

Uncertainty on Climate Model Projections

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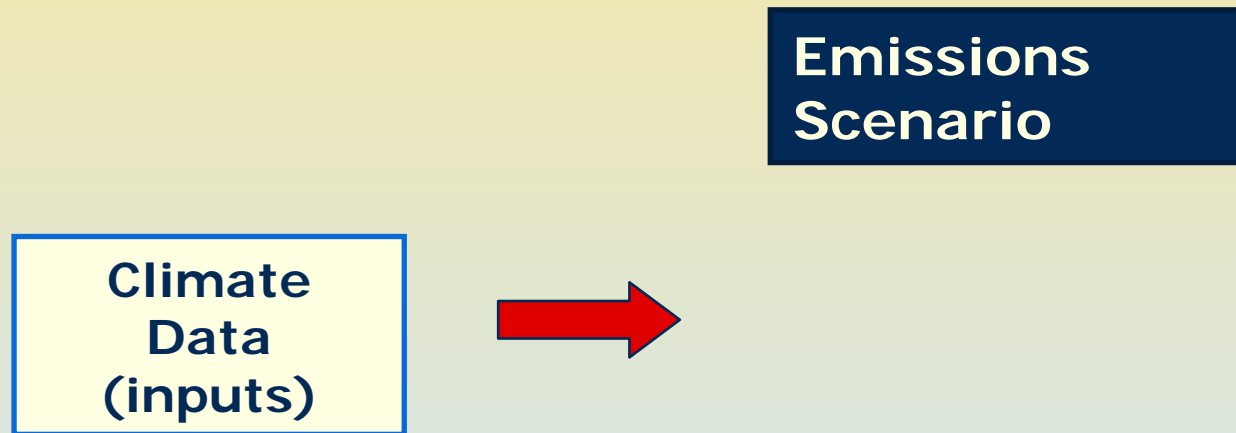
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Hydrologidag
26 Oct 2010

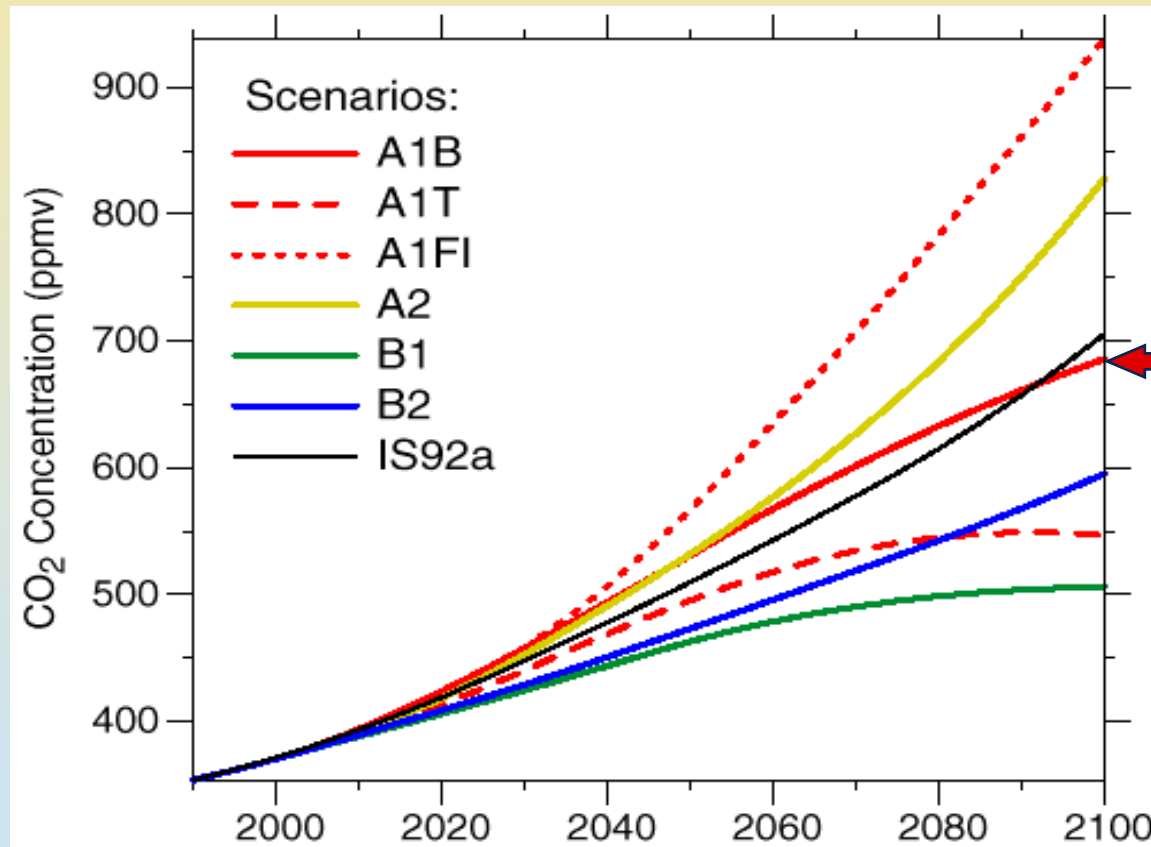
Outline

- Sources of Uncertainty
- Downscaling Methods
- Outputs / Deliverables
- Conclusions

