Regclim

Regional Climate Development under Global Warming

Final Report, Phase I, II, and 2002

1997-2002

Introductory Remarks

This report complements the RegClim Progress Report of December 15th 2001 with the activities carried out in 2002. The full report covers the entire period from the start in the autumn 1997 to ultimo December 2002. The report starts with the form from the Research Council of Norway for "Sluttrapportering". The relevant information asked for in that form is referred to by chapter and paragraph numbers in the main body of the report that follows immediately after.

RegClim is the oldest and first of a series of "co-ordinated projects". In many ways the project has opened up unknown fields in the way of running projects. The project has undergone two full phases and a one-year "phase" in 2002. During this time there have been numerous amendments to the structure, aims and milestones of the project, and a large number of scientists have been associated on a more or less permanent basis. It would be an impossible task to recover all detailed information during the entire period, and even more problematic to present the information in a meaningful and clear way. We therefore keep the structure of the last progress report of December 15th 2001, and add the information for the Phase 2002 in the same format.

RegClim has been active in publishing results scientifically and has emphasized the task of popularisation and active use of media. During this long period and given the large numbers of institutions and scientists, it is probable that this final report underestimate these activities.

Oslo May 9th 2003

Trond Iversen
Project Leader

Prosjektnr.: 120656/720
Saksbehandler: Fridtjof Mehlum, miljø og utvikling
Budsjettår: 2002
Prosjektperiode: 1.7.1997 - 31.12.2002
Program/aktivitet: Forskn.prog.klima,-klimaendr.
Prosjekttype: Prosjektstøtte
Fagkode: 453 - Meteorologi

Sluttrapport

Returneres ved prosjektslutt til Norges forskningsråd sammen med eventuelle vedlegg

Vennligst kontroller at alle forhåndsutfylte opplysninger stemmer. Ved feil og nye opplysninger krysser man av i korrekt boks og skriver inn den oppdaterte informasjonen enten på egne ark eller ved å fylle ut sluttrapportskjemaet som ligger på Forskningsrådets hjemmeside på Internett. Dette delvis forhåndsutfylte skjemaet skal altså returneres til Forskningsrådet sammen med eventuelle vedlegg.

A Grunnlagsopplysninger

Dersom navn på prosjektmedarbeidere (dvs. faglige medarbeidere på prosjektet som helt eller delvis er finansiert av Forskningsrådet) ikke framgår av grunnlagsopplysningene nedenfor, fylles opplysningene ut slik:

- Prosjektmedarbeidere: ***Navn, stilling, arbeidssted, finansieringsandel fra Forskningsrådet.*** Oppgi i tillegg om den ansatte er registrert som doktorgradsstudent.

Det er ingen endringer i grunnlagsopplysningene X☐ (kryss av)
Endringer og nye opplysninger er lagt ved på eget ark ☐ (kryss av)

Kommentar: ***Se "Personnel Tables" i vedlagte hovedrapport (Main Report).***

Prosjektopplysninger:

Prosjektansvarlig institusjon: Meteorologisk institutt
Adm.ansvarlig: Direktør Anton Eliassen
Prosjektleder (faglig ansvarlig): Professor Trond Iversen
Prosjektmedarbeider(e):
Veileder:
Prosjekttittel: RegClim -Regional Climate Development under Global Warming, PHASE 2002 (continuation of Phase I and Phase II)

Finansieringsplan:

	1997	1998	1999	2000	2001	2002
Bevilgning/tilsagn fra Forskningsrådet:	2,474,623	4,684,103	5,431,035	7,245,430	7,294,033	7,619,276
Egne midler						2,137,000
Andre offentlige midler						572,000
Andre private midler						156,000
EU-midler						1,000,000

Følgende mål er avtalt for prosjektet:

RegClim has two overall aims. Overall aim I is to estimate probable changes in the regional climate in Northern Europe, bordering sea areas and major parts of the Arctic ("our region"), given a global climate change. Overall aim II is to quantify, as far as possible, the significance of regional scale climate forcings pertaining specifically to our region. This includes processes determining the relatively warm sea-surface-temperature (SST) and modest sea ice cover in the Nordic Seas (Overall aim IIa), and processes related to radiatively active atmospheric contaminants with a regional distribution (Overall aim IIb). In PHASE"2002" there are 7 principal tasks (PT1 to PT7), each lead by a Principal Investigator (PI). PT1. Atmospheric dynamical downscaling Tasks 1.1 - 1.3; PT2. Coupled dynamical downscaling and sea state modelling. Tasks 2.1 - 2.3; PT3. Empirical Downscaling. Tasks 3.1 - 3.3; PT4. The Role of the Nordic Seas: Atmosphere-Ocean Feedback. Tasks 4.1 - 4.3; PT5. Numerical simulations of the climate state of the Nordic Seas and the adjacent oceans. Tasks 5.1-5.5 PT6. Climate response to aerosols and aerosol-cloud interactions. Task 6.1 - 6.7. PT7. Nonlinear chemistry and regional radiative forcing. Tasks 7.1 - 7.4. Each PT contribute to one of the overall aims

B Prosjektsammendrag

Prosjektsammendraget skal kunne brukes i prosjektkataloger/-registre og som grunnlag for annen informasjon fra Forskningsrådet. Nytt prosjektsammendrag utarbeides ved endringer i prosjektets mål/delmål, som medfører at tidligere prosjektsammendrag ikke kan benyttes.
Mindre endringer kan rettes direkte i teksten under. Dersom det utarbeides nytt prosjektsammendrag krysser man av i korrekt boks nedenfor og skriver inn det oppdaterte sammendraget som forklart øverst på side 1.
Sammendraget skal inneholde informasjon om følgende elementer: ***Bakgrunn for prosjektet, problemstilling og betydning av forskningen.*** Sammendraget skal være på maksimalt 200 ord. Tittel og prosjektsammendrag på engelsk utarbeides ved første gangs framdriftsrapportering. Samme retningslinjer for innhold og evt. endringer gjelder for engelsk som for norsk prosjektsammendrag.

Prosjektsammendrag, norsk

Det er ikke registrert norsk prosjektsammendrag for dette prosjektet
Det er ingen endringer i prosjektsammendraget X☐ (kryss av)
Nytt prosjektsammendrag er lagt ved på eget ark ☐ (kryss av)

Prosjektsammendrag, engelsk

Engelsk prosjekttittel: RegClim - regional climate development under global warming; phase 2002
Nåværende engelsk prosjektsammendrag:

There are two overall aims of RegClim. The first is to estimate probable changes in the regional climate in Northern Europe, bordering sea areas and major parts of the Arctic ("our region"), given a global climate change. The second is to quantify, as far as possible, uncertainties in these estimates, inter alia, by investigating the significance of regional scale climate forcings pertaining specifically to our region. This includes processes determining sea-surface-temperature (SST) and sea ice cover in the Nordic Seas, and processes related to radiatively active atmospheric contaminants with a regional distribution (direct and indirect aerosol effects, and tropospheric ozone).

Climate in this connection encompasses the statistical properties of the elements air temperature, precipitation amount, wind at 10m, sea surface salinity and sea surface temperature, and sea-state (wave-height and sea level). Climate scenarios of these parameters in our region will include estimates of typical seasonal variations, typical variations from year to year, and probable changes in severe weather conditions as defined by high wind speeds, large precipitation amounts and extreme sea-state. We also aim at first estimates of inter-decadal variations to the extent global models can simulate this satisfactorily.

In RegClim PHASE"2002" emphasis will be to complement and finalize existing activities, to do more in-depth analyses and a few alternative experiments, and to publish as much as possible of the results so far in RegClim. More information can be found at http: // www . nilu . no / regclim

Det er ingen endringer i engelsk tittel/prosjektsammendrag X☐ (kryss av)
Nytt prosjektsammendrag (+ tittel) er lagt ved på eget ark ☐ (kryss av)

Kommentar: ***Prosjektsammendraget for Phase II var lagt ved. Dette er byttet til Phase 2002***.

C Faglig rapport

Den faglige rapporten skal skrives inn på egne ark merket ”Faglig rapport” som returneres sammen med dette skjemaet, se veiledning øverst på side 1. Merk at det spørres etter periodiserte opplysninger i tiden fra siste framdriftsrapportering. Merk også at tabellene under punkt 2 og 3 SKAL fylles ut på skjemaet.

1 Oppnådde faglige resultater

Beskriv prosjektets oppnådde resultater i forhold til hovedmål, delmål og milepæler som er fastsatt i kontrakt og arbeidsplaner. Beskrivelsen skal også inneholde en samlet konklusjon/egen vurdering av prosjektgjennomføring og ressursbruk. Videre ønskes en vurdering av forholdet til Forskningsrådet i prosjektperioden.
Gi i tillegg en kort ***populærvitenskapelig framstilling*** av de viktigste FoU-resultatene (dvs nye funn, nye problemstillinger, ny kunnskap) som er oppnådd i prosjektperioden, og gi en vurdering av resultatenes nyhetsverdi. Framstillingen vil blant annet bli benyttet som underlag for Forskningsrådets årsrapportering til departementene, eksempelsamlinger på internett mv.

Kommentar: ***Se ” SCIENTIFIC ACHIEVEMENTS” i vedlagte hovedrapport (Main Report).***

2 Vitenskapelige utgivelser og annen publisering

Gjør rede for vitenskapelige utgivelser og annen publisering (som er akseptert) fra prosjektet for hele prosjektperioden i en ***publikasjonsliste*** inndelt etter publikasjonstypene i tabellen nedenfor. De som har mottatt eget publikasjonsskjema fra NSD må fylle ut dette i tillegg. Følgende opplysninger bes oppgitt i listen:
For bøker/artikler i bøker/rapporter: ***Forfatter(e), arbeidets tittel, tittel på bok/artikkelsamling, forlag/utgiver, redaktør, flerbindsverk/serie, sidenr., nr./bind/år, ISSN/ISBN, sted***
For artikler: ***Forfatter(e), arbeidets tittel, tidsskrift/avis, sidenr., nr./vol./år, ISSN***
For foredrag, presentasjoner og lignende: ***Forfatter(e), tittel, arrangement/dato/sted***
Oppgi antall utgivelser etter publiseringstype i tabellen nedenfor.

Publikasjonstyper:	Antall siden forrige rapp.	Antall hele prosjekt-perioden	Antall planlagt etter prosj.slutt
Artikler i vitenskapelige tidsskrifter med referee		47	27
Artikler i andre vitenskapelige tidsskrifter og antologier		77	
Bøker (monografier, lærebøker, antologier (red.))			
Publiserte foredrag fra internasjonale faglige møter/kongresser		45	
Andre rapporter, samt foredrag og presentasjoner fra vitenskapelige/faglige møter		160	

Kommentar: ***Se ”SCIENTIFIC AND OTHER PUBLICATIONS” i vedlagte hovedrapport (Main Report).***

3 Annen forskningsformidling

Gjør rede for andre formidlingstiltak enn publiseringsvirksomhet (dvs. deltakelse i vitenskapelige og allmennrettede/brukerrettede konferanser og møter, høringer, utstillinger og lignende) for hele prosjektperioden i en ***liste*** som skal inneholde følgende opplysninger:
For deltakelse i arrangementer: ***Arrangement, arrangør og arrangementsdato***
Innslag om prosjektet i massemedia: ***Mediets navn, type innslag og dato***
Oppgi antall formidlingstiltak etter tiltakstypene i tabellen nedenfor.

Andre forskningsformidlingstiltak:	Antall siden forrige rapport	Antall hele prosjekt-perioden	Antall planlagt etter prosj.slutt
Allmennrettede formidlingstiltak (populærvitenskapelige artikler/høringer/utstillinger)		92	
Brukerrettede formidlingstiltak (møter/seminarer i dep., næringsliv, organisasjoner)			
Oppslag vedrørende prosjektet i massemedia		114	

Kommentar: ***Se "POPULAR PUBLICATIONS AND MEDIA" i vedlagte hovedrapport (Main Report).***

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4 Andre resultater

Gi en kort beskrivelse av andre resultater i prosjektperioden som:

- Veiledning, kurs, undervisning

Several Master students have taken the Thesis on subjects related to RegClim, based on the modell tools developed in RegClim, and supervised by RegClim scientists. This applies both to University of Oslo and University of Bergen. Bidrag også fra BCM-gruppa i Bergen til en ingeniør-avhandling ved MeteoFrance.

