

Progress in implementing one-way and two-way ROMS+ICE coupling with atmospheric models over an Arctic polynya

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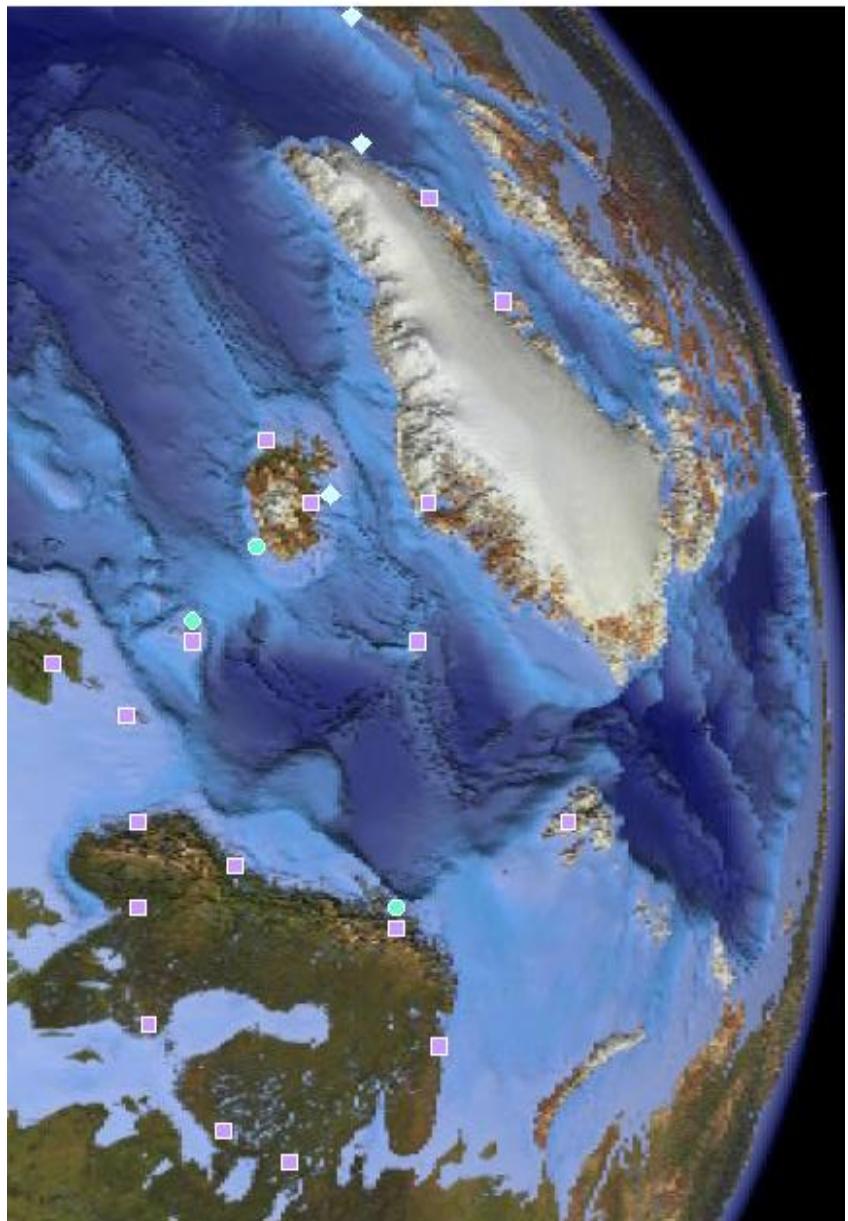
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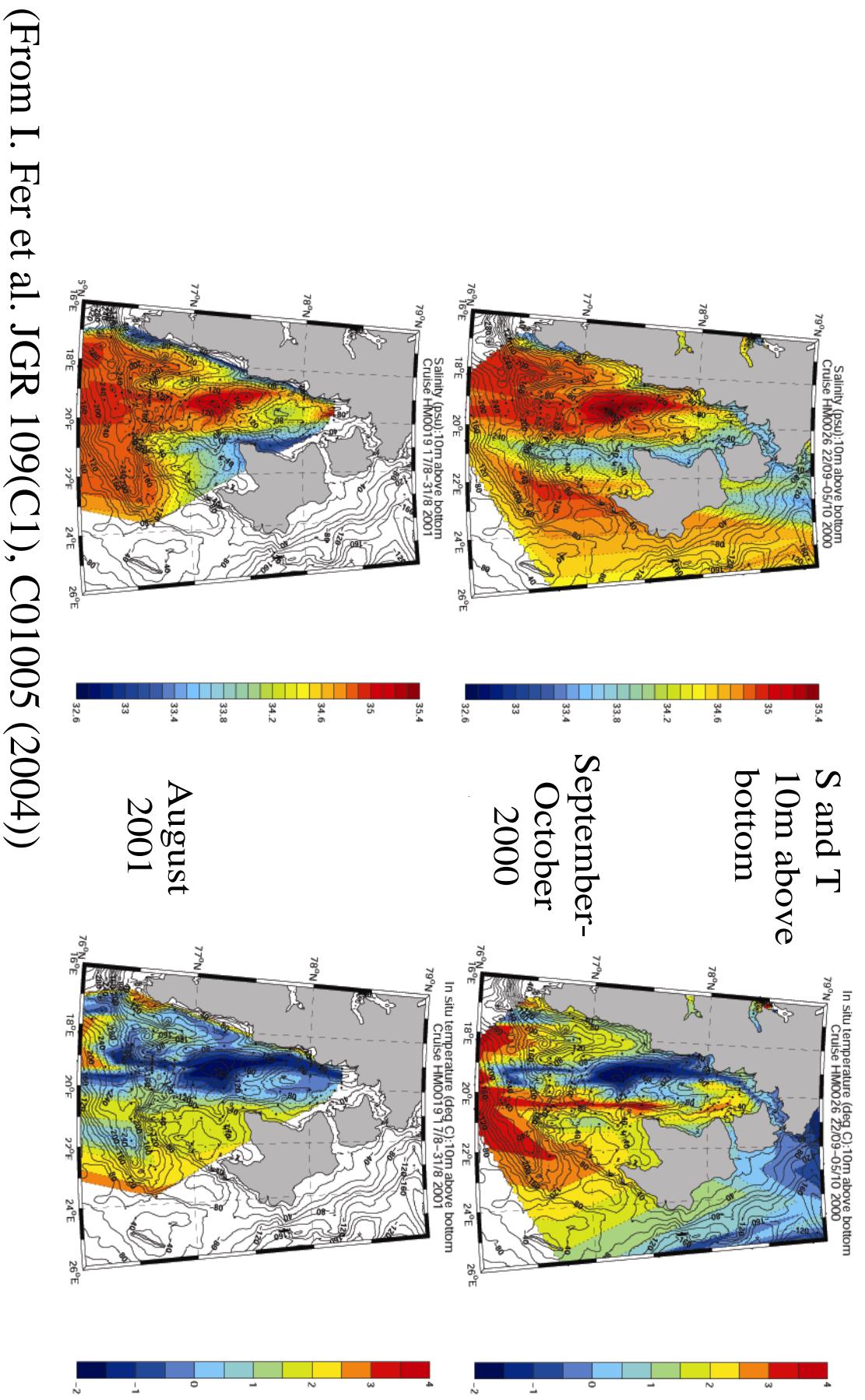
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Introduction

