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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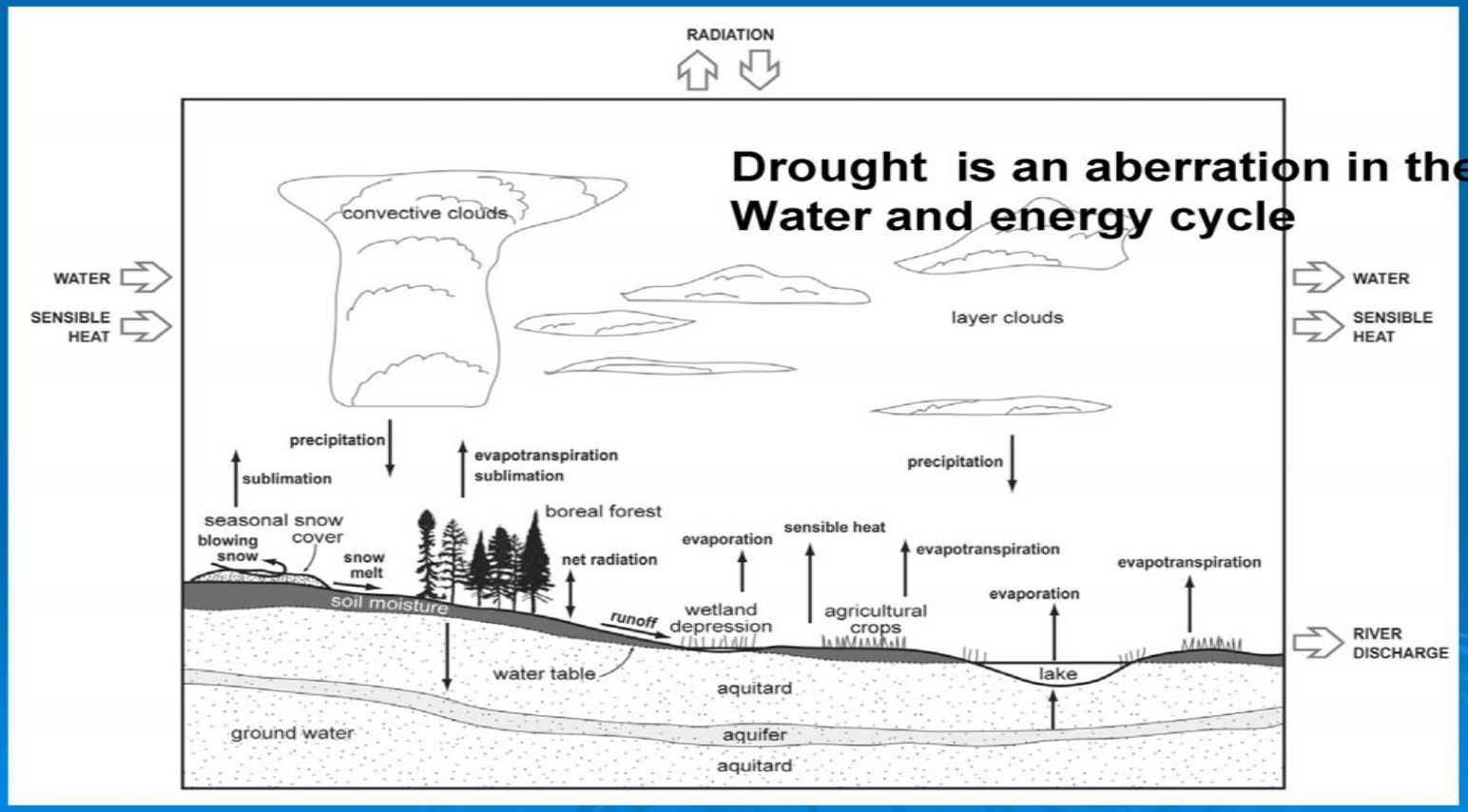
What do we want to do?

- 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



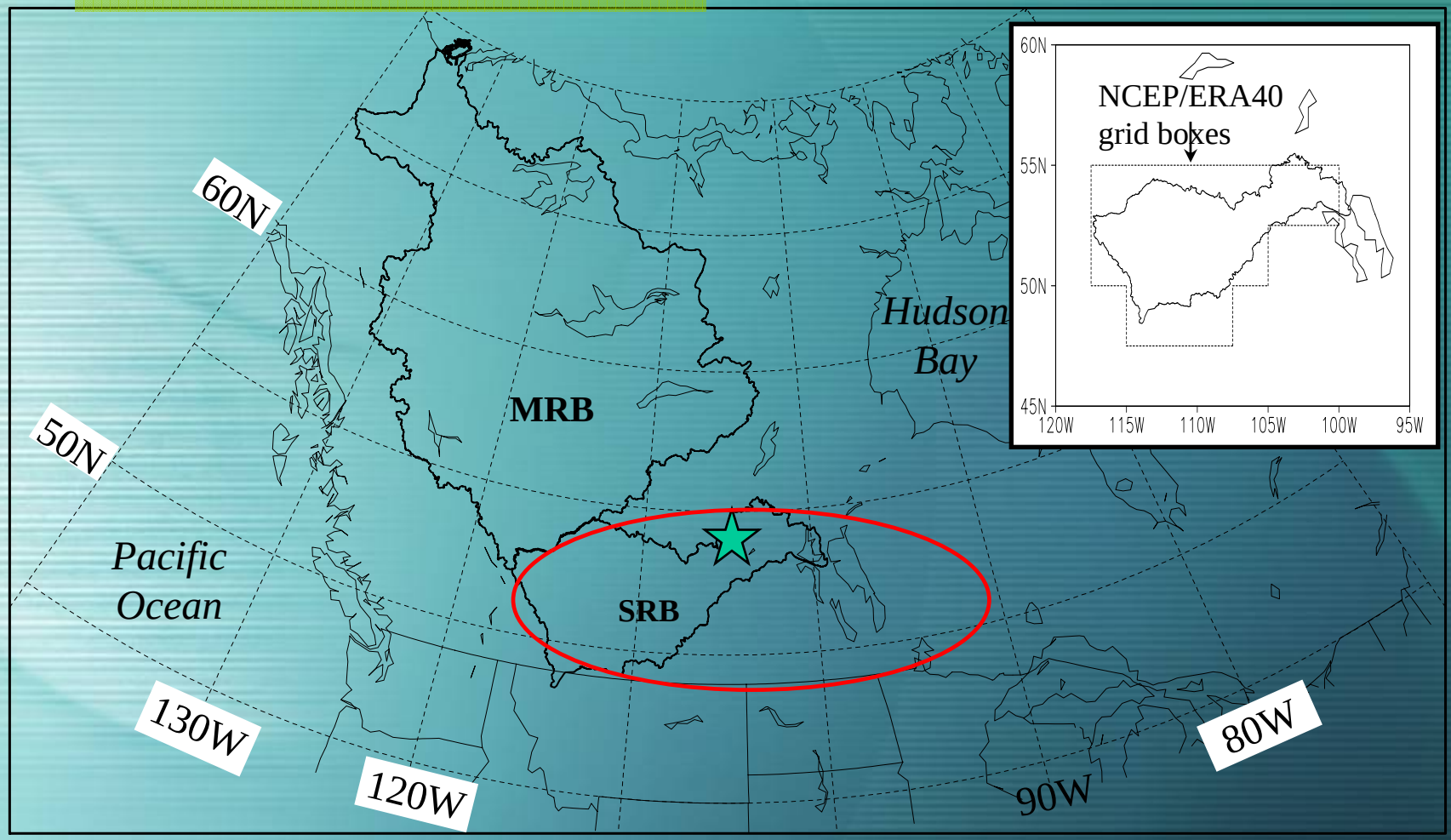
Why the 1999-2004 Canadian Prairie Drought Case?

