Disha Sardana

Education

Ph.D. in Immersive Analytics,
Virginia Tech, Blacksburg, VA, USA

M.S. in Electrical Engineering (Electromagnetics),
Virginia Tech, Blacksburg, VA, USA

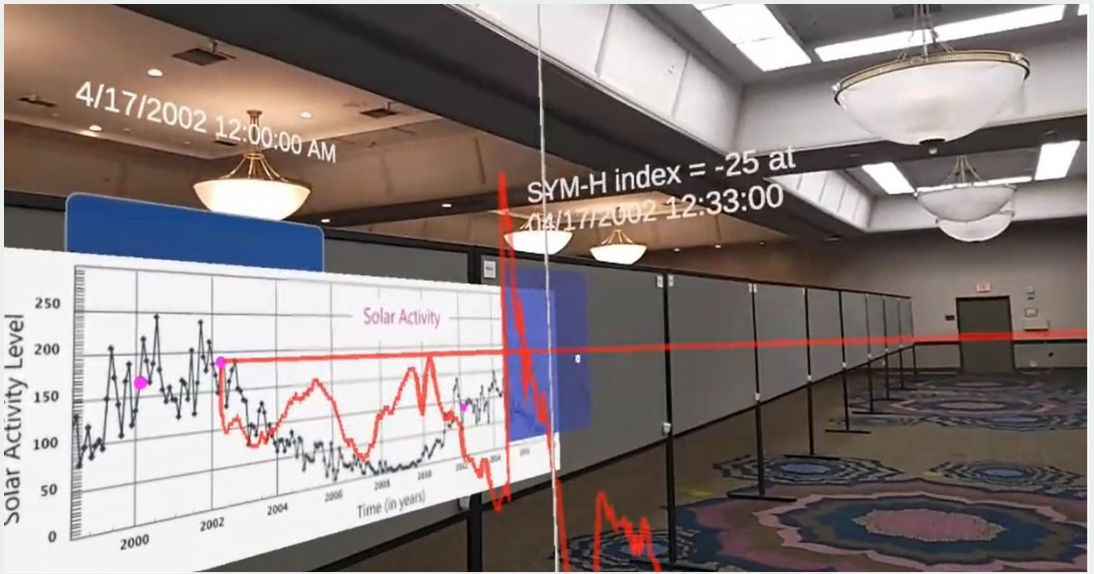
Research Interests: Space Weather, Augmented/ Virtual Reality, Immersive Analytics

Immersive Space Weather Analytics

Individualized Interdisciplinary Ph.D. Research, Virginia Tech

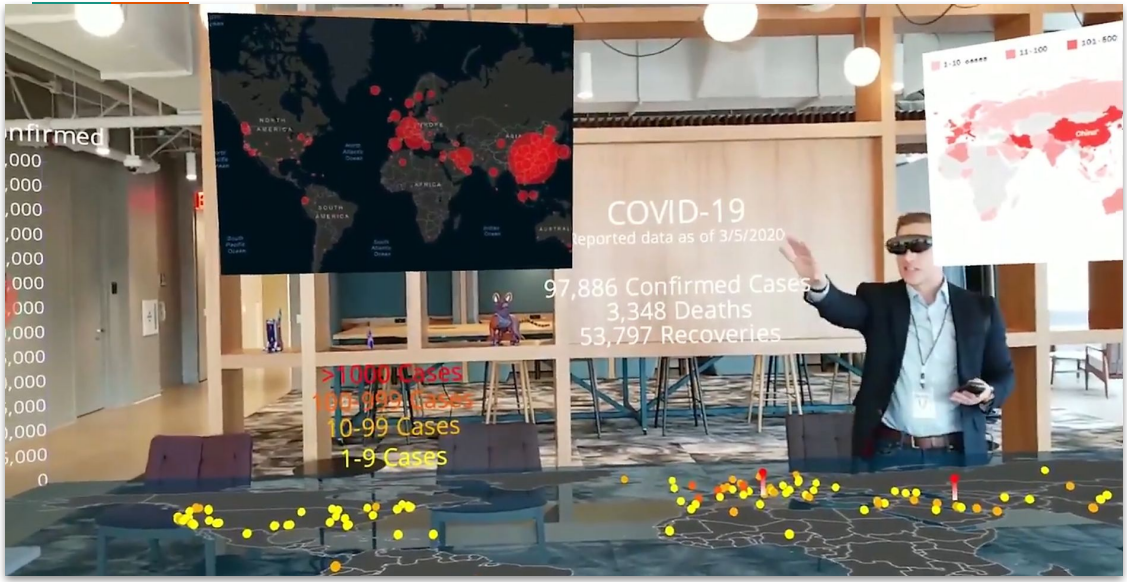
Presented by Disha Sardana

At 4th Eddy Cross-Disciplinary Symposium, Golden, CO October 31st, 2023



Outline

Motivation



The Immersive Analytics Approach Enables:

