Preparation of Image Data from All Sky Camera for the Study of Gravity Waves in the Upper Atmosphere

Young-Bae Ham(astro422@kopri.re.kr)[1,4], Jeong-Han Kim[1], Geonhwa Jee[1], Changsup Lee[1], Sumanta Sarkhel[5], Jong-Kyun Chung[2], Yong Ha Kim[3]

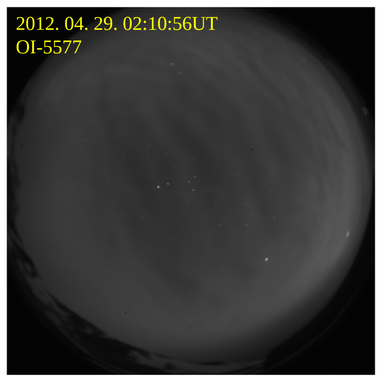
[1]Division of Polar Climate Change, Korea Polar Research Institute, Korea, [2]Division of Space Science, Korea Astronomy and Space Science Institute, Korea, [3]Department of Astronomy and Space Science, Chungnam National University, Korea, [4]Department of Astronomy and Space Science, Kyung Hee University, Korea, [5]Department of Physics, Indian Institute of Technology Roorkee, India

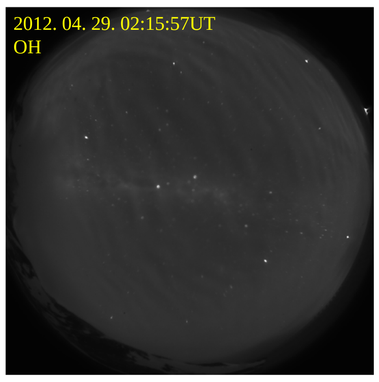
Abstract

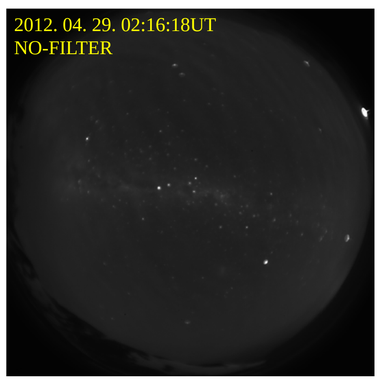
The tip of the Antarctic Peninsula, where King Sejong Station (KSS) is located, is known for extremely strong gravity wave activity. Since 2008, Korea Polar Research Institute has been operating All Sky Camera at KSS to investigate the gravity wave activity in the mesosphere and thermosphere regions. ASC system with three different filters can capture the 2-D structures of gravity wave in the upper atmosphere. However, the data analysis requires pre-processing of the image data from the ASC system. In this study, we present the processes of data preparation of the image data for obtaining physical parameters of the gravity wave in the upper atmosphere.

Raw image data

ASC system of Korea Polar Research Institute uses three different filters (OH, OI-5577, and OI-6300) to capture the 2-D structures of the gravity waves in different altitudes.



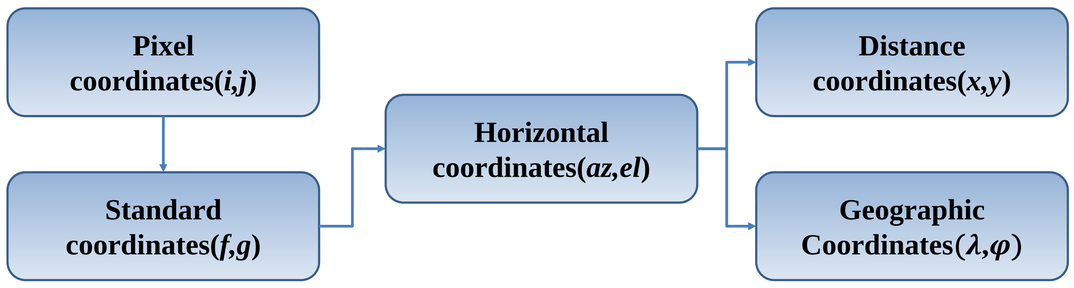




Filter	Wavelength	Emission height
OH	720~910nm notched at 865nm	~85km
OI-5577	557.7nm	~97km
OI-6300	630.0nm	~250km

Coordinate Transformations

To derive the horizontal parameters of the gravity waves appeared in raw images, it is essential to conduct coordinate transformations. To perform the transformations, we uses a standard coordinate which is introduced at Garcia et al., 1997. The goal of the coordinate transformations is to achieve the distance coordinates from pixel coordinates in the raw images. The procedure of the coordinate transformations is like below.

