

The First WISE Case Study:
A Water and Energy Balance
Investigation of the 1999-2004 Severe
Drought in the Canadian Prairies

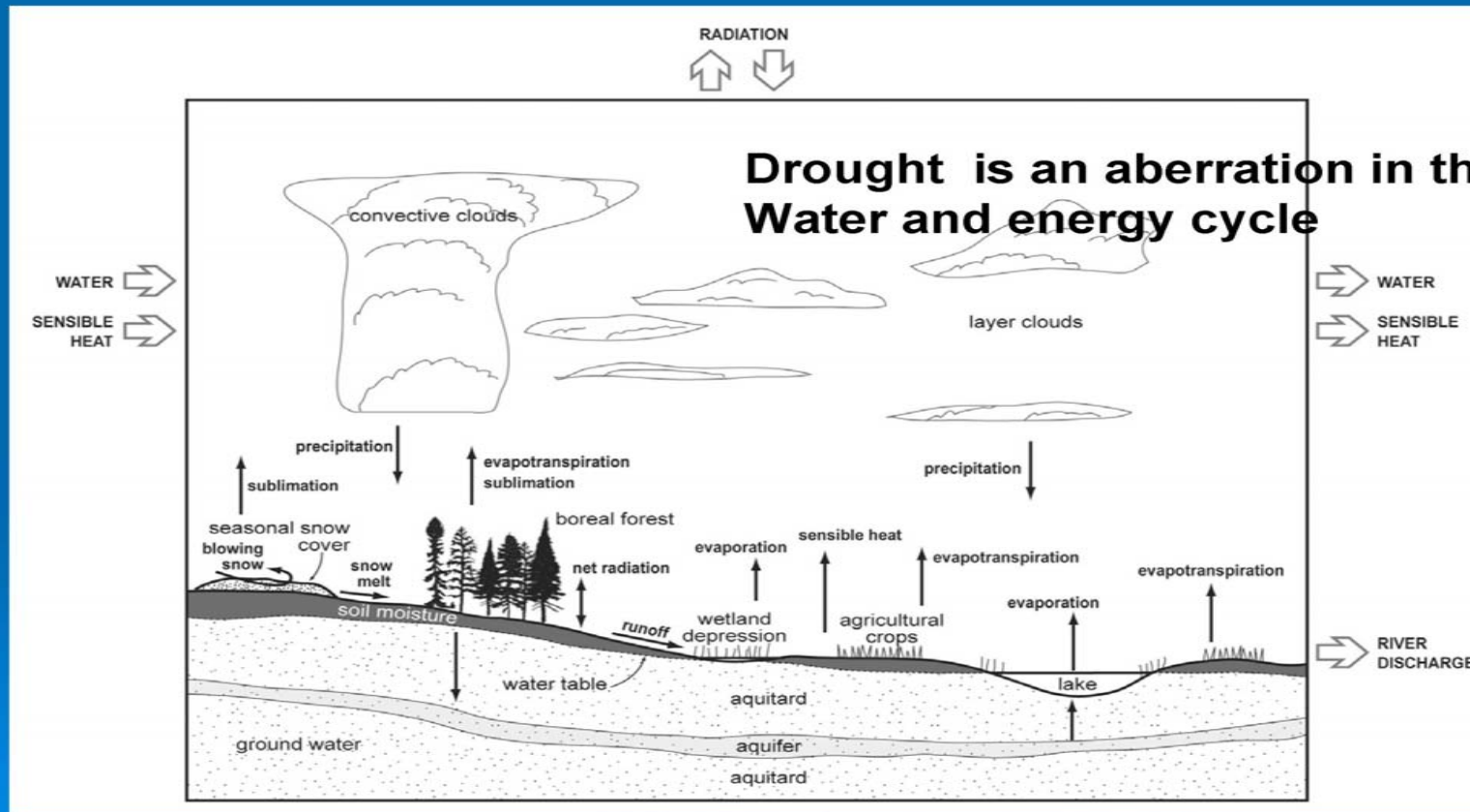
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What do we want to do?

- Use the WEBS approach to study extreme hydrometeorological events
- The first study will be a drought case
 - Drought is the most serious hydrometeorological extreme event in many places around the world

WATER AND ENERGY CYCLING



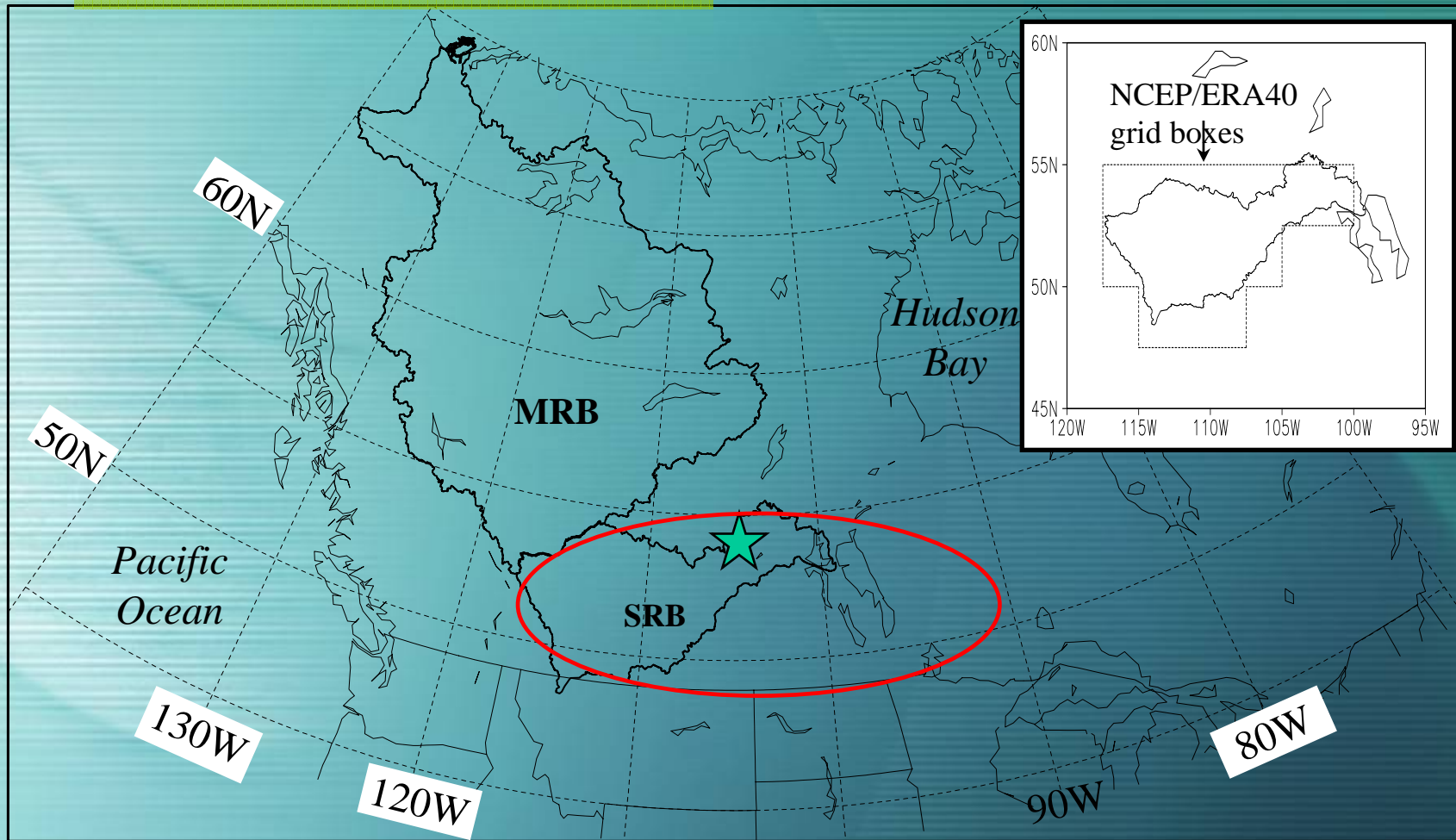
Why the 1999-2004 Canadian Prairie Drought Case?