- 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!

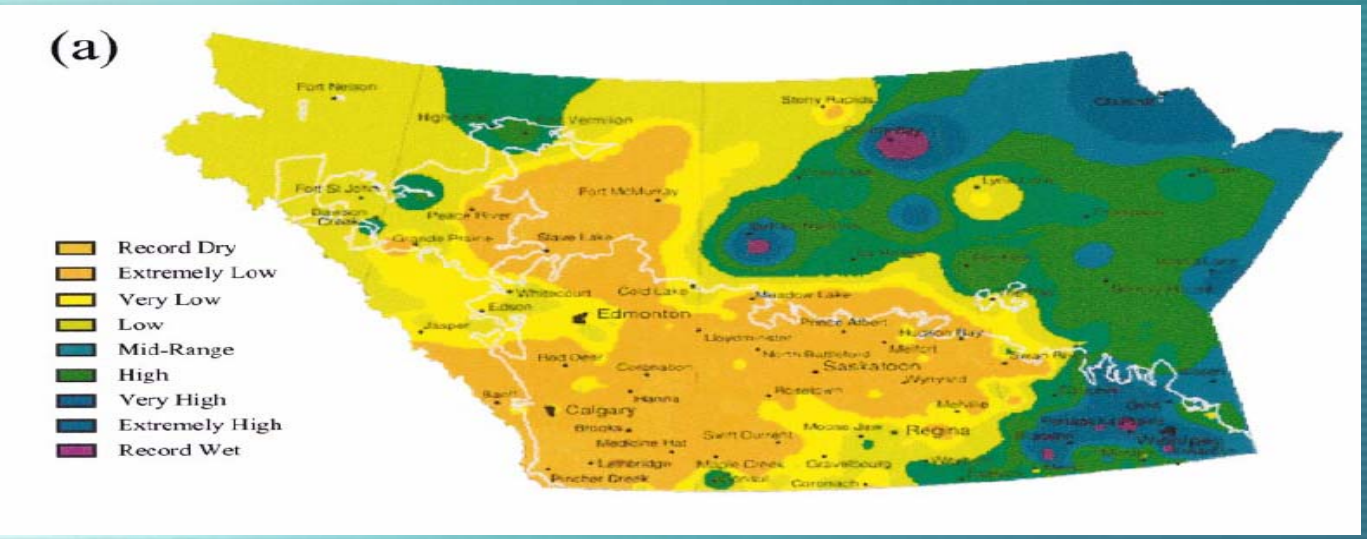
Southern Saskatchewan, April 2002

Huge impacts on:

- society
- economy

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

Precipitation Anomalies



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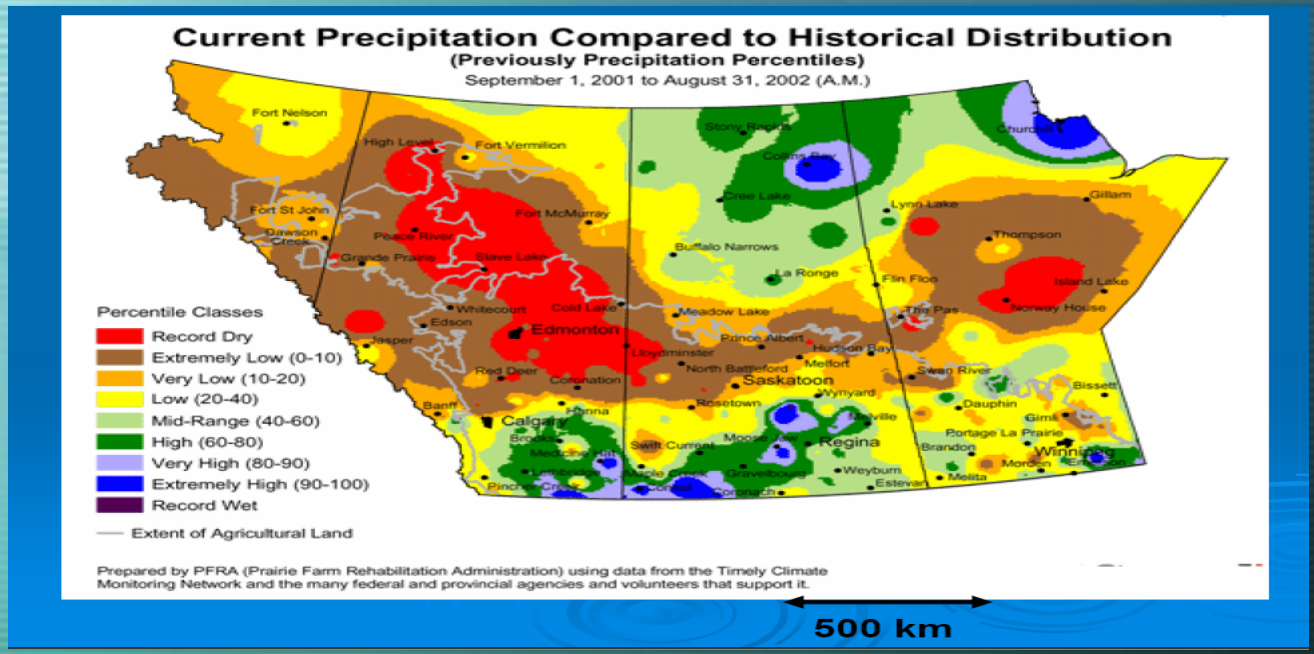