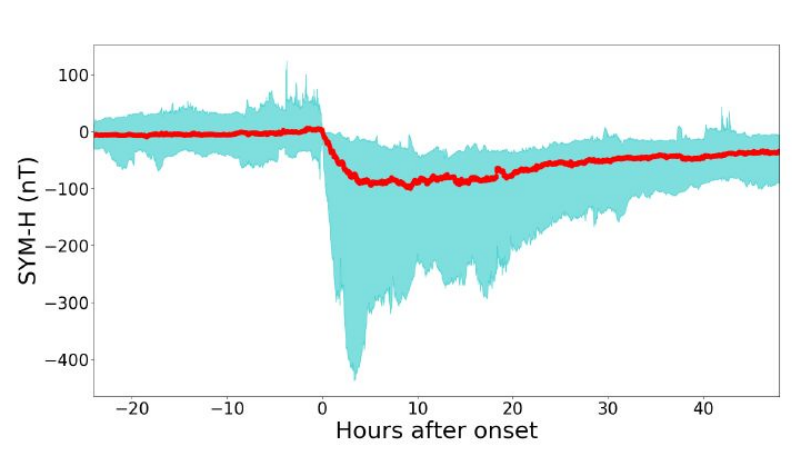
- Experiencing the data in three or more dimensions
- Engaging **multiple senses** like sound and sight
- Leveraging human **embodiment**, **interaction** capabilities, and sense of **presence**

An update on COVID-19 from Magic Leap and Flow Immersive team, with an additional explanation on why this geospatial 3d representation is an improvement over flat maps.

[Published on Mar 6, 2020 by Flow Immersive on X: https://twitter.com/flowimmersive/status/1236001785527054336]

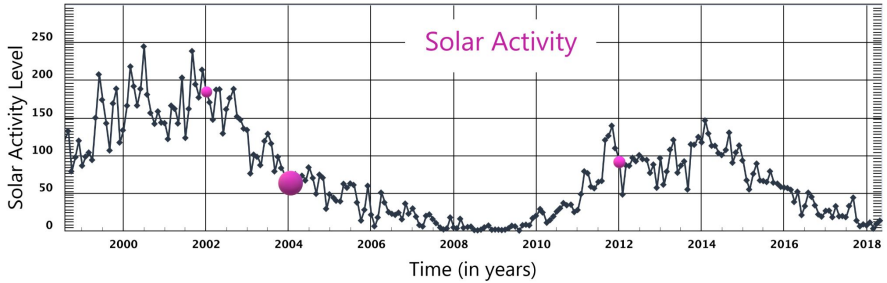
Application in the Space Weather Domain

Variable #1. SYM-H Index



The average SYM-H profile of the 37 large storms is plotted in red with the time referenced from the onset time. The cyan envelope shows the variability in the SYM-H profiles in the entire dataset. [Debchoudhury, 2020]

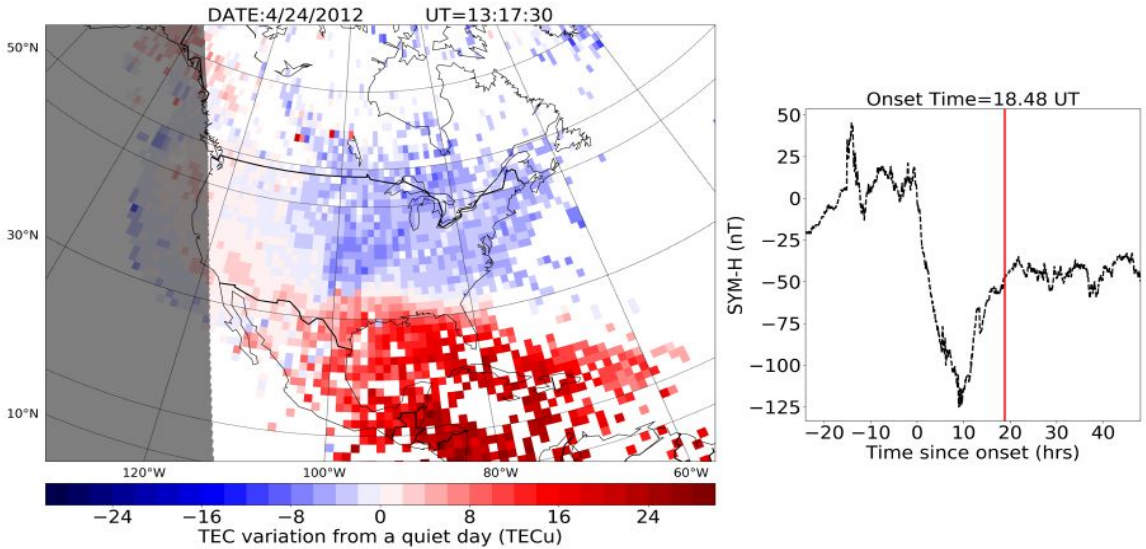
Variable #2. Solar Activity Level (Sunspot Number)