- Forskernettverk

RegClim has been a useful instrument to establish international co-operation. Many Letter of Intents for co-operation have been signed (see application for RegClim Phase III).
A Nordic network called RESMoNA has been established financed by the Nordic Council of Ministers through the Nordic Arctic Research Programme. All 5 Nordic countries are involved, and there are annual meetings.

- Brukernytte, patenter

Results from RegClim are very useful for further research on impacts and possible consequences of climate change in Norway. Hopefully all this will help decision-makers to agree on correct measures for the future.

- Annet

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5 Prosjektmedarbeidere finansiert av Forskningsrådet

Kommentar: ***Se "Personnel Tables" i vedlagte hovedrapport (Main Report).***

5.1 Doktorgrads- og postdoktorstipendiaters virksomhet

Gi opplysninger om ***avbrudd, permisjoner og fratredelser.*** Oppgi også tidspunkt for disputas for doktorgradsstipendiater.

Dr.-grader avlagt i hele RegClim-perioden:

Alf Kirkevåg: Direct radiative forcing of climate due to tropospheric black carbon and sulphate aerosols. Universitetet i Oslo. Defended for the degree of Dr. Scient, June 2000

Øyvind Seland: A physical process oriented scheme for modelling tropospheric suphate and black carbon. Universitetet i Oslo. Defended for the degree of Dr. Scient. October, 2001.

Mats Bentsen: Modelling the decadal variability in the North Atlantic/Arctic by an Atmosphere-Ocean General Circulation Model. Defended for the degree of Dr. Scient. 3 September 2002.

Yongqi Gao: Evaluation of the Ocean Ventilation Processes in an Isopycnic Coordinate Ocean General Circulation Model. Defended for the degree of Dr. Scient. 6 February 2003.

Odd Helge Otterå: A model study of the glacial circulation and biogeochemistry with focus on the high northern seas. Thesis submitted for approval, April 2003 - to be defended 10 July 2003.

5.2 Utenlandsopphold

Oppgi utenlandsopphold av mer enn tre måneders varighet siden forrige rapportering. Angi ***navn på prosjektmedarbeideren, perioden, utenlandsk institusjon og land.*** Det skal i tillegg redegjøres særskilt for utbyttet av oppholdet.

I RegClim 2002: Ett utenlandsophold av lengre varighet: Øyvind Seland, Igf-UiO. Tidligere har Jon Egill Kristjansson og Trond Iversen hatt utenlandsopphold, men det er rapportert per 15. desember 2001.

Name: Post Doc. Øyvind Seland
Periode: 4 months, July – October 2002
Institution: Pacific Northwest National Laboratory (PNNL), Richland, Washington, U.S.A.
This was arranged as part of the newly established co-operation between Igf-UiO and PNNL.. Host at PNNL was Dr. Steve Ghan, and he also interacted with several other scientists there, e.g., Richard Easter. The purpose of this collaboration is to strengthen the effort to improve the parameterisations of aerosols and the associated physical and chemical processes in global climate models. During this visit Øyvind Seland implemented PNNL's aerosol scheme into the new version of NCAR's climate model, the Community Climate System Model (CCSM). The atmospheric component of this coupled model system is termed Community Atmospheric Model (CAM). Seland also performed adjustments of the aerosol modules at PNNL and Igf-UiO, to facilitate interchanges of components between the two groups. More info on the PNNL group is provided through the web page:
http://www.pnl.gov/atmos_sciences/as_clim.html

Prosjektleder (faglig ansvarlig):	For prosjektansvarlig institusjon (adm. ansvarlig):
Sted: .... Dato:	Sted: ....Dato: ....
Underskrift:	Underskrift: ....
Professor Trond Iversen	Det norske meteorologiske institutt - Oslo Professor Anton Eliassen

MAIN REPORT

of the RegClim Final Report 1997 - 2002

INSTITUTIONS

met.no Norwegian Meterological Institute
P.O. Box 43, Blindern, N-0313 Oslo, Norway

IMR Institute of Marine Research
P.O. Box 1870 Nordnes, N-5024 Bergen, Norway

NERSC Nansen Environmental and Remote Sensing Center
Edv. Griegsvei 3A, N-5037 Solheimsviken, Norway

Gfi-UiB Geophysical Institute, University of Bergen
Alléç. 70, N-5007 Bergen, Norway

Igf-UiO Department of Geophysics - The University of Oslo
P.O. Box 1022, Blindern, N-0315 Oslo, Norway

NILU The Norwegian Institute of Air Research
P.O. Box 100, N-2027 Kjeller, Norway

PERSONNEL

Project Management Phase 2002

Project Leader:	Professor Trond Iversen, Igf-UiO	trond.iversen@geofysikk.uio.no
Co-Project Leaders:	Professor Sigbjørn Grønås, Gfi-UiB	sigbjorn@gfi.uib.no
	Dr. Eivind A. Martinsen, met.no	eivind.ansgar.martinsen@met.no
Scientific Secretary	Dr. Chris R. Lunder, NILU	chris.lunder@nilu.no

Principal investigators Phase 2002

During the earlier phases there have been changes in the Principal Tasks (PT), both with respect to numbering and with respect to the leaders of each PT: the Principal Investigators. Here we summarize the PIs belonging to the 7 PTs for RegClim Phase 2002.

There was a considerable re-numbering of PTs in Phase 2002. In order to simplify the tables and the reporting, we report the progress and the achievements for each PT with numbers corresponding to earlier phases. In this Table is denoted under which PT the reporting for 2002 is allocated. Where nothing is mentioned the reporting is under the same PT-number.

PT 1	Professor Thor Erik Nordeng, met.no	t.e.nordeng@met.no
PT 2 **(Reported under PT7)**	Professor Lars Petter Røed, met.no	larspetter.roed@met.no
PT 3	Eirik Førland, met.no	e.forland@met.no
PT 4	Dr. Nils Gunnar Kvamstø, Gfi-UiB	nilsg@gfi.uib.no
PT 5 **(Reported under PT2)**	Professor Helge Drange, NERSC	helge.drange@nrsc.no
PT 6 **(Reported under PT5)**	Professor Jón Egill Kristjánsson, Igf-UiO	j.e.kristjansson@geofysikk.uio.no
PT 7 **(Reported under PT6)**	Professor Ivar Isaksen, Igf-UiO	ivar.isaksen@geofysikk.uio.no

Personnel Tables

Resources Phase I

Project participants Phase I

Persons not covered by NFR are also included. Many persons have only contributed during certain periods.

IMR=Inst. for Marine Research

NILU=Norwegian Inst. for Air Research

DNMI=Norwegian Meteorological Inst.
= **met.no**

NERSC=Nansen Environment and Remote Sensing Centre

Igf-UiO=
Dep. of Geophysics, Univ. of Oslo

Gfi-UiB=
Geophysics Inst., Univ. of Bergen

NAME	INST.	PT
Albretsen, J.	DNMI	7
Asplin, L.	IMR	8
Bartonova, E.	NILU	6
Benestad R.	DNMI	3, 8
Bentsen, M.	NERSC	4
Berg, T.	NILU	Scient.secr.(1998-99)
Berglen, T. Flatlandsmo	Igf-UiO	6
Berntsen, T.	Igf-UiO	6
Bjørge, D.	DNMI	1
Budgell, P. W.	IMR	7
Drange, H.	NERSC	2 (PI)
Dyngeseth, H.	Gfi-UiB	4
Engedahl, H.	DNMI	7
Furevik, T	Gfi-UiB/NERSC	2, 4
Førland, E.j	DNMI	3 (PI)
Grønås, S.	Gfi-UiB/DNMI	Co-pr. leader
Hackett, B.	DNMI	2
Häkkinen, S.	DNMI-guest	7
Hanssen-Bauer, I.	DNMI	3, 8
Haugen, J.E.	DNMI	1
Høiskar, B. A.	NILU	Scient.secr. (1999)
Iden, K.A.	DNMI	8 (PI), 3
Ingvaldsen, R.	IMR	8
Isaksen, I.S.A.	Igf-UiO	6
Iversen, T.	Igf-UiO/DNMI	Proj. leader, 5
Johannessen, O.M.	NERSC	2
Kirkevåg, A.	Igf-UiO	5, 6
Kristjánsson, J.E.	Igf-UiO	5 (PI)
Kvamstø, N.G.	Gfi-UiB	4 (PI)
Liasæther, K.A.	NERSC	2
Lunde, A.	DNMI	2
Martinsen, E.A.	DNMI	Co-pr. leader
Melsom, A.	DNMI	7
Mork, K.A.	IMR	2, 4
Myhre, G.	NILU	6
Nordeng, T.E.	DNMI	1 (PI), 5
Otterå, O.H.	NERSC	2, 7
Pacyna, J.	NILU	6
Røed, L.P.	DNMI	7 (PI)
Sagen, H.	IMR	8
Seland, Ø.	Igf-UiO	5, 6
Shi, X.B.	DNMI	7

Project participants Phase I (contd.)	Simonsen, K.	NERSC	2
	Skeie, P.	Gfi-UiB	4
	Slørdal, L.H.	NILU	Scient.secr.(1997)
	Solberg, S.	NILU	6
	Stordal, F.	NILU	6 (PI), 8
	Sætra, Ø.	DNMI	7
	Tveito, O.E.	DNMI	3
	Ulstad, C.	DNMI	2
	Vignes, O.	DNMI	1
	Wahl, D.	DNMI	8
	Wettre, C.	DNMI	7
	Ødegård, V.	DNMI	5
	Ødegård, M.	DNMI	1, 7
	Ådlandsvik, B.	IMR	2
	Secretary Personell	DNMI	Secr., Proj. Coord.

Allocation of funding Phase I

Project Management				**Resources (knok)**	
PT No.	Year	Institution	Expense Type	Financed by project	Own/other financial support
Management	1997	DNMI	Personnel		251
		NILU	Personnel	200	1
			Operat. Costs	263	
Management	1998	DNMI	Personnel		251
		NILU	Personnel	300	6
			Operat. Costs	682	
		DNMI	Technical ass, and hardware for data storage		335
Management	1999	DNMI	Personnel		251
		NILU	Personnel	302	41
			Operat. Costs	537	
		DNMI	Technical ass, and hardware for data storage		335

Principal Task 1				**Resources (knok)**	
Principal Task No	Year	Institution	Expense Type	Financed by project	Own/other financial support
PT 1	1997	DNMI	Personnel	293	84
PT 1	1998	DNMI	Personnel	629	84
PT 1	1999	DNMI	Personnel	629	84

Principal Task 2				**Resources (knok)**	
PT No	Year	Institution	Expense Type	Financed by project	Own/other financial support
PT 2	1997	NERSC	Personnel	168	
		DNMI	Personnel	191	
		IMR	Personnel	168	
PT 2	1998	NERSC	Personnel	293	
		DNMI	Personnel	293	
		IMR	Personnel	335	
PT 2	1999	NERSC	Personnel	251	46
		DNMI	Personnel	251	

		IMR	Personnel	126	

Principal Task 3				**Resources (knok)**	
PT No	Year	Institution	Expense Type	Financed by project	Own/other financial support
PT 3	1997	DNMI	Personnel	210	84
PT 3	1998	DNMI	Personnel	419	503
PT 3	1999	DNMI	Personnel	419	503

Principal Task 4				**Resources (knok)**	
PT No	Year	Institution	Expense Type	Financed by project	Own/other financial support
PT 4	1997	GfI-UiB	Personnel	210	
PT 4	1998	GfI-UiB	Personnel	419	
PT 4	1999	GfI-UiB	Personnel	524	
		DNMI	Personnel	419	
		IMR	Personnel	168	
		NERSC	Personnel	272	50