- Certainly an extreme event - the worst drought in over a hundred years in the Canadian Prairies!
- The event overlapped the CEOP and MAGS
 - Builds upon datasets and tools developed for MAGS WEBS and CEOP
- The study also benefits from DRI, a current large Canadian drought research initiative that focuses on the event

Objectives of the Study

- To evaluate the surface and atmospheric water and energy budgets, and their deviations from the mean state, for the Canadian Prairie region during the 1999-2004 drought period by using various source datasets
- To assess how well aspects of the extreme event are represented in the various datasets and to explore implications of the assessment results to the use of current model/assimilation/remote-sensing products in drought monitoring and study applications, and to the improvement of drought predictions

The Canadian Prairies



BERMS CEOP reference site (star)

A CANADIAN NATURAL DISASTER

The 1999-2004/05 drought was one of the worst natural disasters that Canada has ever suffered!



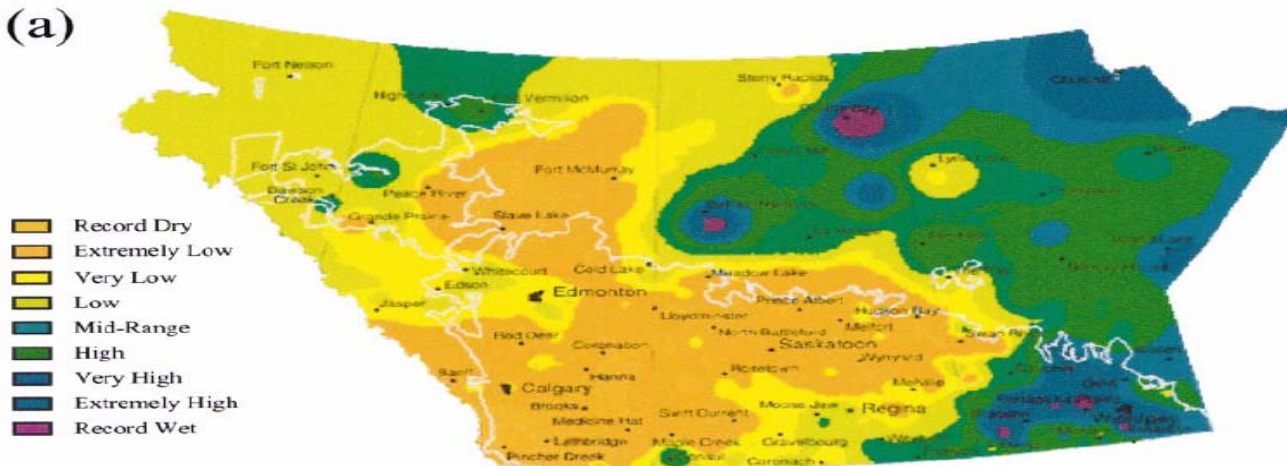
Southern Saskatchewan, April 2002

Huge impacts on:
society
economy

Causing economic loss of more than \$3.6B for Canada in 2002 alone

Precipitation Anomalies

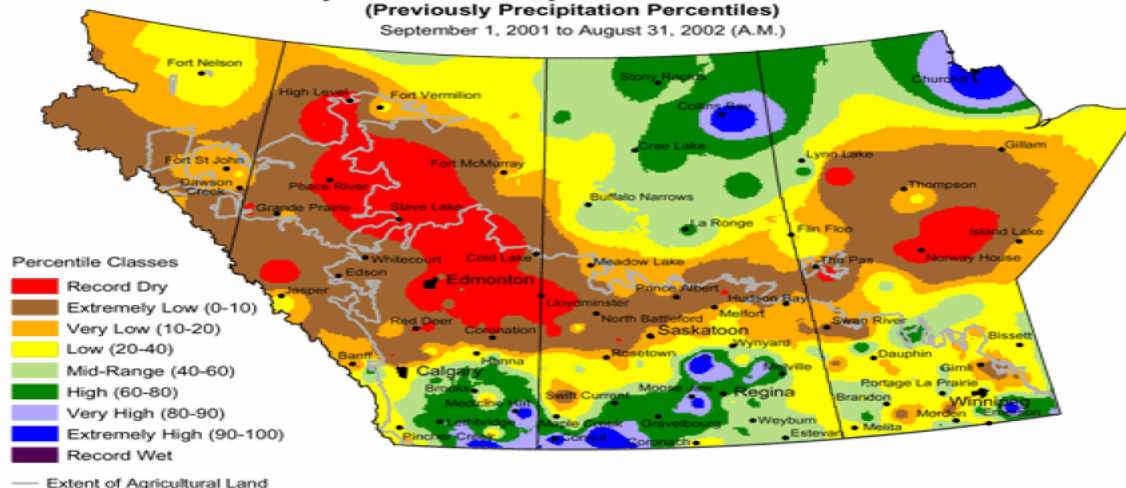
(a)



00-01

Current Precipitation Compared to Historical Distribution

(Previously Precipitation Percentiles)
September 1, 2001 to August 31, 2002 (A.M.)



Prepared by PFRA (Prairie Farm Rehabilitation Administration) using data from the Timely Climate Monitoring Network and the many federal and provincial agencies and volunteers that support it.