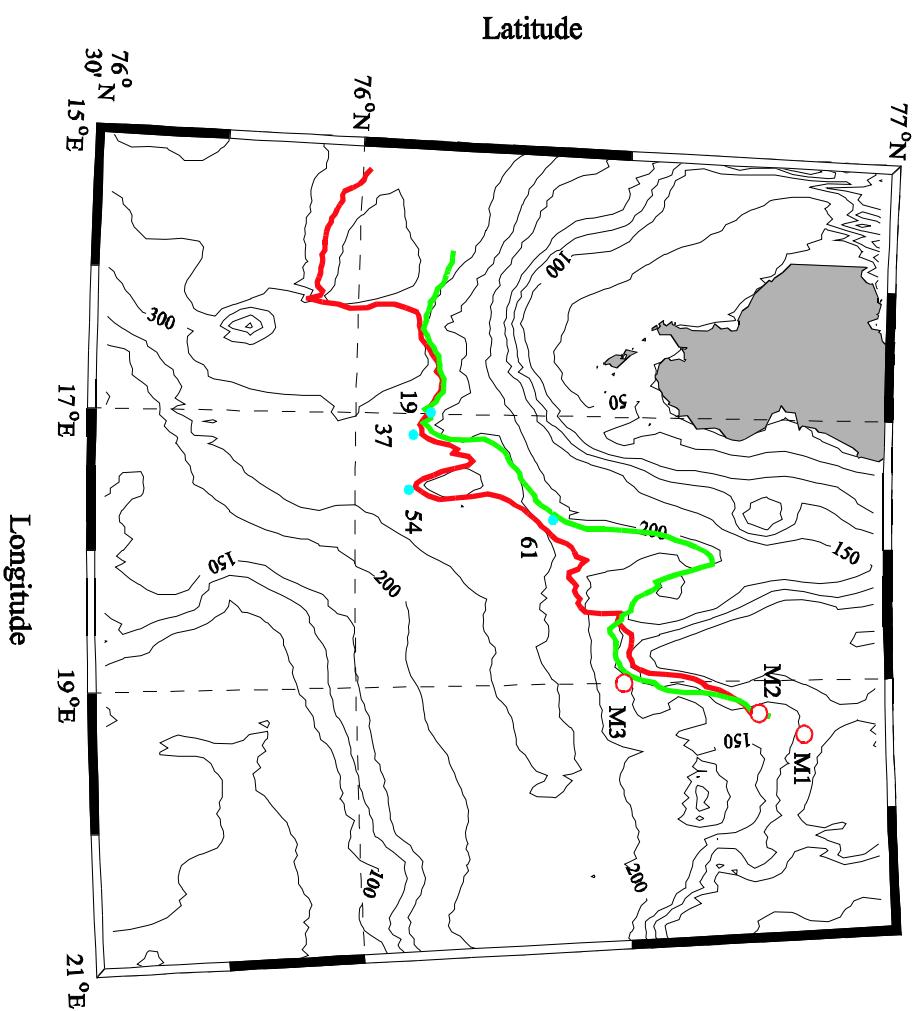
- Brine rejection during ice formation over polar continental shelf areas is thought to make a substantial contribution to the generation of oceanic deep water, with significant consequences for the interior ocean circulation, and for the global climate on decadal to millenial timescales.



