

# Influence of Solar Glare on Traffic Flow

Kim, Hoyong

Post Doctoral Fellow  
Department of Civil Engineering  
Missouri University of Science and  
Technology  
Rolla, Missouri, USA  
kimhoy@mst.edu

Baik, Hojong

Assistance Professor  
Department of Civil Engineering  
Missouri University of Science and  
Technology  
Rolla, Missouri, USA  
baikh@mst.edu

Kim, Jisook

PhD student  
Graduate school of GIS  
Pusan National University  
Busan, South KOREA  
kjisook@gmail.com

# Content

- **What is Sun Glare?**
- **Test Site and Data Collection**
- **Computational Process**
  - Step 1: Solar Intensity
  - Step 2: Traffic Data
  - Step 3: Solar Intensity and Traffic Data
- **Evaluation of Solar Glare Influence on Traffic Flow**
  - Spatial and Temporal Relation between Sun Glare and Traffic Flow
- **Further Study**

# Does solar glare bother drivers?



Note What is not visible



ambulance turning left....



...and a Stop Sign!!

# Study Area and Data Collection

## ● Study Area

- Interstate highway
- I-64: St. Louis Area



## ● Data

### Road Data

- Shape file
- Polyline M

### MoDOT TMS

- Accident Location
- Accident Date
- Weather
- Etc.

### Traffic.com

- Detector Location
- 5 minute Speed
- 5 minute Volume
- Etc.

- Detector Location



## ● Tools

### ArcGIS

- Select by Location
- Select by Attribute
- Buffer
- Dynamic Segmentation

### Matlab

- Data Collection from TMS
- Data Collection from Traffic.com
- Calculate Intensity Time
- Drawing Intensity Time Graph

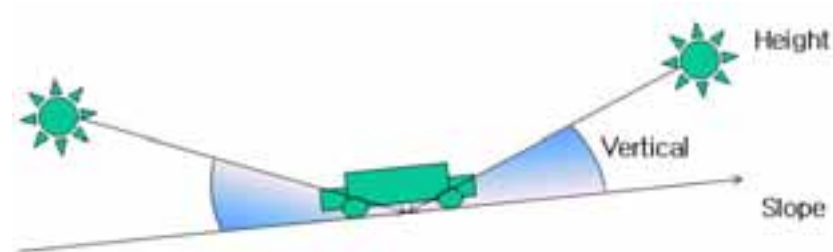
# Computational Process

Step 1: Solar Glare Intensity

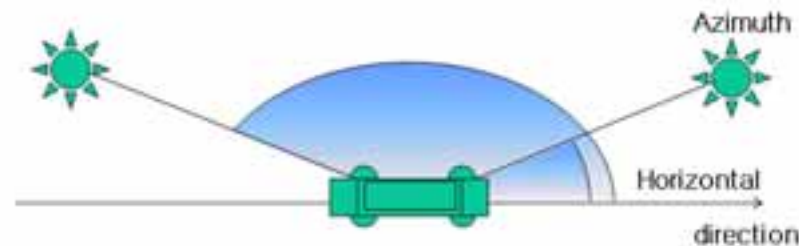
Step 2: Traffic Data

Step 3: Solar Glare Intensity and Traffic Data

# How do we measure the intensity of Solar Glare?

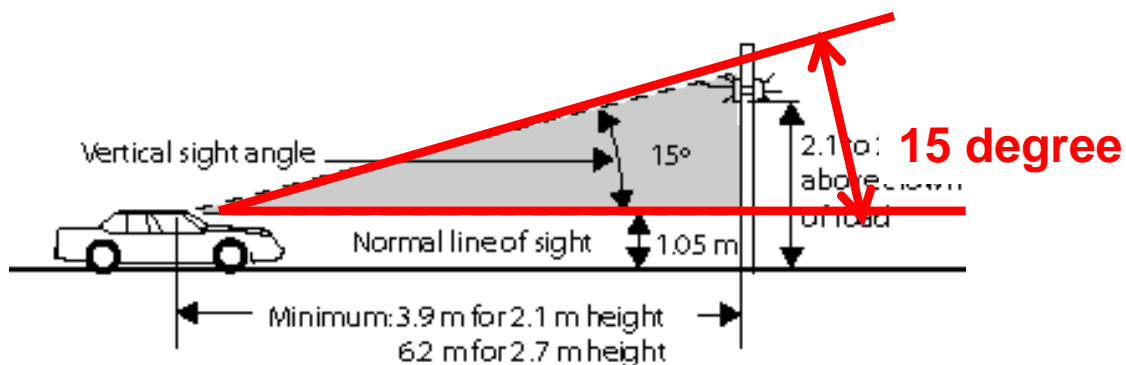


- **Vertical Angle =  $F_n$**  (slope of road segment, elevation of sun)

