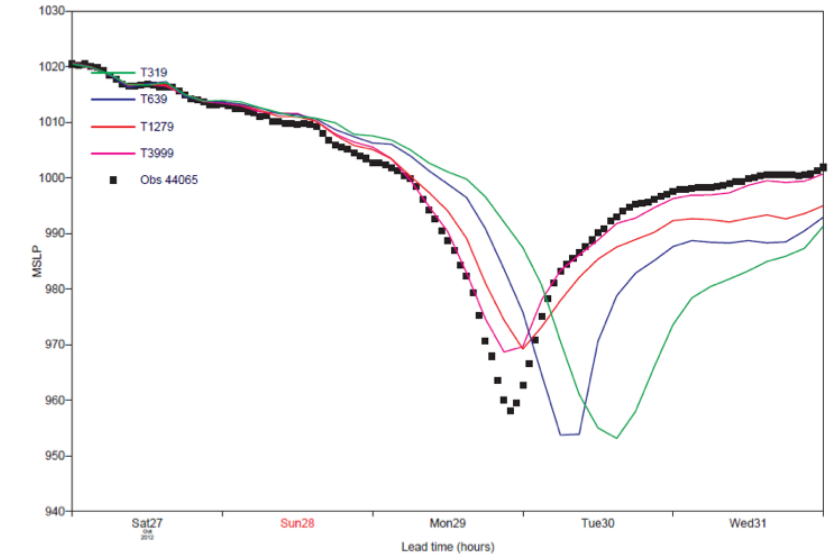
Sandy - Operational forecast



Morris Bender, NOAA/GFDL (http://www.wunderground.com/blog/JeffMasters)