Sources of Uncertainty

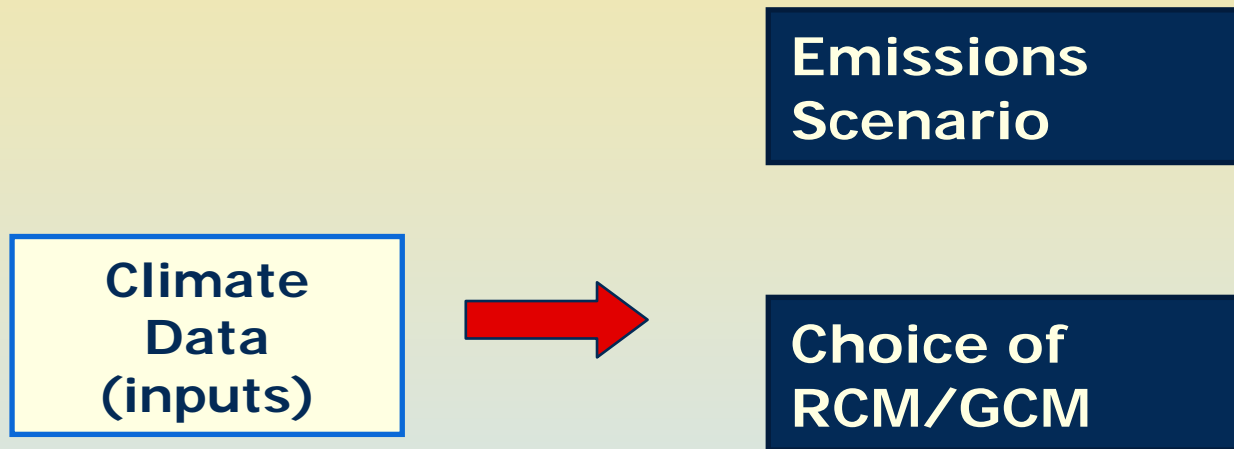


ENSEMBLES Climate Change Scenarios



ENSEMBLES (A1B)

Sources of Uncertainty



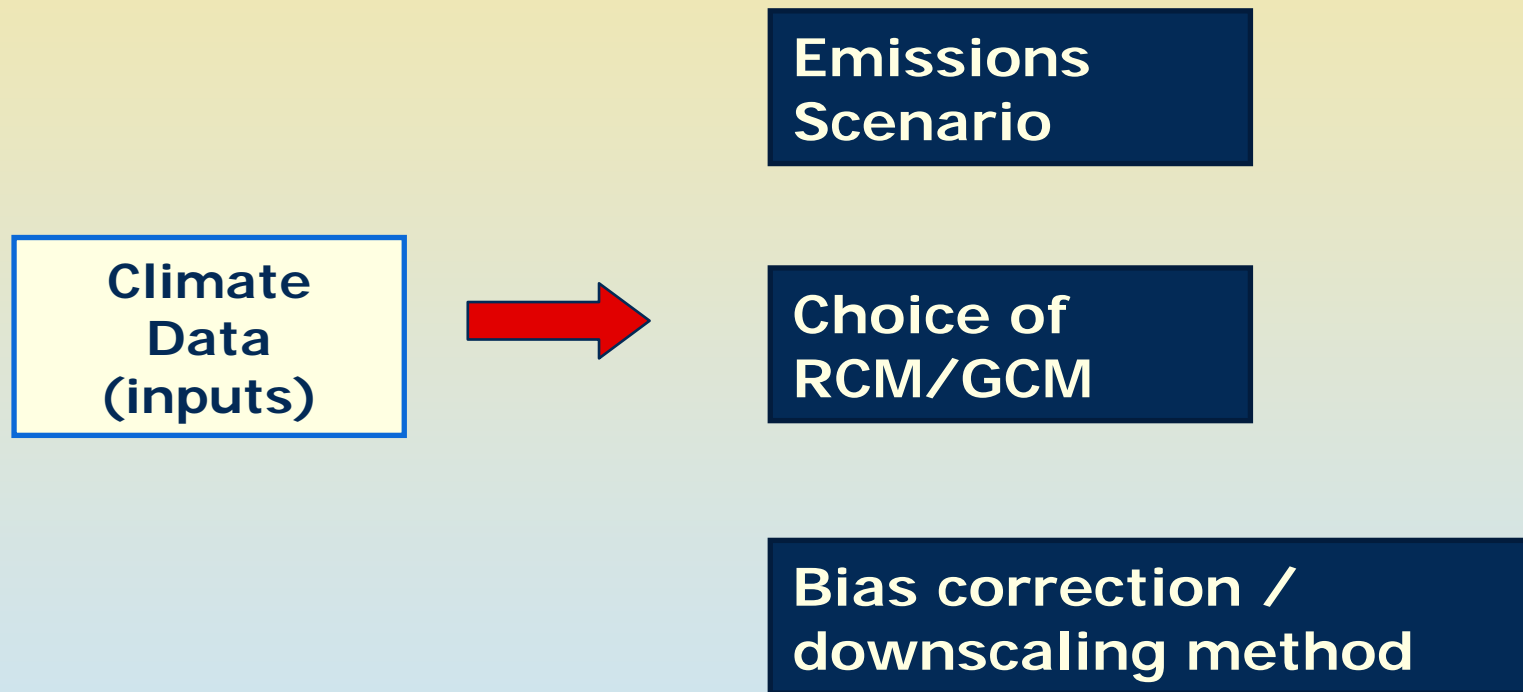
ENSEMBLES Climate Model MATRIX

GCM / RCM	METO-HC Standard	METO-HC Low sens.	METO-HC Hi sens.	MPIMET Standard	MPIMET Ens.m. 1	MPIMET Ens.m. 2	IPSL	CNRM	NERSC	MIROC	CGCM3
METO-HC	2100	2100*	2100*	2100 (late 2010)							
MPIMET				2100			2050*				
CNRM								2100			
DMI				2100*				2100	2100* (01/2010)		
ETH	2100										
KNMI				<u>2100*</u> <u>2100*</u>	<u>2100*</u>	<u>2100*</u>				<u>2100*</u>	
ICTP				2100							
SMHI		2100*		<u>2100*</u> <u>2100*</u>					2100		
UCLM	2050										
C4I			2100*	2050 (A2)*							
GKSS							2050*				
METNO	2050*								2050*		
CHMI								2050* (12/2009)			
OURANOS**											2050*
VMGO**	2050*										

