Futurs du noyau dynamique
Future of dynamical cores

Mikhail Tolstykh,
Marchuk Institute of Numerical Mathematics RAS,
Hydrometcentre of Russia

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Tribute to Jean-Francois Geleyn

Jean-Francois Geleyn introduced me into the world of numerical weather prediction.

This had changed my scientific career dramatically

Lessons from Jean-Francois

- Do not be afraid of doing something that nobody has tried.
- If somebody has done something, it probably can be done better.
- If you see a wall on your way, stop and think: the should be a way around.
- Implement your ideas efficiently (both algorithmically and in coding) (i.e. long time step)

A view on global NWP models

``Weather Forecasting Factory" by Stephen Conlin, 1986.
Based on the description in 'Weather Prediction by Numerical Process', by L.F. Richardson, 1922

http://mathsci.ucd.ie/~plynch/Publications/RFFF-WX-02-NoAbs.pdf
Courtesy of P.Lynch

Current global NWP models

WGNE table

http://wgne.meteoinfo.ru/nwp-systems-wgne-table/wgne-table/

Horizontal resolution

~ 7-25 km

Vertical resolution

50-137 levels

Forecast Centre (Country)	2019	2020
ECMWF (Europe)	Coupled O-A 0.25 TCo1279 L137 (~9km)	Coupled O-A 0.25 TCo1279 L137 (~9km)
Met Office (UK)	10km L70 7days	10km L70 7days
Météo France (France)	~T_L1198c2.2 L105 (7km on W Europe to 36km)	~T_L1798c2.2 L105 (from 5km on W Europe to 24km)
DWD (Germany)	13 km L90 (6.5 km L60 for Europe)	13 km L120 (6.5 km L80 for N-Atlantic, Europe)
HMC (Russia)	0.24°x0.17° L51	0.1°x0.08° L104
NCEP (USA)	C768 L64 (13 km)	C768 L64 (13 km)
Navy/FNMOC/NRL (USA)	T425L60	T681L60
CMC (Canada)	Yin-Yang (0.14°x0.14°) L84 coupled atm-ocean-ice	Yin-Yang (0.14°x0.14°) L84 coupled atm-ocean-ice
CPTEC/INPE (Brazil)	20km L64	TBD
JMA (Japan)	TL959 L100	TL959L100
CMA (China)	GRAPES(0.25, L90)	GRAPES(0.15, L90)
KMA (Korea)	12km L120	
NCMRWF (India)	10kmL70	
BoM (Australia)	12 km L120	12 km L120

Future global models

- Resolution ~3-5 km
- Nonhydrostatic
- Scalable at O(10^5 processor cores)
- Include atmospheric composition models

(Air mass conservation)

Question to solve 1

- Grid?
  - icosahedral (DWD)
  - cubed sphere (NCEP, UKMO)
  - Yin-Yang (ECCC)
  - reduced lat-lon (ECMWF)

Review by Staniforth, Thuburn , QJRMS 2012

No obvious winner so far

Question to solve 2

- Time integration scheme?

 - Horizontally explicit, vertically implicit

- Semi-implicit

If the semi-implicit scheme is chosen, the solver should be local (i.e. multigrid)

The choice strongly affects scalability

Question to solve 3

- Advection:

-Eulerian

- Semi-Lagrangian

Arguments for both. Dominance of semi-Lagrangian advection disappears.

Question to solve 4

- Scalability: only local communications between processor cores are preferred.

(1 remote operand~10 local operand~100 Flops). There are some exceptions for GPUs, XeonPhi.

- In dynamical core, preferably, local approximations. Examples: low-order finite differences, finite volumes (NCEP,…,), finite elements (UKMO,…), discontinuous Galerkin method, spectral elements (NCAR, …)

More questions

- Choice of equations set and prognostic variables
- Choice of vertical coordinate
- …

There exist arguments for many choices

SLAV model

Federal Service for Hydrometeorology and Environmental Monitoring

HYDROMETEOROLOGICAL CENTRE OF RUSSIA

10-days operational medium range forecasts

0.225° in lon, 0.16°-0.24° in lat, 51 levs.

LETKF-based ensemble prediction system

0.9° in lon, 0.72° in lat, 96 levs, ongoing development.