Principal Task 5				**Resources (knok)**	
PT No	Year	Institution	Expense Type	Financed by project	Own/other financial support
PT 5	1997	IGf-UiO	Personnel		84
		DNMI	Personnel	126	
PT 5	1998	IGf-UiO	Personnel	182	84
		DNMI	Personnel	210	
PT 5	1999	IGf-UiO	Personnel	695	84
		DNMI	Personnel	210	
		NILU	Personnel	84	

Principal Task 6				**Resources (knok)**	
PT No	Year	Institution	Expense Type	Financed by project	Own/other financial support
PT 6	1997	NILU	Personnel	168	
		IGf-UiO	Personnel	105	
PT 6	1998	NILU	Personnel	335	
		IGf-UiO	Personnel	210	
PT 6	1999	NILU	Personnel	251	255
		IGf-UiO	Personnel	209	

Principal Task 7				**Resources (knok)**	
PT No	Year	Institution	Expense Type	Financed by project	Own/other financial support
PT 7	1997	DNMI	Personnel	144	88
		NERSC	Personnel	42	
PT 7	1998	DNMI	Personnel	126	84
		NERSC	Personnel	126	
PT 7	1999	DNMI	Personnel	42	84

Principal Task 8				**Resources (knok)**	
PT No	Year	Institution	Expense Type	Financed by project	Own/other financial support
PT 8	1997	DNMI	Personnel	84	84
		NILU	Personnel	21	
		IMR	Personnel	84	
PT 8	1998	DNMI	Personnel		84
		NILU	Personnel	42	
		IMR	Personnel	84	
PT 8	1999	DNMI	Personnel		84
		NILU	Personnel	42	61

Resources Phase II, personnel and allocation of funding

Project Management				**Resources (knok)**		**Position (Percentage of position in project)**	
Principal Task No	Year	Institution	Name of fellow/ Expense Type	Financed by project	Own/other financial support	Financed by project	Own/other financial support
Manage-ment	2000	met.no	Trond Iversen		96		20
		met.no	Sigbjørn Grønås		96		20
		met.no	Eivind A. Martinsen		96		20
		NILU	Britt Ann K Høiskar	306		40*	
		met.no	Gunn Nygård	40		10	
			Operat. Costs	556			
		met.no	Technical ass, and hardware for data storage		365		
Manage-ment	2001	met.no	Trond Iversen		96		20
		met.no	Sigbjørn Grønås		96		20
		met.no	Eivind A. Martinsen		96		20
		NILU	Britt Ann K Høiskar	306		40*	
		met.no	Gunn Nygård	40		10	
			Operat. Costs	635			
		met.no	Technical ass, and hardware for data storage		365		
Manage-ment	**2002**	met.no	Trond Iversen		105		20
		met.no	Sigbjørn Grønås		105		20
		met.no	Eivind A. Martinsen		105		20
		NILU	Chris Lunder	236		30*	
		met.no	Gunn Nygård	26		7	
			Operat. costs	469			

Principal Task 1				**Resources (knok)**		**Position (Percentage of position in project)**	
Principal Task No	Year	Institution	Name of fellow/ Expense Type	Financed by project	Own/other financial support	Financed by project	Own/other financial support
PT 1	2000	met.no	Thor Erik Nordeng		96		20
		met.no	Jan Erik Haugen	480		100	
		met.no	Dag Bjørge	480		100	
PT 1	2001	met.no	Thor Erik Nordeng		96		20
		met.no	Jan Erik Haugen	480		100	
		met.no	Dag Bjørge	480		100	
PT 1	**2002**	met.no	Thor Erik Nordeng		105		20
		met.no	Jan Erik Haugen	524		100	
		met.no	Dag Bjørge	524		100	

Principal Task 2				**Resources (knok)**		**Position (Percentage of position in project)**	
Principal Task No	Year	Institution	Name of fellow/ Expense Type	Financed by project	Own/other financial support	Financed by project	Own/other financial support
PT 2	2000	NERSC	Helge Drange	373		78	
		NERSC	Mats Bentsen	37		8	
		NERSC	Kjetil Lygre	22		5	
		IMR	Bjørn Ådlandsvik	192		40	
PT 2	2001	NERSC	Helge Drange	241		50	

		NERSC	Mats Bentsen	50		10	
		NERSC	Odd Helge Otterå	45		9	
PT 2 **(named PT 5 in 2002)**	**2002**	NERSC	Helge Drange	322		61	
		NERSC	Mats Bentsen	150		27	
		NERSC	Anne Britt Sandø		520	99	
		NERSC	Yongqi Gao		520	99	
		NERSC	Kjetil Lygre		282	54	
		NERSC	Odd Helge Otterå		250	48	
		IMR	Bjørn Ådlandsvik	131		25	

Principal Task 3				**Resources (knok)**		**Position (Percentage of position in project)**	
Principal Task No	Year	Institution	Name of fellow/ Expense Type	Financed by project	Own/other financial support	Financed by project	Own/other financial support
PT 3	2000	met.no	Eirik Førland		144		30
		met.no	Rasmus Benestad	456		95	
		met.no	Inger Hanssen-Bauer	24	312	5	65
		met.no	Ole Einar Tveito		96		20
		met.no	Knut A. Iden		24		5
PT 3	2001	met.no	Eirik Førland		144		30
		met.no	Rasmus Benestad	432		90	
		met.no	Inger Hanssen-Bauer	48	192	10	40
		met.no	Ole Einar Tveito		96		20
		met.no	Torill Engen Skaugen		120		25
PT 3	**2002**	met.no	Eirik Førland		131		25
		met.no	Rasmus Benestad	524		100	
		met.no	Inger Hanssen-Bauer		315		60
		met.no	Ole Einar Tveito		52		10
		met.no	Torill Engen Skaugen		105		20
		met.no	Knut A. Iden		26		5

Principal Task 4				**Resources (knok)**		**Position (Percentage of position in project)**	
Principal Task No	Year	Institution	Name of fellow/ Expense Type	Financed by project	Own/other financial support	Financed by project	Own/other financial support
PT 4	2000	GfI-UiB	Nils Gunnar Kvamstø		144		30
		GfI-UiB	Paul Skeie	434		90	
		GfI-UiB	Tore Furevik	240		50	
		IMR	Bjørn Ådlandsvik	96		20	
		NERSC	Tore Furevik	240		50	
		NERSC	Mats Bentsen	96	315	20	66
PT 4	2001	GfI-UiB	Nils Gunnar Kvamstø		144		30
		Gfi-UiB	Asgeir Sorteberg	400		83	
		GfI-UiB	Tore Furevik	240		50	
		Gfi-UiB	Frode Vikebø	123		25	
		IMR	Bjørn Ådlandsvik	40		8	
		IMR	Kjell Arne Mork	8		2	
		NERSC	Tore Furevik	240		50	
		NERSC	Mats Bentsen	192		40	
PT 4	**2002**	GfI-UiB	Nils Gunnar Kvamstø		207		30
		GfI-UiB	Tore Furevik	40		8	
		NERSC	Jan Even Øie Nilsen	240		50	
		GfI-UiB	Asgeir Sorteberg	480		92	
		Gfi-UiB	Martin Miles	200		38	
		NERSC	Mats Bentsen	232		44	

Principal Task 5				**Resources (knok)**		**Position (Percentage of position in project)**	
Principal Task No	Year	Institution	Name of fellow/ Expense Type	Financed by project	Own/other financial support	Financed by project	Own/other financial support
PT 5	2000	IGf-UiO	Jon Egill Kristjánsson		96		20
		IGf-UiO	Alf Kirkevåg	372		80	
		IGf-UiO	Øyvind Seland	410		100	
		IGf-UiO	Trond Iversen		48		10
PT 5	2001	IGf-UiO	Jon Egill Kristjánsson		96		20
		IGf-UiO	Alf Kirkevåg	510		100	
		IGf-UiO	Øyvind Seland	450		100	
		IGf-UiO	Trond Iversen		48		10
PT 5 **(named PT 6 in 2002)**	**2002**	IGf-UiO	Jon Egill Kristjánsson		105		20
		IGf-UiO	Alf Kirkevåg	524		100	
		IGf-UiO	Øyvind Seland	524		100	
		IGf-UiO	Trond Iversen		52		10
		met.no	Jens Debernard	105		20	

Principal Task 6				**Resources (knok)**		**Position (Percentage of position in project)**	
Principal Task No	Year	Institution	Name of fellow/ Expense Type	Financed by project	Own/other financial support	Financed by project	Own/other financial support
PT 6	2000	NILU	Frode Stordal	240	120	50*	25*
		NILU	Gunnar Myhre	240	240	50*	50*
		IGf-UiO	Tore F. Berglen	210	120	44	25
		IGf-UiO	Alf Kirkevåg	96		20	
		IGf-UiO	Ivar Isaksen		60		10
		IGf-UiO	Jostein Sundet		50		10
		IGf-UiO	Terje Berntsen		50		10
PT 6	2001	NILU	Frode Stordal	240	120	50*	25*
		NILU	Gunnar Myhre	48	48	10*	10*
		NILU	Mona Johnsrud	144		30*	
		IGf-UiO	Tore F. Berglen	210	120	44	25
		IGf-UiO	Ivar Isaksen		60		10
		IGf-UiO	Jostein Sundet		50		10
		IGf-UiO	Terje Berntsen		50		10
PT 6 **(named PT 7 in 2002)**	**2002**	NILU	Frode Stordal	136	120	26*	23*
		NILU	Gunnar Myhre	48	48	9*	9*
		NILU	Mona Johnsrud	288		55*	
		IGf-UiO	Tore F. Berglen	317		66	
		IGf-UiO	Ivar Isaksen		60		10
		IGf-UiO	Jostein Sundet		50		10
		IGf-UiO	Terje Berntsen		50		10

Principal Task 7				**Resources (knok)**		**Position (Percentage of position in project)**	
Principal Task No	Year	Institution	Name of fellow/ Expense Type	Financed by project	Own/other financial support	Financed by project	Own/other financial support
PT 7	2000	met.no	Lars Petter Røed		91		19
		met.no	Arnhild Lunde	1			
		met.no	Arne Melsom	33		7	
		met.no	Bruce Hackett	9		2	
		met.no	Harald Engedahl	8		2	
		met.no	Ingerid Fossum	4		1	
		met.no	Jon Albretsen	448		93	
		met.no	Xiaobing Shi	227		47	
		met.no	Øyvind Sætra	94	119	20	25
		IMR	Paul Budgel	80		17	
		IMR	Bjørn Ådlandsvik	16		3	
PT 7	2001	met.no	Lars Petter Røed	40	94	8	19
		met.no	Arne Melsom	9		2	
		met.no	Bruce Hackett	5		1	
		met.no	Ingerid Fossum	1			
		met.no	Jon Albretsen	124		26	-
		met.no	Jens Debernard	478		100	
		met.no	Xiaobing Shi	257		53	
		met.no	Øyvind Sætra	191		40	
		IMR	Paul Budgell	8		2	
		IMR	Bjørn Ådlandsvik	40		8	
PT 7 **(named PT 2 in 2002)**	**2002**	met.no	Lars Petter Røed	105	105	20	20
		met.no	Joseph LaCasce	210		40	
		met.no	Cecilie Mauritzen	210		40	
		met.no	Jens Debernard	419		80	
		met.no	Xiaobing Shi	105		20	
		IMR	Kjell Arne Mork	20		4	
		IMR	Bjørn Ådlandsvik	85		16	

SCIENTIFIC ACHIEVEMENTS
(Ch. 1 in the Form for Final Report)

After a popular summary, this chapter consists of three parts: Status as compared to plans; Major scientific results; and Contributions to national and international climate research.

Popular Summary

The following is a popular summary of the main activities in RegClim since the beginning, but with emphasis on results in 2002.

