Hydrological Applications of LST Derived from AVHRR

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Outline

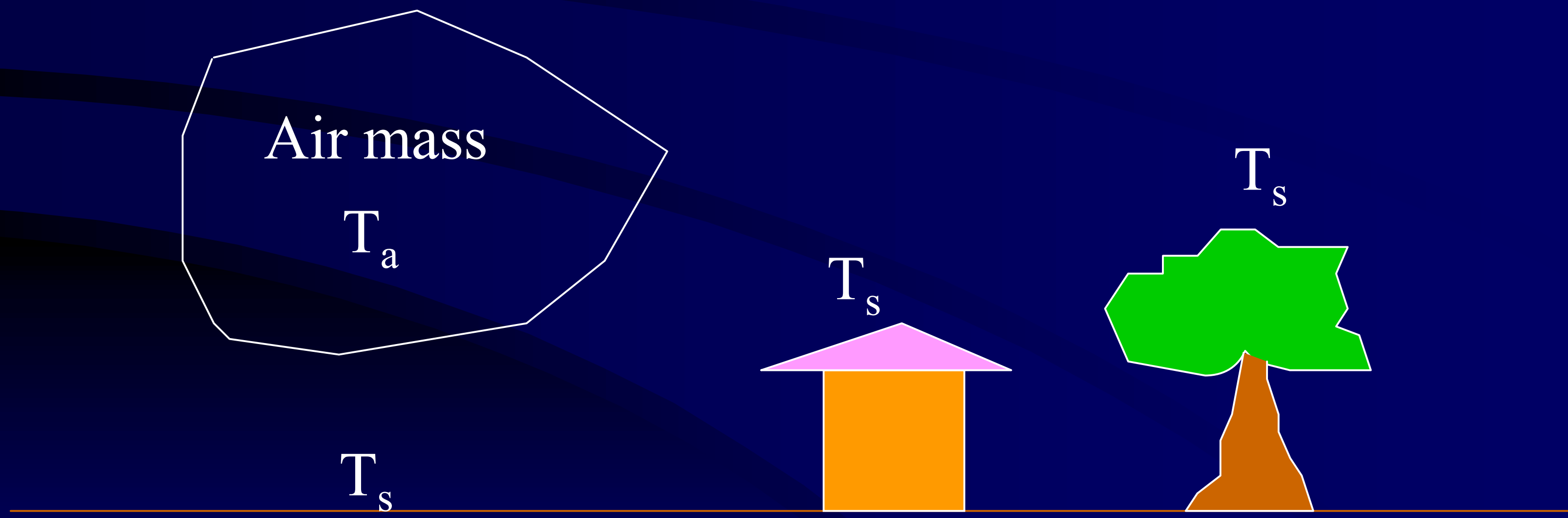
- Introduction
- All about LST
- Model Development (T_a Vs LST)
- Applications
  - Potential Evapo-Transpiration
  - Soil Moisture Monitoring/ Hydrologic Modeling
  - Drought Indices (KBDI, PDSI)
- Conclusion

Introduction

- AVHRR - Advanced Very High Resolution Radiometer
- It is a sensor aboard NOAA - POES.
- AVHRR has one visible, one near infrared and three thermal infrared channels
- Currently NOAA 12, 14, 15, 16 are operational.
- Research focus on thermal channels

All about LST

- Land Surface Temperature (LST), T_s is the temperature just above the land surface
- LST is different from air temperature, T_a



LST from AVHRR

- Split-window Algorithm to extract LST
  - to account for absorption in measured signal due to CO_2, water vapor etc.. present in the atmosphere
- Ulivieri et al. (1994):

