Towards A Better Understanding and Improved Predictions of Hydroclimate Extremes in the Canadian Prairies

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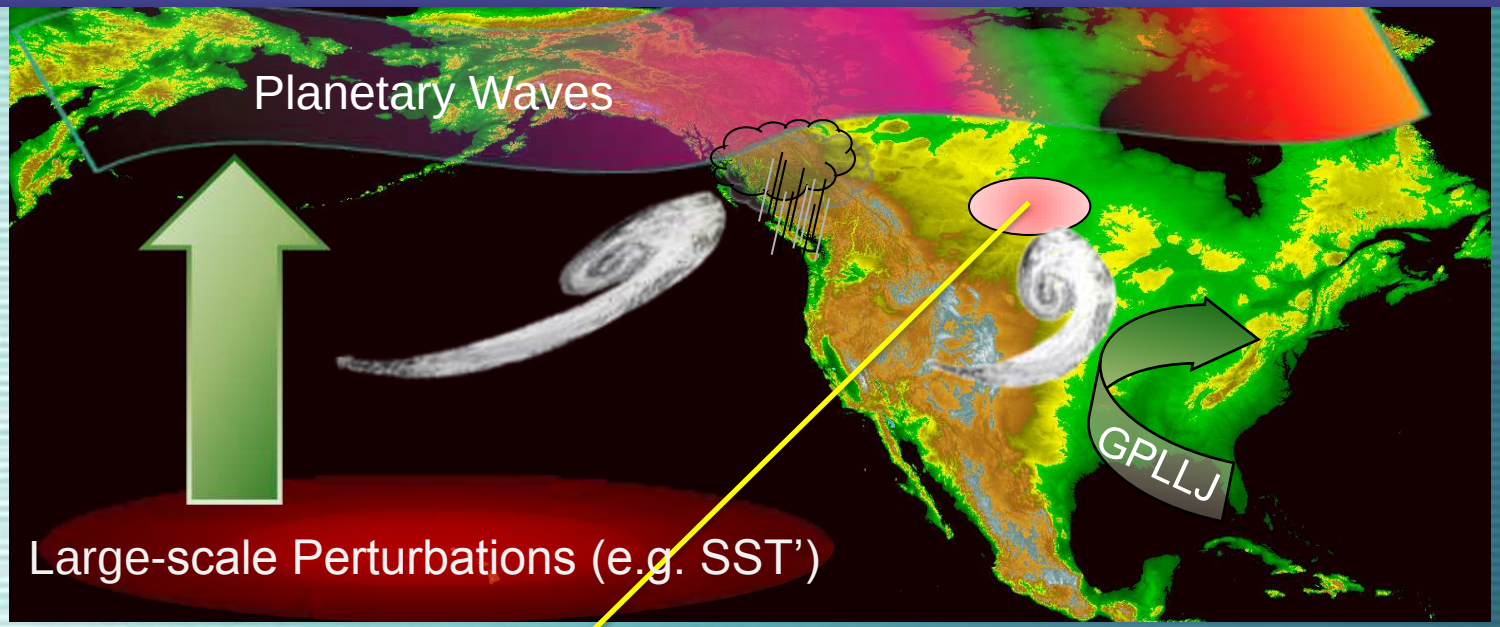
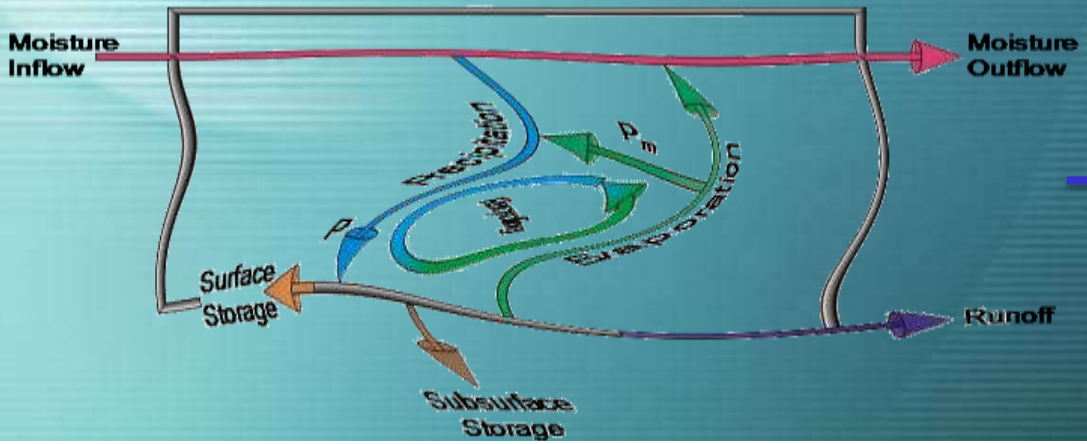
A better understanding of causal mechanisms that govern the regional hydroclimate response to large-scale forcings is essential for improving their predictions



Disturbed Regional Water Cycle



Drought?

Pluvial?

Large separation of scales between the forcings and the regional water cycling processes, and the complex topographic settings of the Prairies make it an extremely challenging problem

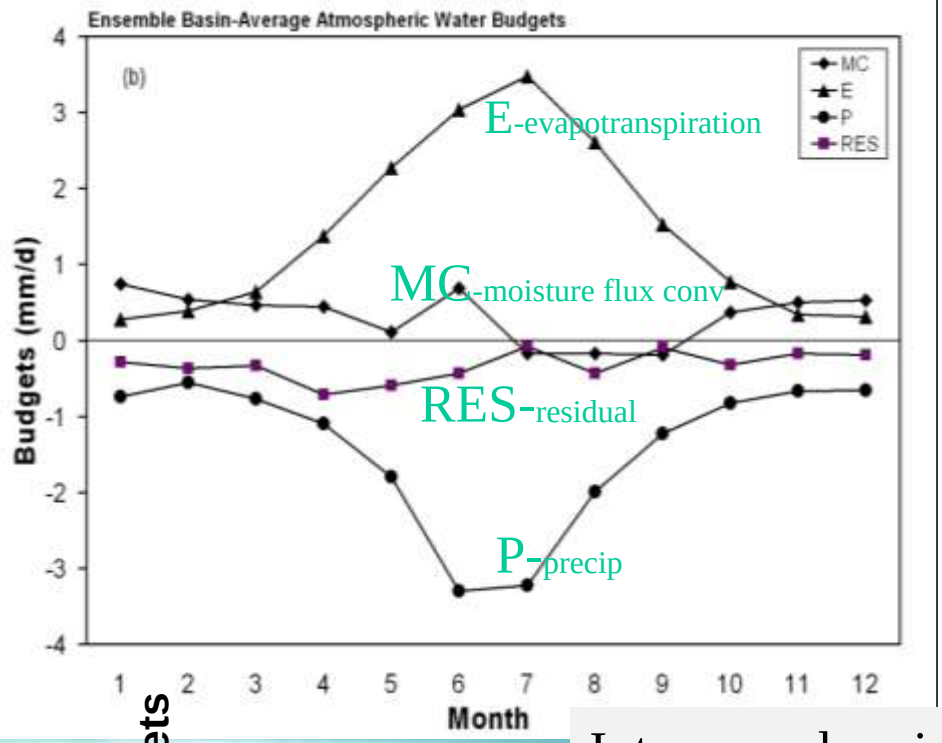
Objectives of Study

- To assess the intra-seasonal and inter-annual variations of water budgets for the Canadian Prairies
- To better understand the interplay between regional and larger-scale processes in governing the hydroclimate variability and development of extremes in the region
- To improve the prediction of warm-season hydroclimate variability and extremes in the Prairies

