University of Lethbridge

Biology 3850 – Topics in Prairie Conservation

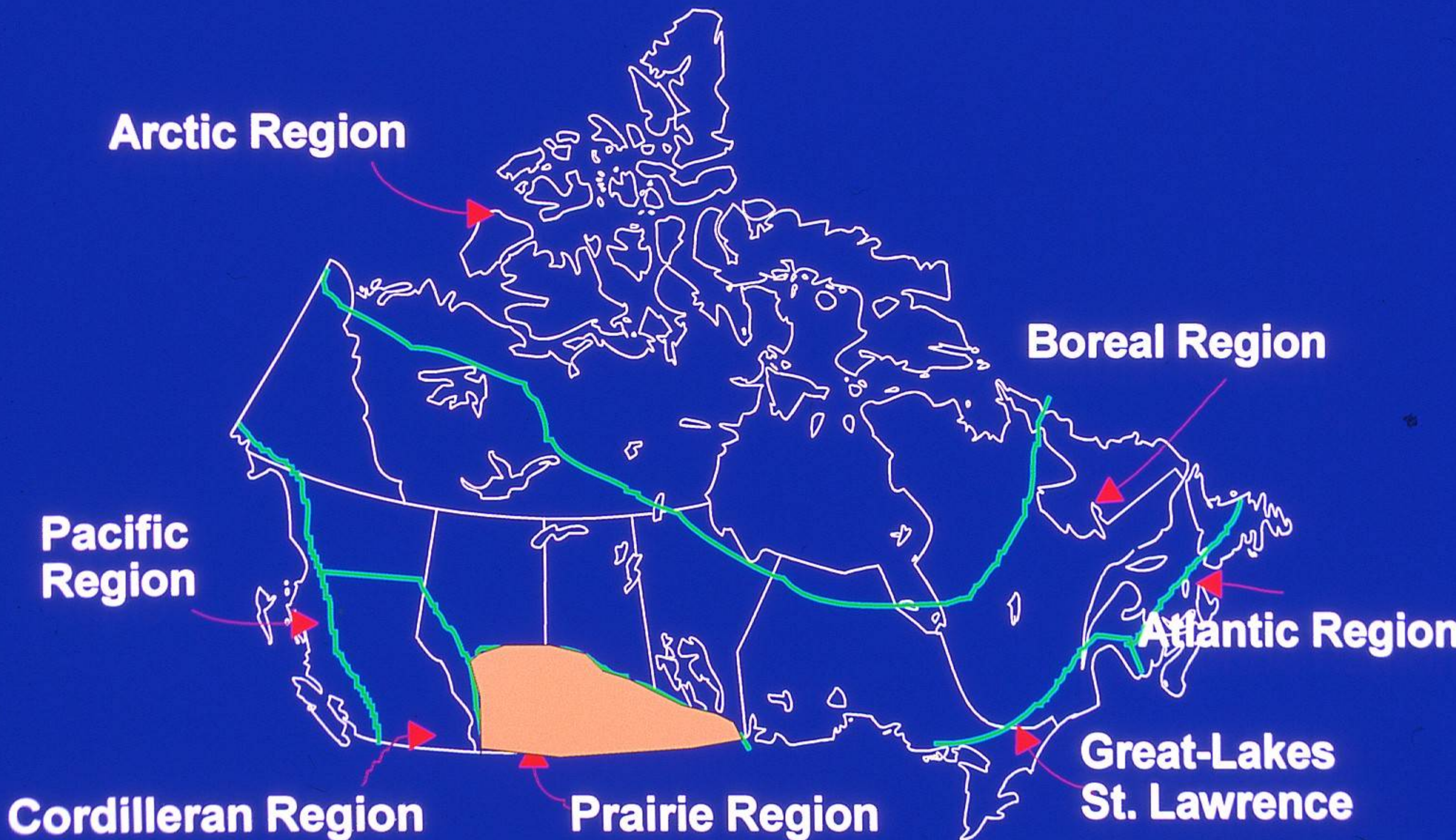
Module 2 – Climate
Module 2a – Ecological Land Classification
Module 5 – Information and Research

Livio Fent

Topics in Prairie Conservation

Module 2: The Prairie Landscape
Climatic Phenomena

Climatic Regions of Canada



Climatic Controls of the Prairies

- Radiation
    * Insolation
    * Heat Balance

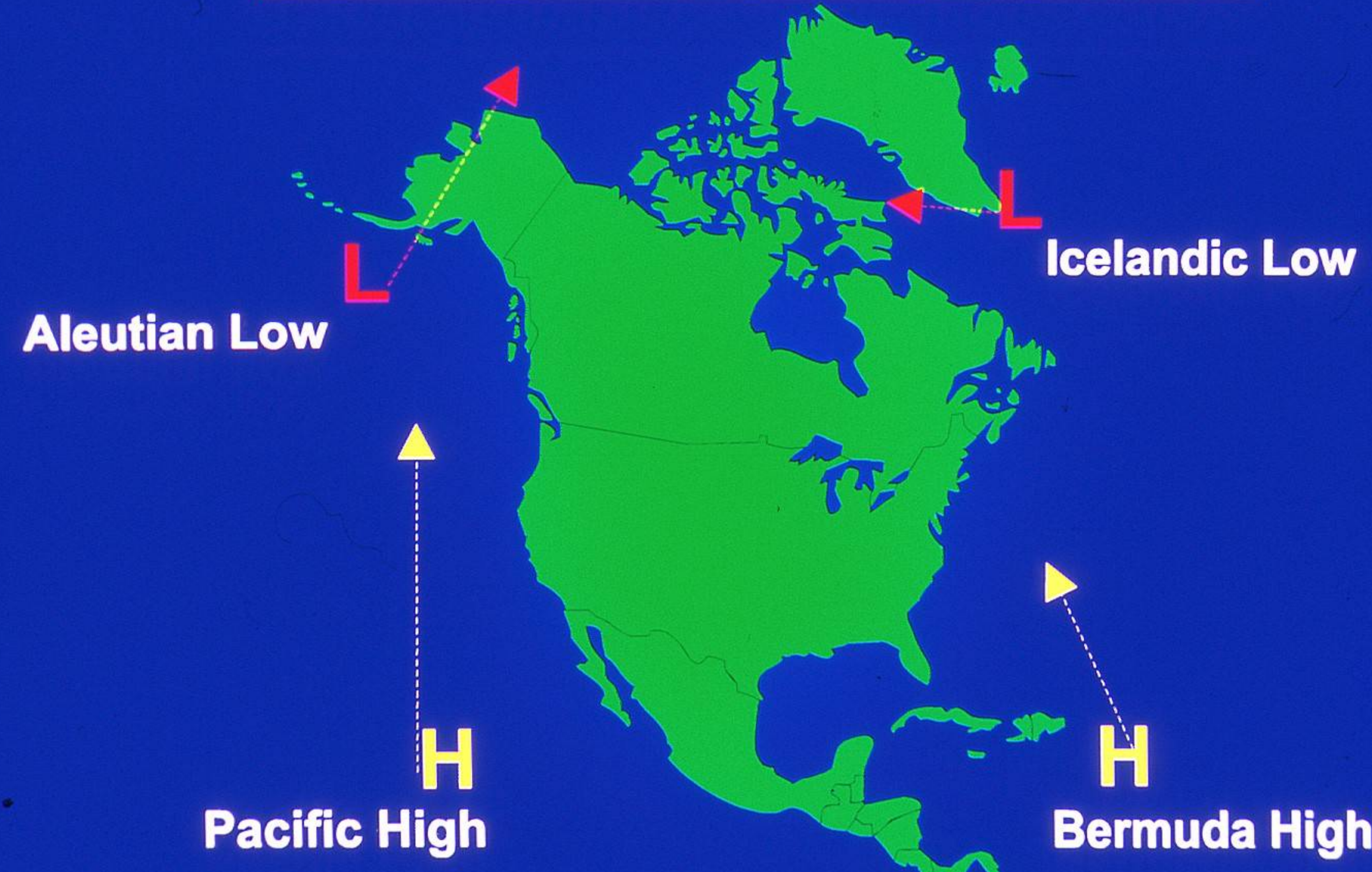
- Atmospheric Circulation
    * General Circulation
        Seasonal effects on Temp, Precip

- Topography
    * Effects of the Cordilleran System
    * The Interior Plains

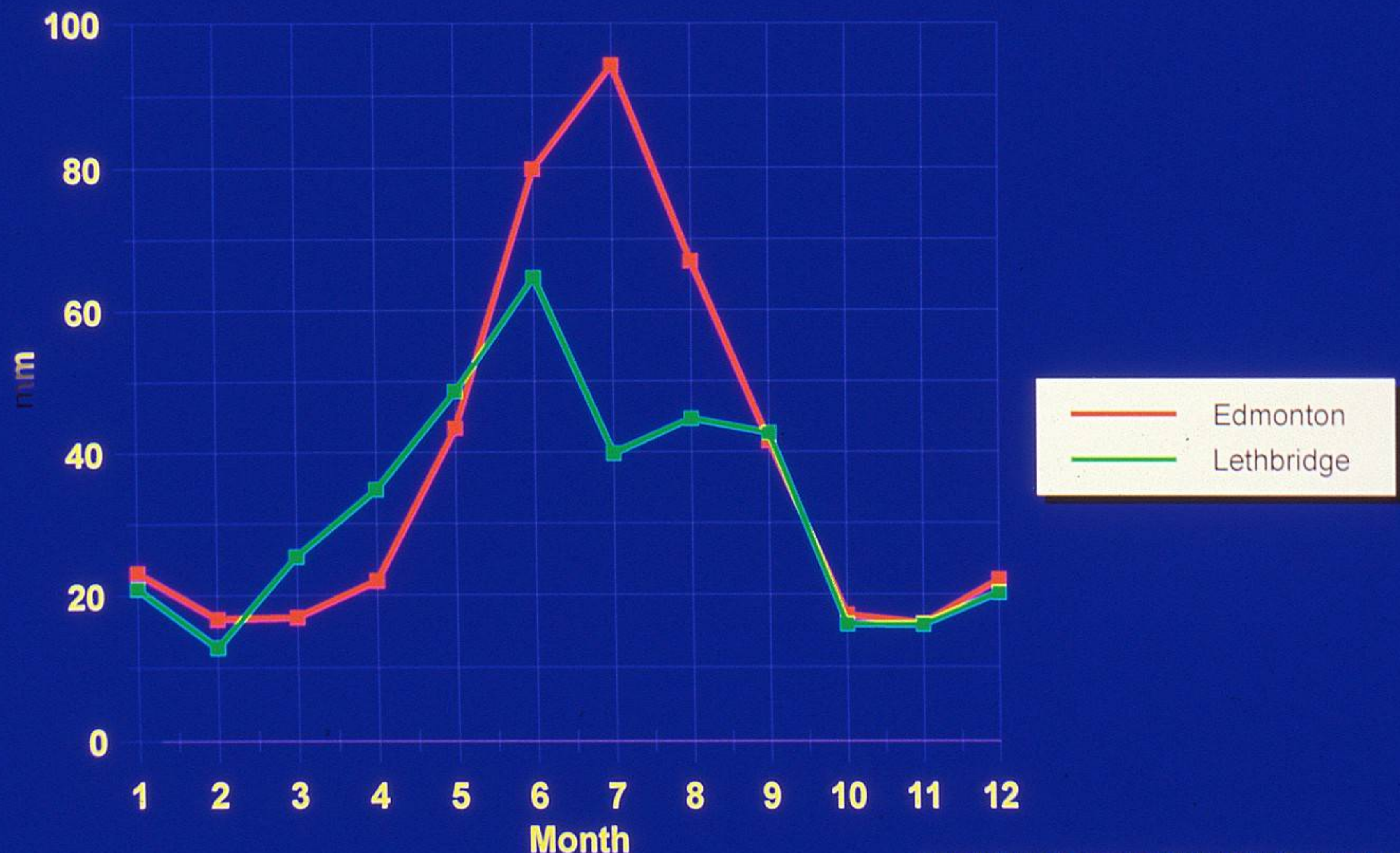
Climatic Phenomena of the Prairies

- Macroscale effects: General Circulation - El Nino
- Mesoscale effects: The chinook
- Microscale effects: Insolation - Topographic effects