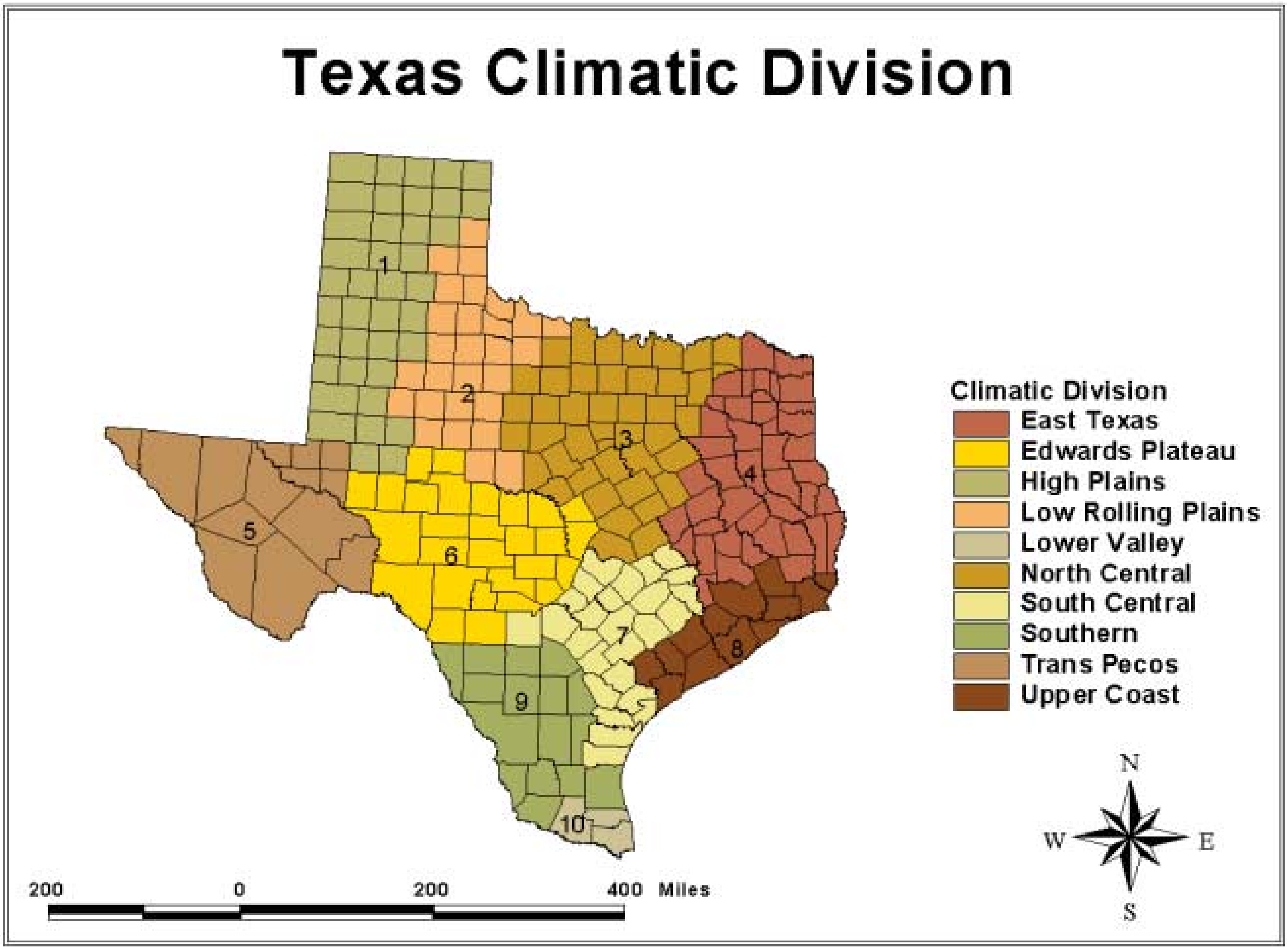
$$LST = T_4 + 1.8(T_4 - T_5) + 48(1-\varepsilon) - 75\Delta\varepsilon$$