State-of-the-art modelling of the physics and dynamics of the climate system was in reality initiated in Norway when RegClim was launched as a co-ordinated project in 1997. Some scattered activities had been running in Bergen and Oslo, and the further global modelling was based on this. Furthermore, the atmospheric limited-area modelling for weather forecasting at met.no provided a strong basis for dynamical downscaling, which use the same type of model tools. Finally, there were strong groups of atmospheric chemistry modellers in Oslo. Thus, the ample general competence in atmospheric and oceanic modelling in Oslo and Bergen at the time provided good grounds for a quick development of climate modelling activities when resources became available in RegClim. There are now three model systems available for physical climate modelling in RegClim: the Bergen Climate Model (BCM) and GCM-Oslo are global coupled models, and HIRHAM-Oslo is a model for atmospheric dynamical downscaling. The latter model is underway being coupled to a limited area ocean and ice model to RegCM-Oslo. Statistical methods are also used for downscaling. The existing competence in statistical analysis of climate data at met.no quickly produced results in RegClim.

During 1997-2002 RegClim has worked with two overall aims: to prepare for impact studies of climate change by downscaling global climate scenarios in our region; and to reduce the uncertainty in our region's climate development by investigating the role of the Nordic Seas, and the significance of forcing patterns brought about by pollutants with large regional contrasts. Considerable steps forward have been provided in both overall aims, but a wide range of results remain to be produced in the four years to come (Phase III).

Overall Aim 1: Regional climate scenarios

RegClim's first result for Norway's climate was an analysis of the historical record at Norwegian climate stations. The annual temperature in Norway increased at average by 0.05-0.10°C per decade during the 20th century, and the annual precipitation by up to 1.8% per decade in some areas.

The results from the first regionalized climate change scenario for Norway during the next 50 years were produced in 2000 with HIRHAM-Oslo. The basic global scenario from Max-Planck-Institute in Germany is amongst those giving moderate changes compared to others, and it reproduces the present global climate better than any other scenario. In our region changes are still predicted to be considerable up to 2050. For the country of Norway as a whole, a 0.25 C/decade increase in annual temperature is estimated. The warming is stronger in northern areas (0.4 C/decade) compared to southern areas (0.2 C/decade) and tends to be stronger inland than along the coast. The heating rate during the winter months is nearly twice that of the summer months. Annual precipitation is projected to increase in all regions by 10 % on the average with a relative increase in frequency of both heavy precipitation amounts and days without precipitation. The largest increase for this scenario is estimated in the western parts of the country during the autumn (25%) and the smallest increase is found in the inland part of the south-eastern areas in spring. Only a small increase is found for the average wind speed, but the frequency of events with strong wind is estimated outside the coast of western Norway during the autumn and outside Troms and Finnmark in winter.

Calculations of wave and storm surge based on the wind results above, show that the average wave and storm surge climate towards 2050 is similar to the present-day's (1980-1999) climate. The trend in annual mean significant wave height is hardly significant. For ”extremely extreme” waves (those exceeded only 0.1% of the cases), however, has a significant increase in autumn of about 2 m. The ”normally extreme” waves (exceeded 1% of the cases) increase by only 0.5 to 0.75 m over the 50-year period. Similarly the trend for the “normally exstreme” storm surge is only 5 - 10 cm increase over 50 years, and it is not statistically significant. These extreme events are rare, and the results should be used cautiously and complemented with further scenarios to increase the statistical basis. Furthermore, the applied ARCM is known to underestimate the highest wind speeds**.**

Empirical downscaling of the same scenario with statistical methods gives very similar results for monthly temperature and precipitation data. Depending on region in the Norwegian mainland, average annual warming rates of 0.2 to 0.5°C/decade were estimated, and 0.6°C per decade on Svalbard. The empirically downscaled precipitation scenario indicated an increase in the annual precipitation of 0.3 to 2.7 %/decade at the Norwegian mainland. Deviations between dynamical and empirical downscaling occur predominantly for summer precipitation and winter temperatures over inland localities. Summer precipitation in the form of showers is believed to be better handled by dynamical downscaling, whilst the empirical methods are believed to be more correct in winter situations dominated by shallow inversions.

The results of the MPI climate model and its HIRHAM-Oslo regionalisation, both show a too weak Icelandic low for the present climate. The future “scenario” time-slice shows a stronger Icelandic low than the “present” time slice, indicating a strengthening of the westerlies over Norway in the future according to this model realisation. However, this is only one possible scenario, which needs to be complemented by additional calculations, since the degree of regional climate variability is not fully covered by only one scenario. Depending on the dominating motion of low-pressure systems (storm tracks), very different regional patterns of climate change may result for Norway. The reason for this regional sensitivity is the Scandinavian mountains that separate the maritime climate on the west coast from the continental to the east. A considerable spread was seen after empirical downscaling of scenarios from 17 different global climate models. This emphasizes the importance of running several scenarios also for dynamical downscaling, which will provide important input to impact assessments. First results from a second dynamical downscaling of results from the Hadley-Centre's global climate model, indicate considerably different regional results for Norway from the first results presented in 2000.

It has long been viewed as a drawback of dynamical downscaling that climate change in a bounded region may be caused by changes in forcing well outside this area. For example, most cyclones that give bad weather in Scandinavia are “born” around Newfoundland. A new method has been developed and used to calculate the forcing change patterns that yield maximal change in Northern Europe. This indicates that forcing changes over the northern parts of the North Atlantic Ocean and the Arctic determines much of the changes in wintertime European climate. This strengthens the potential of dynamical downscaling in general, but in our region it also points to a huge area of uncertainty.

Simulations with a coupled ice-ocean model covering the Northern Seas (including the Arctic Ocean) have been performed. The results show drastic differences in the annual mean ice thickness between those based on observed meteorology and those based on the climate model. This points to the fact that our region's area of forcing sensitivity is associated with considerable errors in many global climate models. Pure atmospheric downscaling can not be expected to repair this shortcoming.

Overall Aim 2a: The role of the Nordic Seas

The Atlantic - Nordic Seas - Arctic region is of key importance for the climate in northwestern Europe in general, and in Scandinavia in particular. In addition, the marine climate state in our region controls to a high degree the productivity of the marine ecosystem, and are consequently of vital importance for the bordering nations. To describe our marine climate system, a global ocean model, with an embedded sea ice module, (oceanic part of BCM) has been modified and improved, and validated against key observations from the region. The model is forced with realistic atmospheric fields for the period 1948 to present. The obtained model fields show how the ocean responds to the major atmospheric circulation patterns, in particular the increase in the observed North Atlantic westerlies since the mid 1960'ies. Long lived anomalies in sea surface temperature and salinity are found, propagating through the Nordic Seas from the Arctic to the Atlantic, and vice versa. The performed simulations show a marked increasing trend and profound decadal scale variations in the basin scale thermohaline circulation of the Atlantic Ocean (Atlantic Meridional Overturning Current, AMOC). The performed simulations have shown that it is likely that the strength of the Atlantic meridional overturning circulation and the associated heat transport has varied considerably over the last 50 years with a decreasing trend of 1-2 Sv and 0.15 PW between 1950-1960, and a 3.5-4.5 Sv and 0.2 PW increase since 1960, respectively. The trend and variability also affect the Nordic Seas through the northward transport of warm and nutrient rich water masses. Detailed analysis of the simulated ocean response to the atmospheric forcing has been carried out and has been published in a series of peer-refereed publications.

Similar atmospheric sensitivity experiments with a global atmospheric model (atmospheric part of BCM) have shown that the North Atlantic climate is sensitive to forced sea ice changes in the Labrador Sea. More sea ice than normal in the Labrador Sea normally associated with high NAO-index and mild, stormy winters in Scandinavia, produces an atmospheric response which reduces the NAO index. Similarly, situations with less sea ice than normal, produce an atmospheric response which increases the NAO-index. This response therefore seems to constitute a negative feedback in the climate system.

A 300 years long control integration with present levels of CO_2 has been performed with the BCM, and analysed for mean and transient climate. The model captures many of the main features of the observed climate, and in particular the simulation of radiation, clouds and fresh water fluxes is well reproduced. The model system is also realistically simulating the oceanic 3-D circulation. For the large-scale variability, focus has been put on the ENSO and NAO/AO modes of variability. It turns out that BCM captures both these modes, and gives realistic frequency distribution and areas of influence. As many other models, however, BCM tends to produce a too weak Icelandic low, and the storm tracks tend to proceed over Europe rather than bend northwards into the Norwegian Sea and Barents Sea.

A CMIP2 (1% CO2 per year increase) simulation (80 years) has been performed with BCM. The simulation exhibits an increasing trend in both global mean surface temperature and global mean precipitation. A comparison has shown that these two quantities are remarkably close to the corresponding ensemble means of the 19 CMIP2 members. The NAO pattern closely resembles the control integration. However there is a slight easterly shift in the centres of action, which is more in line with the NCEP data, which represent the characteristics of the leading MSLP mode for the last 50 years. The CMIP2 simulation shows a trend towards more positive winter NAO index values, corresponding to a one standard deviation increase in the MSLP difference between Gibraltar and Iceland in 100 years (0.06 hPa per year increase). Thus this simulation supports recent studies suggesting that changes in greenhouse gas forcing may have an impact on natural mode of variability such as the NAO. However, the BCM run supports the model results of Max-Planck-Institute that increasing CO2-levels to become doubled over ca. 70 years has little impact on the meridional and vertical overturning in the North Atlantic Ocean.

Overall Aim 2a: The role of the contrasting regional influence of pollutants

The pollutants studied are tropospheric ozone and aerosol particles. Ozone is produced photochemically where NOx, CO and VOC are abundant. These gases have natural sources, but anthropogenic sources, such as traffic and industry, dominate in densely populated regions A large fraction of aerosol particles forms in the atmosphere through oxidation of precursor gases (e.g., SO_2), but important particles are also released directly (e.g. soot). Precursor gases and primary particles of anthropogenic origins are produced mainly by the burning of fossil fuels and biomass, as well as by various industrial activities.

Ozone is a climate gas that absorbs infrared radiation from the Earth's surface. Similar to aerosols, tropospheric ozone resulting from human activity is not evenly distributed and regional variations in their impact on climate can be expected. Results show that the tropospheric ozone has continued to change after 1990. The radiative forcing resulting from tropospheric ozone produced by from surface and aircraft emissions from 1990 to 1996, was estimated at about $0.04\,Wm^{-2}$. This is approximately 10% of the forcing of increased tropospheric ozone from 1850 to 1990, and about 20% of the radiative forcing due to changes in well-mixed greenhouse gases from 1990 to 1996. However, this forcing is nearly balanced by the negative contribution due to change in tropospheric ozone resulting from reduced stratospheric ozone.

Aerosols can affect climate directly through scattering and absorption of solar radiation. In addition, some of these particles can serve as cloud condensation nuclei and thus influence the climate indirectly through the number and size of cloud droplets. This applies to e.g., sulphate, which attracts humidity, but to a less extent to soot, which is water repellent in pure condition. Through the increase in the number of cloud condensation nuclei in the atmosphere, human activity may lead to increased cloudiness and reduced cloud droplet size. Both effects lead to increased solar radiation reflectivity and enhanced cooling by the clouds.

Changes in sulphate loading and tropospheric ozone from ship emission have been calculated. Costal sulphate in Europe is estimated to increase with 3 to 10 % due to ship traffic. The estimated direct radiative forcing from ship emissions are for sulphate – 0.02 W/m^2 for sulphate and 0.04 W/m^2 for ozone as global average. The corresponding numbers for sulphate and ozone from all sources since preindustrial times are –0.04 W/m^2 and 0.35 W/m^2, respectively. The regional changes in sulphate loading from emission changes from 1985 to 1996 for different regions are estimated to have changed substantially. Significant reductions in the sulphate level are estimated over Europe, while we estimate large increases in the sulphate levels over China between 1985 and 1996. In the latter case the increase in sulphur compounds are estimated to affect the ozone levels.

