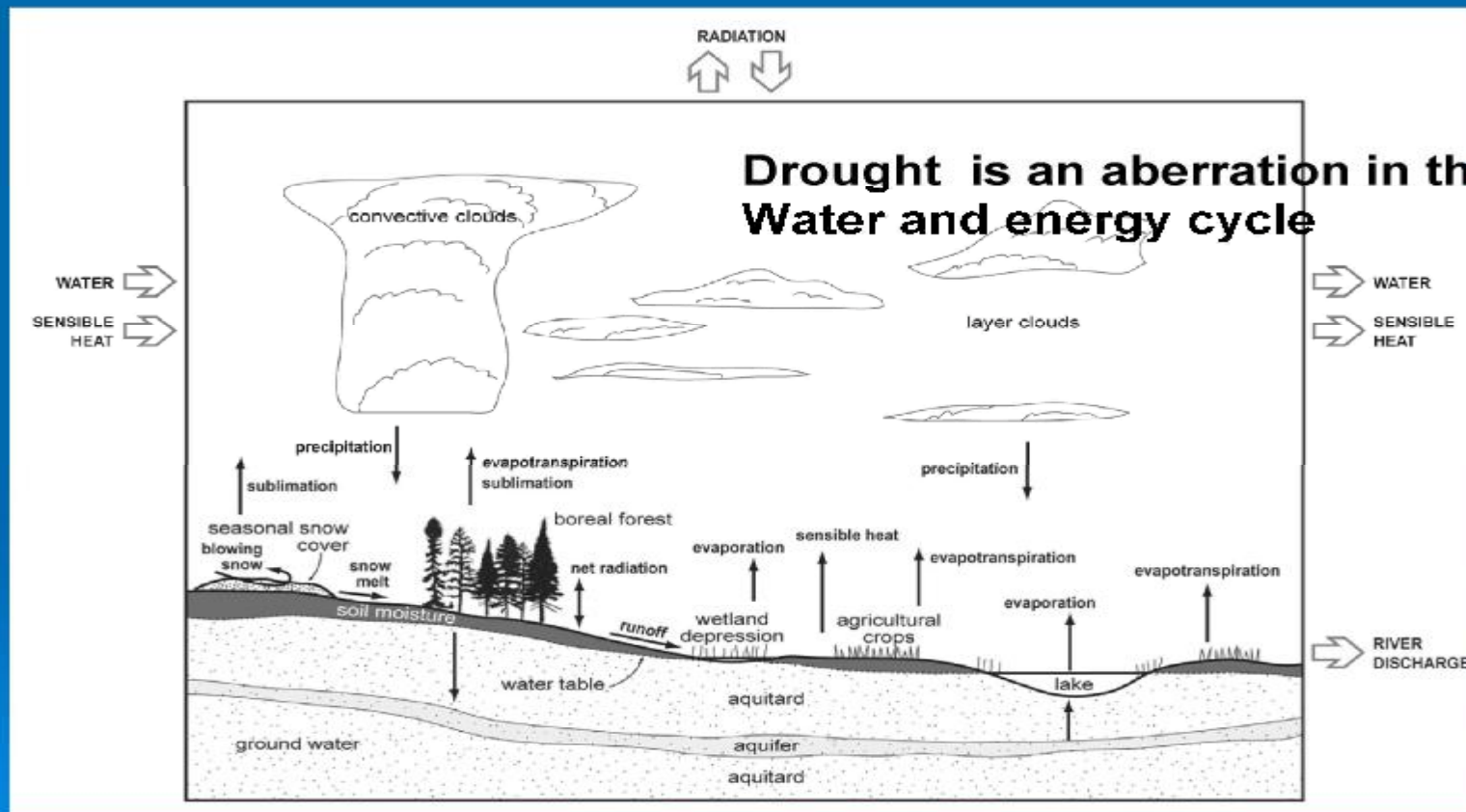


The DRI Water and Energy Budget Study (DRI-WEBS)

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Why DRI-WEBS?

