Determining Cloud-Level Winds in the Venus Atmosphere with Telescopic Infrared Images of the Venus Nightside and a Team of Citizen Scientists

Mark A. Bullock, Vincent Corbett, Dennis Green, David H. Grinspoon, Sarah Hink, Marta Lindsay, Kevin McGouldrick, Larry Stearns, Carver Thomason, and Ching-Hsuan Tseng, Jonathan Nickerson, Art Tarr, Carlos Romero, Michael Davison, Debra Davis

Denver Museum of Nature & Science

November 3, 2010

Research Problem

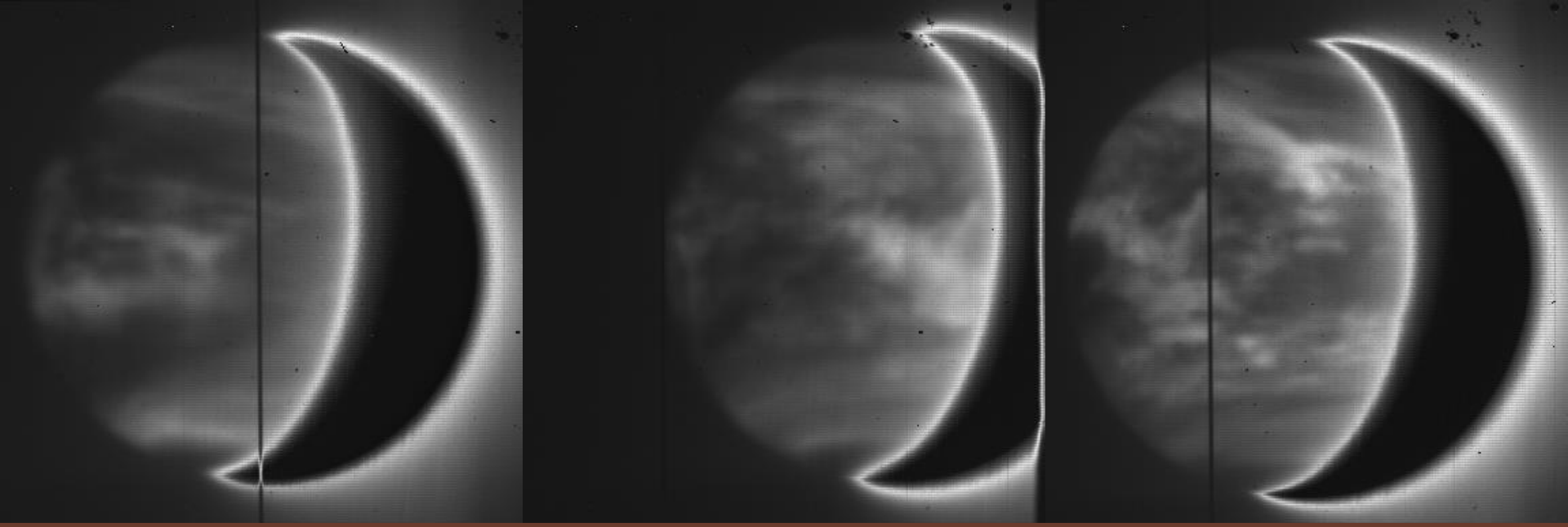
- How fast are the winds on Venus?
- How do they vary in time and with latitude?