500 km

01-02

Water and Energy Budgets

Atmospheric Water

$$\frac{\partial Q}{\partial t} = E - P + MC + RESQ$$

Surface Water

$$\frac{\partial W}{\partial t} = P - E - N + RESW$$

Atmospheric Temperature

$$C_p \frac{\partial \{T\}}{\partial t} = QR + LP + SH + HC + REST$$

Surface Temperature

$$C_v \frac{\partial \{T_s\}}{\partial t} = QRS - LE - SH + G$$

Source: John Roads

Q=Atmospheric Precipitable Water, mm

W=Surface Water (M+S), mm

M=Soil Moisture, mm

S=Snow, mm

T=Atmospheric Temperature, K

Ts=Surface Skin Temperature, K

T2=Surface Air Temperature (at 2m), K

E=Evaporation, mm/day

P=Precipitation, mm/day

MC=Moisture Convergence, mm/day

N=Runoff, mm/day

LP=Latent Heat of Condensation, W/m**2

SH=Sensible Heat (which is positive upward), W/m**2

HC=Dry Static Energy Convergence, W/m**2

LE=Latent Heat of Evaporation (which is positive upward), W/m**2

QR=Atmospheric Radiative Heating (which is negative), W/m**2

QRS=(NSW+NLW)=Surface Radiative Heating, W/m**2

NSW=Net Shortwave Radiation at the Bottom of Atmosphere (BOA), W/m**2

NLW=Net Longwave Radiation at the Bottom of Atmosphere (BOA), W/m**2

NSW (0)=Net Shortwave Radiation at the Top of Atmosphere (TOA), W/m**2

NLW (0)=Net Longwave Radiation at the Top of Atmosphere (TOA), W/m**2

RESQ=Atmospheric Residual Water Forcing, mm/day

RESW=Surface Residual Water Forcing, mm/day

REST=Atmospheric Residual Dry Static Energy Forcing, W/m**2

G=Surface Residual Temperature Forcing, W/m**2

Datasets

Local (L), regional (R) and global (G) observations

Parameter	Source	Resolution	Coverage Period
Precipitable Water	Rawinsondes (L)	Sites	Various - Current
	GVAP/NVAP (G)	1 deg	1988-1999
Snow	SSMI (R)	25 km	1978 Dec - 2003 Mar (Dec-Mar)
Surface Air Temperature	CANGRID (R)	50 km	1895 - 2003 Dec
Atmospheric Enthalpy	Rawinsondes (L)	Sites	Various - Current
Precipitation	CANGRID (R)	50 km	1895 - 2003 Dec
	CMAP (G)	2.5 deg	1979 - 2003 Sep
	GPCP (G)	2.5 deg	1979 - 2003 Dec
Discharge	WSC (L)	sites	1913 - Current (The Pas)
Radiative Fluxes	ISCCP FD (G)	280 km	1983 Jul - 2001 Jun
	BERMS (L)	Sites	1994 - Current
Sensible/Latent Heat Flux	BERMS (L)	Sites	1994 - Current
Cloud Cover	Surface Obs (L/R)	Sites	Various - Current

Global (G) and regional (R) analysis and model datasets

Dataset	Resolution	Coverage period
CRCM (R)	51 km	1997 Apr - 2003 Dec
CMC (R)	35/24 km	1997 Mar - Current
NCEP-R2 (G)	2.5 deg	1979 Jan - Current
ERA-40 (G)	2.5 deg	1957 Sep - 2002 Aug

Other Datasets:

- * NARR
- * NLDAS-E, GLDAS
- * new CRCM (with CLASS-3)
- * high resolution blended precip data?
- * other model data?
- * CEOP satellite data?
- * Others.....

Assessment Period and Focuses:

- Study period: 1999-2002 for the formation and mature phases of the drought, and for the maximum overlap of available datasets
- Longer-term budget climatologies from ERA-40, NCEP-R2 and precipitation observations
- Focus on both the regional mean and spatial-temporal variability of the budgets

The SRB Climate System in a Nutshell: Ensemble Mean Annual Cycles of Water and Energy Budgets