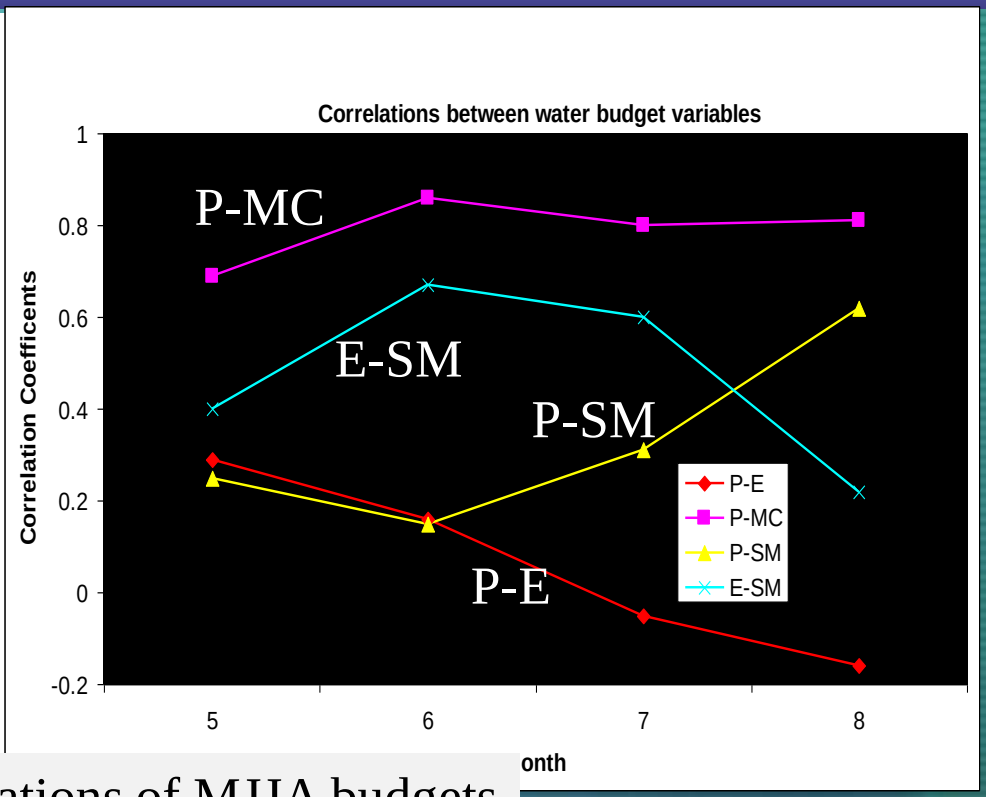
Regional Water Budget Assessments

- Shorter-term budget assessed by using various datasets and evaluated using available observations to provide guidance for selecting appropriate datasets for long-term variability study
- Long-term (1960-2002) budget estimates from ERA-40 (MC, E), CANGRID (P), VIC-simulation (SM), NCEP (MSLP and storm-detection)
- The use of quasi-independent datasets to evaluate different budget terms will increase our confidence in the statistical or physical relationships that are established to exist between them

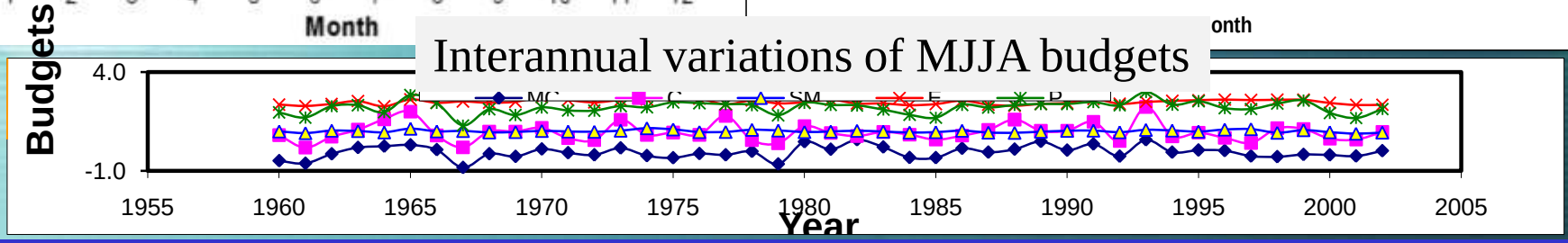
Atmos Water Budgets: Annual Cycle



Contemporaneous Correlations



Interannual variations of MJJA budgets

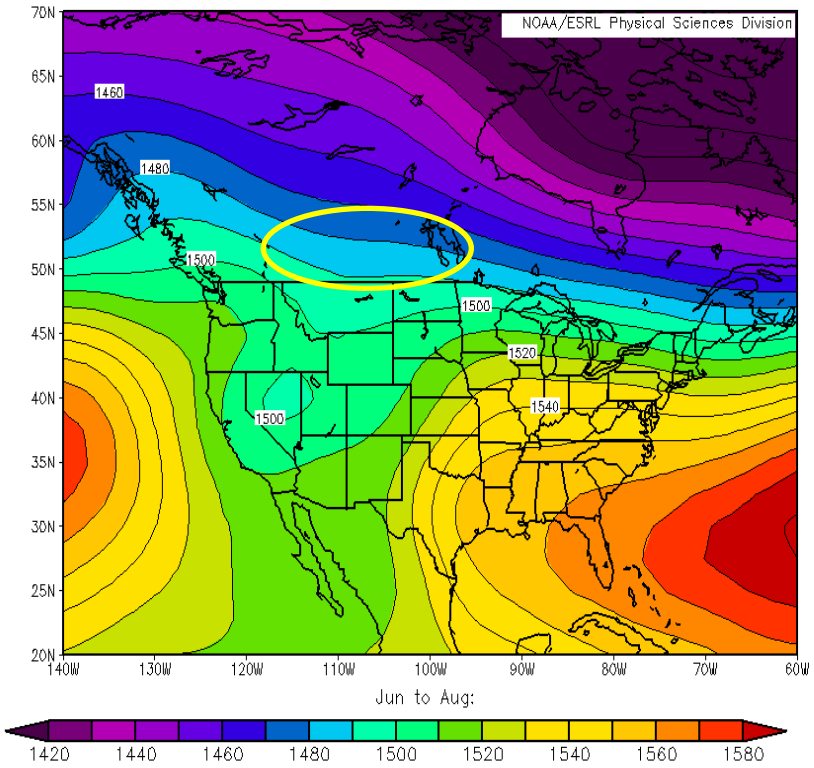


Two Paradoxes of Prairie Warm-Season Water Cycling:

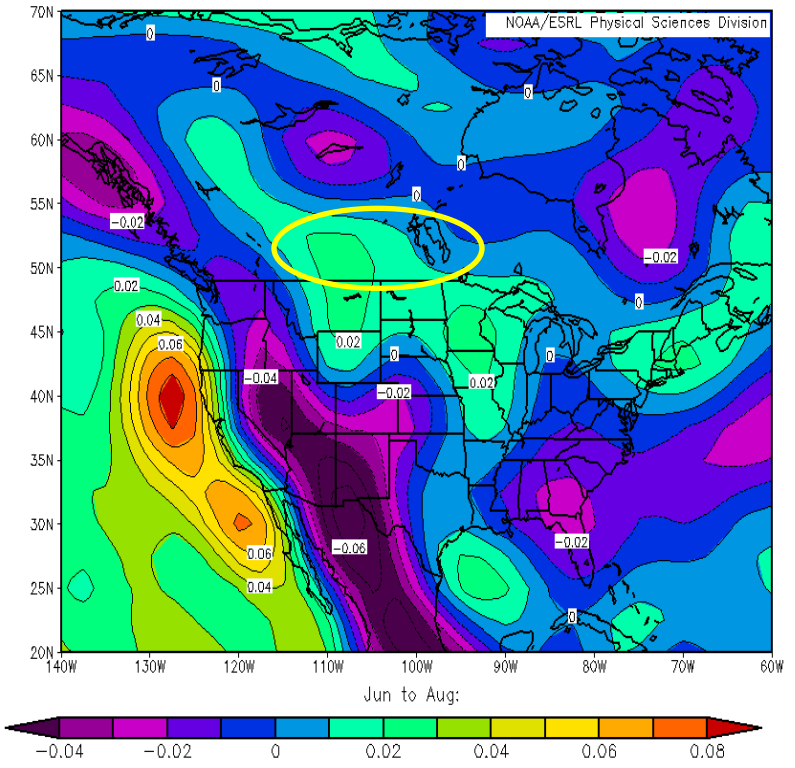
1. Strong evapotranspiration E but P-E correlation is low
2. Weak moisture flux convergence MC but P-MC correlation is high