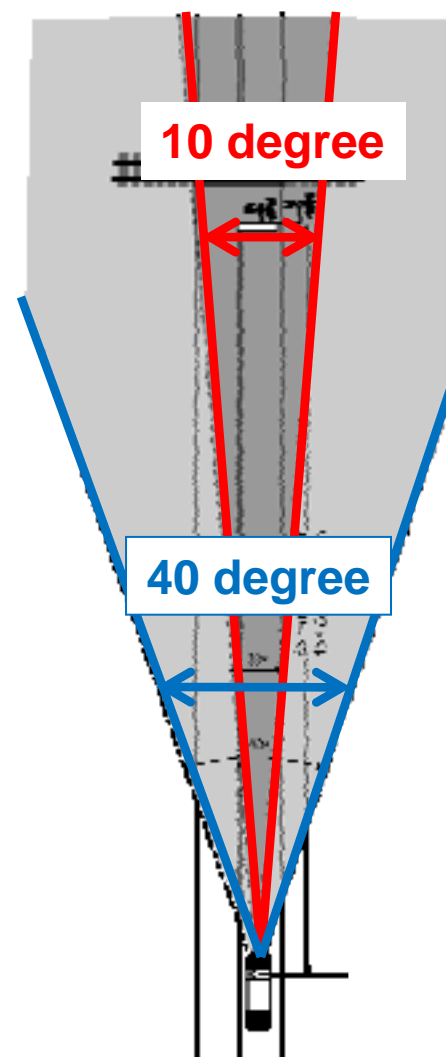


- **Horizontal Angle =  $F_n$**  (direction of road segment, azimuth of sun)

# Driver's Cone of Vision

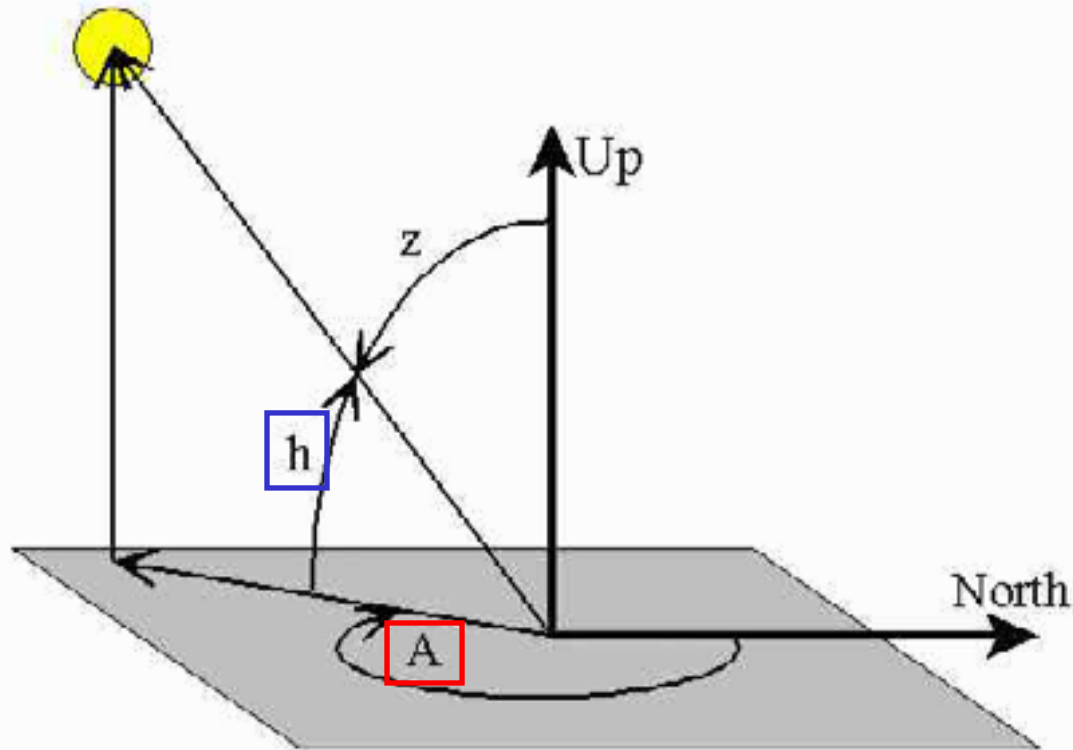


● Vertical cone of vision



● Horizontal cone of vision

# Elevation and Azimuth of Sun



$h$  = elevation angle, measured up from horizon

$z$  = zenith angle, measured from vertical

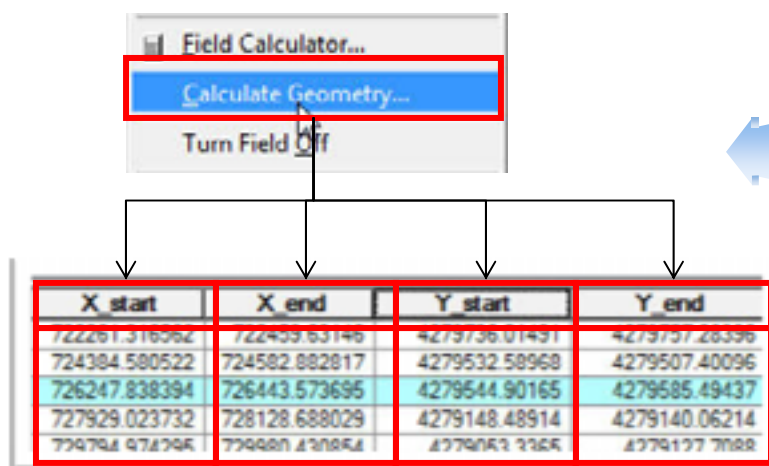
$A$  = Azimuth angle, measured clockwise from North

Source : [www.solsticeamateur.com/SolarGeneral.htm](http://www.solsticeamateur.com/SolarGeneral.htm)

