MEDIUM-SCALE GRAVITY WAVES OBTAINED FROM AIRGLOW ALL-KSY OBSERVATIONS OVER CACHOEIRA PAULISTA

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Abstract

Images obtained from OH and OI 557.7 nm airglow emissions were used to investigate the characteristics of medium-scale gravity waves observed in the mesosphere and low thermosphere region, between 1998 and 2013 over the Cachoeira Paulista Observatory, SP, Brazil (22.4ºS; 45.0 ° O). Using the keogram technique, the results showed that 142 gravity wave events observed in the airglow emission have the following characteristics: horizontal wavelength between 50 and 500 km, observed period between 20 and 80 min, phase velocity between 40 and 100 m/s. The propagation directions of medium-scale gravity waves showed a season variation: in the summer the waves propagate to Northeast and Southeast directions, during autumn the waves propagate mainly to Northwest direction, in winter almost an isotropic propagation were observed, while during spring the waves propagate to Northeast and Southeast. A comparison of propagation directions between small and medium-scale gravity waves was also performed, showing that the main propagation directions of small and medium-scale gravity waves are similar for each season of the year. The results led us to conclude that both small and medium scale gravity waves may be related to the same wave source at the lower atmosphere. The meteorological phenomena that were related to generate small-scale gravity waves over Cachoeira Paulista are the cold frontal and convective systems.

Introdution

- In recent years, atmospheric gravity waves constitute an area of great research activity due to the effects of these waves on atmospheric circulation, structure and variability (FRITTS and ALEXANDER, 2003).

- Gravity waves are horizontal propagation waves composed of vertical displacements resulting from the imbalance between the pressure gradient and the force of atmospheric gravity.

- The sources of gravity waves are associated with convective storms, cold front activities, orographic effect, wind shear, and wave-wave interactions (FRITTS and ALEXANDER, 2003).

- The studies about medium-scale gravity waves (MSGWs) were carried out in the North, Northeast and Central regions of Brazil. However, studies of MSGWs on the Southeast region of Brazil have not been conducted and will be the object of study in this presentation.

Gravity Waves

Small scale waves are easily visible in a single image obtained by the optical equipment.

Small scale waves: $\lambda_H < 50$ km

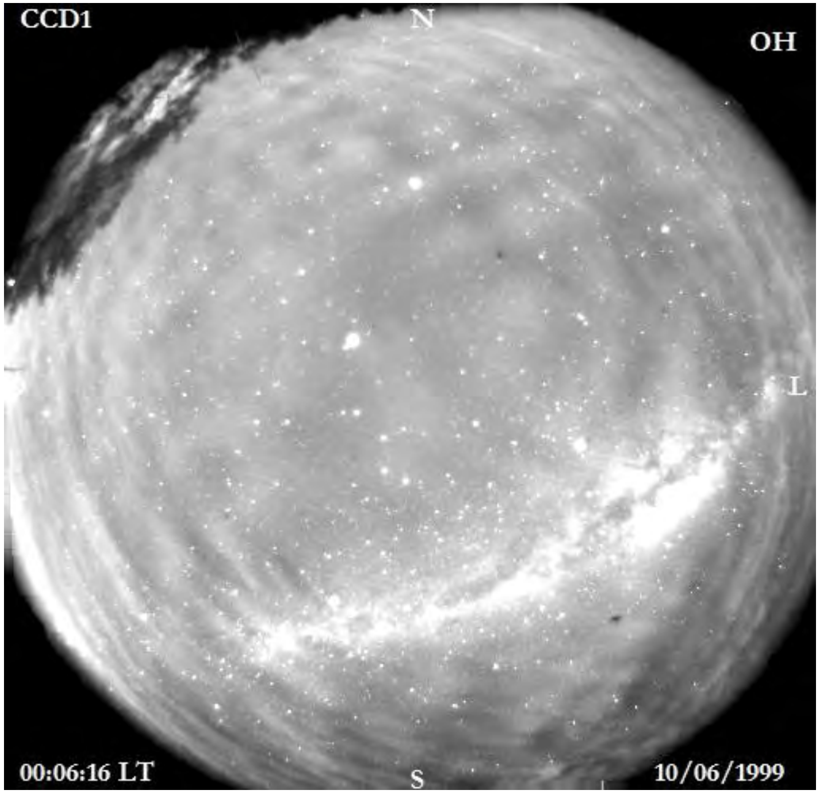


Figure 1: SSGWs.

Medium scale waves require a series of images to visualize the passage of the wave by optical equipment.

Medium-scale waves: $\lambda_H > 50\ km$

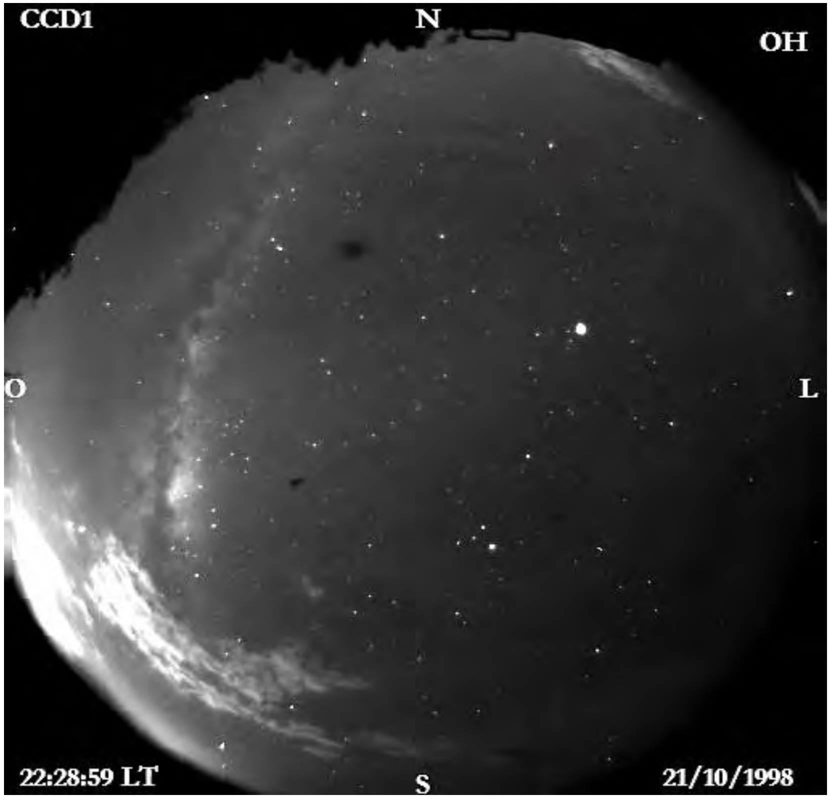
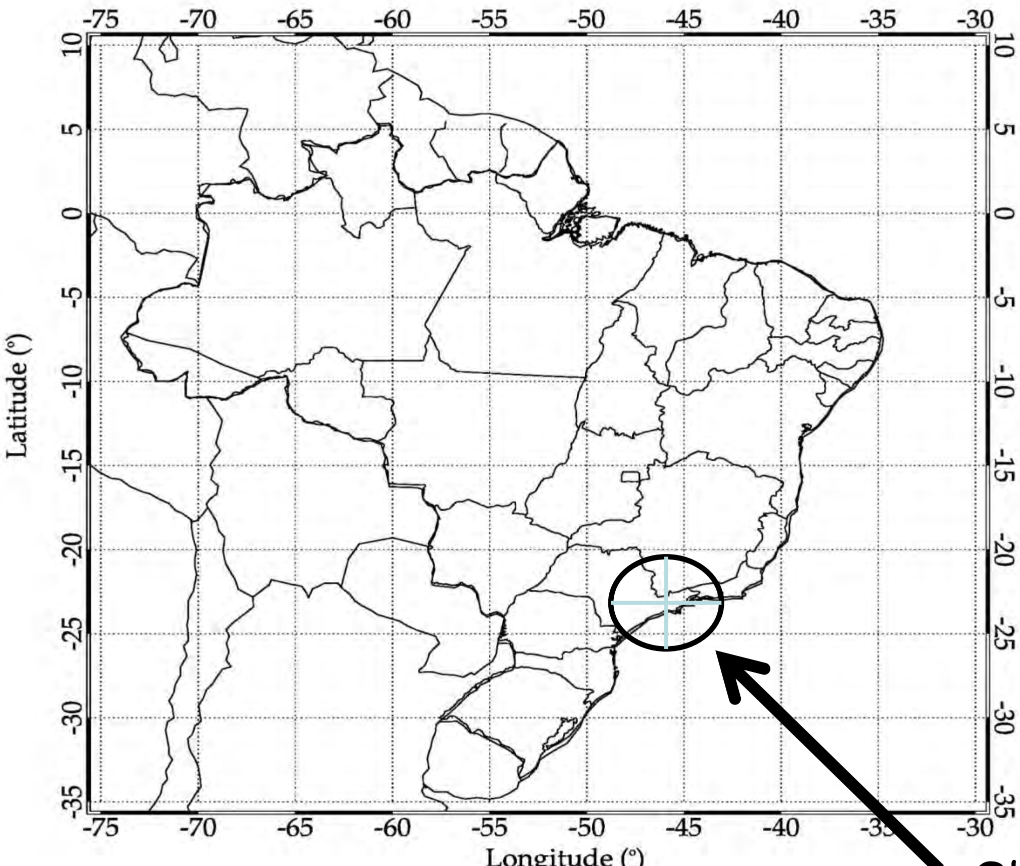