Resolving the E–P & MC-P Paradoxes

JJA Z850mb

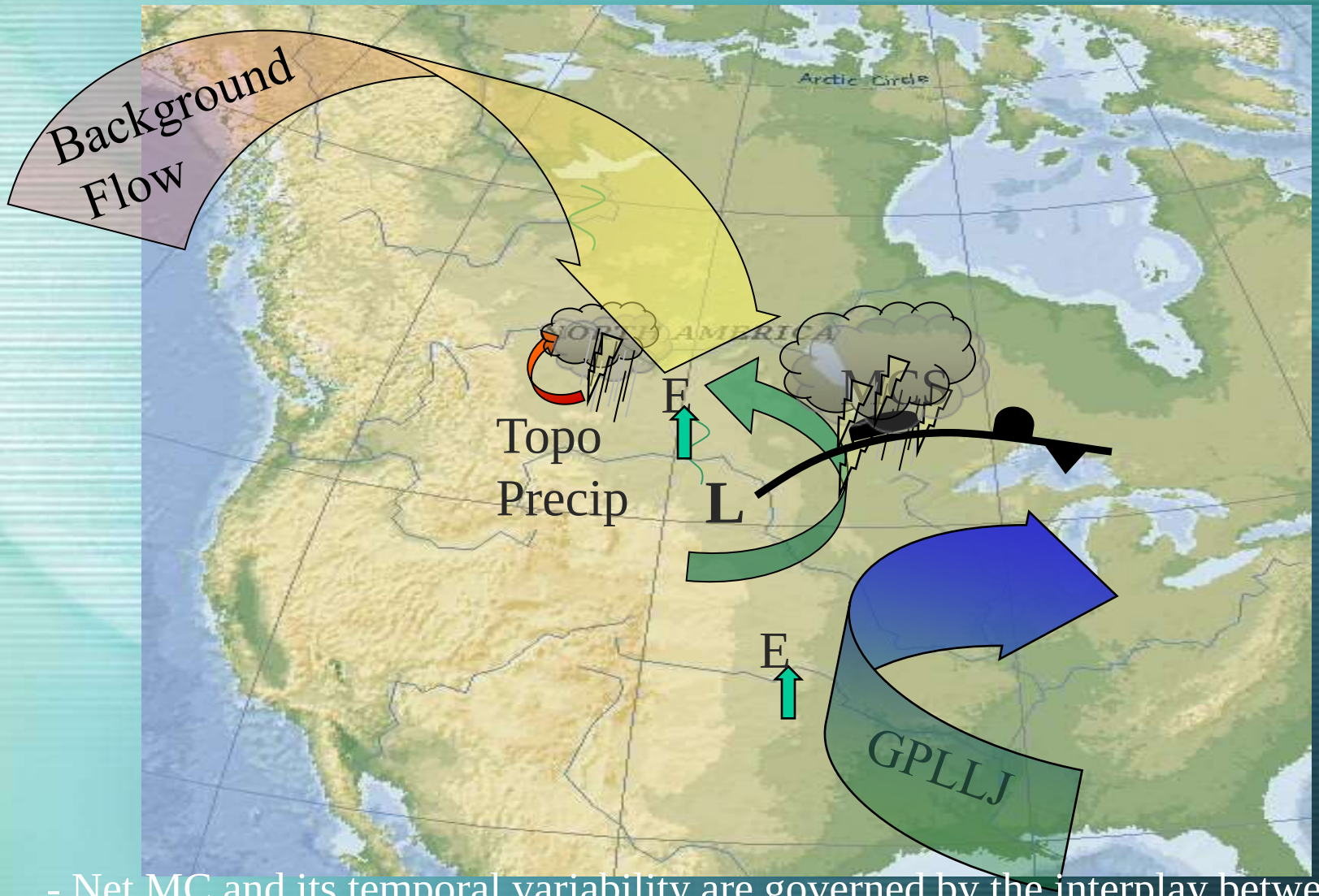


Ω850mb



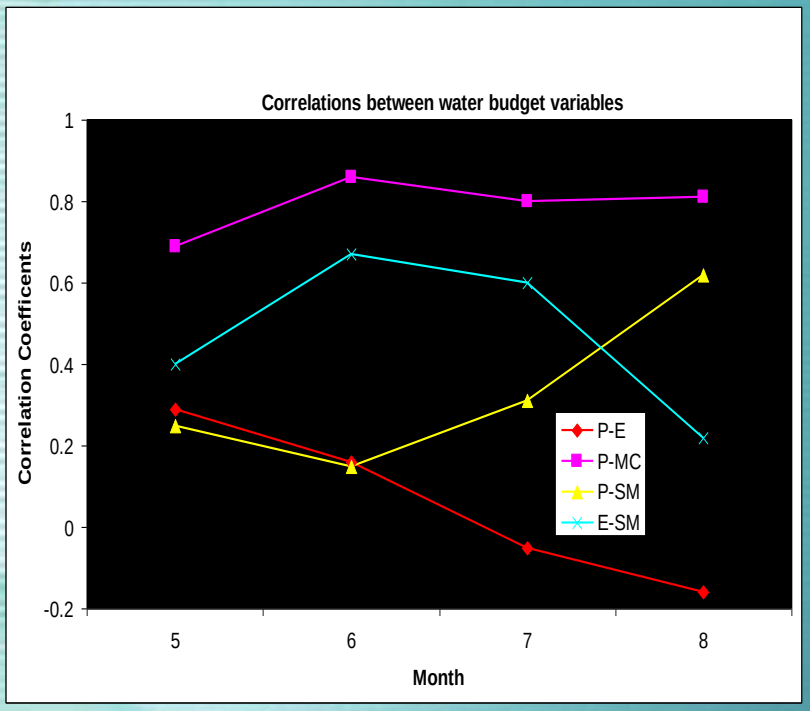
Normally, E is high due to the wet soil from snowmelt and high atmospheric demand due to the dry mean subsiding cross-barrier flow but the mean diverging low-level flow also transports much of the local moisture out of the Prairies and suppresses precip development