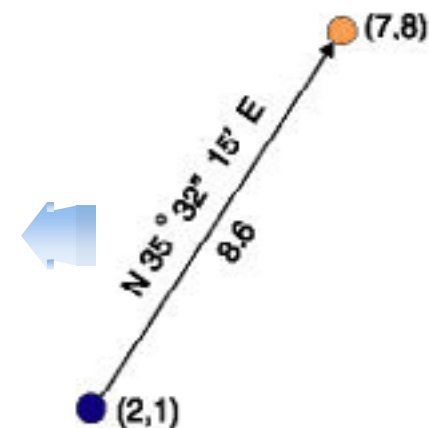


# Direction and Slope of Road Segment

$$d = \text{Atan}\left(\frac{(X_{\text{end}} - X_{\text{start}})}{(Y_{\text{end}} - Y_{\text{start}})}\right)$$



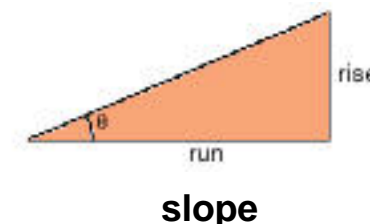
**ArcGIS**  
- Calculate Geometry



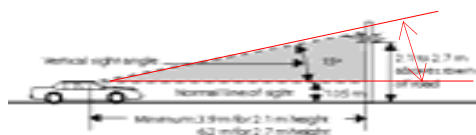
Direction

$$\theta = \text{Atan}(\text{rise}/\text{run})$$

**ArcGIS**  
- DEM  
- Spatial Analysis  
- Slope

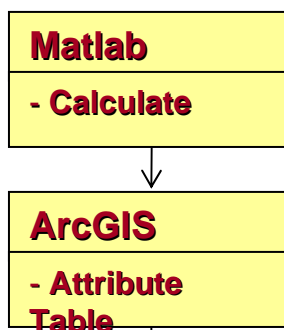


# Calculation of Intensity Solar Glare



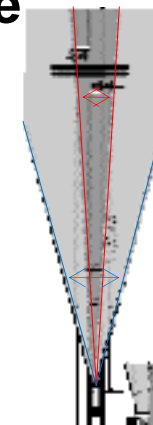
## Vertical Gap Angle

Index	Angle
0	"-90~0"
1	"0~15"
2	"15~30"
3	"30~45"
4	"45~"



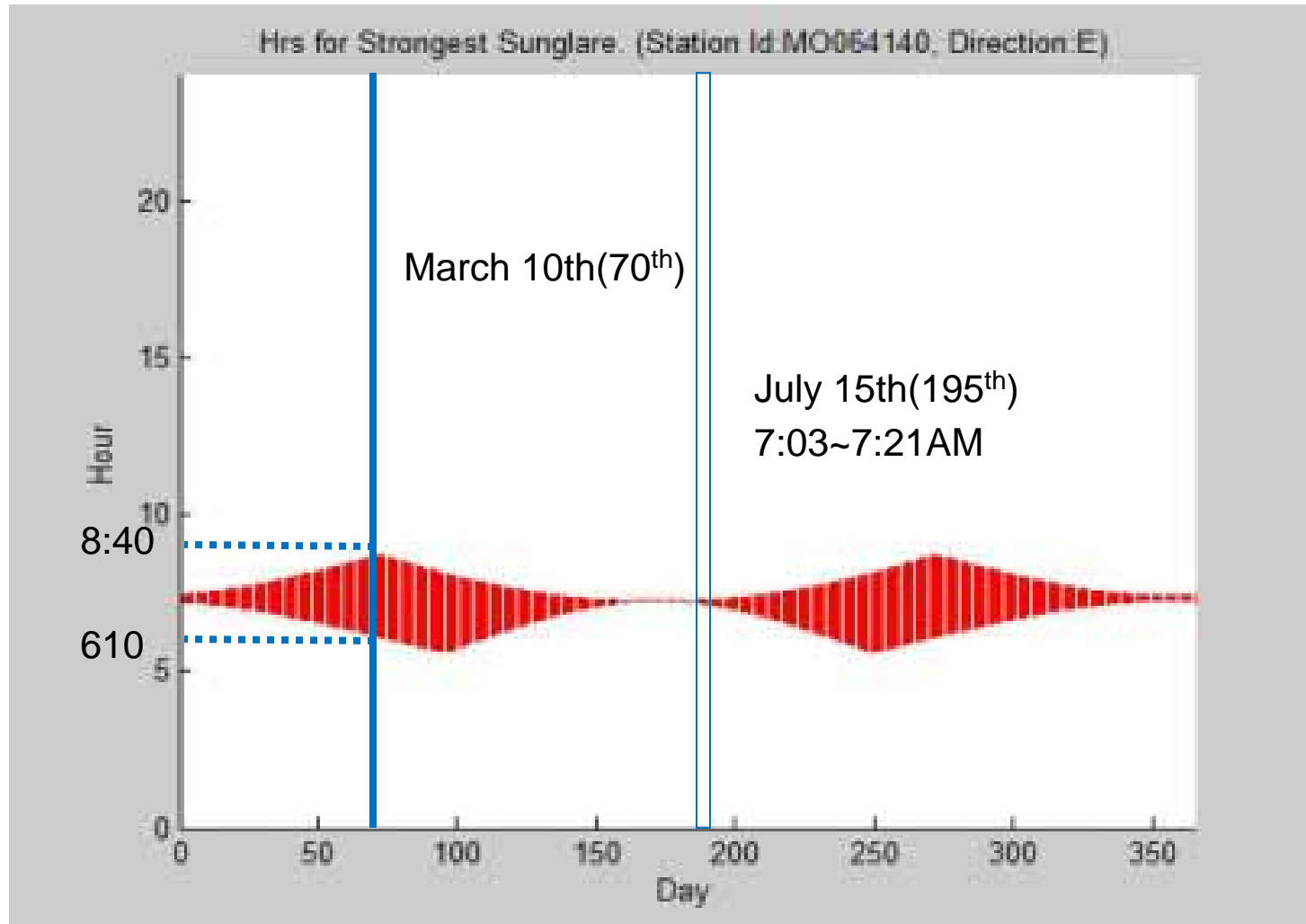
## Horizontal Gap Angle

Index	Angle
1	"0~5"
2	"5~20"
3	"20~45"
4	"45~90"
0	"90~"