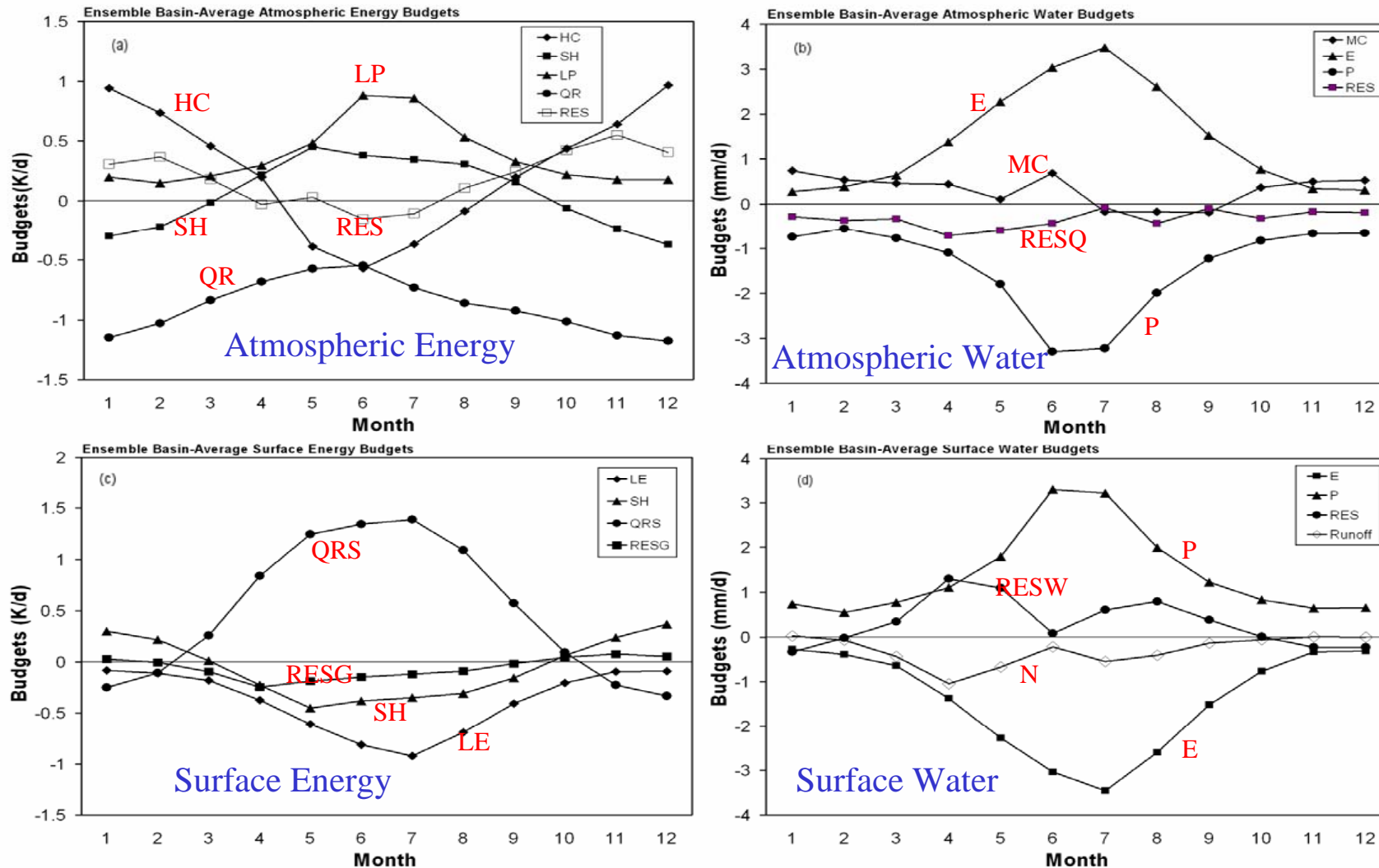
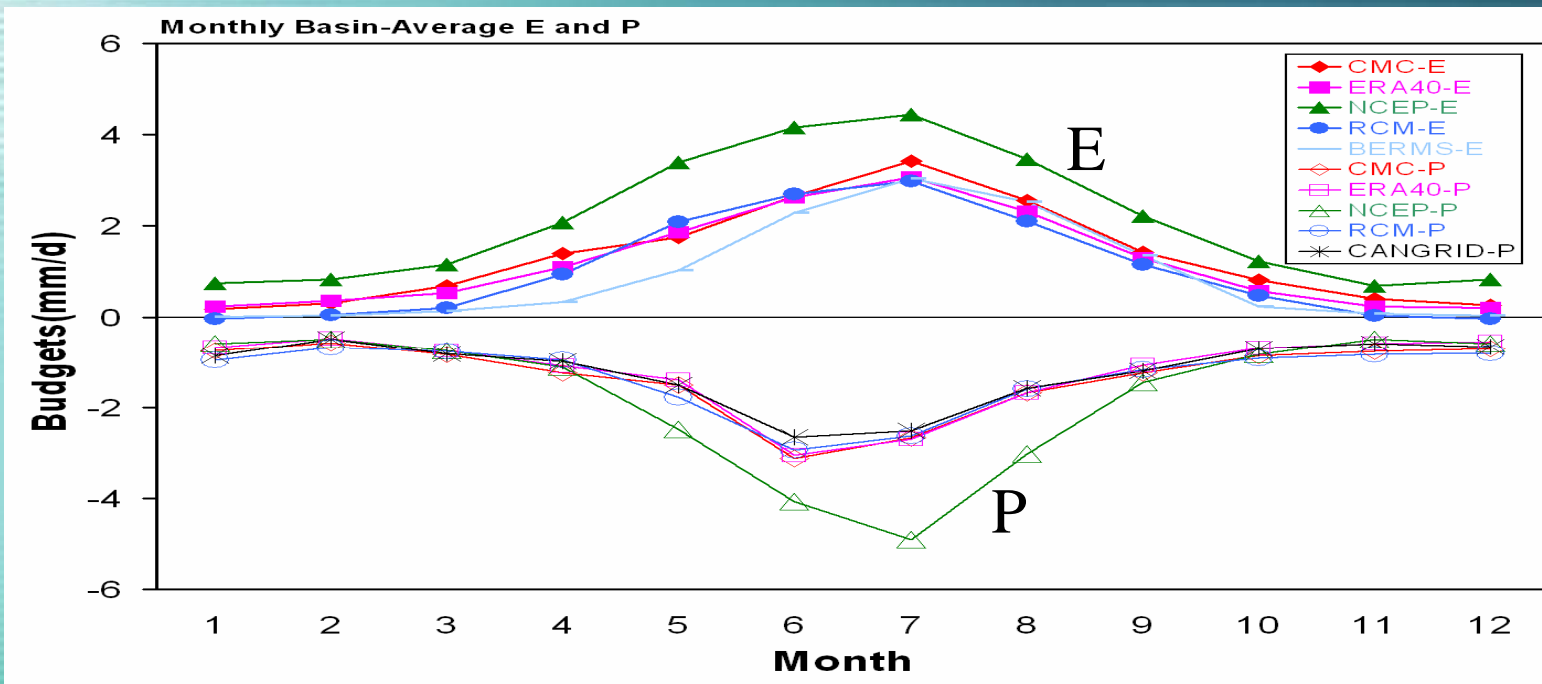
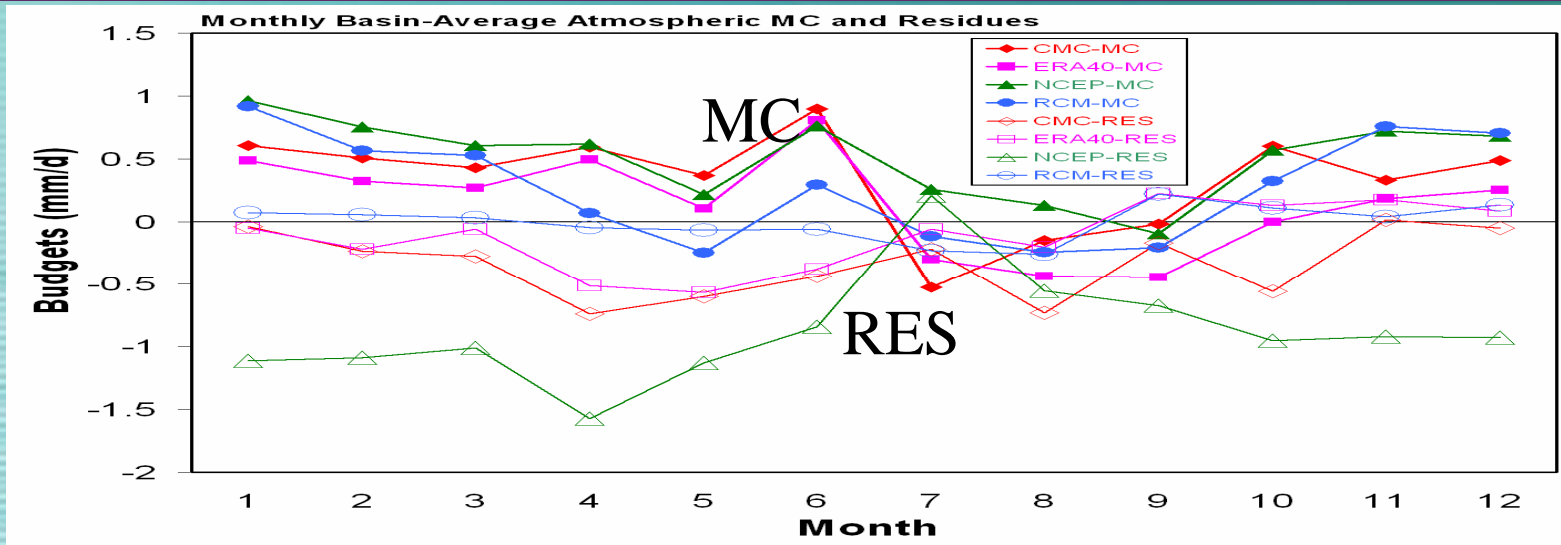