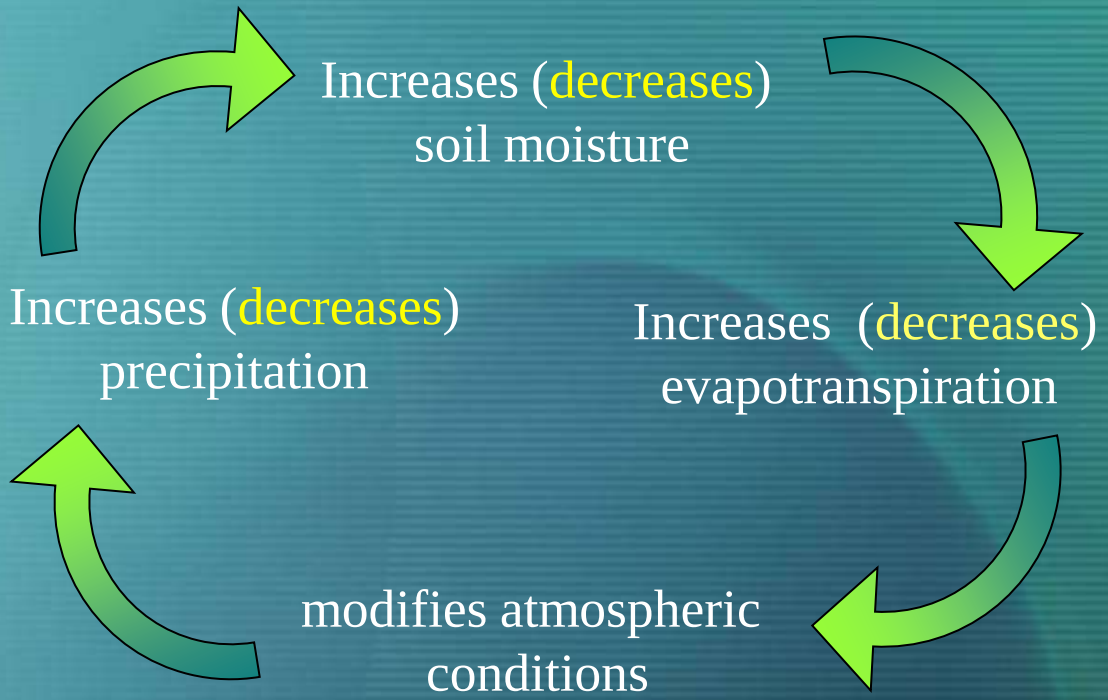
Resolving the E-P & MC-P Paradoxes…cont



- Net MC and its temporal variability are governed by the interplay between the mean cross-barrier flow and countering transient cyclonic storm flows
- Moisture transport into the region by the storm flows also offsets or regulates the effects of reduced local E during dry conditions

Implications for Air-land Coupling over the Prairies

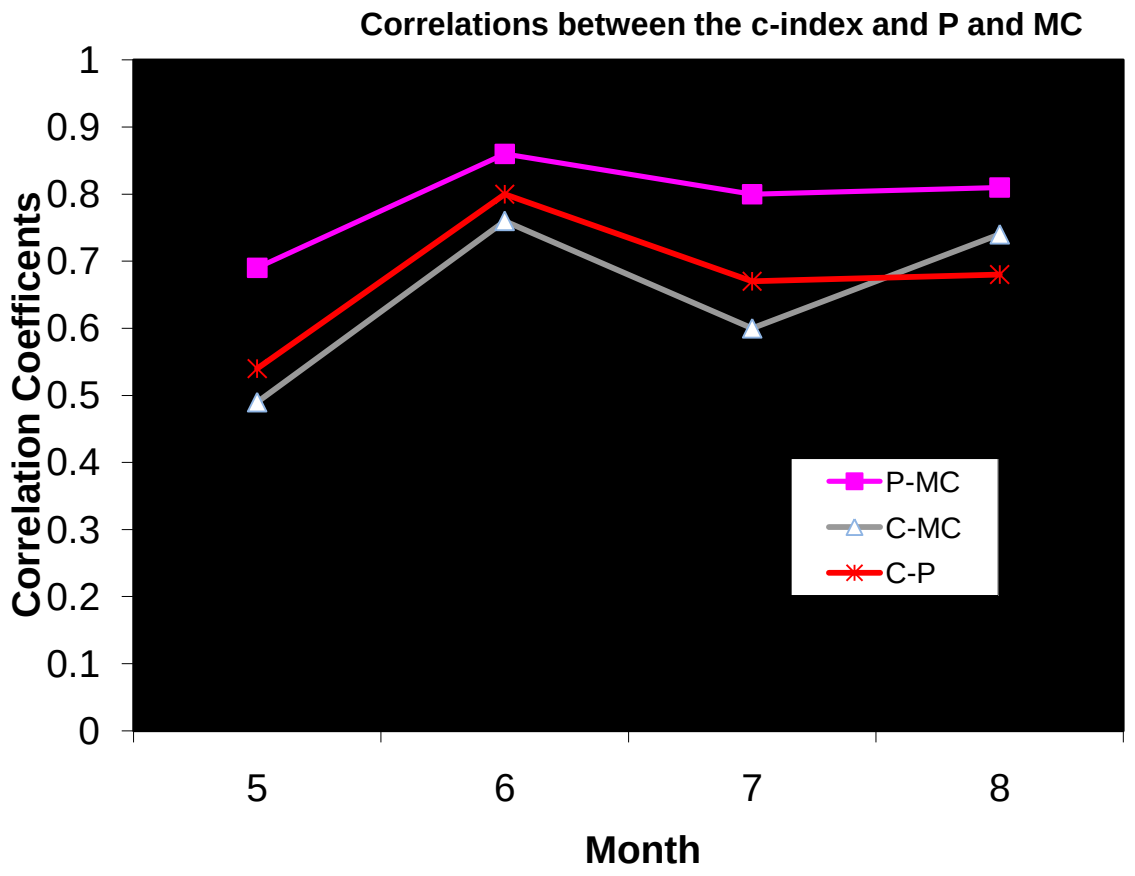




Correlation results suggest that strong air-land coupling is unlikely in the Prairies under normal conditions

Dry soil conditions, especially during Spring when the linkages between E and P is the strongest, can compound the effects of low storm activities to induce extreme dry conditions (the reverse is not true)

Contemporaneous Correlations Between the C-index and P/MC



C = | C1 * C2|, C1>0, C2<0
= 0 , otherwise

C1 = Vertically-integrated meridional moisture flux from surface to 700 hPa at (265E,47.5N) and averaged from 260-270E

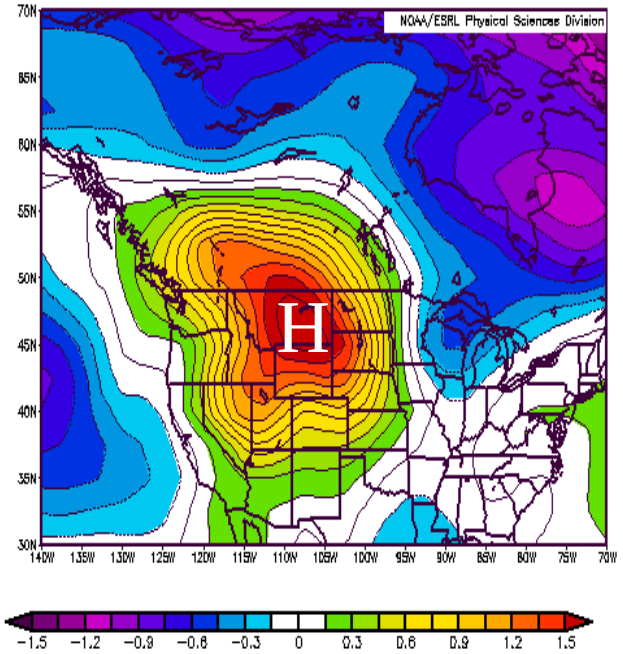
C2 = Vertically-integrated zonal moisture flux from surface to 700 hPa at (255E,52.5N) and averaged from 52-55N

- Computed from 6-hourly ERA40 data and averaged for monthly means

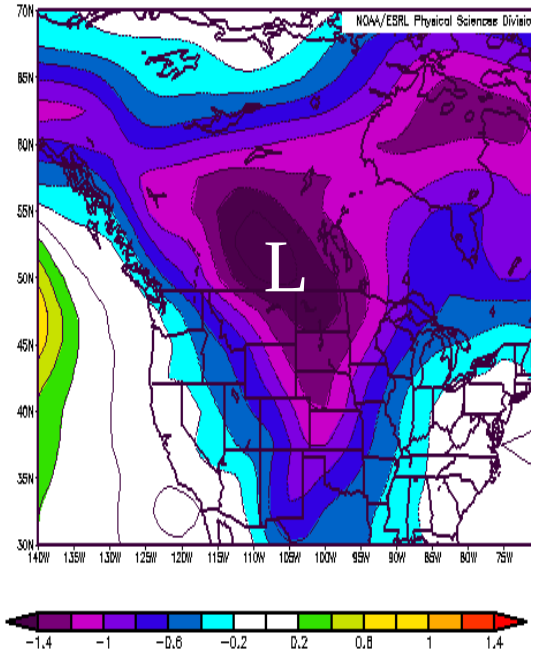
- A measure of cyclonic moisture transport into the Prairies from the south and it also gives a measure of cyclonic activities in the southern vicinity of the Prairies