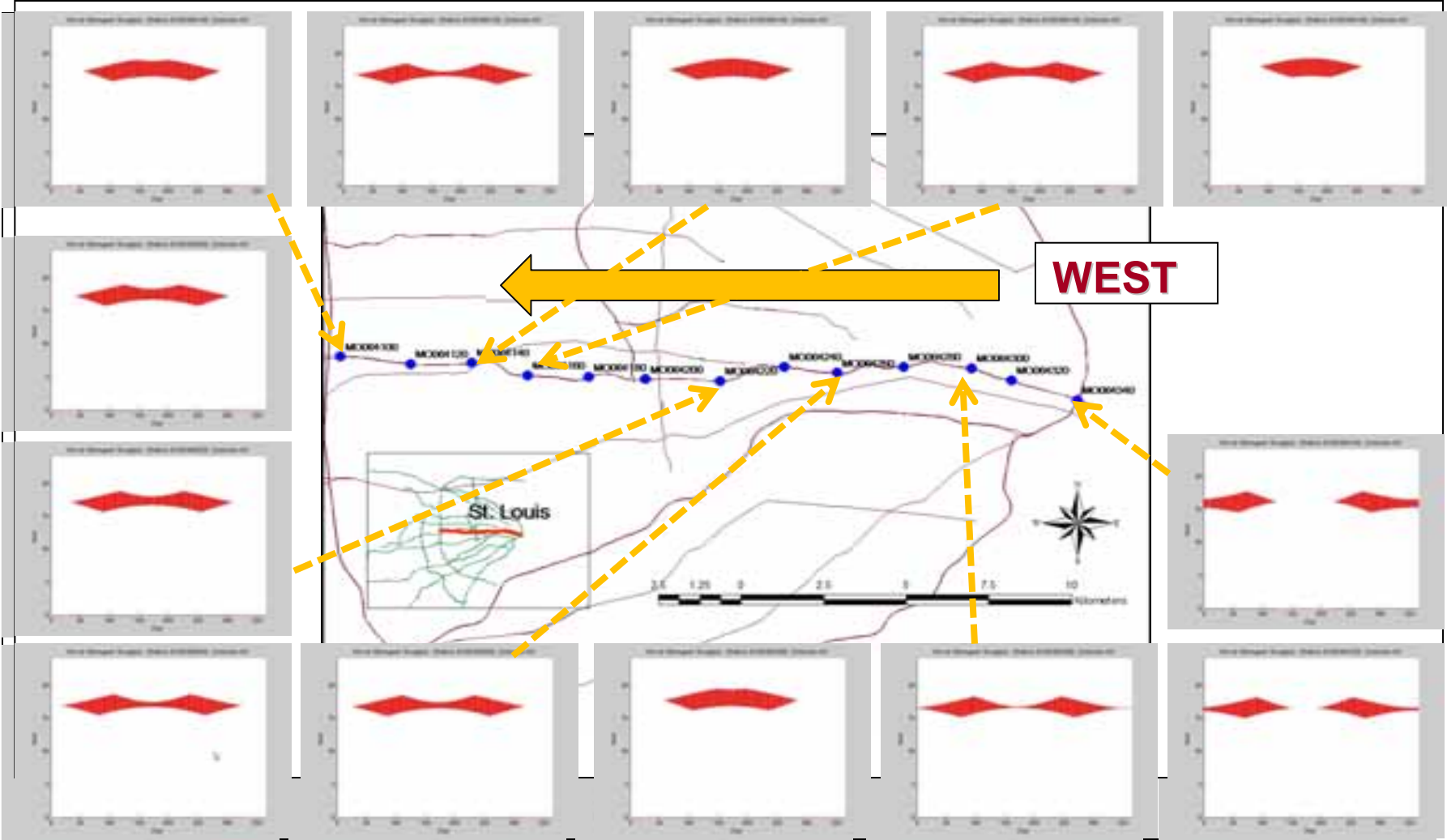


	azimuth	Direction2	log	Elevat	F_log	T_log	slope	azi2	Vertical	Horizontal	V_value
	61.648152	129.127262	6.4	173	5.9	6.4	-0.5	151.648152	9.565255	22.52089	1
	-50.128489	36.579499	21.4	154	20.9	21.4	-0.75	39.871511	10.799312	3.292012	1
	58.134454	121.759686	6.4	173	5.9	6.4	-0.5	148.134454	5.49103	26.374768	1
	-64.063968	31.455831	21.4	154	20.9	21.4	-0.75	25.936032	12.423633	5.519799	1
	68.740748	137.073134	4.4	153	3.9	4.4	3.5	158.740748	13.496248	21.667614	1
	59.913913	132.859217	4.4	153	3.9	4.4	3.5	149.913913	14.243415	17.054696	1
	64.715147	161.501123	2.4	177	1.9	2.4	0	154.715147	14.702102	6.785976	1
	73.226761	132.859217	4.4	153	3.9	4.4	3.5	163.226761	15.32888	30.367544	2
	101.010149	214.168545	14.5	154	14.5	15	0.75	191.010149	15.347252	23.158396	2
	43.072414	132.859217	4.4	153	3.9	4.4	3.5	133.072414	16.097169	0.213197	2
	43.213008	162.592926	2.4	177	1.9	2.4	0	133.213008	16.527714	29.379918	2
	-37.586146	48.323519	20.9	148	20.4	20.9	1.5	52.413854	16.898867	4.090335	2
	-87.513593	342.645479	33.5	177	33.5	34	0	2.486407	17.101001	19.840928	2
	-69.036089	31.455831	21.4	154	20.9	21.4	-0.75	20.963911	17.655912	10.49192	2

