COURSE TITLE: THE POLAR OCEANS, CLIMATE CHANGE AND CLIMATE RESTORATION

COURSE DESCRIPTION

The introductory part of the course summarises our knowledge of the climate system and the way that it operates. We begin by looking at radiative transfer in the atmosphere and how energy moves between different levels and forms. Then we look at the climates of the past, including the extreme past before the climate was cool enough to exhibit periodic ice ages. From the physical basis of climate we move to the carbon cycle and examine how carbon transfer processes affect, and modulate, climate change.

We move next to the atmosphere, ocean and cryosphere. We look at the polar vortex, the jet stream, and other mechanisms by which energy is transferred within the atmosphere. Next we introduce the cryosphere and take the reader through a voyage of ice development in which the annual cycle of heating and cooling determines ice thickness while the ice motion is governed mainly by the wind. The wind also causes ice deformation and the impressive vision of pressure ridges reaching 40 m or more below the surface. After covering the regions where the ice and open ocean compete for dominance, i.e. the marginal ice zone, we look at icebergs and their role in transferring ice mass into the ocean from the great ice sheets. Then we take the facts of Arctic amplification, showing that the warming of the Arctic is much faster than that of any other region of the planet, and look at what this means for the accelerating rate of ice thinning and shrinkage and the feedbacks that this has upon the entire global system, not just sea ice. Albedo reduction (accelerating warming), the possibility of massive methane release from the warming Arctic seabed, the increase in ice melt from the Greenland and Antarctic ice sheets leading to faster sea level rise, the break-up of jet stream circulation leading to extreme weather events, and changes in the thermohaline circulation of the ocean, all can be traced back to sea ice loss.

The urgent need to deal with climate change is made clear by these analyses, and we show that emissions reduction, the standard proposed solution, does not offer the hope of restoring the climate, but only of slowing the climate's descent into a dangerous state. The sheer difficulty of accomplishing emission reduction in a planet filled with infrastructure designed for a fossil fuel world, is also discussed. Only carbon dioxide removal can really save the climate, and we introduce the topic of how this can be done and scaled up to the necessary global level.

SYLLABUS
Consisting of 15 3-hour sessions

1. An introduction to climate
The meaning of climate
Radiative transfer in the atmosphere
Paleoclimate
The carbon cycle

2. Climate perturbations
Milankovitch cycles and ice ages
Greenhouse gas absorption bands
Energy transfer in the atmosphere and ocean

3. The physics of sea ice and ice formation
Oceanographic background – Arctic and Antarctic
What happens when sea water cools
Growth of ice crystals
Brine cells and brine rejection
Salinity structure
Summer melt processes
First- and multi-year ice

4. Ice growth and decay
Thermodynamic model
Equilibrium thickness
Sensitivity of thickness to changes in forcing
Sensitivity to albedo.

5. Ice dynamics
Ice motion - driving forces
Free drift solution
Ice interaction
The dynamics of polynyas

6. The ice thickness distribution
Ridge and lead formation
Geometry of pressure ridges
The probability density of ice thickness and its evolution
Mathematical form of ridges and leads distributions
The ridging and rafting process
Ridge evolution and decay
Ice interaction with structures
Ice interaction with the seabed

7. The marginal ice zone
Ice floes
Waves in ice
Modelling development of floe size distribution
Eddies

8. Icebergs and ice islands
Distribution in Arctic and Antarctic
Physical properties
Dynamics
Decay and breakup
Role in the oceans and in sediment transport
Iceberg scouring – depths, incidence, seabed interaction
Mechanics of iceberg and ice island interaction with structures
Upstream detection of ice islands
Towing icebergs - a source of fresh water?

9. Oil spills under ice
Scope of the under ice blowout problem

Other sources of spills under and in ice
Physical behaviour of crude oil in very cold water
Dynamics of a rising oil-infested bubble plume
Incorporation of oil in rough sea ice – containment factors
Ice growth under an oil layer
Oil penetration into brine drainage channels
Oil transport by ice
The melt process and mode of final oil release
Oil behaviour in pancake ice and the marginal ice zone

10. Two important ice regions – Greenland Sea and Beaufort Sea
East Greenland waters
Greenland Sea convection zone
South Greenland and the Storis
Baffin Bay and Nares Strait ice conditions
The Lincoln Sea and waters north of Greenland
The Beaufort Gyre and its variability
Changes in ice conditions in central Beaufort Sea
The Beaufort Sea coastal zone
The summer Beaufort Sea as a new MIZ
Methane release from seabed

11. Thinning and retreat of sea ice in response to global change
Satellite data on retreat
Parkinson - retreat in sectors, Arctic and Antarctic
What is found in Antarctic
Thinning - the submarine and other evidence
Model predictions of a future seasonal Arctic ice cover

12. Arctic feedbacks and acceleration of global change
Albedo change and snowline retreat
Greenland ice sheet melt and global sea level rise
Offshore methane release and its threat to climate
Changes in thermohaline circulation
Extreme weather events and the jet stream

13. Saving planet Earth from climate change
Ice ages and their causes
The coming of the anthropocene
Exponential growth of greenhouse gases
Geoengineering as a way of delaying warming
Marine cloud brightening and other techniques

14. The need for carbon dioxide drawdown
Paris climate agreement and its defects
Need for CO_2 removal
Possible techniques compared

15. Direct air capture and state of emergency
Direct air capture methods currently in use

Most effective upscaling approaches
Targets to avoid serious catastrophe.

BACKGROUND READING:
Two books are recommended: “A Farewell to Ice” by Peter Wadhams (Korean edition published 2018), and "Ice in the Ocean" by P Wadhams (Taylor and Francis, 2000). Another very useful book which is relevant to the course is "Global Warming - the Complete Briefing" by Sir John Houghton, 3rd Edn (Cambridge University Press). During the course there will be specific references to material that could be pursued further in sources such as

“On Sea Ice” by Willy Weeks (Univ. Alaska Press)
- “The Geophysics of Sea Ice” (ed. N Untersteiner)
- “The Physics of Ice-Covered Seas” (Univ Helsinki)
- “The Drift of Sea Ice “ (M Lepparanta)
- “Field Techniques for Sea Ice Research” (ed. H. Eicken)
- “Introduction to Carbon Capture and Sequestration” (Berend Smit et al.,
- Imperial College Press)