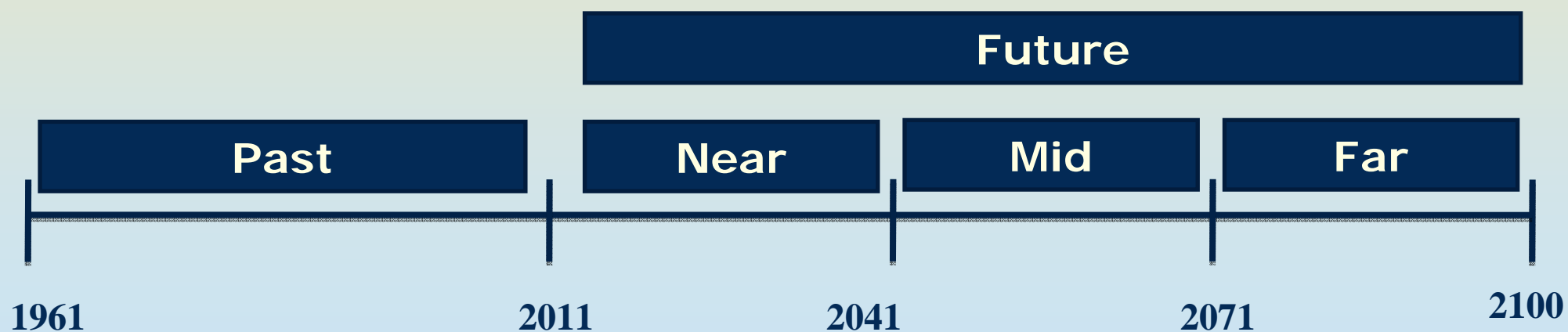
ENSEMBLES Climate Model MATRIX

GCM / RCM	HADCM			ECHAM5	ARPEGE	BCM
	METO-HC Standard	METO-HC Low sens.	METO-HC Hi sens.	MPIMET Standard	CNRM	NERSC
METO-HC	2100	2100*	2100*	2100 (late 2010)		
MPIMET				2100		
CNRM					2100	
DMI				2100*	2100	2100* (01/2010)
ETH	2100					
KNMI				2100*		
ICTP				2100		
SMHI		2100*		2100*		2100
C4I			2100*			

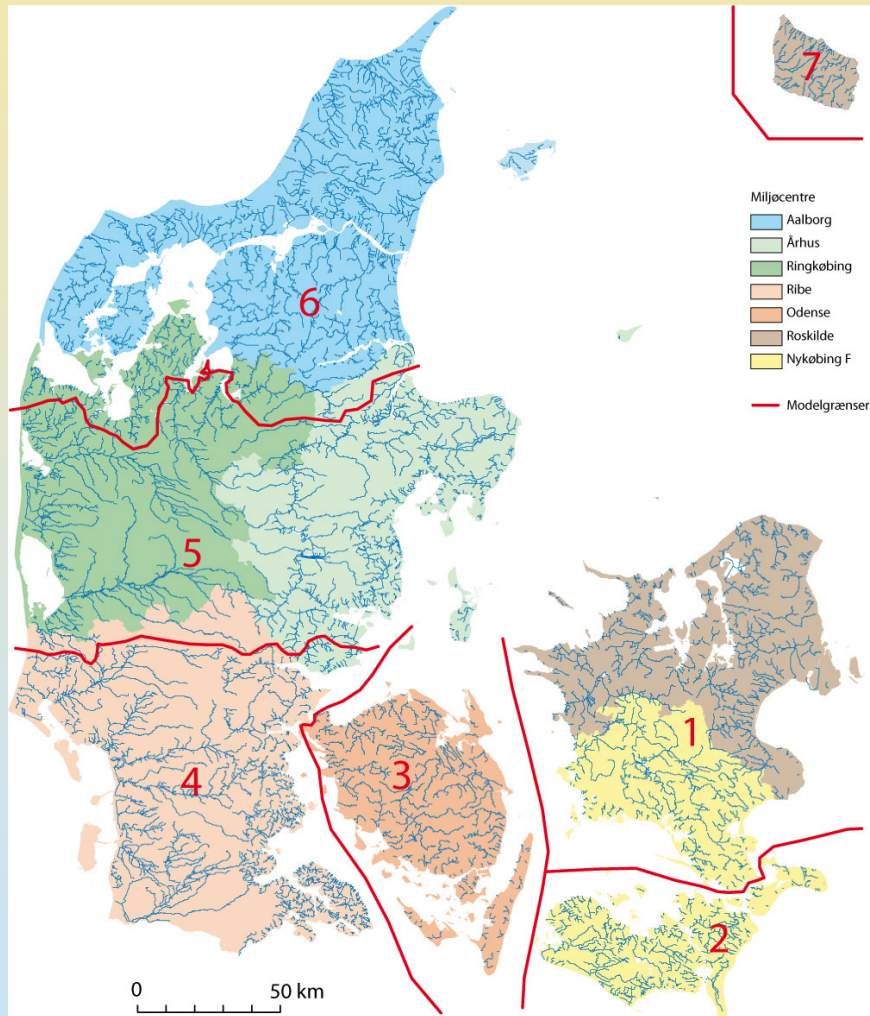
Sources of Uncertainty



Downscaling: Timescale



Downscaling: Spatial Scale



- ◆ All of Denmark
- ◆ DK-submodels (7)

Delta Change Method

- Monthly or seasonal transfer functions
- State variables (temp) - absolute change is applied