Research Solution

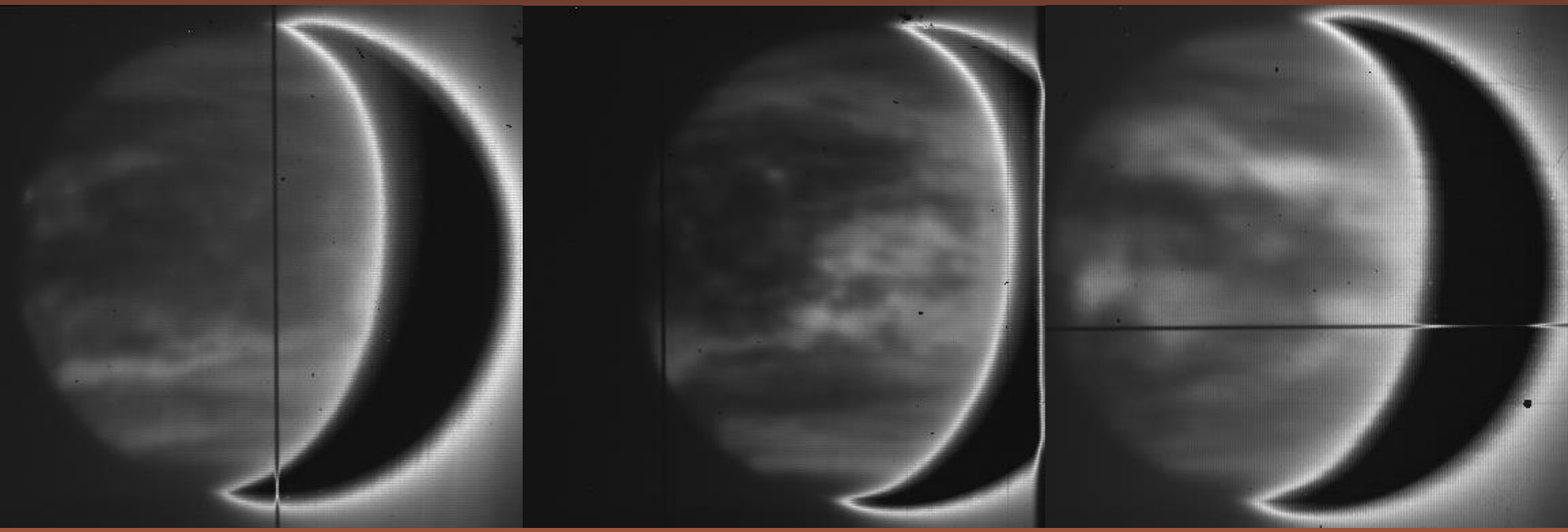
- Take many, many images of the Venus clouds.
- Track cloud features and calculate velocities.

Acquiring the Data

- More than 80,000 2.3 μm images of the nightside of Venus, 2001-2007.
- Images acquired using the SpeX imager and spectrometer on the 3-m NASA Infrared Telescope Facility (IRTF)