WATER AND ENERGY CYCLING



Objectives of DRI-WEBS

- To evaluate the surface and atmospheric water and energy budgets for the Canadian Prairie region, and their deviations from the mean state during drought periods, by using various source datasets
- To assess the credentials of the various datasets in representing the budgets and to explore implications of the assessment results to the use of current model/assimilation/remote-sensing products in drought monitoring and research applications, and to the improvement of drought predictions

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
NARR (R)	32 km	1979 Jan - Current
NCEP-R2 (G)	2.5 deg	1979 Jan - Current
ERA-40 (G)	2.5 deg	1957 Sep - 2002 Aug

Expected Outcomes

- T Comprehensive datasets for studying water and energy cycling in the Prairies
- T Long-term and drought-period climatologies of water and energy budgets for the Prairie region
- T Assessments of how well aspects of the budgets 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
- T Publications summarizing the results

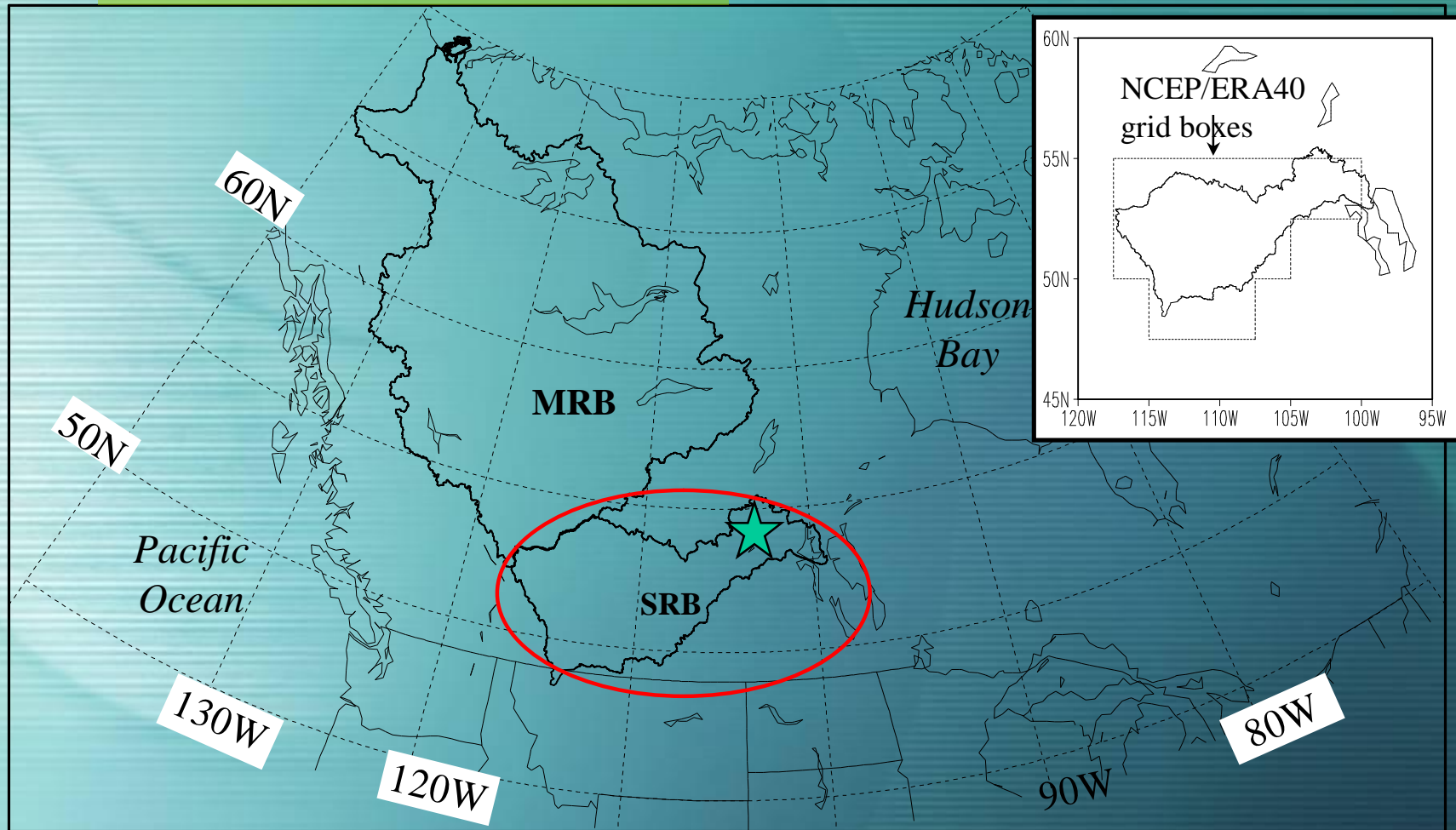
2006 Achievements

- T Completion of initial data acquisition and processing
- T Completed assessments of mean budgets for the SRB
- T Paper summarizing some of the results to be appeared in the CEOP special issue of JMSJ (Feb 07)
- T Initiated networking for a DRI-wide WEBS effort
- T Started analysis of temporal-spatial variability of budgets

Initial Assessment Period and Focuses:

- Study period: 1997-2002 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, NARR and available observations

The Canadian Prairies



BERMS CEOP reference sites (star)

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.

