SICE:
simple sea ice scheme

Possibilities and limitations

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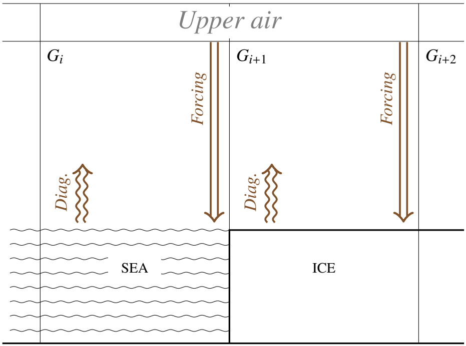
Sea ice in SURFEX v7

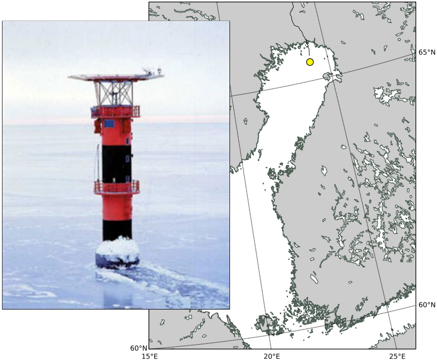


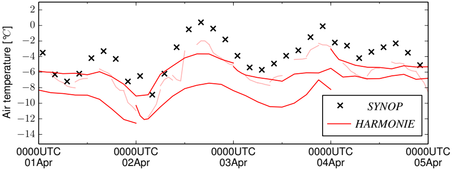
Sea ice as seen by SURFEX ICEFLUX scheme

- Assuming SURFEX in coupled mode within HARMONIE
- SEA tile is handled by SEAFLUX scheme, 'ECUME' option
- Only two states of SEA grid cell
  - open sea
  - fully covered by ice
- Ice areas are determined through surface temperature

Drawbacks

Kemi I station (№ 02863)
April 2013

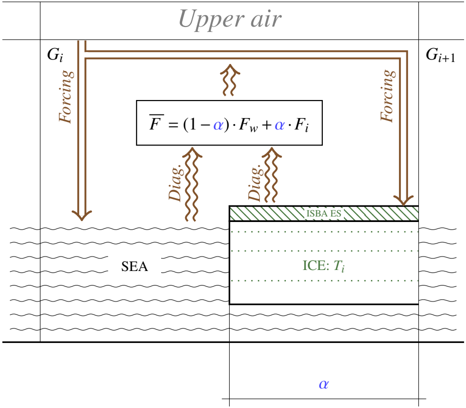




- Forecast depends on external data
- Harmonie in NWP mode updates ice surface temperature once per cycle
- Sharp temperature gradients over ice edge
- Unrealistic 2 meter temperatures

Kemi I lighthouse: photo by Finnish Maritime Administration.

SICE: simple sea ice scheme



Sea ice as seen by SURFEX with SICE scheme

- Uses SURFEX' standard routines for heat diffusion
- Ice thickness is uniform and fixed
- Ice covered areas are defined by ice concentration field

- Scheme solves heat diffusion in a thick layer of sea ice
- Snow on ice is modeled through calls to ISBA ES

SICE: simple sea ice scheme

$$\begin{cases} C_t \frac{\partial T_i}{\partial t} = F - \lambda \left. \frac{\partial T_i}{\partial z} \right|_{z=0} & \text{if } z = 0, \\ C_i \frac{\partial T_i}{\partial t} = \frac{\partial}{\partial z} \lambda \frac{\partial T_i}{\partial z} + \frac{\partial Q}{\partial z} & \text{if } 0 < z < H, \\ T_i = T_{frz} & \text{if } z = H, \end{cases}$$

- Linearized w.r.t. T_i version of surface heat balance is used
- Temperature is resolved through implicit finite difference scheme
- Diagnostics are taken from the ICEFLUX scheme
- For ice albedo a simple temperature based parameterization is used
- Thermal properties of ice layer are defined by set of empirical formulations