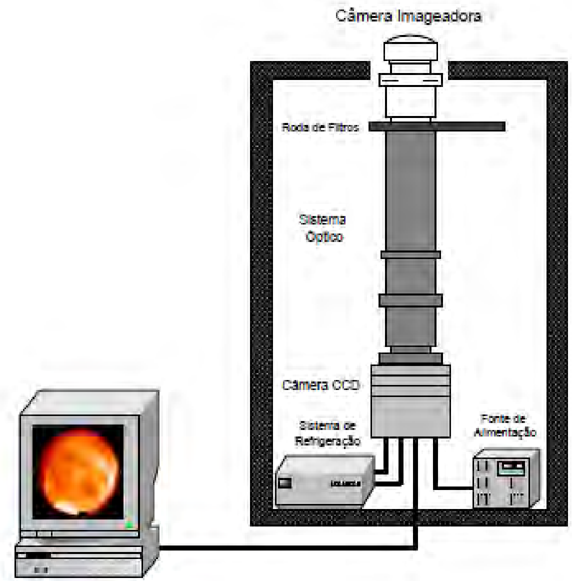
Figure 2: MSGWs.

Instrumentation – Methodology

- In order to study gravity waves, airglow emissions should be observed using All-Sky imagers.



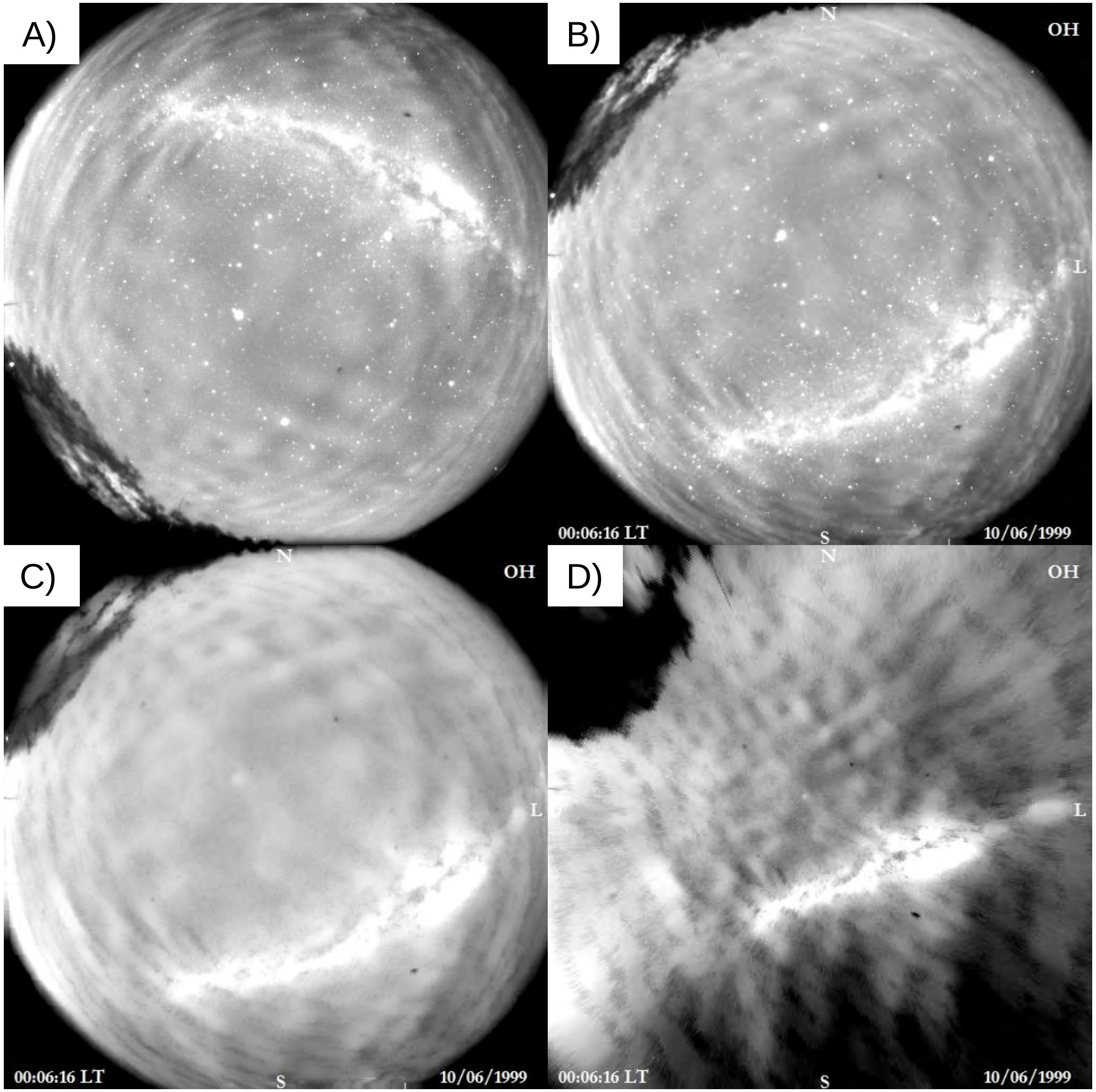
Observation Site



Source: Wrasse, 2004.

