Emergency Management Issues Special Interest Group

Annual Meeting

Spatial Climatology of the Wind Environment in the Central Great Valley of Eastern Tennessee

KR Birdwell, PhD Candidate
University of Tennessee / UT-Battelle
Oak Ridge National Laboratory

EMERGENCY MANAGEMENT- PLANNING TO Win

May 3 - 6, 2010 Renaissance Las Vegas Hotel • Las Vegas, Nevada

emi sig
EMERGENCY MANAGEMENT ISSUES SPECIAL INTEREST GROUP

Complex Terrain Meteorology and Emergency Response

Complex terrain introduces a spatial-meteorological challenge for those who would characterize the effects of weather and climate on safety and security.

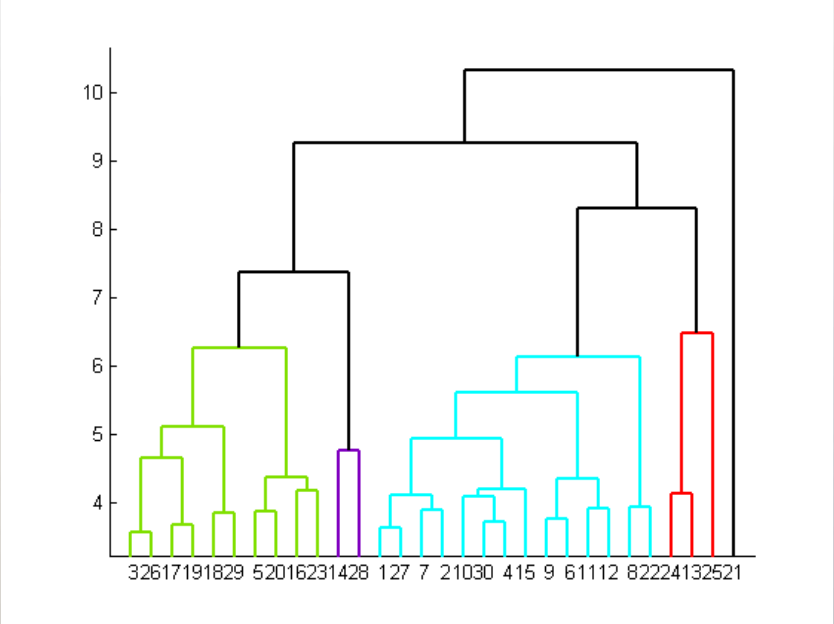
Although a variety of diagnostic and prognostic techniques are currently In use to quantify risks from meteorological conditions and associated pollutants, the accuracy of model estimates remains limited by a number of factors including:

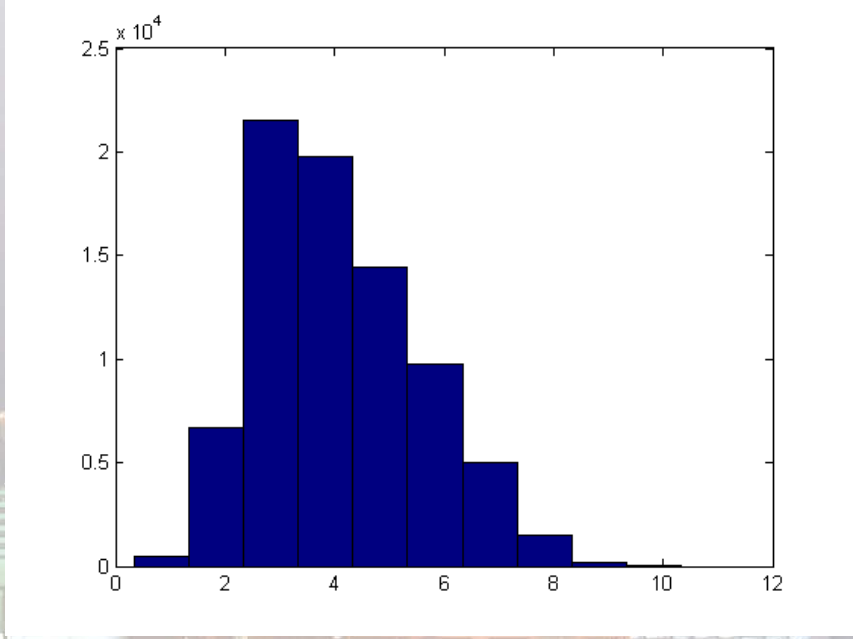
(1) Accuracy of flow data at fine spatial scales
(2) Inadequate quantification of wind field frequency distributions and correlation with ambient meteorology.
(3) A limited assessment of local meteorological conditions affected by complex terrain and landscape features.

Statistical Techniques and Data Preparation

- Quality assured data set (30 wind measurement points + ambient met)
- Complete Linkage (Farthest Neighbor) Cluster Analysis
- Post-cluster distance measure analysis (7 to 15 Classes)
- Calculation of 30-dimensional centroids and distances from centers
- Centroid refinement based on reduced data set (outliers excluded)
- Elimination of redundant or statistically non-robust centers
- Seeded K-Means cluster analysis (refined Complete Linkage seeds)
- Synoptic analysis and adjustment of classes based on synoptics or ambient meteorology.

Statistical Analysis Description





Statistical Findings / Pitfalls

- Technique did a good job of separating the majority of wind classes.

- An average of 10 significant classes were determined per month (range of 8 to 12 with lower numbers in winter and higher in summer)

- There was some confusion between Forced Channeling – Down Valley, Along Valley (Thermal) Down, and Pressure Driven Channeling – Down classes. There was also some confusion between Forced Channeling – Up Valley flow and Along Valley (Thermal) – Up Flow.

  These were separable with ambient meteorological information (synoptics, ambient solar radiation, stability, additional tower data).

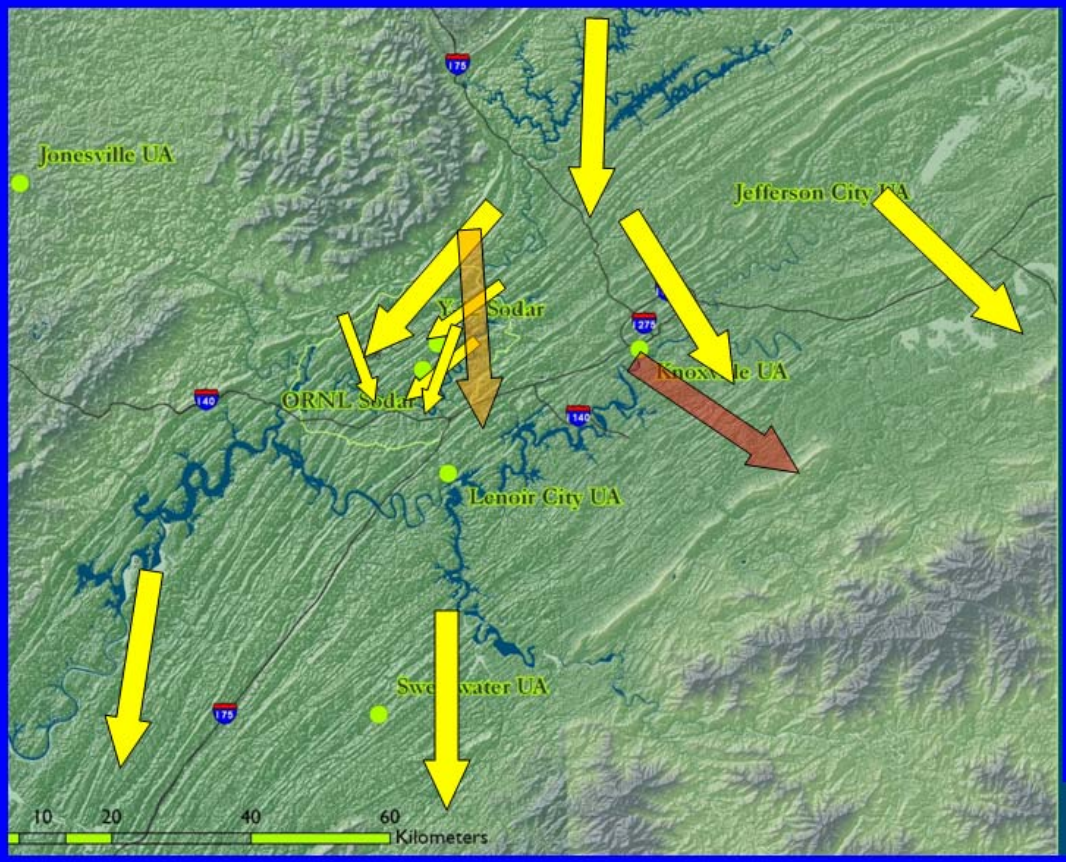
- Cophenet "explanatory" values ranged from 55-70% with an increase of 5-15% after removal of outliers.

- K-Means analysis "on average" realigned around 30% of the Complete Linkage clustered hours.

emi sig
EMERGENCY MANAGEMENT ISSUES SPECIAL INTEREST GROUP

Wind Field Patterns – Vertically Coupled

February 2009 – Class 4 : VCF N / RV FCH 15%



Synoptic: Variable
NNW, NE, Some SW
PGrad: Strong Up
LV: Weak Up
UV: Mod Up
Stability:
Surface – D/E
GV – W. Stable
Time Day: All
Solar: 135 Wm2
Mix Ht: 416 m
RV: FCH 0-30 deg
(Greatest at Y12)
Wds 1k ft: N 2 mph
Wds 2kft: NW 23 mph

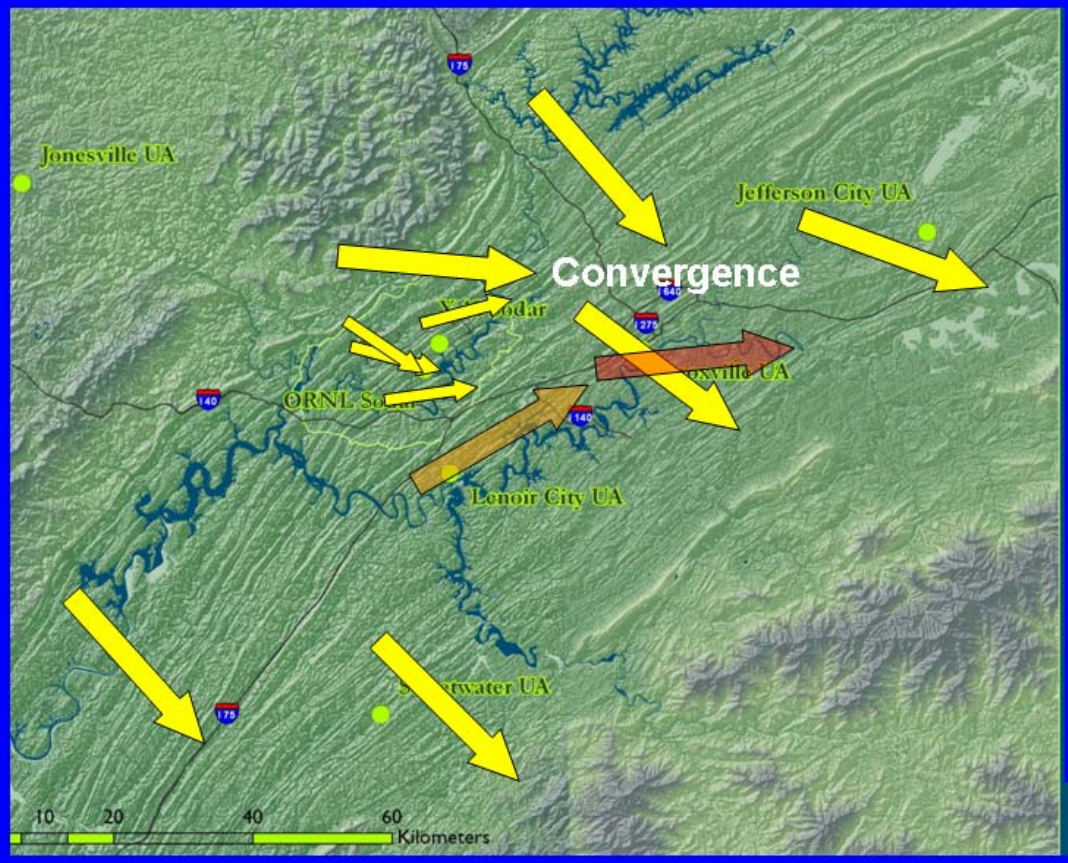
Comments:
Minor SW Flow at ORNL at 350m may represent influence of transition flows (N to S).