- A substantial proportion of the ice-formation and brine-rejection process is associated with the formation of coastal polynyas during periods with offshore winds.



(From I. Fer et al. JGR 109(C1), C01005 (2004))



Storfjord outflow plume path after Killworth (2001): Descent rate: 1/400.

Green path: derived over smoothed bathymetry.

Red path: derived over raw bathymetry: better fit to observations!

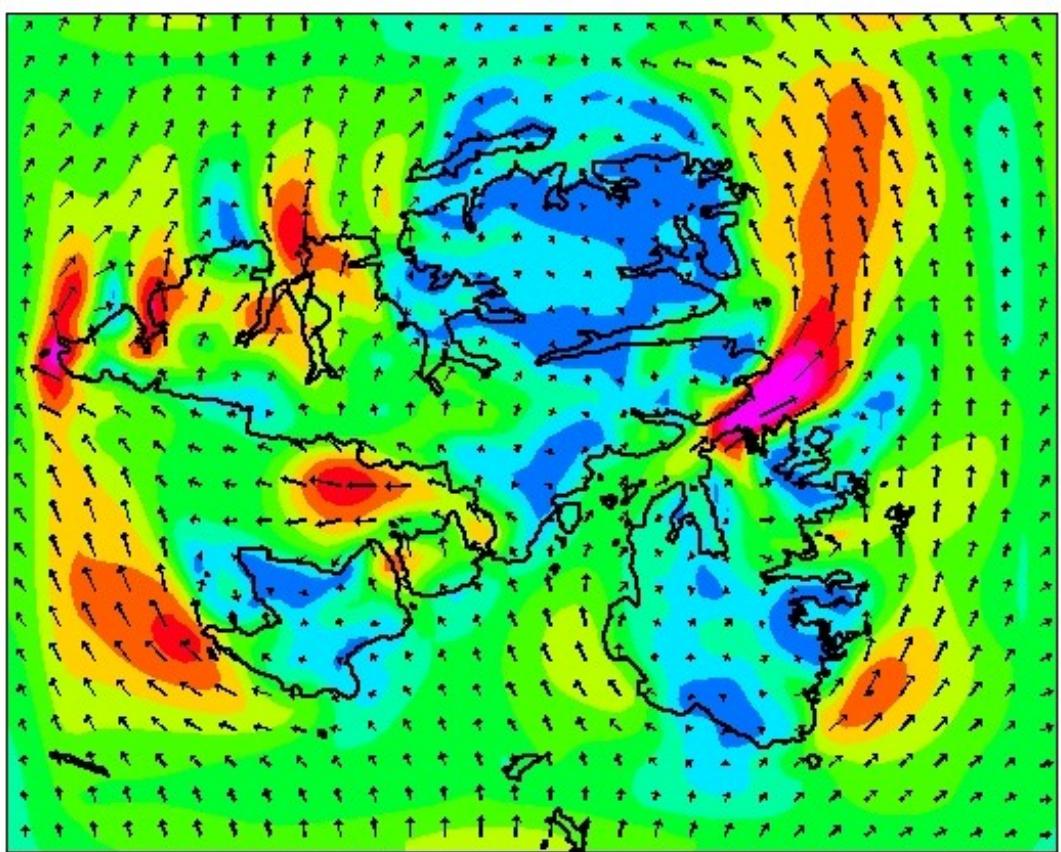
Blue dots: Stations where the core of the plume was observed during Lance, July 01.