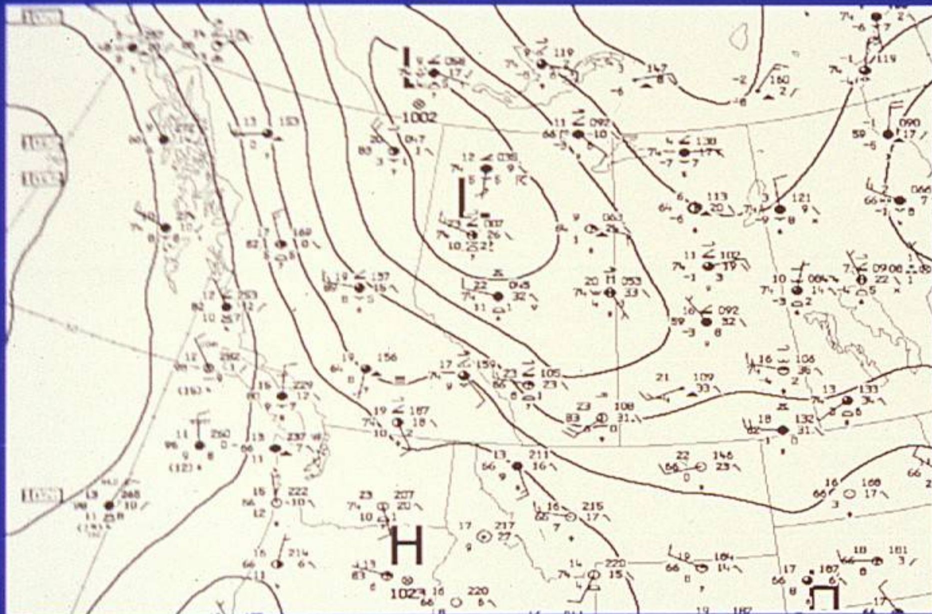
Semi-Permanent Circulation Pattens



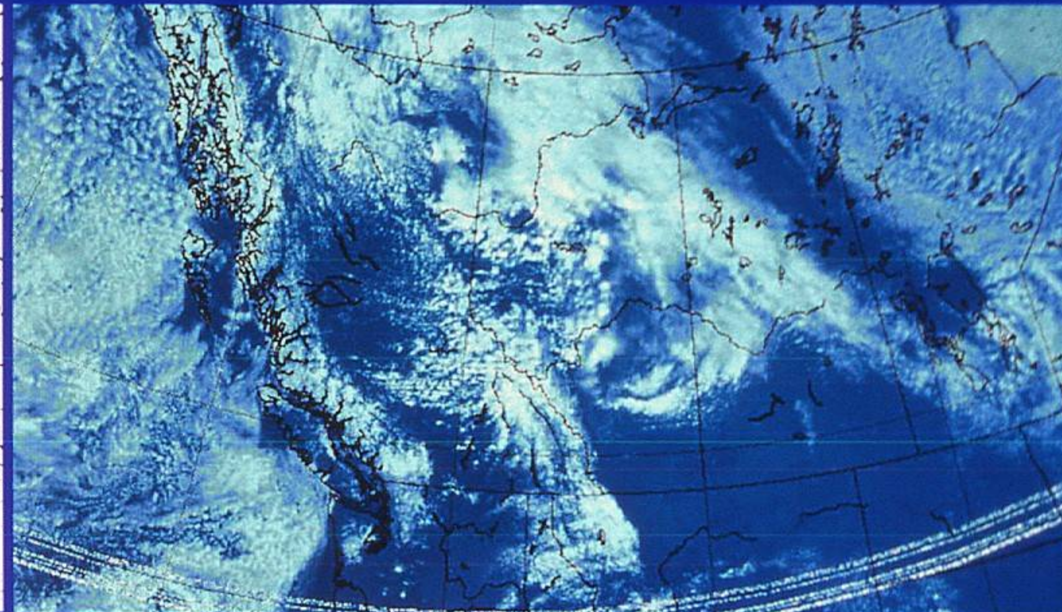
Precipitation Comparison: Prairie vs Parkland



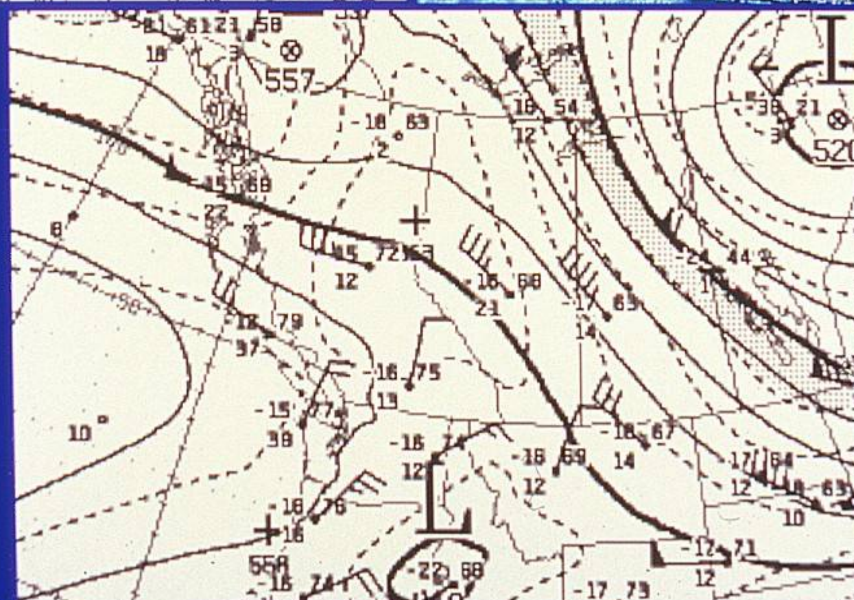
Mid - Summer Synoptic Conditions



Surface Pressure



GOES 9 satellite image



500mb Pressure Level

Effects of El Nino on the Prairies

- Decreased Precipitation
  - Minimal snow cover
  - Low soil moisture
  - Drought conditions

- Increased Insolation
  - Higher evaporation/transpiration
  - Higher photosynthetic activity

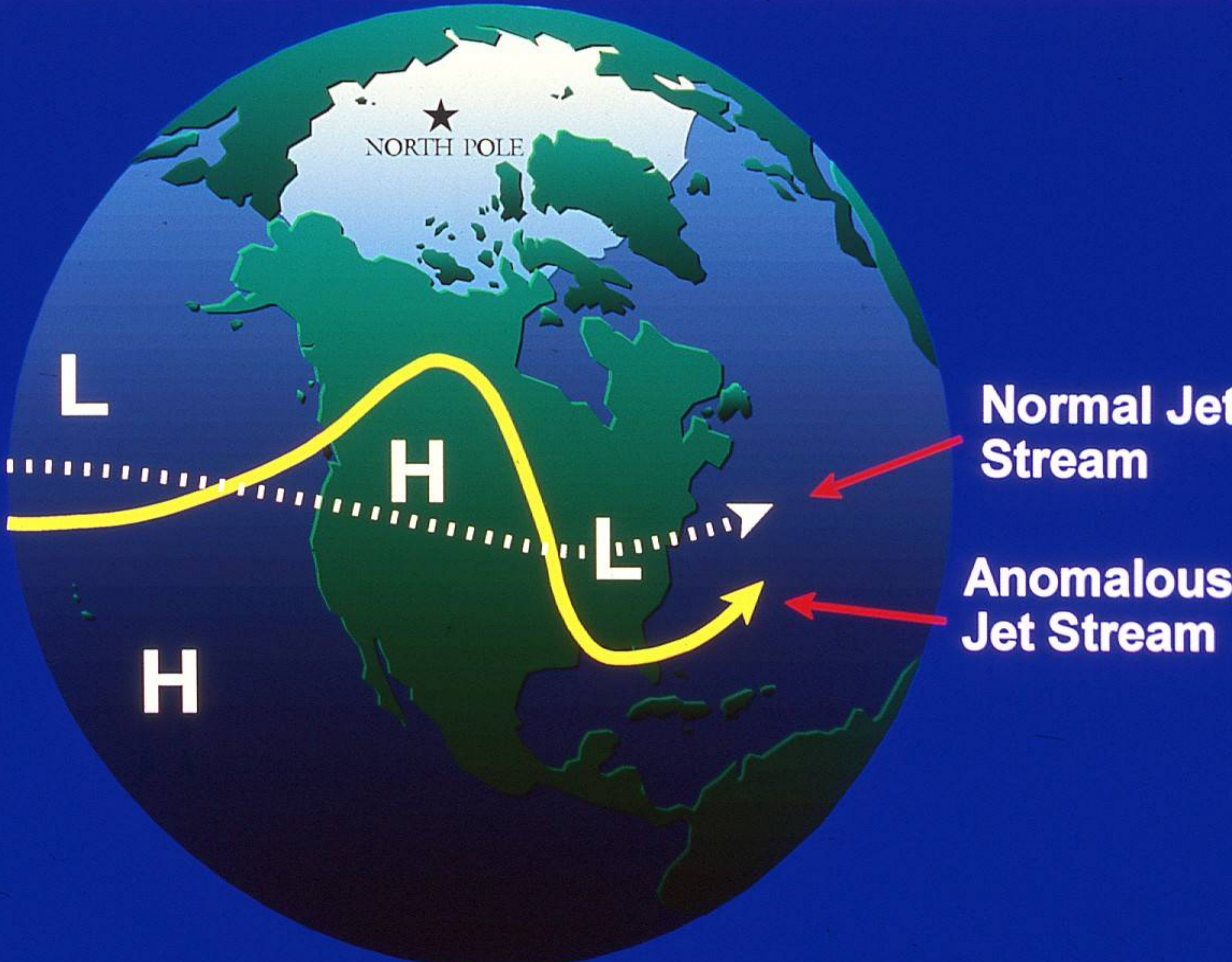
- Increased chinook frequency and intensity
  - Higher wind frequency and intensity
  - Higher evaporation/transpiration

- Increased Temperature

The El Niño Event: Driving Forces

- Sea surface temperature off Peru rises. Temprature rise higher than normal.
- Negative Southern Oscillation: Walker Circulation convergence cell off Peru intensified
- Subsidence in the subtropical areas around Hawaii intensified, high pressure ridge along the west coast of North America
- Aleutian Low intensifies, barometric differences intensify jet stream

The El Niño Event: Pacific-North American Drivers



The Chinook Mechanism 1

Equation of State - $pV = CT$

Hydrostatic Equation - $dp/dz = -\rho g$

The *dry adiabatic lapse rate* is derived from the two conceptual equations:

$$dT/dz = -g/c_p \quad >> \quad -\Gamma$$

$$\Gamma = g/c_p = 0.98\,^{\circ}C/100m$$

The Chinook Mechanism 2

Adiabatic lapse rate:

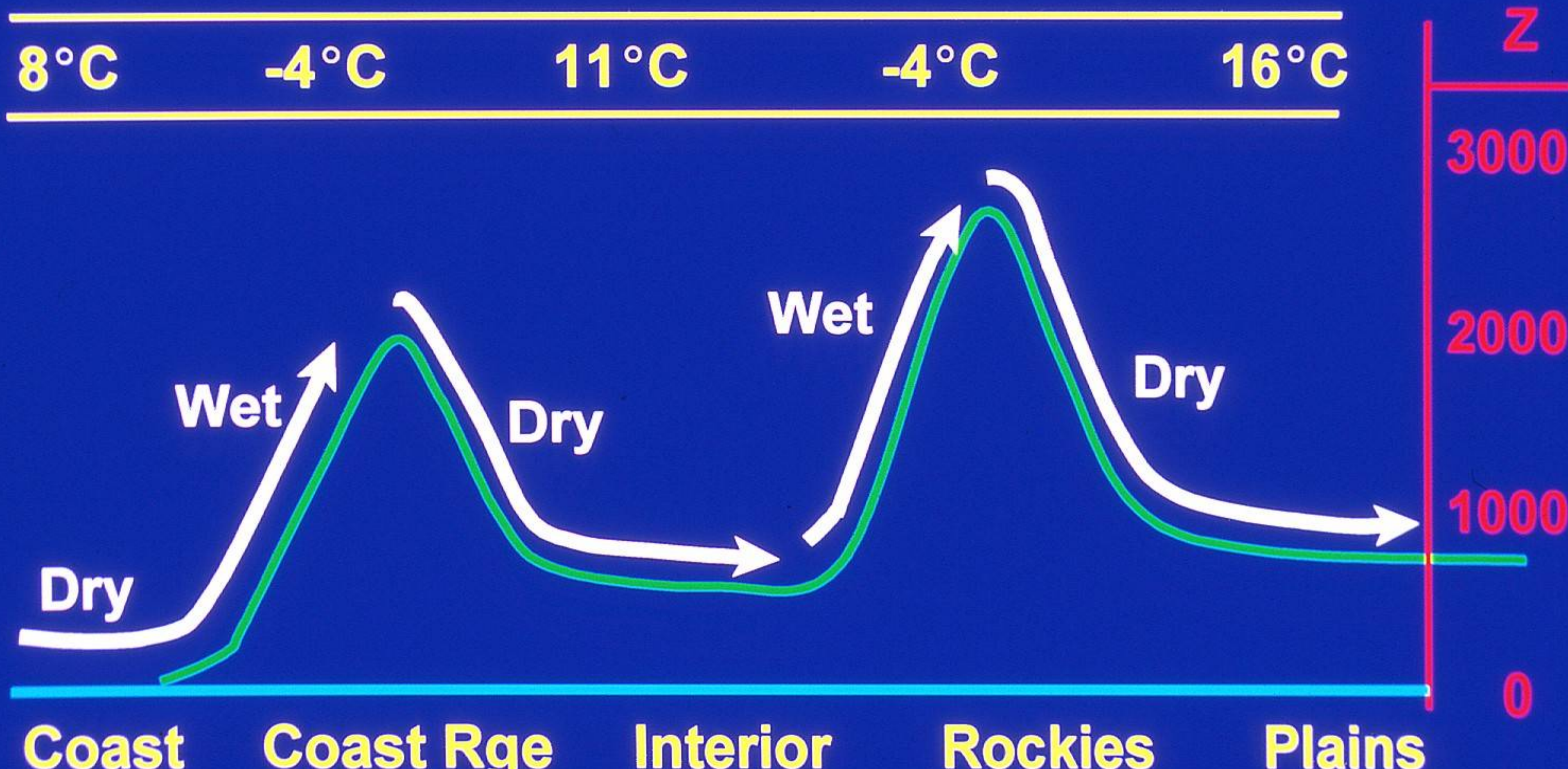
$$dT/dz = -g/c_p \quad >> \quad -\Gamma$$