Sulphate aerosols grow by accumulation of water when water vapour is available in the atmosphere. The growth is very strong when the relative humidity is high. Global climate models, which average the humidity over a coarse grid therefore underestimate growth of sulphate particles and its radiative forcing. Our calculations show that the underestimate may amount to 30-40%.

An improved representation of aerosols has been developed as a part of RegClim for use in the global climate model GCM-Oslo. The annually averaged global direct radiative forcing by anthropogenic BC and sulphate for IPCC scenarios for the years 2000 and 2100 is estimated at -0.11 and 0.11 Wm^{-2}, respectively. Largest positive forcing (due to absorption by BC aerosols) is found at high northern latitudes, in the tropics and over China, while the largest negative contributions (due to scattering by sulphate aerosols) come from middle northern latitudes, with a maximum over the eastern USA. For the indirect we find a globally averaged radiative forcing due to these indirect effects combined of -1.8 Wm^{-2}. This can be compared to the warming effect of anthropogenic greenhouse gases of about +2.5 Wm^{-2}. The indirect effect has large regional variations; it is largest over SE Asia, but is also large over the North Atlantic, central parts of Africa and Europe. Globally this balances the anthropogenic greenhouse effect during the northern hemisphere summer, whilst in NH winter the particles reduce the greenhouse forcing by less than 50%.

These estimates are uncertain, and a continued effort is necessary to reduce the uncertainties. In particular RegClim has shown and published that the way deep convective clouds are modelled to influence the particles is particularly crucial. Furthermore, we have also demonstrated that the relation between particle numbers and production of new cloud droplets is crucial and uncertain.

The first results with GCM-Oslo coupled to a slab-ocean model run for 50 years under equilibrium radiative conditions, shows some regional impacts due to the direct effect, but considerable climate change due to the indirect effect. Due to feedback with the ocean sea-ice, considerable effects are seen in the Arctic, even though the particle forcing is small locally. There are significant regional impacts in our region, but perhaps more important is the imposed change in the tropical precipitation belt (ITCZ). The tropical rainbelt is modelled to be displaced several degrees towards the south, with potentially considerable regional impacts. These results remain to be published.

1.1 Status of work

This is the status in relation to the target schedule for each task up to and including RegClim 2002. The reporting for Phase I and Phase II refers to the status by the end of those phases.

Principal Task 1 (PT1): Dynamical Downscaling

Principal Investigator : ***Thor Erik Nordeng, met.no***

The main purpose of this PT1 has been (1) to establish a regional climate model, i.e. the HIRHAM model, suitable for dynamical downscaling of global climate scenarios (Task 1.1); (2) to perform a HIRHAM simulation with analysed boundary conditions in order to verify the model against analysed fields and observations (Task 1.2); and (3) to perform a regional climate change simulation with the HIRHAM model using boundary conditions from a global scenario experiment. In this way a more detailed quantitative description of expected changes in weather parameters in the future, i.e. precipitation, temperature and wind (Task 1.3-1.4). The work plan to complete these goals covered both phase I and phase II.

Phase I

The part of the work to be carried out in part I was completed in phase I, for task 1.1-1.2 a few months delayed according to the plan, and for task 1.3-1.4 according to the plan.

Phase II

Task 1.1: Implementation and set-up of HIRHAM

Completed in phase I, a few month delayed according to the plan. Identical set-ups have been used for the two main climate experiments in PT1 (1.2 and 1.3-1.4). Additionally, in phase II some development work has been done in order to prepare the HIRHAM model for future higher resolution climate experiments and make the model computationally more efficient. In cooperation with PT7, a prototype of a coupled ice-ocean-atmosphere climate model has been coded and multiyear experiments have been carried out. However, all experiments reported so far under PT1 are made with the uncoupled HIRHAM atmospheric model.

Task 1.2: 5 year HIRHAM run forced with ECMWF analysis

Completed in phase I, a few month delayed according to the plan. In phase II this task was extended to a 15 year HIRHAM run, which covers the complete ECMWF ERA-15 reanalysis period. Completed during spring 2000.

Task 1.3a: 5 year HIRHAM run forced with an AOGCM for present climate, high NAO-index.

Task 1.3b: 5 year HIRHAM run forced with an AOGCM for present climate, low NAO-index.

Task 1.4a: 5 year HIRHAM run forced with an AOGCM for future climate, high NAO-index.

Task 1.4b: 5 year HIRHAM run forced with an AOGCM for future climate, low NAO-index.

Tasks 1.3-1.4 were completed according to the plan, but more results than planned were obtained. The planned 4x5 year integrations were extended 1) to a 2x20 year HIRHAM simulation (1980-1999 and 2030-2049) completed in phase II during spring 2000 2) to 70 year HIRHAM simulation (1980-2049) completed in phase II during spring 2001. The data from 1) seems correct and have been used for distribution of results from the RegClim project. However, analysis of the additional central 30 years in 2) has not yet been completed.

Phase 2002

Task 1.1: Further analysis, reporting and publications of results from dynamical downscaling

Task 1.1 was started, but not completed in 2002. One manuscript from PT1 was submitted to Climate Dynamics, but a revised version could not be finalized in 2002.

Task 1.2: Sensitivity to global forcing model (depending on data availability

Task 1.2 was completed according to plan, but continues in phase III. One additional regional downscaling experiment with HIRHAM has been made in 2002, i.e. forced by the IPCC SRES A2 scenario as simulated by the Hadley Centre HadCM3 model. The global data were distributed through the EU project PRUDENCE, and simulation covers the two periods 1961-1990 and 2071-2100. Development of methods for common analysis of the available scenarios from RegClim has been initiated

Task 1.3: Sensitivity to choice of integration area

Tasks 1.3 was started, but not completed in 2002. The HIRHAM simulation forced by the AOGCM data used in phase II were repeated for 2x20 years on two additional smaller integration domains. These experiments showed that the regional response in e.g. precipitations patterns, at least quantitatively, is quite sensitive to the choice of integration domain. Additional simulations forced by ECMWF ERA-15 reanalyses on the same integration domains have been initiated. The results may be of importance for the setup of future simulations with HIRHAM.

Principal Task 2 (PT2): Basin scale ocean modelling of the Nordic Sea

Principal Investigator: ***Helge Drange, NERSC***

Phase I

The work in this phase was completed according to plan. The project started with two OGCMs: POM and MICOM. At the end of Phase I, it was decided to adopt MICOM for the prognostic long-term simulations in RegClim, whereas POM will be devoted to dynamical downscaling purposes in the project. Later (see PT7) it has been decided also to use a MICOM-version for downscaling purposes.

Phase II

Task 2.1: Establish an ice-ocean regional circulation model

Based on the status of the two ocean models (MICOM and POM) involved in Phase I of RegClim, it was decided to adopt MICOM for the prognostic long-term simulations and POM to sensitivity studies in Phase II. *Work completed at the end of Phase I (in accordance with the schedule).*

Task 2.2: Quantification of the mean ocean and sea ice states and the natural variability of the states during the last 50 years

Completed at the end of 1999.

Task 2.3: Model validation

Completed Summer 2000.

Task 2.4: Identification and quantification of the driving mechanisms for the simulated natural variability

Completed at the end of 2001.

Task 2.5: Sensitivity to the model results to model formulations

Completed at the end of 2000.

Phase 2002 In 2002 this was PT 5

Task 5.1: Fulfil integrations of the coarse, intermediate and fine resolution versions of the Nansen Centre version of MICOM

Completed according to plan: A total of six integrations have been completed with a global version of the Miami Isopycnic Coordinate Ocean Model (MICOM): Four with a coarse resolution version of the model (ca. 80 km resolution in the North Atlantic Ocean; Bentsen et al., 2003), one with a medium resolution version (40 km; Nilsen et al., 2003) and one with a high-resolution version (20 km, Hátún et al, 2003).

Task 5.2: Perform preliminary analysis of the obtained fields

Completed according to plan: Analyses presented in Furevik et al. 2002, Bentsen et al. 2003, Gao et al 2003, Hátún et al, 2003, and Nilsen et al. 2003.

Task 5.3: Assess the skill with which observed seasonal to decadal fluctuations in the Atlantic Ocean can be simulated

Completed according to plan: The simulations of the AMOC for all model systems yield a long-term mean value of 18 Sv and decadal variability with an amplitude of 1-3 Sv. Comparison with observational proxy indices for the AMOC, e.g. the thickness of the Labrador Sea Water, the strength of the baroclinic gyre circulation in the North Atlantic Ocean, and the surface temperature anomalies along the mean path of the Gulf Stream, shows similar trends and phasing of the variability, indicating that the simulated AMOC variability is robust and real (Bentsen et al. 2003, Nilsen et al. 2003, Hátún et al, 2003).

Task 5.4: Elucidate the mechanisms responsible for the formation, propagation and decay of dynamic and thermodynamic inter-annual to decadal time-scale anomalies in the Atlantic Ocean

Completed according to plan: Mixing indices have been constructed for the Labrador, the Irminger and the Greenland-Iceland-Norwegian (GIN) Seas (Bentsen et al. 2003). While mixing in the Labrador and the GIN Seas are in opposite phase, and clearly linked to the NAO as observations suggest, the mixing in the Irminger Sea is in phase with or leads the Labrador

Sea. Newly formed deep water is seen as a slow, anomalous cold and fresh, plume flowing southward along the western continental slope of the Atlantic Ocean, with a return flow of warm and saline water in the surface. In addition, fast-traveling topographically-trapped Kelvin waves propagate southward along the continental slope towards equator, where they go east and continue northward along the coast of Africa. It is furthermore demonstrated for the northern part of the Atlantic that that an atmospheric pattern with similarities to the NAO is the main driving force to the inter-annual variations in the winter-time volume exchanges through the Denmark Strait and the Faroe-Bank Channel.

Task 5.5: Analyse how and why simulation skill depends on model resolution

Completed according to plan: The basin scale features and variability modes are fairly similar amongst the different model versions. However, for specific current systems, like for the Gulf Stream system and for the inflow of Atlantic Water (AW) to the Nordic Seas, differences are apparent. Generally, the extension of the Gulf Stream system (i.e., the North Atlantic Drift) follows a more eastward path in the Atlantic Ocean as the horizontal resolution increases. This has implications for, for instance, the flow of AW into the Nordic Seas. In fact, with the 40 km version of the model, the observed variability of the AW into the Nordic Seas follows the observed variability closely (Nilsen et al, 2003).

Principal Task 3 (PT3): Empirical Downscaling

Principal Investigator: ***Eirik Førland, met.no***

Phase I

Task 3.1 was completed. The other tasks (3.2-3.5) were in progress in accordance with the project plan.

Phase II

Task 3.1: Establishing datasets for empirical downscaling

Completed according to plan.

Task 3.2: Development of empirical relationships between observed large-scale atmospheric fields (predictors) and local climate variables (predictands).

Completed according to plan.

Task 3.3: Testing the established relationships on independent observed data

Completed according to plan.

Task 3.4: Evaluation of control simulations of atmospheric circulation, and use of the established relationships to check consistency between observed and simulated local climate

Completed according to plan.

Task 3.5: Application of established relationships on large-scale fields projected by AOGCM to infer changes in local climate characteristics

Completed according to plan.

Task 3.6: Adaptation of downscaled scenarios for impact studies, with emphasis on hydrological consequences

Completed according to plan, but will be finalized in 2002.

Phase 2002

Task 3.1 Local climate scenarios based upon empirical downscaling

Completed according to plan: Empirical downscaling based upon combination of predictors is reported by Benestad et al, (2002) and Benestad (2002g). Local climate scenarios for selected locations based on several AOGCMs are presented in Benestad et. al (2002a,b) and Benestad (2000a,b,c). Differences between local scenarios deduced by dynamical and empirical downscaling techniques are analysed by Hanssen-Bauer et al. (2002). Climate scenarios for the Norwegian Arctic are emphasized in Benestad et al (2002a,b) and Hanssen-Bauer (2002), and the influence of the sea-ice extension on Fennoscanidian climate is evaluated by Benestad & Tveito (2002).