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Water and Energy Budgets

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

$$Cv \frac{\partial \{Ts\}}{\partial t} = QRS - LE - SH + G$$

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) BERMS (L)	280 km Sites	1983 Jul - 2001 Jun 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

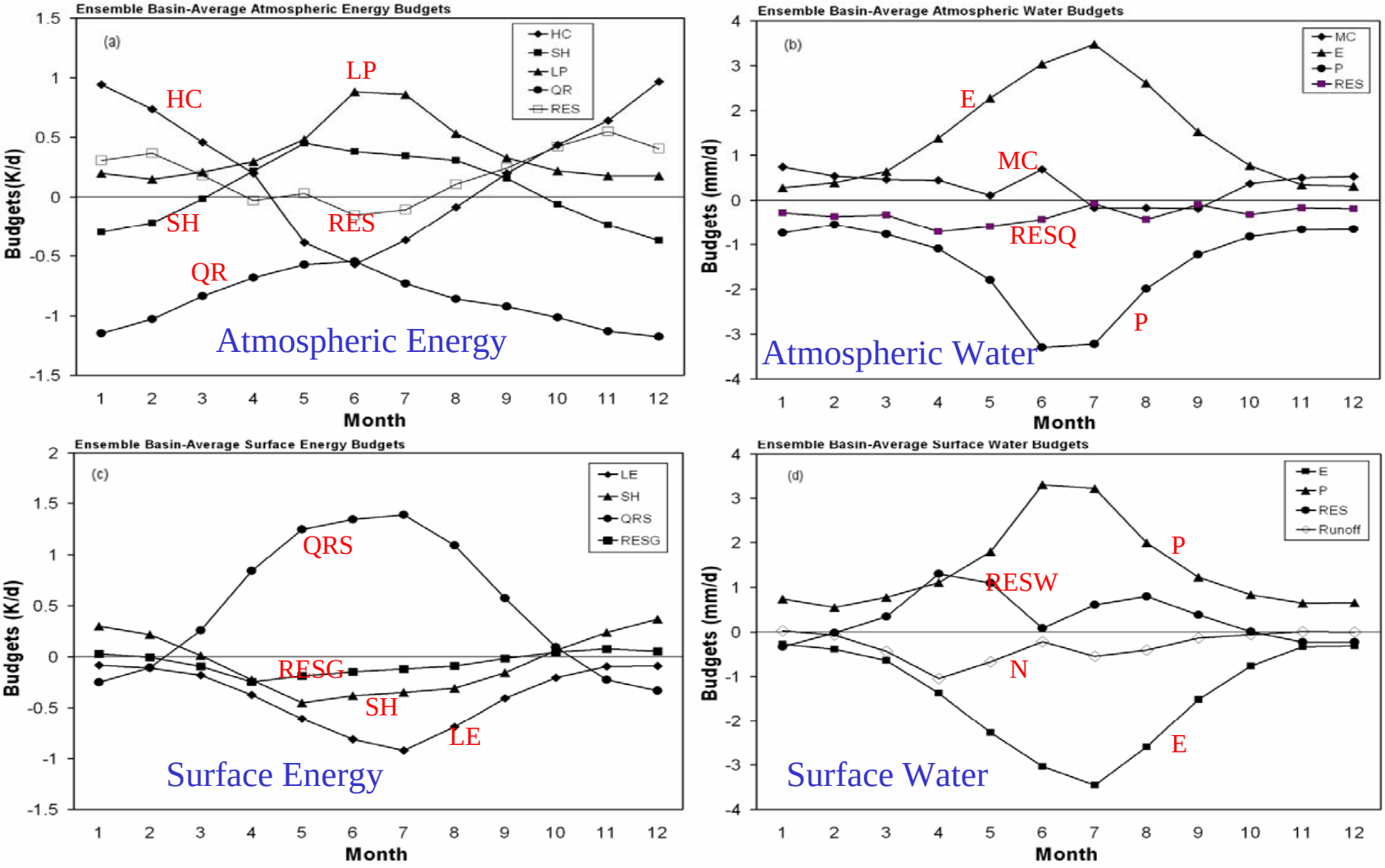
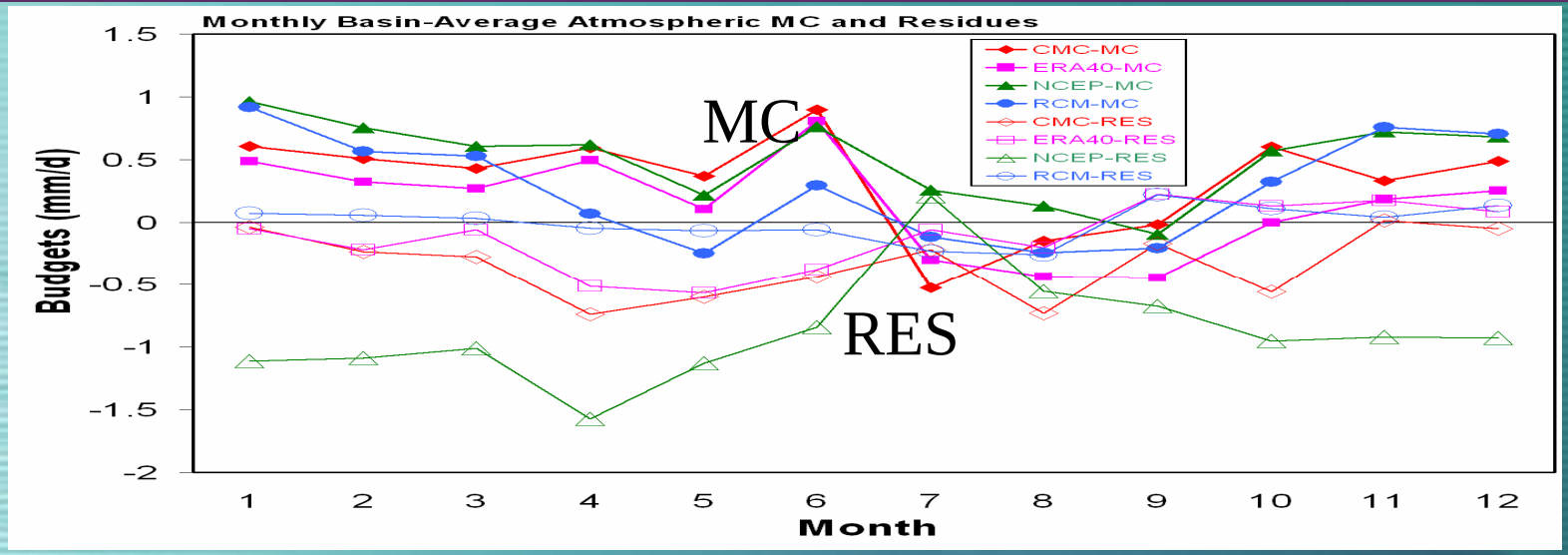
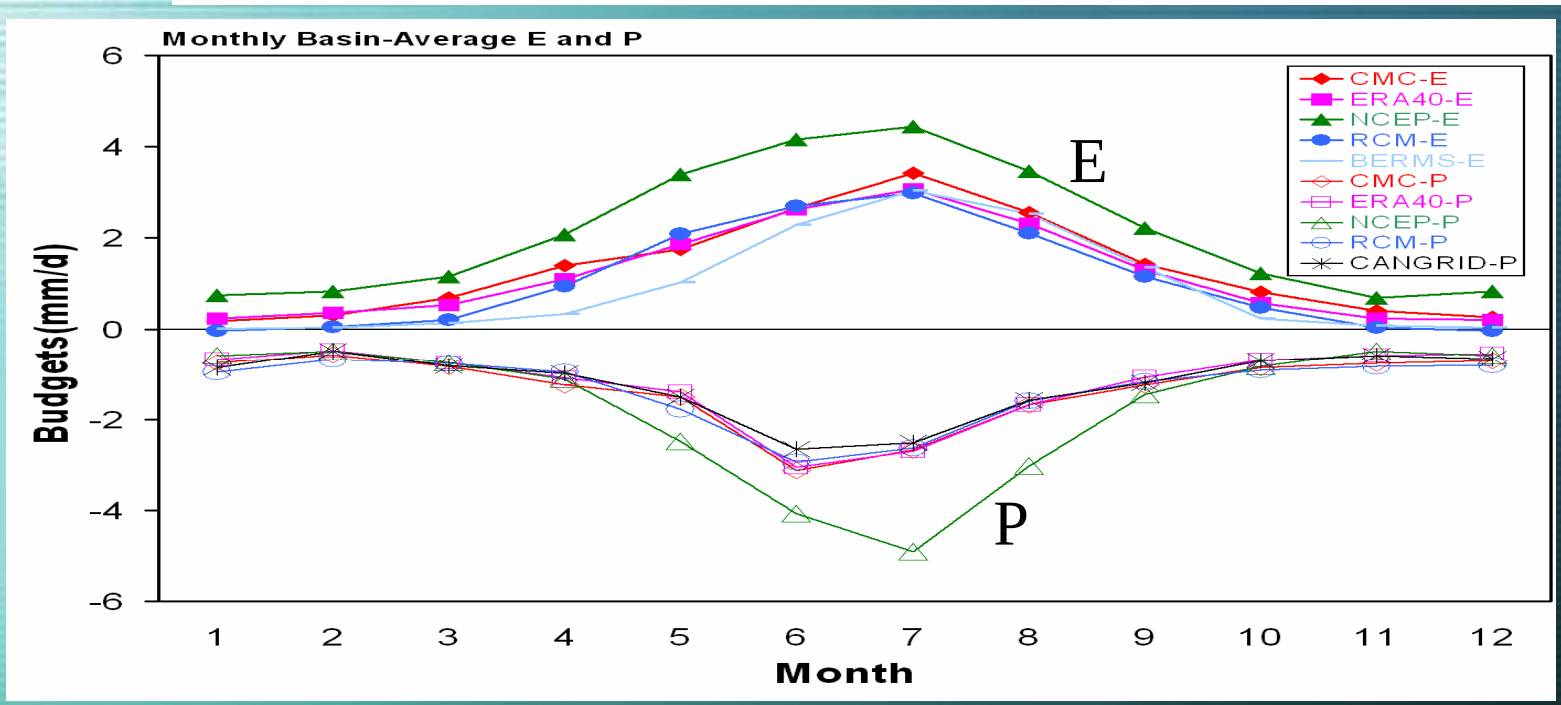