May 4, 2004 Venus 2.3 μm May 5, 2004 IRTF May 6, 2004



May 8, 2004 Eliot Young May 9, 2004 Mark Bulllock May 10, 2004

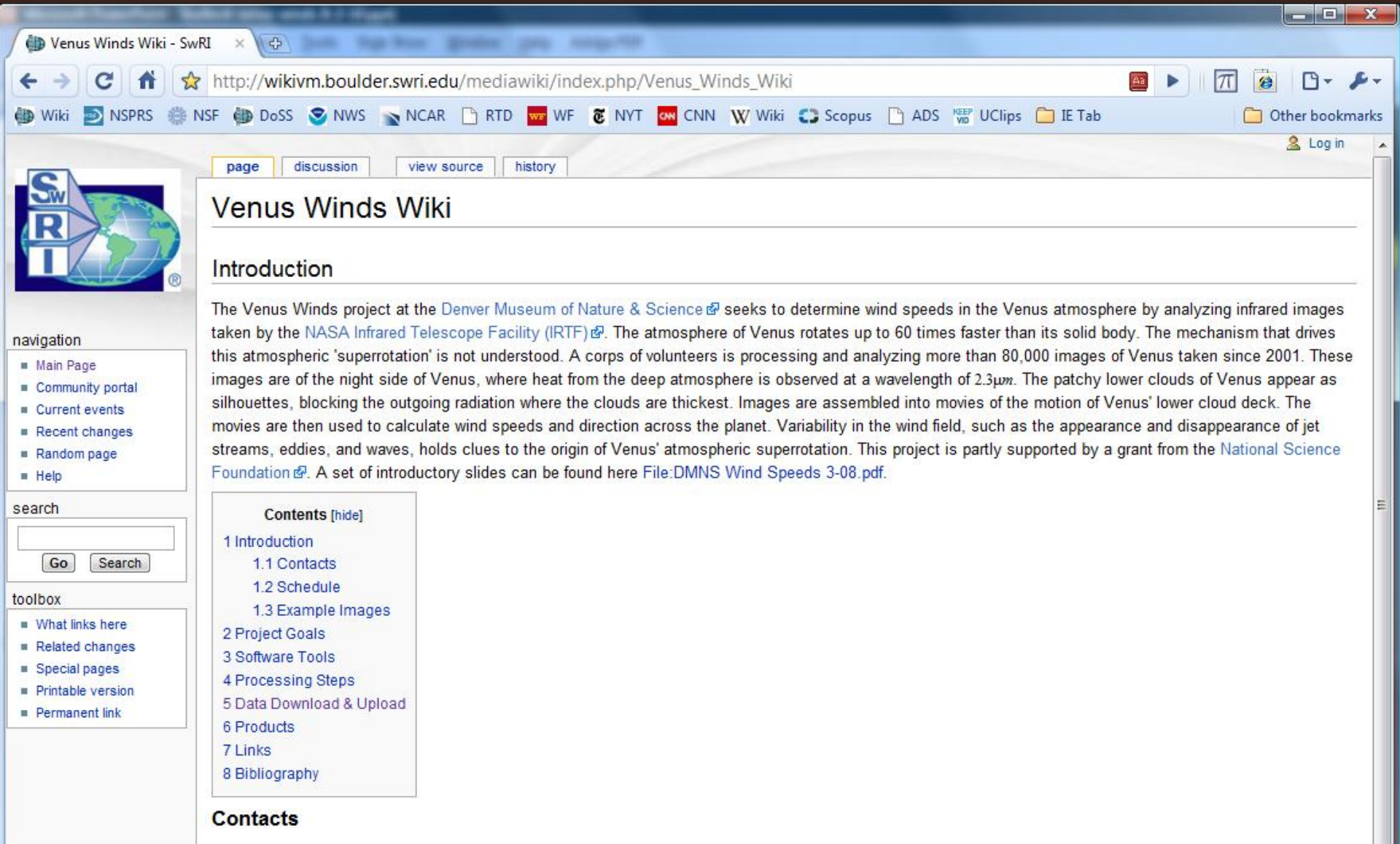
Research Implementation Problem

- How do we analyze 80,000 images?
  - Sort by image quality
  - Flat field the images
  - Remove spectrometer slit
  - Co-register the images
  - Remove scattered sunlight
  - Co-add images for best contrast
  - Choose fiducial points and calculate velocities