(See I. Fer et al. JGR 109(C1), C01005 (2004))

Generating an artificial polynya (Lars H. Smedsrød, 2003)



Computed airflow over Svalbard, using MM5 model (Anne D. Sandvik)





Models

- In order to quantify the air-sea exchange processes involved, we are running ROMS with a dynamic-thermodynamic sea ice component, with input from the MM5 mesoscale atmospheric model, for Storfjorden (Svalbard).

Coupling

- Since there are great differences in the surface boundary conditions between ice-covered and open water areas, which will cause substantial changes in the atmospheric boundary layer, we are in addition implementing two-way coupling of ROMS+ice with the WRF mesoscale atmospheric model.

Size of grid: Goal—a 1–2 km grid, 300×300 grid points.

Fixed parameters: Terrain elevation, sea ice, Sea surface temperature, Substrate temperature, Snow cover, Latitude, Longitude, Map scale factor, Coriolis parameter, Land-use category



Exchanged variables chosen from:

U_{10} , V_{10} , Surface sensible and latent heat flux, Surface downward shortwave and longwave radiation, 2 m temperature, 2 m water vapour mixing ratio, surface albedo, Ground and sea-ice temperature, sea-ice fraction, Frictional velocity, roughness length, Monin-Obukhov length, snow height, snow cover, rainfall (convective and non-convective), Surface net radiation, water-equivalent snow depth.

Coupling method proposed

- Initially, we proposed to use the OASIS model coupler:
 - Developed under Program for Integrated Earth System Modelling (PRISM)
 - Version 3 available from CERFACS, Toulouse
 - OASIS3 synchronizes the exchanges of coupling fields between the models being coupled, and performs 2D interpolations and transformations between the source and target model.
 - Modularity and flexibility have been particularly emphasized in the OASIS3 design.
 - But the ROMS code would have to be modified to run under OASIS

Coupling method used

- The WRF I/O API MCT Coupling Implementation.
- An implementation of the WRF I/O Application Programming Interface using the Argonne Model Coupling Toolkit (MCT) and the Message Passing Environment Utilities (MPEU) libraries.
- ROMS 2.1 and the WRF atmospheric model now contain code implementing this coupling software (written by Dan Schaffer (NOAA) and Chris Moore).
- Versions used in the BCCR implementation:
 - WRF version 1.3, with coupling code made available to us by Dan Schaffer
 - ROMS 2.1 beta with ice code by Paul Budgell (*ROMS2.1beta+ice*), plus the ROMS 2.1 (*ROMS2.1final*) coupling code
 - * It was simpler to add the coupling routines from *ROMS2.1final* to *ROMS2.1beta+ice*, rather than to add the ice code to *ROMS2.1final*.

Status (one-way coupling)

- One-way MM5 → ROMS coupling has been set up for the Barents Sea. A finer grid for the Storfjorden area will be implemented.
- A quasi-one-dimensional ROMS simulation has been performed at a fine scale by Lars H. Smedsrød to simulate the freezing of an artificial polynya.



Status (two-way coupling)

- ROMS and WRF compile successfully on the IBM Regatta at Bergen (Para//ab).
- Now in the testing phase (stripped down ‘minimal’ model system, employing two unix (AIX) processes, one for the WRF part and one for the ROMS part of the model). Compiled with debugging enabled.