SICE: implementation

```fortran
!...
MODEL_FIELD(                                    &
   'TICE',                                      &
   'Ice temperature',                           &
   'K',                                         &
   [M%NUM_POINTS, M%NUM_LAYERS, 0],&
   P2 = M%T                                     &
          ),                                    &
MODEL_FIELD(                                    &
!...
```

- Minimal changes of the existing code
- Model-specific data stored locally
- Model IO is controlled by a descriptor-based list

SICE uses OO approach and Fortran 2003

```fortran
select case(CSCHEME)
  case('SCHEME_A')
    call scheme_a(...)
  case('SCHEME_B')
    call scheme_b(...)
end select
```

```fortran
call scheme%run(...)
```

SICE: implementation

```fortran
select case(CSCHEME)
  case('SCHEME_A')
    ! Scheme call...
  case('SCHEME_B')
    ! Scheme call...
end select
```

```fortran
call scheme%run(...)
```

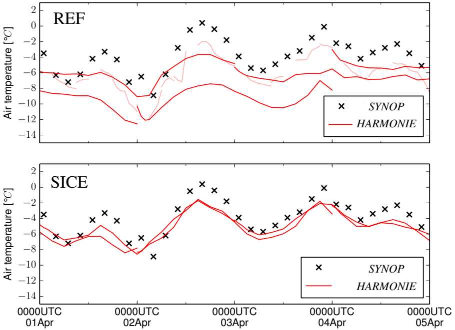
```
  call     _gfortran_select_string
  testl    %eax, %eax
  je       .L3
  cmpl     $1, %eax
  je       .L4
  /*...*/
.L3
/*...*/
  call scheme_a_
/*...*/
```

```
movq     -488(%rbp), %rax
movq     8(%rax), %rax
movq     40(%rax), %rax
call     *%rax
```

- Shorter code, clear structure
- Eliminated call to the Fortran runtime

SICE: impact on forecast

Kemi I station (№ 02863)
April 2013



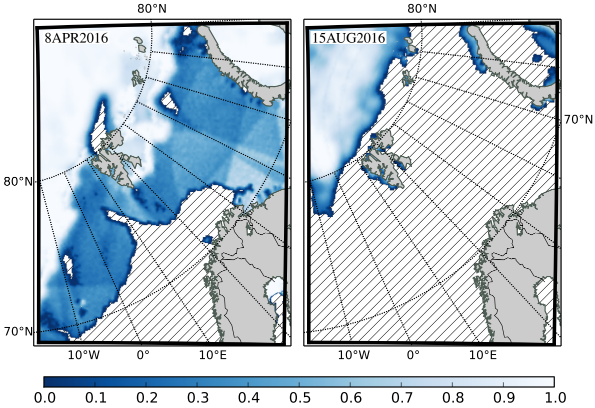
- Improved 2 meter temperature forecast
- Almost no impact on mean sea level pressure
- SICE-enabled HARMONIE tends to produce higher 10 meter wind speeds over ice covered areas

Limitations of the simple ice scheme

- 1D model without any parameterization of ice dynamics
- Prescribed uniform ice thickness
- Scheme is driven by the external ice fraction field, thus depends on its quality
- Snow-free setup is not realistic and often causes too warm ice surface
  - but snow-enabled configuration has several problems
- Simplistic initialization procedure
- No assimilation
  - ice scheme runs freely from cycle to cycle

External ice fraction data

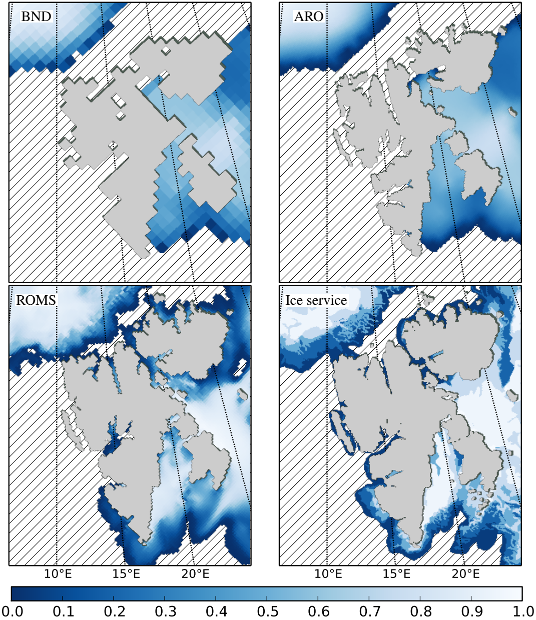
Examples of erroneous external ice fraction