MSLP composited for days with daily precip rate P (averaged over the western prairies)

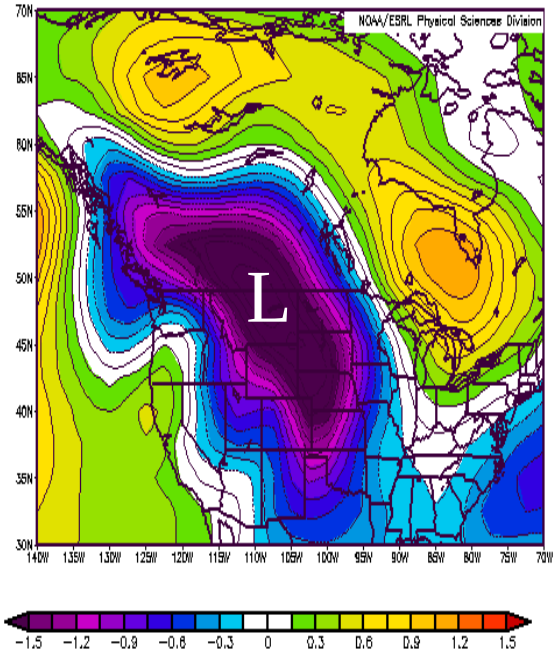
P: 0.4-0.6 mm/d



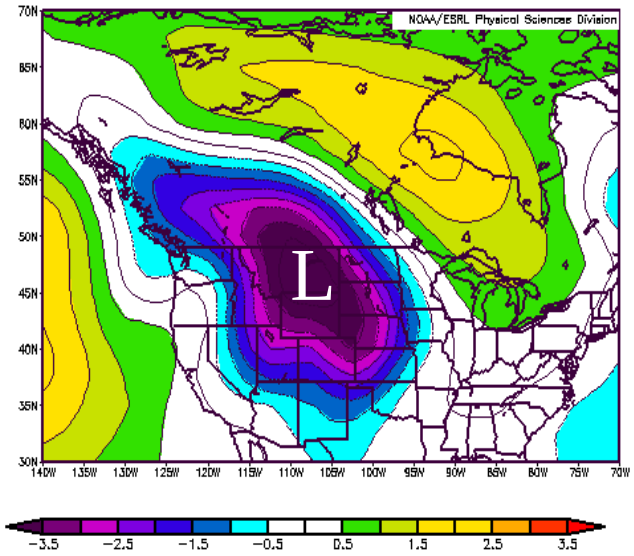
P: 1.4-1.6 mm/d



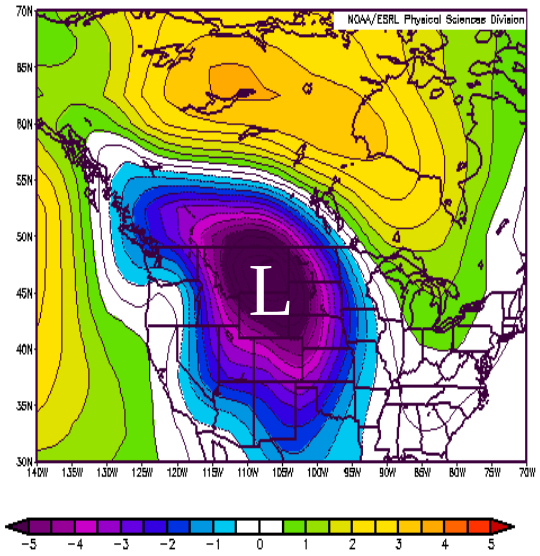
P: 2.5-3.5 mm/d



P: 6.5-7.5 mm/d



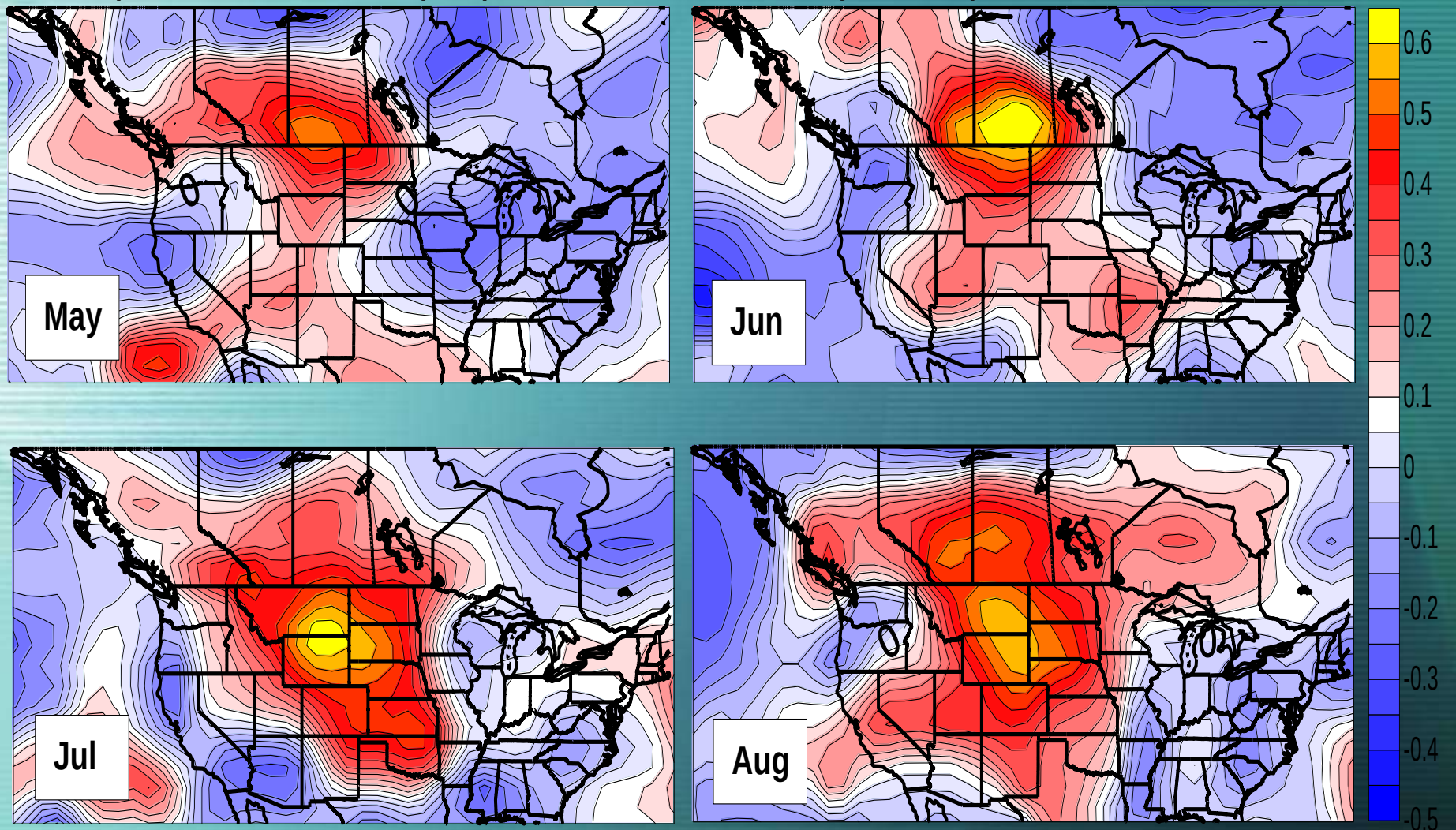
P >10 mm/d



Composite synoptic patterns associated with warm season precip events of different intensity during 1950-2008 over the western Prairies