# Solar Glare over 24hours (=x) 365 Days (=y) (at a given segment of highway)



# Solar Glare over 24hours (=x) 365 Days (=y) (at a given segment of highway)



# **Evaluation of Solar Glare Influence on Traffic Flow**

# Traffic Data

- **Every 5 minutes, each traffic detector collects**
  - Speed (mile/hr), Volume (veh/5-min), etc.
- **We need to use only normal days in the analysis**
  - i.e., we need to filter out special days that experienced accidents, bad weather, etc.



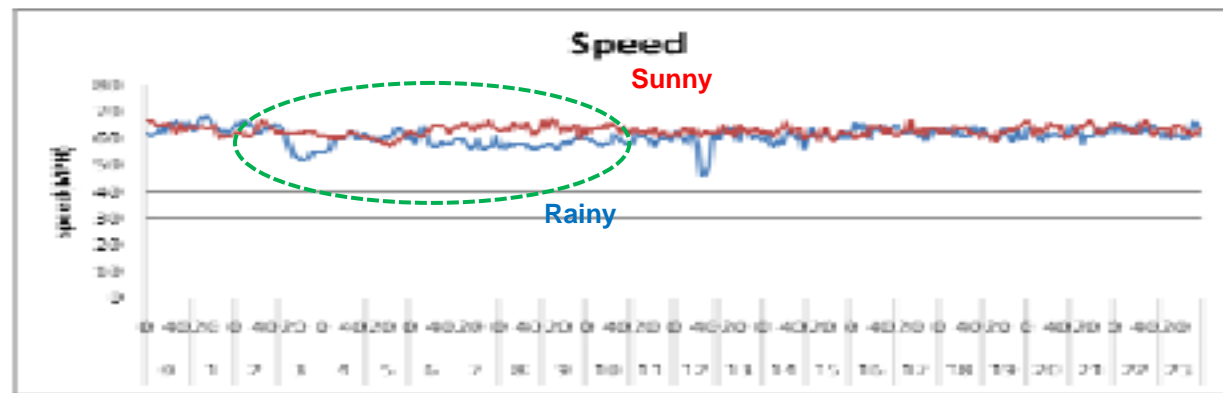
# Traffic Data (Data Filtering)

- 24-hour Speed at a given location

- Day 1: Normal day, Day 2: Day with accident



-Weather



# Traffic Data (Accident Locations for Filtering)

## ● Accident Location

**MoDOT TMS**

- Accident Location
- Accident Date



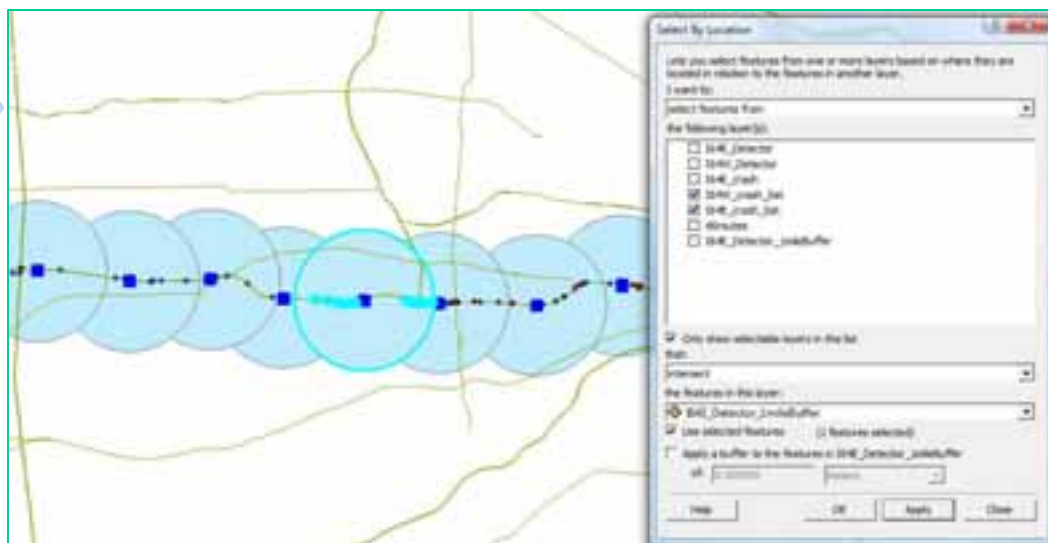
**ArcGIS**

- Dynamic Segmentation



**ArcGIS**

- Buffer
- Select by Location...