$$T_{\Delta}(i, j) = T_{\text{obs}}(i, j) + \Delta_T(j)$$

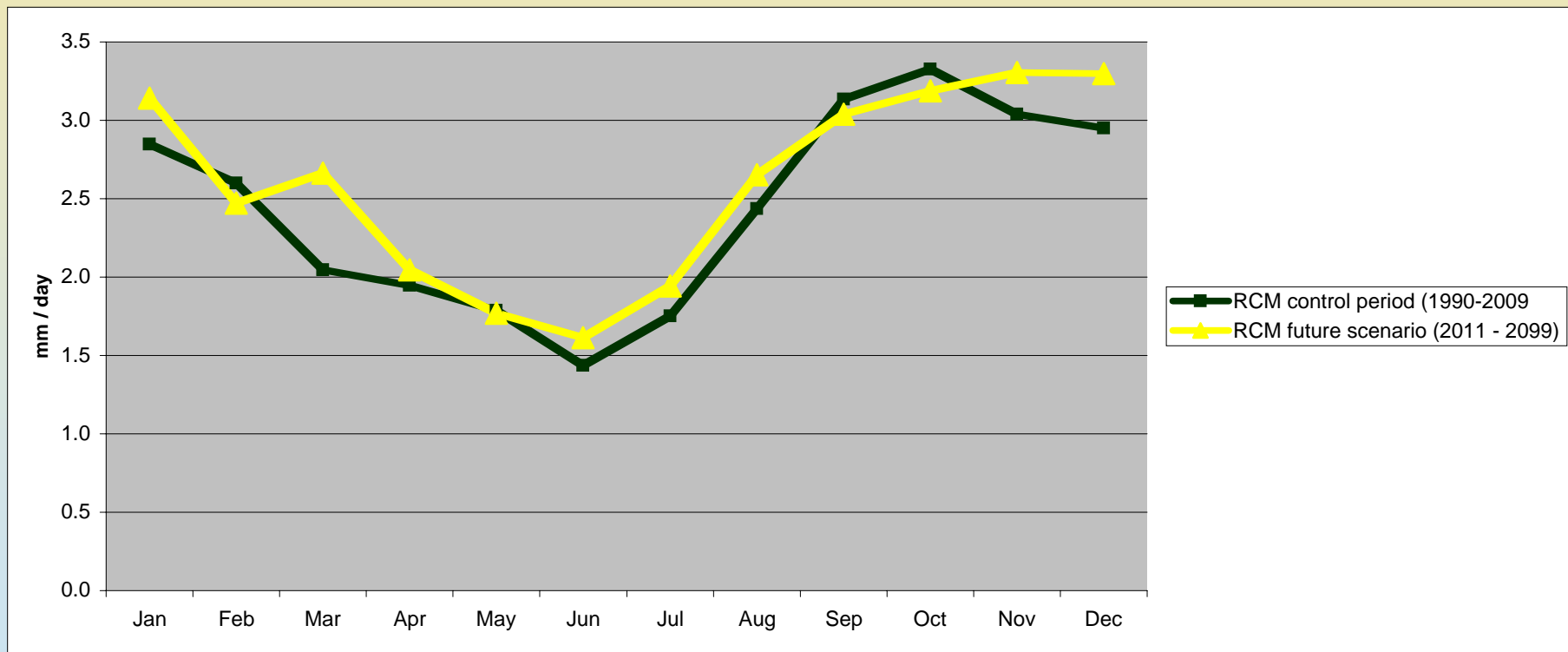
- Flux variable (precip) - relative change is applied

$$P_{\Delta}(i, j) = \Delta_P(j) * P_{\text{obs}}(i, j)$$

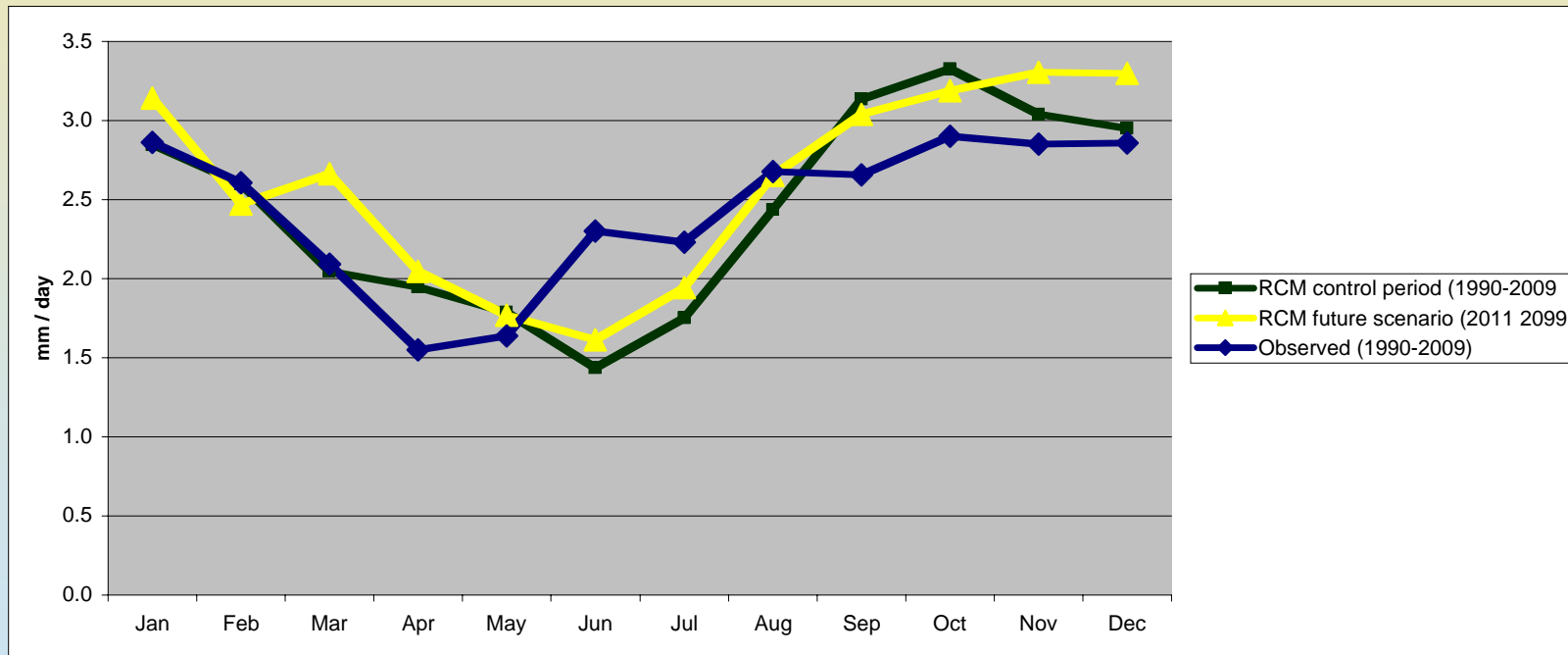
Histogram Equalization Method

- Normalizes daily climate data (cumulative distribution functions) based on the distribution of rainfall intensity on an annual scale