Pseudo(wet)adiabatic lapse rate:

$$dT/dz = -\Gamma - \text{(latent heat factor)}$$

$$dT/dz \approx 0.6\ ^{\circ}C/100m$$

The Chinook Mechanism 3



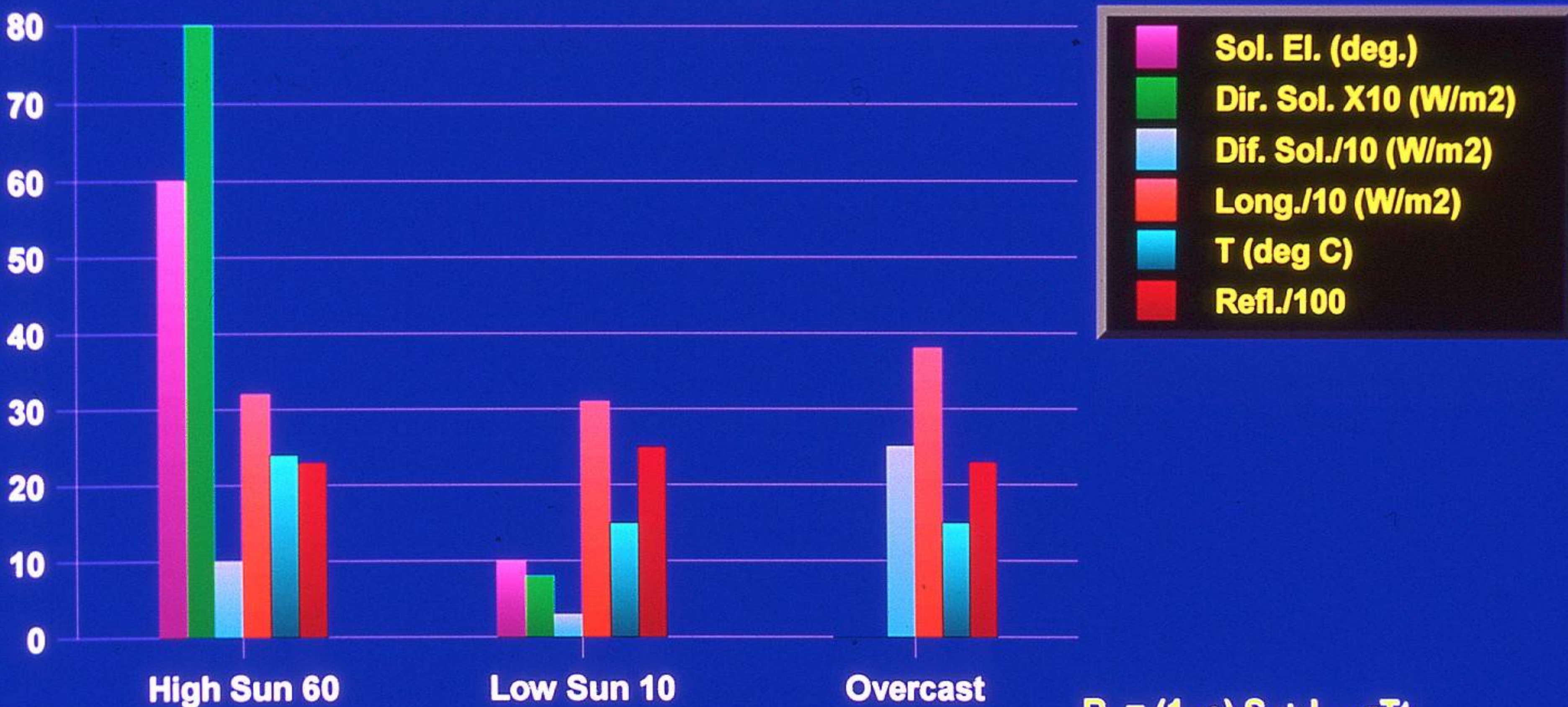
Insolation: Topographic Modifiers 1

Radiative Exchange:

$R_n = (1 - \rho)\, S_t + L_d - \sigma T^4$

ρ = reflection coeficient (0 to 1)
S_{total} = Shortwave radiation (= $S_{direct\ perpendicular} \sin\beta + S_{diffuse}$)
L_{down} = Longwave radiation
σ = Stefan-Boltzmann constant (5.67×10^{-8} W m^{-2} K^{-4})
T = Radiative temperature (ground)

Insolation: Topographic Modifiers 2



$$R_n = (1 - \rho) S_t + L_d - \sigma T^4$$

Sol. El. (deg.)	60	10	0
Dir. Sol. X10 (W/m	80	8	0
Dif. Sol./10 (W/m2)	10	3	25
Long./10 (W/m2)	32	31	38
T (deg C)	24	15	15
Refl./100	23	25	23

Topics in Prairie Conservation

Module 2b: The Prairie Landscape
Ecological Land Classification
Field Exercise

Definition

Ecological land classification is an approach which endeavors to subdivide the landscape into significant ecological units and organize complex interrelationships into identified geographical areas with similar properties.

Hirsch et al. 1978

Uses of Ecological Land Classifications

- Wildlife habitat definition
- Special natural features
- Landscape planning
- Biodiversity studies
- Natural resource planning
- Parks Management

The ‘ecological units’ of ELCs

- Soil Type
- Vegetation
- Moisture regime
- Slope
- Geomorphology (surficial geology)

The Hiearchical Approach in ELCs

Ecoprovince	Grasslands, Boreal Forests, Tundra etc..
Ecoregion	Mixedgrass, drygrass, fescue ..
Ecodistrict	Lucustrine, fluvial, glacial-fluvial, moraine ..
Ecosection	Western wheatgrass/glacial-fluvial
Ecosite	Blue gramma-western wheatgrass-prickly pear cactus/glacial fluvial
Ecoelement	Sagebrush/bentonitic clay outcrops

Classification Symboliztion

Example of symbol: 20G2.1/1

Mixedgrass prairie

Natural subregion or Ecoregion

Glacial-Fluvial

Ecodistrict

South slope

Ecosection

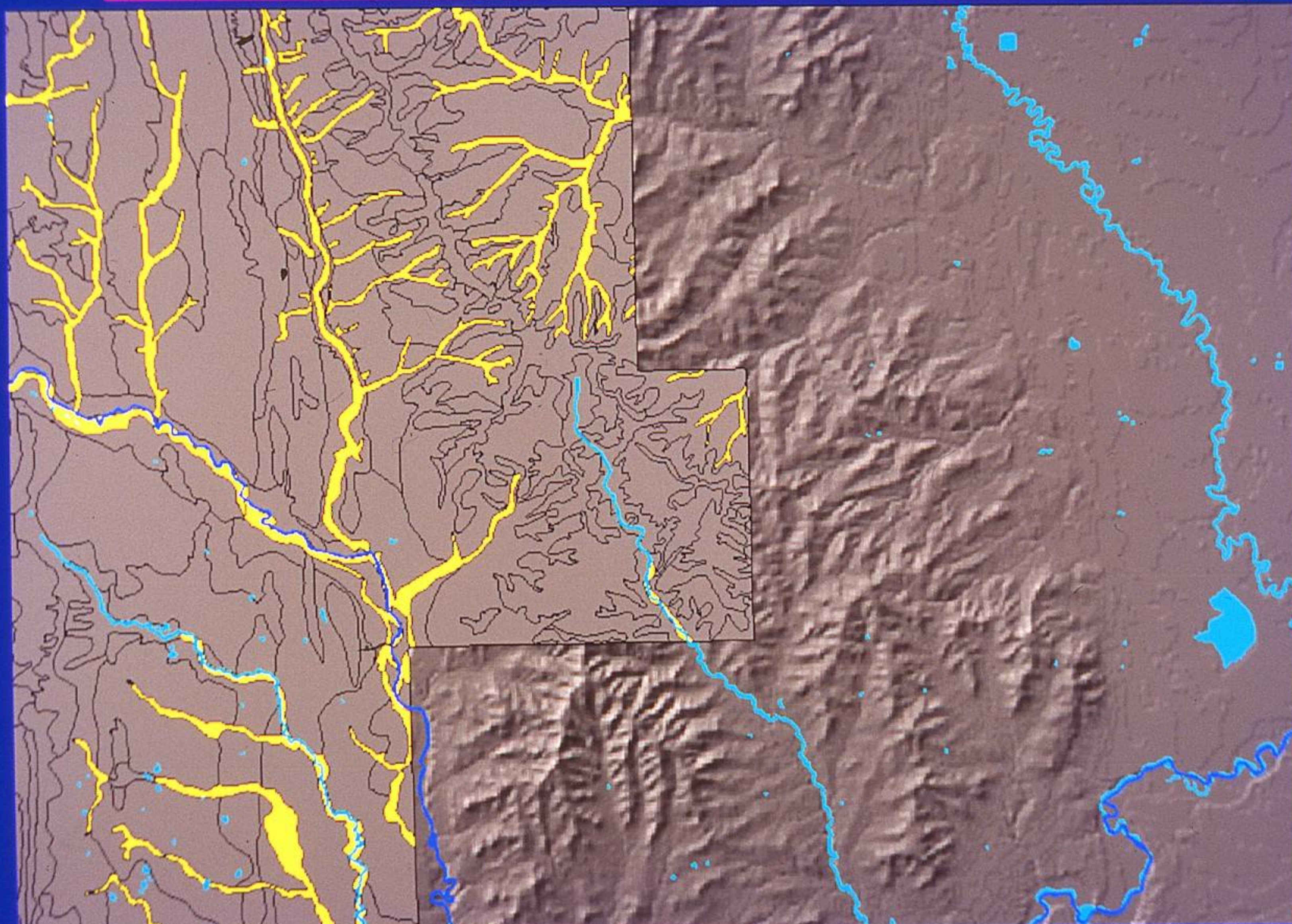
South slope - blue gramma/ Needle & thread community