Solar activity level from 1999-2018. The approximate 11-year solar cycle variation is visible, as are the higher frequency fluctuations that modulate this periodicity.

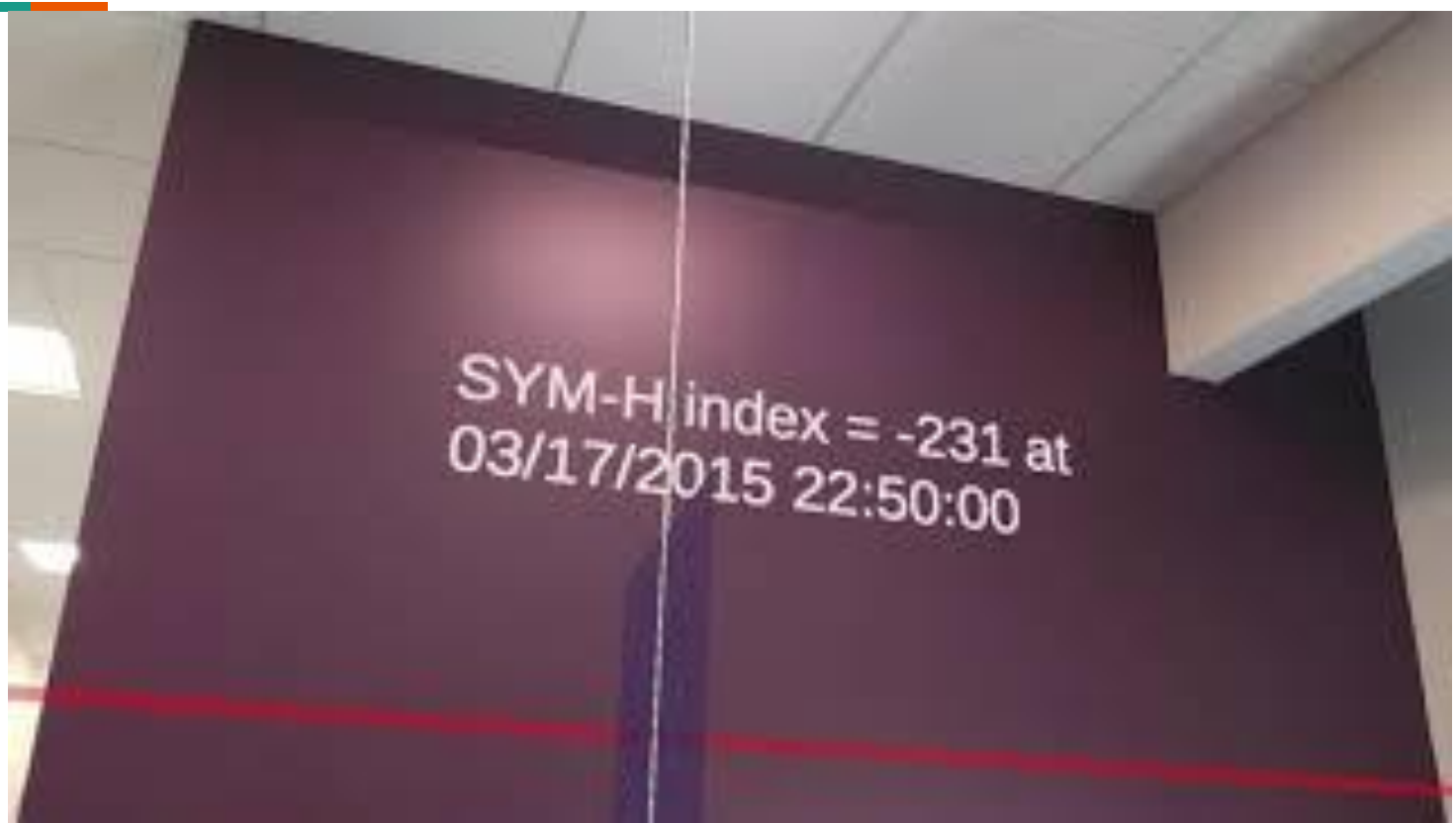
The pink spheres visually mark the presence of a solar storm. The size of the pink sphere indicates the intensity of a storm and is numerically mapped to the minimum SYM-H value of the storm over its full duration.