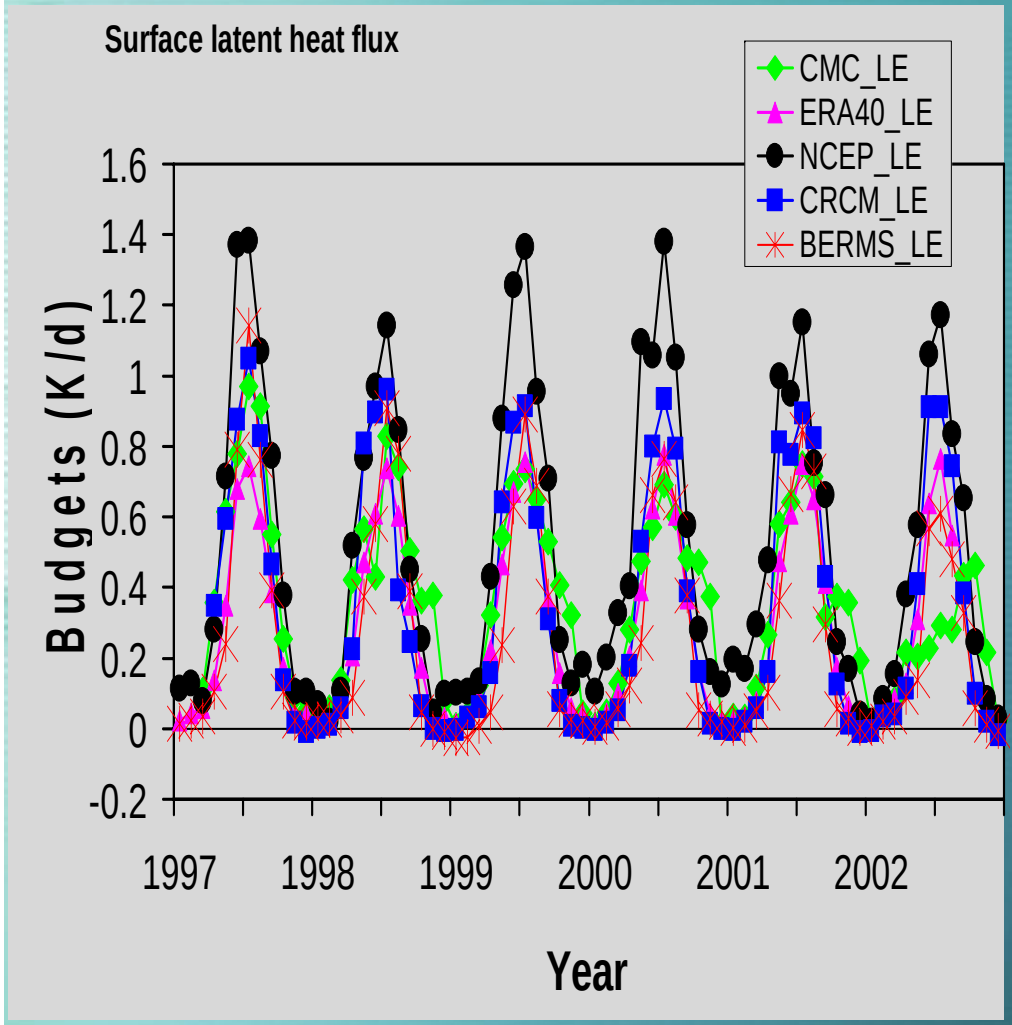
Figure 3. Mean annual cycle of ensemble (NCEP-R2, ERA-40, CMC and CRCM) basin-average budgets for (a) atmospheric energy, (b) atmospheric water, (c) surface energy and (d) surface energy.

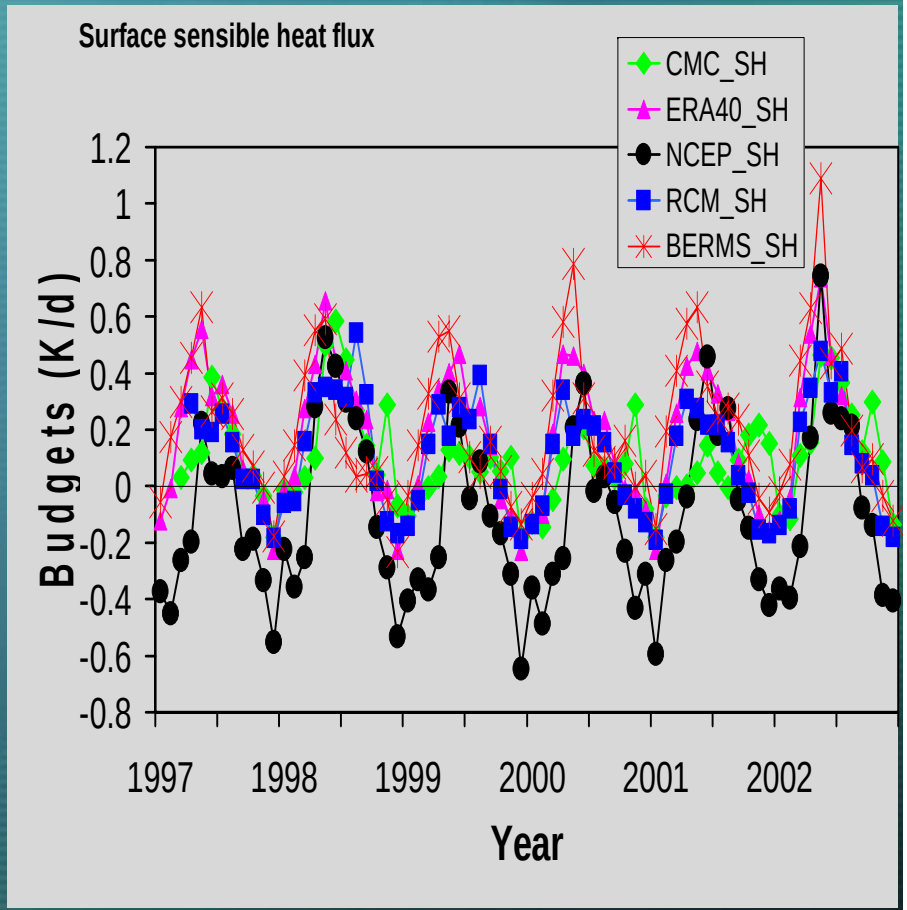
Variability among Budgets Assessments - Annual Cycles of Atmospheric Water Budgets