Instrumentation – Methodology

Spatial Calibration



Correction of distortion of the image by the lens Fish-eye:

A. Align an original image with geographic north, and center with zenith.

B. Second, withdrawal of stars from the image to be analyzed (MAEKAWA, 2000).

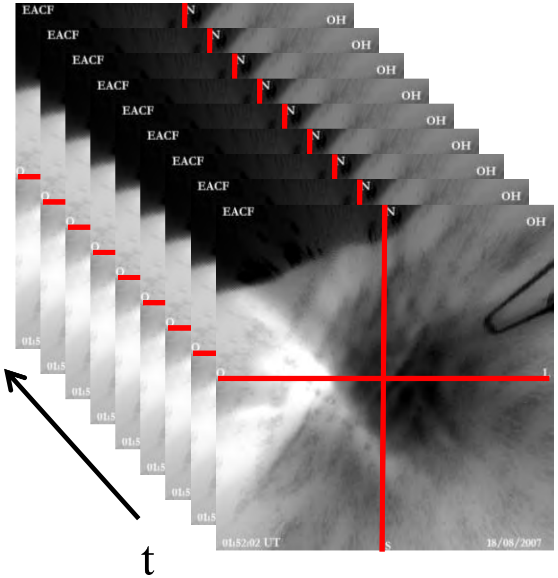
C. Third, map the images from the default coordinate to the geographic coordinate.

D. Finally, maps can be obtained in geographic coordinates with a resolution of km / pixel.

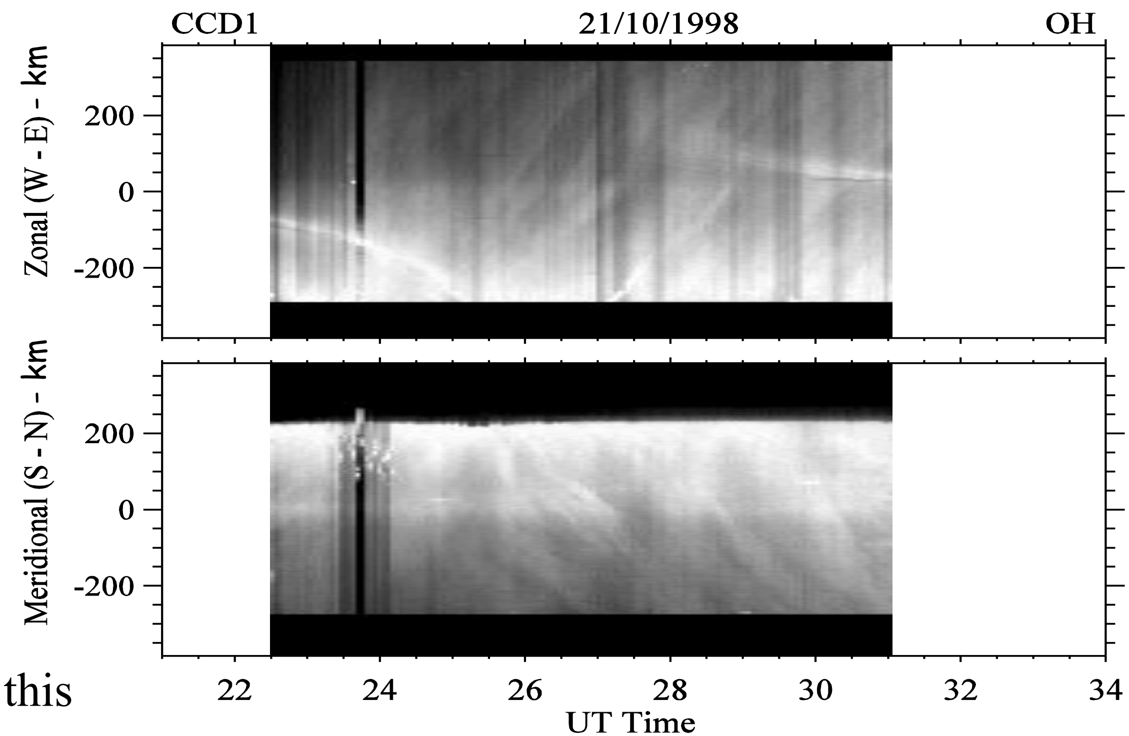
Keogram Technique

- They are southern and zonal cuts of any image.

Series of Images



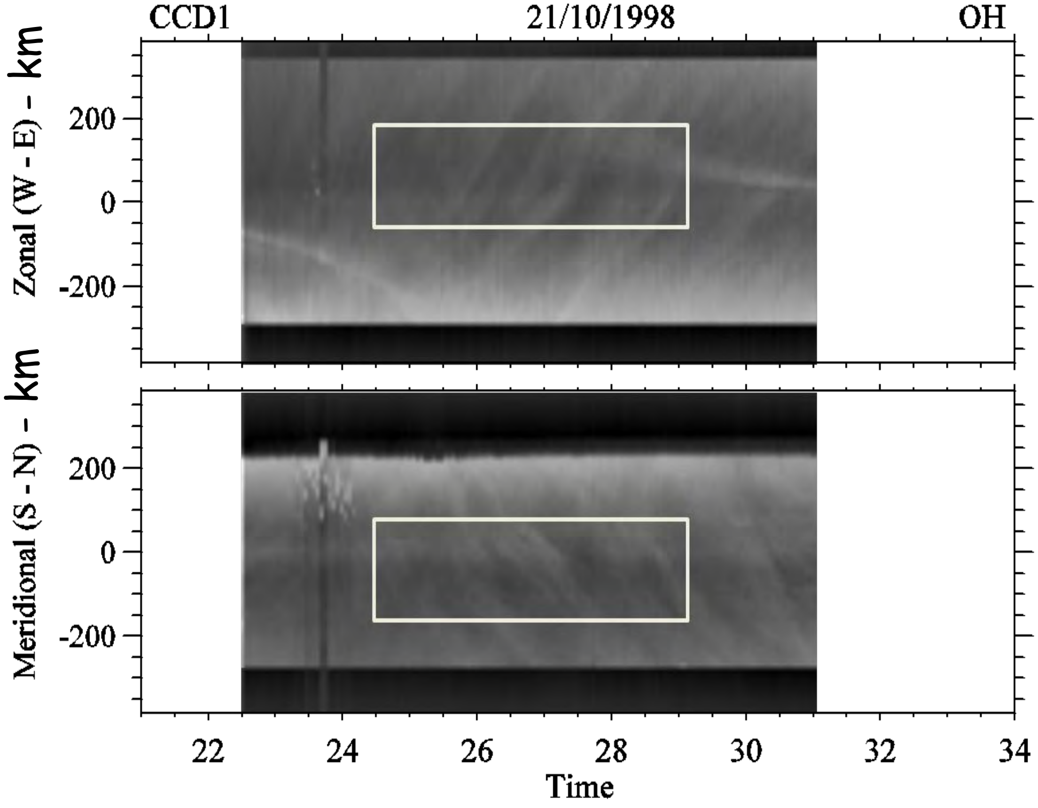
1. A clear night is selected.
2. From the series of images of this night, zonal and southern cuts are made to the center of each image.
3. These images are a function of time.
4. Keogram for one night depending on the time of observation.