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

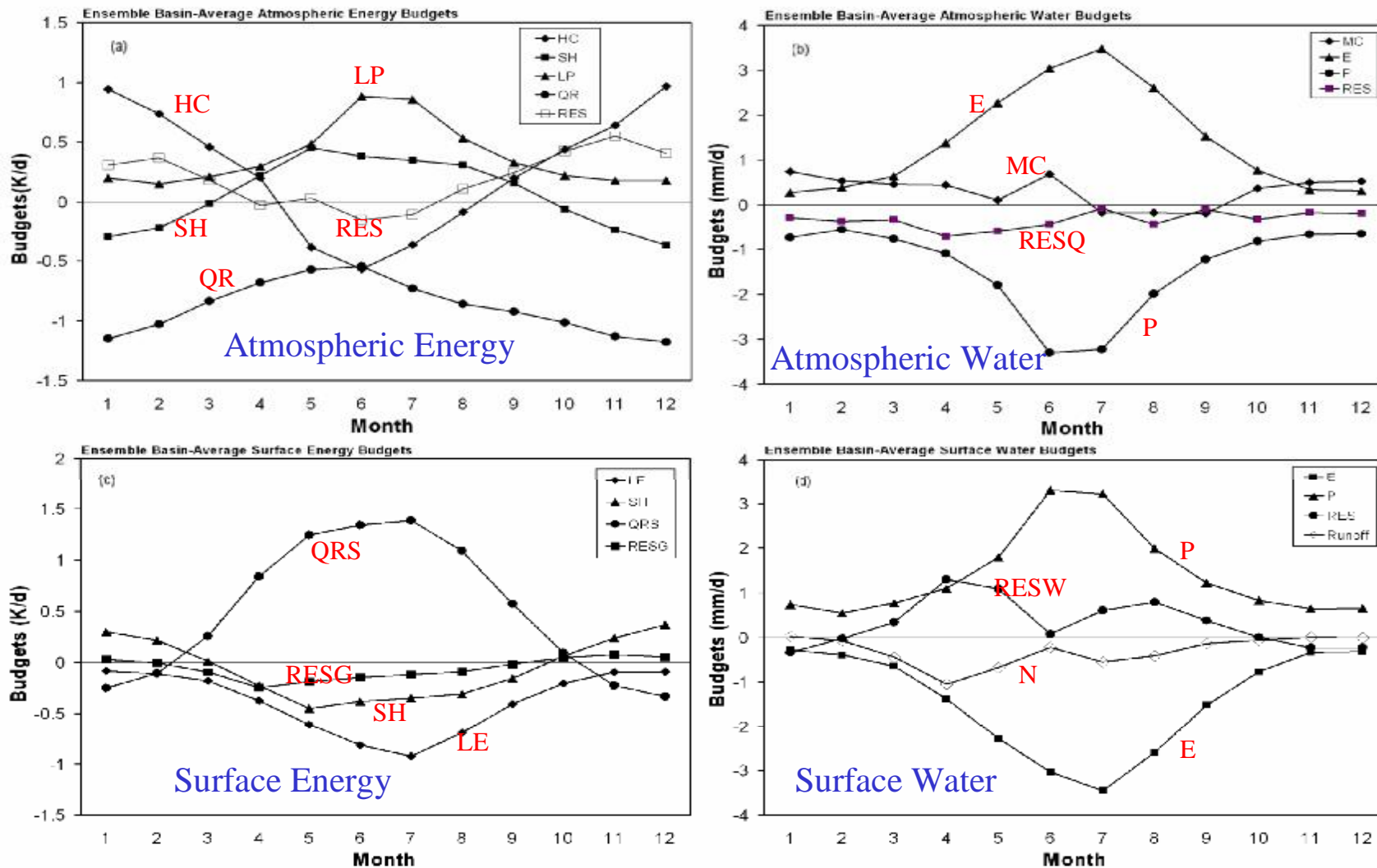
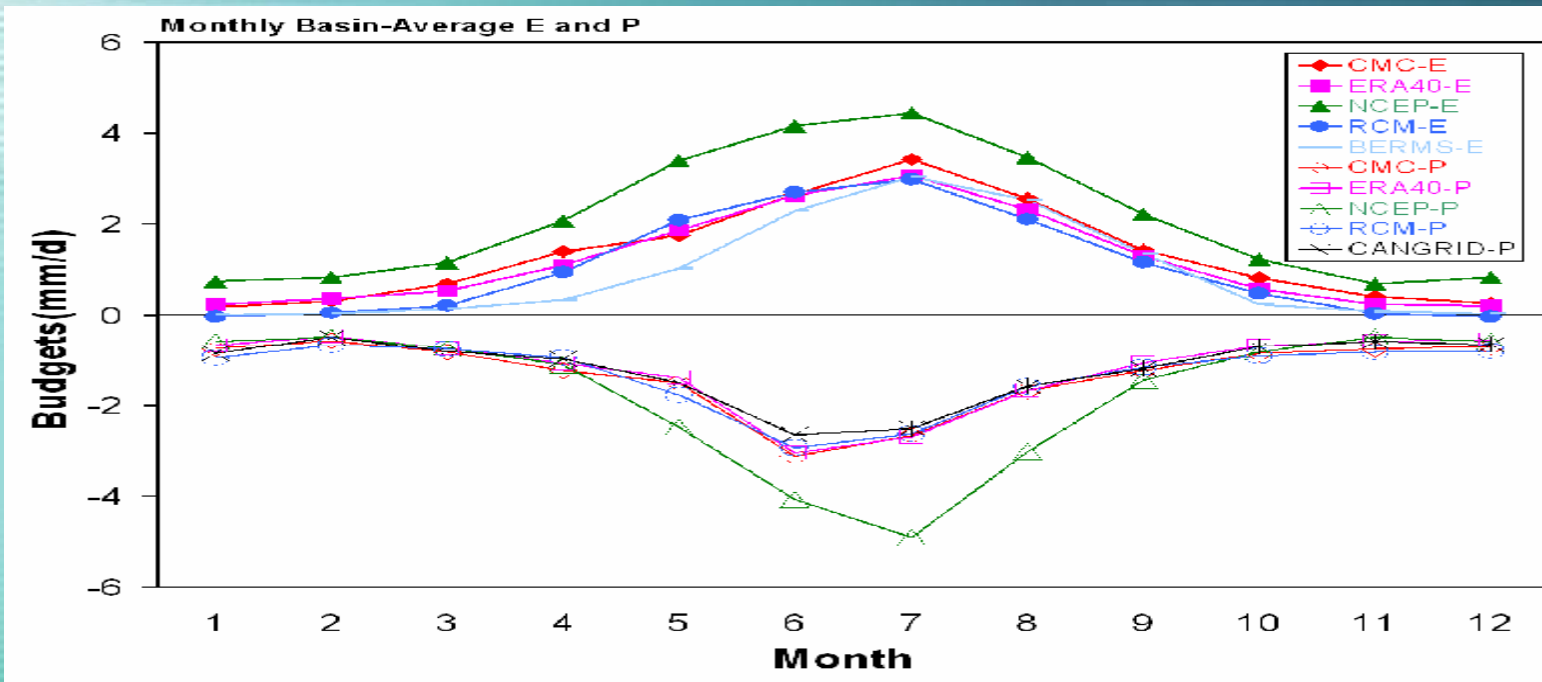