Ecosite

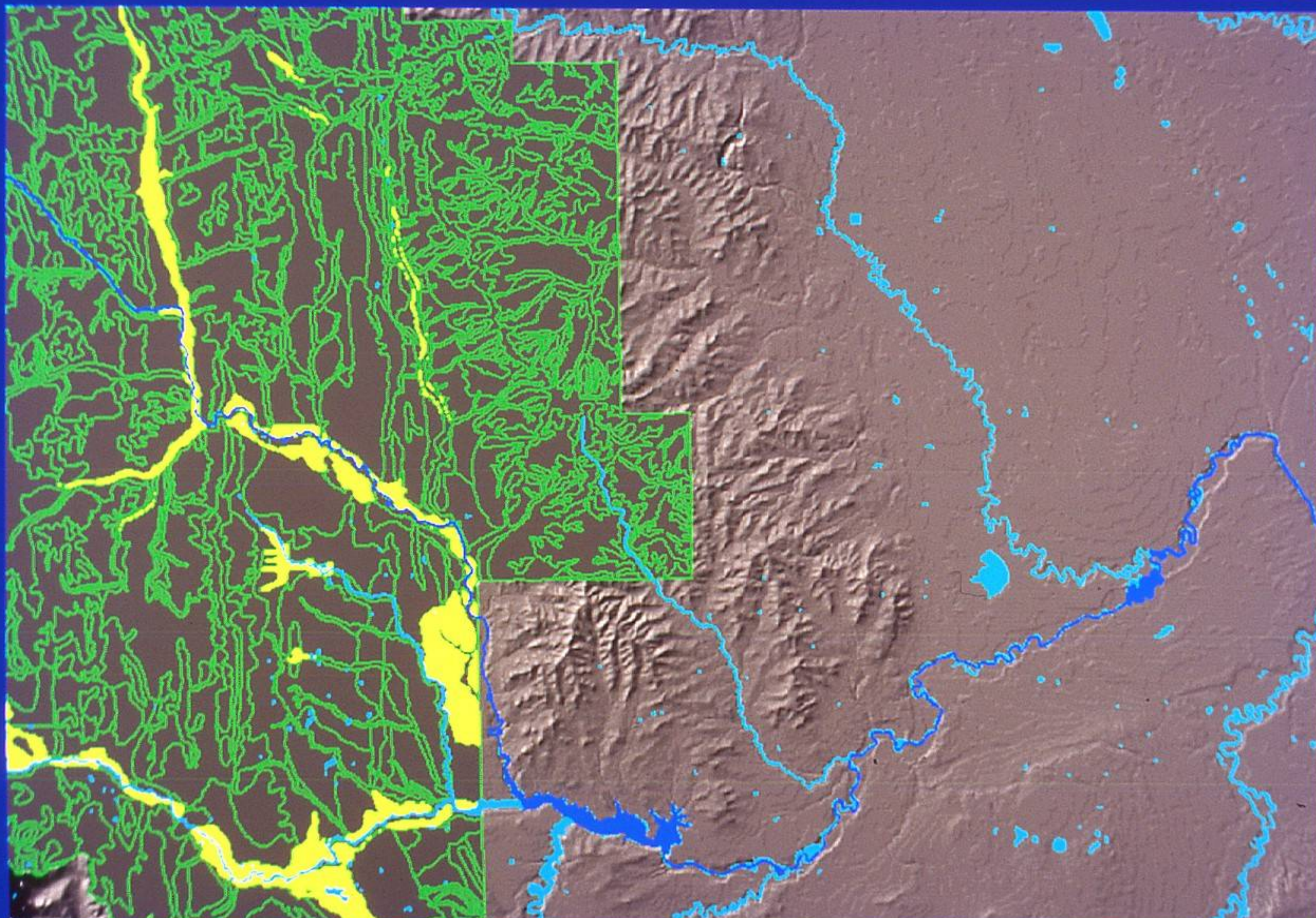
Sagebrush clusters

Ecoelement

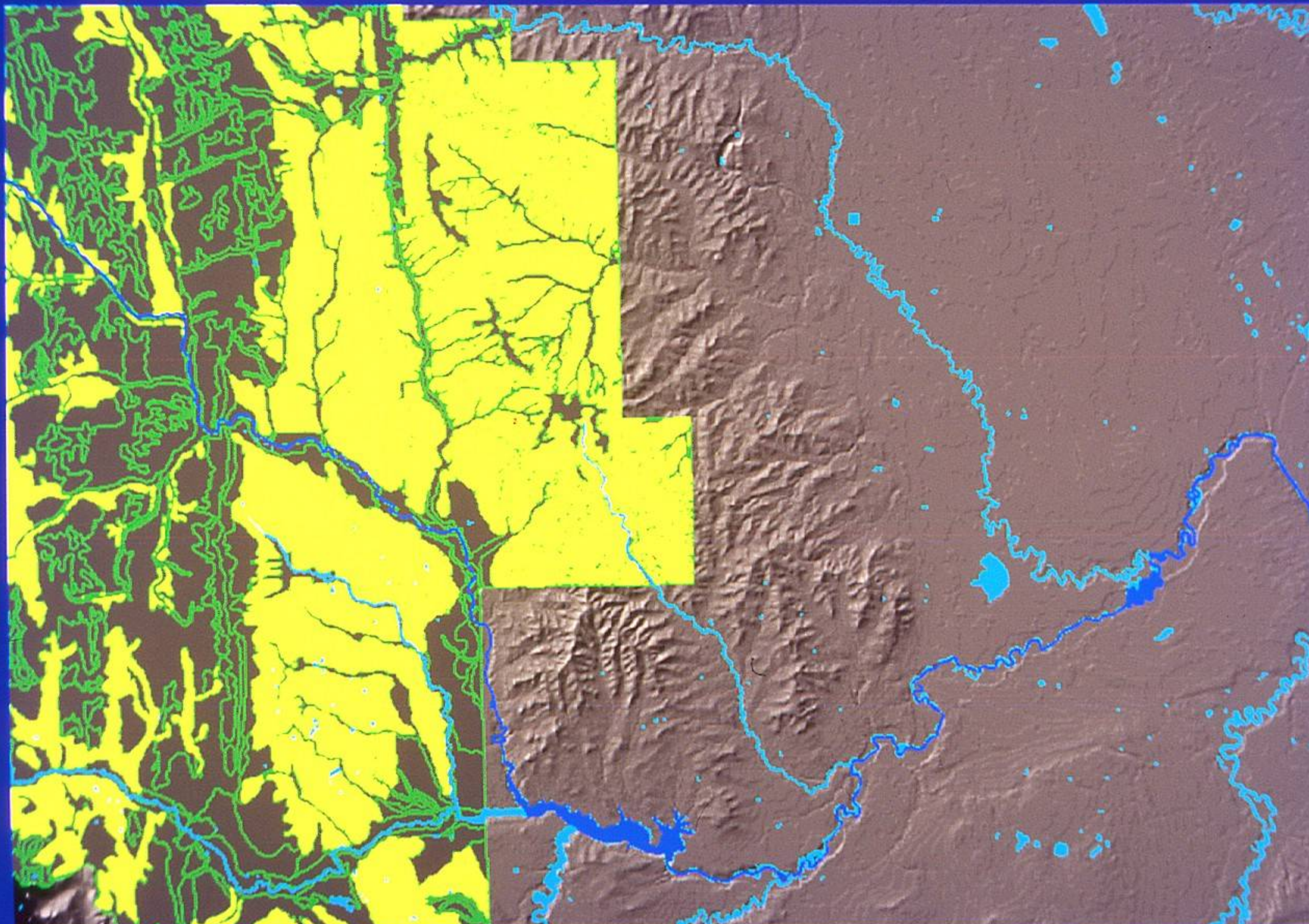
Porcupine Hills ELC: Fluvial Ecosections



Porcupine Hills ELC: Glacialfluvial Ecosections



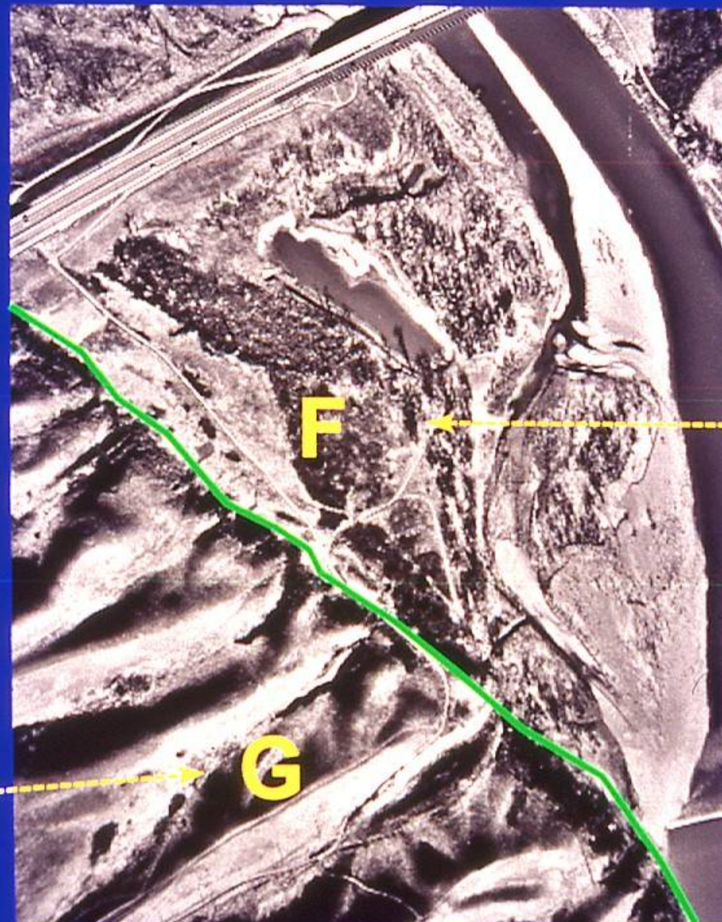
Porcupine Hills ELC: Morainal Ecosections



Mapping the ELC: Lethbridge Valley

- Using the aerial photographs, begin with the major landscape divisions such as morainal, lacustrine, glacial-fluvial, fluvial and so on..

Continental glacier melt water and current fluvial action are responsible for defining the depth and incisions of the valley walls



Fluvial process have been and are currently active in shaping the morphology of the valley floor.

Mapping the ELC: continued

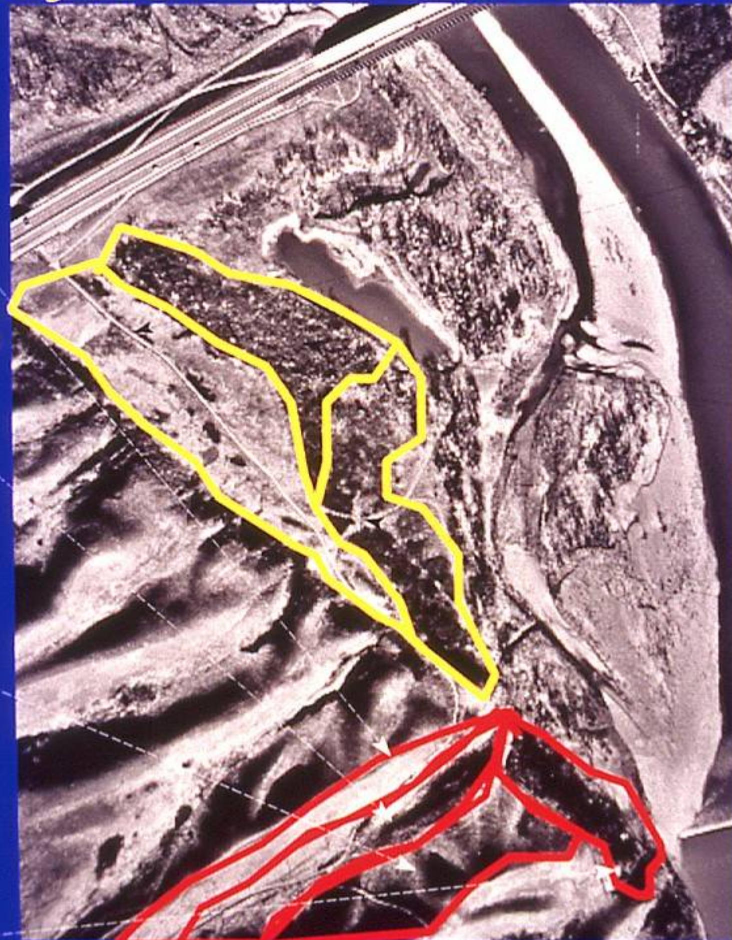
- Next, focus on the ecosections. Major ecosections on the glacial-fluvial terrain are associated with slope and aspect . On the riparian zone they are associated with elevation (moisture)

South facing, steep slope, xeric, gramma dominant. (G1.1)

Coulee trough, moderate slope, mesic, crested wheatgrass (G2.1)

North facing, steep slope, subxeric, buckbrush (G3.1)

East facing, steep slope, hygric, chokecherry-saskatoon (G4.1)



Level, mesic, crested wheatgrass-buckbrush dominant (F1.1)

Level, hydric, chokecherry dominant (F2.1)

Level, subhydric, buckbrush dominant (F3.1)

The Classification Table

Code	Vegetation Community	Slope	Face	Moisture
G1.1	W. whtgrass-b. gramma	steep	S	Xeric
G1.2	W.whtgrass-b. gramma	moderate	S	Xeric
G2.1	rose-buckbrush	steep	N	Xeric
G2.2	buffaloberry-chokecherry	moderate	E	Hygric
F1.1	Cr. Whtgrass-buckbrsh	level	-	Mesic
F2.1	Chokecherry	Level	-	S.hydric
F2.2	S.brome-poplar	Level	-	S.hydric
F2.3	chickweed-poplar	Level	-	Hygric

Assignment Details

- Review the assignment material, familiarize yourself with the area, especially with identifying the main vegetative species

- On Thursday, as you do your field walk, make yourself a rough field map on one of the overheads, you can produce the final version later

- You will be working in groups (assigned on field day), each group will submit one final version of the ELC table and map. Ensure each group member's name appears on the final submitted version.

- The assignment is due next class.