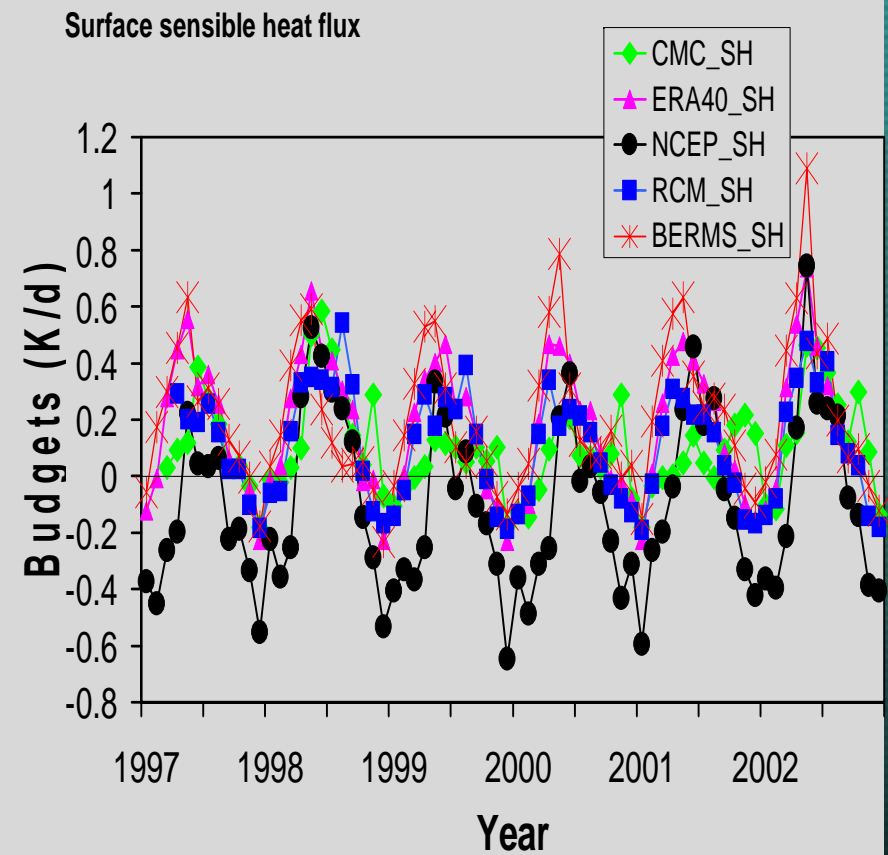
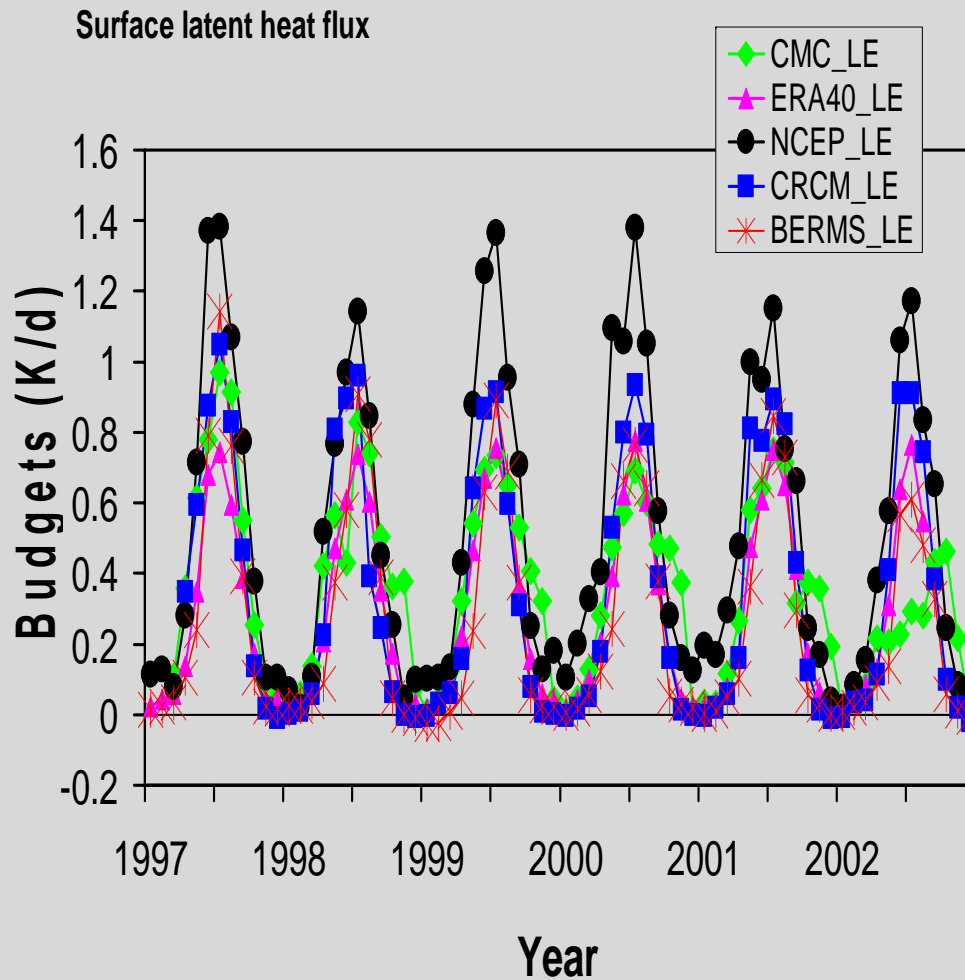