Example of Keograma generated with the data of the work for 21-10-1998.

Spectral Analysis - FFT

Using a selected region in the Keogram it is possible to obtain the parameters of medium scale gravity waves.



The calculations to obtain the parameters in the selected region are:

$$\tau = \frac{1}{f(\omega)} \quad [\min];$$

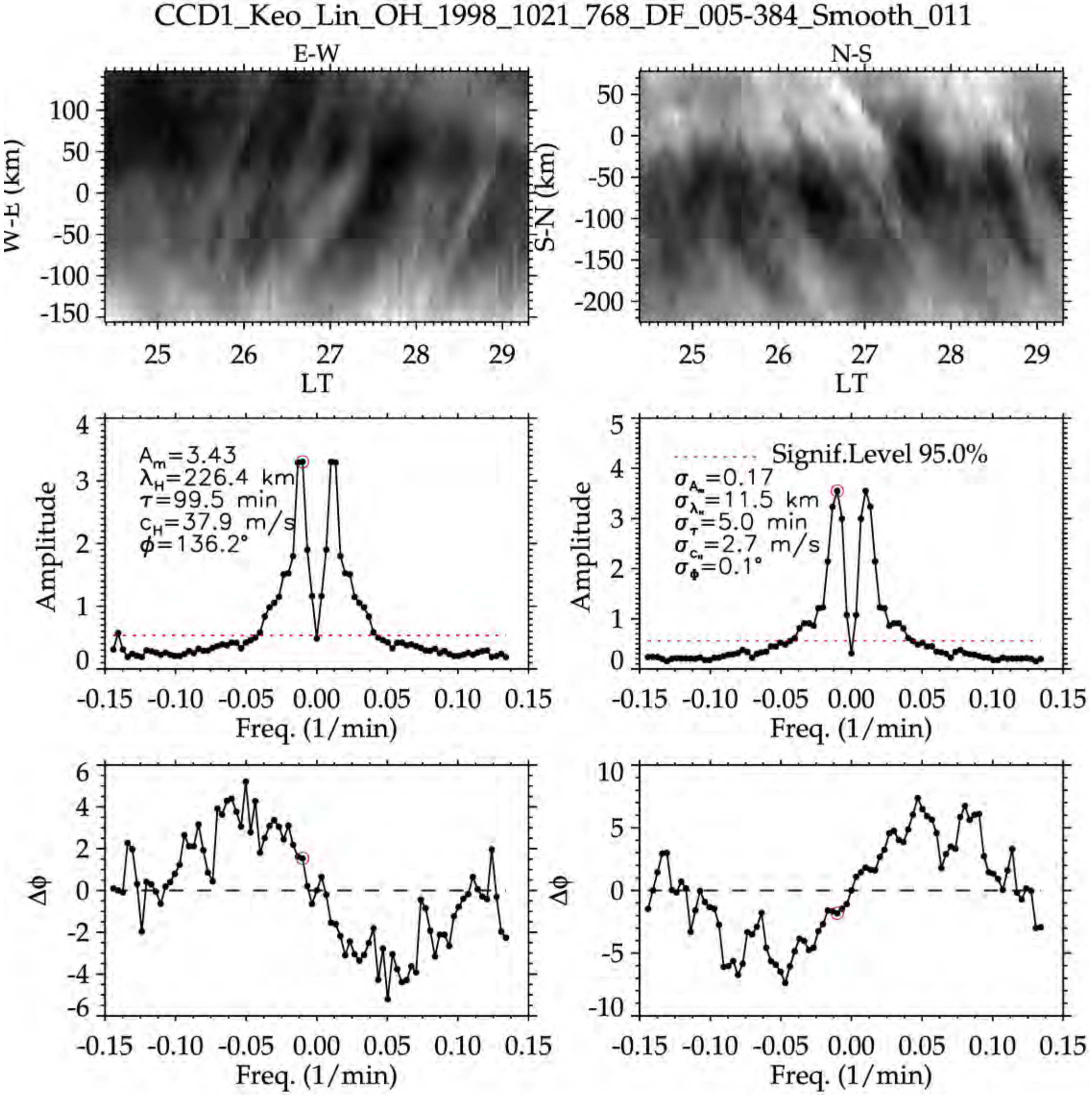
$$\lambda_{NS,LO} = \frac{\Delta d}{\frac{\Delta\phi}{360^\circ}} \quad [km];$$

$$\lambda_H = \frac{\lambda_{NS} . \lambda_{LO}}{\sqrt{\lambda_{NS}^2 + \lambda_{LO}^2}} \quad [km];$$

$$C_H = \frac{\lambda_H}{\tau} \quad [m/s];$$

$$\varphi = \cos^{-1}\left(\frac{\lambda_H}{\lambda_{NS}}\right) \quad [^\circ].$$

Result of Spectral Analysis



Wave parameters:

τ = 99,5 ± 5,0 min;