Topics in Prairie Conservation
Module 5
Information and Research

Northern Fescue Grassland
Brush Encroachment

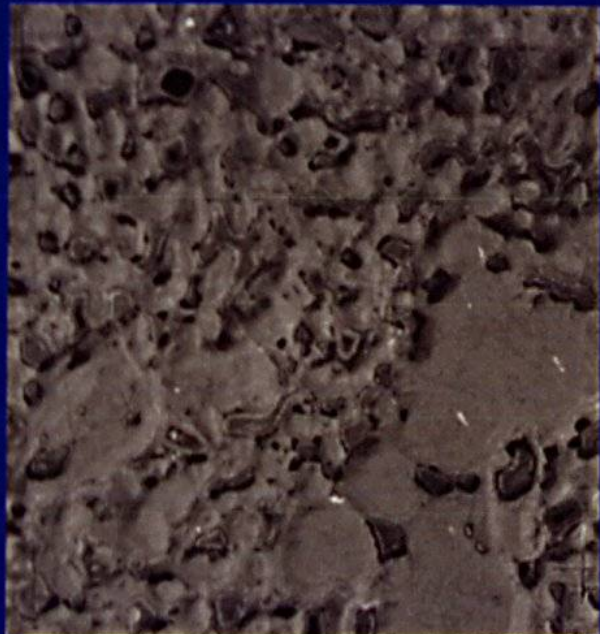
Statement and Purpose

- Brush is encroaching onto the fescue grassland; what is the degree of encroachment?
- Fire and grazing are recognized as brush control methods, are climate and topography significant factors?
- Should brush expansion be controlled? What are the ecological/agricultural pros and cons?

Methodology: Image Sources and Analysis

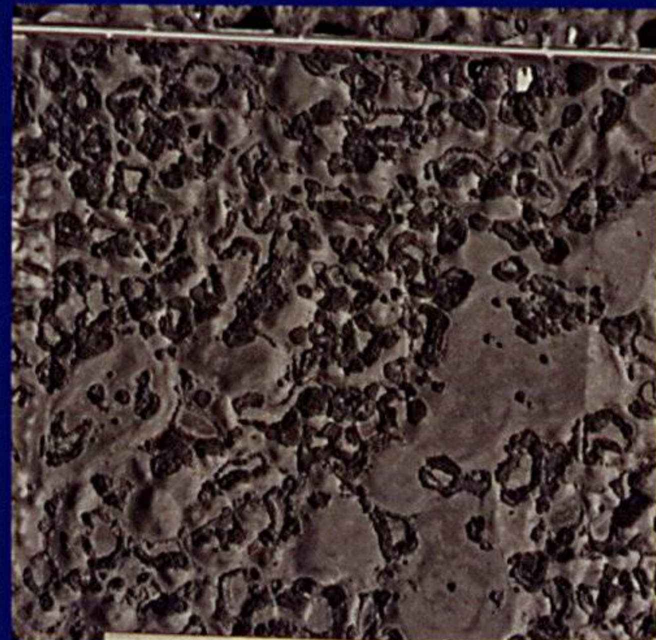
- Aerial photos from 1950, 63, 67, 74, 86, 93, 98 were scanned and evaluated.
- Image analysis using grey level theshholding and textural classifiers
- Images converted to binary maps of brush occurrence; area derived (GIS)
- Map algebra used to combine 1950 and 1998 images to show change pattern.