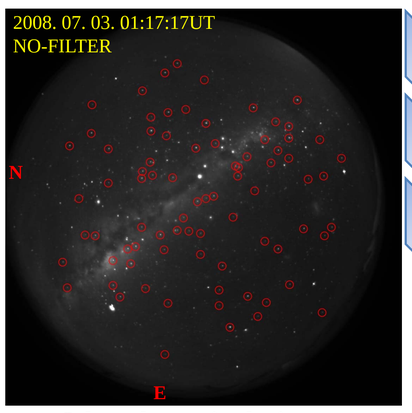


Determination of the transformation matrix

$$\begin{bmatrix} f \\ g \end{bmatrix} = \begin{bmatrix} a_0 & a_0 & a_0 \\ b_0 & b_0 & b_0 \end{bmatrix} \begin{bmatrix} 1 \\ i \\ j \end{bmatrix}$$

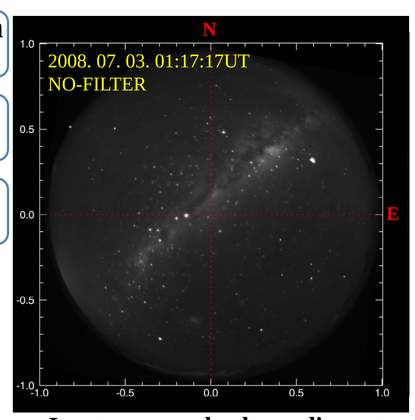
$$\begin{bmatrix} f \\ g \end{bmatrix} = G(el) \begin{bmatrix} \sin(az) \\ \cos(az) \end{bmatrix}$$

Pixel coordinates (i,j) can be changed into standard coordinates (f,g). See the left equations. If some sets of (f,g) and (i,j) are known, we can find the transformation matrix by applying method of least squares. Stars appeared in a image can be used in giving input parameters to method of least squares. (i,j) can be achieved directly from a raw image and (az,el) can be achieved from some planetarium softwares or astronomical almanac. Once we determine the transformation matrix and achieve (f,g), other coordinate transformations can be done easily.

