SI^3

Sea Ice modelling Integrated Initiative:

A new unified sea-ice model for NEMO

Sea Ice & NEMO

In the beginning…

★3 sea-ice models used in NEMO (LIM, CICE, GELATO)

Resulting in…

★duplications
★waste of man power
★difficult to maintain the coupling with NEMO

Solution…

★Sea Ice modelling Integrated Initiative (SI^3) was born
(from CRNS, BAS, CPOM, NOC, CMCC, CNRM, Mercator, UCL, UKMO)

➡ SI^3 based on LIM3 but (will) incorporate key functionalities from CICE & GELATO

NEMO 4.0 versus 3.6

Physics

Numerics

Performance

Developers
& users friendly

Physics

✓ **lateral melting**

$$\frac{dA}{dt} = -P \times W$$

(Rothrock & Thorndike 1984) *(Josberger 1979)*

✓ **Ice-atm. drag**

$$C_d = C_h = Cst + 2.23 \times 10^{-3} \times (1 - A)^{1.1}$$ *(Lupkes et al. 2012)*

$$C_d \neq C_h \propto (A, atmosphere\_stability)$$ *(Lupkes et al. 2015)*

✓ **Landfast ice**

$$\tau_{bot} = \sum_{h_i > \Gamma h_{ocean}} a_i \tau_{par}$$ *(Lemieux et al. 2015)*

✓ **Melt ponds**

$$V_{pnd}^{t+\Delta t} = \left[V_{pnd}^{t} + (0.15 + 0.55A) \times dV_{melt} \right] \times e^{0.01(T_{ref} - T_{ai})/T_{ref}}$$

(Holland et al. 2012)

Numerics

✓ **Advection scheme: Ultimate-Macho (up to 5th order)** *(Leonard 1991)*

Cheaper than Prather, especially for multi-tracers

✓ **Adaptive EVP** *(Kimmritz et al. 2017)*

Converges 4-5 times faster than regular EVP

✓ **Coupling interface** *(West et al. 2016)*

Compatibility with Jules interface at Met-Office, i.e. conductivity as surface forcing (instead of fluxes)

Performance

✓ All thermodynamics is 1D

```
      DO jl = 1, jpl

         CALL ice_thd_1d2d( jl, 1 )                ! --- Move to 1D arrays --- !

         CALL ice_thd_zdf                          ! Ice/Snow Temperature profile
         CALL ice_thd_dh                           ! Ice/Snow thickness
         CALL ice_thd_pnd                          ! Melt ponds formation
         CALL ice_thd_ent( e_i_1d(1:npti,:) )      ! Ice enthalpy remapping
         CALL ice_thd_sal( ln_icedS )              ! --- Ice salinity --- !
         CALL ice_thd_temp                         ! --- temperature update --- !
         CALL ice_thd_da                           ! --- lateral melting --- !

         CALL ice_thd_1d2d( jl, 2 )                ! ---Move to 2D arrays ---!

      END DO
```