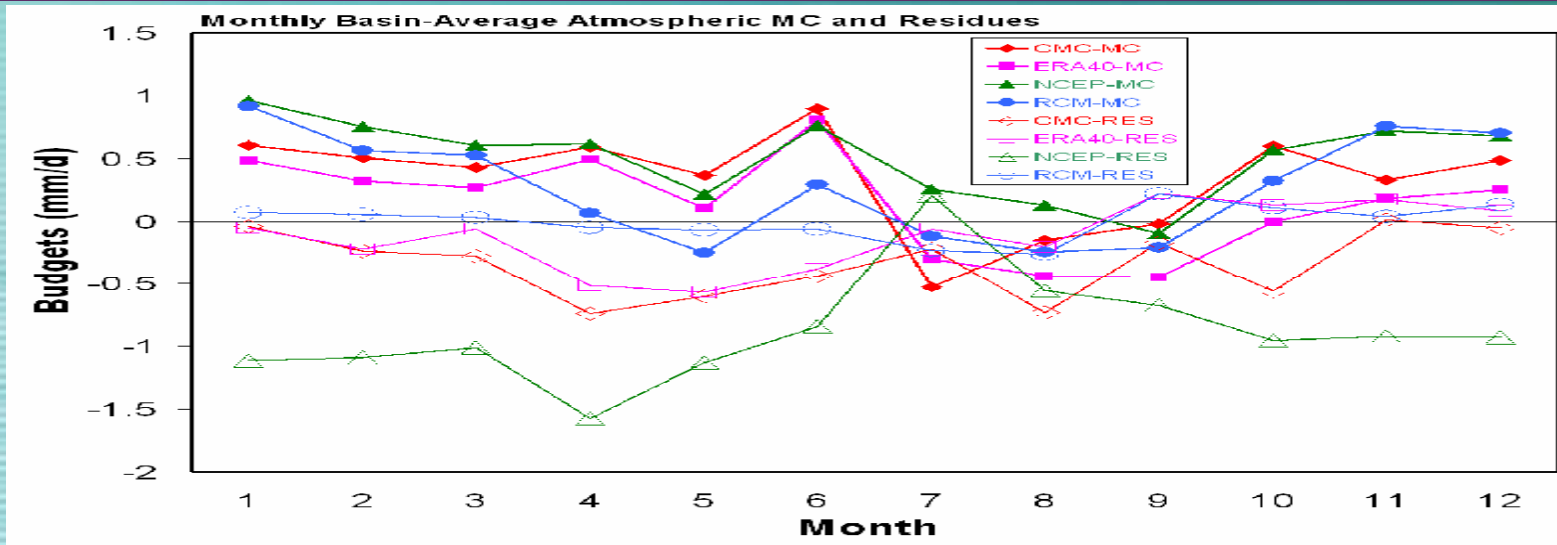