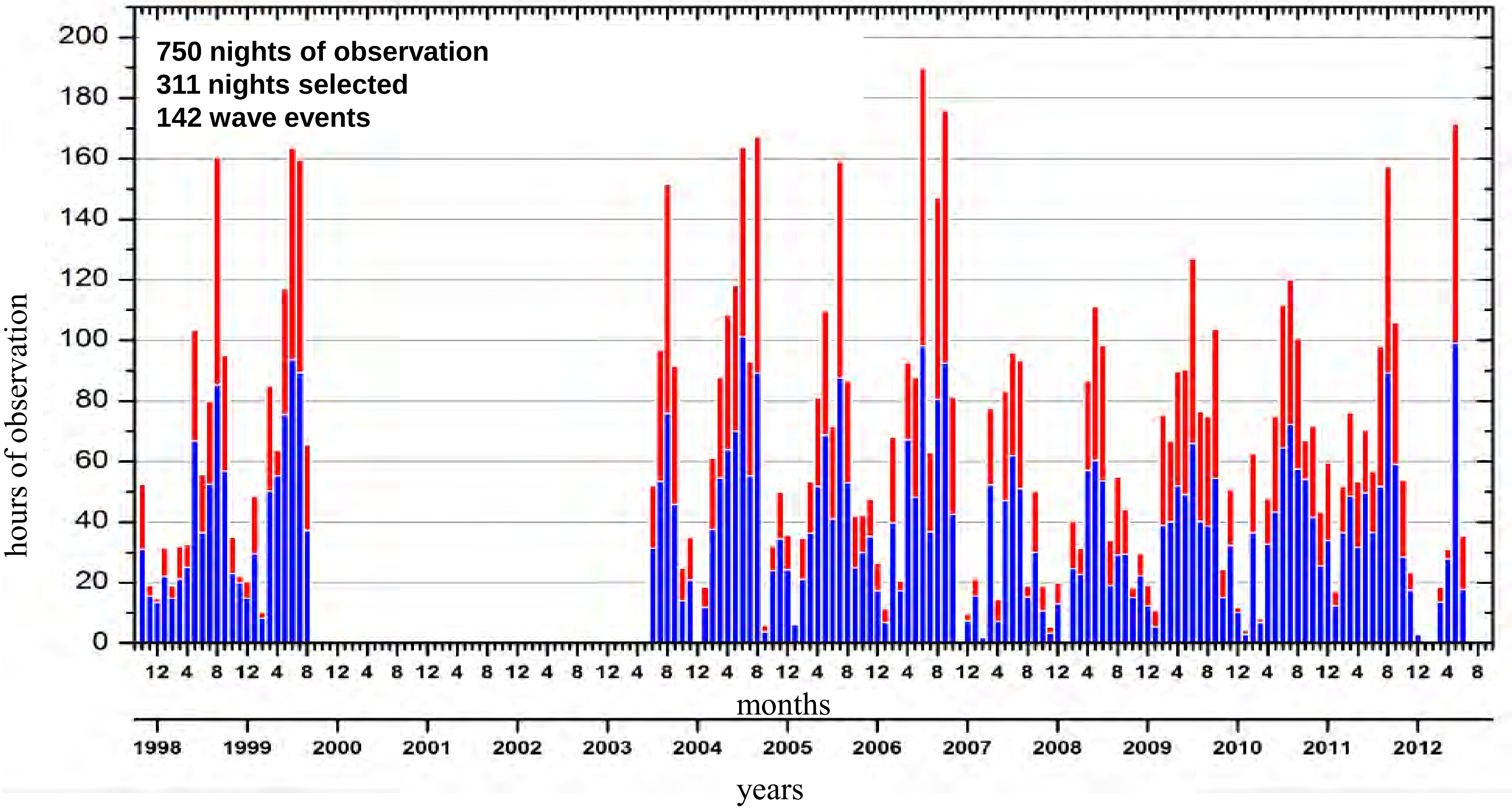
λ_H = 226,4 ± 11,5 km;

C_H = 37,9 ± 2,7 m/s;

φ= 136,2° ± 0,1°.

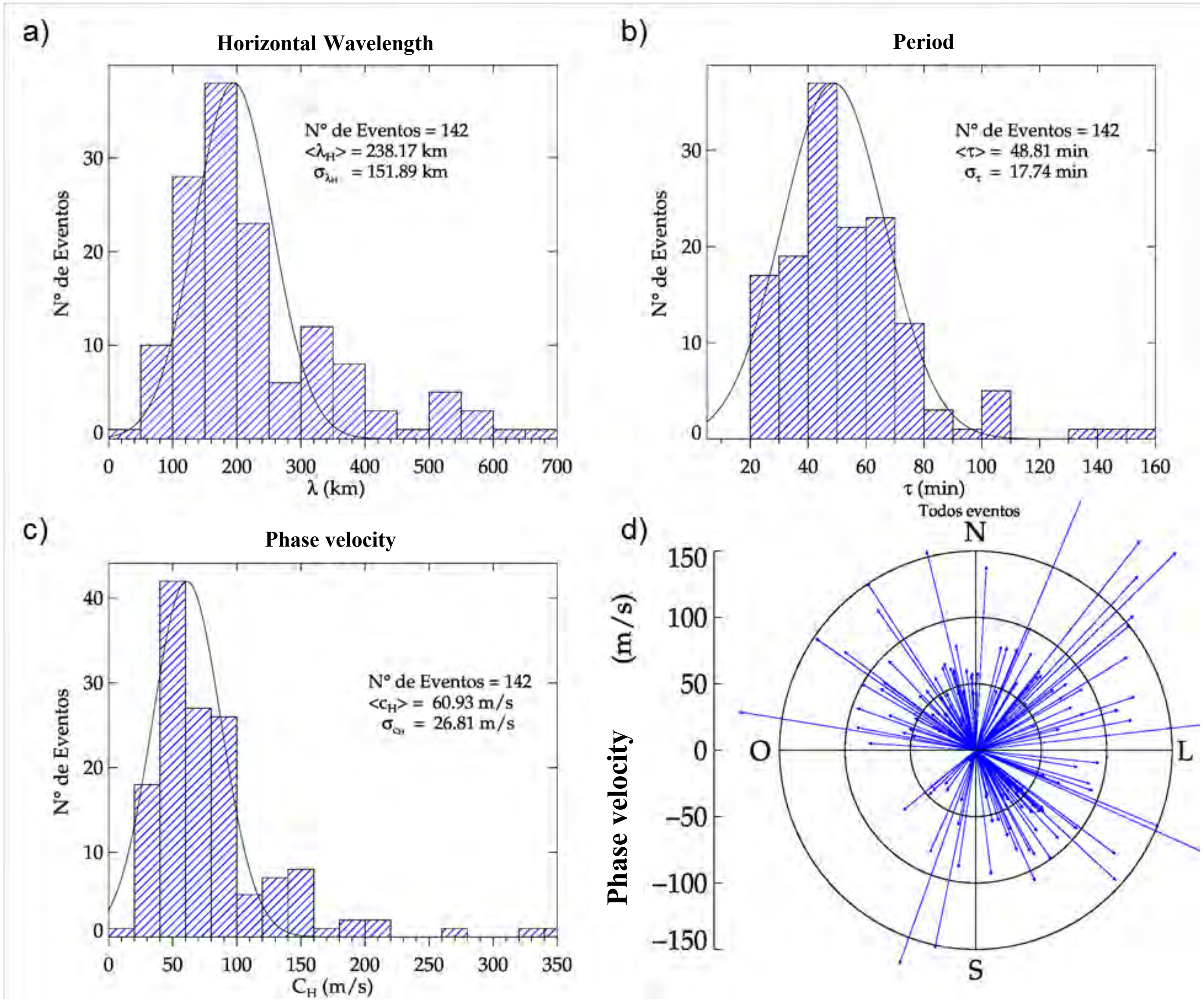
Airglow observation at CP

1. The data were obtained between the years of 1998 and 2013 of the emissions OH and OI 557,7 nm;
2. From this database of airglow images, we obtained 750 nights with observations, among which 311 presented some type of medium scale oscillation;
3. Using the preselected nights spectral analysis was applied, where it was possible to characterize 142 events of medium-scale gravity waves.