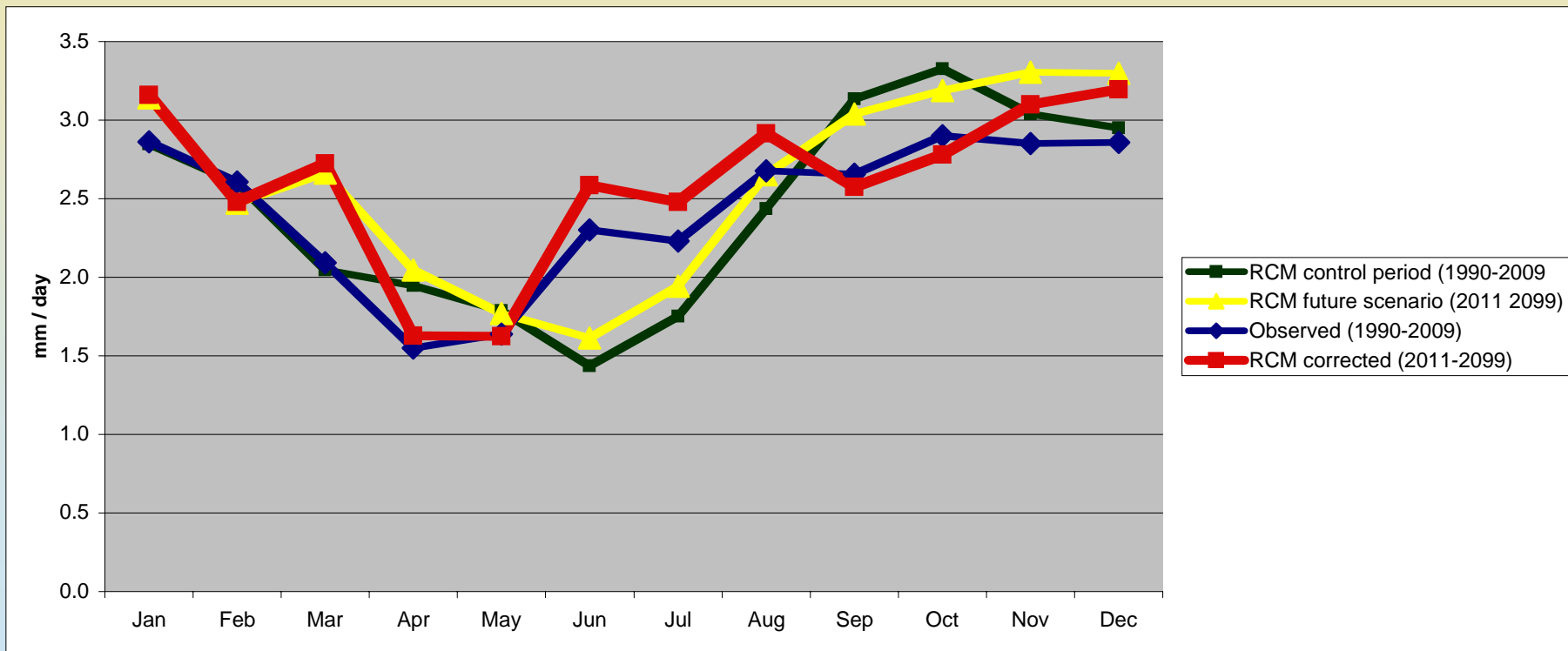
BCM-DMI Climate Model: hindcast and future scenarios



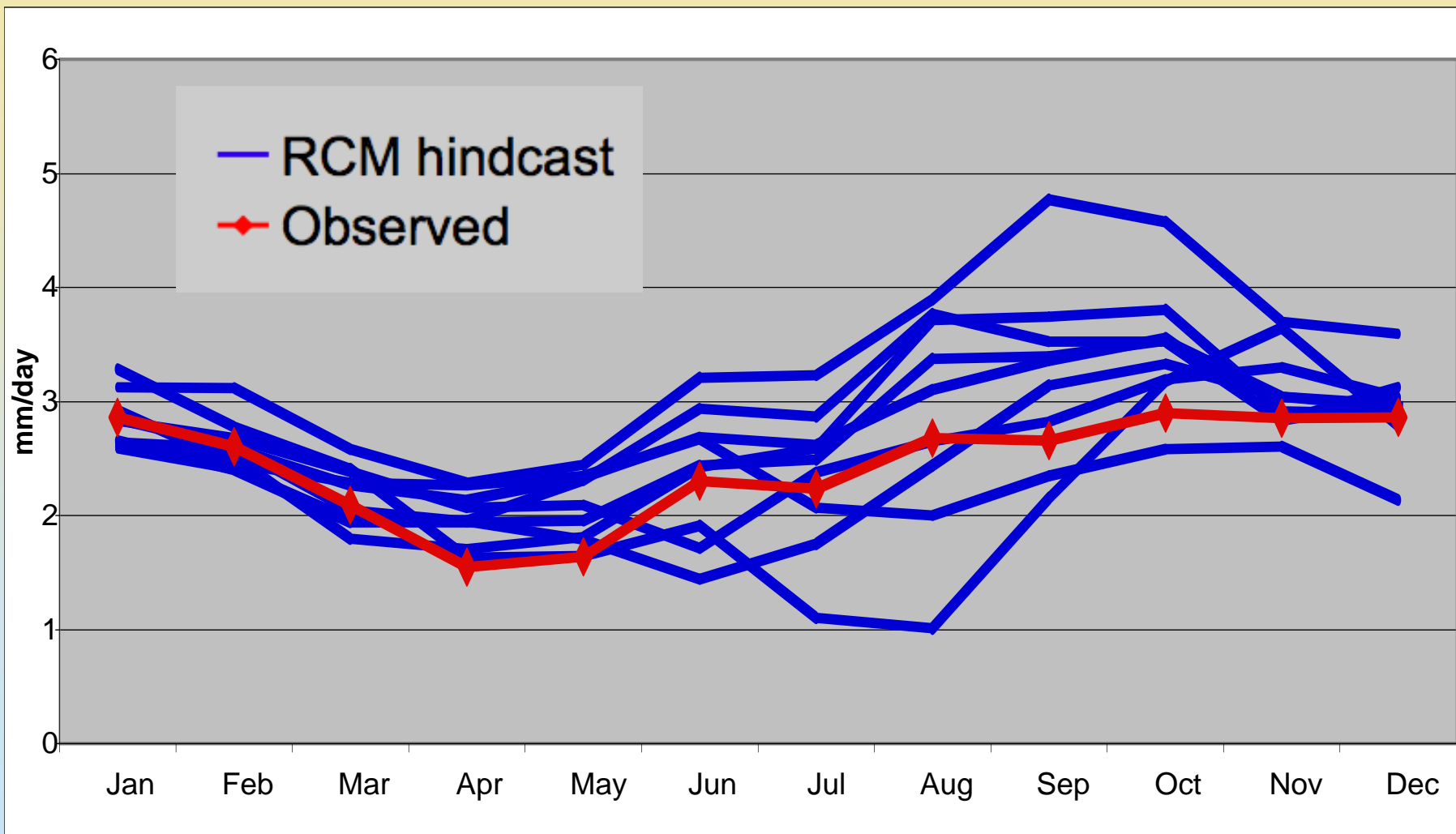
BCM-DMI Climate Model: hindcast and future scenarios vs. Observed data