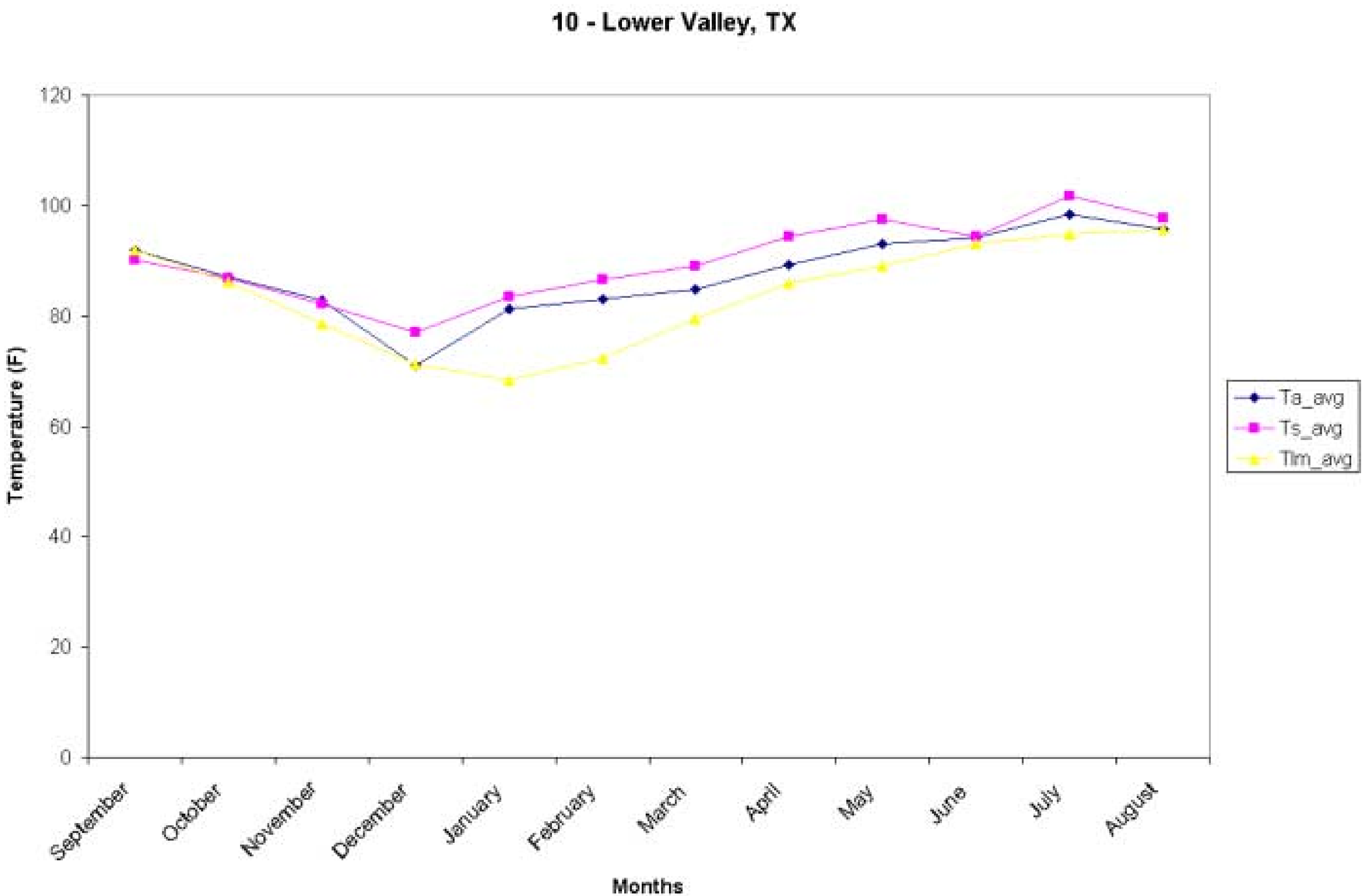
Where:

T_4	-	Channel 4 temperature (ºK)
T_5	-	Channel 5 temperature (ºK)
ε	-	Average emissivity $(\varepsilon_4 + \varepsilon_5)/2$
$\Delta\varepsilon$	-	$\varepsilon_4 - \varepsilon_5$.