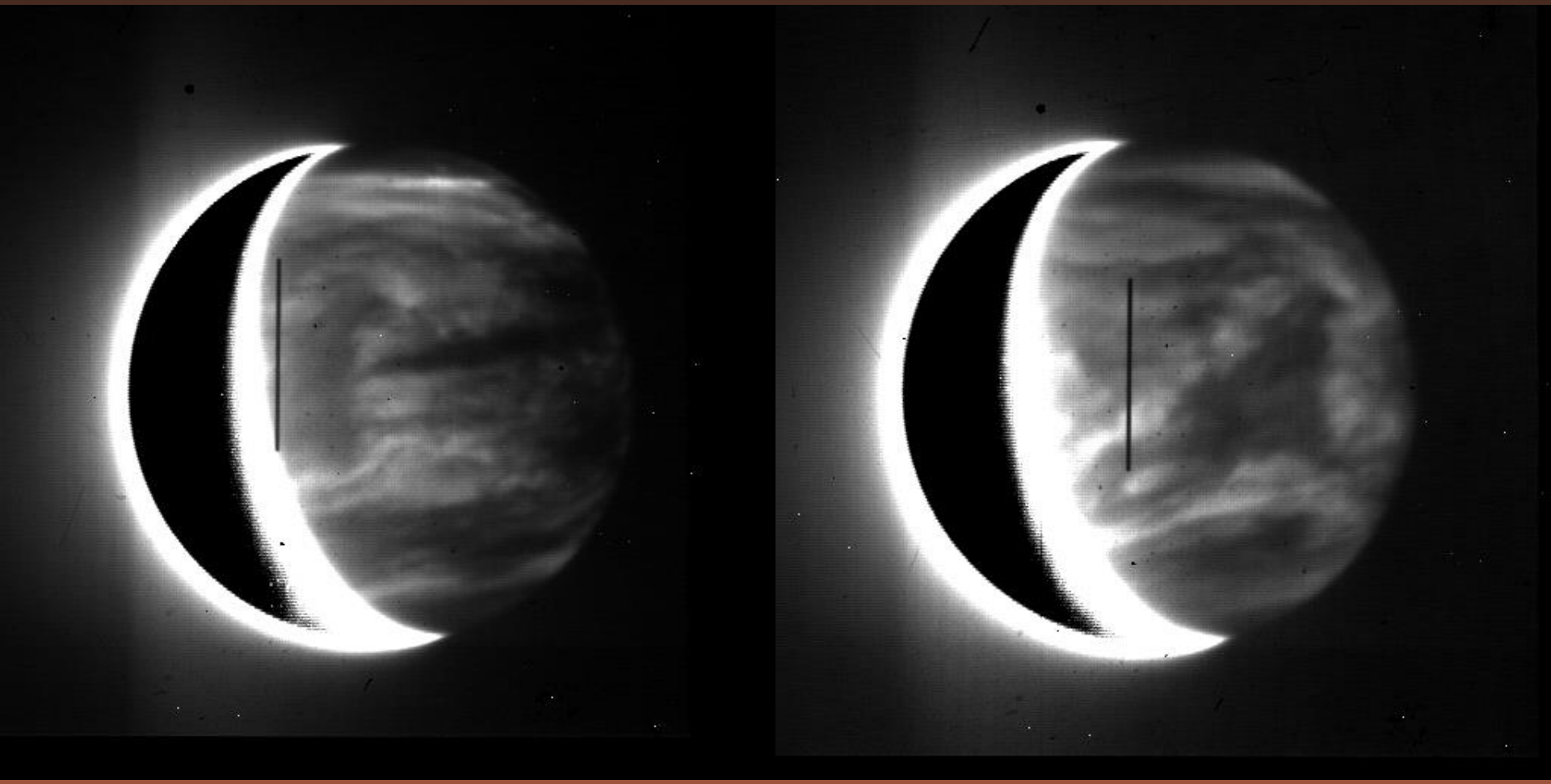
Research Implementation Solution

- Put together a team of citizen scientists who are willing to pore over the images, process them, and calculate velocities.
- Make movies of Venus cloud motion.