Results: Image Sequence Products



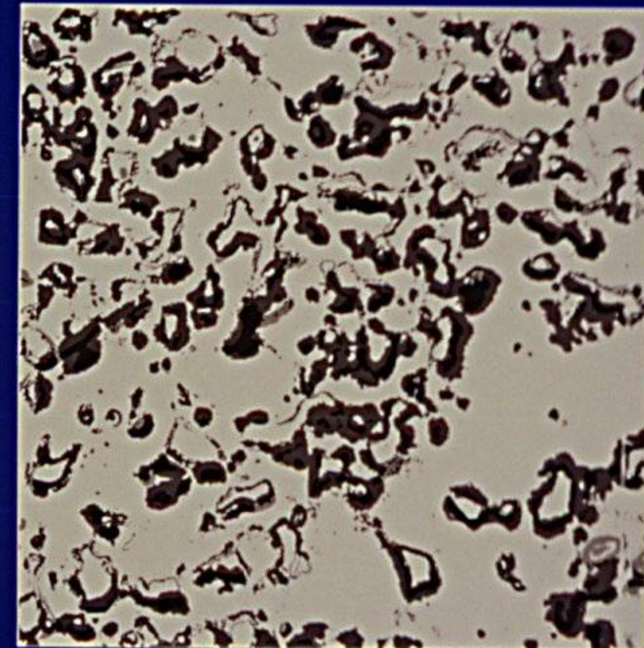
1950

166 387 m²



1998

543 682 m²



Combined mask

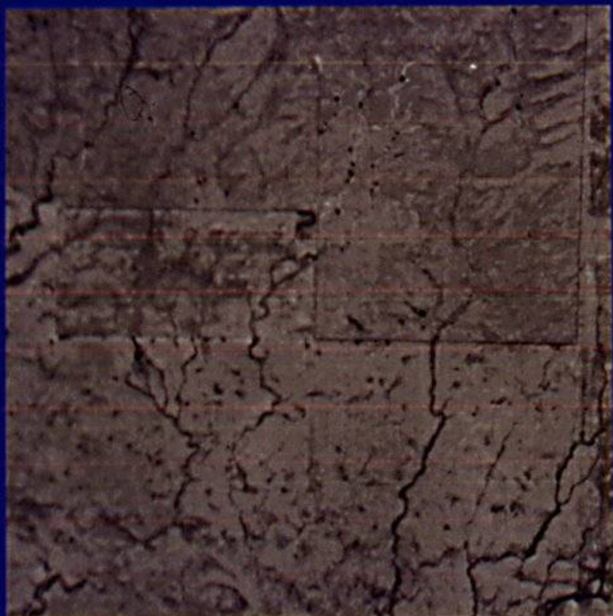
Brush area

Rumsey Natural Area - twp 34, rge 19, sec 31

Results: Image Sequence Products

Hand Hills Ecological Reserve - Sections 23 - 26

1950

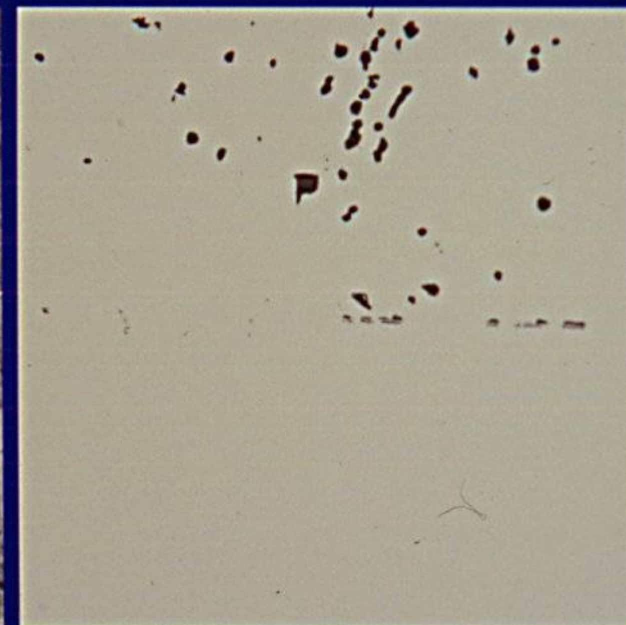


12 794 m²

1998

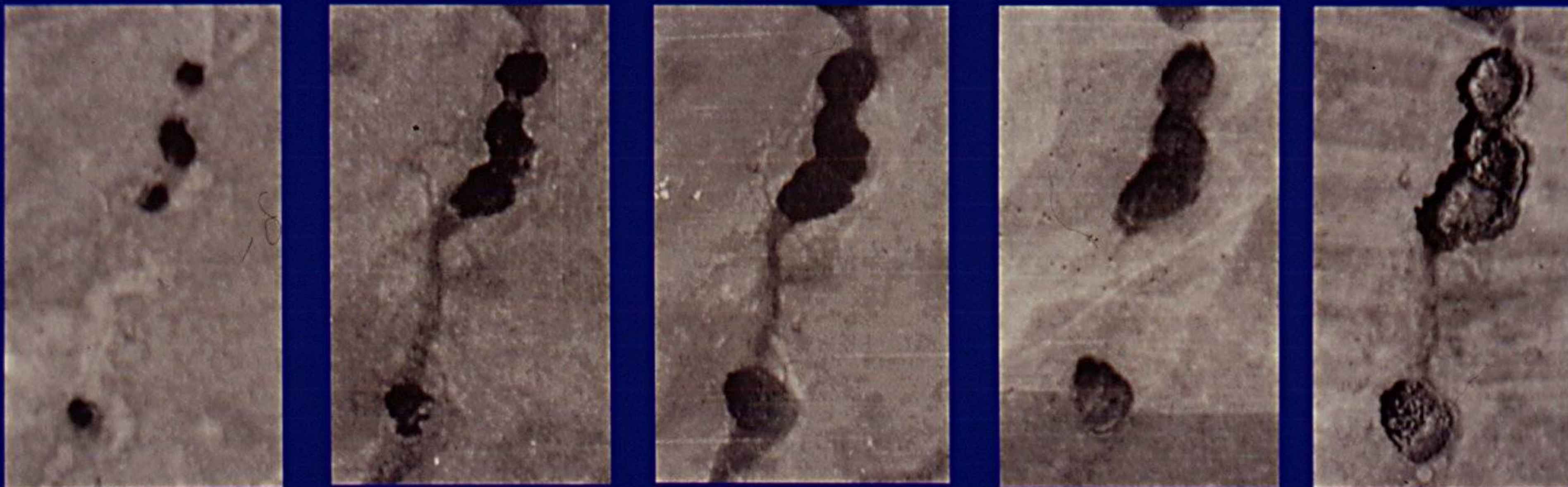
110 263 m²

Combined mask



Brush Area

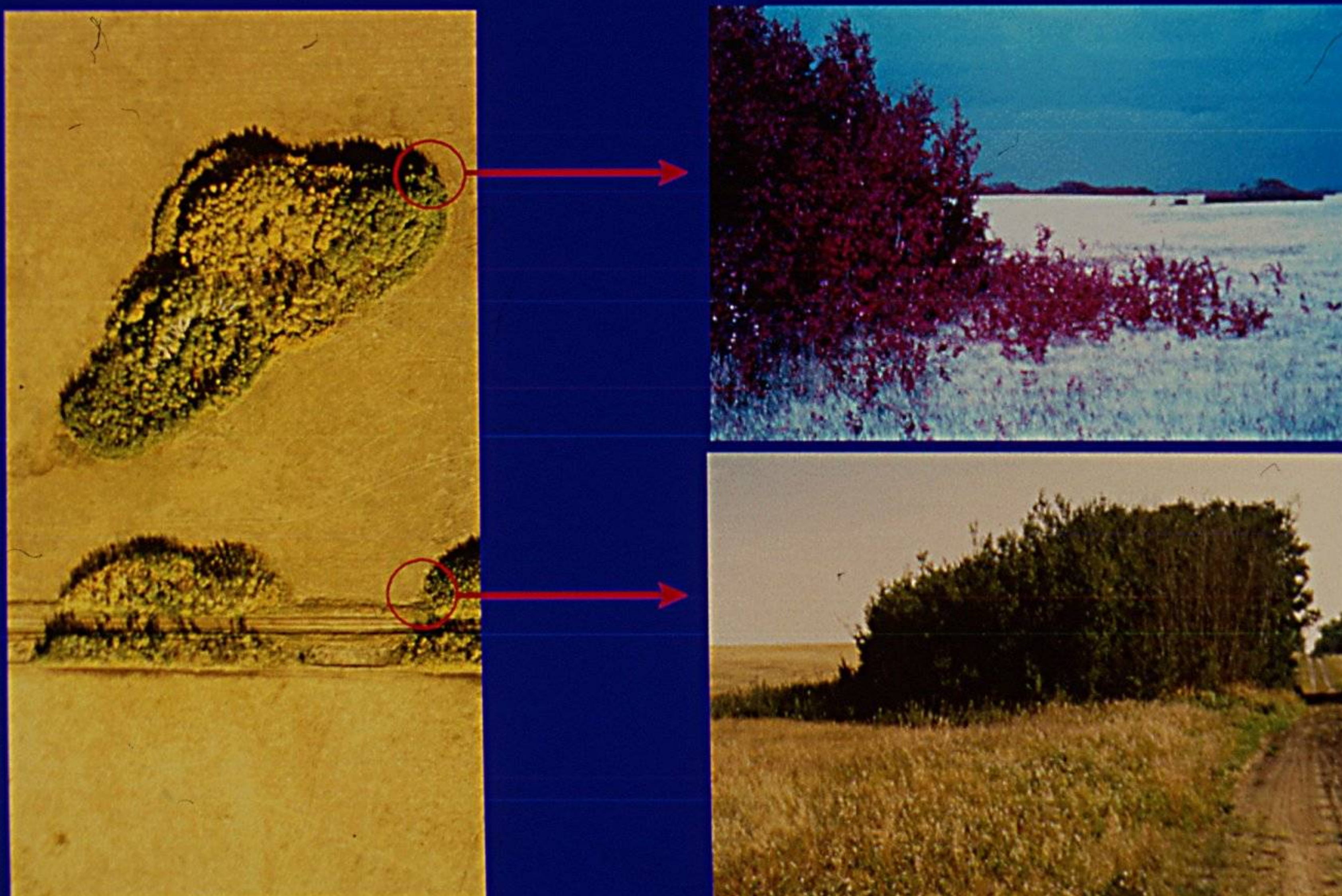
Aspen Clone Expansion: Time series



1950 1963 1974 1986 1998

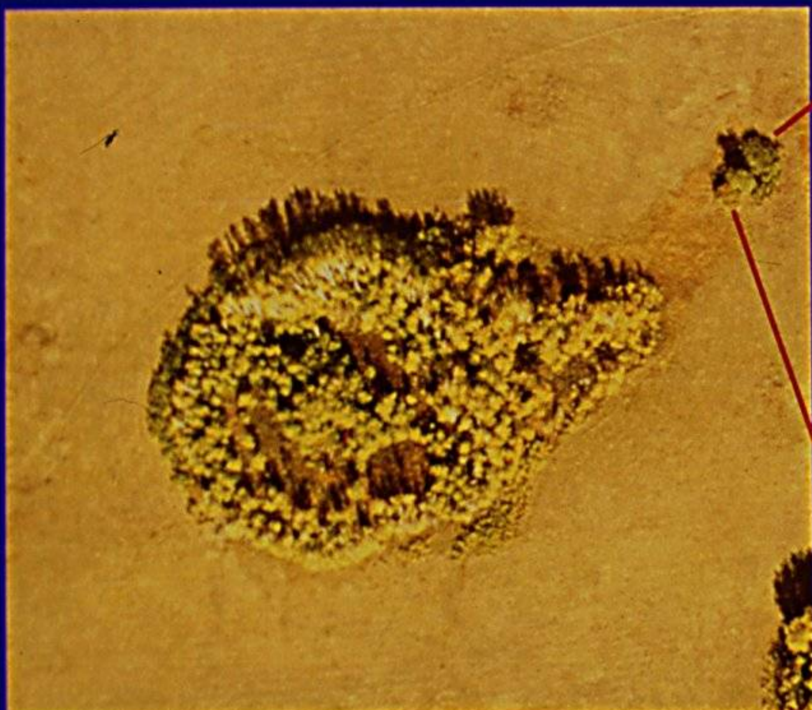
Hand Hills Ecological Reserve - Section 25

Aspen Clone Root Sucker Propogation



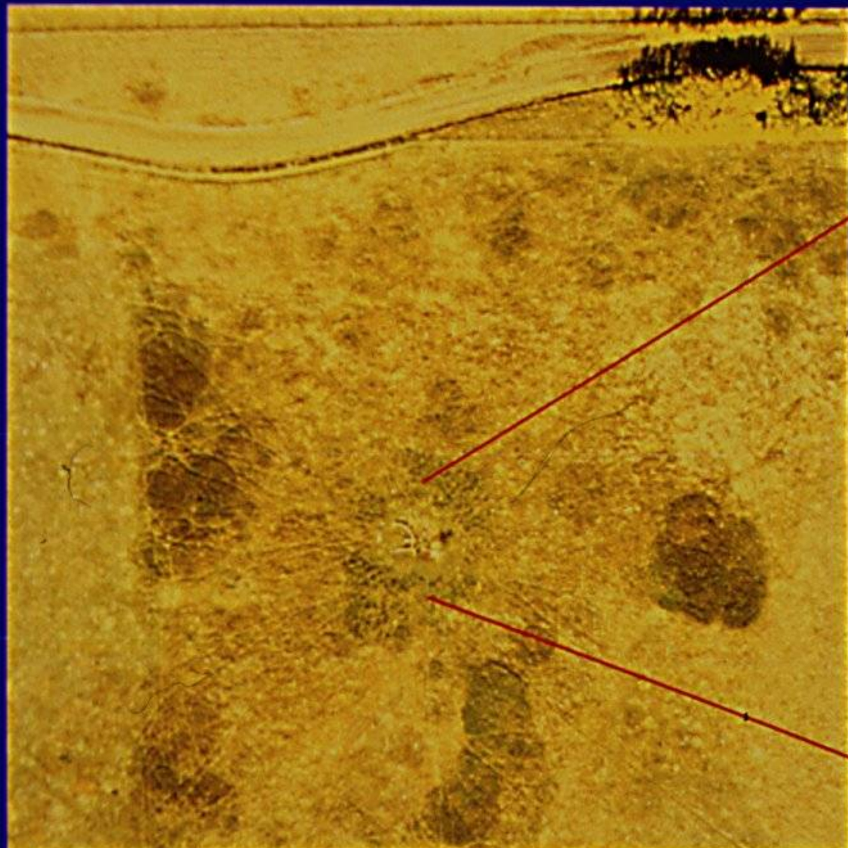
Aspen Clone Establishment

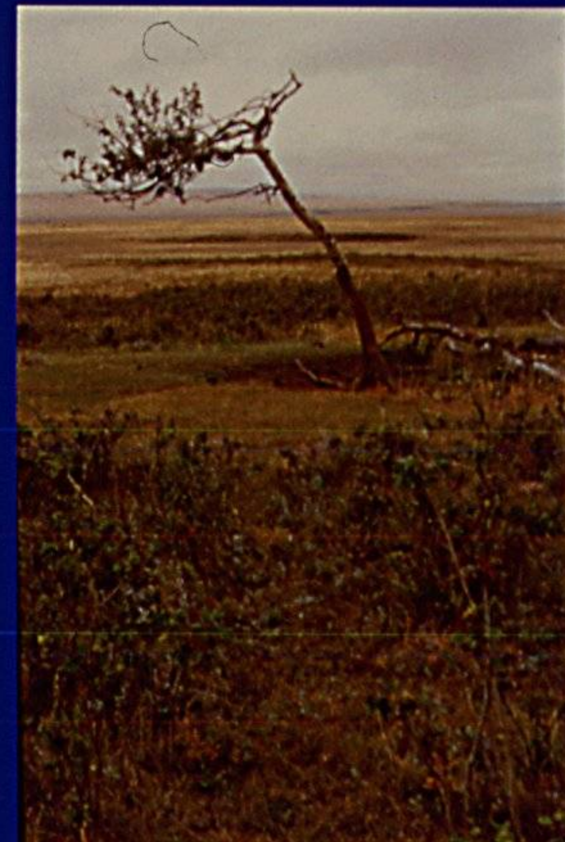
Aspen Clone Genesis: Seed germination



Ample moisture condition critical for survival following germination.

Aspen Clone Degradation: Grazing





Aspen island degradation since 1974

Brush Expansion: Limiting Factors

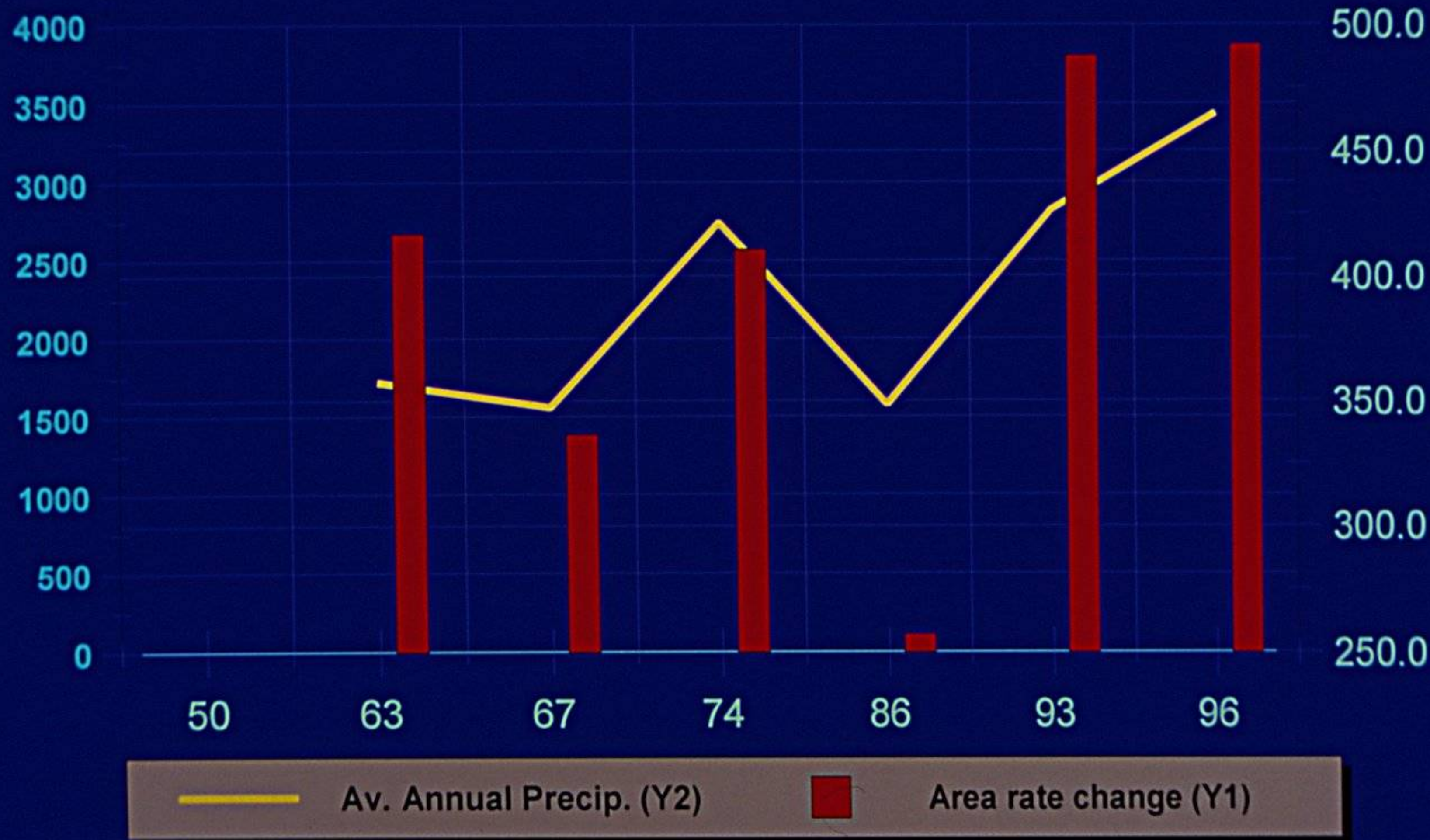
Fence line contrasts

Light to moderate grazing

Heavy to Severe grazing

Brush Expansion: Limiting Factors - Precip.

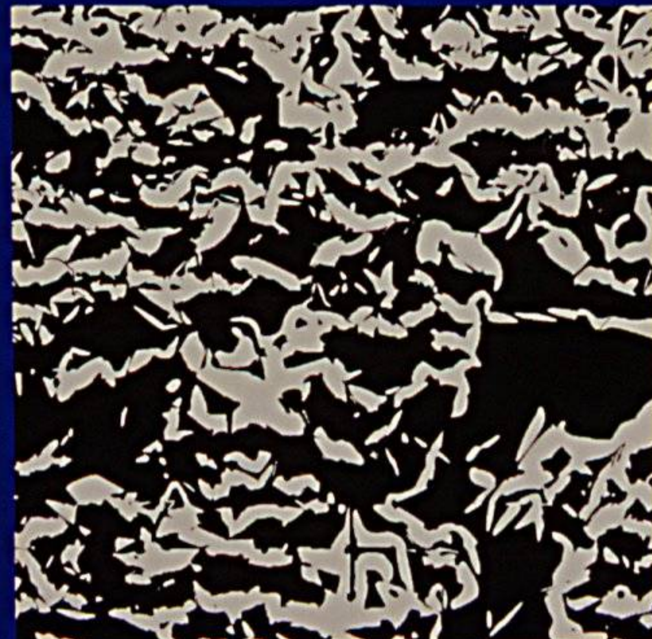
Hand Hills Ecological Reserve - Sections 23 - 26