Locations of storms that have the greatest impacts on Prairie precip

Map of correlation between precip over western Prairies and cyclone frequencies in NA



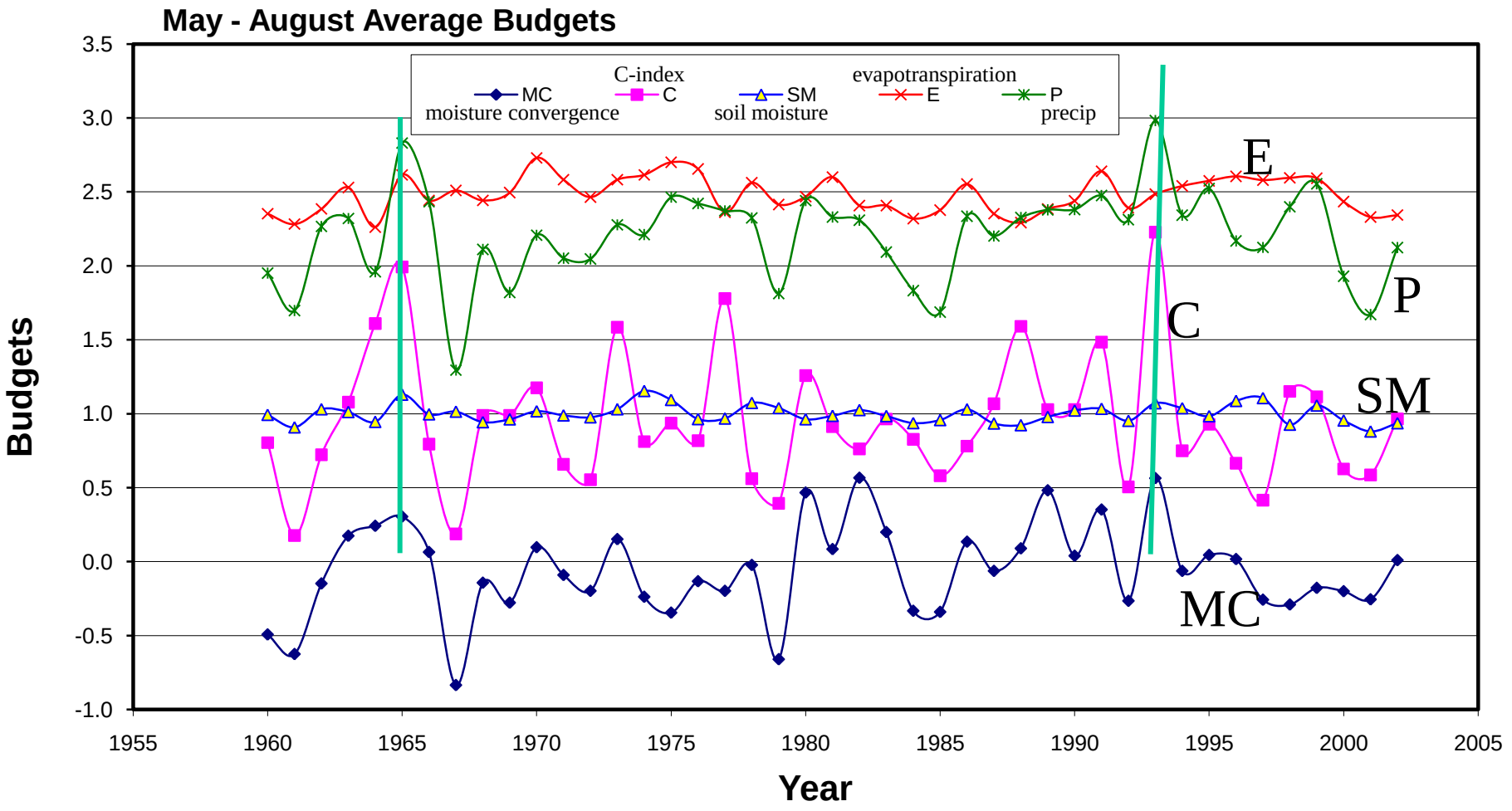
Hypotheses for Prairie drought and pluvial development

Pluvials develop when substantially higher than normal frequency of cyclonic disturbances occur in the southern vicinity of the Prairies and surface wetness in the region is close to normal

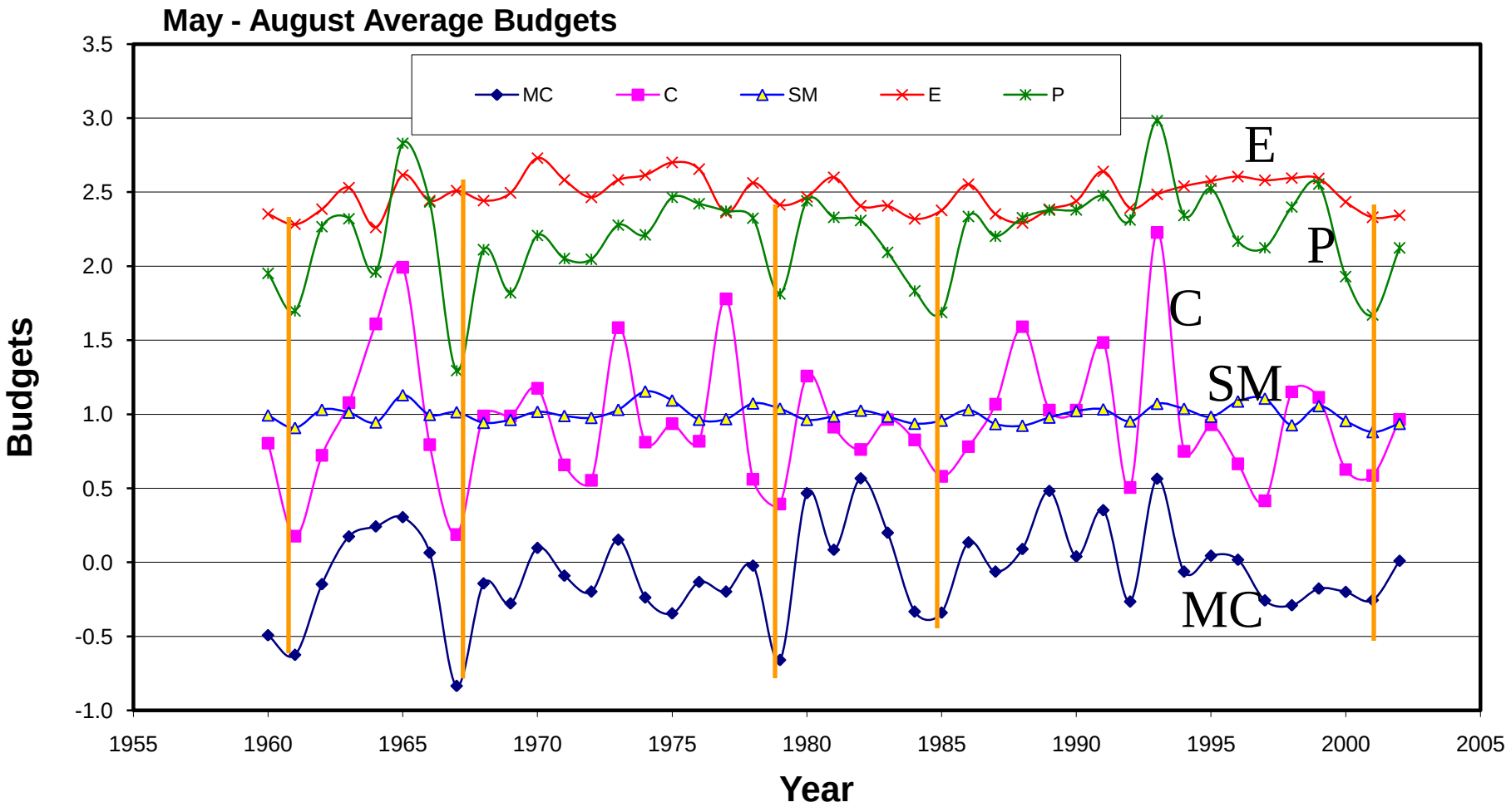
Droughts develop when the occurrence of cyclonic disturbances over the southern vicinity of the Prairies is anomalously low, and