Performance

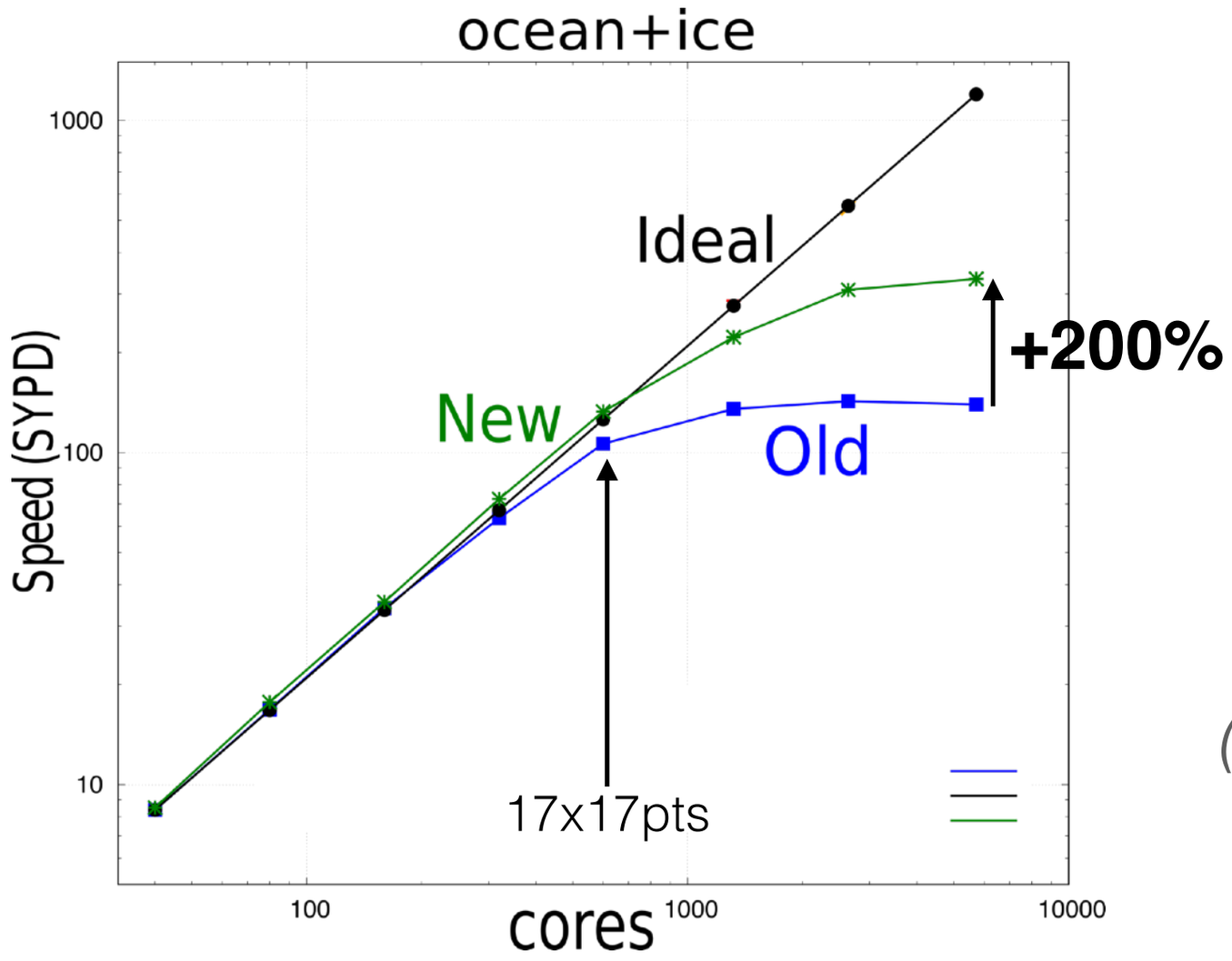
- ✓ **All thermodynamics is 1D**
- ✓ **Reduced MPP communications**

```
CALL lbc_lnk_multi( zs1, 'T', 1., zs2, 'T', 1., zs12, 'F', 1. )
```

Performance

- ✓ **All thermodynamics is 1D**
- ✓ **Reduced MPP communications**
- ✓ **Ongoing work on drastically improving scalability**

  up to ~10x10 points per core (at least)



(E. Maisonnave & S. Masson)