Knox site influenced by UA winds.

emi sig
EMERGENCY MANAGEMENT ISSUES SPECIAL INTEREST GROUP

Wind Field Patterns – Vertically Coupled

February 2009 – Class 6 : VCF WNW / Mtn. Convergence 10%

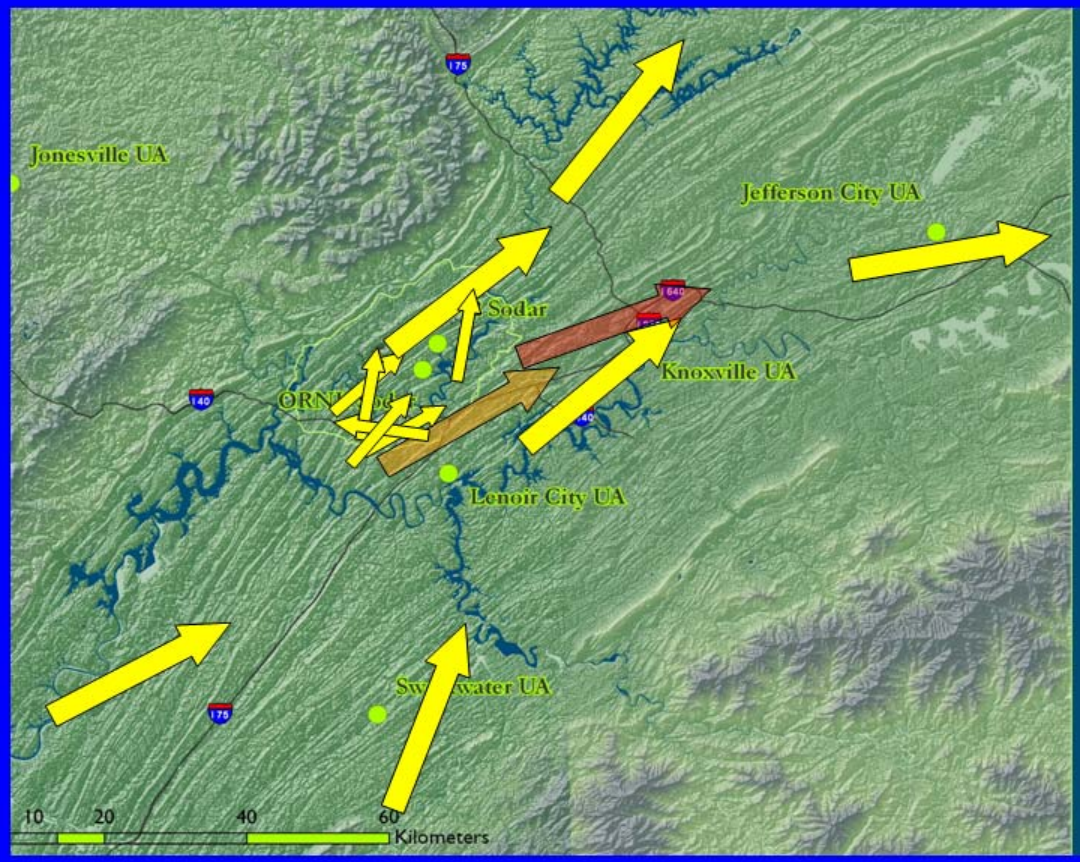


Synoptic: SSW-NNW (WNW-NW Core)
PGrad: V. Strong Up
LV: Mod Up
UV: V. Strong Up
Stability:
Surface - D
GV – Unstable
Time Day: All
Solar: 147 Wm2
Mix Ht: 855 m
RV:
Sub-RV 5-10 deg
Gap Flow 30 deg
Wds 1k ft: WNW 7 mph
Wds 2kft: WNW 30 mph

Comments:
Arctic Outbreak Pattern
Convergent flow downwind of Cumberland Mts. and enhanced by RV.

Wind Field Patterns – Forced Channeling Up

October 2009 – FCH Up Night / Local Flow CV – 14%



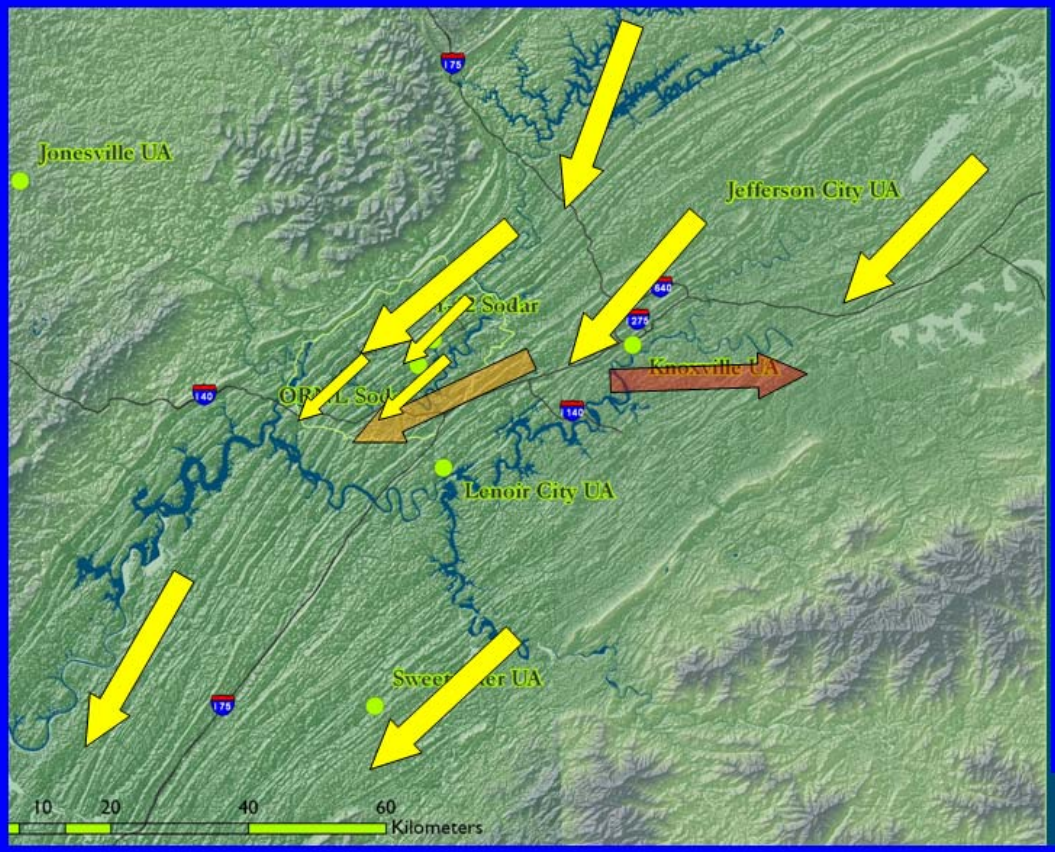
Synoptic: S-W
PGrad: Neutral
UV: Weak Down
LV: Weak Up
Stability:
Sfc: E
GV: Weakly Stable
Time Day: All (Evening)
Solar: 96 Wm2
Mix Ht: 282 m
RV: FCH 5-40 deg;
Local / Drainage
Wds 1k ft: WSW 3 mph
Wds 2kft: WSW 15 mph

Comments:
Night time up valley Forced Channeling with RV / surface local flows.

emi sig
EMERGENCY MANAGEMENT ISSUES SPECIAL INTEREST GROUP

Wind Field Patterns – Forced Channeling Down

October 2009 – Class 1 : FCH Down – 23%



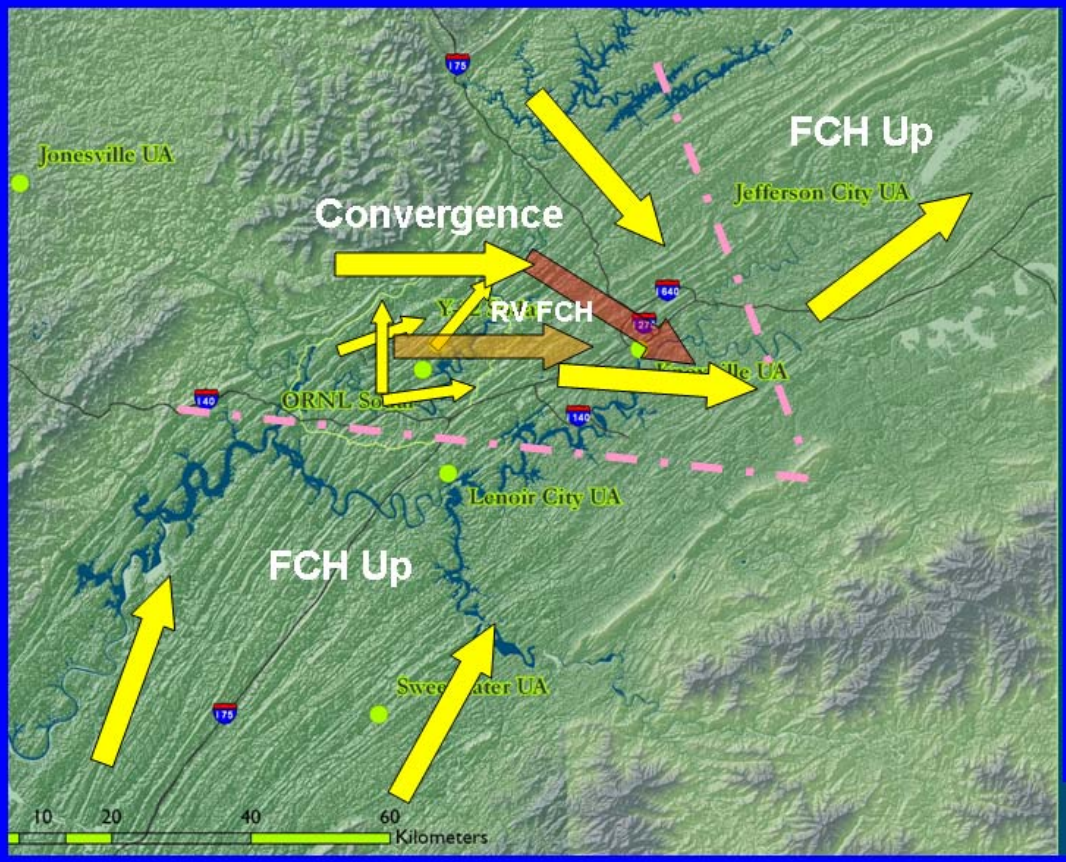
Synoptic:
Light NNE-ESE
Frequent CAA
PGrad: Mod Down
LV: Neutral
UV: Mod Down
Stability:
Sfc: D/E
GV: Stable
Time Day: All
Solar: 139 Wm2
Mix Ht: 418 m
RV: FCH 0-20 deg
Minor Local Flows
Wds 1k ft: ENE 5 mph
Wds 2kft: W 9 mph