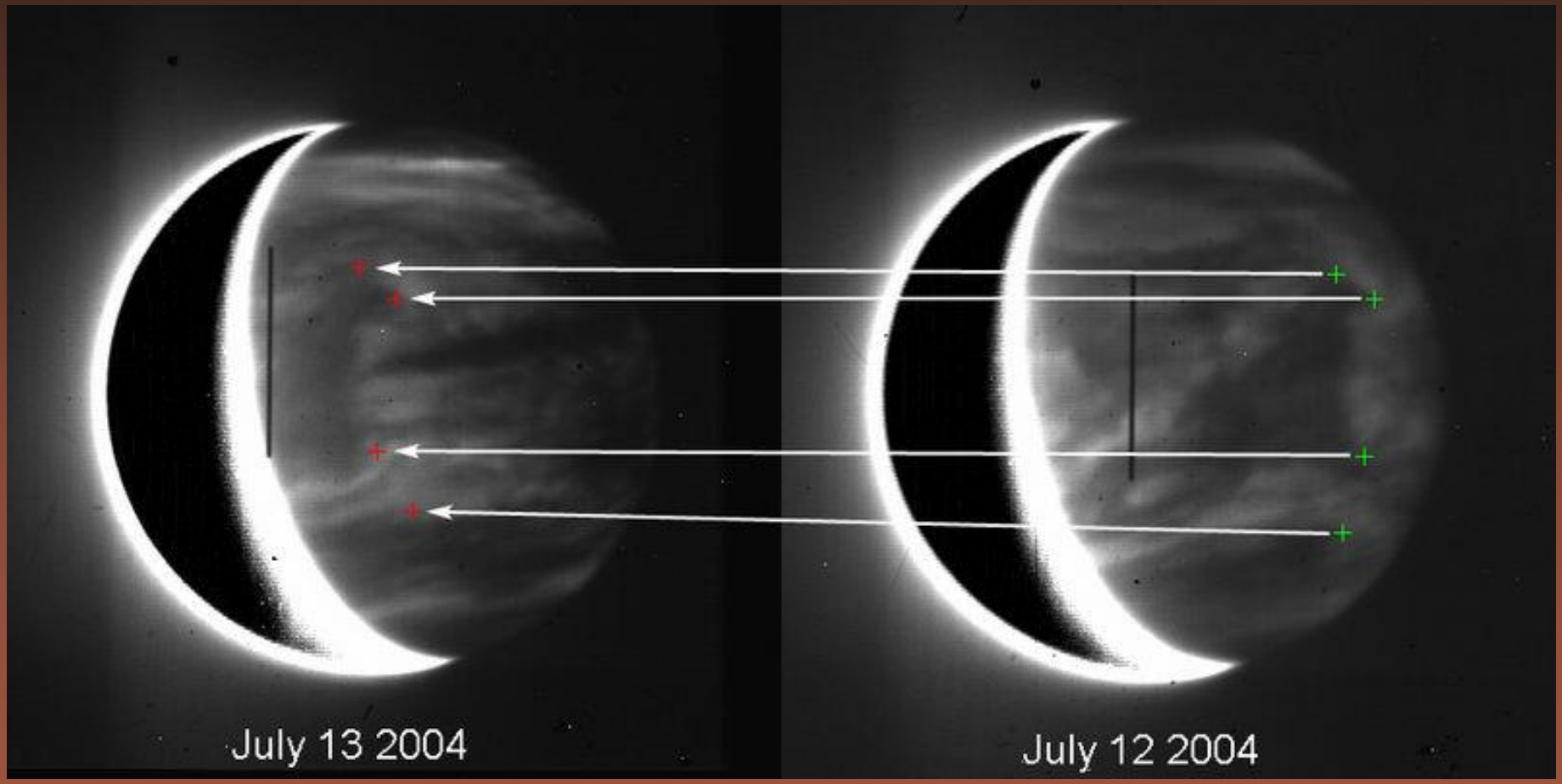
Citizen Science Collaboration



Example Images

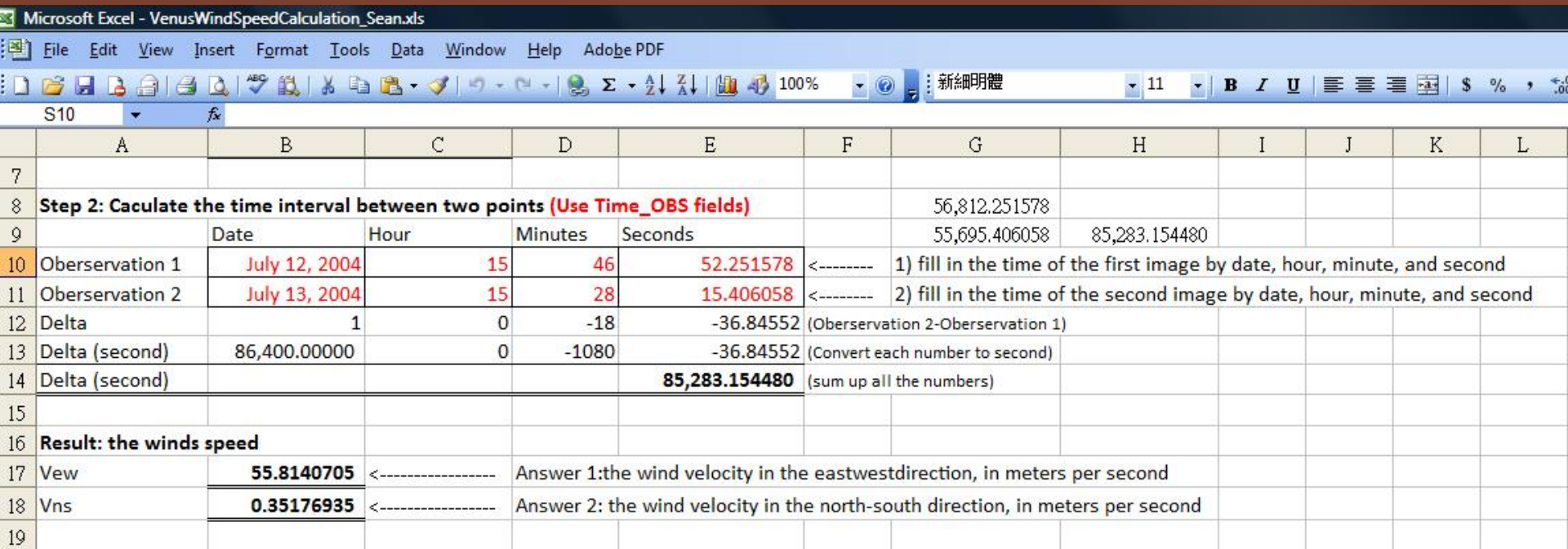


Analysis Example



Wind Velocity Calculations

- Precise co-registration done by Carver Thomason using FITSRegister (in house software).
- All participants found points and calculated wind speeds using Excel spreadsheet by Ching-Hsuan Tseng.