## ● Filtering

- 1 mile Buffer from detector
- Select by Location



# Traffic Data (Weather Data for Filtering)

## All Saturday(52week)

Year	Month	Day	Index	Moring	Afternoon
2006	7	1	27	1	1
2006	7	8	28	1	1
2006	7	22	29	1	1
2006	7	29	30	1	2
2006	8	5	31	1	1
2006	8	12	32	3	1
2006	8	19	33	1	1
2006	8	26	34	3	N/A
2006	9	2	35	1	1
2006	9	9	36	1	1
2006	9	16	37	1	1
2006	9	23	38	3	3
2006	9	30	39	3	N/A
2006	10	7	40	1	1
2006	10	14	41	1	1
2006	10	21	42	1	3
2006	10	28	43	3	1
2006	11	4	44	1	3
2006	11	11	45	3	N/A
2006	11	18	46	N/A	3
2006	11	25	47	1	1
2006	12	2	48	1	3
2006	12	9	49	1	1
2006	12	16	50	3	3
2006	12	23	51	1	1
2006	12	30	52	1	2
2007	1	6	1	3	1
2007	1	13	2	2	2
2007	1	20	3	N/A	3
2007	1	27	4	3	3
2007	2	3	5	N/A	3
2007	2	10	6	3	1
2007	2	17	7	5	3
2007	2	24	8	2	3
2007	3	3	9	3	3
2007	3	10	10	6	3
2007	3	17	11	3	3
2007	3	24	12	1	1
2007	3	31	13	3	3
2007	4	7	14	1	1
2007	4	14	15	2	2
2007	4	21	16	N/A	1
2007	4	28	17	N/A	3
2007	5	5	18	1	1
2007	5	12	19	1	1
2007	5	19	20	1	1
2007	5	26	21	3	3
2007	6	2	22	3	2
2007	6	9	23	1	1
2007	6	16	24	1	1
2007	6	23	25	N/A	3
2007	6	30	26	N/A	N/A

## I-64E(25week)

Year	Month	Day	Week	Moring	Afternoon
2006	7	1	27	1	1
2006	7	8	28	1	1
2006	7	22	29	1	1
2006	7	29	30	1	2
2006	8	5	31	1	1
2006	8	19	33	1	1
2006	9	2	35	1	1
2006	9	9	36	1	1
2006	9	16	37	1	1
2006	10	7	40	1	1
2006	10	14	41	1	1
2006	10	21	42	1	3
2006	11	4	44	1	3
2006	11	25	47	1	1
2006	12	2	48	1	3
2006	12	9	49	1	1
2006	12	23	51	1	1
2006	12	30	52	1	2
2007	3	24	12	1	1
2007	4	7	14	1	1
2007	5	5	18	1	1
2007	5	12	19	1	1
2007	5	19	20	1	1
2007	6	9	23	1	1
2007	6	16	24	1	1

## I-64W(25week)

Year	Month	Day	Week	Moring	Afternoon
2006	7	1	27	1	1
2006	7	8	28	1	1
2006	7	22	29	1	1
2006	8	5	31	1	1
2006	8	12	32	3	1
2006	8	19	33	1	1
2006	9	2	35	1	1
2006	9	9	36	1	1
2006	9	16	37	1	1
2006	10	7	40	1	1
2006	10	14	41	1	1
2006	10	28	43	3	1
2006	11	25	47	1	1
2006	12	9	49	1	1
2006	12	23	51	1	1
2007	1	6	1	3	1
2007	2	10	6	3	1
2007	3	24	12	1	1
2007	4	7	14	1	1
2007	4	21	16	N/A	1
2007	5	5	18	1	1
2007	5	12	19	1	1
2007	5	19	20	1	1
2007	6	9	23	1	1
2007	6	16	24	1	1