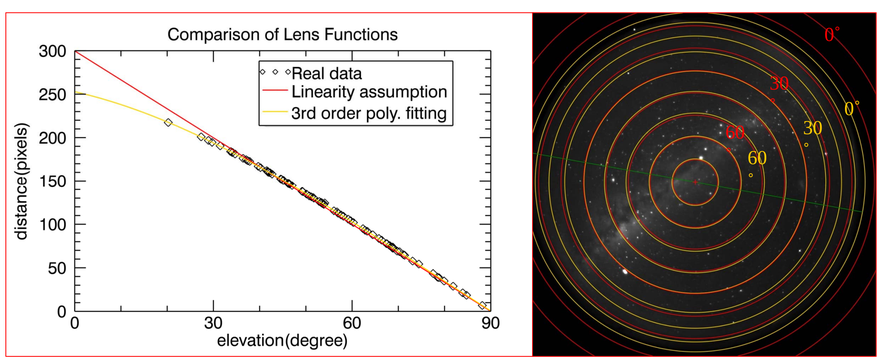


<Selected stars in the image >

1. Select stars and obtain their information
2. Check the lens function
3. Find transformation matrix

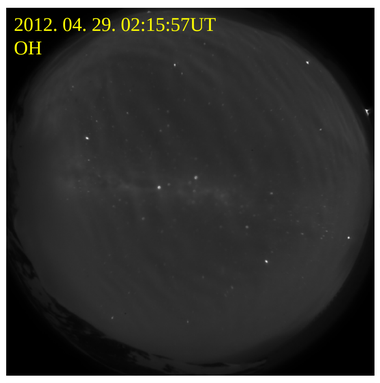


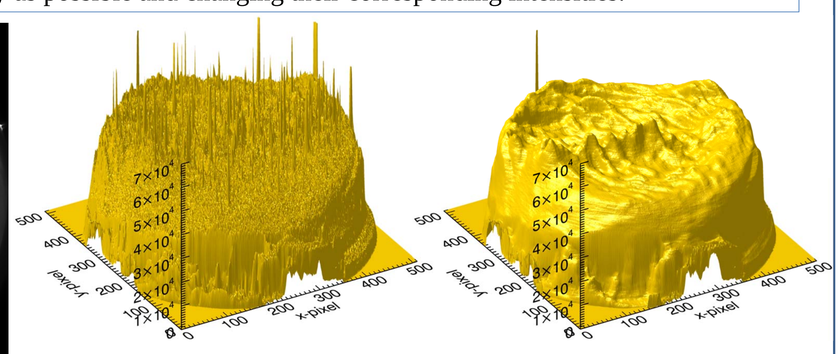
<Image on standard coordinates>



Star removal

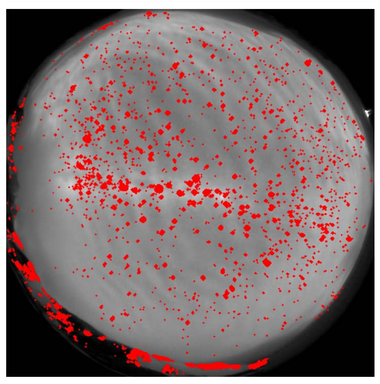
When images are plotted in the distance coordinates, the shape of stars far from the zenith becomes radially enlarged shape. Therefore, star removal should be done before projecting images onto the distance coordinates. To avoid blurring that could happen in star removal process, we focused on finding the location of stars as accurately as possible and changing their corresponding intensities.



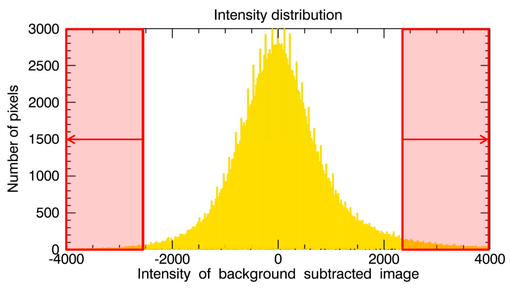


<Raw image> <Median-filtered image>

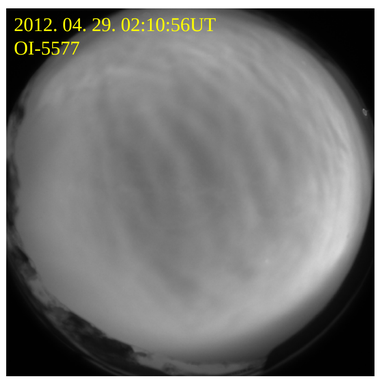
Subtract the median-filtered image from the raw image

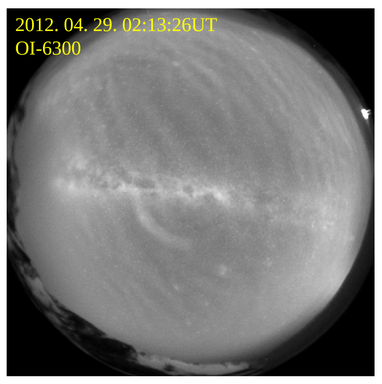


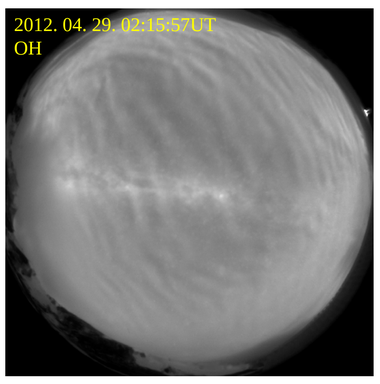
Take pixels in the upper and lower tail.