Comments:
Flow deeper than 350m RV turns winds at least 20 deg further from general GV flow.

emi sig
EMERGENCY MANAGEMENT ISSUES SPECIAL INTEREST GROUP

Wind Field Patterns – Forced Channeling

June 2009 – Class 6 : FCH Up / Mtn. Convergence 15%



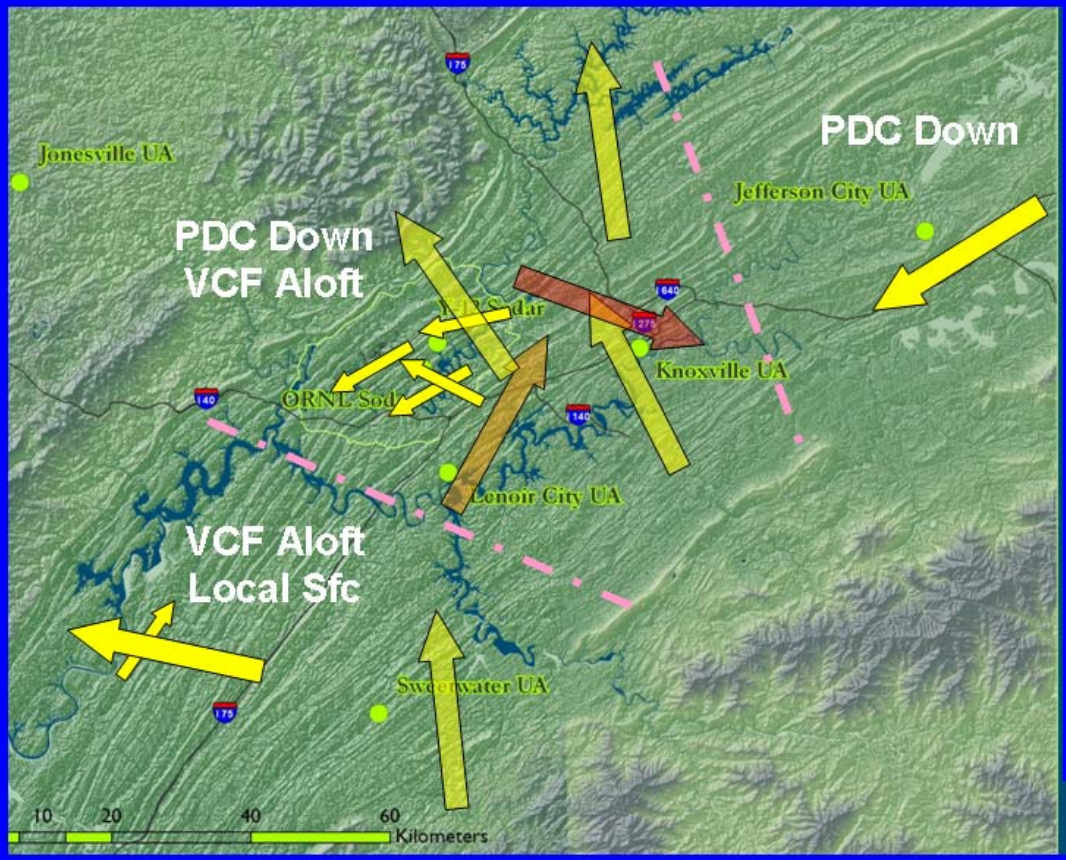
Synoptic:
NNE-SE (29%)
S-WSW (32%)
W-N (39%)
PGrad: W eak Down
LV: Weak Up
UV: Mod Down
Stability:
Surface - E
GV – Unstable
Time Day: All Ex. Aftn.
Solar: 128 Wm2
Mix Ht: 393 m
RV: FCH Up to 60 deg
Wds 1k ft: W 2 mph
Wds 2kft: WNW 17 mph

Comments:
Flow is noted for moderate Mix Depth and split PGrad.

emi sig
EMERGENCY MANAGEMENT ISSUES SPECIAL INTEREST GROUP

Wind Field Patterns – Pressure Driven

February 2009 – Class 8 : PDC Down UV-CV / VCF SSE Aloft LV-CV 4%



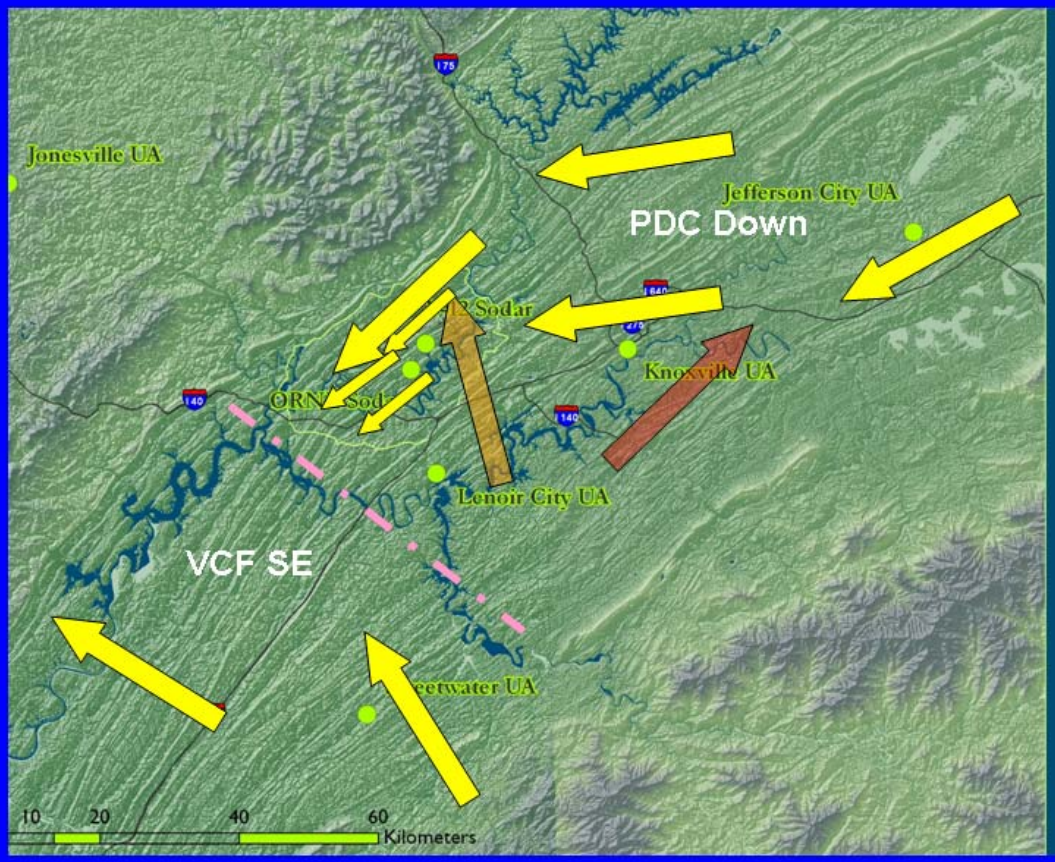
Synoptic: SSE-SW
PGrad: Mod Down
LV: Neutral
UV: Mod Down
Stability:
Sfc – E/F
GV - Unstable
Time Day: Night
Solar: 28 Wm2
Mix Ht: 158 m
RV: FCH 5-10 Sub-RV
Turning SE above RV
Wds 1k ft: SSW 5 mph
Wds 2kft: WNW 18 mph

Comments:
Very complex flow characterized by very shallow PDC Down in UV-CV by VCF above RV in most of LV/CV. LV shows local flow patterns as well. Flow at T114 is somewhat anomalous.

emi sig
EMERGENCY MANAGEMENT ISSUES SPECIAL INTEREST GROUP

Wind Field Patterns – Pressure Driven

October 2009 Class 9: PDC Down UV-CV / VCF SE LV – 8%

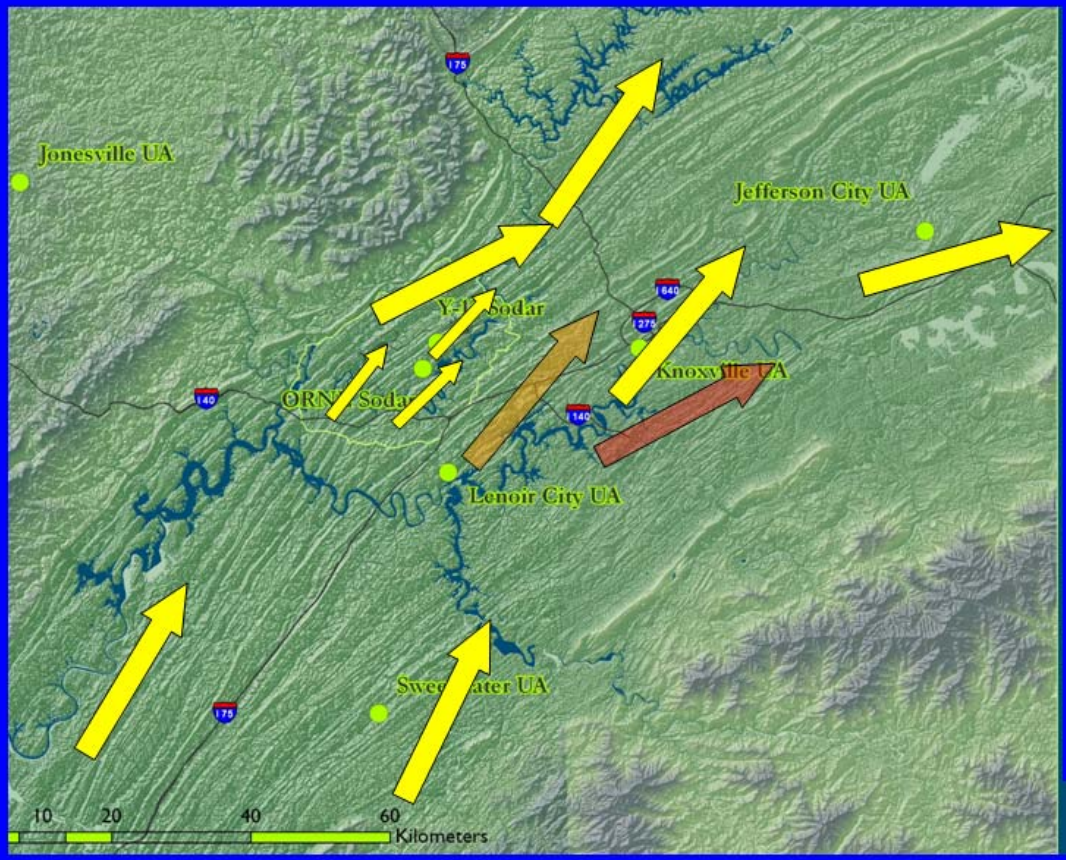


Synoptic: ESE-SSW
PGrad: Strong Down
UV: Strong Down
LV: Neutral
Stability:
Sfc: E
GV: Weakly Unstable
Time of Day: All
(Weak Afternoon)
Solar: 48 Wm2
Mix Ht: 221 m
RV: FCH 15-35 deg
Sig turning Ridgetop
Wds 1k ft: SSE 5 mph
Wds 2kft: SW 19 mph