Figure 3. Mean annual cycle of ensemble (NCEP-R2, ERA-40, CMC and CRCM) basin-average budgets for (a) atmospheric energy, (b) atmospheric water, (c) surface energy and (d) surface energy.

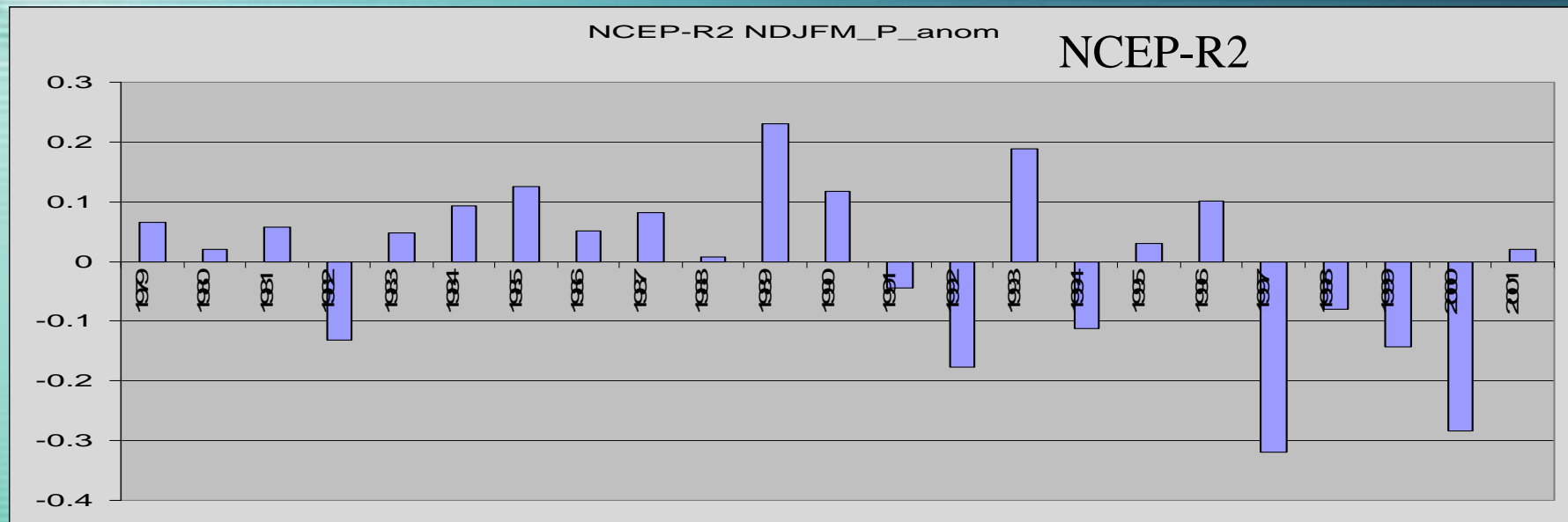
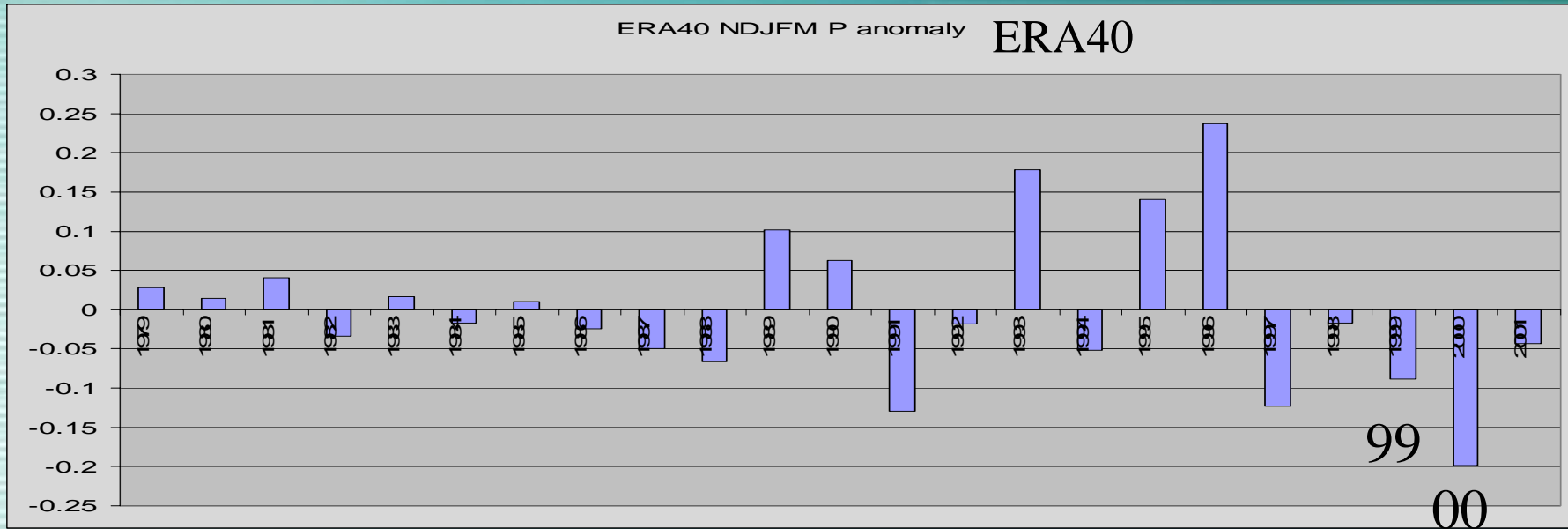
Variability among Budgets Assessments - Annual Cycles of Atmospheric Water Budgets



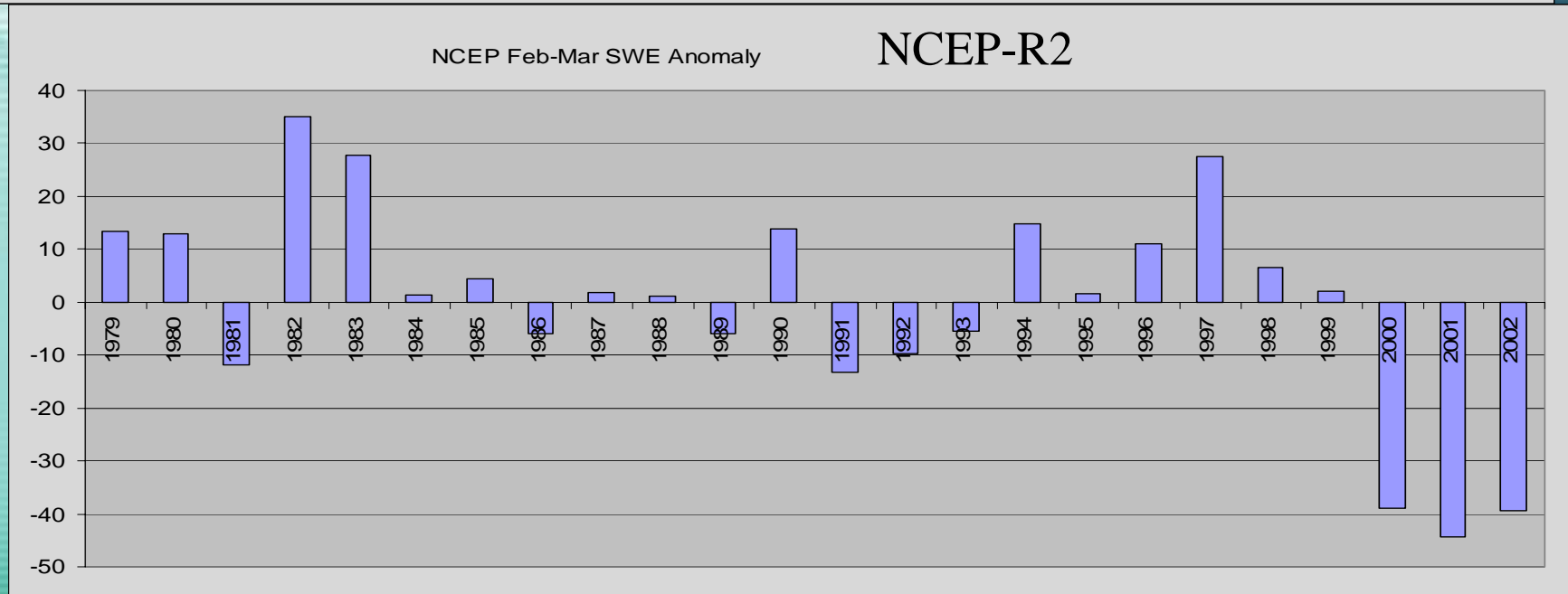
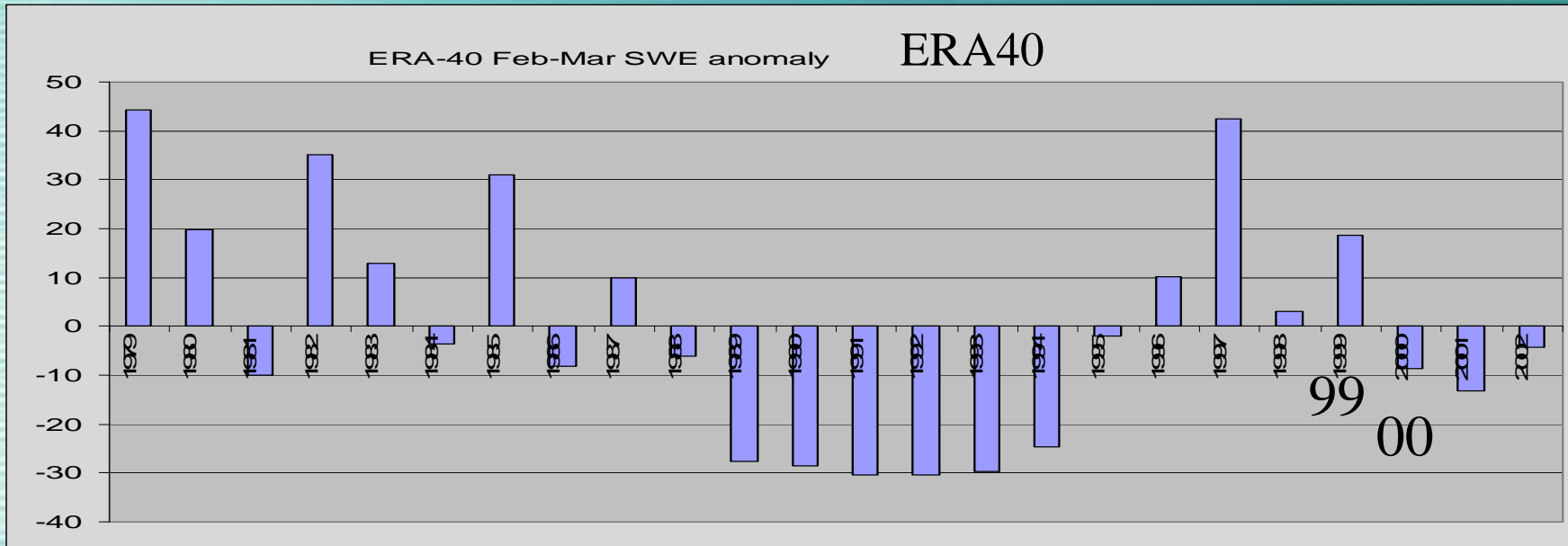
Variability among Budgets Estimatescont.... Surface SH and LE near BERMS Site