LST and air temperature

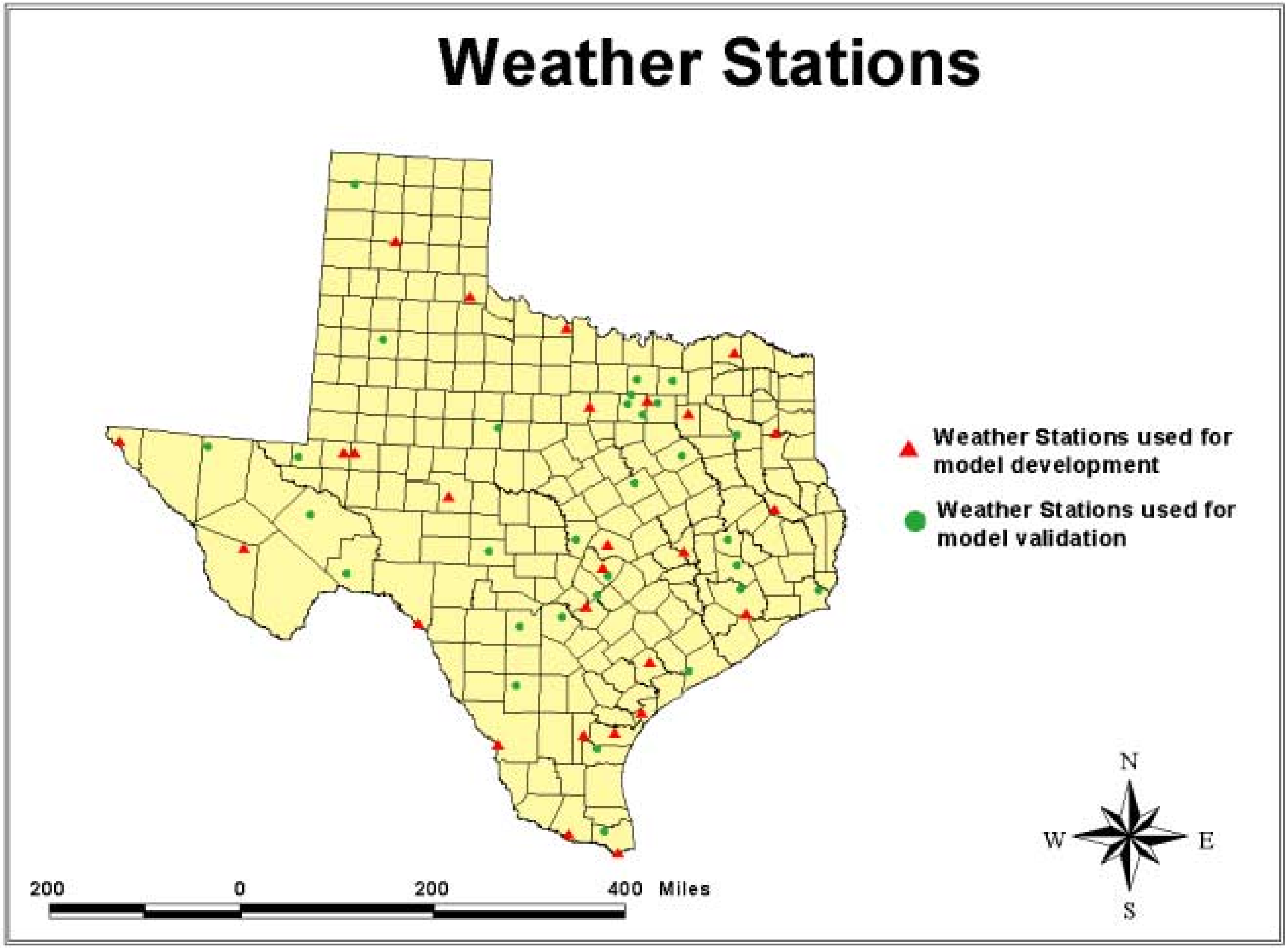
- Maximum and Minimum air temperatures
- T_a (max) from afternoon overpass
  - T_a(min) from morning overpass
- T_s and T_a (max) are linearly related
- However, this relationship varies with location
- Hence, long term monthly mean air temperature is included in the model


Texas Climatic Division
1
2
3
4
5
6
7
8
9
10
Climatic Division
East Texas
Edwards Plateau
High Plains
Low Rolling Plains
Lower Valley
North Central
South Central
Southern
Trans Pecos
Upper Coast
N
W
E
S
200
0
200
400 Miles