Brush Expansion: Limiting Factors

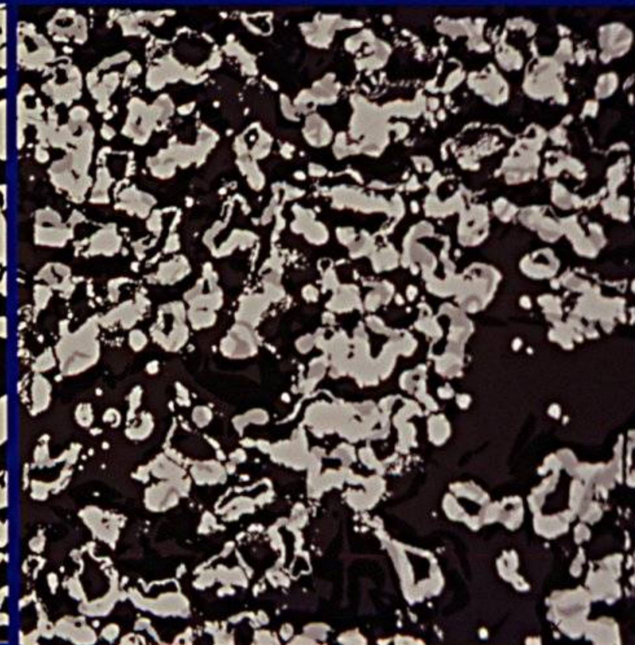
Topography

Hillshaded DEM



DEM Stratification

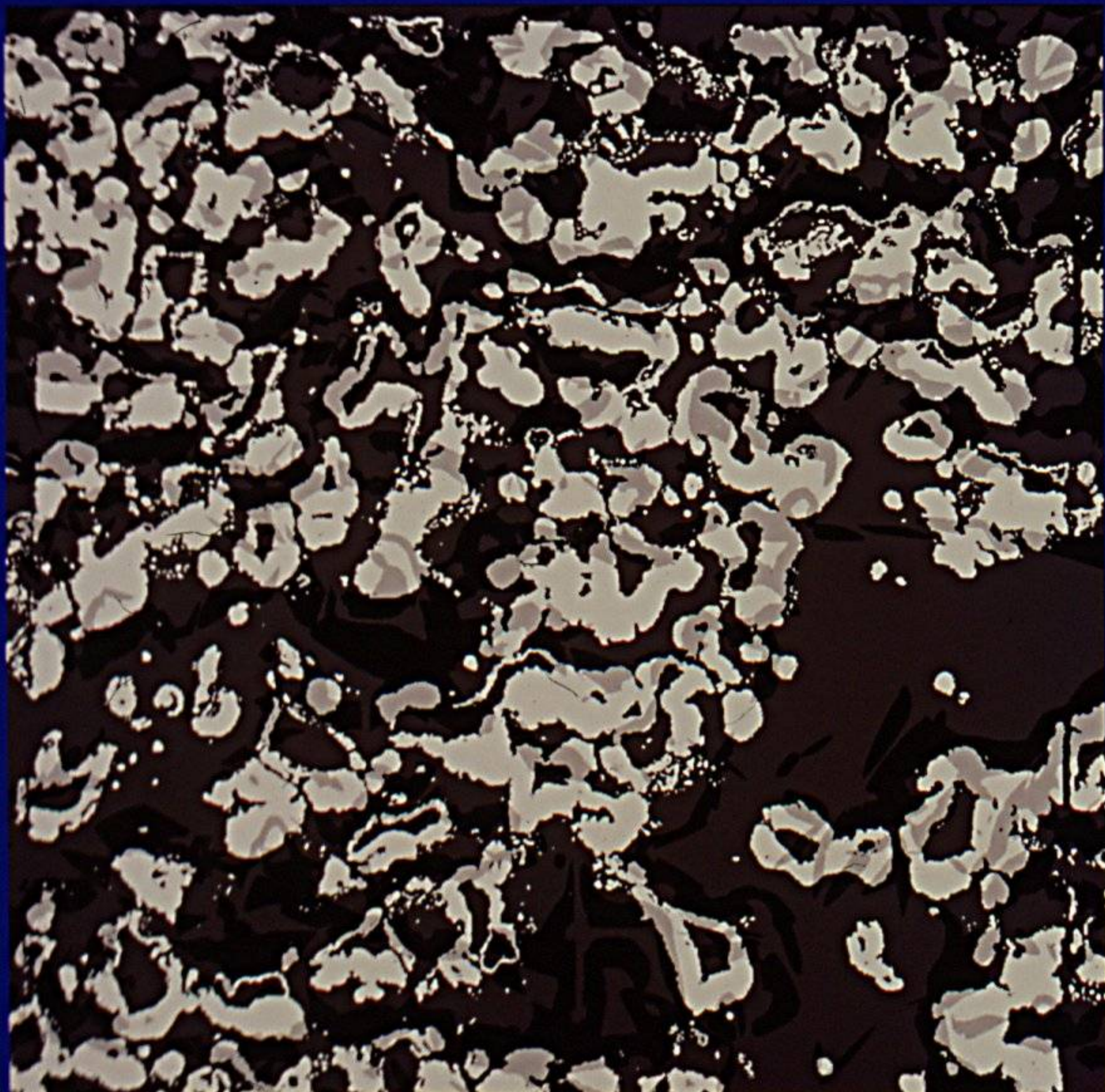
- North Facing
- < 865 m.
- < 5°



**Combined DEM Srat.
And brush coverage**

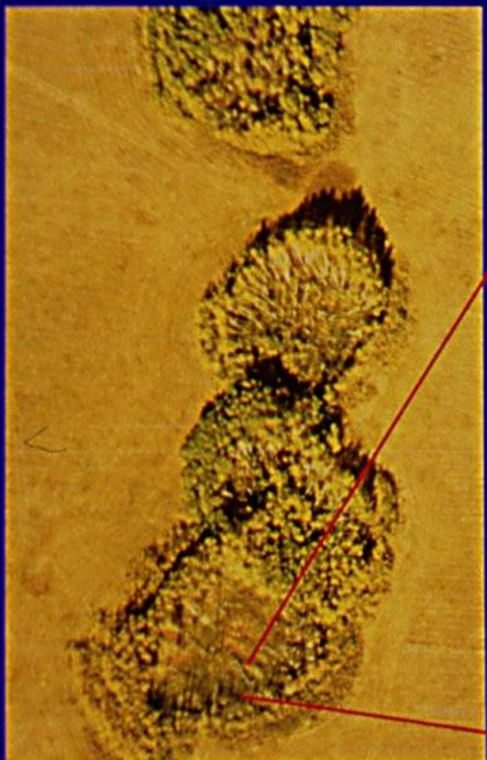
Rumsey Natural Area - twp 34, rge 19, sec 31

Brush Expansion: Limiting Factors



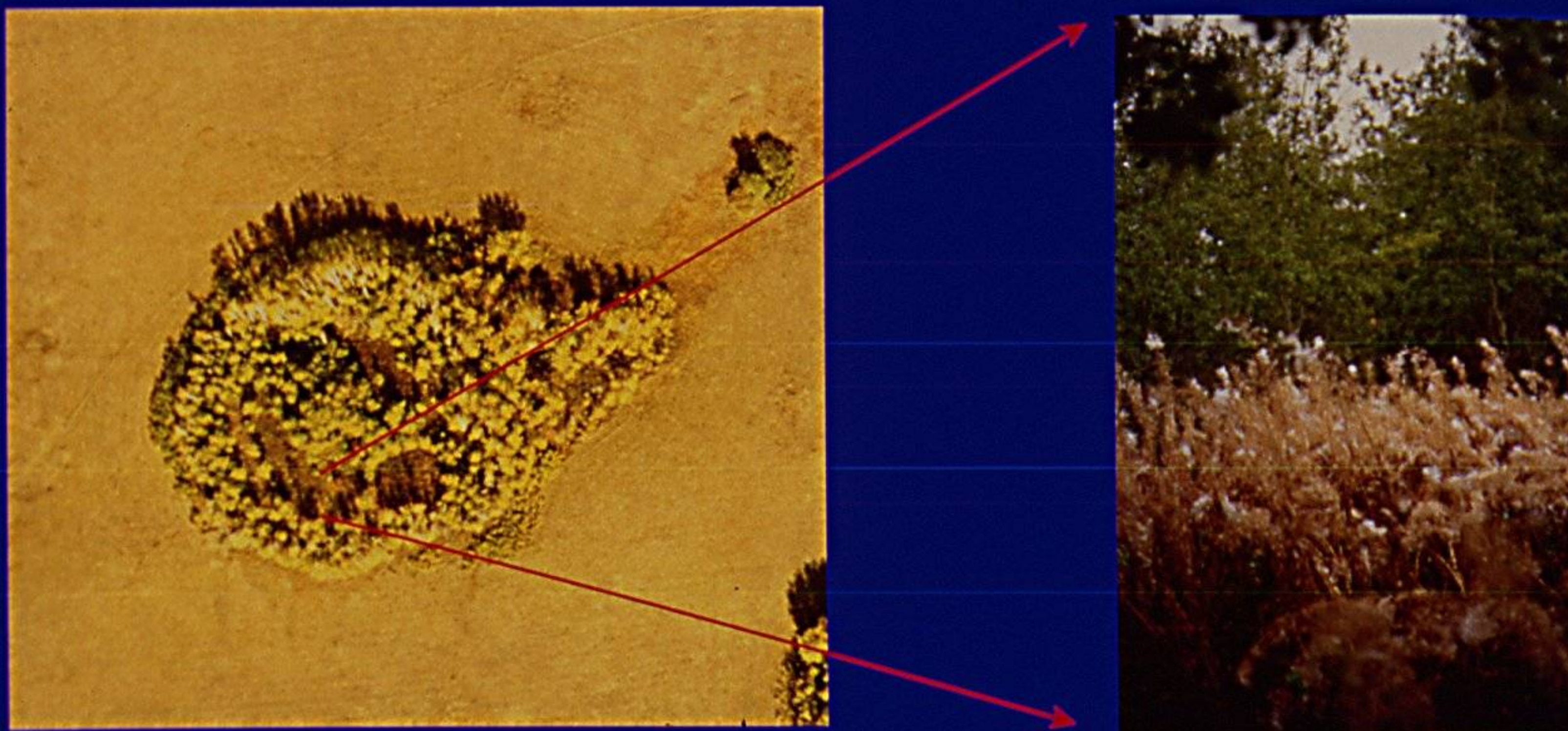
- No Brush cover DTM conditions not met.
- No Brush cover DTM conditions met.
- Brush cover present, DTM conditions not met
- Brush cover present, DTM conditions met

Aspen Succession1: What next?



Dead old growth aspen with Brome/thistle ground cover

Aspen Succession2: What next?



Fireweed (foreground), Aspen (back)

Brush Encroachment: N. Fescue Grassland

Concluding Considerations

- Should brush expansion be controlled?
- What are the ecological arguments for and against control?
- What are the agricultural pros and cons?
- Is the presentation perspective biased?

Climate addendum:
Atmospheric physical relationships

Livio Fent

Gas Laws in Meteorology: Deriving the Equation of State

Object is to relate the variables of Pressure, Volume, Mass And Temperature as they relate to gases:

- Basic definitions:
  - Density: $\rho = M/V$, M=mass, V=volume
  - Boyle's Law: $PV = P'V' = k$ (relates pressure and volume)
  - Gay-Lussac: $V - V_o = V_o \alpha_p t$ (relates volume and temperature

(constant pressure, α_p= coefficient of expansion

$$V = V_o (1+\alpha_p t)$$

$$V = V_{os} (1+\alpha_{ps} t)$$ (standard pressure)

Relating Temperature, Volume, Pressure

Combining Boyle and Gay-Lussac relationships:

$PV = P_s V_s = P_s V_{os}(1 + \alpha_p t)$, relating standard pressure, volume, and temperature

$= P_s V_{os} \alpha_p (1/\alpha_p + t)$

If $P_s V_{os} \alpha_p$ are all constant, then represent by C, also,

$1/\alpha_p + t = 273 + t = T$, therefore:

PV = CT

The Equation of State in Meteorology

Relating the equation of state to moles and Mass:

ν=volume occupied by 1 mole

$\nu = V/n$ (any volume / number of moles) or $V = n\nu$

$C = nR$ $PV = nRT$

M, V, m -----> Mass, Volume, gram-molecular weight

$n = M/m$ -------------> $PV = M/m\ RT$

From the definition of density: $V/M = 1/\rho = \alpha$

----------> $P\alpha = R/m\ T$ ---------------> $\mathbf{P = \rho\ R/M\ T}$

Equation of State with respect to Water Vapor (e)

$e=\rho_w R/m_w\ T$ (e is the partial pressure of water vapor)

---------------------------> $\rho_w=(em_w)/(RT)$

$P_d=\rho_d\ R/m_d\ T$ (equation of state for dry air)

---------------------------> $\rho_d=(P_d m_d)/(RT)$

* An increase of water vapor decreases the density of air

* An increase in temperature also decreases the density of air.

Virtual Temperature

Definition: Temperature of dry air having the same pressure as the density of moist air.