Microsoft Excel - VenusWindSpeedCalculation_Sean.xls

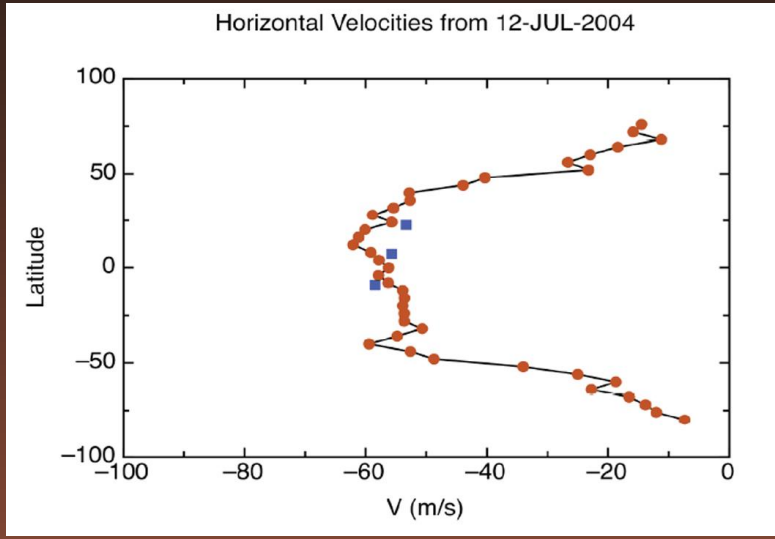
File Edit View Insert Format Tools Data Window Help Adobe PDF

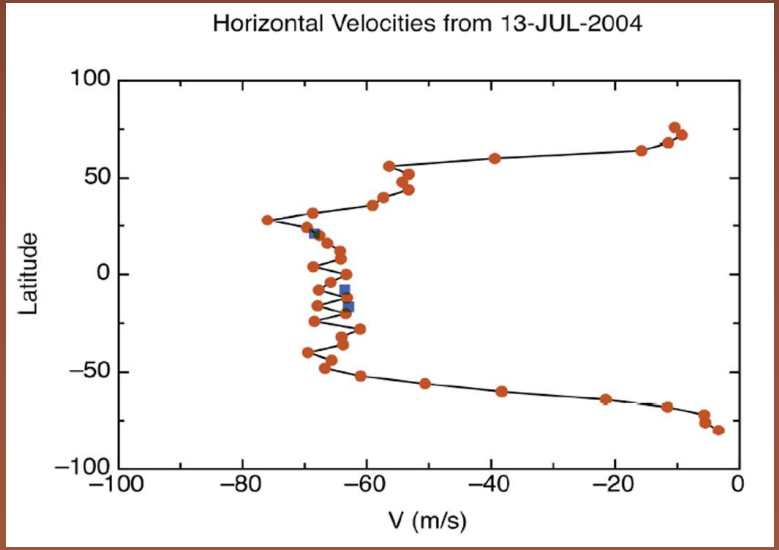
S10

	A	B	C	D	E	F	G	H	I	J	K	L
7												
8	**Step 2: Caculate the time interval between two points (Use Time_OBS fields)**						56,812.251578					
9		Date	Hour	Minutes	Seconds		55,695.406058	85,283.154480				
10	Oberservation 1	July 12, 2004	15	46	52.251578	<--------	1) fill in the time of the first image by date, hour, minute, and second					
11	Oberservation 2	July 13, 2004	15	28	15.406058	<--------	2) fill in the time of the second image by date, hour, minute, and second					
12	Delta	1	0	-18	-36.84552	(Oberservation 2-Oberservation 1)						
13	Delta (second)	86,400.00000	0	-1080	-36.84552	(Convert each number to second)						
14	Delta (second)				**85,283.154480**	(sum up all the numbers)						
15												
16	**Result: the winds speed**											
17	Vew	**55.8140705**	<----------	Answer 1:the wind velocity in the eastwestdirection, in meters per second								
18	Vns	**0.35176935**	<----------	Answer 2: the wind velocity in the north-south direction, in meters per second								
19												

Conclusions

- A diverse group of motivated, involved citizen-scientists can work with large datasets to produce new scientific discoveries.
- We saw that equatorial west-east winds are around 60 m/s.
- Winds taper off towards the poles.
- Some nights show evidence of mid-latitude jets.
- Next steps: Movies and a publication.





Future Work – Analyzing Spectra