10 - Lower Valley, TX
Temperature (F)
120
100
80
60
40
20
0
September
October
November
December
January
February
March
April
May
June
July
August
Months
Ta_avg
Ts_avg
Tlm_avg

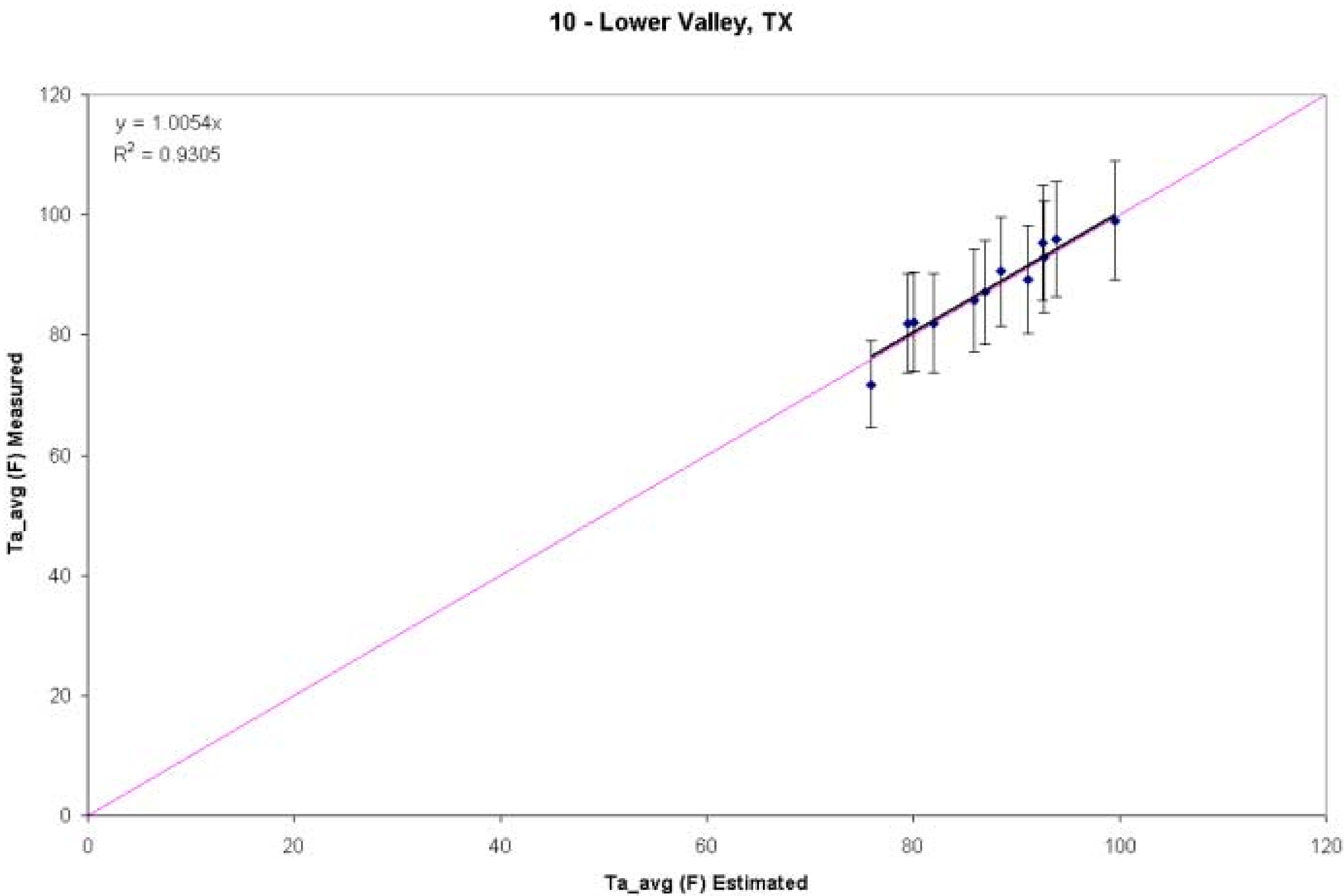
Model Development

- Multiple Linear Regression Model
  - $T_a = m_1 T_s + m_2 T_{lm}$
- T_a (max) from 27 weather stations was used for model development
- T_a (max) from 30 weather stations was used for model validation (independent dataset)
- T_s Vs T_a (max) relationships has been established for each of the10 climatic zones of Texas