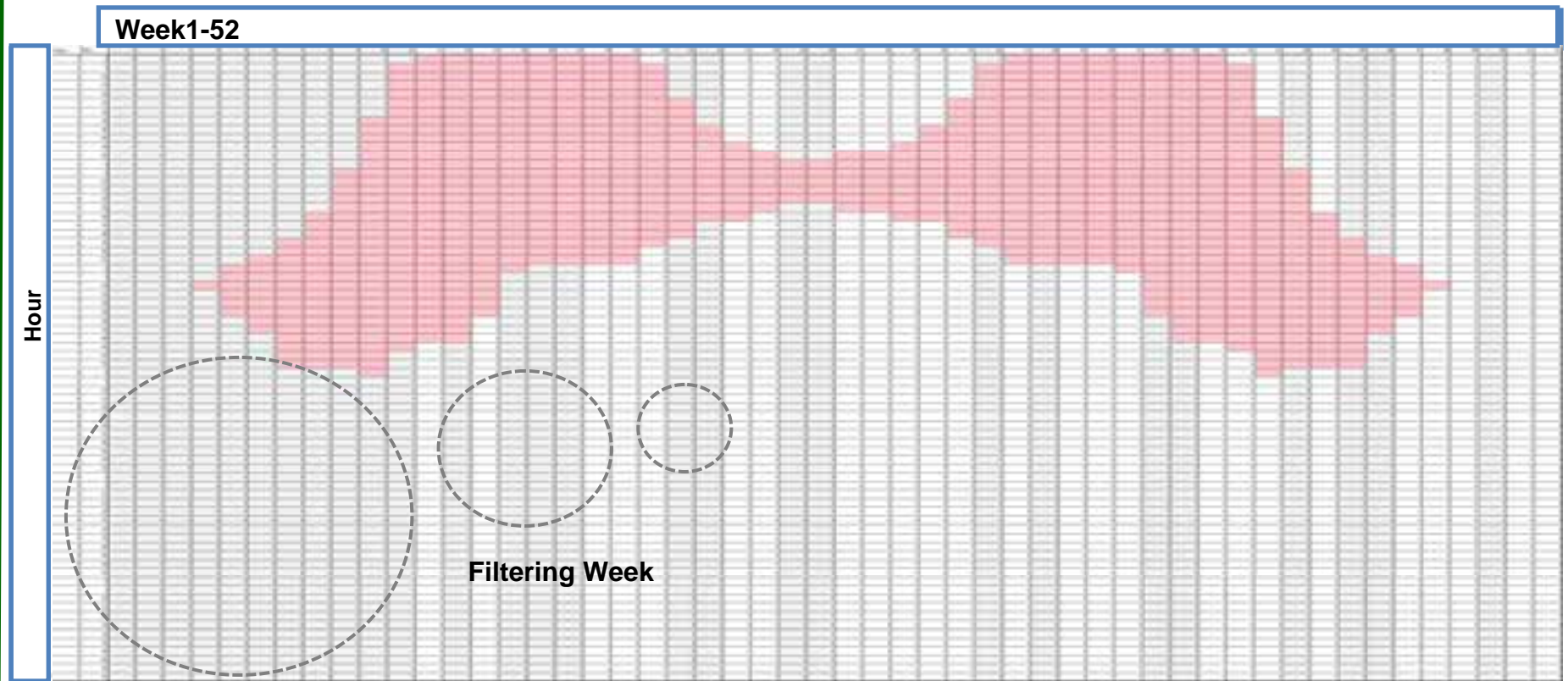


**MoDOT TMS**  
- Weekday  
- Weather

### Weather Index

CLEAR	1
RAIN	2
CLOUDY	3
FREEZING	4

# Intensive Solar Glare (24-hr on all 52 Saturdays)



# Speeds with and without Sun Glare

Available (25week)



● Compare Two Speeds

Calculate 'without solar glare' average volume(speed, speed variance, etc...) (ex: 16week, 5:00-5:05)

Calculate 'with solar glare' average volume (speed, speed variance, etc...) (ex: 9week, 5:00-5:05)

# Comparison of Two Speeds

Average speed		
Time	Without	With
500	54.5	56.0
505	54.0	54.0
510	55.7	51.5
515	52.7	51.5
520	53.3	50.0
525	52.0	54.0
530	50.7	52.5
535	51.3	53.0
540	51.0	54.5
545	53.0	54.5
550	52.0	54.5
555	51.0	52.5
600	53.3	54.0
605	51.0	54.0
610	51.0	39.7
615	53.7	56.7
620	55.0	56.0
625	55.0	56.5
630	53.7	57.7
635	54.7	56.0
640	54.0	50.0
645	55.3	54.0
650	55.0	38.7
655	54.3	56.5
700	55.0	58.0
705	56.0	59.3
710	55.3	58.3
715	55.0	58.0
720	41.7	56.3
725	55.0	57.3
730	52.0	57.0
735	54.3	59.0
740	40.7	58.7
745	52.5	58.7
750	52.5	59.0
755	55.7	59.7
800	54.5	62.0

## T-test

- For compare mean : paired-sample T-test
- Here  $S_{X_1 X_2}$  is the grand standard deviation

Paired Samples Statistics

	Mean	N	Std. Deviation	Std. Error Mean
Pair 1 Others	52.90	37	3.242	.533
I-T	54.85	37	4.721	.776

$$t = \frac{\bar{X}_1 - \bar{X}_2}{S_{X_1 X_2} \cdot \sqrt{\frac{2}{n}}}$$

Paired Samples Correlations

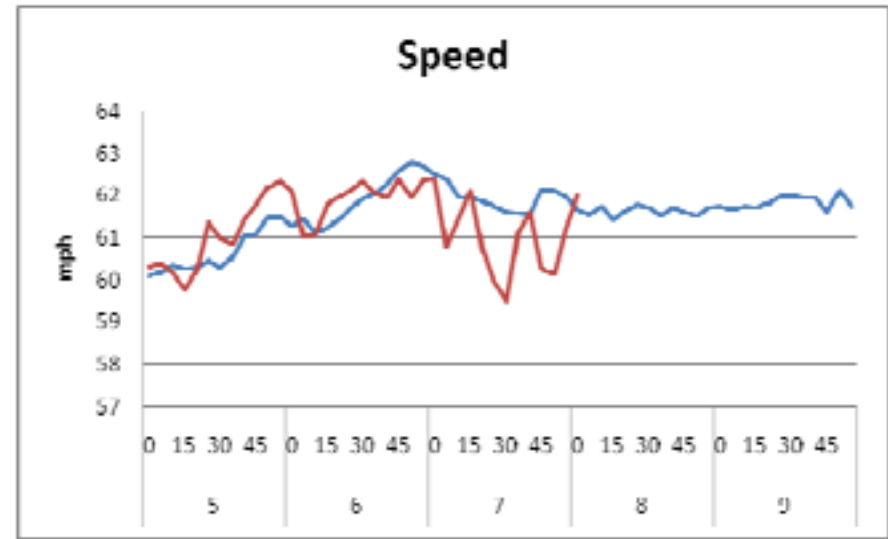
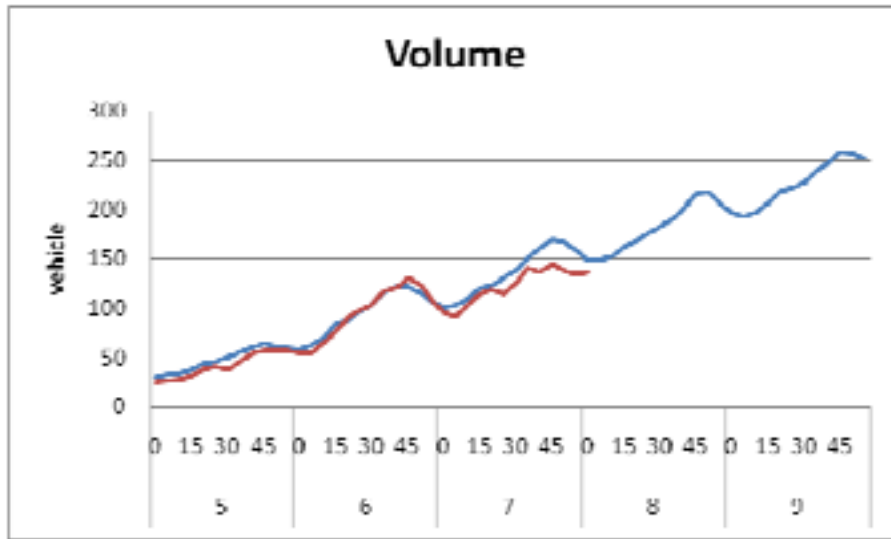
	N	Correlation	Sig.
Pair 1 Others & I-T	37	.019	.913