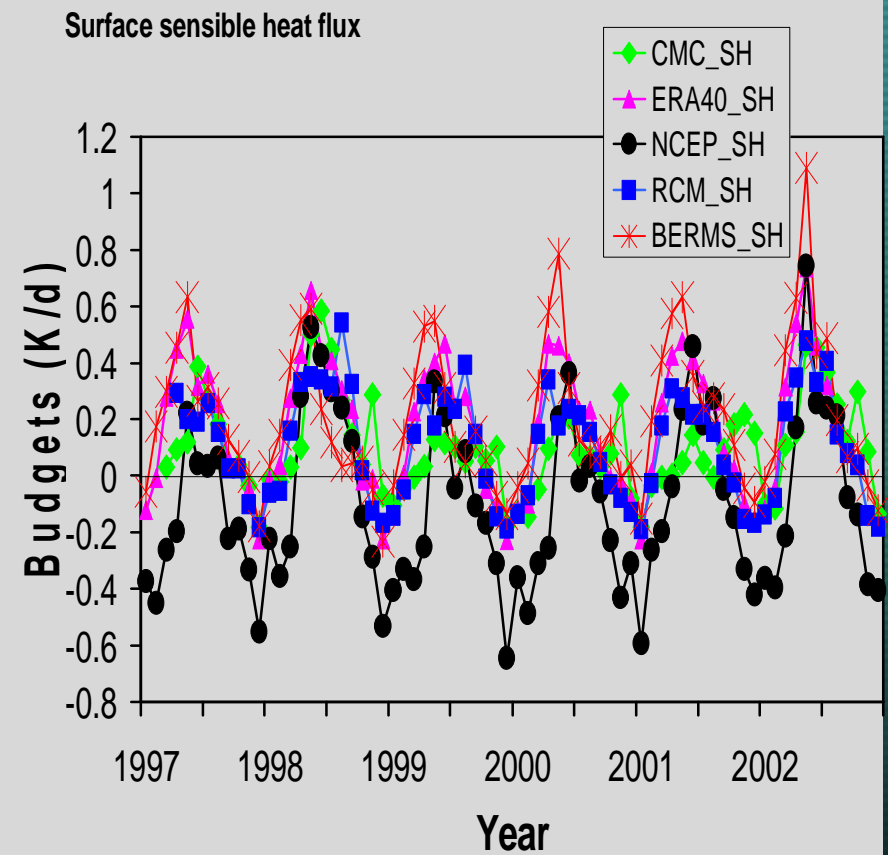
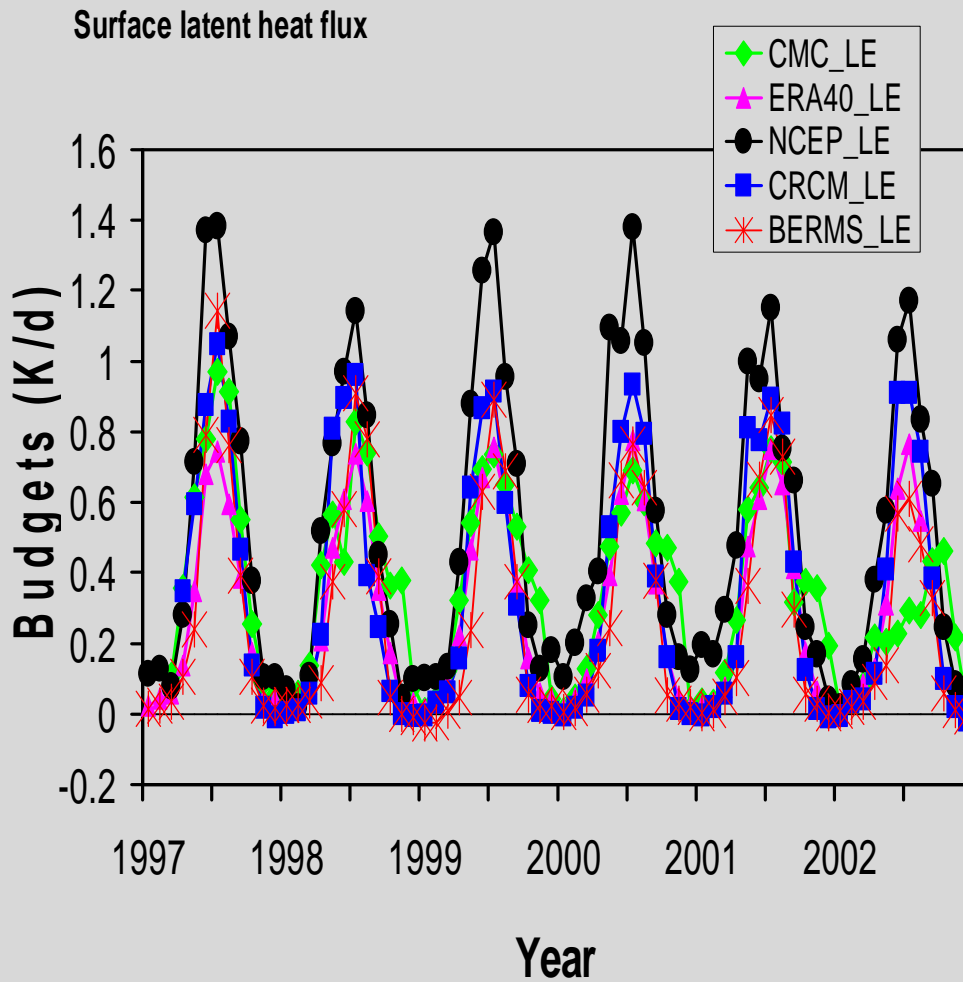