Developers & users friendly

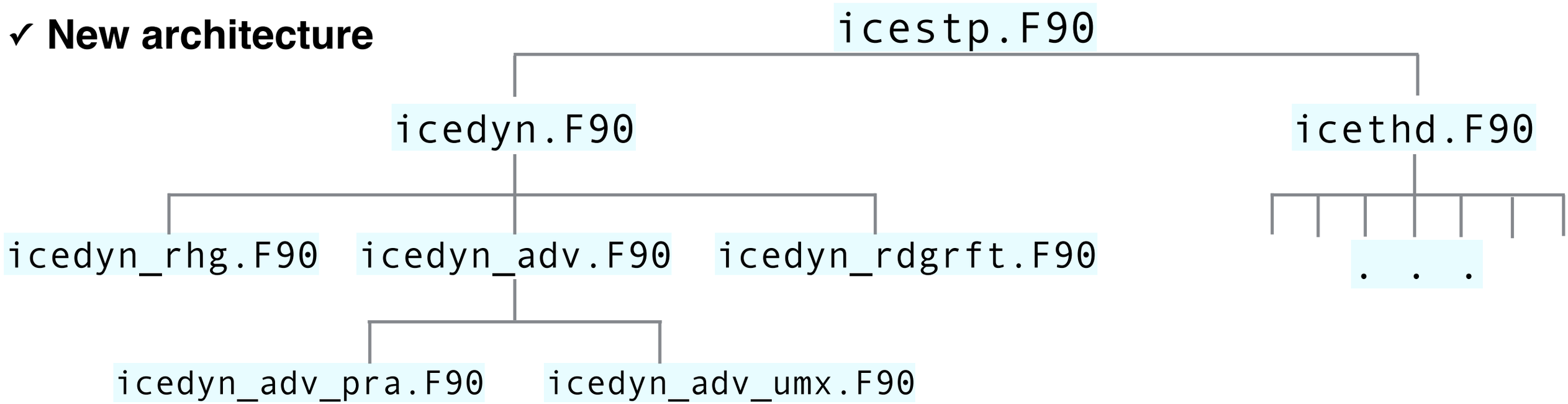
✓ **Comprehensive set of outputs (CMIP compliant + universal units + names)**

```
<field id="icetemp"       long_name="Mean ice temperature"                    unit="degC" />
<field id="icettop"       long_name="temperature at the ice surface"          unit="degC" />
<field id="icetbot"       long_name="temperature at the ice bottom"           unit="degC" />
<field id="icetsni"       long_name="temperature at the snow-ice interface"   unit="degC" />
```

Developers & users friendly

✓ **Comprehensive set of outputs (CMIP compliant + universal units + names)**

✓ **New architecture**



✓ **New namelist**

```
ln_adv_Pra  = .false. !  Advection scheme (Prather)
ln_adv_UMx  = .true.  !  Advection scheme (Ultimate-Macho)
   nn_UMx   =   5     !     order of the scheme for UMx
```

Developers & users friendly

- ✓ **Comprehensive set of outputs (CMIP compliant + universal units + names)**
- ✓ **New architecture**
- ✓ **New namelist**
- ✓ **Decoupled processes (switch off/on)**

```
ln_icedH = .true. !  activate ice thickness change from growing/melting (T) or not (F)
ln_icedA = .true. !  activate lateral melting param. (T) or not (F)
ln_icedO = .true. !  activate ice growth in open-water (T) or not (F)
ln_icedS = .true. !  activate brine drainage (T) or not (F)
```