Weather Stations
Weather Stations used for model development
Weather Stations used for model validation
200
0
200
400 Miles
N
W
E
S

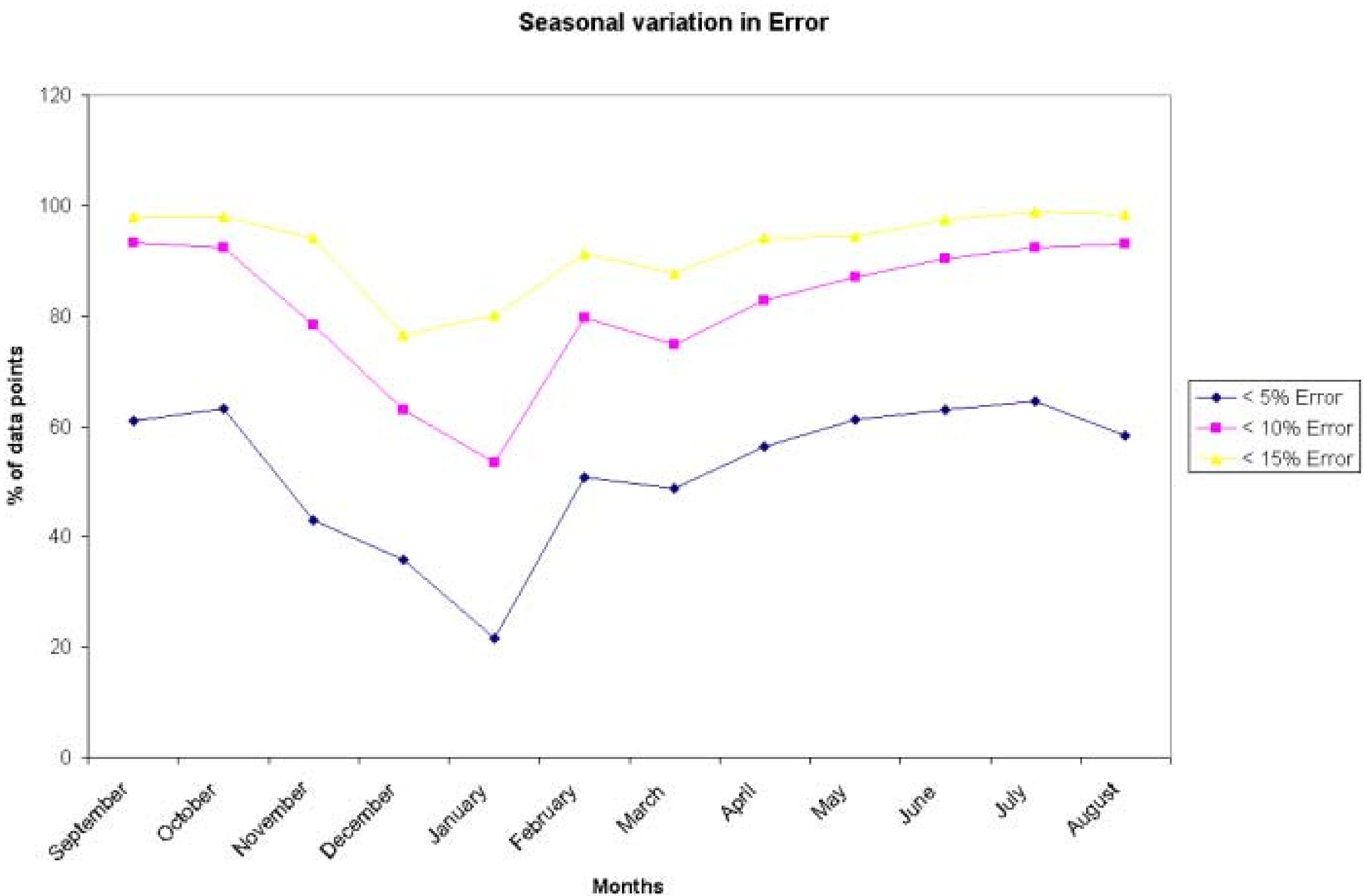
Regression Coefficients

Climatic Zone	m_1	m_2	R^2
1	0.73	0.19	0.93
2	0.66	0.31	0.94
3	0.86	0.14	0.95
4	0.66	0.40	0.87
5	0.65	0.24	0.96
6	0.62	0.35	0.93
7	0.69	0.29	0.94
8	0.62	0.40	0.90
9	0.69	0.29	0.94
10	0.70	0.29	0.94


10 - Lower Valley, TX
y = 1.0054x
R2 = 0.9305
Ta_avg (F) Measured
Ta_avg (F) Estimated
0
20
40
60
80
100
120

Model Validation

Climatic Zone	Slope	R^2
1	1.02	0.88
2	0.96	0.90
3	0.99	0.92
4	0.99	0.90
5	1.01	0.92
6	1.03	0.86
7	1.01	0.95
8	1.00	0.89
9	1.01	0.95