RESULTS

Medium Scale Gravity Wave Parameters (MSGW)

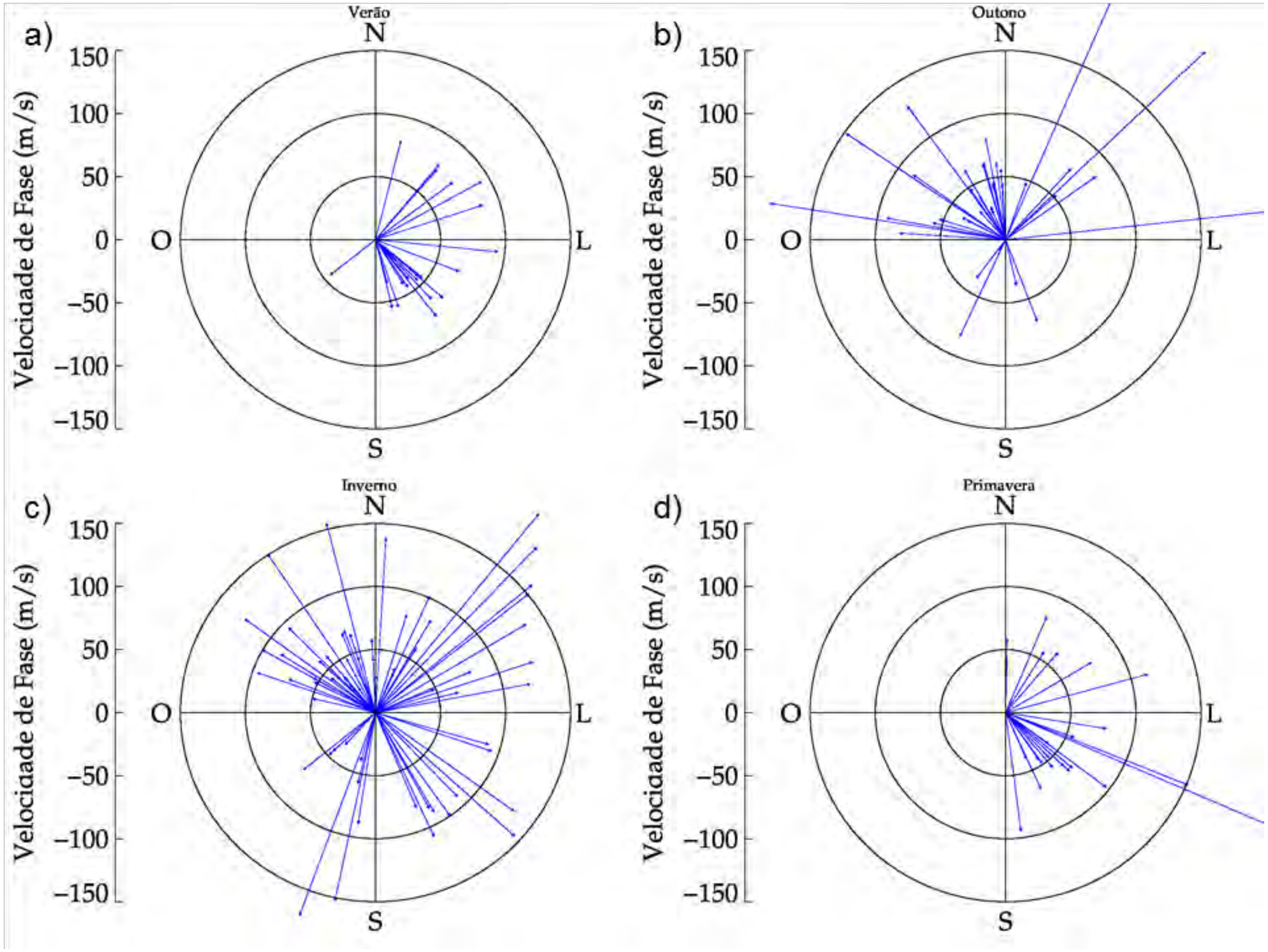


The mean value and standard deviation for each wave parameter was obtained from a Gaussian distribution.

MSGW - Comparison

Authors	Location (Country)	Observation time	Wave Events (Emission)	λ_H (km)	τ (min)	C_H (m/s)
Present Paper	Cachoeira Paulista (Brasil)	~11 year 1998-2013	142 (OH, OI)	50-400	20-80	40-100
Ding et al. (2004)	Adelaide (Austrália)	7 year 1995-2001	1300 (OH, OI)	10-200	10-30	20-250
Suzuki et al. (2009)	Resolute Bay (Canada)	1 year 2005-2006	61 (Na)	100-400	20-80	40-120
Essien (2015)	São João do Cariri (Brasil)	11 year 2000-2010	537 (OH)	50-450	10-100	20-120
Taylor et al. (2009)	Cariri e Brasília (Brasil)	3 months Set-Nov 2005	26 (OH)	50-350	20-100	40-80
Paulino et al. (2011)	Boa Vista (Brasil)	2 months Out-Dez 2002	15 (OH)	50-250	20-120	25-75

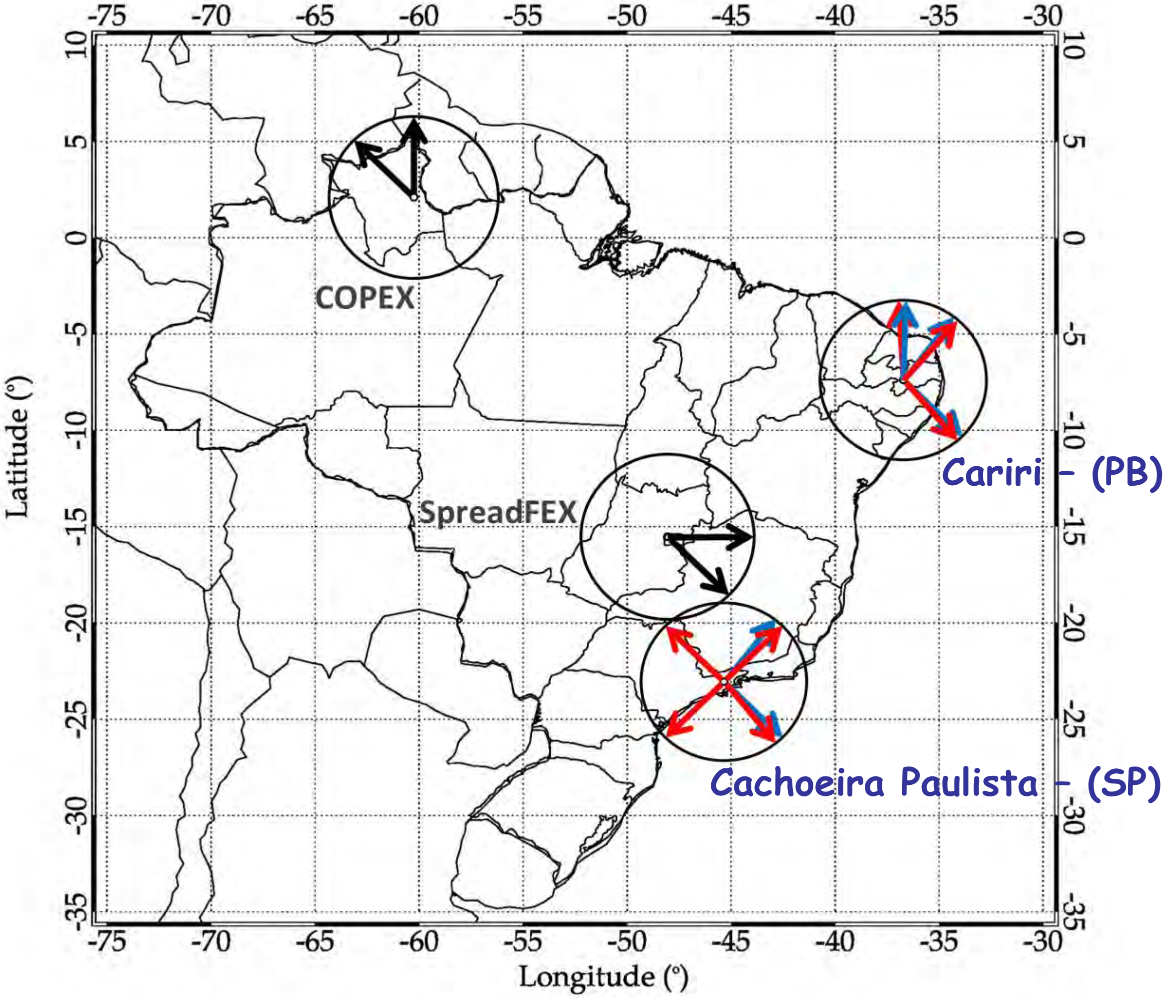
Seasonal Distribution of MSGW Propagation Direction