Star-removed images. Contrast have been enhanced.

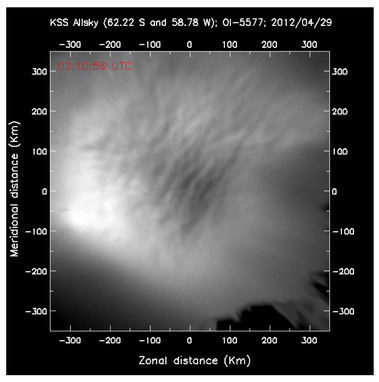


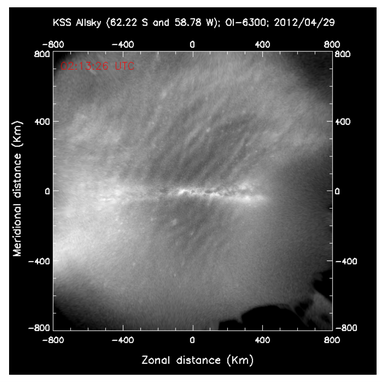


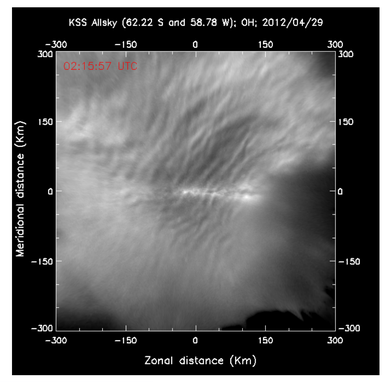


Unwarping images

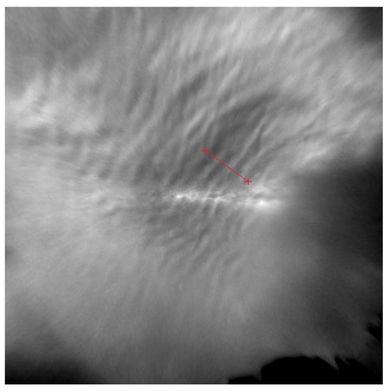
All sky images are distorted because of the characteristics of fish eye lens. In order to correct this distortion, a projection of images onto equally-spaced grid has to be performed, and it is called unwarping. The resulting unwarped images in distance coordinates can be used in calculating physical parameters of gravity waves. And unwarping images is also necessary in order to plot images with geographic maps.

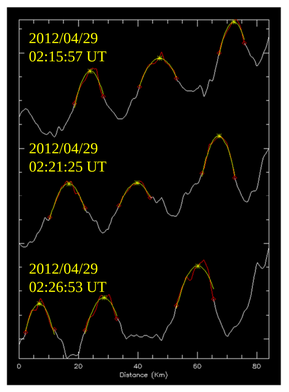






Determination of wave parameters





1. Draw a line parallel to propagating direction
2. Take intensity profiles from consecutive images on the same line
3. Calculate wave parameters

Summary

- we presented the processes of data preparation of ASC images for the study of gravity waves in MLT region.
- Assuming that there's linear relation between the elevation angle and the pixel distance from the zenith is a easy way and its error is small or negligible in middle and high elevation region, but it may lead to non-negligible error in low elevation region depending on the format of the lenses.
- Determination of the transformation matrix needs to be done only once. But whenever there are physical changes or adjustments in all sky camera system, it has to be done again.
- In determination of wave parameters, FFT or Lomb-Scargle Periodogram analysis can be used as well.

Reference

- 조환성, 보현산 전천 카메라를 이용한 대기 중량파 관측, Master Dissertation, Korea National University of Education (2006).
- F. J. Garcia, M. J. Taylor, and M. C. Kelley, Two-dimensional spectral analysis of mesospheric airglow image data, Applied Optics, Vol. 36, Issue 29, pp. 7374-7395 (1997).