Variable #3. Total Electron Content (TEC)

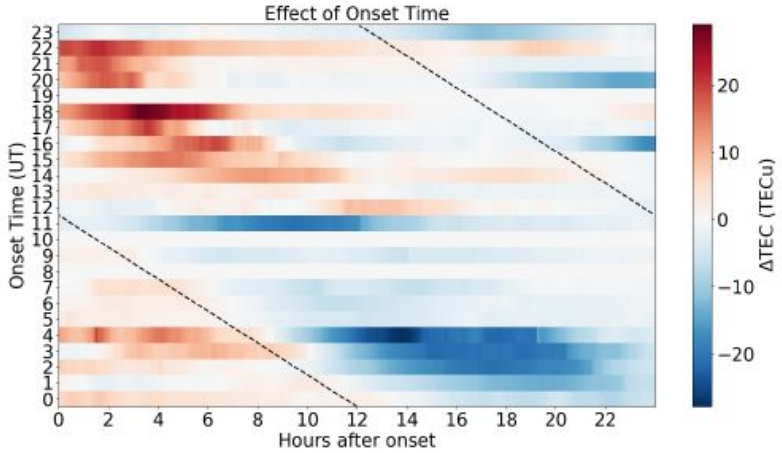


The left panel shows a time snapshot of storm enhanced densities over the continental US sector in the main phase of an intense geomagnetic storm with onset time at 18 UT. The SYM-H signature for the storm is shown in the right panel, where the red vertical line denotes the time of the snapshot. The x-axis of the right panel is referenced to the onset time of the storm [Debchoudhury, 2020].

Examples of Space Weather Datasets in a Mixed Reality Environment



Correlation between the Sunrise Terminator and Delta TEC

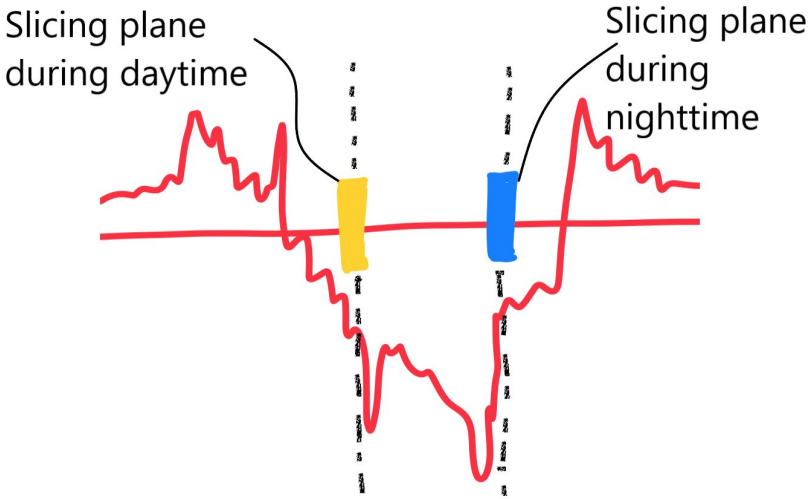


Temporal evolution of delta TEC in the aftermath of the **37 large storms** in the high-west U.S. sector, plotted over a 24 hour period following each onset time. The diagonal dashed lines show the sunrise terminators, which clearly correlate with patterns in the TEC data [Debchoudhury, 2020].

The storms with onset time (UT) before noon show a clear correlation between the sunrise terminator and storm-induced change in TEC.

**The Figures are reproduced with permission of the Journal of Geophysical Research: Space Physics.*

An Immersive Approach to Identify Correlations



- In the current study, the correlation shown on the previous slide is presented ***creatively using sound and visual representations in an immersive mixed-reality environment.***
- Instead of showing timestamps, the onset of day and night are shown visually through the yellow and blue colors of the slicing plane.
- This approach mitigates issues that might arise due to participants attempting to convert from UT to local time.