Comments:

Wind Field Patterns – Thermal Up Valley

August 2009 – Class 12 : AVF Up 3%



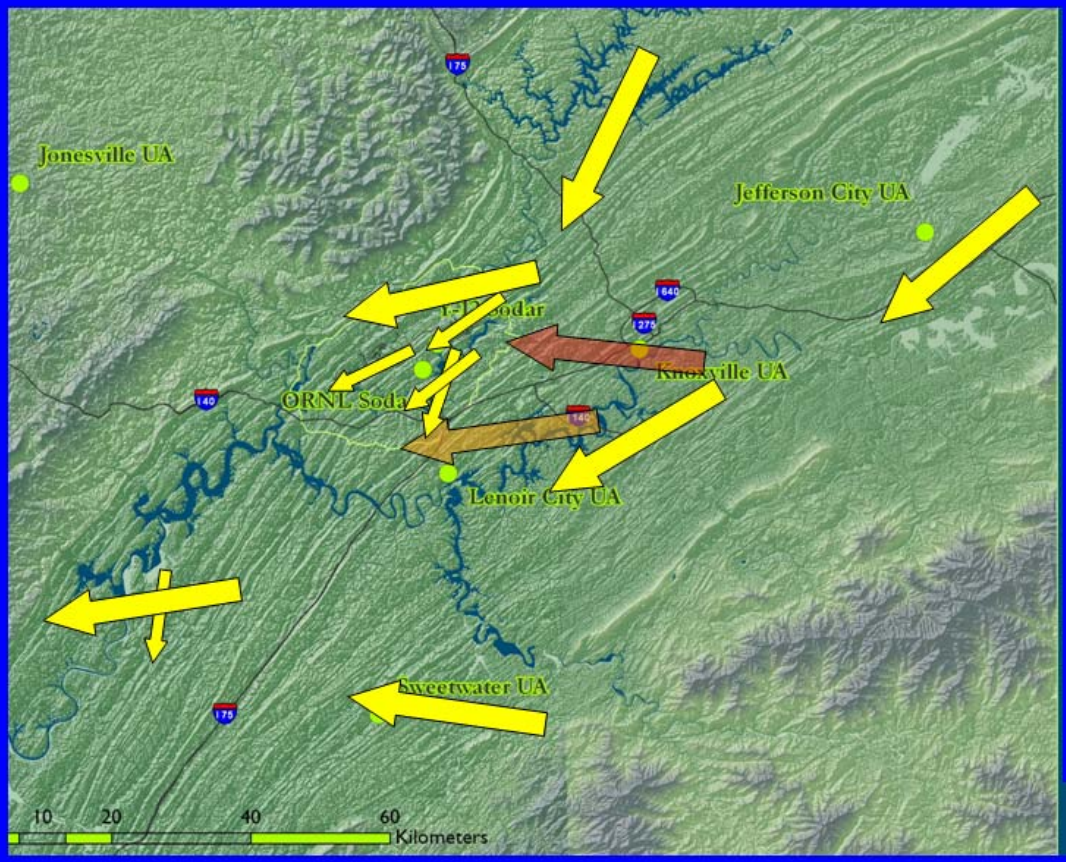
Synoptic: SW-S
PGrad: Mod Down
LV: Neutral
UV: Mod Down
Stability:
Surface – B/C
GV – Unstable
Time Day: Afternoon
Solar: 612 Wm2
Mix Ht: 1788 m
RV: 5-10 deg FCH
Wds 1k ft: NE 9 mph
Wds 2kft: ESE 4 mph

Comments:

emi sig
EMERGENCY MANAGEMENT ISSUES SPECIAL INTEREST GROUP

Wind Field Patterns – Thermal Down Valley

August 2009 – Class 6 : AVF Down 10%



Synoptic: NNE-ESE and SE-WSW (shallow flow)
PGrad: Strong Down
LV: Neutral
UV: Strong Down
Stability:
Sfc – E/F
GV – V. Unstable
Time Day: Night
Solar: 25 Wm2
Mix Ht: 271 m
RV: 0-20 FCH
Local Flows <30m
Wds 1k ft: E 4 mph
Wds 2kft: E 6 mph

Comments:
Winds aloft are very light.

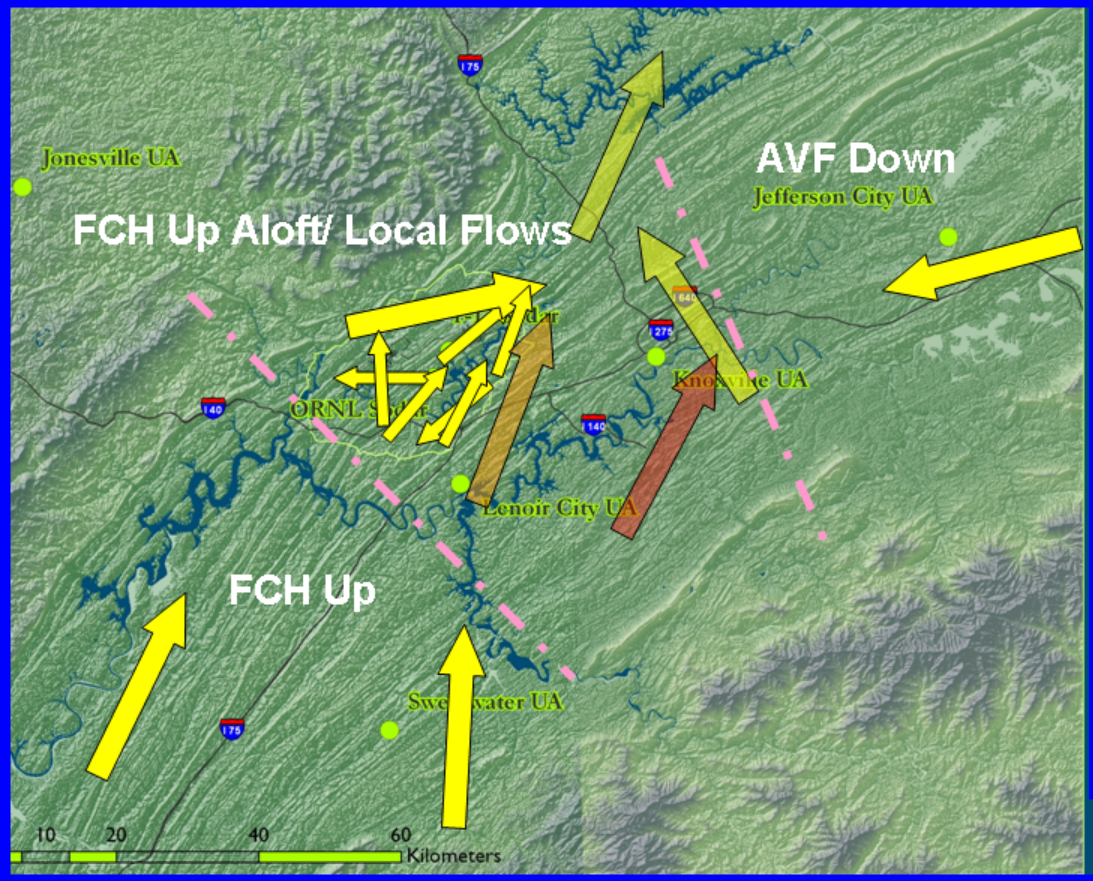
Mtn. breeze evident at Sweetwater.

Local flow activity at 30m or less.

emi sig
EMERGENCY MANAGEMENT ISSUES SPECIAL INTEREST GROUP

Wind Field Patterns – Thermal / FCH Mix

August 2009 – Class 10 : FCH LV / FCH Up Aloft - Local Flows CV 7% AVF Down UV



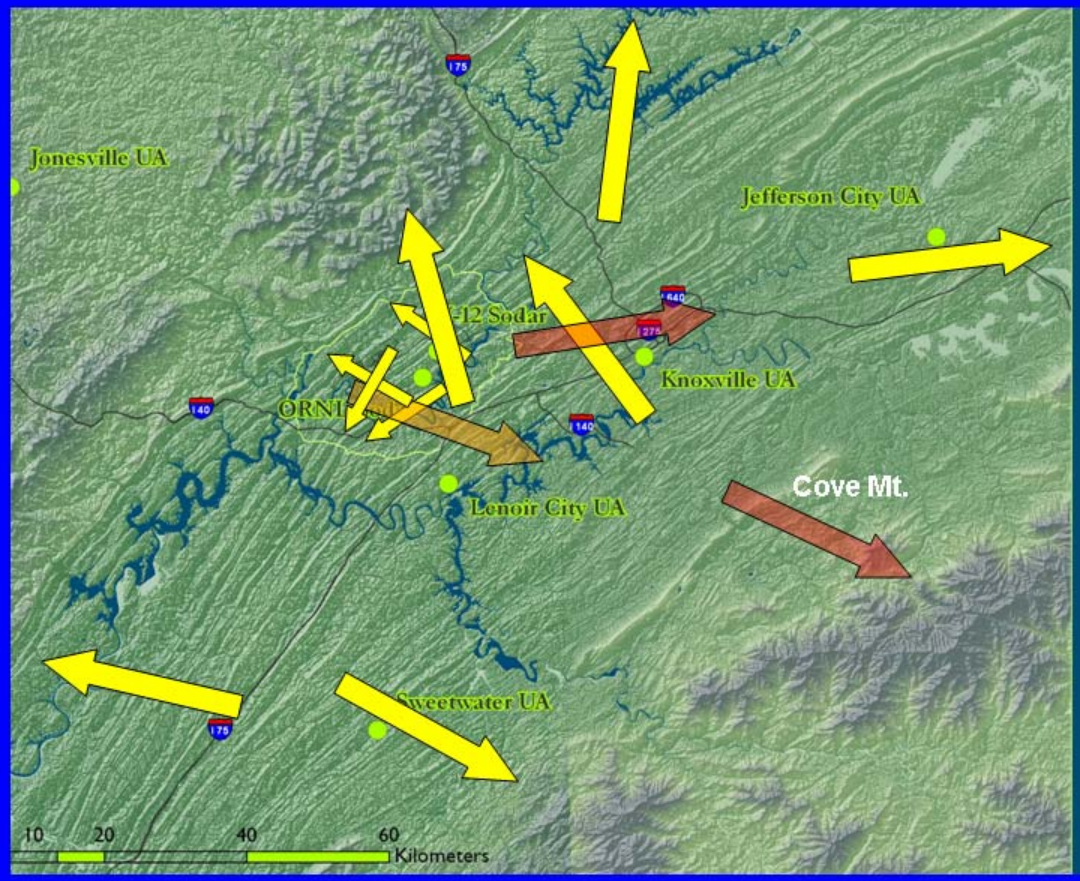
Synoptic: S-WSW
PGrad: Mod Down
LV: Weak Up
UV: Mod Down
Stability:
Surface – E/F
GV – Very Unstable
Time Day: Night
Solar: 15 Wm2
Mix Ht: 187 m
RV: Local Flows
Wds 1k ft: SSW 7 mph
Wds 2kft: SSW 11 mph

Comments:
Very complex local flows in CV.