10	1.01	0.93


Seasonal variation in Error
120
100
80
60
40
20
0
% of data points
September
October
November
December
January
February
March
April
May
June
July
August
Months
< 5% Error
< 10% Error
< 15% Error

Applications

- Potential Evapo-Transpiration
- Soil Moisture Monitoring/ Hydrologic Modeling
- Drought Indices
  - KBDI
  - PDSI

Potential Evapo-Transpiration

- Energy Balance Model

$$R_n = \lambda E + H + G$$

Where:

R_n	=	net radiation flux ($kJ.m^{-2}.s^{-1}$),
λE	=	latent heat flux,
H	=	sensible heat flux to the air,
G	=	sensible heat flux to the soil.

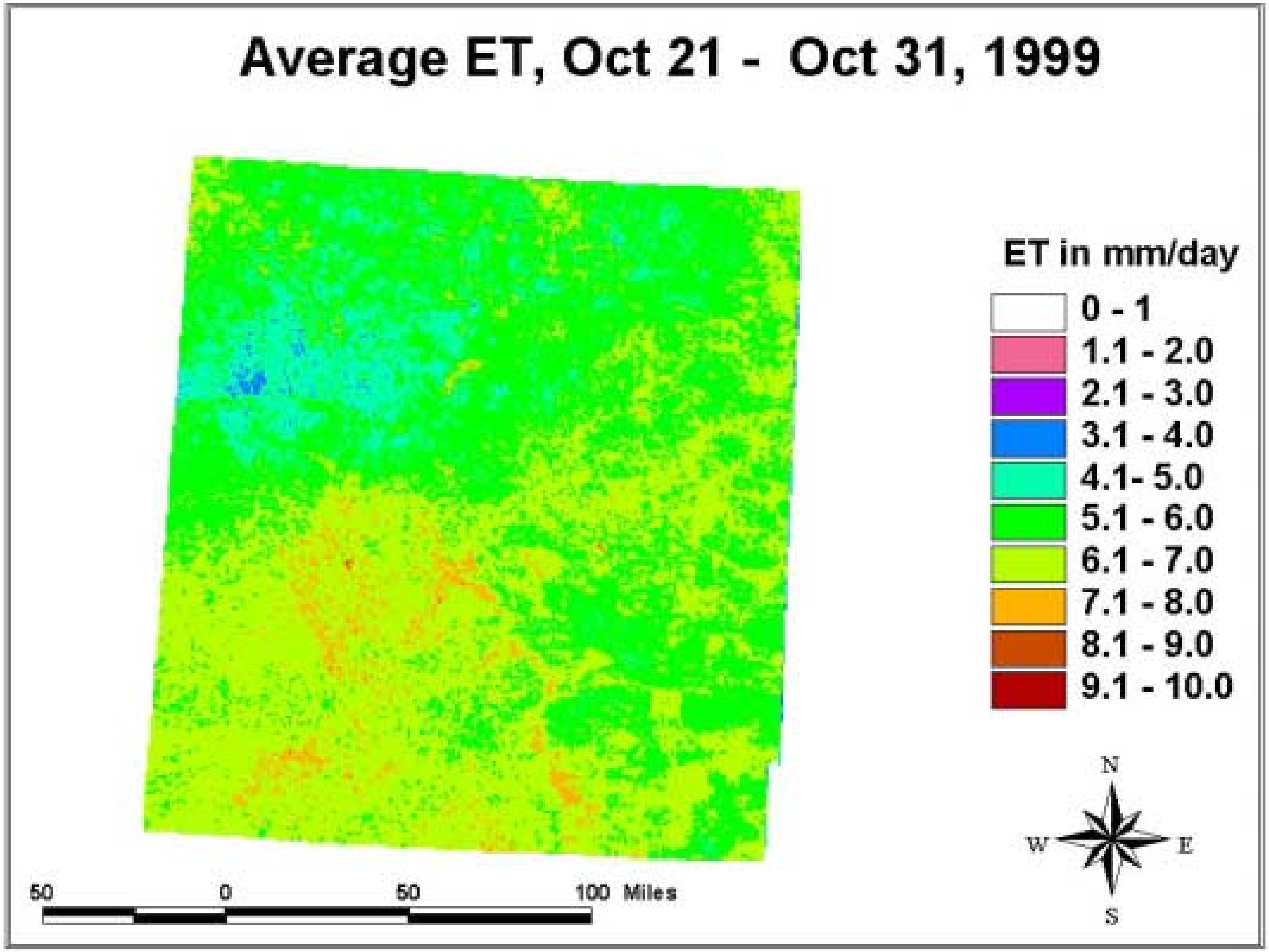
Potential Evapo-Transpiration (Contd..)