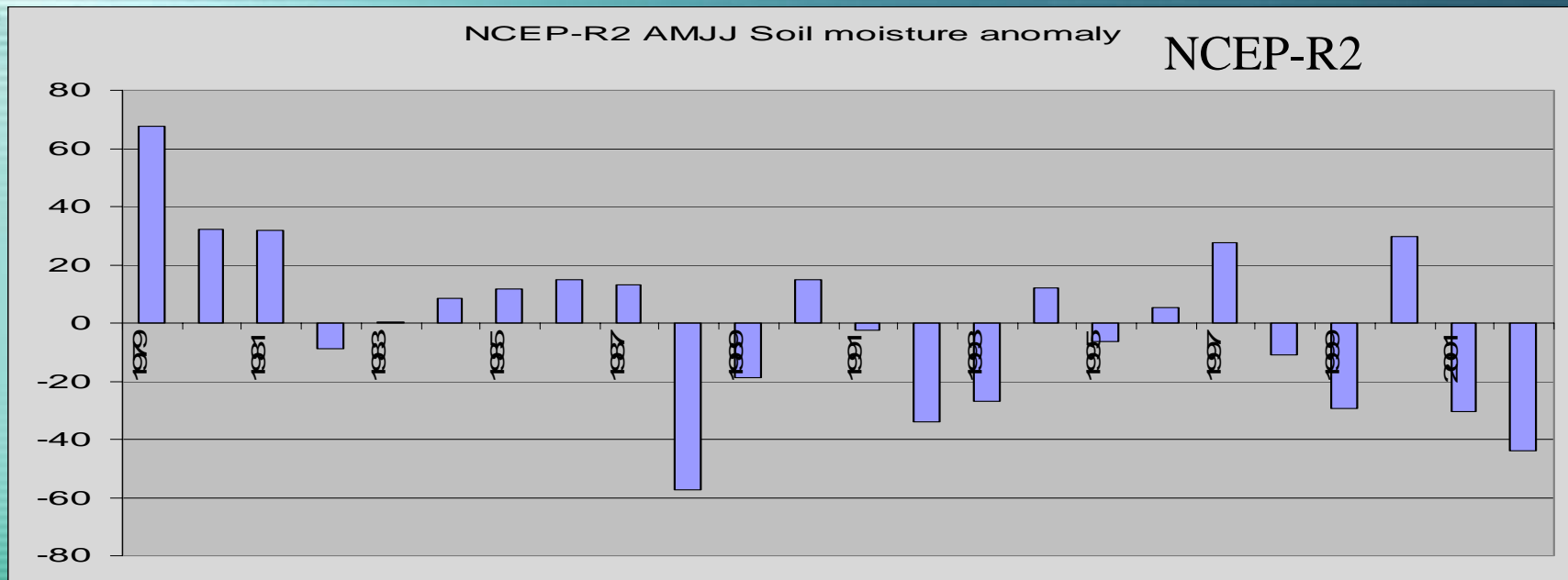
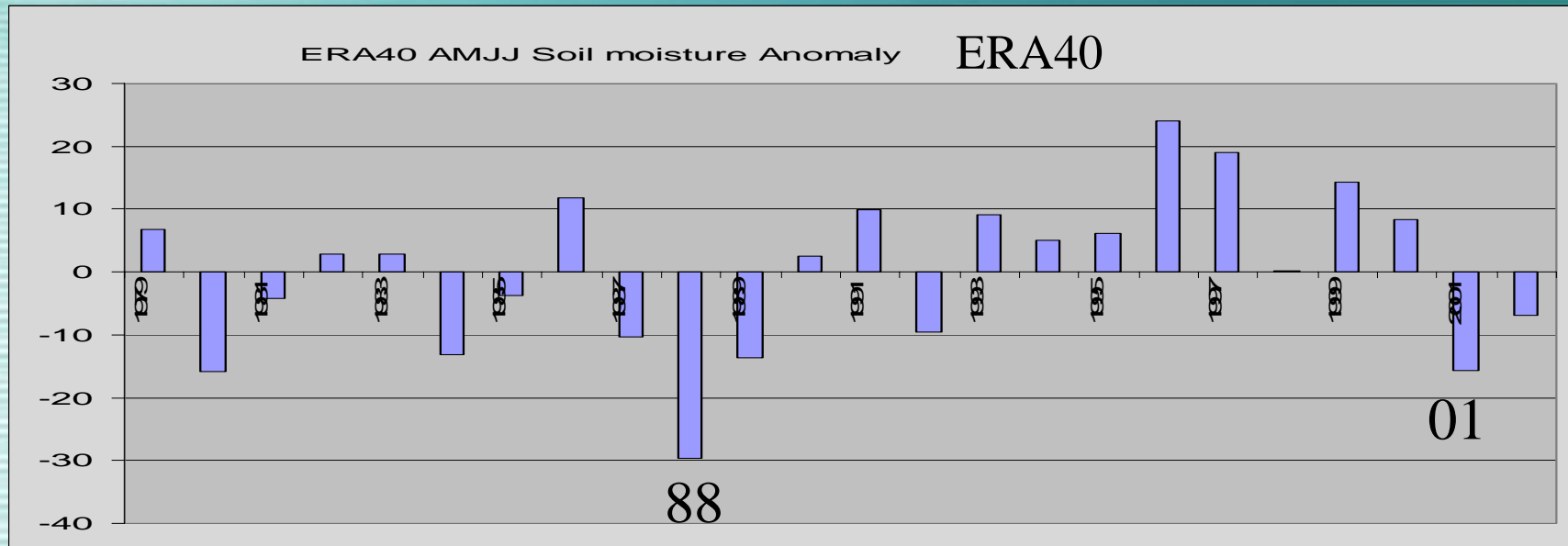
Variability among Budgets Estimatescont....NDJFM P anomalies (mm/d)