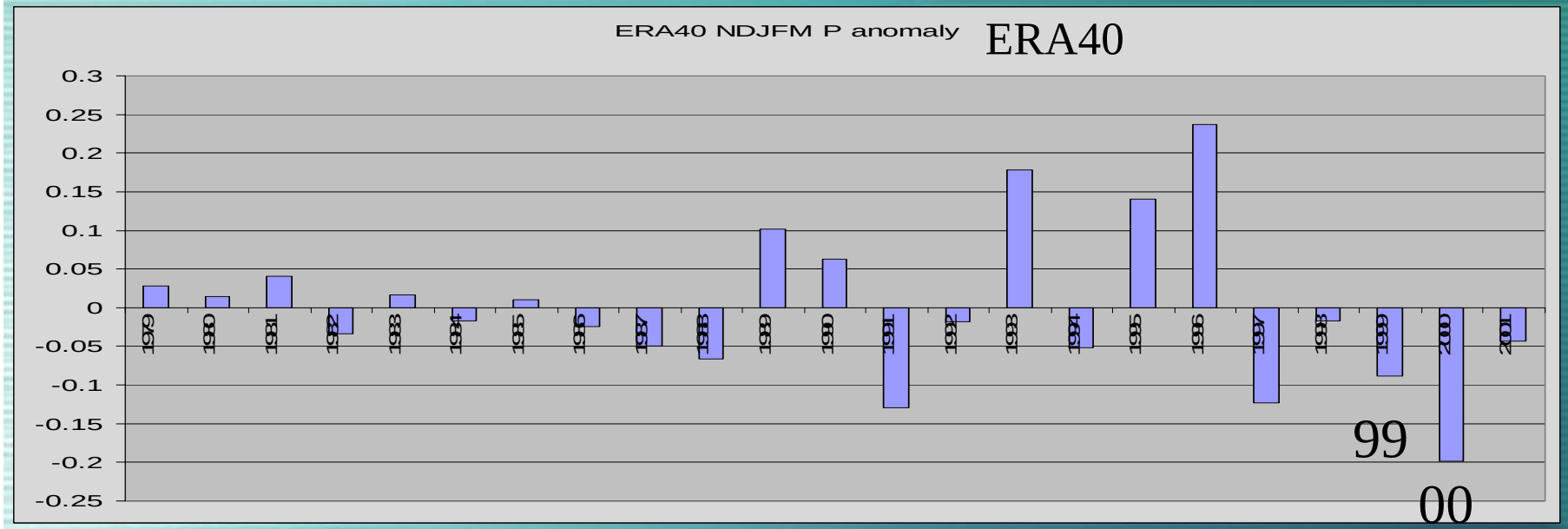


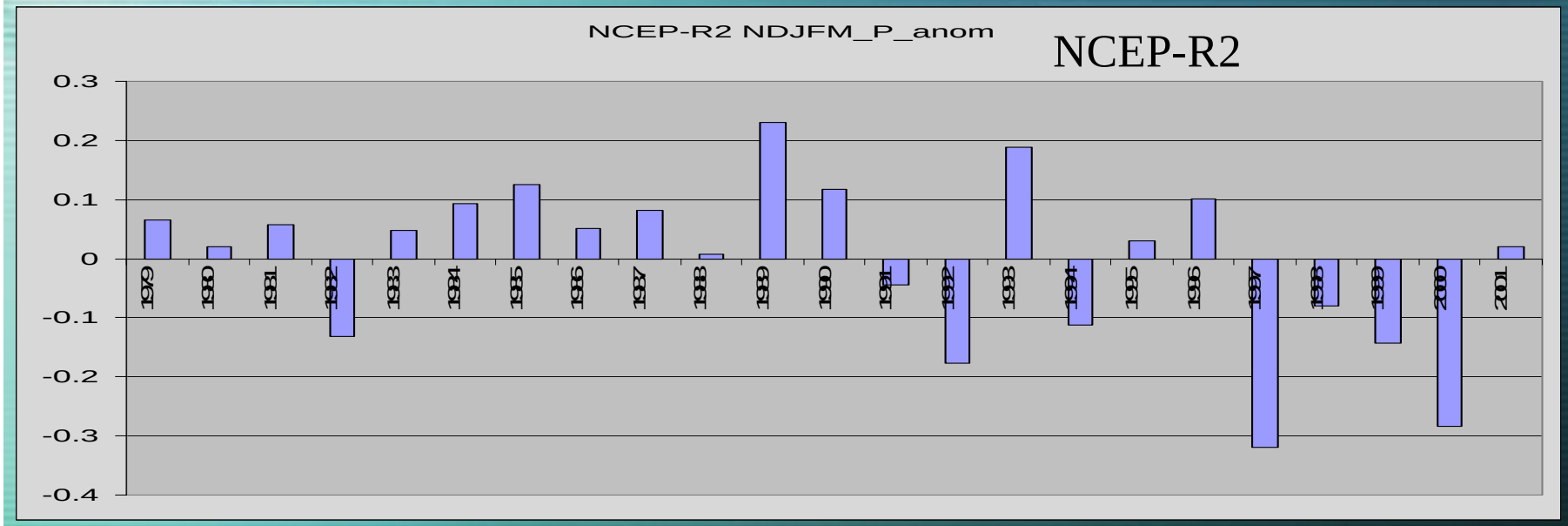
Variability among Budgets Estimates ….cont…. Surface SH and LE near BERMS Site