Figure 3. Mean annual cycle of ensemble (NCEP-R2, ERA-40, CMC and CRCM) basin-average budgets for (a) atmospheric energy, (b) atmospheric water, (c) surface energy and (d) surface water.

Variability among Budgets Assessments - Annual Cycles of Atmospheric Water Budgets



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

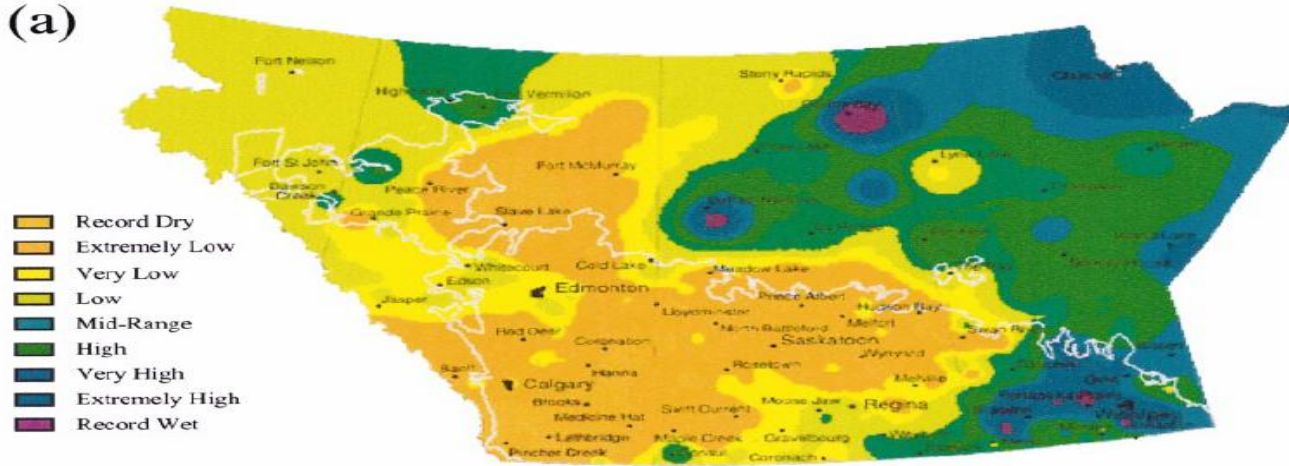


Summary of mean budget results

- T Some estimates of budget components compare well to obs but residuals in the balance are often as large as the budget components in all datasets
- T Budgets from analysis datasets based on more “modern” assimilation systems (CMC, NARR, ERA-40) compared the best to obs
- T NCEP-R2 over-predicts warm-season water cycle for the region
- T Strong cold bias in CRCM affects its capability to accurately simulate drought in the region
- T Water closure problem

Drought is a highly variable hydrometeorological phenomenon

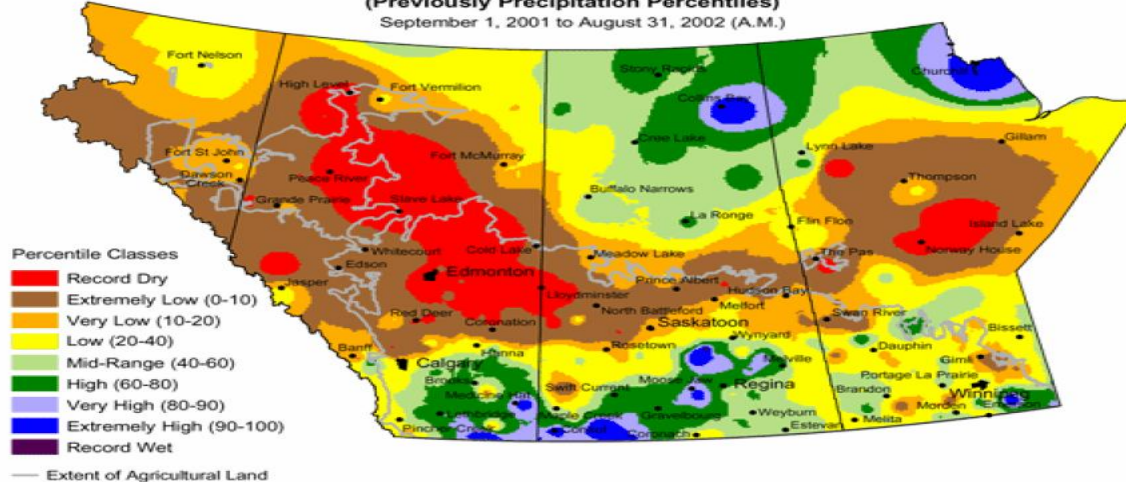
(a)