BCM-DMI Climate Model: corrected



Denmark Mean Daily Precip /Month: Observed vs. RCM Scenarios 1990-2009



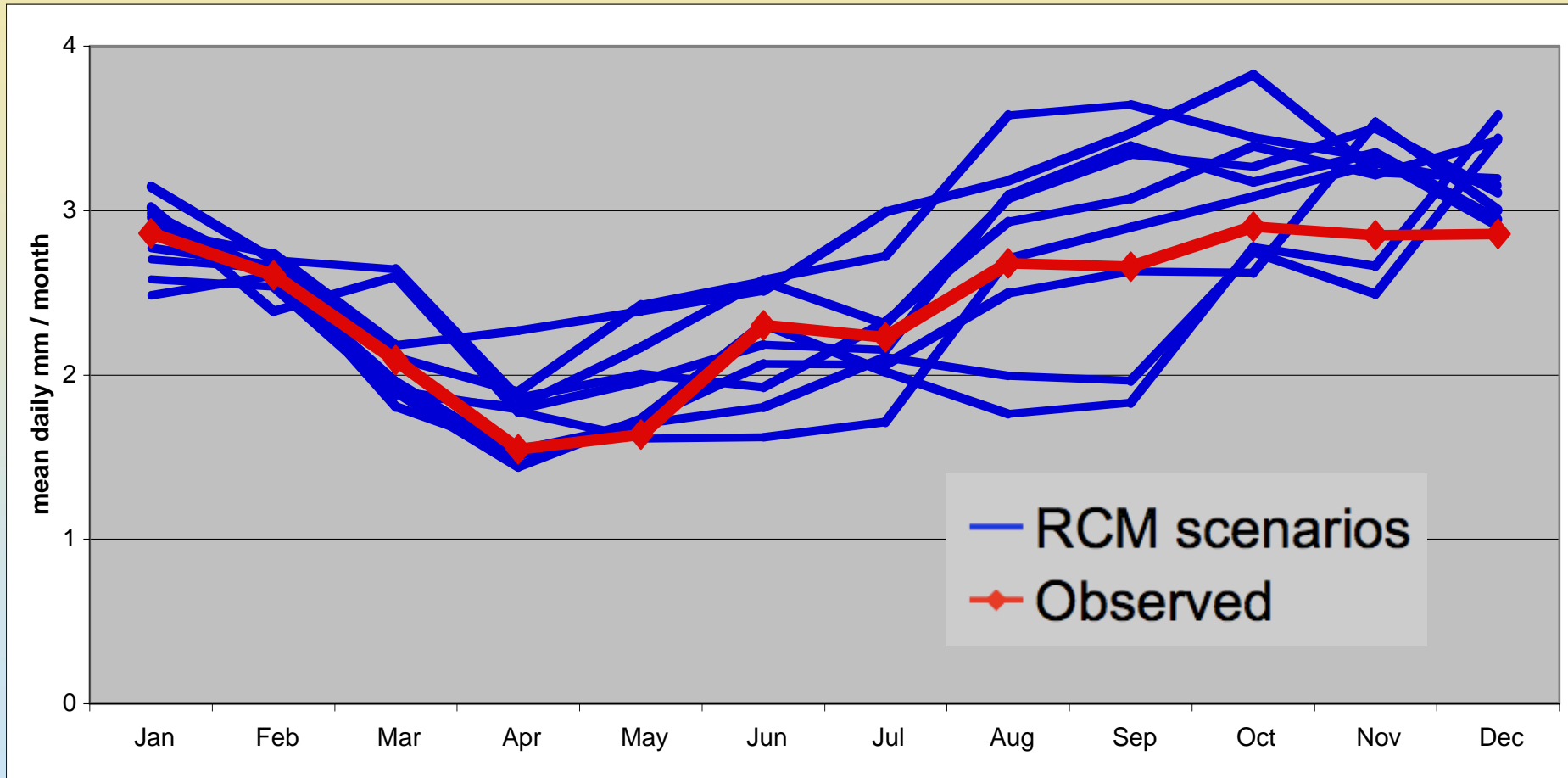
Denmark Mean Daily Precip /Month: RCM Scenarios %Error 1990-2009

% Error	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
ARPEGE-CNRM	2	-6	9	46	43	16	-7	-25	-12	-11	-9	-25	2
ARPEGE-DMI	15	6	15	5	1	-17	-51	-62	-19	9	28	-2	-6
BCM-DMI	-1	0	-2	26	9	-38	-22	-9	18	15	7	3	1
BCM-SMHI	-1	3	14	33	28	-25	7	-1	6	10	16	6	8
ECHAM-DMI	9	19	23	47	49	39	45	45	80	58	30	26	39
ECHAM-ICTP	-8	-1	8	38	42	17	17	16	26	22	-1	9	16
ECHAM-KNMI	-7	-8	-7	25	19	6	12	26	28	22	7	4	10
ECHAM-MPI	-8	-4	-14	10	10	5	16	39	41	31	2	1	11
ECHAM-SMHI	28	31	27	56	59	41	41	55	47	39	22	44	41