- Sensible Heat Flux

$$H = -\rho_a . C_p . h_h . (T_a - T_s)$$

Where:

H	=	sensible heat flux ($kJ.m^{-2}.s^{-1}$),
ρ_a	=	density of air ($kg.m^{-3}$),
C_p	=	specific heat of air ($kJ.kg^{-1}.{}^{o}C^{-1}$),
h_h	=	transport coefficient ($s.m^{-1}$),
	=	$u_2/208$ (Grass Reference),
u_2	=	wind velocity($m.s^{-1}$),
T_a	=	air temperature (ºC),
T_s	=	land surface temperature (ºC).


Average ET, Oct 21 - Oct 31, 1999
ET in mm/day
0 - 1
1.1 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1- 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
N
W
E
S
50
0
50
100 Miles

Soil Moisture Monitoring

- Using a water balance model
  - $SWC_t = SWC_{t-1} + (\text{Precipitation} - ET - \text{Runoff})$
- Precipitation from NEXRAD
- ET from AVHRR
- Runoff using SCS curve number technique
- Useful to calculate:
  - irrigation requirements
  - irrigation scheduling
  - water allocation from reservoir

Drought Indices

- KBDI (Keetch-Byram Drought Index)
  - An index of Forest Fire Potential
  - Uses maximum air temperature and precipitation to indicate fire potential in a scale of 0 to 800
  - Current scale - county level
  - Max. air temperature from AVHRR
  - Precipitation from NEXRAD
  - with GIS and remote sensing technique the spatial accuracy could be improved to 4km X 4km

Drought Indices (contd…)

- PDSI (Palmer Drought Severity Index)
  - An index of Meteorological / Hydrological / Agricultural Drought
  - Uses a simple water balance model to indicate drought in a scale of -4 to 4.
  - Current scale - climatic division
  - improved water balance model using distributed parameters obtained from GIS and remote sensing data
  - spatial accuracy of 4km X 4km

Conclusion

- Energy fluxes between the land surface and the atmosphere
- Daily coverage
- Improved spatial accuracy
- Good tool for regional scale monitoring
- Drought monitoring and information system
- MODIS - Moderate Resolution Imaging Spectroradiometer

Questions?