Using Sound to Augment Data Analysis

Data	Auditory Stimulus	Parameter Mapping
Delta TEC data shown in the line-plots	Triangle wave	Pitch modulation
Sunrise/ Sunset terminator across the time-series delta TEC data	Rooster sound Sound of cicadas	NA

Rationale:

- The auditory modality is superior in detecting temporal changes and patterns as compared to the visual stimuli. [John H Flowers and Terry A Hauer, 1995]
- Natural sounds are found to be relaxing and helpful in the perception and interpretation of data. [B. S. Mauney and B. N. Walker, 2004]

Using Sound to Identify Correlations

Trends identified by 50 study participants with no prior knowledge of space weather

Trends observed by the participants	Audio-visual	Visual only
Correlation b/w solar activity levels and other variables of interest	13	8
Insights about solar activity level plot	31	34
Insights about SYM-H index plot	8	10
Overall identified trends	**52**	**52**

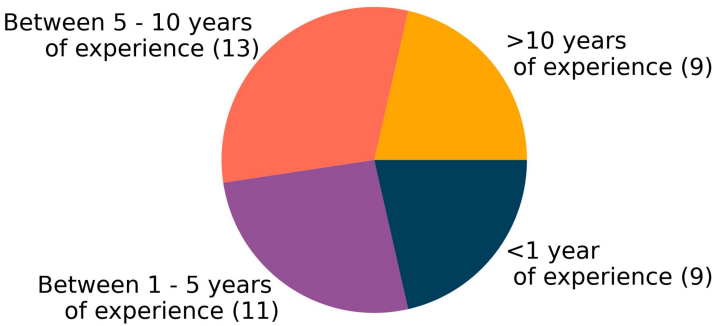
1st Correlation Study: SYM-H Index and Solar Activity Level

Trends observed by the participants	Audio-visual	Visual only
Relation b/w extrema and sunrise/ sunset	40	15
Drop and rise pattern between delta TEC and terminators	16	14
Insights about delta TEC values	12	11
Overall identified trends	**68**	**40**

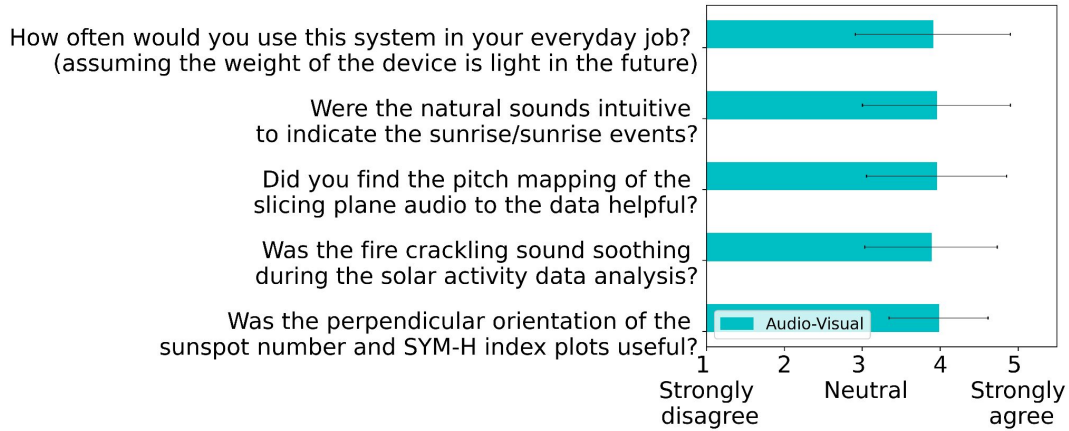
2nd Correlation Study: Delta TEC

Demo with Space Science Experts at the CEDAR 2023 Workshop

Demo with 42 Space Science Experts



Level of space science expertise



Mean of the user responses from the post-study survey (42 space science experts) for the audio-visual scenario at CEDAR 2023 workshop

Future Directions

Immersive analytics and the judicious use of sound can be applied to study other correlations in space-science datasets, such as:

1. *Auroral oval expansion and equatorward propagation of energy vs. particle precipitation intensity, solar wind speed, and solar wind density*
2. *Duration and intensity of equatorial spread F vs. onset time, season, and the magnitude of the pre-reversal enhancement*
3. *Satellite and ground-based gravity wave and TID signatures vs. the location and duration of large tropospheric storm systems*
4. *Space-based single event upset rates vs. satellite location, sunspot number, locus of sunspots on the solar disk, solar wind speed, ring current intensity, and other geophysical variables that might be related to electronic system malfunctions*

Such future studies may help to discover new relationships and coupling mechanisms that are currently unknown and/or misunderstood.

Thank you!