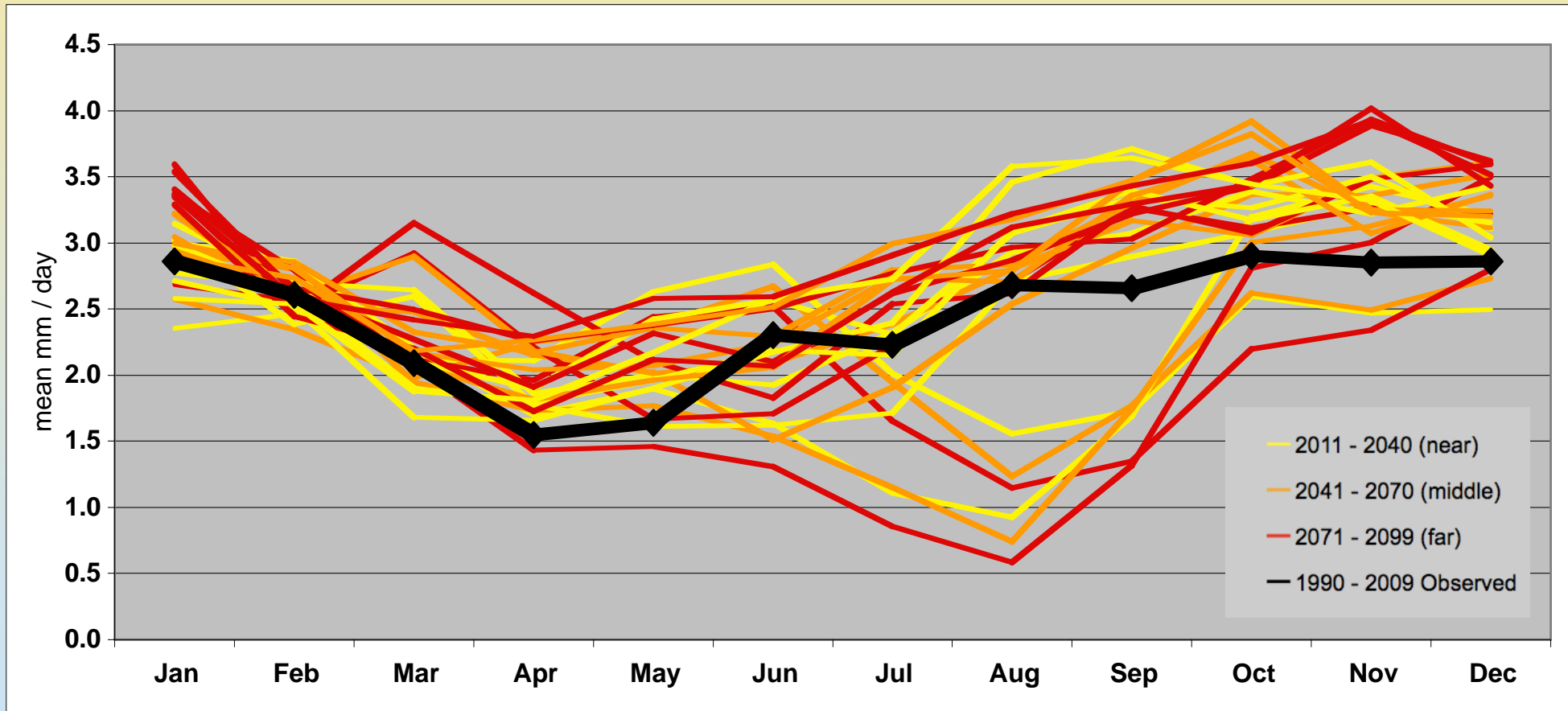
Delta Change Factors (precip): Future Scenario 2011 - 2100

Delta Change	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ARPEGE-CNRM	0.9	1.0	0.9	0.9	1.1	1.0	0.9	0.7	0.7	1.0	0.9	1.3
ARPEGE-DMI	0.9	1.0	0.9	1.0	1.0	0.8	0.9	0.7	0.7	0.9	0.9	1.2
BCM-DMI	1.1	1.0	1.3	1.0	1.0	1.1	1.1	1.1	1.0	1.0	1.1	1.1
BCM-SMHI	1.2	1.0	1.2	1.1	1.0	1.1	1.0	1.1	1.1	1.0	1.0	1.2
ECHAM-DMI	0.9	0.8	0.8	0.9	1.0	0.8	0.9	0.9	0.7	0.8	0.9	0.9
ECHAM-ICTP	1.2	1.1	1.0	1.0	1.0	0.9	1.0	1.0	1.0	1.0	1.3	1.0
ECHAM-KNMI	1.2	1.1	1.1	1.0	1.1	0.9	1.0	0.9	1.0	1.0	1.1	1.1
ECHAM-MPI	1.1	1.0	1.1	1.0	1.1	0.9	1.0	0.8	0.9	0.9	1.2	1.1
ECHAM-SMHI	1.1	1.1	1.1	1.1	1.0	0.9	1.0	0.9	1.0	1.0	1.2	1.1

Corrected Future Scenarios: 2011 – 2099 (all Denmark)