- SICE uses ice concentration data from an external source to define ice covered grid cells
- Sometimes these data contain errors
- Areas with unrealistic amounts of ice should be filtered, but for some cases it's a tricky task

External ice fraction data

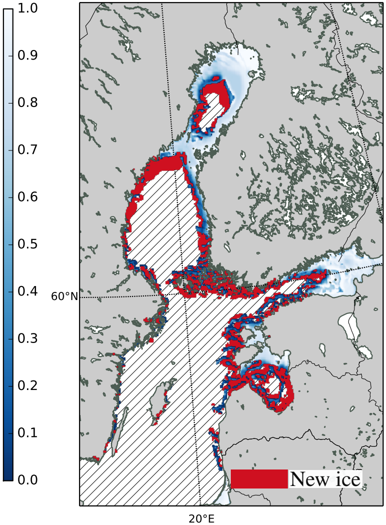
Ice concentration, 21MAR2016



- Ice concentration fields in HARMONIE provided by boundary files
- Resolution of boundary data does not allow to reproduce small elements of coastline
- Ice fraction in fjords is result of filling and extrapolation

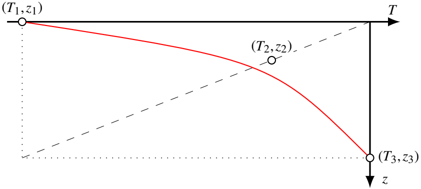
Initialization of new ice

Ice concentration, 09-10FEB2017



- Two options for initial ice temperature in off-line mode
  - Ice temperature is uniform
  - Ice surface temperature is defined by the composite SST field, internal – via linear interpolation
- In coupled mode temperature of new ice is derived from temperature of existing ice

Initialization of new ice



$$\Pi = \int_0^H T dz$$

$$T(\eta) = (1-\eta)^2 T_1 + 2\eta(1-\eta) T_2 + \eta^2 T_3$$

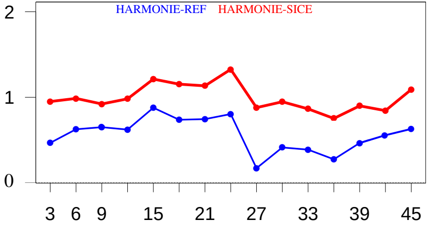
$$\begin{cases} z(\eta) = (1-\eta)^2 z_1 + 2\eta(1-\eta) z_2 + \eta^2 z_3 \\ z_2 \equiv \frac{z_3}{T_1 - T_3}(T_2 - T_3) \end{cases}$$

$$\Pi = \frac{1}{6} H (T_1 + 4T_2 + T_3)$$

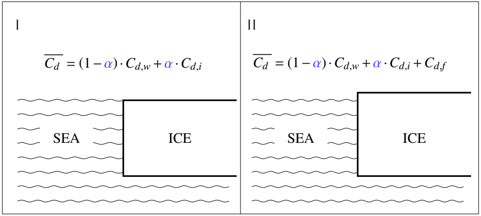
- New ice is not set to freezing temperature
- Information from the nearest edge of old ice is used
- Shape function is introduced to minimize differences of thermal profiles between old and new ice

10 meter wind speed over ice

10 meter wind speed ME [m/s] 01-31MAR2013



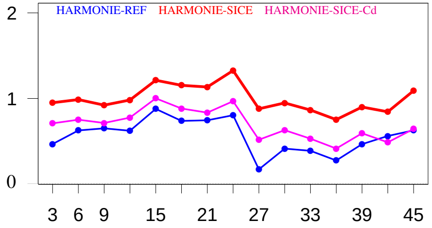
Average drag over ice



- SICE introduces additional amounts of open sea in areas that not fully covered by ice
- Increased amount of open sea causes decrease of average drag over ice