- Initialization of MPI data communication appears to be successful.

- Debugger (IBM xldb) can be used, with 2 windows, one for each process.

```

Programs Favorites Settings Desktop (4) Terminal xldb[1.2.4...]
Locals For air_ocean() in master.f90 (5) XTerm 16:40:28
H 18 gf
$ mycolor: +2
mycomm: +3
myerror: +0
mykey: +0
mystring: "COMPONENT_ID=2,COMPONENT_NAME=roms"
myvalue: -780993632
first: true
master: true
peatm_last: +0
sou
socn_comm_world: +0
scalars: []
sou
nathm_steps: +15
nrun: +1

myrank: +1
ocn_comm_world: +0
scalars: []
nathm_steps: +1
nrun: +1

mycolor: +1
mycomm: +0
myerror: +0
mykey: +0
mystring: "COMPONENT_ID=1,COMPONENT_NAME=wrf"
myvalue: -780993632
first: false
master: true
peatm_last: +0
ocn_comm_world: +0
myrank: +0
scalars: []
nathm_steps: +15
nrun: +1

```

Locals For air_ocean() in master.f90

```

107 ! nodes. Variational data assimilation (4DVAR)
108 ! requires more thinking.
109 !
110 ! /work/jenkins/modelling/WRF-ROM
111 write(*,*)"air_ocean.F: nATHM_steps = ",nATHM_
112 write(*,*)"air_ocean.F: nOCN_steps = ",nOCN_
113 IF (MyRank.le.peatmLast) THEN
114 write(*,*)"air_ocean.F: About to call wrf_
115 CALL wrf_init (MyCOMM)
116 CALL wrf_run (nATHM_steps, MyValue)
117 CALL wrf_finalize
118 ELSE
119 ! first=.TRUE.
120 Nrun=1
121 write(*,*)"air_ocean.F: About to call roms_
122 CALL roms_init (first, MyCOMM)
123 write(*,*)"air_ocean.F: Exit from roms_init"
124 CALL roms_run
125 CALL roms_finalize
126 END IF
127 !
128 Terminates all the 1 processing.
129 !
130 !
131 !
132 CALL ext_mctcexit (MyError)
133 CALL mpi_finalize (MyError)

```

Locals For air_ocean() in master.f90

```

100 ! /work/jenkins/modelling/WRF-ROMS/Regatta/roms
101 ! in ensemble forecasting. ROMS is run over an ensemble loop.
102 ! variational data assimilation ROMS is run over outer and inner loops.
103 ! This requires a different code structure than the simple one.
104 ! For now, the outside loop is deactivated and "Nrun" is set to 1.
105 ! In ensemble forecasting, a full atmosphere-ocean coupling is
106 ! but each member of the ensemble needs to be run on different
107 ! nodes. Variational data assimilation (4DVAR) is more complicated.
108 ! requires more thinking.
109 !
110 write(*,*)"air_ocean.F: nATHM_steps = ",nATHM_
111 write(*,*)"air_ocean.F: nOCN_steps = ",nOCN_
112 IF (MyRank.le.peatmLast) THEN
113 write(*,*)"air_ocean.F: About to call wrf_init"
114 CALL wrf_init (MyCOMM)
115 CALL wrf_run (nATHM_steps, MyValue)
116 CALL wrf_finalize
117 !
118 ELSE
119 ! first=.TRUE.
120 Nrun=1
121 write(*,*)"air_ocean.F: About to call roms_init"
122 CALL roms_init (first, MyCOMM)
123 write(*,*)"air_ocean.F: Exit from roms_init"

```

- Errors occur during data exchange—it is probably necessary to eliminate errors due to incorrect specification of the data exchange format (in a file which is in NetCDF format).

Conclusion

- Brine formation during freezing in coastal polynyas may contribute towards deep-water formation, and thus thus the meridional overturning circulation and the global climate system.
- In order to quantify this process adequately, detailed coupled atmosphere–sea ice–ocean hydrodynamic and thermodynamic model studies are required.
- At BCCR, within the NFR-funded ProcClim project, we are setting up a coupled system comprising ROMS 2.1 beta with an ice module, and the WRF atmospheric model, coupled using the MCT Argonne model coupling toolkit, inter-process communication being by MPI.
- The coupled model system has been successfully compiled and linked, and work is in progress to set up correctly the data exchange routines.