Propagation of Medium Scale Gravity Waves over Brazil

Winter.

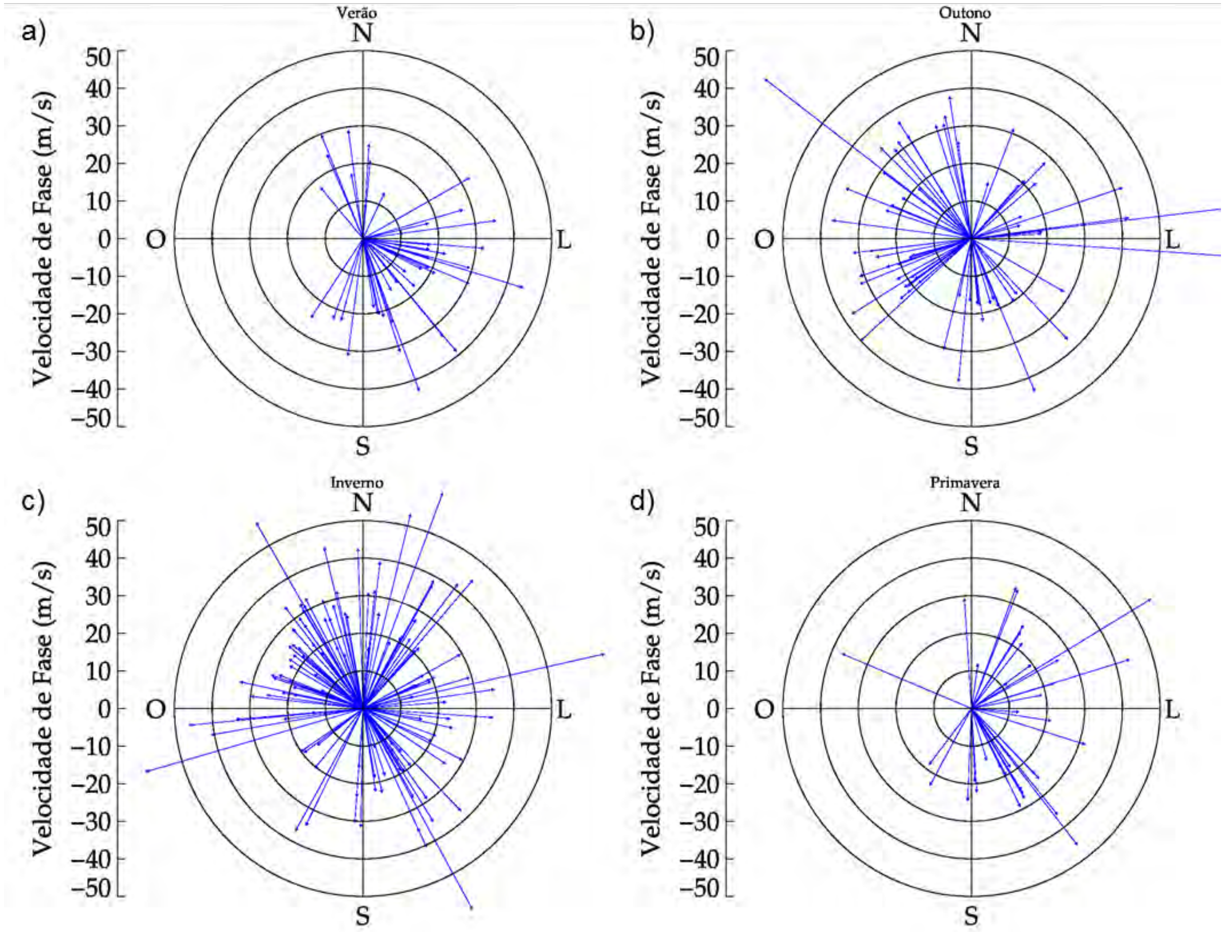
Summer.



Red arrows represent the preferred direction for the winter season.

Blue arrows represent the preferred direction for the summer season.

Seasonal Distribution of SSGW Propagation Direction

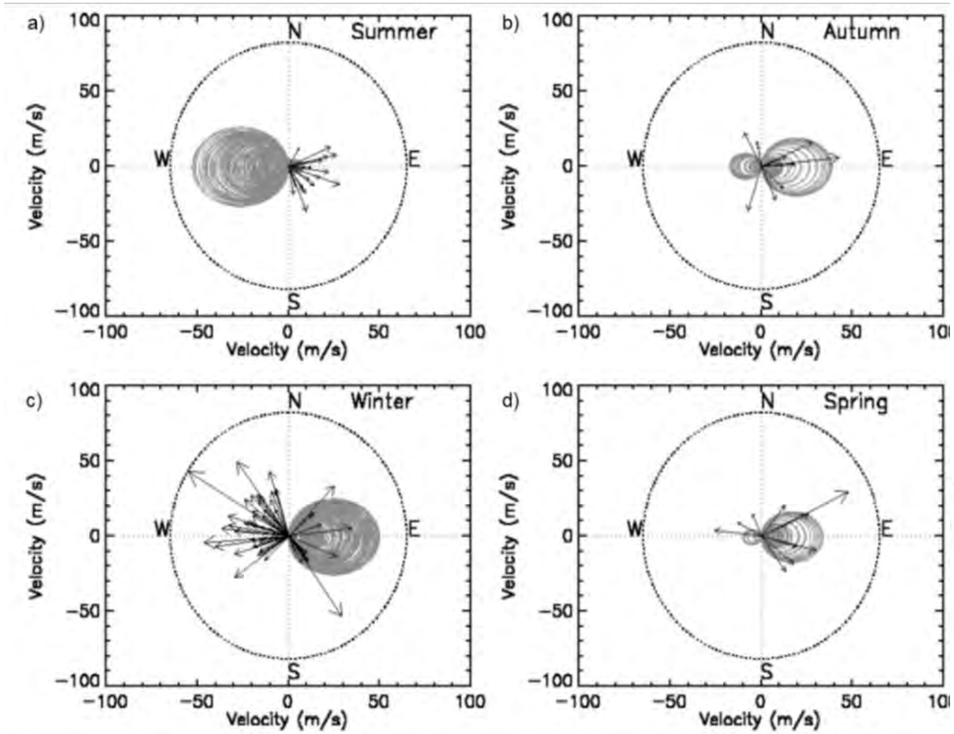


Source: Adapted from Wrasse (2004).