Despite moderate PGrad in UV, high presure influence and strong GV instability argue for AVF Down in UV rather than PDC Down.

Wind Field Patterns – Mountain Breezes

July 2009 – Day Time Mountain Breezes – 11%



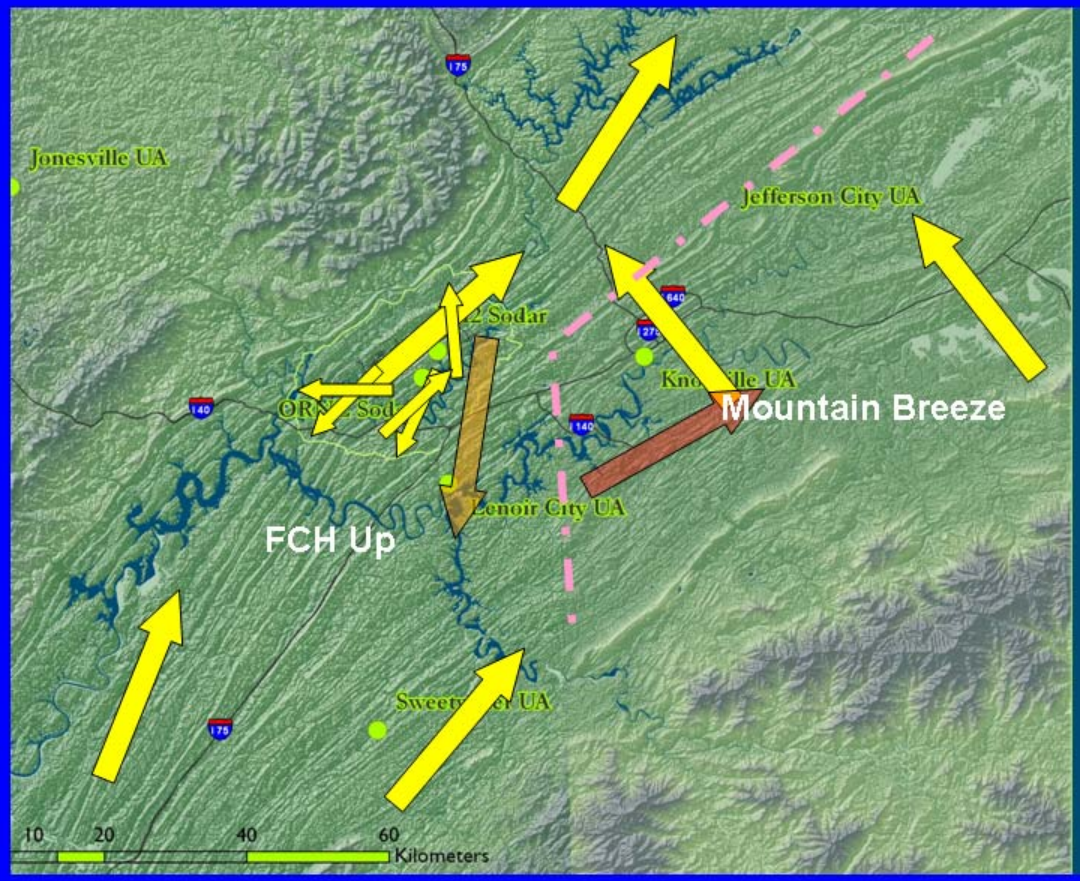
Synoptic: W–NW Front
PGrad: Weak Up
UV: Neutral
LV: Weak Up
Stability:
Sfc: C/D
GV: Unstable
Time Day/Erly. Evening
Solar: 444 Wm2
Mix Ht: 1525 m
RV: Local Circulations
Wds 1k ft: WNW 4 mph
Wds 2kft: W 5 mph

Comments:
Daytime local circulations in RV
Cove Mt. readings for this class are consistent with Mountain Breeze phenomena.

emi sig
EMERGENCY MANAGEMENT ISSUES SPECIAL INTEREST GROUP

Wind Field Patterns – Smoky Mt. Breeze

July 2009 – FCH Up / Smoky Mtn Breeze – 10%



Synoptic: W-NNW
PGrad: Neutral
UV: Weak Down
LV: Weak Up
Stability:
Sfc: E/F
GV: Unstable
Time Day: Night
Solar: 42 Wm2
Mix Ht: 265 m
RV: 5-20 deg FCH
Wds 1k ft: WSW 2mph
Wds 2kft: WSW 14 mph

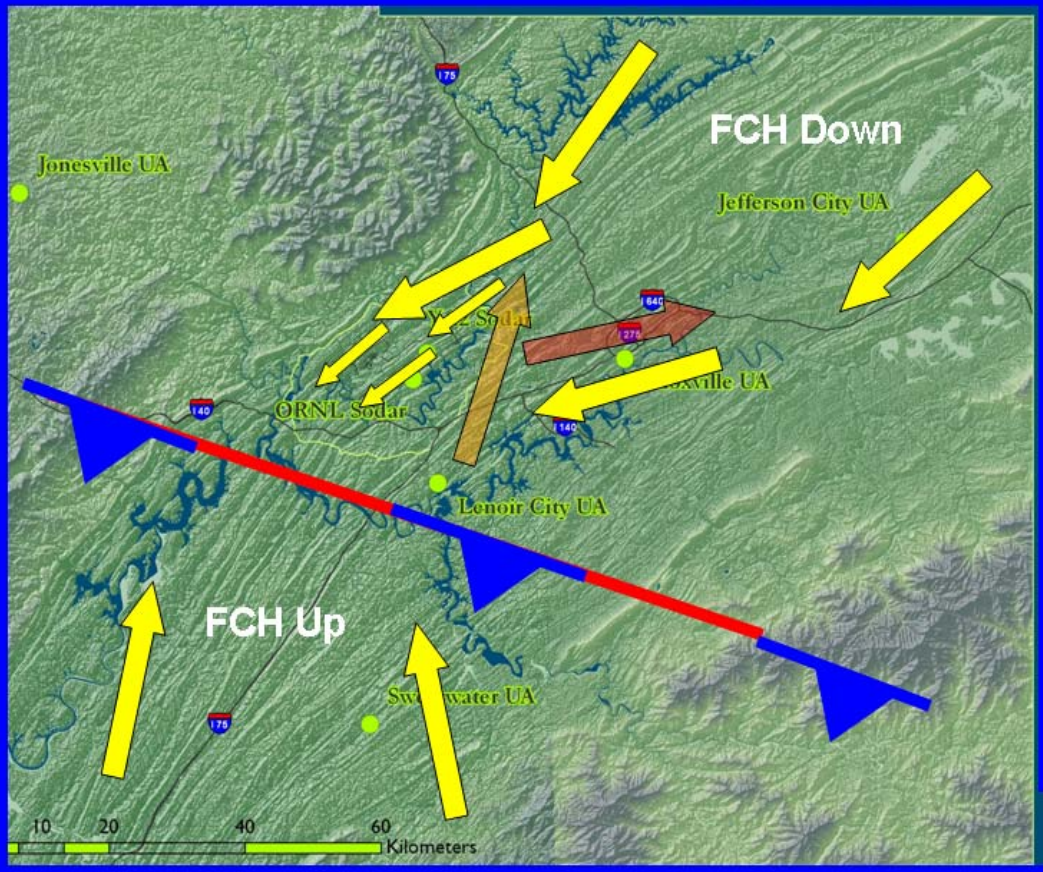
Comments:
Weak surface stabilty allows synoptic flow to mix to surface /

ORNL Sodar not representative of UA flow here due to relatively deep Mix Ht and varied synoptic pressure gradient.

emi sig
EMERGENCY MANAGEMENT ISSUES SPECIAL INTEREST GROUP

Wind Field Patterns – Frontal Activity

June 2009 – Class 1 : – Frontal Activity (FCH Up LV / FCH Down 10%



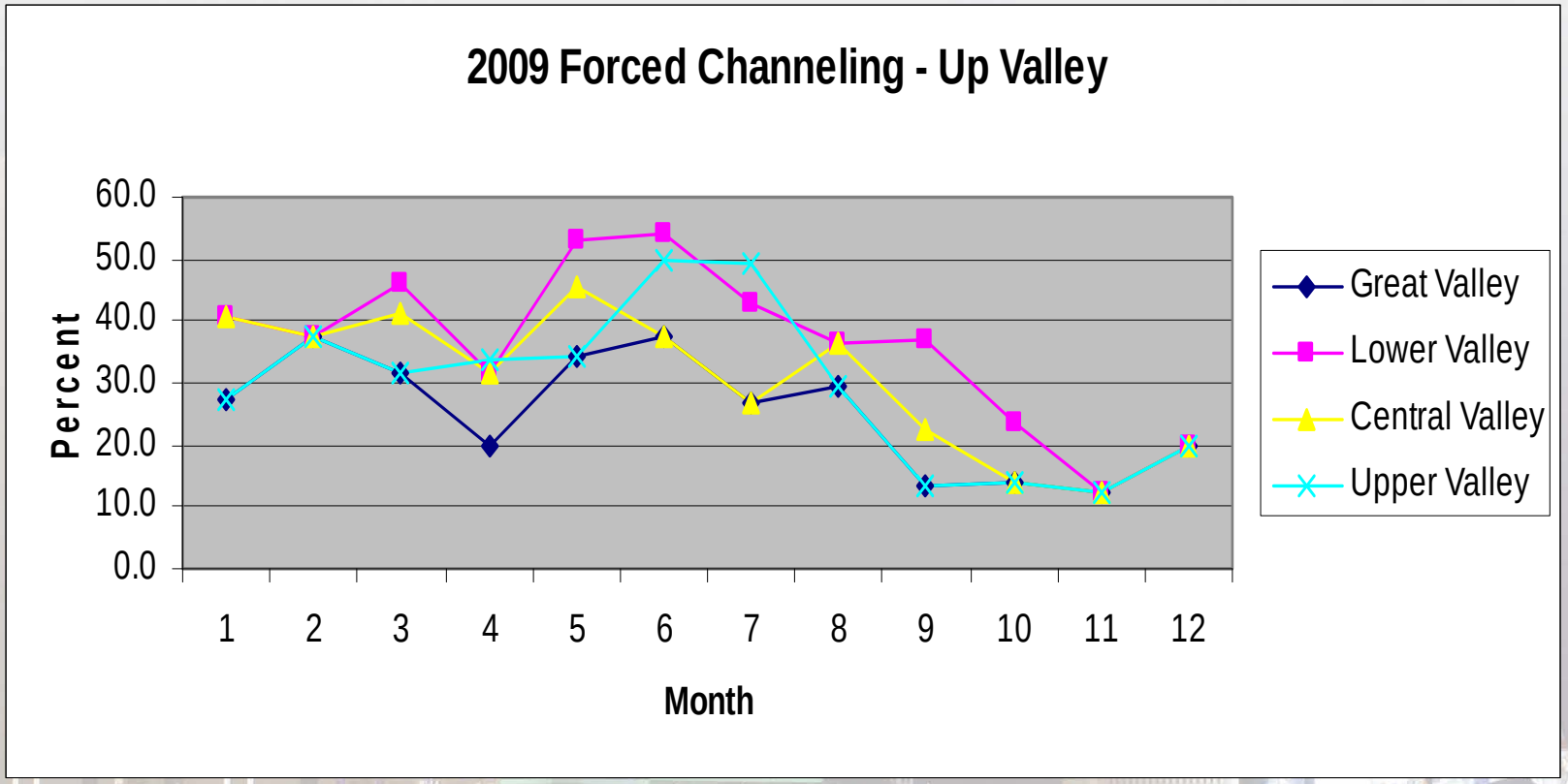
Synoptic: SSE-WSW 70%
NNE-ESE 20%
Other 10%
PGrad: Mod Down
LV: Weak Up
UV: Mod Down
Stability:
Sfc - E
GV : Vert Unstable
Time Day: All Exc. Aftn.
Solar: 96 Wm2
Mix Ht: 264 m
RV: FCH 5-20 deg
Wds 1k ft: SSW 3 mph
Wds 2kft: WSW 13 mph