Developers & users friendly

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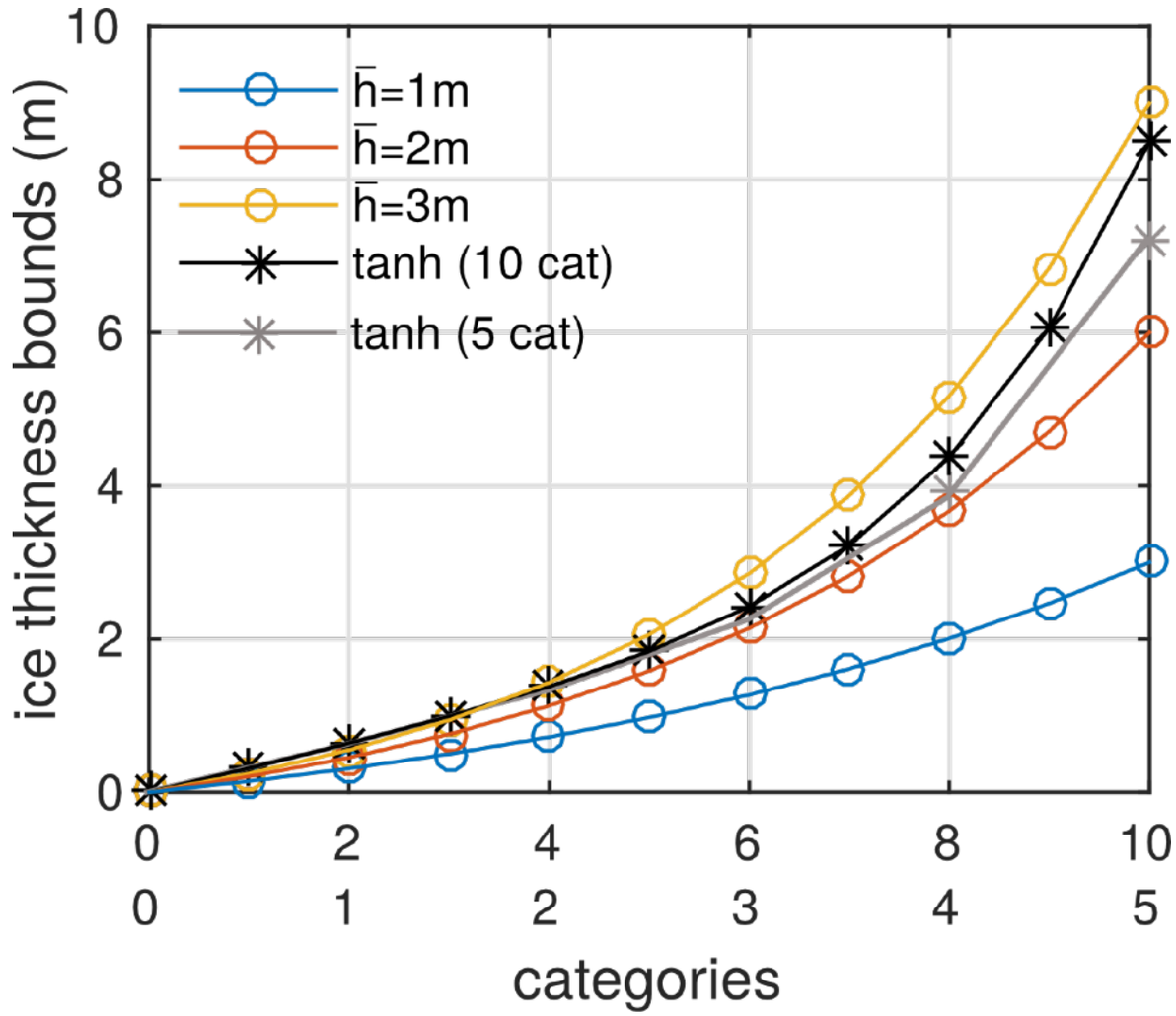
✓ **New architecture**

✓ **New namelist**

✓ **Decoupled processes (switch off/on)**

✓ **Ice categories (user defined and $h^{-\alpha}$)**



Developers & users friendly

- ✓ **Comprehensive set of outputs (CMIP compliant + universal units + names)**
- ✓ **New architecture**
- ✓ **New namelist**
- ✓ **Decoupled processes (switch off/on)**
- ✓ **Ice categories (user defined and $h^{-\alpha}$)**
- ✓ **Open boundaries (input cat $\neq$ output cat)**