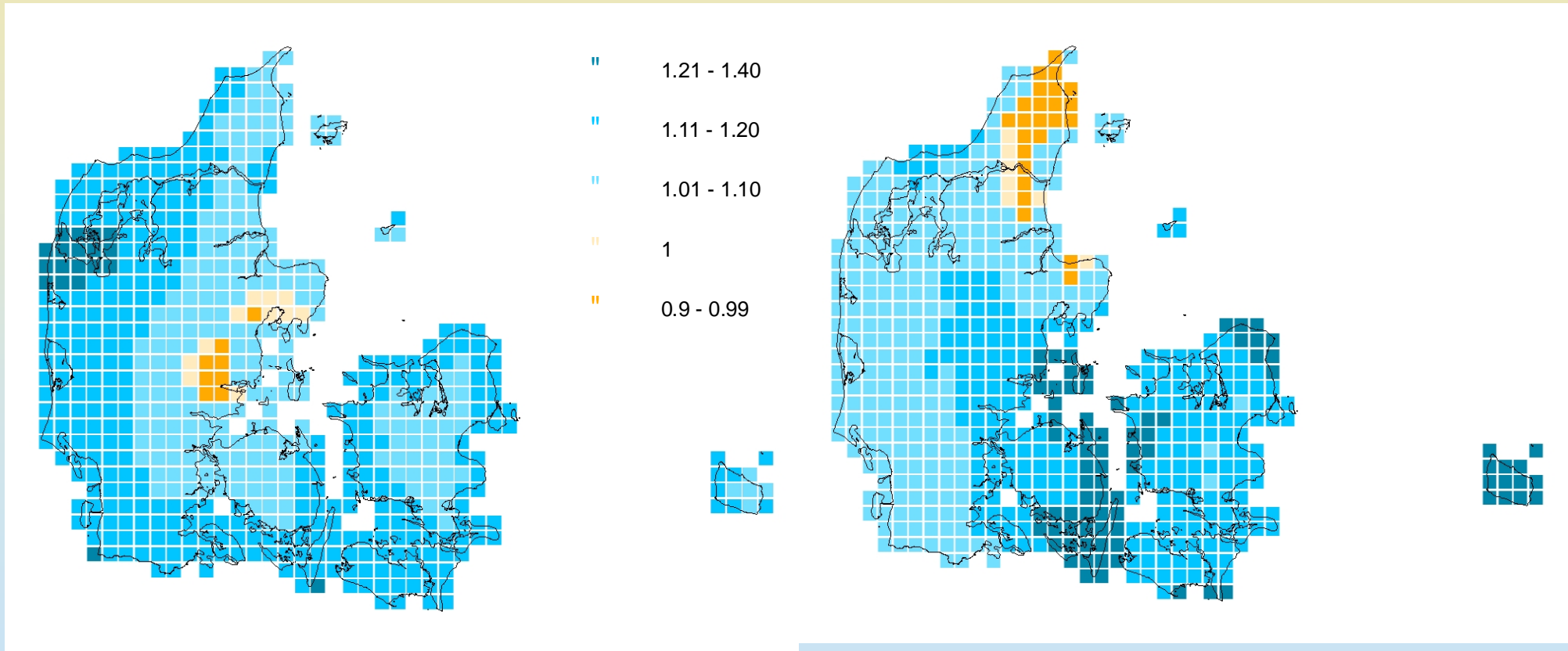
Denmark Mean Daily Precip / Month Future (near, middle, far)



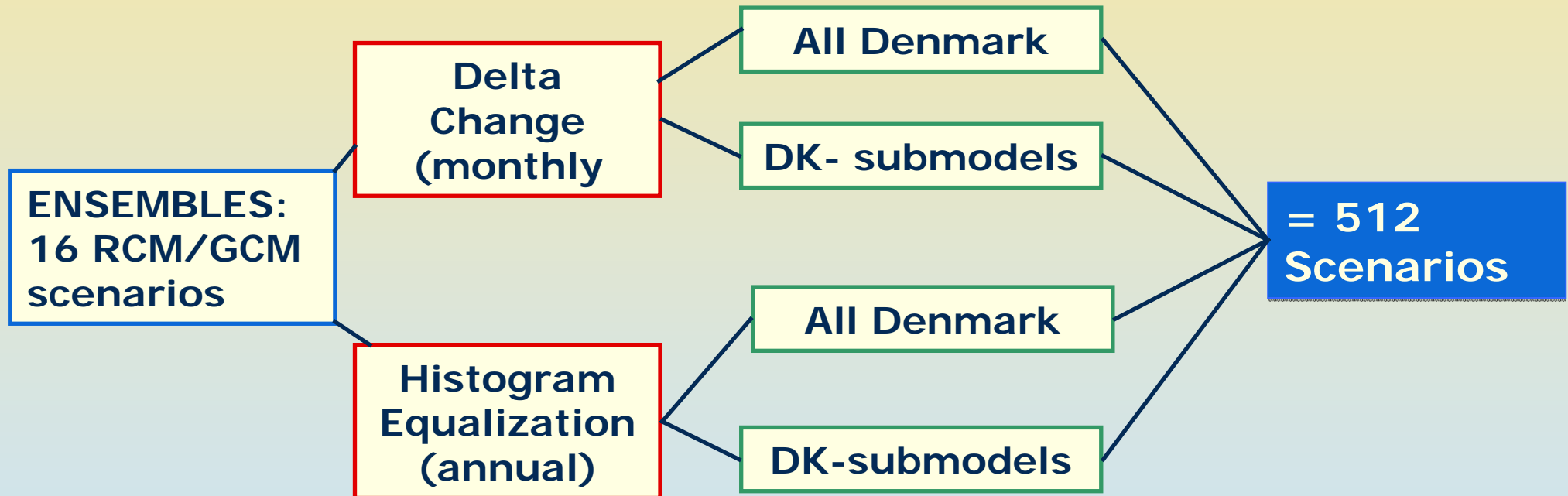
Spatially Distributed Delta Change Factors (BCM-DMI)

winter

summer



Outputs / Deliverables



Forward Uncertainty Analysis

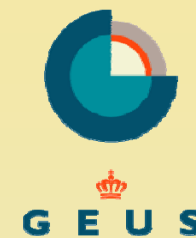
- ◆ 512 scenarios are speculations about future boundary conditions, used as climate inputs to hydrological (DK-model) simulations over Denmark
- ◆ Evaluate uncertainty between entire methodologies by comparing hydrologic outputs from all 512 scenarios
- ◆ Disentangle uncertainty with subsets of comparisons between:
 - Choice of RCM/GCM
 - Downscaling/bias correction methods
 - Spatially distributed (7 catchments) vs. applications to all of Denmark

Conclusions

- ◆ Based on the ENSEMBLES climate change scenarios for Denmark, there is no clear tendency for future precipitation changes
- ◆ Future climate has uncertainty, hydrological change results are completely conditional on choice of scenario, downscaling method, and spatial / temporal restraints
- ◆ Important to incorporate multiple climate model predictions and uncertainty in climate change impact studies



Thank you!



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