10 meter wind speed over ice

10 meter wind speed ME [m/s] 01-31MAR2013



- Introduced additional term in averaging procedure reduces 10 meter wind speed bias
- This additional term uses ice concentration as one of its parameters, thus depends on quality of external ice fraction field

SICE: current status

SICE in operational HARMONIE

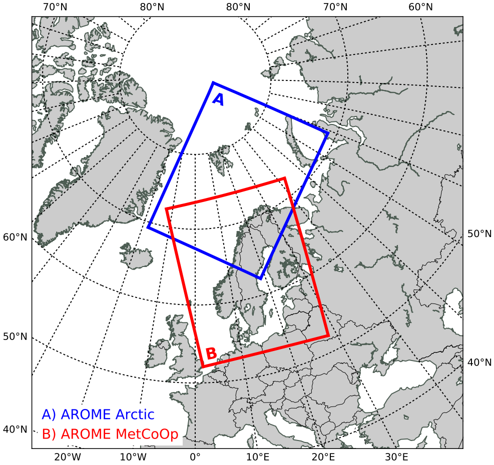
- AROME Arctic
- AROME MetCoOp

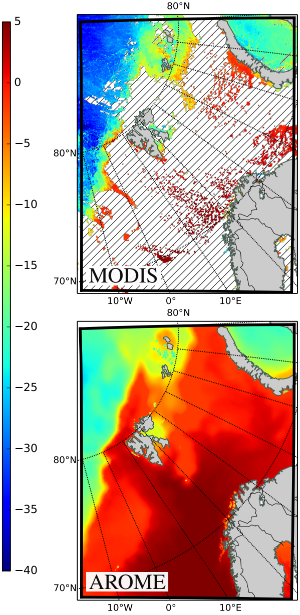
SICE operational setup

- snow block is switched off
- 4 ice layers
- ice thickness 0.75 meters
- ice concentration
  - Baltic sea – HIROMB data
  - Atlantic and Arctic ocean – data by ECMWF boundary files

SICE: current status

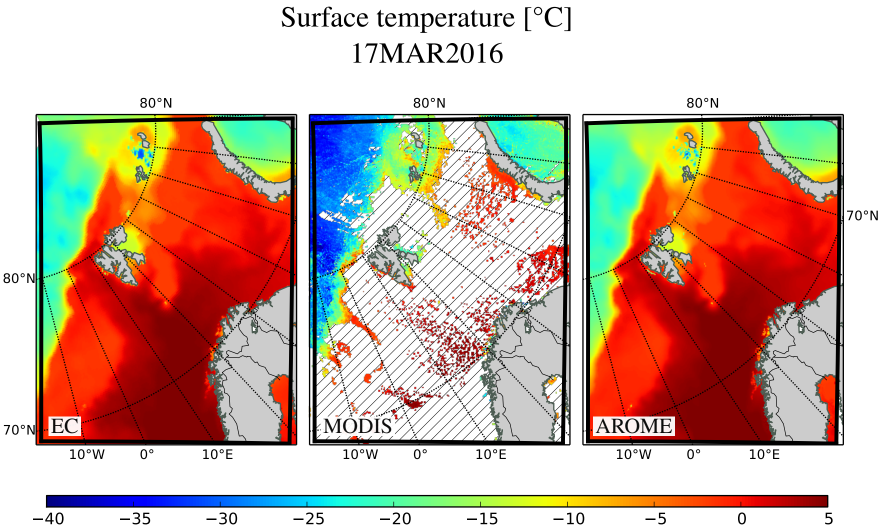
Surface temperature [°C]
17MAR2016





Locations of MetCoOp and Arctic HARMONIE domains

SICE: current status



Future plans

- Improve handling of snow on ice.
- Port ice mass balance parameterizations from HIGHTSI
- Sea ice analysis

Questions?