Task 3.2 Adaptation of downscaled scenarios for impact studies.

Completed according to plan: GIS-based tools are used to map detailed spatial distribution of scenarios of temperature, precipitation, degree-days, heating and growing season (Hanssen-Bauer et al (2002), Skaugen & Tveito (2002a,b). Changes in frequency distributions for temperature and precipitation at selected locations are reported by Hanssen-Bauer et al (2002) and Benestad & Melsom (2002), and changes in frequencies of consecutive dry/wet months are analysed by Benestad (2003b). Scenarios for changes in extremes for daily rainfall and temperature are presented by Imbert (2002), T.Skaugen et al (2002) and Benestad (2003a). Dynamically downscaled daily values (from PT1) have been adjusted to be site specific by use of statistical techniques (T.E.Skaugen et al 2002). In collaboration with the Norwegian Water Resources and Energy Directorate (NVE), the adjusted temperature and rainfall series are used in hydrological modelling. Scenarios for changes in e.g. runoff, evaporation and snow accumulation are reported by Roald et al (2002).

Task 3.3 Uncertainty in regional/local scenarios

Completed according to plan: Differences in regional climate development between different AOGSMs are reported by Benestad (2002,b,d). Sensibility experiments of estimates related to different predictor domains, and different predictor combinations are reported in Benestad (2002a,b,d) and Benestad & Melsom (2002). Analyses of statistical confidence intervals for local scenarios are reported by Hanssen-Bauer et al (2002). A collaboration is established with SweClim/Gothenburg University (GU) concerning comparison of results from empirical downscaling in Norway and Sweden. Joint datasets are established, and the clim.pact tools (Benestad, 2003a,c) are made available for the GU-team.

Principal Task 4 (PT4): The Role of the Nordic Seas: Atmosphere-Ocean Feedback

Principal Investigator: ***Nils Gunnar Kvamstø, GfI-UiB***

Phase I

Task 4.1: Control simulation with AGCMS

Completed according to plan. Reported in Kvamstø (1998a), RegClim, General Technical Report No. 1.

Task 4.2: Sensitivity experiments with AGCMS

Completed according to plan. Reported in Kvamstø (1998b), RegClim, General Technical Report No. 2. This task has been extended into Phase II.

Task 4.3: Technical coupling of ARPEGE/MICOM and initialisation

Started and continued in Phase II.

Phase II

Task 4.2: Sensitivity experiments with AGCMS

Completed according to plan. Reported in Skeie and Kvamstø (2000), RegClim, General Technical Report No.4 and Kvamstø et al (2001).

Task 4.3: Technical coupling of ARPEGE/MICOM and initialisation

Completed, but delayed according to plan. The delay was about 6 months and occurred because we had to extend the interpolation library in the coupler. Reported in Furevik et al. (2000a), RegClim, General Technical Report No. 4, Furevik et al. (2000b), RegClim, General Technical Report No. 5 and Kvamstø et al. (2000), RegClim, General Technical Report No. 5.

Task 4.4: Control run with AOGCMS on present climate

Completed according to plan. Reported in Furevik et al. (2001).

Task 4.5: Future climate (CMIP2) simulation with coupling

In progress and will be finished in 2002.

Phase 2002

Task 4.1 CMIP2 simulation with BCM in regular mode (contd. 4.5 phase II):

*Completed according to plan***.** Reported in Sorteberg et al. 2002. RegClim, General Technical Report No. 6.

Task 4.2 Simulation of present climate with variable horizontal resolution in BCM:

Started, but has been taken out of the project due to limited/reduced computer and man resources.

Task 4.3 Preparation of a transient scenario simulation with BCM for RegClim phase III: Started and will continue in phase III.

Principal Task 5 (PT5): Indirect Effects of Aerosols

Principal Investigator: ***Jon Egill Kristjánsson, Igf-UiO***

Phase I

The work in this phase has mainly progressed as planned. Using a mechanistic approach, a simplified life-cycle scheme was developed for two aerosol types; i.e., sulphate and black carbon. This module was tested out and implemented in an elaborated version of the NCAR CCM3.2, CCM-Oslo. Coupled to an ocean model we call this model system GCM-Oslo. Another module was developed, where the sulphate and black carbon aerosols were combined with various background aerosols, in order to construct size distributions a posteriori. The size segregated aerosols were used on the one hand for computations of aerosol radiative properties, enabling estimates of the direct effect of aerosols, and on the other hand, for computations of cloud droplet number concentrations. The latter were combined with appropriate modifications of the condensation and radiation schemes of the CCM-Oslo, enabling estimates to be made of the aerosol indirect effect. This research was continued in Phase II (Tasks 5.1, 5.2, 5.3, 5.6, 5.7).

In a separate effort a recently developed approach for treating entrainment and detrainment in deep convection was attempted for shallow convective situations, which are common in our region throughout the year. The results were rather inconclusive, and due to limited resources it was decided not to continue this effort, which was mainly internally financed by met.no.

Phase II

Task 5.1: Development of a simplified aerosol modelling scheme suited for estimating size segregated particle composition

In progress and will be completed in accordance with plan.

Task 5.2: Parameterization of CCN concentrations for given aerosol loading: Tabulations and implementation in NCAR CCM3

In progress but will be delayed compared to plan.
So far, the cloud droplet number concentrations have been obtained in the GCM simulations by using the Köhler equation and making assumptions on the subgrid scale supersaturation. These assumptions take crudely into account differences between convective and stratiform clouds and continental and maritime clouds. The plan was to develop more accurate relationships between the atmospheric state and the aerosol loading on the one hand and cloud droplet number concentrations on the other. This was planned done with the aid of a thermodynamic box model. This has not been done yet, partly because it was felt that other approaches might be less time consuming and more fruitful. Contact has been established with Dr. Steven Ghan at PNNL in Richland, WA, U.S.A., who has developed a fairly sophisticated method for obtaining subgrid scale vertical velocities, hence determining cloud droplet initiation. This, combined with the introduction of a continuity equation for cloud droplet number, accounting for sources and sinks [Ghan et al., 1997; Lohmann et al., 1999], seems to be a sound approach that will be attempted in PT5.

Task 5.3: Develop methods to incorporate CCN information into the cloud parameterization scheme of NCAR CCM3

In progress and will be completed in accordance with plan.

Task 5.4: Investigate need for introducing new prognostic variables (precipitation, snow, ice) or new diagnostic quantities (more detailed treatment of cloud droplet spectra, etc.)

In progress but will be delayed according to plan.
As mentioned under Task 5.2, above, it is planned to develop a continuity equation for cloud droplet number concentration, accounting for sources (condensation due to adiabatic cooling) and sinks (coalescence, evaporation through inhomogeneous mixing). The study of cloud processes in general, which was included in phase I, has been removed in phase II, meaning that the focus is now entirely on aerosol-cloud-climate effects. Hence, little attention has been given to expansions of the condensation scheme itself through the introduction of new variables (precipitation, snow, ice).

Task 5.5: Develop SCM for cloud microphysics investigations

Completed according to plan.

Task 5.6: Sensitivity experiments in SCM and GCM

In progress and will be completed according to plan.

Task 5.7: Derivation of cloud optical properties due to aerosols

Completed according to plan.

Task 5.8 (common with PT6: Task 6.7): Interactive modelling of the total effects of ozone and aerosols in AGCM

In progress but will be delayed compared to plan.
It has proved more complicated than expected to merge together the modules for aerosols developed in PT5 and the module for ozone developed in PT6. This has to do with different approaches being used, including different model tools. As the research in PT6 now gradually makes more use of the NCAR CCM3, such merging may become more feasible. Before this is done, however, the direct and indirect effects of aerosols need to be merged, hence accounting for the 'semi-direct effect' [e.g., Lohmann and Feichter, 2001], and this work is currently under way.

Phase 2002 In 2002 this was PT 6.

Task 6.1: Coupling together modules for direct and indirect effect with life-cycle scheme for sulphur and black carbon aerosols.

Completed in the beginning of 2003.

Task 6.2: Improvements in the treatment of aerosols: background aerosols; organic carbon aerosols; influence of cloud dynamics.

In progress. This a continuously ongoing task for the improvement of the aerosol description, and it will continue in AerOzClim.

Task 6.3: Improved treatment of supersaturation for indirect effect calculations.

A diagnostic scheme is completed and is successfully in operation.
The production rate of CCNs, which is based on presumed supersaturation that compensate for cloud aging, gives results in line with other existing schemes.
The next level scheme, *a prognostic equation for cloud droplet number, is in progress*. Code for obtaining nucleation term (the most difficult part of the problem) has been obtained from Steve Ghan at PNNL. Hooks for implementation of this code and codes for the microphysical source/sink terms have been partly implemented in the GCM. The further development will be carried out mainly by cand.scient. Trude Storelvmo in the COMBINE[1] project (NFR 155968/720), and partly in AerOzClim.

Task 6.4: Multi-year GCM simulations of radiative forcing and regional climate response.

Completed according to plan.
The slab ocean model was introduced, and the aerosol modules were modified to run interactively, i.e., in a ‘climate response’ mode, instead of a ’radiative forcing’ mode. A large number of 50-year simulations were then carried out for both the indirect and direct effects of aerosols on climate. The results have been partly reported in Cicerone, and a scientific journal paper is under preparation. The results show many interesting features, for instance there is a statistically significant southward shift of the ITCZ for both the indirect and direct effect, due to interhemispheric differences in aerosol loading, and hence radiative forcing. Another interesting feature is a strong ice-albedo feedback at high latitudes associated with the indirect effect. There is also a considerable positive cloud feedback that contributes to yield the largest cooling in these regions. Publications under development.

Principal Task 6 (PT): Direct Climate Effects of Regional Contaminants

Principal Investigator: ***Frode Stordal NILU*** *(Until December 2000)*
Ivar Isaksen, Igf-UiO *(From January 2001)*

Phase I.

Task 6.1: Establish emissions of ozone precursors

Completed according to plan.

Task 6.2: Regional distribution and radiative forcing of tropospheric ozone

Completed according to plan.

Task 6.3: Regional distribution and radiative forcing of aerosols

Completed with minor deviations from plan: work based on Oslo CTM2 somewhat delayed.

Task 6.4: Application of cloud optical properties in modelling of the indirect aerosol effect

This task was moved to PT5 at an early stage in Phase I.

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[1] Combined Observationally and Modelling Based Investigation of the aerosol iNdirect Effect

Task 6.5: Development and implementation of simplified chemistry schemes

This work was initiated in Phase I, and only preliminary results produced.

Task 6.6: Validation and possible improvements of radiation schemes in AGCM

Completed according to plan.

Task 6.7: Interactive modelling of ozone and particles (direct effect) in AGCM

This work was found rather resource demanding. In Phase I, only planning and preparations were made.

Phase II

Task 6.1: Modelling of regional distribution of ozone and the resulting radiative forcing

Progress according to plan.

Task 6.2 : Modelling of regional distribution of aerosols and the resulting radiative forcing

Progress according to plan.

Task 6.3: Development and implementation of simplified chemistry schemes

Progress according to plan.

Task 6.4: Validation and possible improvement of radiation schemes in AGCM

Progress according to plan

Task 6.5: Interactive modelling of particles (direct effect) in AGCM

In progress. Will be completed in AerOzClim

Phase 2002 In 2002 this was PT 7

Task 7.1: Analysis and validation of satellite data for aerosols – Verification of model results

Progress according to plan. One paper accepted for publication (J. Atm.Sci). Work continue.

Task 7.2 Time-slice experiments with CTM: Interaction between sulphate and ozone

Progress according to plan, One paper to be sent to publication (JGR)

Task 7.3 Implementation of organic carbon and black carbon in CTM

Progress according to plan. One paper in press (JGR). Work continue.

Task 7.4 Radiative forcing of gases and aerosols in CTM

Progress according to plan. One paper on radiative forcing from ship emission accepted for publication in JGR, and one paper on radiative forcing from sulphate aerosols in press (J. Atm. Sci.)