Developers & users friendly

✓ **Comprehensive set of outputs (CMIP compliant + universal units + names)**

✓ **New architecture**

✓ **New namelist**

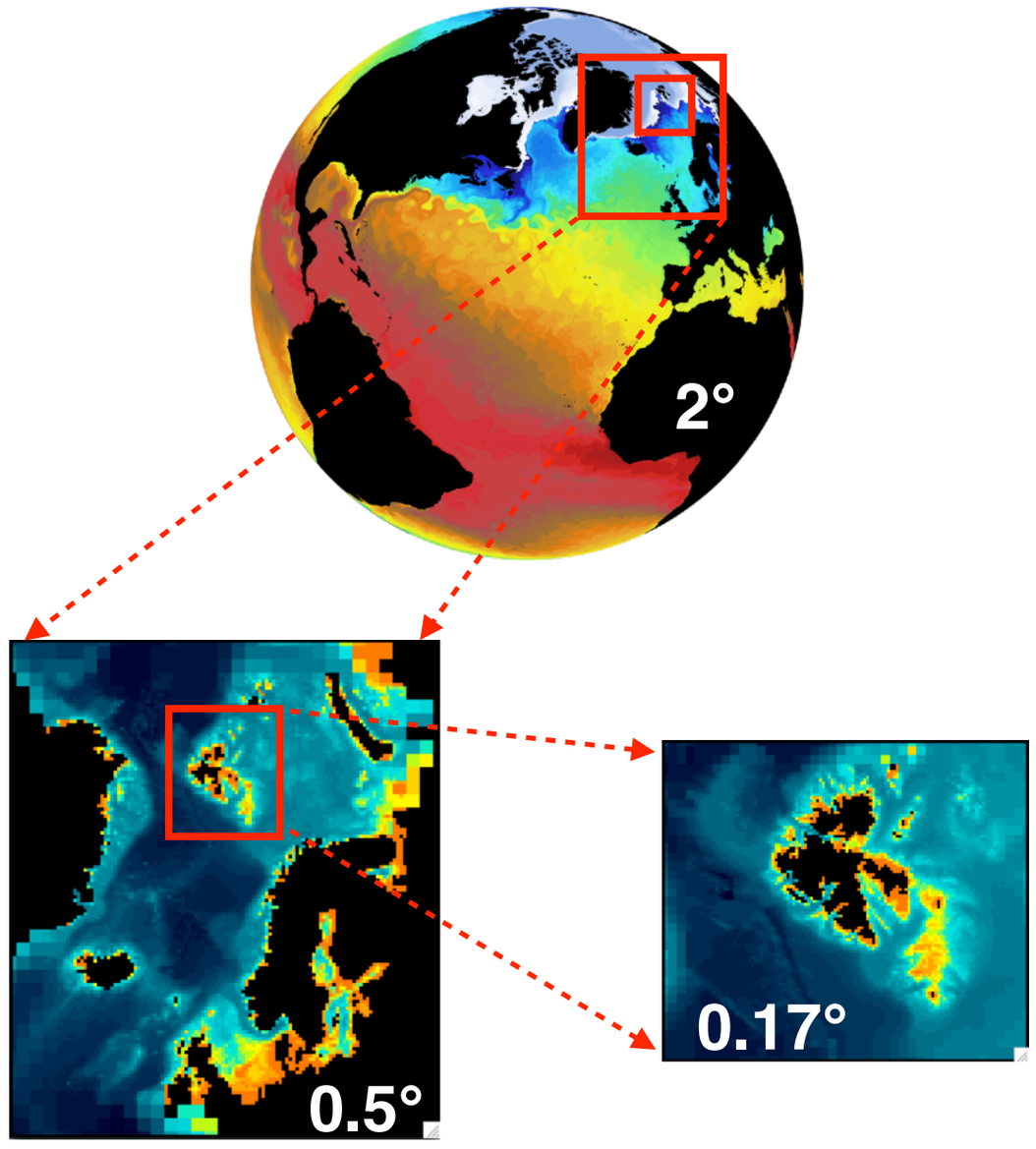
✓ **Decoupled processes (switch off/on)**