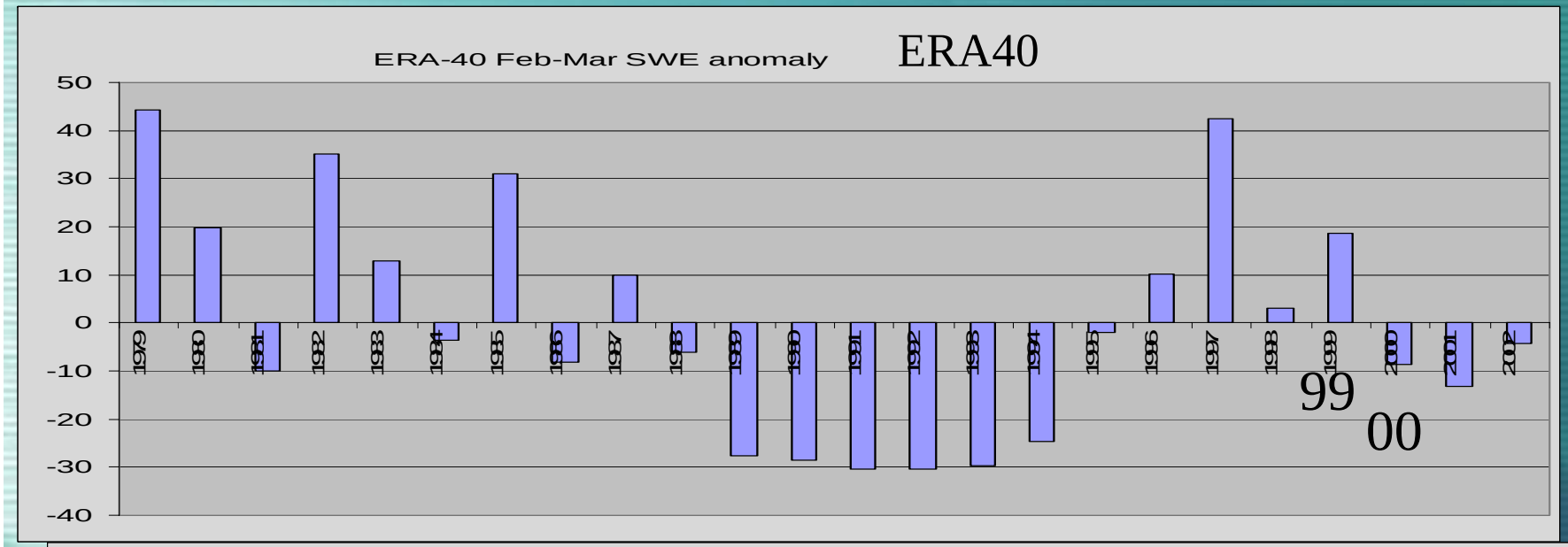


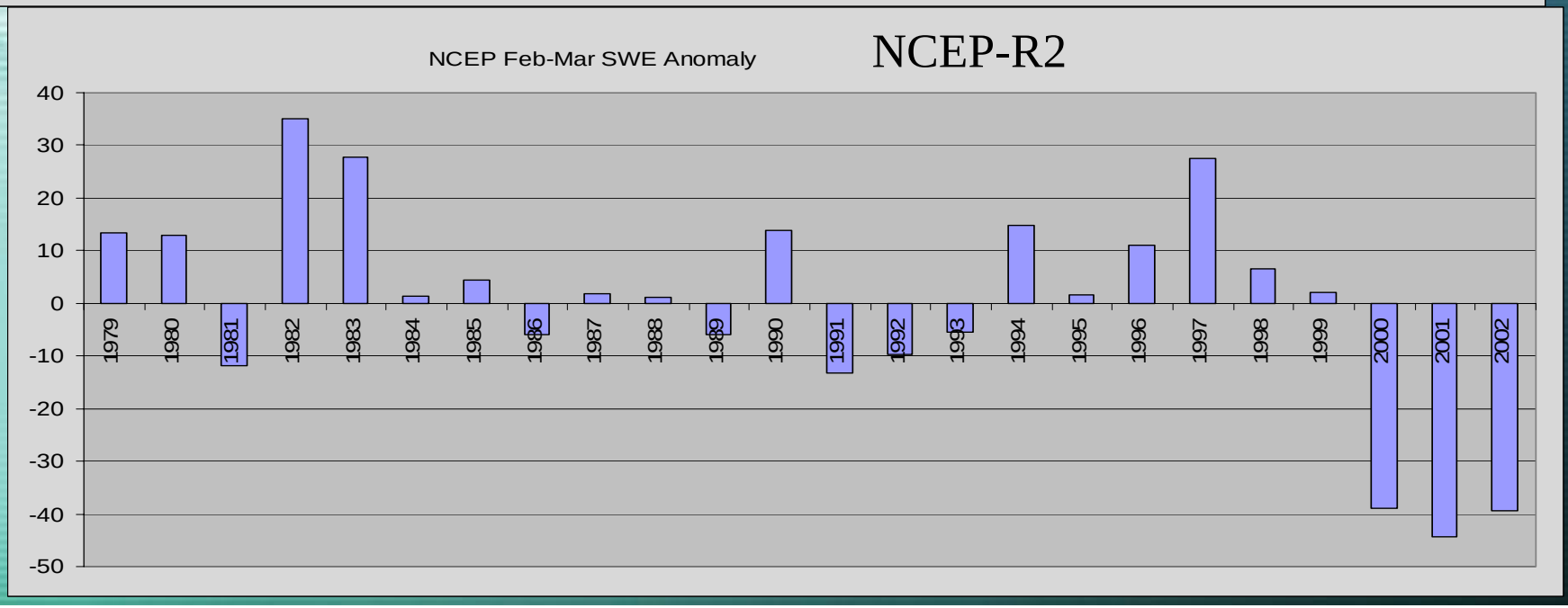
Variability among Budgets Estimates ….cont….NDJFM P anomalies (mm/d)