Principal Task 7 (PT7): Air-ice-ocean interface processes and sea-state modelling

Principal Investigator: ***Lars Petter Røed, met.no***

Phase I

During this phase PT7 was named “Parameterization of sea-ice” and consisted of two tasks only, namely:
Task 7.1 Development of a sea ice model
Task 7.2 Coupling to POM and MICOM
Both tasks are completed with delays, but with some enhancements with regard to the original plan.
Task 7.1 was delayed about one year. Midway through the development it was decided to deviate from the plan and embark on a development of a sea ice model almost from scratch, invoking recent enhancements and new findings found in the literature.
Task 7.2 was likewise delayed with about half a year (that is into Phase II). Interestingly this task turns out to be an almost never ending endeavour. In a sense it is still ongoing, since the task initiated the development of a more complete coupler, able to couple the three spheres; that is, the atmosphere, the cryosphere, and the hydrosphere, that is, not only the sea ice and the ocean model.

Phase II

For this phase the present name for PT7 was adopted. Moreover PT7 was enlarged to seven tasks in which whole or parts of subtasks from PT4 and PT2 was moved to PT7.

Task 7.2: Coupled ice-ocean models

In addition to the former Task 7.2 of Phase I parts of Task 2.2 of Phase I was incorporated and the end date moved to mid 2000. Completed, but delayed about half a year compared to plan (see Phase I remarks above).

Task 7.3: Technical coupling of HIRHAM and WAM (1.7.00-31.12.01)

This is Task 4.7 of Phase I. Abandoned. It was deemed more efficient to move the resources set aside for this task to 7.2 and 7.6 to strengthen the development of the more complete coupler invoking all relevant fluxes (see also comments to 7.6 below).

Task 7.4: Air-sea interaction case studies (1.1.01-31.12.00)

This is Task 4.8 of Phase I. Tightly connected to Task 7.3 and hence abandoned for the same reason.

Task 7.5: Sensitivity of the Norwegian Atlantic Current to anomalous forcing

This is Task 4.5 of Phase I. Continued as Task 2.2 and 2.3 in Phase II 2002.

Task 7.6: Dynamic boundary condition

This is a completely new task invented for Phase II. In progress but will be delayed about a year compared to plan. Delay due to a much more ambitious plan regarding the development of a coupler (see scientific achievements). Continued as Task 2.2 of Phase II 2002

Task 7.7: Storm surge and wave statistics

This is Task 2.3 of Phase I. Continued as Task 2.1 of Phase II 2002.

Phase 2002 In 2002 this was PT 2.

Task 2.1: Storm surge and wave statistics

This is a continuation of Task 7.7 of Phase II. Completed according to plan.

Task 2.2: Establishment of an atmosphere-ice-ocean regional climate model

This is a continuation of part of Tasks 7.5 and 7.6 of Phase II. In view of the evaluation of the project it was decided to use MICOM as the sole ocean model in RegClim. Thus a coupling of MICOM and the ice model MI-IM had to be performed, before coupling the new regional ice-ocean system to the atmosphere model HIRHAM.. Partially completed in that the coupling is performed, but with non-satisfactorily results. Decided to continue the work in the continuation of RegClim. At the time of writing the coupled ice-ocean system is working satisfactorily.

Task 2.3: Validate to the extent possible the developed AORCM

This is a continuation of parts of Tasks 7.5 and 7.6 of Phase II. Due to the delay in Task 2.2. this task is not completed according to plan.

1.2 Major scientific results

Here is focused on the findings during Phase 2002. Major findings in Phase I and Phase II were reported in the progress report of December 2001, which was the basis for RegClim's second international evaluation. This is not repeated here. That report can also be found on RegClim's web-page.

Phase 2002

Overall Summary

Trond Iversen, Project Leader of RegClim

During 2002 a considerable amount of results has been produced by the three main climate model systems of RegClim: the RegCM-Oslo, the BCM, and the GCM-Oslo.

New results from *downscaling* focused on wind, sea-state and storm surge along the Norwegian coast, and on changes in extreme (i.e. rare) weather conditions. Considerable changes in sea-state and storm surge is only seen for the very rare and extreme events. Hence there is a problem of the level of confidence for these extremes, and there is a need for extending the simulations with more ensemble members. Further analysis of the downscaling of the GSDIO-scenario from Max-Planck-Institute focused on changes in return frequencies of extreme precipitation intensities and wind speeds. Due to the limited periods of simulations, only changed statistics for daily and 5-day present annual extremes were estimated, and shorter return periods are estimated towards 2050.

Tests have also been made to reveal to what extent the atmospheric downscaling over a relatively large domain, covering substantial portions of the North Atlantic Ocean, is able to change the large-scale flow pattern due to better resolution in the downscaling model. This analysis was made by flow-regimes analyses. Only changes with low levels of significance are seen. Examples of preparation of impact-related parameters were also presented based on results from empirical downscaling.

Further experiments with atmospheric dynamical downscaling has been made by 1) varying the integration domain for the RCM, and 2) by downscaling the adjusted A2-scenario produced by the Hadley Centre with the HadCM3/AM3. Further testing is needed, but it is evident that the Hadley-scenario displays a preference for a different regional flow regime than the earlier downscaled MPI-scenario. This confirms the finding from empirical downscaling of 17 global scenarios to the IPCC Third Assessment Report. The regional spread over parts of Norway is considerable between the models. Hence the results for Norway's possible climate development presented so far strongly need to be complemented.

A considerable step forward has been made with the *Bergen Climate Model* (Arpege coupled to MICOM with Oasis) during the latest year. In addition to sensitivity tests with atmosphere-only and ocean-only model versions, a coupled control run over 300 years has been made, as well as an 80-year CMIP2 simulation in which CO2 increases 1% per year. The control run shows a stable climate with a fairly well simulation of a regional flow pattern such as the North Atlantic Oscillation (NAO). Flux adjustments are needed. The CMIP2-run show a trend towards a higher NAO index as CO2 increases, but there is no sign of a weakening of the North Atlantic Ocean meridional overturning current (AMOC) as a response of increased freshwater forcing. This confirms the results also reported with eth ocean-only experiments. So far the experiments with the BCM does not indicate a significant change of the oceanic transport of heat in the North Atlantic Ocean, and discussions points to a number of negative feedbacks that tend to stabilize our region's climate. Many other models give different results, even though the MPI-Hamburg model gives the same result as BCM. More ensemble members and scenarios are planned in the forthcoming RegClim Phase III.

Also results from model response calculations of *anthropogenic aerosols* have taken a major step forward recently. Atmosphere-only simulations of the direct and indirect aerosol effects were presented using the Oslo-version of the NCAR CCM3.2 model (CCM-Oslo or GCM-Oslo when coupled to an ocean model). The calculations are based on a new scheme for the life-cycle of sulphate and black carbon that enables *a posteriori* estimates of particle size and composition. Experiments show a considerably large sensitivity with respect to the model formulation of processes in deep convective clouds. The indirect effects also depend crucially on the assumption behind realised super-saturations and microphysical properties of clouds. Test calculations with chemical transport and radiative transfer models that are more advanced than present climate models can use, have been made. In particular the global radiative forcing of sulphate is seen to be sensitive to grid resolution down to 100 km grid resolution. Also, up to a factor 2 difference in sulphate radiative forcing is seen depending on the vertical distribution of relative humidity.

Further experiments have been done as equilibria calculations with a slab ocean model coupled to the new atmospheric model version. Significant climate responses are seen both for the direct and indirect aerosol forcing, but with the latter being by far larger. The northern hemisphere cools more than the southern due to aerosols, and amplitudes are particularly large in the Arctic due to sea-ice feedback. For precipitation, considerable changes are seen in tropical areas where the tropical rainbelt (ITCZ) is systematically displaced a few degrees southwards.

Principal Task 1 (PT1): Dynamical Downscaling

Principal Investigator : Thor Erik Nordeng, met.no

After the production of the first RegClim scenario during phase I and II, the achievements during 2002 had to be concentrated around further reporting, presentations and necessary preparations for impact studies, in addition to the planned work. One additional climate change experiment with HIRHAM, based on HadCM3 SRES A2 simulation was completed in 2002, but other simulations are needed in phase III to focus on the uncertainty in the regional climate response for the Nordic areas. Additional experiments using data from the first MPI IS92a simulation was made in order to focus on the uncertainty due to choice of integrations domain. The new domains were smaller than the original, the smallest being only slightly larger than the area of interest, i.e. Scandinavia and the Nordic Sea areas. Due to differences in e.g. storm tracks, the regional response in precipitation and wind patterns varied in these experiments, and these differences be considered as part of the total uncertainty.

Principal Task 2 (PT2): Basin scale ocean modelling of the Nordic Sea

Principal Investigator: ***Helge Drange, NERSC***

The performed simulations with global and regional NERSC versions of MICOM have shown that for prescribed atmospheric forcing (in this case the NCAR/NCEP re-analyses for the period 1948 to present), the temporal evolution of the strength of the Atlantic Meridional Overturning Circulation (AMOC) is weakly dependent on the model initial state. This finding indicates that the predictability of the strength of the AMOC may not be critically dependent on a 3-dimensional, observational based initial state of the Atlantic Ocean.

It is further shown that it is likely that the strength of the AMOC and the associated heat transport have varied considerably over the last 50 years with a decreasing trend of 1-2 Sv and 0.15 PW between 1950-1960, and a 3.5-4.5 Sv and 0.2 PW increase since 1960, respectively. The simulated decadal-scale variability in the strength of AMOC is caused by surface density anomalies in the North Atlantic sub-polar gyre, either originating in the North Atlantic or by density anomalies propagating from the Nordic Seas. The density anomalies are linked to, but are not necessarily identical to, the pattern of NAO/AO forcing.

Finally, it is shown that the representativeness of the formation, propagation and decay of key observed, large-scale dynamic and thermodynamic anomalies in the North Atlantic Ocean depends on model resolution, and that the anomalies can be realistically simulated with model resolutions of 40 km or less.

Principal Task 3 (PT3): Empirical Downscaling

Principal Investigator: ***Eirik Førland, met.no***

Empirically and dynamically downscaled scenarios for temperature and precipitation for Norway based upon the same global scenario (MPIs GSDIO integration with emission scenario IS92a) were compared. Though the differences between the approaches are not statistically significant, empirical downscaling systematically leads to larger projected increase in annual mean temperature than dynamical downscaling does. The difference is at maximum during winter and/or spring at localities exposed for temperature inversions. Empirical downscaling projects larger winter warming in inland valleys than at more freely exposed localities, and thus implies a reduced intensity or frequency of winter inversions. It is argued that less favourable conditions for ground inversions are consistent with the future projection of increased winter wind speeds and reduced snow-cover. For precipitation, both downscaling approaches project statistically significant increase in western Norway during autumn, and in southern Norway during winter. The only significant difference between the results is that dynamical downscaling projects increased summer precipitation in southwest Norway, while the empirically downscaled scenario shows no significant change. For summer precipitation the present empirical models do not include any predictor carrying the "climate change signal", and thus the results from the dynamical downscaling are probably more realistic concerning summer precipitation.

Empirical downscaling temperature scenarios were produces for 3 localities in the Svalbard archipelago, based upon mixed 2-meter temperature and sea level pressure fields. The scenarios were derived using large-scale fields from ECHAM4/OPYC3, HadCM3 and NCAR-CSM climate change experiments, and utilizing common empirical orthogonal functions. There are substantial differences between the scenarios from the various models. Those downscaled from HadCM3 indicate significantly stronger warming in this area than the other models. Much of these differences can be explained in terms of different descriptions of the sea ice extent in the area. A reasonable model description of the present-day sea ice conditions in the area is thus crucial for making realistic future projections.

