RCAO, a coupled atmosphere-ice-ocean-land model of the Arctic

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Coupled model setup

- **Standalone model components**
  - Atmosphere, ocean+sea ice

- **Technical coupling**
  - external coupler: OASIS4

- **Coupling algorithm**
  - ocean delivers state variables, atmosphere responds with fluxes

Example: RCAO coupling scheme described in:
RCO (ocean)

- Z-coordinates, rotated coordinates
- Arctic: 0.5° resolution
- free surface
- low dispersion advection
- Mixing options
  - K-eps, Philander/Pacanowski, KPP
- Bottom boundary layer (BBL)
- Climatological Arctic River runoff
- Open boundary conditions
- sea ice model
  - Semtner thermodynamics
  - EVP rheology

RCO described in:
Meier, Döscher and Faxen, 2003:
A multiprocessor coupled ice-ocean model for the Baltic Sea: application to salt inflow, JGR, 108 (C8), 3273
RCA (atmosphere)

- HIRLAM based regional atmosphere model optimized for climate studies:
  - Arctic 0.5° resolution
  - Prognostic variables: U, V, T, CW, Ps and TKE
  - Semi-Lagrangian dynamics, 0.5° resolution
  - 6th order implicit horizontal diffusion scheme
  - Davies lateral boundary relaxation scheme
  - HIRLAM fast two band radiation scheme
  - Kain-Fritsch meso-scale convection
  - Rasch-Kristjansson large-scale condensation
  - Turbulent Kinetic Energy (TKE) vertical mixing scheme
  - Has been run over the Arctic in ARCMIP runs
  - Applications in other regions (North America, Africa, collaboration partners in South America)
  - Possible improvements:
    - Cloudiness, radiation and turbulence in the stable boundary layer (dry-turbulence-moist turbulence)
    - Optical properties of ice crystals (ice clouds)
    - Surface flux representation in the stable boundary layer

description in:
Arctic applications

• Currently:
  – Sensitivity studies
  – Predictability studies
  – Regional climate scenario experiments
  – Short term forecast (weather and sea ice), data assimilation (HIRLAM-HIROMB model)

• future:
  – Seasonal prediction
  – Bio-geo-chemical component
Sea ice extent in RCAO simulations

Spinup phase

Arctic sea ice extent

Arctic summer sea ice extent
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Summer sea ice extent anomaly in four ensemble runs

Arctic summer sea ice extent decrease in coupled model

--- coupled runs
--- ERA40 or sat observation
Sea ice extent

- **Summer**
  - Ensemble mean
  - ERA-40

- **Winter**
  - Ensemble mean
  - ERA-40
Mean T2m north of 70°N

--- red RCAO ensemble
--- black ERA-40

Arctic Ocean T2m jas

summer

Arctic Ocean T2m jfm

winter

Arctic Ocean T2m my

annual means
Surface pressure in standalone atmosphere and coupled model
Predictability t2m winter

- **Internal Variability**
  - Mean internal variability, winter 1980-2000
  - Total variability
  - External/Internal

- **External Variability**
  - External variability, winter t2m

Dominating internal variability in Fram Strait area
Pelagic variables:

- nitrate \((NO3)\)
- ammonium \((NH4)\)
- phosphate \((PO4)\)
- autotrophs \((A1,A2,A3)\) (diatoms, flagellates, cyanobacteria)
- zooplankton \((ZOO)\)
- detritus \((DET)\)
- oxygen \((O2)\)
- Hydrogen sulfide \((H2S)\) is included as negative oxygen.

The sediment contains nutrients in the form of benthic nitrogen \((NBT)\) and phosphorus \((PBT)\).

Aggregated process descriptions for oxygen dependent nutrient regeneration, denitrification and adsorption of ammonium to sediment particles as well as re-suspension and permanent burial of organic matter.

Meier, Eilola, Almroth SMHI
Regionalization is done for “time-slices” from GCMs.

Results archived from a GCM-run:

- Present-day or a “control” climate (1961-1990)
- Climate scenario (2071-2100)

Time:

- 1800
- 1900
- 2000
- 2100

CO₂
Annual mean phytoplankton concentration [mgChl/m$^3$] (0-10m) for different nutrient load reduction scenarios


Present climate
Comming activities

• Modell improvements
  – cloud - radiation scheme (SLP bias problem)
  – Improved vertical mixing in the ocean
  – Ice classes
• Additional predictability - studier under
  – different parameterizations
  – different climates
• Hindcast runs driven with improved reanalysis products (ERA-interim)
• RCO (ocean-ice standalone) runs of 20th century within AOMIP
• Regional Arctic climate scenarios, based on Bergen Climate model (BCM) and other GCMs.
• Simulations of 2007/2008 (RCO and RCAO)
• RCAO as an ASM:
  – SCOBI_Arctic
The End