✓ **Ice categories (user defined and $h^{-\alpha}$)**

✓ **Open boundaries (input cat ≠ output cat)**

✓ **AGRIF**

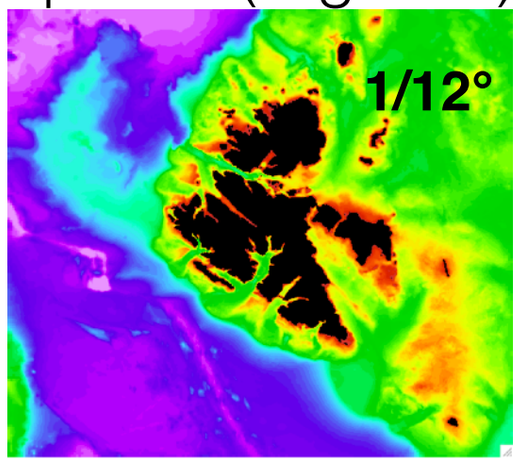
fully compatible with the sea ice model
revised tool to build an agrif configuration
(nesting tool)



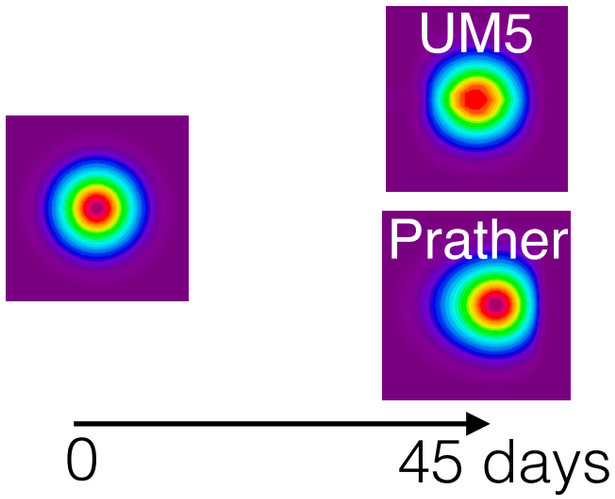
Developers & users friendly

- ✓ **Comprehensive set of outputs (CMIP compliant + universal units + names)**
- ✓ **New architecture**
- ✓ **New namelist**
- ✓ **Decoupled processes (switch off/on)**
- ✓ **Ice categories (user defined and $h^{-\alpha}$)**
- ✓ **Open boundaries (input cat ≠ output cat)**
- ✓ **AGRIF**
- ✓ **2 new demonstration configurations with sea-ice**

Spitz12 (regional)



IceDyn (Ice dynamics)



NEMO 4.0 versus 3.6

Physics

- ✓ lateral melting
- ✓ Ice-atm. drag
- ✓ Landfast ice
- ✓ Melt ponds

Numerics

- ✓ Ultimate-Macho
- ✓ Adaptive EVP
- ✓ Coupling interface

Performance

- ✓ All thermodynamics is 1D
- ✓ Reduced MPP communications
- ✓ Drastic improvement of scalability

Developers & users friendly

- ✓ Comprehensive set of outputs
- ✓ New architecture & namelist
- ✓ Decoupled processes
- ✓ Ice categories
- ✓ Open boundaries
- ✓ AGRIF + demonstration cases

Near future plans

funding from IS-ENES3 + IMMERSE + CMEMS

✓ **evaluation of SI³**
- rheologies (aEVP, EVP, VP, EAP)
- advection schemes (Prather, UM, Remapping)

✓ **test the functioning of the new features**
- landfast ice
- form drags

✓ **determinate the range of applications of SI³ parameterizations**
i.e. shall we use the same setup for a 2° global simulation & 1 km regional?

✓ **implement new parameterizations and physics**
- topographic melt ponds
- form drags (Tsamados)
- rheologies (EAP, VP)

✓ **Documentation!!**

Why using NEMO4.0?

✓Easier to setup regional ice-covered configurations

✓Enable 2-way nested simulations with AGRIF

✓Faster to run on a large number of cores

✓Documentation up-to-date (euh…soon)

✓starting point for many future sea-ice developments and evaluations

Organization