Subseasonal and seasonal probabilistic forecast

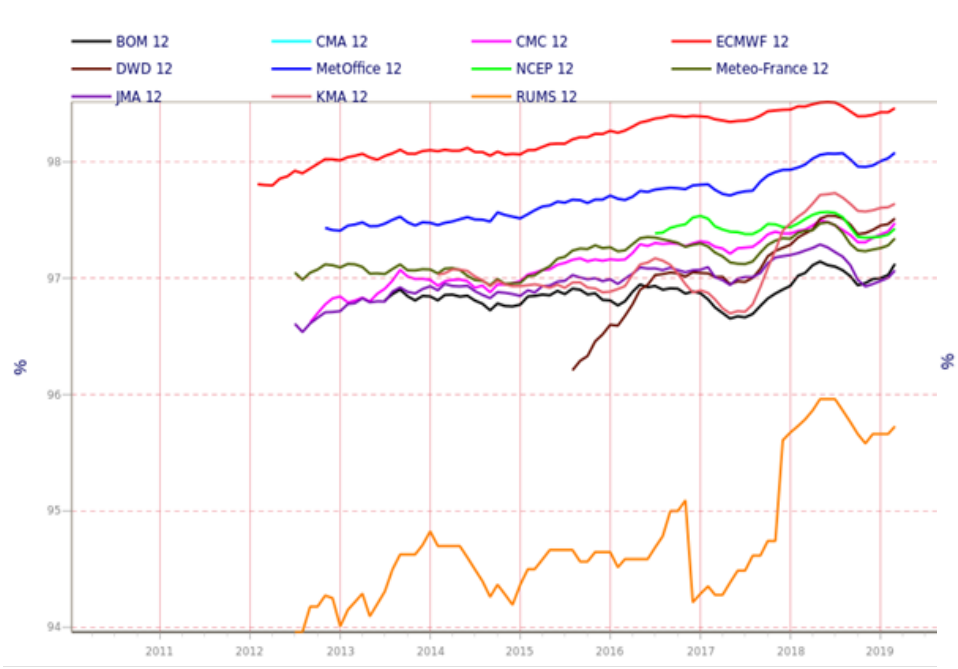
(WMO S2S Prediction project)

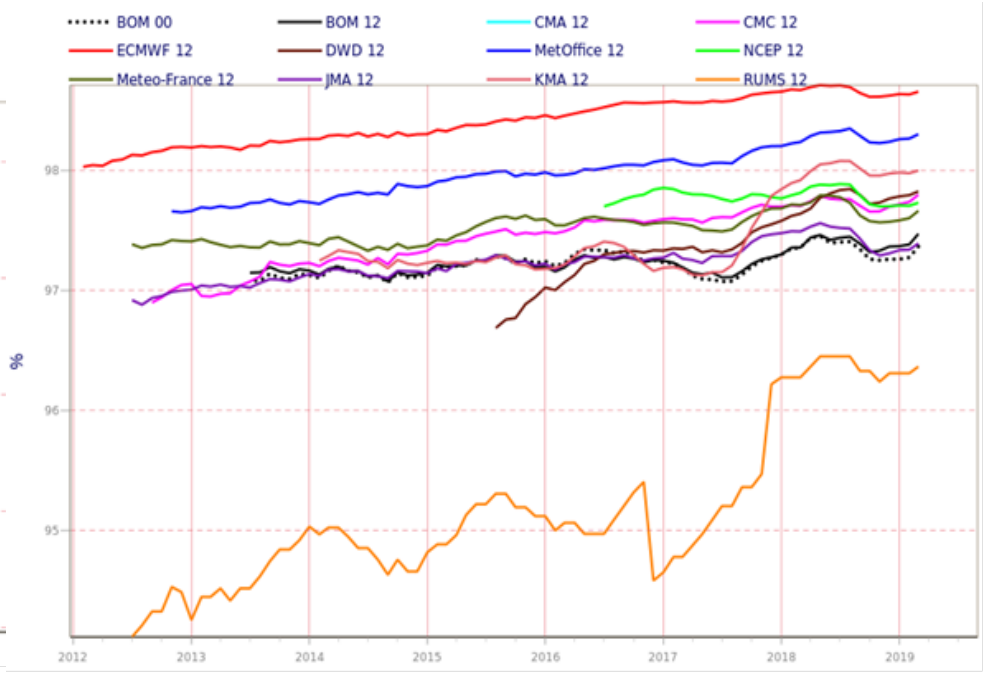
1.4°x1.1°L28 currently,

0.9°x0.72°L96, by the end of this year.

Subseasonal-to-Seasonal S2S Prediction Project

Changes on ACC for 72hr forecast of H500 (left) and H250 (right) in 2012-2019 for SLAV (orange), ECMWF (red), UKMO (blue). Northern extratropics, 12 UTC run. Moving average over 12 months.