Paired Samples Test

		Paired Differences				t	df	Sig. (2-tailed)	
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower				Upper
Pair 1	Others - I-T	-1.951	5.677	.933	-3.844	-.059	-2.091	36	.044

- Probability(0.044) is less than significance level(0.05)
- Two group(intensity time and others) mean values are different under 5% significance level

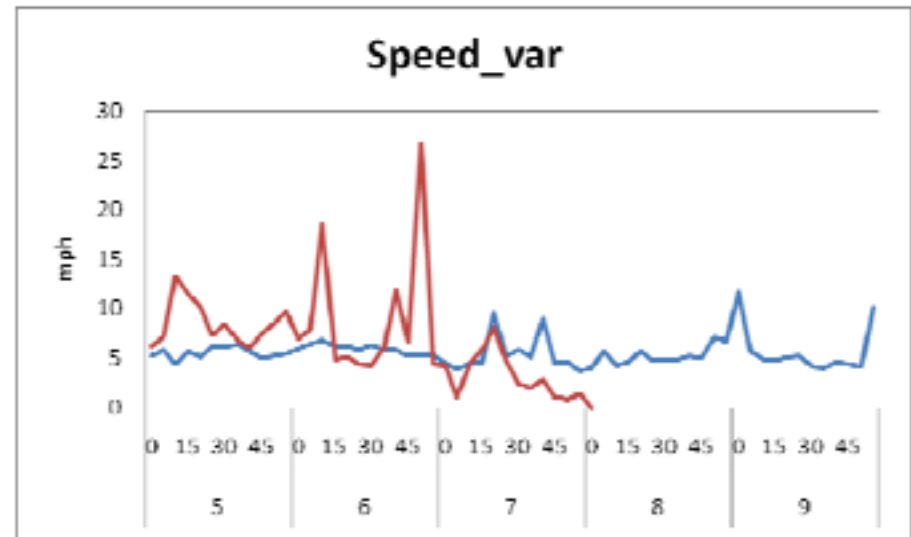
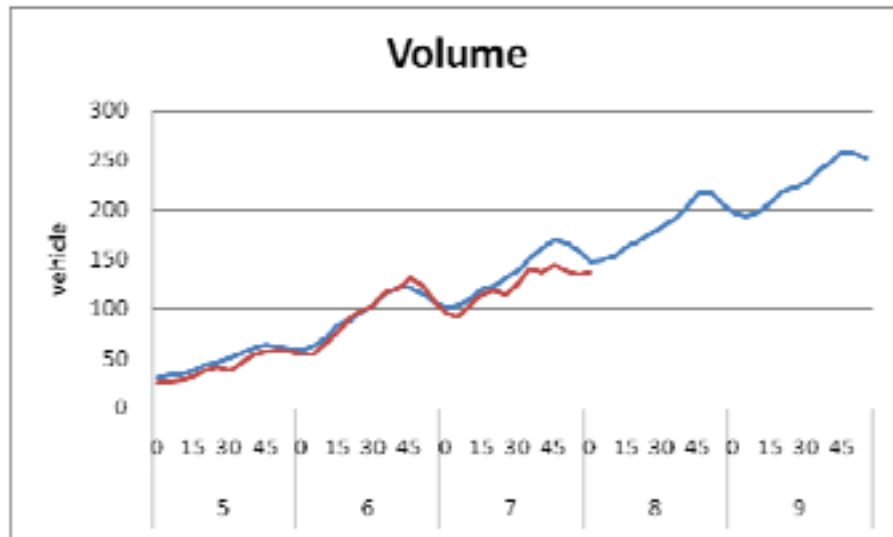
# Was the Speed Comparison Fair?



Legend  
■ With Solar Glare  
■ Without Solar Glare

- Volumes shows almost same pattern.
- But, speeds are considerably different in with and without sun glare condition.

# Any other Comparison?



Legend  
■ With Solar Glare  
■ Without Solar Glare

- According to traffic safety researches, speed variance is highly correlated to rear-end crashes.

# Conclusion and Further Study

# Conclusion and Further Study

- **In this study, we showed that**
  - **sun glare influences traffic speed.**
  - **Sun glare also increases speed variance. (Need to be more studies)**
  
- **This study can be applied in**
  - **Identification of hazardous locations and time due to solar glare**
  - **improving the traffic control procedure**
  
- **As a further study, the team is developing a user-friendly tool**



**Thank You**