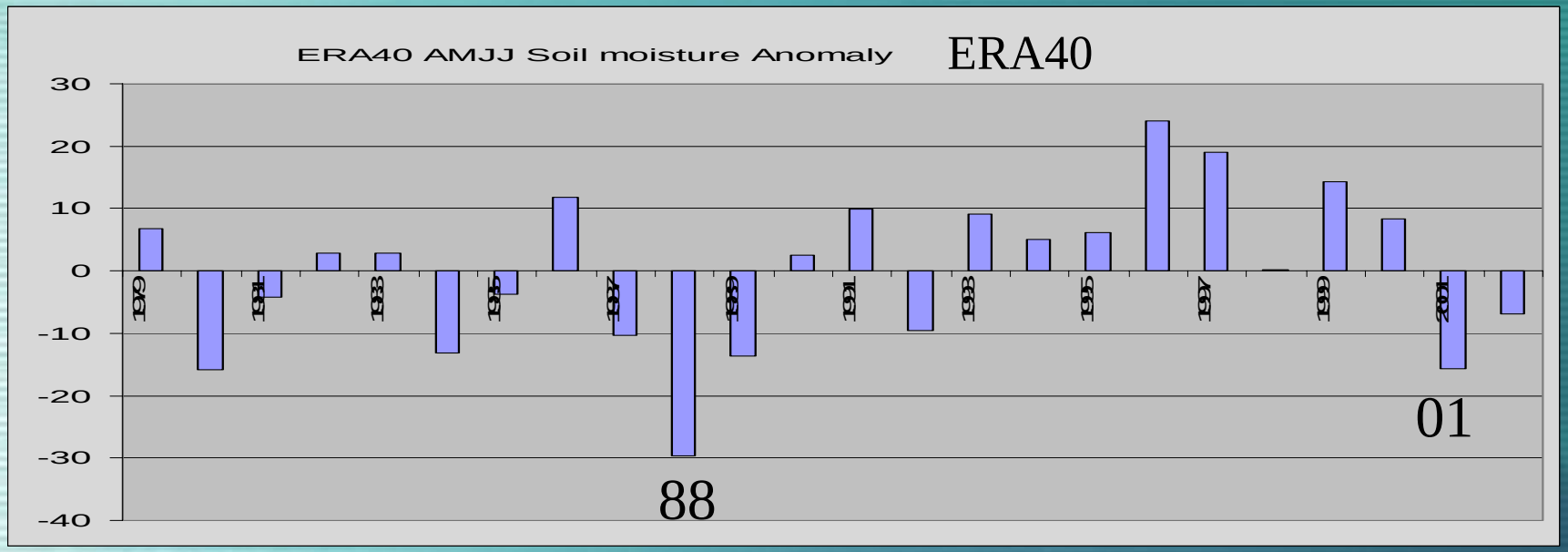


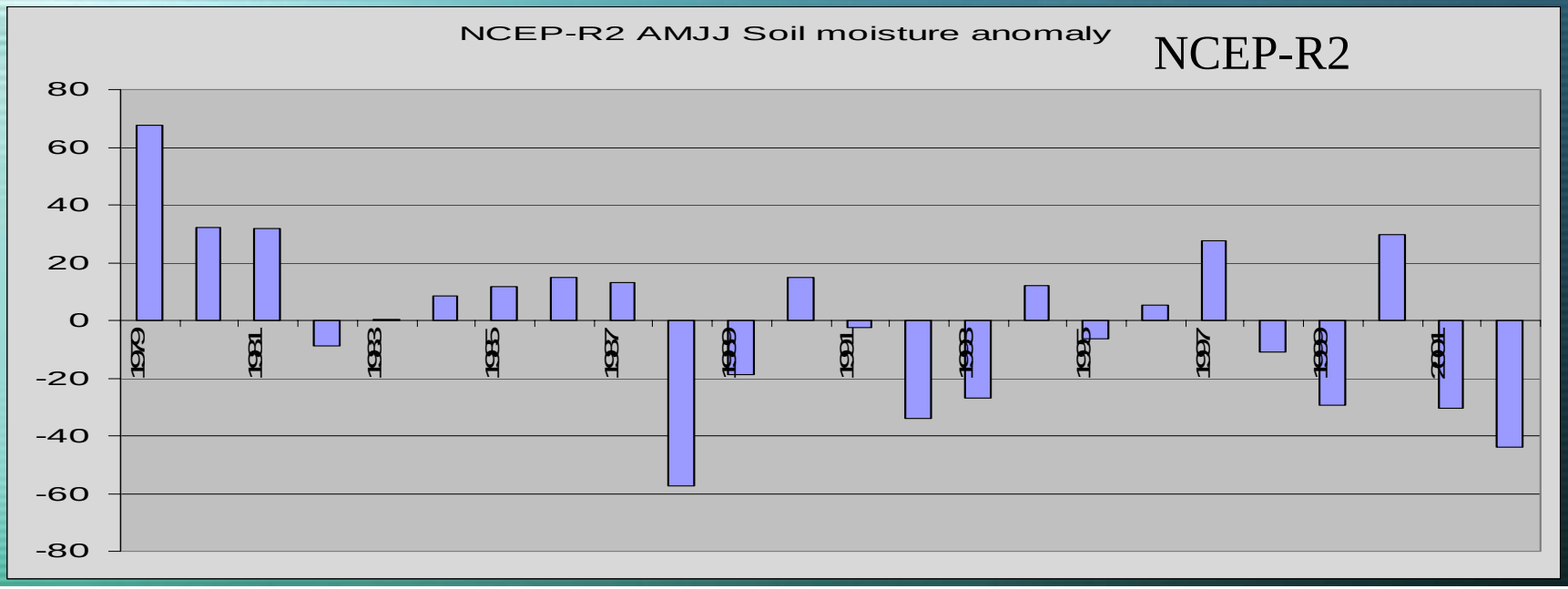
Variability among Budgets Estimates ….cont….NDJFM SWE Anomalies (mm)





Variability among Budgets Estimates ….cont….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 10^9J/km2,
moisture fluxes in mm/day
energy fluxes in K/day.