Variability among Budgets Estimatescont....NDJFM SWE Anomalies (mm)



Variability among Budgets Estimatescont....AMJJ Soil Moisture anomalies (mm)



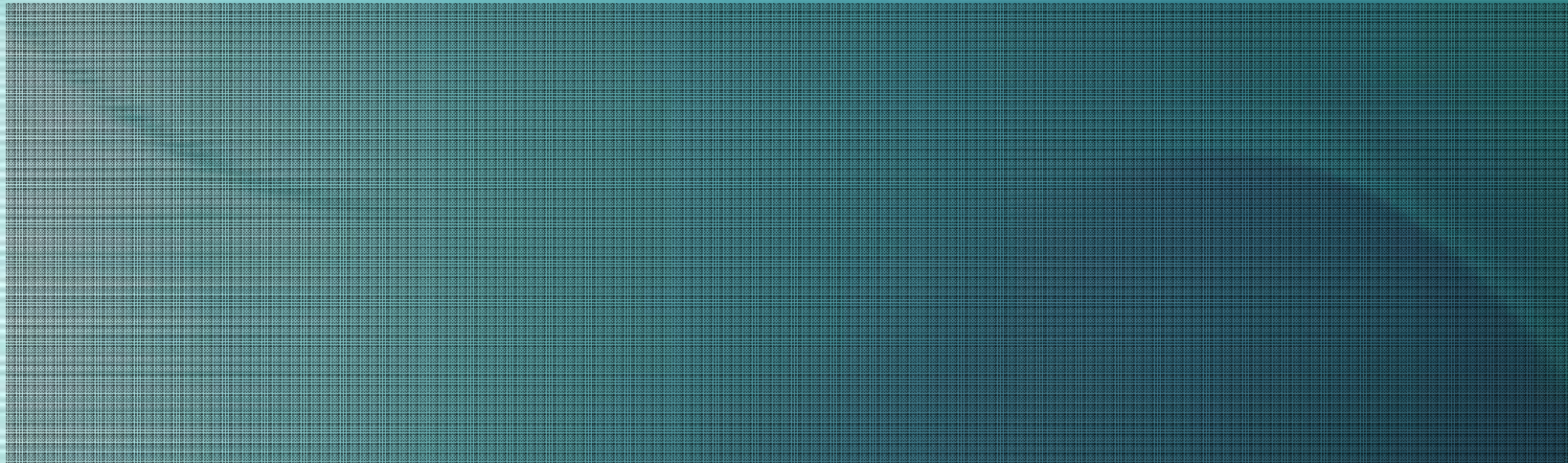
Deliverables:

- ❖ Comprehensive datasets for studying water and energy cycling during the extreme drought event
- ❖ **WEBS diagnostics for the drought event**
- ❖ Assessments of how well aspects of the extreme event are represented in the various datasets and their implications for the use of current model/assimilation/remote-sensing products in drought monitoring and study applications, and for the improvement of drought predictions
- ❖ **Joint publications**

Timeline

- ❄ 2006-2007 spring: Data acquisition, preliminary data processing and calculations
- ❄ 2007 summer: WEBS calculations
- ❄ 2007 autumn: Result analysis
- ❄ 2008: Joint publication summarizing results of the study

People:



Next Steps

- ❄ Need your participation!
- ❄ Data acquisition and processing, WEBS calculations – task-sharing and coordination

Summary of annual basin-average water and energy budgets for the SRB 1997-2002

Data\Para	Q	M	SWE	T2m	H	P	E	MC	N	HC	SH	RESQ	REST
NCEP	10.63	318.3	14.95	276.1	2.26	1.73	-2.09	0.51	-0.53	0.34	-0.15	-0.88	0.23
CMC	10.94	224.6	15.55	275.8	2.30	1.32	-1.32	0.34	-0.01	0.17	0.12	-0.34	0.21
CRCM	10.68	218.8	30.29	273.7	2.30	1.33	-1.05	0.28	-0.31	0.41	0.12	0.00	-0.01
ERA-40	10.85	382.3	15.09	276.6	2.27	1.22	-1.20	0.14	-0.36	0.14	0.13	-0.16	0.35
Reg Obs	10.64		23.84	276.2	2.31	1.20	-0.93		-0.12		0.21		
Globl Obs	10.81					1.00							
						1.07							
Average	10.76	286.0	19.9	275.7	2.29	1.30	-1.32	0.32	-0.27	0.27	0.09	-0.35	0.19
ERA Avg 79-98	10.84	383.2	15.2	276.0	2.27	1.21	-1.21	0.26	-0.38	0.07	0.14	-0.26	0.40
Average(MRB)	9.27	276.1	44.5	270.0	2.33	1.32	-1.14	0.55	-0.58	0.39	-0.01	-0.29	0.16
%Error	1.18	27.53	34.56	0.40	0.95	18.61	34.59	48.27	76.89	49.35	160		
%Error(MRB)	4.51	14.68	36.96	0.55	1.29	18.71	38.08	17.42	48.34	22.42	3475		
Data\Parameter	LP	QRS	QR	TOA SWD	TOA SWU	TOA LWU	BOA SWD	BOA LWU	BOA SWU	BOA LWD	Cloud cover	RESW	RESG
NCEP	0.46	0.56	-0.88	2.56	0.81	2.08	1.60	3.10	0.36	2.42	43	0.89	-0.15
CMC	0.36	0.46	-0.85	2.49	0.85	2.03	1.46	3.05	0.36	2.41	48	0.00	0.02
CRCM	0.35	0.43	-0.87	2.54	0.99	1.99	1.47	2.93	0.37	2.26	47	0.03	-0.03
ERA-40	0.33	0.53	-0.94	2.56	0.88	2.10	1.39	3.13	0.29	2.56	59	0.34	-0.07
Reg Obs		0.56					1.35	2.91	0.15	2.43	60		
Globl Obs		0.51	-0.87	2.55	0.95	1.95	1.40	3.14	0.31	2.57	68		
Average	0.38	0.51	-0.88	2.54	0.90	2.03	1.45	3.04	0.31	2.44	54	0.32	-0.06
ERA Avg79-98	0.33	0.53	-0.92	2.56	0.87	2.09	1.38	3.10	0.28	2.54	59	0.39	-0.06
Average(MRB)	0.25	0.36	-0.93	2.12	0.80	1.89	1.12	2.77	0.25	2.27	61	0.25	-0.03
%Error	15.47	10.51	3.88	1.15	8.19	3.06	6.11	3.02	24.74	4.27	16.16		
%Error(MRB)	17.03	13.66	5.80	1.13	9.70	3.11	8.78	3.18	21.46	5.16	12.31		

All water storage terms are in mm,
T2m in K, enthalpy (H) in 10⁹J/km²,
moisture fluxes in mm/day
energy fluxes in K/day.