Discussion

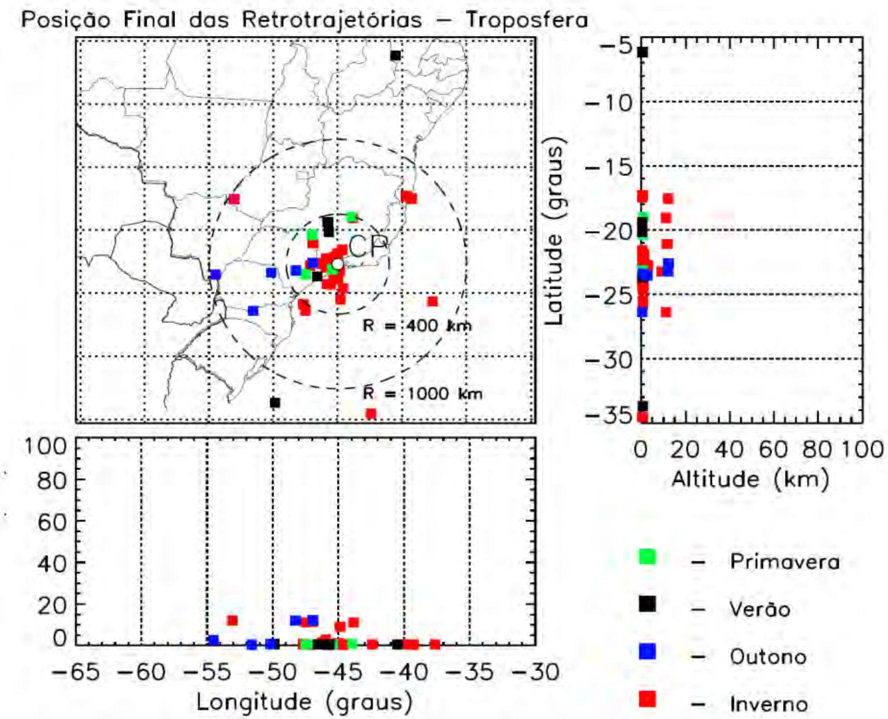
Results found for small scale gravity waves compared

Wind Filtering



Source: Adapted, Medeiros et al. (2004, p5.)

Tropospheric Sources



According to Wrasse (2004) wave sources at CP were related to: cold fronts (22%), convective systems associated with cumulonimbus clouds (25%) and orographic effect (33%).

Summary and Conclusions

- Approximately 11 year of observations between (1998-2013) resulted in 142 medium scale gravity wave events.
- The main characteristics of **medium-scale gravity wave parameters** were:

$$\tau = 20 - 80\ min;$$

$$\lambda_H = 50 - 400\ km;$$

$$C_H = 40 - 100\ m/s\,.$$

- The preferred **directions of propagation** of **medium-scale gravity waves** for each season were:

    -Summer (Northeast and Southeast);

    -Autumn (Northwest);

    -Winter (Isotropic);

    -Spring (Northeast and Southeast).

- The **comparison** between small and medium scale gravity waves showed that:

    - The **preferred wave propagation directions** are similar for each season of the year.

- Medeiros et al. (2004) stated that **small-scale gravity waves** are influenced by the neutral wind, especially if the phase velocity of the wave is small. **Medium-scale gravity waves** are also affected by the neutral wind.
- Wrasse (2004) presented the main sources for small scale gravity waves. It is believed that **medium-scale gravity waves** should be generated by the same sources: **frontal systems** and **convective systems**.

Future Papers

- To study the intrinsic parameters of medium scale gravity waves.
- Use the ray tracing technique to study the propagation of **medium scale gravity waves** and infer the propagation height of these waves and their possible sources of generation.

Acknowledgments

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References

•DING, F. et al. Occurrence characteristics of medium-scale gravity waves observed in OH and OI nightglow over Adelaide (34.5°S, 138.5°E). **Journal of Geophysical Research D: Atmospheres**, v. 109, n. 14, p. 1–10, 2004.

•ESSIEN, P. **Long-Term Observation of Medium Scale Gravity Waves Over Brazilian Equatorial Region**. [s.l.] Universidade Federal de Campina Grande - UFCG, Campina Grande, 2015.

•FRITTS, D. C.; ALEXANDER, M. J. Gravity wave dynamics and effects in the middle atmosphere. **Reviews of Geophysics**, v. 41, n. 1, p. 1–64, 2003.

•MAEKAWA, R. **Observations of gravity waves in the mesopause region by multicolor airglow imaging**. [s.l.] Kyoto University, 2000.

•MEDEIROS, A. F. et al. Observations of atmospheric gravity waves using airglow all-sky CCD imager at Cachoeira Paulista, Brazil (23° S, 45° W). **Geofisica Internacional**, v. 43, n. 1, p. 29–39, 2004.

•PAULINO, I. et al. Mesospheric gravity waves and ionospheric plasma bubbles observed during the COPEX campaign. **Journal of Atmospheric and Solar-Terrestrial Physics**, v. 73, n. 11–12, p. 1575–1580, 2011.

•SUZUKI, S. et al. Statistical characteristics of polar cap mesospheric gravity waves observed by an all-sky airglow imager at Resolute Bay, Canada. **Journal of Geophysical Research: Space Physics**, v. 114, n. 1, p. 1–8, 2009.

•TAKAHASHI, H. et al. Simultaneous observation of ionospheric plasma bubbles and mesospheric gravity waves during the SpreadFEx campaign. **Annales Geophysicae**, v. 27, n. 4, p. 1477–1487, 2 abr. 2009.

•TAYLOR, M. J. et al. Characteristics of mesospheric gravity waves near the magnetic equator, Brazil, during the SpreadFEx campaign. **Annales Geophysicae**, v. 27, n. 2, p. 461–472, 2009.

•WRASSE, C. M. **Estudos de Geração e Propagação de Ondas de Gravidade Atmosféricas**. (INPE-12249-TDI/978). Tese (Doutorado em Geofisica Espacial) - Instituto Nacional de Pesquisas Espaciais - INPE, São José dos Campos, 2004, 253p. Disponível em: <http://urlib.net/sid.inpe.br/jeferson/2004/05.24.10.59>.

- Thank you!