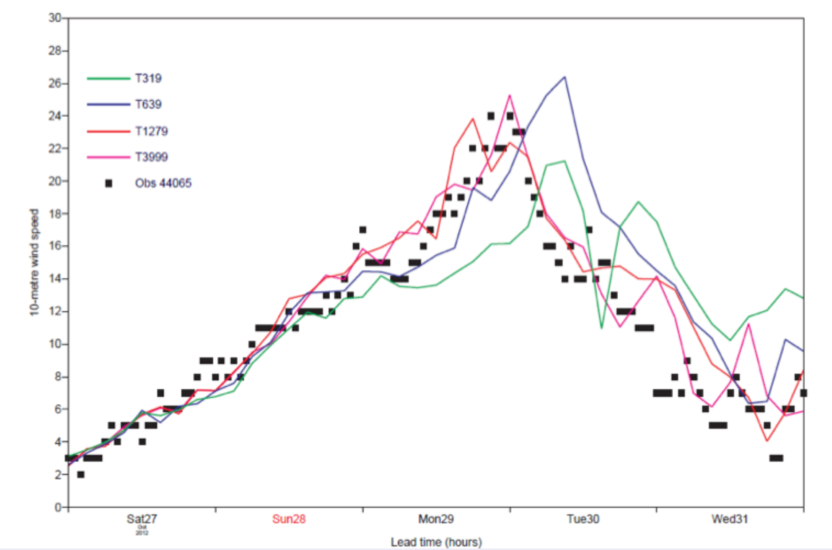
Sandy: impact of the resolution

MSLP



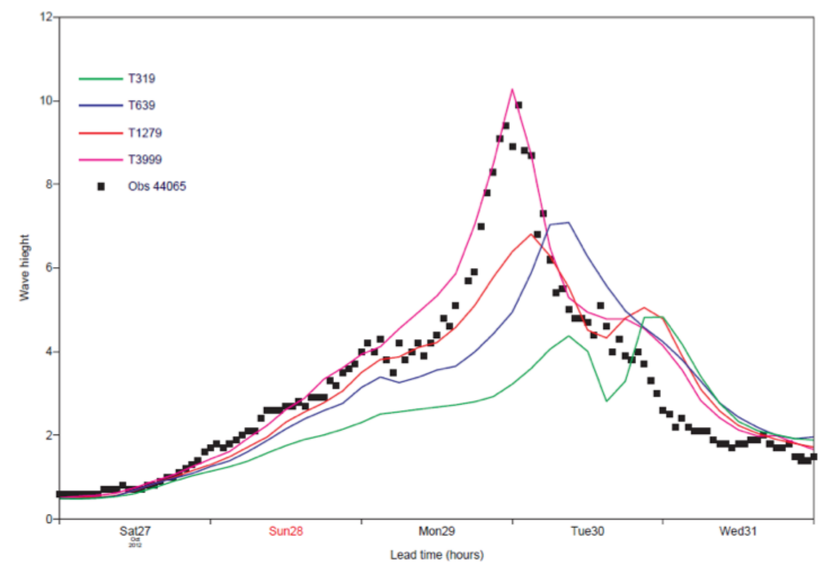
Sandy: impact of the resolution

Wind



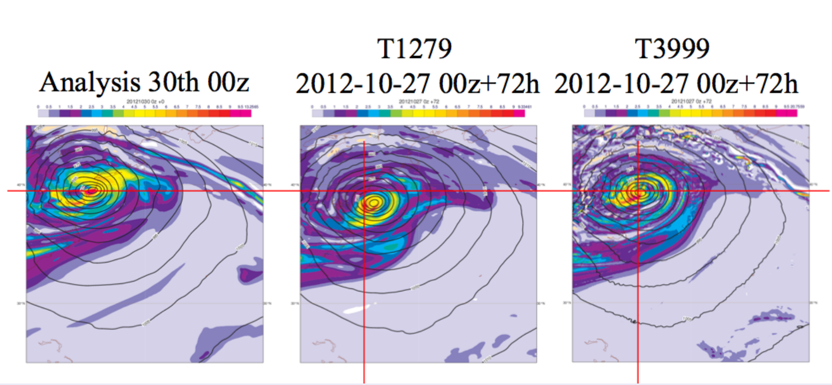
Sandy: impact of the resolution

Wave



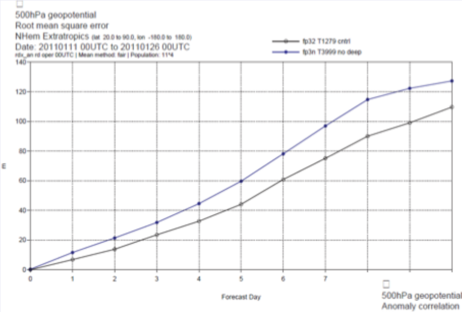
Sandy: impact of the resolution

Perfect position

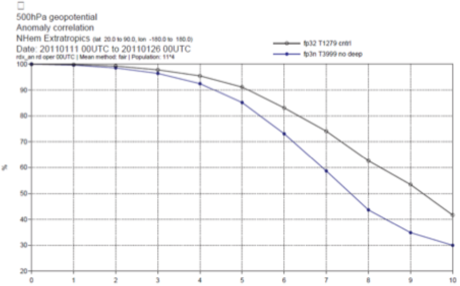


T3999/T1279

but what about scores?

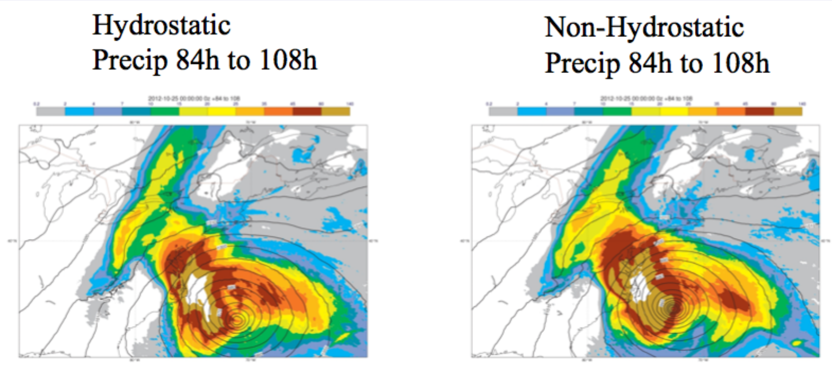


T3999 scores with explicit deep convection starting from a T1279 analysis



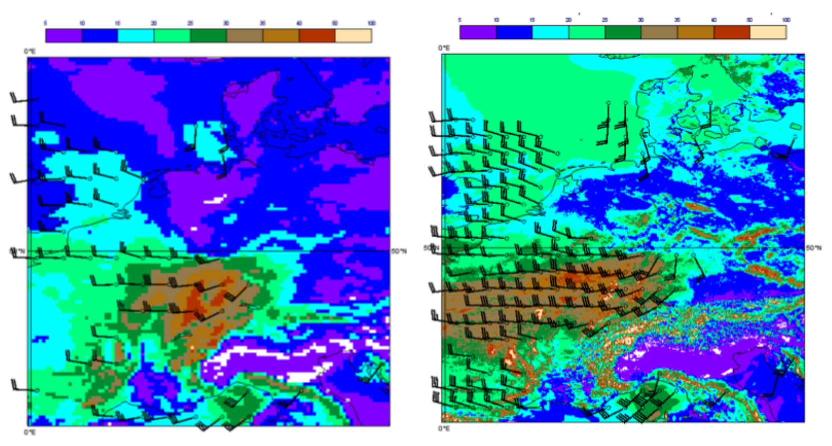
T3999: H versus NH

From which resolution do we really need a NH model?



T7999

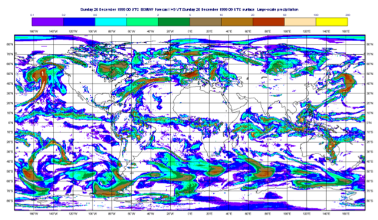
Lothar storm (Christmas 1999)



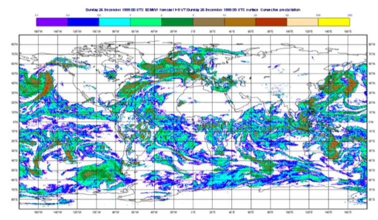
T7999: physics?

without deep convection scheme

prognostic cloud scheme

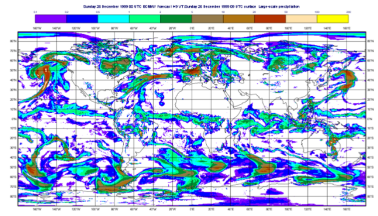


shallow conv. scheme

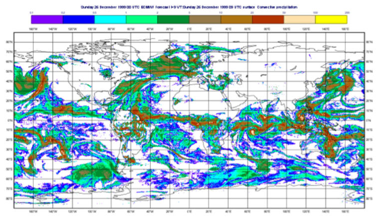


with deep convection scheme

prognostic cloud scheme



shallow+deep conv. scheme



IFS spectral semi-implicit semi-Lagrangian dynamical core
$\Rightarrow$ 2025, T4000

Unified (anelastic) system

Adaptation of the unified anelastic system of equations (Arakawa and Konor, 2008) to the IFS numerical characteristics: NH simpler system, hopefully, no need of the iterative-centered-implicit scheme (+ no X-term, maybe better compatibility with vertical finite element, better consistency with current physics...)

New framework: PantaRhei project (European Reasearch Council)

- Combine the best of the IFS and EULAG (P. Smolarkiewicz): a NH global EULAG configuration conditioned by the hydrostatic IFS solution
- A code ready for new supercomputer architecture (CRESTA project, G. Mozdzynski and M. Hamrud)