Extreme droughts develop when anomalously low occurrence of favorable cyclonic disturbances occurs in conjunction with dry surface conditions that result from a previous dry year and/or low winter precipitation - a plausible mechanism that contribute to the development of multi-year extreme drought conditions

Previous Pluvial Periods: 1965, 1993

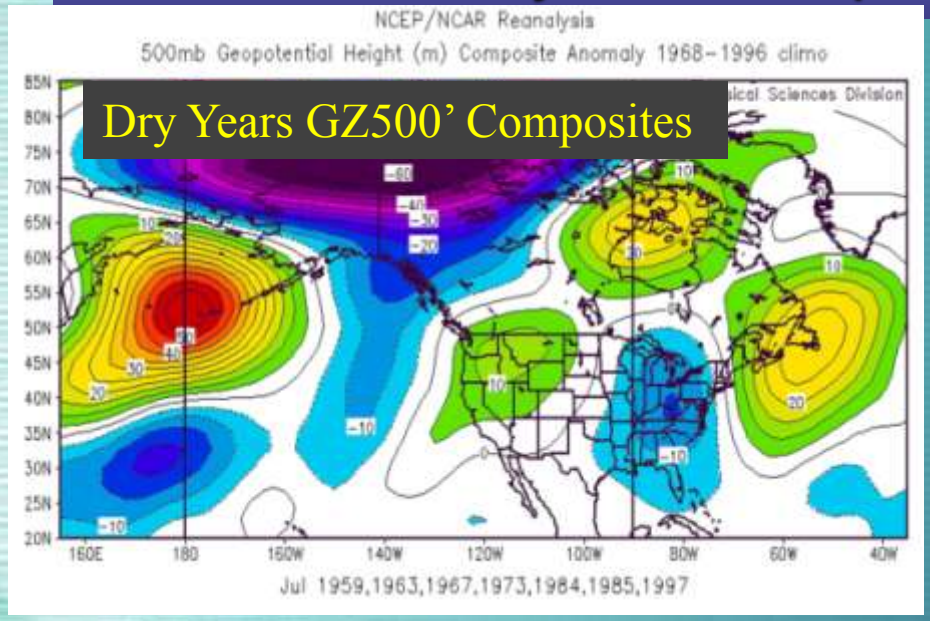


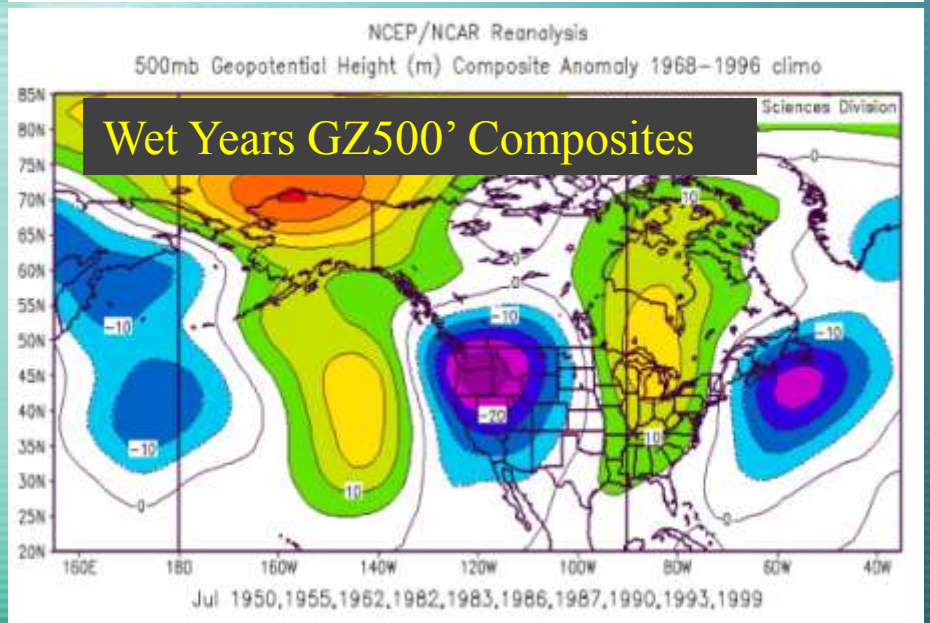
Previous Drought Periods: 1961, 1967, 1979, 1985, 2001

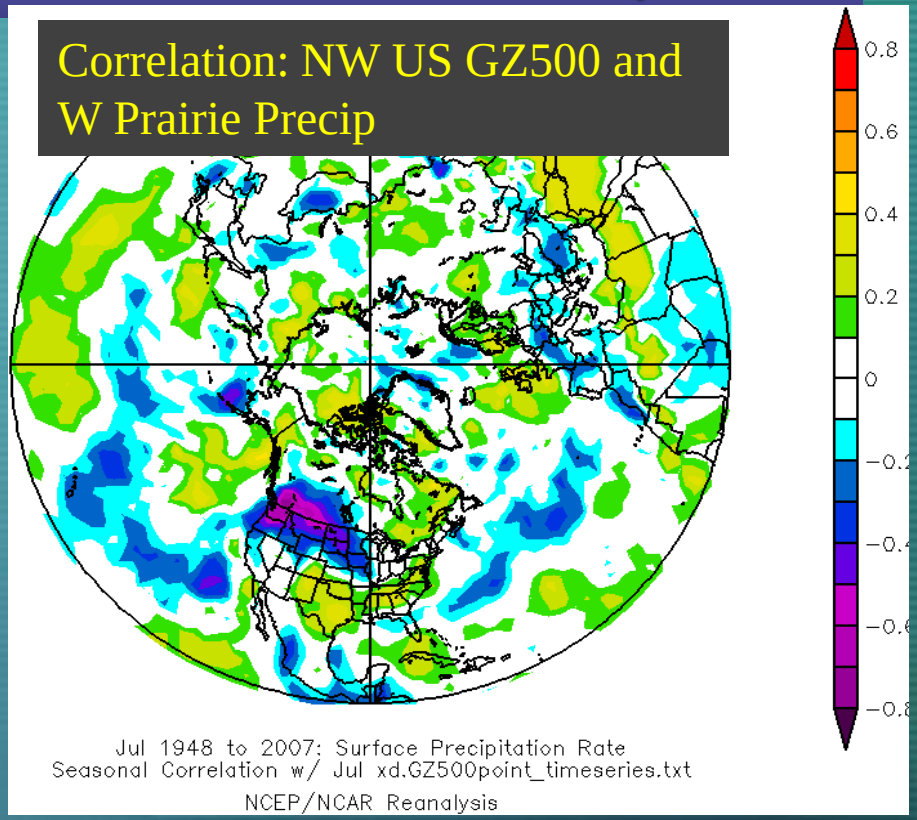


Winter precip for 60/61 and 2000/01 winters are the lowest among the years

Relationships Between GZ500 Anomaly over NW U.S./S. BC and Cyclone Frequencies and Prairie Precip