Comments:
20% DV Flow is deep enough to reach 1k ft (ORNL Sodar).

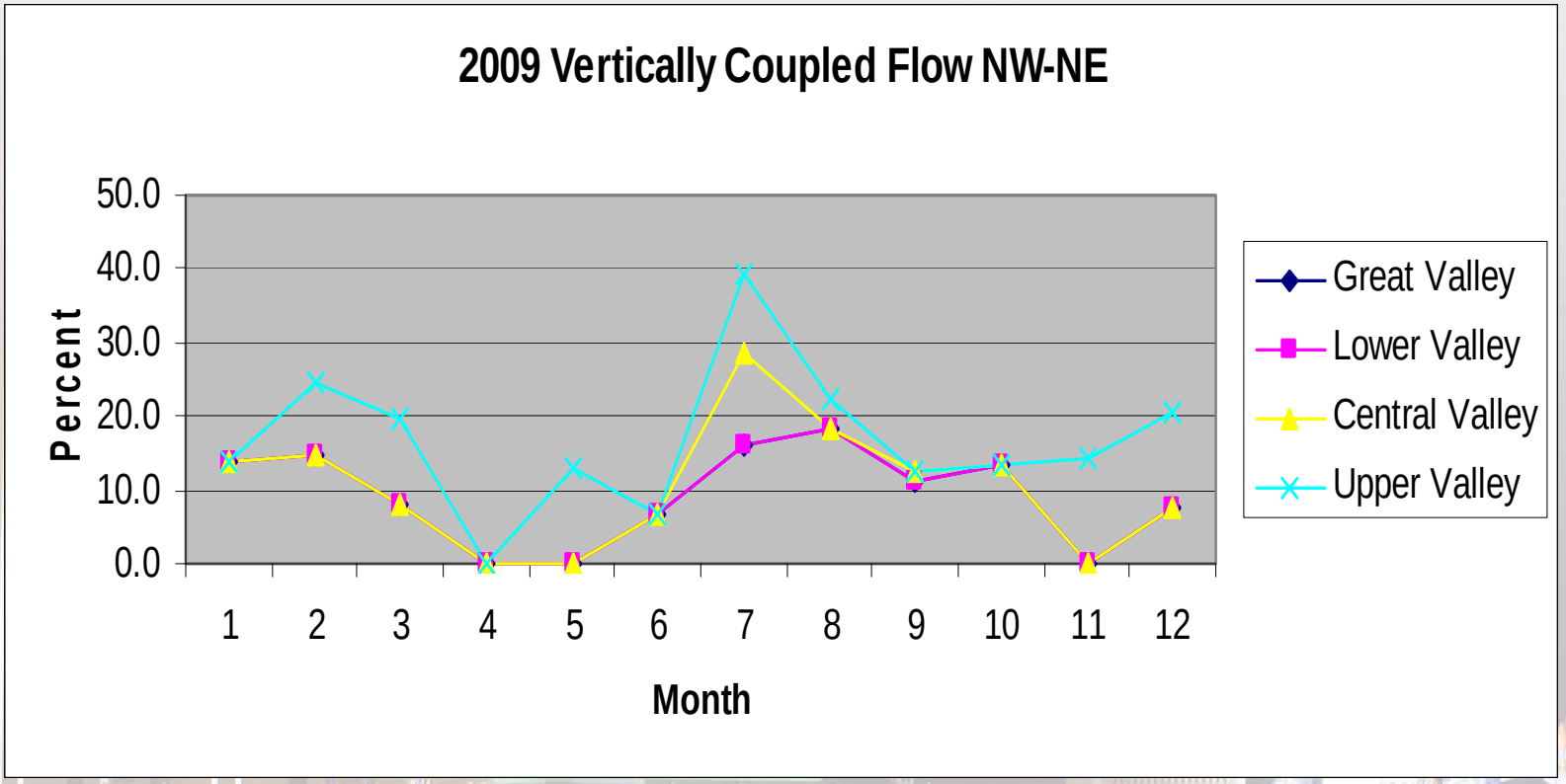
Frequent frontal zone activity best explains split pattern. HP to NE frequently drives Sfc flow in UV/CV