00-01

Current Precipitation Compared to Historical Distribution

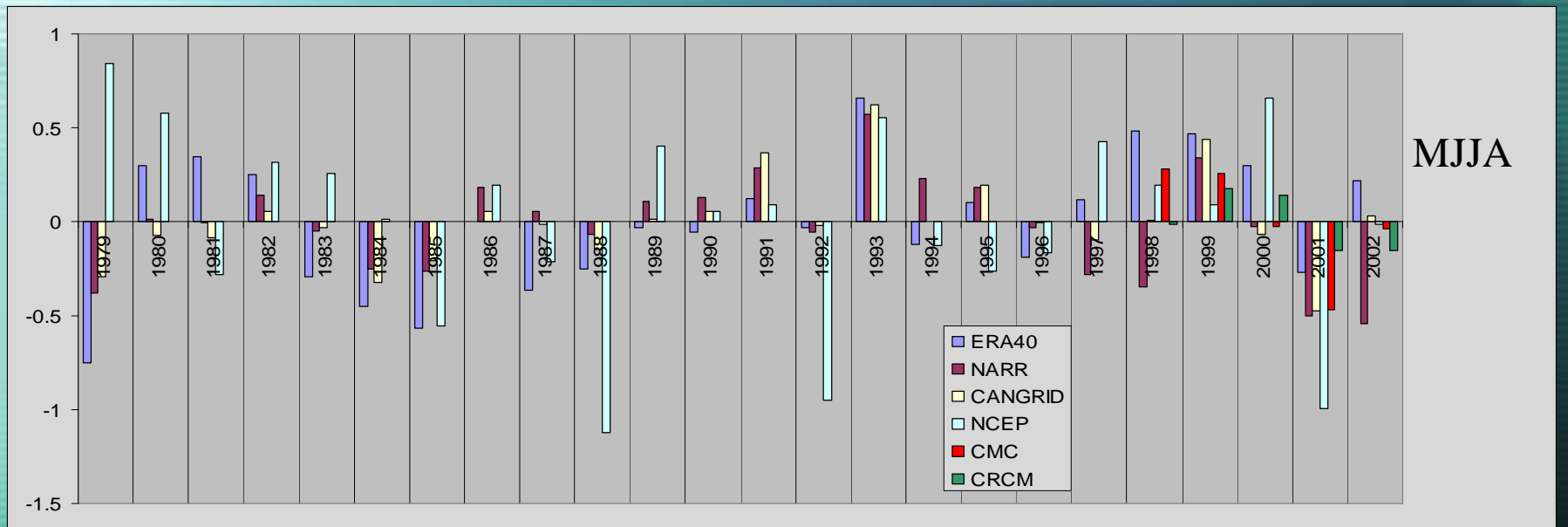
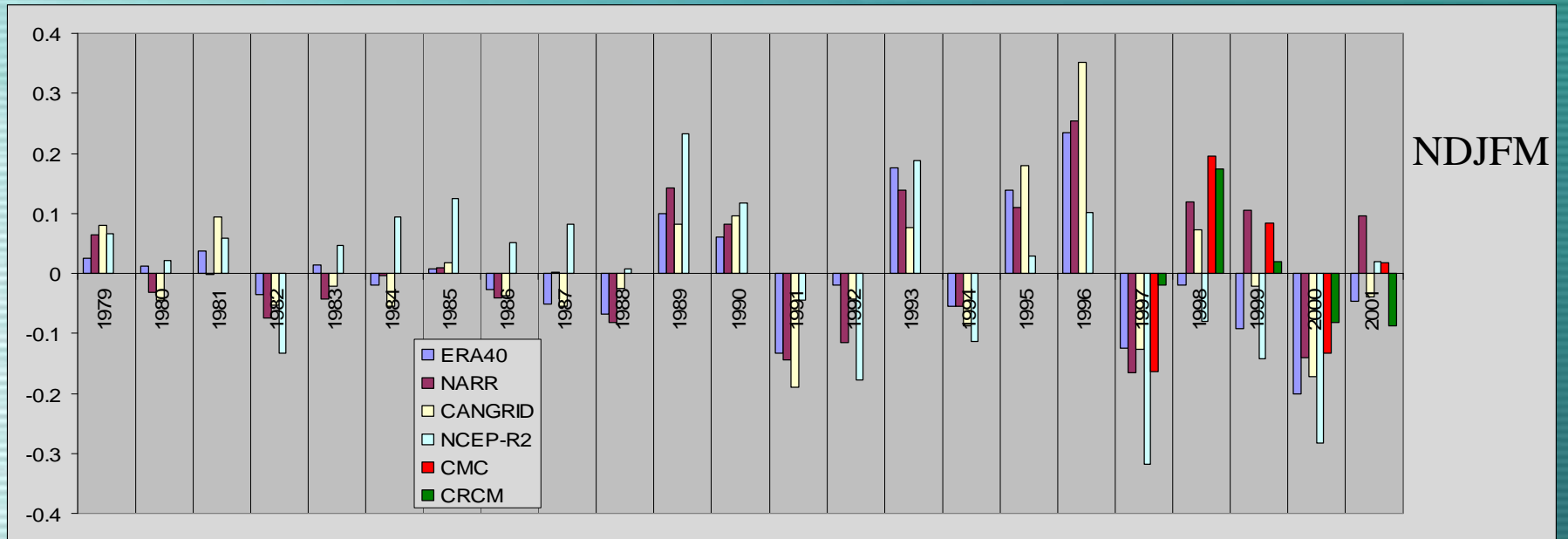
(Previously Precipitation Percentiles)
September 1, 2001 to August 31, 2002 (A.M.)



01-02

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.

Variability among Budgets Estimates - Seasonal P anomaly Timeseries



Issues

- T Data acquisition and processing, and the WEBS calculations involve tremendous efforts
- T Need “smart” DRI data servers
- T Water closure problem
- T Need your participation

Issues ...Additional Datasets:

T DRI-acquired or developed datasets

T NLDA S-E, GLDAS

T new CRCM (with CLASS-3)

T other model data (through GEWEX and CEOP)

T CEOP satellite data ...

Plan for 2007

- T To complete the analysis of spatial and temporal variability of budgets
- T To complete drought-period budget analysis
- T Improve surface water budget closure through coordinated collaborations within the network
- T Linkage with similar international efforts
- T Start the study of mechanisms that work behind the numbers