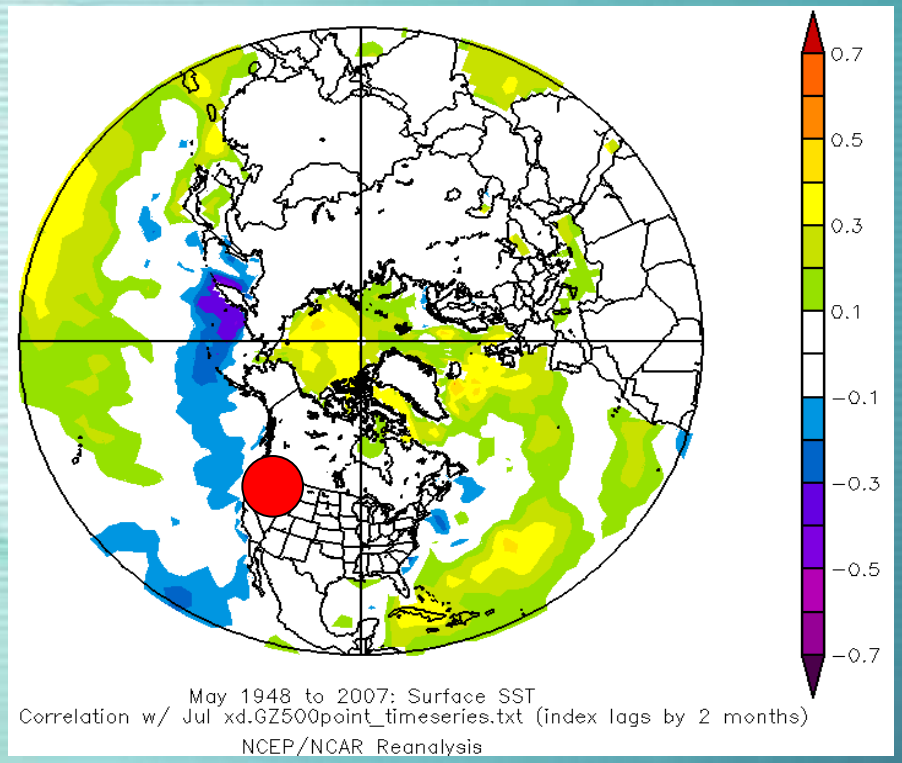




Correlations between NW US GZ500 and

	May	Jun	Jul	Aug
Prairie Precip:	-0.45	-0.43	-0.57	-0.69
Cyclone Freq:	-0.66	-0.47	-0.63	-0.72

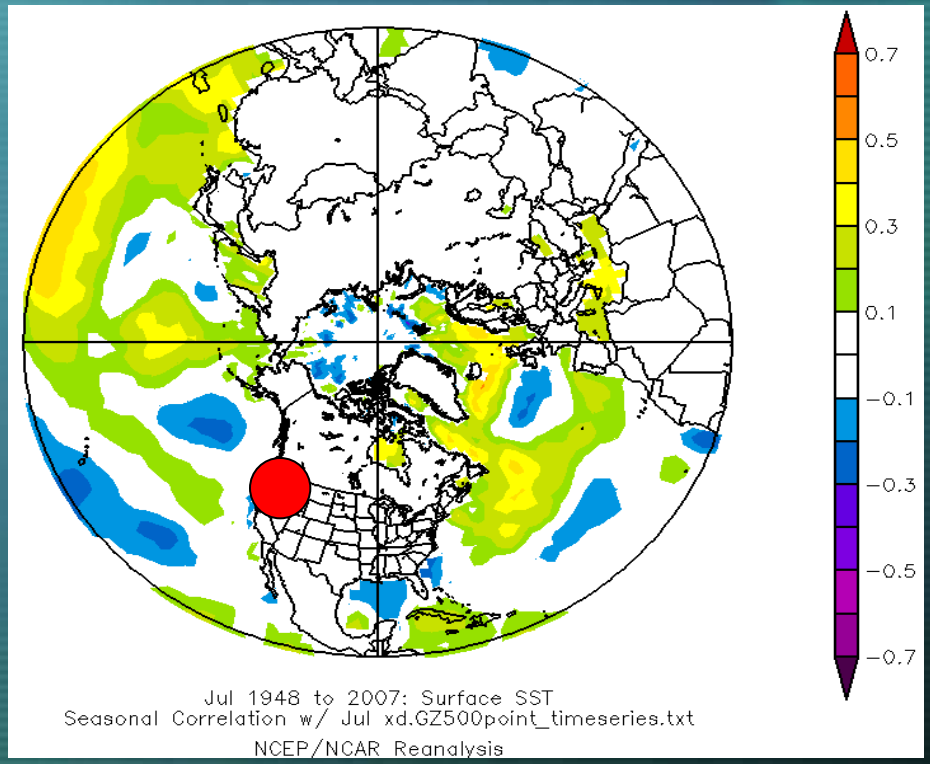
What is the nature of these stationary eddies?



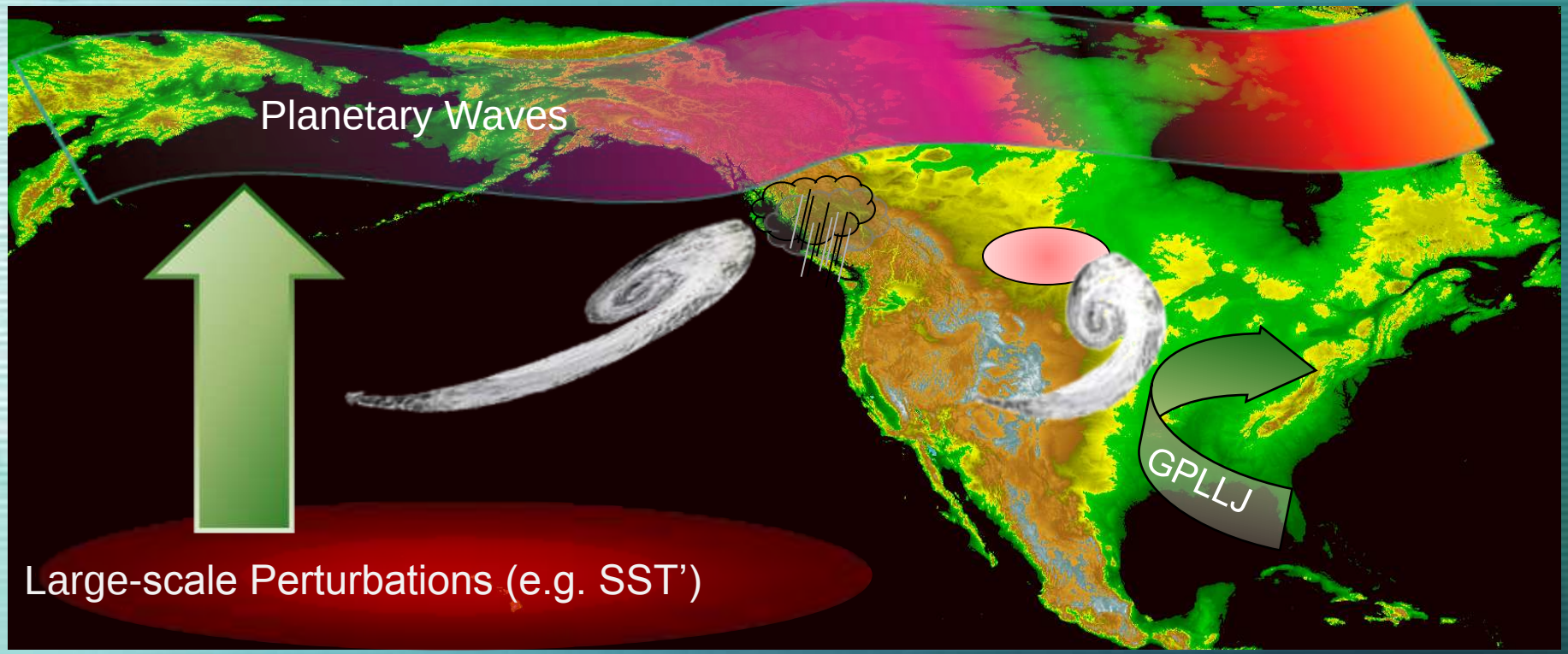
2-mon lagged correlations between NH SST and July GZ500 over NW U.S.

Forced or Free Modes?

Contemporaneous correlations between NH SST and July GZ500 over NW U.S.



An Hybrid Approach for Predicting Prairie Hydroclimate Extremes



Deterministic — Statistical

The approach can also be useful for climate change studies

What Next?