emi sig
EMERGENCY MANAGEMENT ISSUES SPECIAL INTEREST GROUP

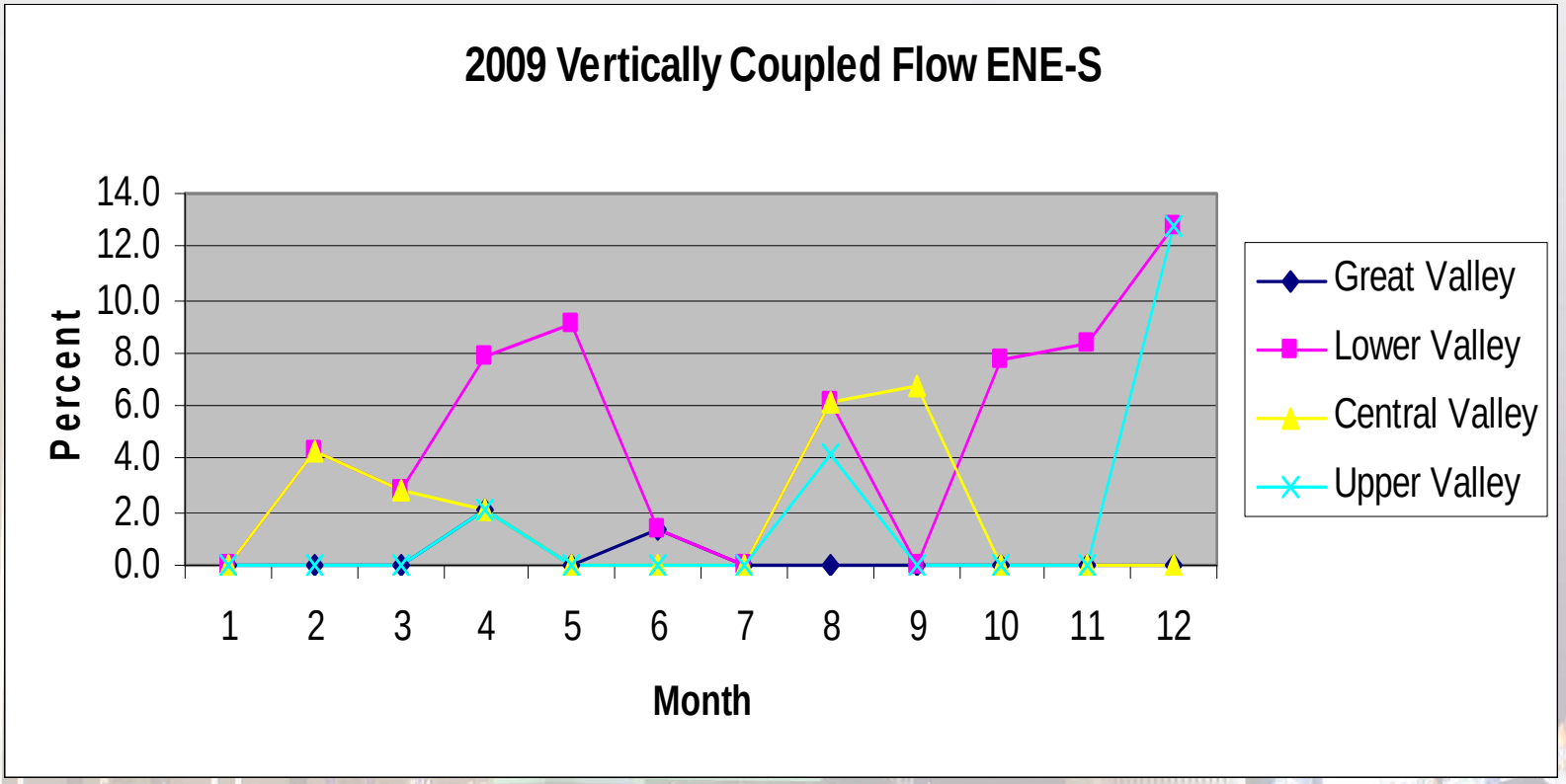
Summary Statistics



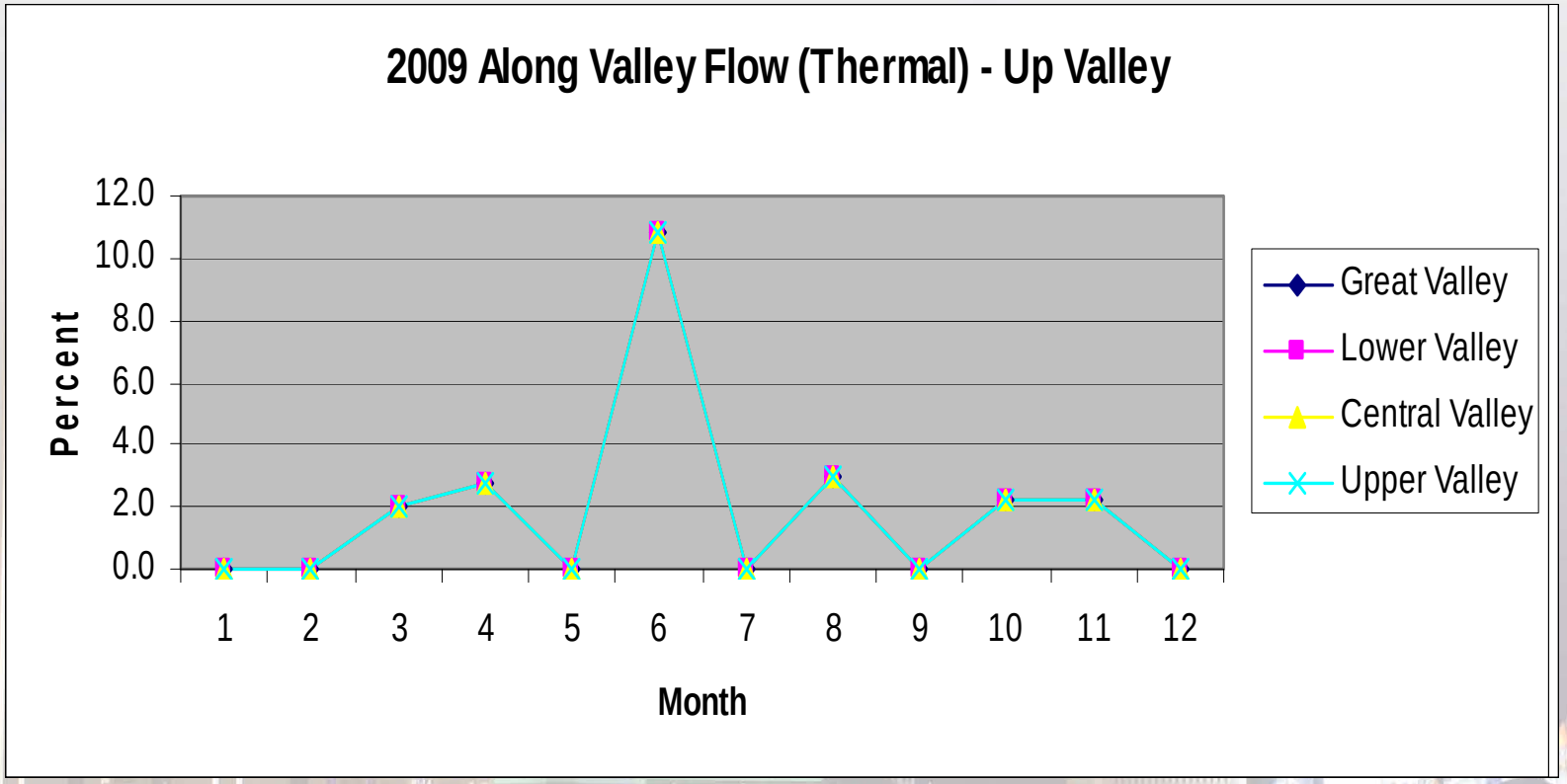
Summary Statistics



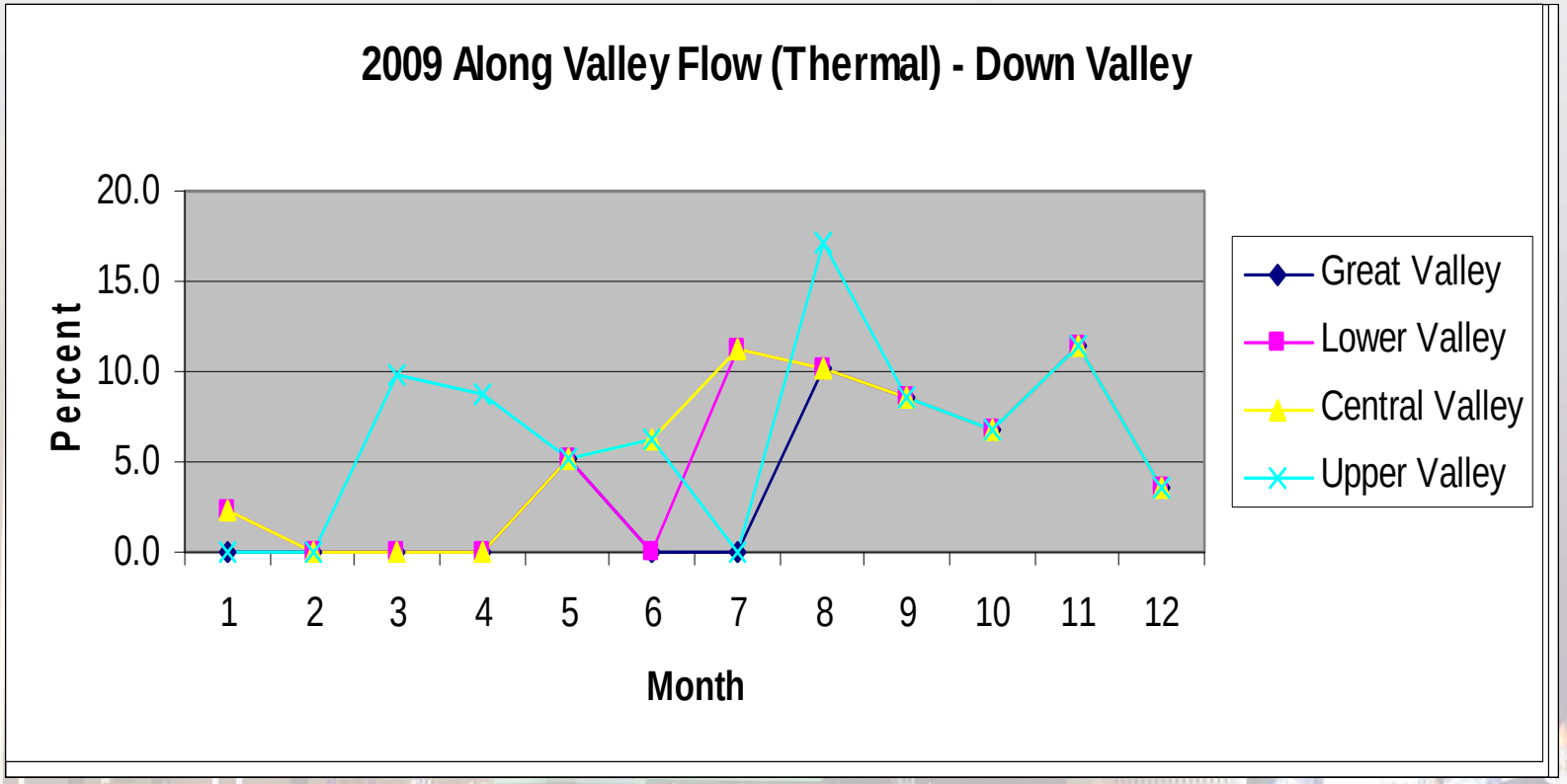
Summary Statistics



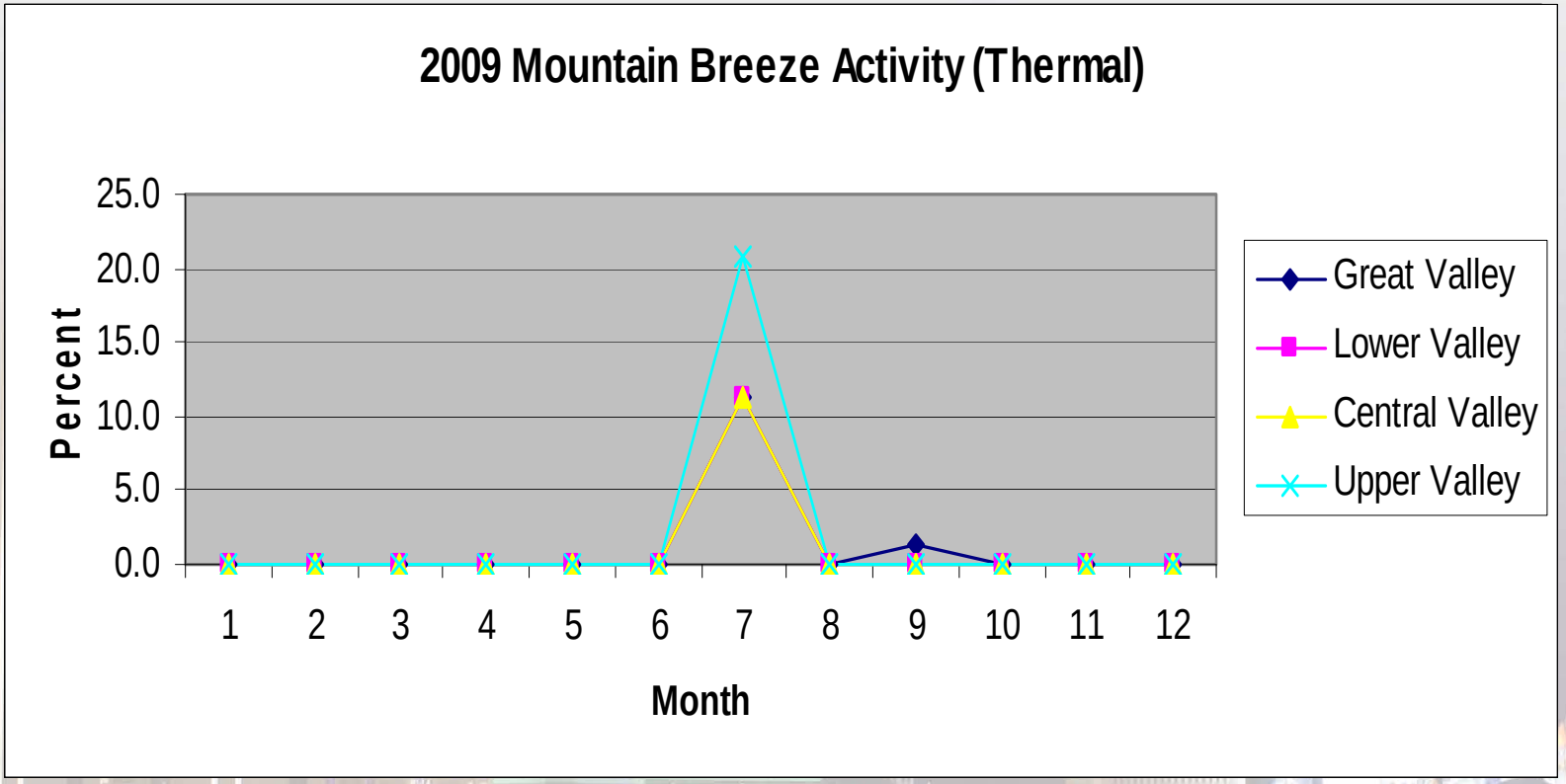
Summary Statistics



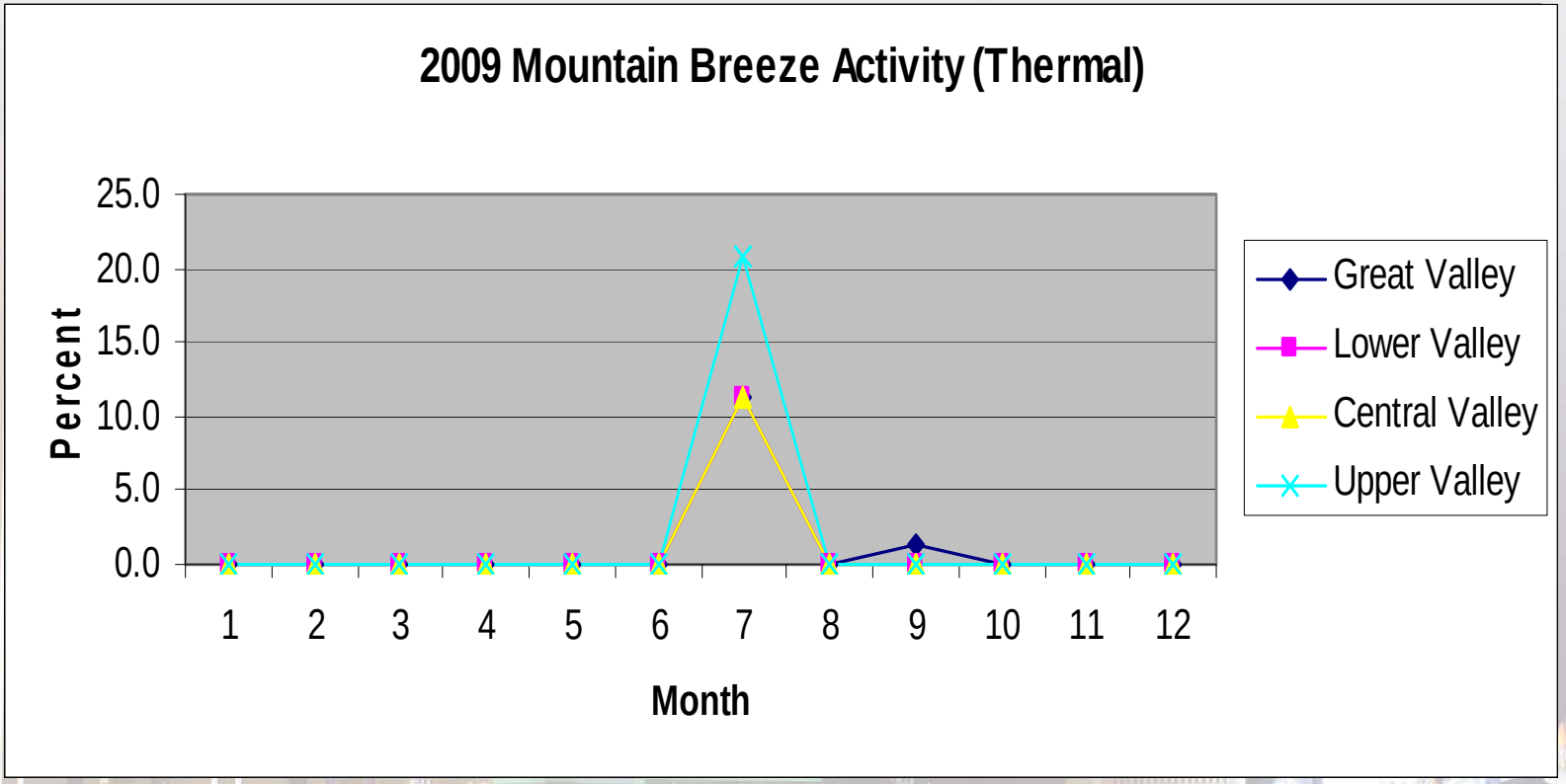
Summary Statistics



Summary Statistics

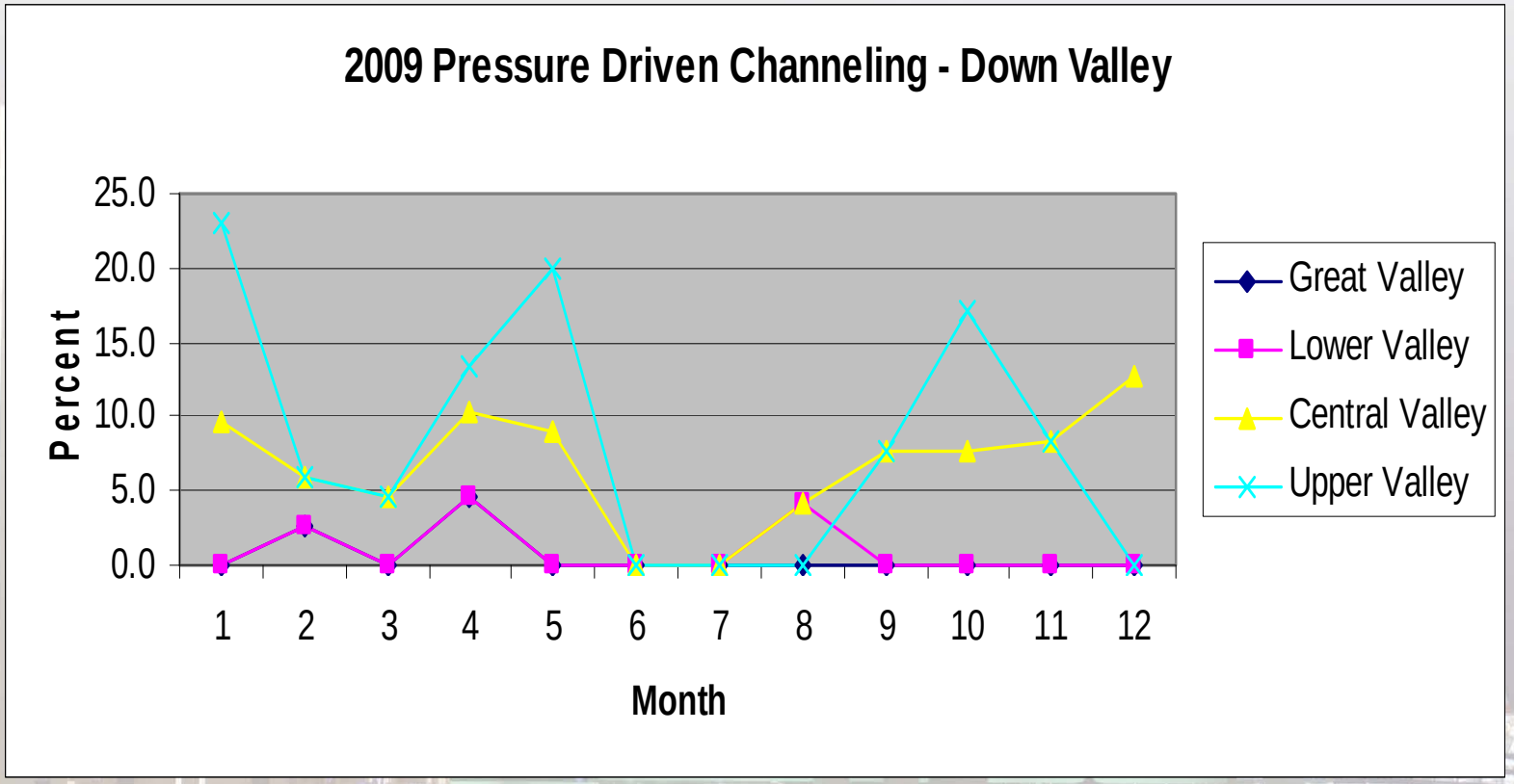


Summary Statistics



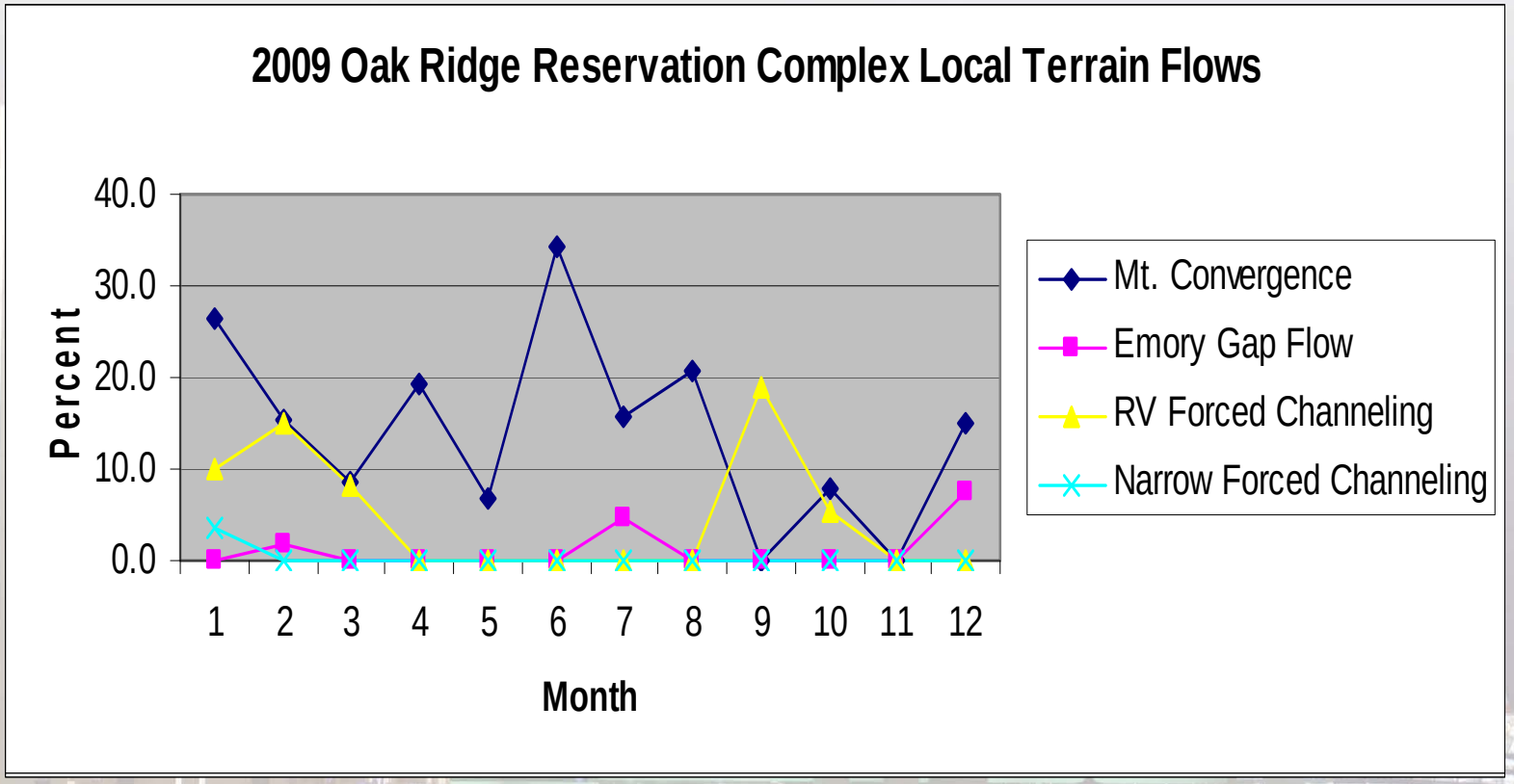
emi sig
EMERGENCY MANAGEMENT ISSUES SPECIAL INTEREST GROUP

Summary Statistics



emi sig
EMERGENCY MANAGEMENT ISSUES SPECIAL INTEREST GROUP

Summary Statistics



Future Plans

- Perform a local Ridge-and-Valley analysis to determine the frequency and distribution of local flow (sub-Ridge-and-Valley) regimes as well as the climatology of wind reversals.
- Perform selected monthly analyses for prior year data to investigate year-to-year variability.
- Use the statistically determined wind classes to perform dispersion analysis in order to better understand the relationships between the dispersion / pollutant environment and wind class frequencies.
- Work with NOAA toward the determining the accuracy and performance of the WRF model in complex terrain environments such as the Great Valley of East Tennessee.