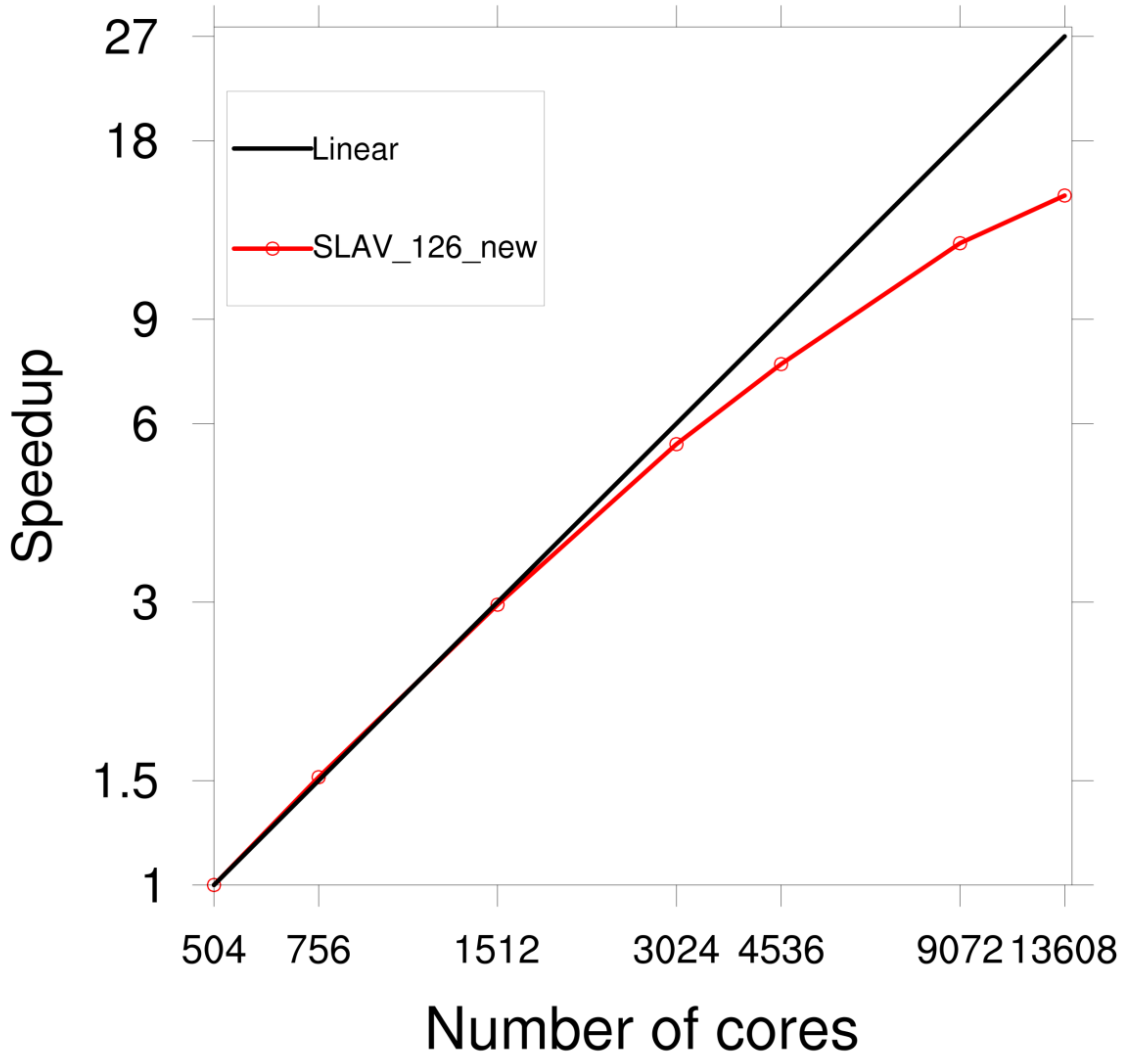


https://apps.ecmwf.int/wmolcdnv

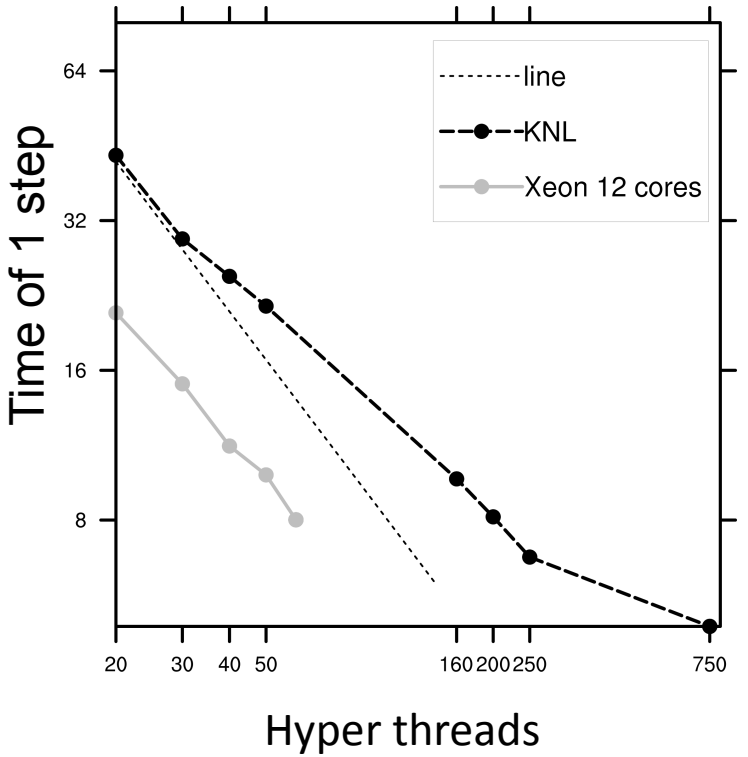
SLAV strong scaling at Cray XC40 x86 Broadwell

3024x1513x126 grid, max. 6 OpenMP threads.

53% efficiency at 13608 cores, 64 % at 9072 cores



SLAV20 **Intel Xeon Phi2** strong scaling (black line) in comparison with RHMC classic cluster (grey line).



Conclusions

- The model resolution increases as computing power grows
- It is more and more difficult to use this power
- Variety of options for each question
- Jean-Francois's goal for computational efficiency remains unchanged