ρ_w=$(em_w)/(RT)$, ρ_d=$(P_d m_d)/(RT)$ (combining the two equations of state):

---------> $\rho_t = \rho_w + \rho_d$ ------> $= (em_w + P_d m_d)/(RT)$ note: $P= P_d+e$, $P_d=P-e$

--------------------> $= (em_w + (P-e)md)/(RT)$

--------------------> $= (em_w + (Pm_d-em_d)md)/(RT) \times Pm_d/Pm_d$

-------------------> $= Pm_{d(}((em_w/Pm_d)+(1-e/P))/RT$, $(m_w/m_d=18/28.9) = 5/8$

molecular weights of wet and dry air

Virtual Temperature

If we call $T^* = T/1-(3/8^*e/P)$, then $\rho = Pm_{\alpha}/RT^*$

Also e/P is a function of the specific humidity (q) or $T^* = T/1 - 3/5^*q$

By means of the virtual temperature it is possible to use the equation of state in terms of the total pressure and the 'molecular weight' of dry air

$P\alpha = (RT^*)/m_d$ or $P=\rho RT/m_d$ (remember, $m_d = 28.9$)

Meteorological Thermodynamics

Definitions: Internal energy of a mass of a gas defined as the total energy of all the molecules in that mass and is proportional to Temperature

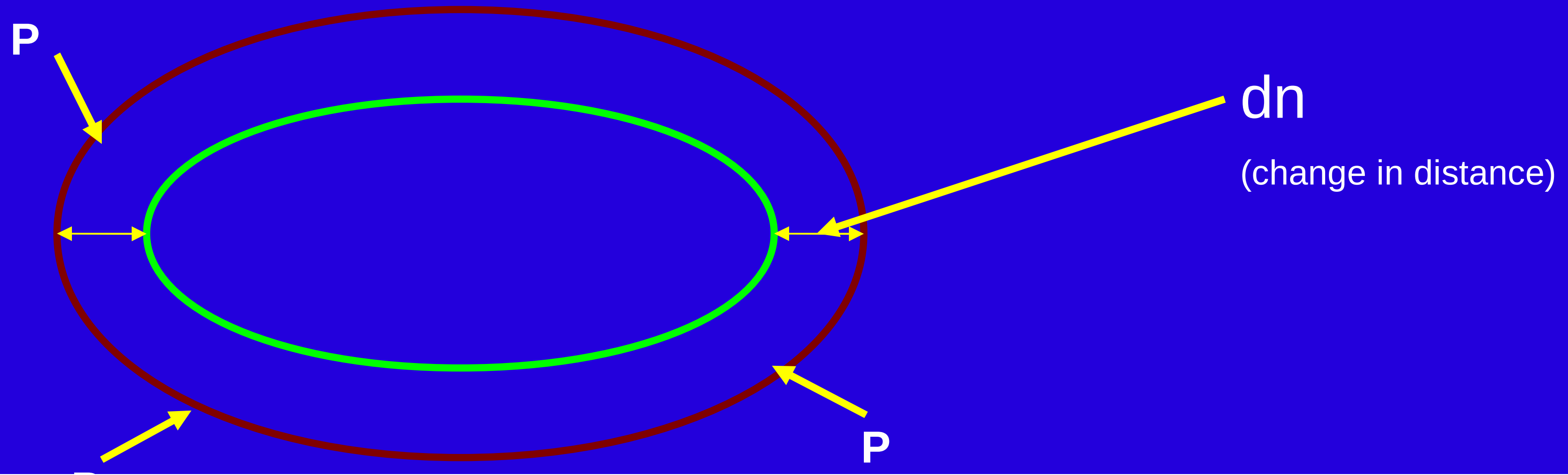
Internal Energy (dE) can be changed by adding heat (dQ) or performing work (dW) (such as compression) --------> $dE = dQ + dW$

This is a statement of the First Law of Thermodynamics

Analyzing the 'dW' (Work) term or Compression

Work done on a gas (compression) is expressed as pressure (P). Pressure is defined as the Force per unit Area:

$$P = F/A \quad \text{or} \quad F = PA$$



Continuing with the 'Work' term..

------> $dW = F\,dn$ change in work is the force (F) acting on the distance (dn)

Since $F = PA$

Then $dW = PA\,dn$

And $-dV = A\,dn$

Then $dW = -P\,dV$ change in work defined in terms of pressure and volume

-------------------> $dE = dQ - P\,dV$ substituting for dW into the first law relationship

Continuing with First Law substitutions..

---------------> $dQ = MC_v dT$ (mass X specific heat at constant volume X change in temp)

-----------------> First Law = $dE = MC_v dT$ if volume is constant ie $PdV = 0$

-----------------> $MC_v dT = dQ - PdV$,

At constant pressure, then,

----------------> $dE = MC_v dT = MC_p dT - PdV$

Or ------------> $M(C_p - C_v)dT = PdV$

The First Law and the Equation of State

-------------> the equation of state: $PV=nRT$

As a differential equation: $P\,dV + V\,dP = nR\,dT$

In a constant pressure process $dP = 0$, so:

-------------> $P\,dV = nR\,dT$

Also, from $M(C_p\text{-}C_v)dT = P\,dV$, substituting for $P\,dV$

---------------> $M(C_p\text{-}C_v)dT = nR\,dT$ (temperature change is canceled)

---------------> $C_p\text{-}C_v = nR/M = R/m$ where m = the gram-molecular weight,(n/M) = (1/m)

---------------> $C_p/C_v = 1 + R/mC_v$ defining the ratio of specific heats

Atmospheric considerations..

With volume measurements being difficult in meteorological applications, it is convenient to consider:

-------------> $MC_v dT = dQ - PdV$

Dividing by M -----> $C_v dT = dQ/M - PdV/M$, $(v/M = \alpha)$

---------------> $dq = C_v dT - Pd\alpha$

Heat change per unit mass

change in specific volume

Considered the general expression for the conservation of energy

Towards a formal definition of the first law of thermodynamics

------> the equation of state, $P\alpha = R/m\ T$ remember, $\alpha=1/\rho$

Differentiating -----------> $P\,d\alpha + \alpha\,dP = R/m\ dT$

--------------------> $P\,d\alpha = R/m\ dT - \alpha\,dP$

--------------------> $dq = C_v dT + R/m\ dT - \alpha\,dP$

Since $C_p - C_v = R/m$, then $C_p = C_v + R/m$

Noting that -------> $dq = (C_v + R/m)\,dT - \alpha\,dP$

Then: ---------------> **$dq = C_p\,dT - R/m\ T\,dp/p$**

Adiabatic Processes

- Processes where no heat is added or taken away, that is, $dq = 0$

Using the definition for entropy, S

----------------> $dS = dq/T = C_p dT/T - R/m \, dP/P = 0$

$= C_p dT/T = R/m \, dP/P$

Adiabatic Processes cont'd

Continuing with $C_p dT/T = R/m\ dP/P$:

Integrating: -------------->

$$\int_{T_o}^{T} Cp\ dT/T = \int_{P_o}^{P} R/m\ dP/P$$

------> $C_p \ln T/T_o = R/m \ln P/P_o = R/m \ln P - R/m \ln P_o$

------> $C_p \ln T/T_o = R/m \ln P/P_o$

$(T/T_o)^{Cp} = (P/P_o)^{R/m}$

$T/T_o = (P/P_o)^{R/mCp}$, where $R/mCp = 0.286$

$T/T_o = (P/P_o)^{0.286}$

The Hydrostatic Equation

------------> Relating pressure with height

dP = dP/dz = -gρ dz = **-g Pm/RT dz**

From C_p dT/T = R/m dP/P,   dP = C_P dT/T * m/R P

And the hydrostatic equation: dP = -g Pm/RT dz

We have ------------------------> α T = -g dz/C_p

Where -g/C_p is the dry adiabatic rate of change

Or 1˚/100m, AKA the dry adiabatic lapse rate

The Hypsometric formula

-----> $dP = - g\rho\, dz$, the hydrostaic equation

-----> $\rho = Pm_d/RT^*$, the equation of state

Combining ---------> $dP = - Pm_d/RT^* g\, dz$

-----------------------> $dP/P = - m_d/RT^* g\, dz$

Most common to express: $dP/P = -m_d g/RT^* (z_2-z_1)$

Integrating, we get : $\ln P_2 - \ln P_1 = -m_d g/RT^* (z_2-z_1)$

Or -----> **$z_2-z_1 = RT^* / m_d g (\ln P_2 - \ln P_1)$**

ie. the hypsometric formula

Potential Temperature and the Stability of Dry Air

Definition:

From $T/T_o = (P/P_o)^{R/md\ Cp\ =\ 0.286}$

$\Theta = T_o = T\ (1000/P)^{0.286)}$ at $P_o = 1000mb$

The potential temperature (θ): sample air would achieve an actual temperature equal to its potential temperature when brought dry-adiabatically to a pressure of 1000mb ---> dry-adiabatic lines (tephigram) constant potential-temperature lines – each can be designated according to its potential temp. (also known as isentropic lines or no entropy change).

Potential Temperature and the dry-adiabatic process

A dry adiabatic process in the atmosphere is a constant potential temperature process (follow the line), this process is valid at all relative humidities below 100% - process is valid until saturation is reached

The principle cause of adiabatic cooling is upward motion. The cooling rate is 1 degree C for every 100 m of lift.

Dry adiabatic vs. environmental lapse rates

The environmental lapse rates (temperature profile) is obtained via radiosondes on balloons. It is the current temperature profile of the atmosphere.

- If the temperature lapse rate is the same as the adiabatic lapse rate it has a *dry adiabatic lapse rate*
- If it is greater then it is called the *super adiabatic lapse rate*

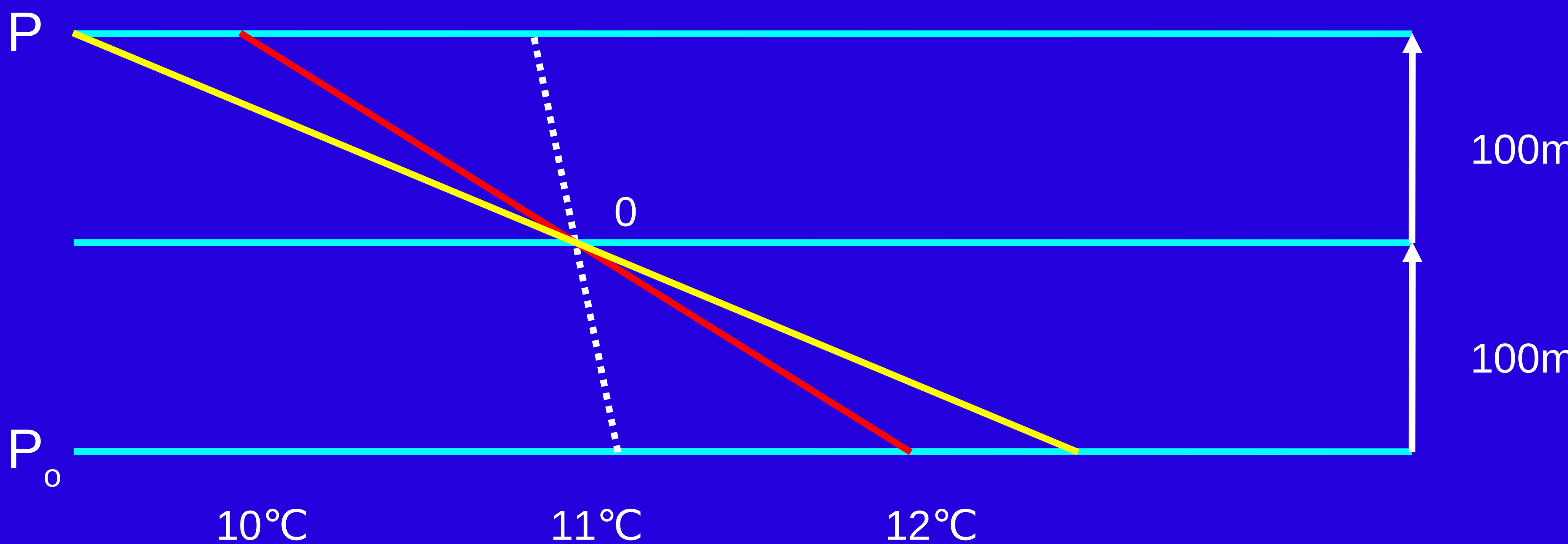
Environmental lapse rate and atmospheric stability

Stability is defined as that condition in the atmosphere in which vertical motions are absent or definitely restricted.

Instability is defined as the state where in vertical movement is prevalent.

The surrounding atmosphere is defined as *stable* or *instable* depending on whether the temperature lapse rate brings about a decrease or increase of the buoyancy forces on an upward-moving parcel of air

Atmospheric Stability



A. Stable Atmosphere, Parcel returns To point 0
γ

Adiabatic Lapse rate
γ_o

B. Unstable Atmosphere, Parcel continues Rise from point 0
γ

Atmospheric Stability con't

Comparing lapse rates:

$\gamma < \gamma_o$ = stable .... $\partial\Theta/\partial z > 0$

$\gamma = \gamma_o$ = neutral .... $\partial\Theta/\partial z = 0$

$\gamma > \gamma_o$ = unstable .... $\partial\Theta/\partial z < 0$

Since the dry adiabatic rate
Is a line of constant temperature

Potential Temperature as an expression of State

A practical way to represent the equation of state in the atmosphere is in terms of temperature pressure and potential temperature.

-------------> $\theta = TP^{-R/m\,Cp} = T(\alpha/\alpha_o)^{R/m\,Cv}$

Using the logarithmic form:

-------------> $\ln\theta = \ln T - R/mC_p \ln P + R/mC_p \ln P_o$

In differential form:

-------------> $d\theta/\theta = dT/T - R/mC_p\, dP/P$