Analyses based on the empirically downscaled temperatures, indicate that the ***growing season*** will increase all over the country. The scenarios (differences between the periods 2021-50 and 1961-90) indicate that the largest increase (30-40 days) in the growing season will occur in coastal parts of Finnmark, in the area from Trøndelag to Lofoten, and in the high mountain areas in Western Norway. In the Trondheimsfjord- and Oslofjord-areas the increase will be less than 20 days. In the south-eastern part of Norway and the area around Trondheimsfjorden the ***heating season*** will be reduced by up to 20 days. In Western Norway, in mountain areas and in large parts of Northern Norway, the heating season will be reduced by more than 40 days. In some coastal areas in Western and Northern Norway, the sum of heating degrees will be reduced by ca. 20%.

Dynamically downscaled daily values (from PT1) have been adjusted to be site-specific by use of statistical techniques. The adjusted temperature and rainfall series are used in hydrological modelling, and scenarios are deduced for changes in e.g. runoff, evaporation and snow accumulation. The results indicate that the ***runoff*** in parts of Western Norway will increase by more than 200 mm/yr from the period 1980-99 to 2030-49. The annual ***evapotranspiration*** will increase by more than 60 mm/yr in parts of Western Norway, but in large parts of south-eastern Norway the increase will be less than 20 mm/yr. The scenarios indicate that the now storage by 1.April will be reduced by more than 500 mm in parts of Western Norway, but will increase in high-altitude areas in Southern Norway.

Analyses of changes (2030-49 vs. 1980-99) indicate increasing levels in ***extreme rainfall*** values. The increase seems to be larger for 1-day than for 5-day values. The regional variability is however significant, and the analyses will be continued in RegClim-Phase III.

Principal Task 4 (PT4): The Role of the Nordic Seas: Atmosphere-Ocean Feedback

Principal Investigator: ***Nils Gunnar Kvamstø, GfI-UiB***

A CMIP2 (1% CO2 per year increase) simulation (80 years) has been performed with BCM. The simulation exhibits an increasing trend in both global mean surface temperature and global mean precipitation. A comparison has shown that these two quantities are remarkably close to the corresponding ensemble means of the 19 CMIP2 members. The NAO pattern closely resembles the control integration. However, there is a slight easterly shift in the centres of action, which is more in line with the NCEP data, which represent the characteristics of the leading MSLP mode for the last 50 years. The CMIP2 simulation shows a trend towards more positive winter NAO index values, corresponding to a one standard deviation increase in the MSLP difference between Gibraltar and Iceland in 100 years (0.06 hPa per year increase). Thus this simulation supports recent studies suggesting that changes in greenhouse gas forcing may have an impact on natural mode of variability such as the NAO.

Principal Task 5 (PT5): Indirect Effects of Aerosols

*Principal Investigator****: Jón Egill Kristjánsson, Igf-UiO***

(Was PT6 in 2002)

In order to estimate the effect of anthropogenic aerosols on the climate and climate change, a number of multi-decadal simulations was carried out, in which the climate system was allowed to respond to the aerosol radiative forcing. These simulations reveal large changes in temperature, precipitation and surface pressure. One important finding is a southward shift of the intertropical convergence zone (ITCZ) by a few hundred km, both from direct and indirect forcing. In both cases the shift is statistically significant at the 95% level or more. Previously, such a shift has been reported by Rotstayn and Penner (2000), as well as by Williams et al. (2001) and Rotstayn and Lohmann (2002), but in all cases only for the indirect effect. In a global average the indirect effect causes a 1.3 K cooling, but the cooling is largest in the northern hemisphere, and has a maximum in the Arctic, due to enhanced sea ice cover. Sensitivity experiments with ice-albedo feedback turned off give a different geographical pattern, more similar to the pattern of the radiative forcing. The direct effect gives a more modest globally averaged cooling of –0.10 K, and there are regions of warming as well as cooling. In the case of the indirect effect the surface pressure shows a rather strong increase over the Arctic, and this increase in strongest in the transition from summer to winter. It appears that this change in flow pattern contributes to produce cold stable air masses that are maintained by radiative cooling throughout the winter. As a result the indirect cooling effect in the Arctic is very strong in winter (about 5 K), even though the indirect radiative forcing is very weak at that time of year.

References:

Rotstayn, L. D., and Penner, J. E., 2000. Precipitation changes in a GCM resulting from the indirect effects of anthropogenic aerosols. *Geophys. Res. Lett*., **27**, 3045-3048.

Rotstayn, L. D., and Lohmann, U., 2002. Tropical rainfall trends and the indirect aerosol effect. *J. Climate*, **15**, 2103-2116.

Williams, K. D., Jones, A., Roberts, D. L., Senior, C. A., and Woodage, M. J., 2001. The response of the climate system to the indirect effects of anthropogenic sulphate aerosol. *Climate Dyn.*, **17**, 845-856.

Principal Task 6 (PT6): Direct Climate Effects of Regional Contaminants

Principal Investigator: ***Frode Stordal NILU*** *(Until December 2000)*
Ivar Isaksen, Igf-UiO (From January 2001)

Comparisons of several sets of atmospheric aerosol loadings from 5 different retrievals of satellite satellite data have been analysed and it is shown that there are significant differences in the obtained loading due to differences in the retrieval procedure. The differences is particular large at high latitudes in the two hemispheres (Myhre et al., 2003a) Several modelling studies have been performed to study the where sulphate formation is calculated with a chemical scheme where there are interaction between the sulphur and the tropospheric ozone chemistry. These studies are performed with the Oslo chemical transport model (the Oslo CTM2). Modelling studies of the transport and distribution of organic and black carbon from biomass burning have been performed, and the results have been compared with observations during the SAFARI campaign off the coast of West Africa in 2000 (Myhre et al., 2003b). The modelling was performed with the Oslo CTM2. Modelling of the uncertainties in the sulphate production has been performed and compared with observations. The results of these comparisons will be published in J. Atmos. Phys, (Myhre et al., 2003b). The development of the model for sulphur-ozone chemistry interaction is completed end extensively tested toward observations. Time slice studies for 1985 and 1996 have been performed and compared. Regional changes due to changes in emission of pollutants and due to the chemical interaction between the ozone and the sulphur chemistry has been analysed and discussed. The differences between the two time slices are particular large over Europe (negative) and over South East Asia (positive) due to changes in the anthropogenic (SO_2) sulphur emissions. Finally, a study of the regional and global impact on ozone and sulphate from ship emission have been performed. This study has been performed in collaboration with a group at Veritas. The group from Veritas has analysed pollution emissions from oceangoing ships, while we have modelled the changes in the sulphate and ozone burdens. Changes in sulphate burden due to ship traffic close to the coast is estimated to have increased with 3 to 10 %, while the radiative forcing due to ship emissions are estimated to be –0.02 W/m^2, and 0,04 W/m^2 for sulphate and ozone respectively.

Principal Task 7 (PT7): Air-ice-ocean interface processes and sea-state modelling

Principal Investigator: ***Lars Peter Rode, met.no***
(Was PT2 in 2002)

New statistical analysis of the results for changes in wind, wave and storm surge climate in the northern North Atlantic supports the earlier RegClim conclusion about small and mostly insignificant changes for most of the areas near Norway. However, a roughening of the maritime climate is expected in the northern North Sea in the autumn season. Also the analysis shows increasing wind, wave height and storm surges in the Barents Sea. The results for the Barents Sea are considered as uncertain and it is expected that a fully coupled atmosphere-ice-ocean dynamical downscaling is needed to give reliable winds in these partly ice-covered areas.

Several new features have been added to the coupled ice-ocean system that should be used in a fully coupled regional atmosphere-ice-ocean model. One example is a prognostic variable that conserves the heat-content of sea ice. This allows for a fully heat conservative atmosphere-ice-ocean coupling interface. This is a very important point for climate models.

1.3 Contributions to national and international climate research

Contributions to IPCC

Some major intermediate results from RegClim have already appeared. In particular, several parts of RegClim have contributed results to the IPCC Third Assessment Report (TAR) of Working Group I. This is a short summary of the main contributions to TAR. It should be mentioned that some contributions from RegClim-scientists to IPCC also are based on results from other projects and activities. This is particularly the case for contributions from air chemistry and radiative forcing. References are listed in the RegClim publication lists in Section 3 below.

Authorship, TAR, Working Group I

Prof. I. Isaksen co-authored the Technical and Policymaker's summaries. (**PT6**)

Lead Authors;

Chapter 4: Prof. Ivar Isaksen, Igf-UiO (**PT6**)
Chapter 6: Dr.Gunnar Myhre, Igf-UiO (**PT6**)

Contributing Authors:

Chapter 4: Dr. T. Berntsen, Dr. Jostein Sundet, Igf-UiO (**PT6**)
Chapter 6: Prof. F. Stordal, NILU (**PT6**)
Chapter 10: Dr. Inger Hanssen-Bauer, Dr. Rasmus Benestad, met.no (**PT3**)

Referenced papers from PT1, PT3, PT5 and PT6 in TAR, WG I:

Chapter 2: Førland & Hanssen-Bauer (2000), Hanssen-Bauer & Førland (1998), Hanssen-Bauer & Førland (2000) (**PT3**)
Chapter 5: Iversen et al. (2001) (PT5), Myhre et al., (1998) (**PT6**)
Chapter 6: Berntsen et al., (2000) (PT6), Iversen et al. (2001) (**PT5**), Myhre et al., (1998), Myhre et al., (2000), Myhre et al. (2001b), Restad et al. (1998) (**PT6**)
Chapter 10: Benestad (1999), Benestad et al. (1999), Hanssen-Bauer & Førland (1998), Hanssen-Bauer & Førland (2000) (**PT3**), Haugen et al. (1999) (**PT1**)

Expert Reviewers: (*this list is probably incomplete*.)

IPCC TAR: Eirik J. Førland, Dr. Inger Hanssen-Bauer, Prof. Sigbjørn Grønås, and Prof. Trond Iversen

Technical Summary and Summary for Policy Makers:

Eirik J. Førland, Prof. Sigbjørn Grønås, and Prof. Trond Iversen.

Use of RegClim results for impact studies, ACIA, and other applications

PT1:

The results from regional dynamical downscaling of climate change scenarios in Norway have been or will be given as input data to:

1. CICERO – Centre for climate research, University of Oslo:
(i) Coordinator for data to Norwegian Transport Plan –Strategic analyses within transport and climate change.
(ii) Socio-economic impacts of climate change in Norway – a pilot study of the energy sector within the SAMRAM program.
(iii) Climate change impacts and vulnerability in Norway – a regional assessment within the SAMSTEMT program.

2. Norwegian Building Research Institute (Byggforsk), Thomas Thiis
The effects of climate change on buildings.

3. University of Oslo, Dept. of Biology, Prof. Nils Chr. Stenseth:
The EcolClim project – The ecological effects of climate fluctuations and change: a multi-disciplinary and integrated approach, application to Norwegian Research council.

4. Agricultural University of Norway:
(i) Department of soil and water science, Lars R. Bakken – Input to soil models for erosion, plants production etc.
(ii) Dept. plant science, Marina A. Bleken – Input to soil models.5. Nasjonal Transportplan 2006-2015. Virkninger av klimaendringer for transportsektoren – en forstudie. Mars 2002. Bl.a. basert på RegClim-data.

PT2:

Input to ACIA about possible changes in the Arctic climate system over the next 50-100 years. Contributing author to Chap. 6: Prof. H. Drange (NERSC).

Three-dimensional current, temperature and salinity fields from the NERSC version of MICOM in PT2 are used as input for an UK/NERC project dealing with the ecological importance, transport and mixing of Calanus finmarchicus in the North Atlantic-Nordic Seas region.

PT3:

Cooperation between met.no and Norwegian Water & Energy Administration (NVE) in a project [financed by the water-power industry and the Research Council of Norway] on consequences of climate change for water power production in Norway.

Cooperation with Arctic Climate Impact Assessment ACIA-Norway to deliver empirical downscaled scenarios for the Norwegian Arctic, and to present RegClim results at three ACIA-workshops in January/February 2002.