New perspectives of climate change impacts on marine anthropogenic radioactivity in Arctic regions

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Resume the present knowledge on:
- sources of Arctic marine radioactivity
- main transport routes in the Arctic
- impact of global warming on transport and behavior

> Compilation of most recent results from ongoing projects, observations, coupled Ocean-Atmosphere Models (IPCC) etc.
> Transfer of present knowledge on radionuclide transport to future scenarios
> Contribution to a better preparedness
Sources

**Remote sources:**
- nuclear reprocessing facilities (Sellafield / La Hague)
- Baltic Sea (Chernobyl)

**Local sources:**
- nuclear test sites
- dumped Objects
- accidents
present status:
- reduction in discharges
- decline of levels

but:
- remobilization of sediments (Irish Sea)
- operational releases (Kola / other power plants)
- oil and gas exploitation
- accidents (shipping, facilities)
Main Transport Routes

Ocean surface
- NCC / NAC through Fram Strait and Barents Sea
- Beaufort Gyre, TPD
- river runoff

Advective time scales
shelf > Fram Strait:
1 - 3 years (ice)
3 - 10 years (ocean)

R.W. Macdonald et al., STE 342 (2005)
**Main Transport Routes**

**Intermediate depths** (200-800 m)
- inflowing Atlantic water masses (Fram Strait / Barents Sea)
- water mass transformation (cooling / ice formation)
- subduction under polar waters

Advective time scales:
- 2-3 decades (200-800 m)
- century scale (depths > 1000m)
- polar warming exceeds global warming

- strongest warming over land masses and in the Barents Sea

- more extreme events in polar regions

- enhanced storm tracks NA to AO

- enhanced advection of warm air and water masses

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Sea ice retreat

- all model scenarios show a rapid ice retreat
- ice free Arctic Ocean in summer 20xx?
- Combined effect of warming, circulation and wind forcing
- Observations support the trend

1400 years Arctic Sea Ice simulations with COSMOS (MPI-Hamburg, A1B-Szenario)

Jungclaus et al. 2010, Grafik: L. Kaleschke
Sea ice retreat

1400 years Arctic Sea Ice simulations with COSMOS (MPI-Hamburg, A1B-Szenario)

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Consequences: sea ice retreat

- decrease of summer ice cover reduces the chance for contaminated sea ice to survive the following summer: retreat of multi-year ice

- only sea ice which is formed close to the Fram Strait can be expected to leave the Arctic Ocean before melting

- sediments incorporated into freezing ice on the shelves may not be able to leave the shelf

- contaminated sediment is only redistributed on the shelf over a period of several freeze/melt seasons.

R.W. Macdonald et al., STE 342 (2005)
Consequences: circulation Atlantic Water loop

- increased Barents Sea throughflow and enhanced in- and outflow through Fram Strait indicate that transport of radionuclides through the Arctic Ocean could occur at a faster rate (Atlantic Water loop)

- enhanced volume inflow to the Barents Sea increases the exchange between shelves and deep basins
Consequences: circulation Amerasian loop

Trend towards an increasing fresh water content!
(Sref=35.0) negativ: S > Sref

MPI-ECHAM5, R. Gerdes pers. comm
Arctic Ocean exhibits a pronounced vertical stratification:

- surface "Halocline" (mixture of fresh water and Polar Water)
- Atlantic Water Masses
- Arctic Deep Waters

M. Karcher et al., MPB 60 (2010)
Consequences: stratification / vertical mixing

- possible stronger winds and diminished ice cover would lead to increased mixing and higher ventilation rates for mid-depth water masses

- an increase of radioactive inventory at mid-depth relative to the surface layer could be a consequence
Consequences: circulation / vertical mixing

- enhanced wind-induced upwelling and downwelling at the shelf break, due to stronger winds and partly due to a reduced period of ice cover in the season
Permafrost retreat

- Permafrost underlies about 25% of the land masses of the Northern Hemisphere

- Permafrost area could be reduced by 12–22% by the year 2100
Consequences: Permafrost retreat

- Thawing frozen ground releases sediment which enter ground water, rivers and lakes
- Drainage channels in permafrost will likely enhance transport into surface waters
- More river runoff, stronger seasonal signals
- Increased transport of riverine material
Consequences: Summary

Increasing levels in Arctic surface waters:

- robust: reduced export of radioactivity by sea ice
- robust: permafrost melting and increasing river discharge
- robust: increasing runoff (precipitation on land / permafrost)
- robust: increasing precipitation / deposition on water

- uncertain: local precipitation
- unknown: new sources for Arctic radioactivity ??

Decreasing levels at the surface:

- robust: stronger wind mixing into greater depths
Consequences: Summary

**Increasing levels in Arctic intermediate waters:**
- robust: enhanced lateral inflow (reprocessing signals)
- robust: turbulent mixing from surface layers
- uncertain: remobilization of contaminated sediments
- unknown: new sources for radioactivity at depth ??

**Decreasing levels in Arctic intermediate waters:**
- robust: enhanced throughflow / flushing
Thank you!
Consequences: Fukushima accident
Consequences: Fukushima accident
Consequences: Permafrost retreat

Current Arctic Vegetation

Present day natural vegetation of the Arctic and neighboring regions from floristic surveys.

Projected Vegetation, 2090–2100

Projected potential vegetation for 2090–2100, simulated by the LPJ Dynamic Vegetation Model driven by the Hadley2 climate model.
- Polar warming exceeds global warming
- Strongest warming over land masses and in Barents Sea
- More extreme events in polar regions