Estimating the daytime vertical E×B drift velocities in the F-region equatorial ionosphere using the IEEY and AMBER magnetic data in West Africa

A. Diaby, V. Doumbia, O. Obrou, F. Grodji, Z. Tuo, E. Yizengaw

Laboratoire de Physique de l'Atmosphère, Université Félix Houphouët-Boigny, Côte d'Ivoire

Space Science Application Laboratory, The Aerospace Corporation, El Segundo, CA, USA

The Equatorial Ionosphere

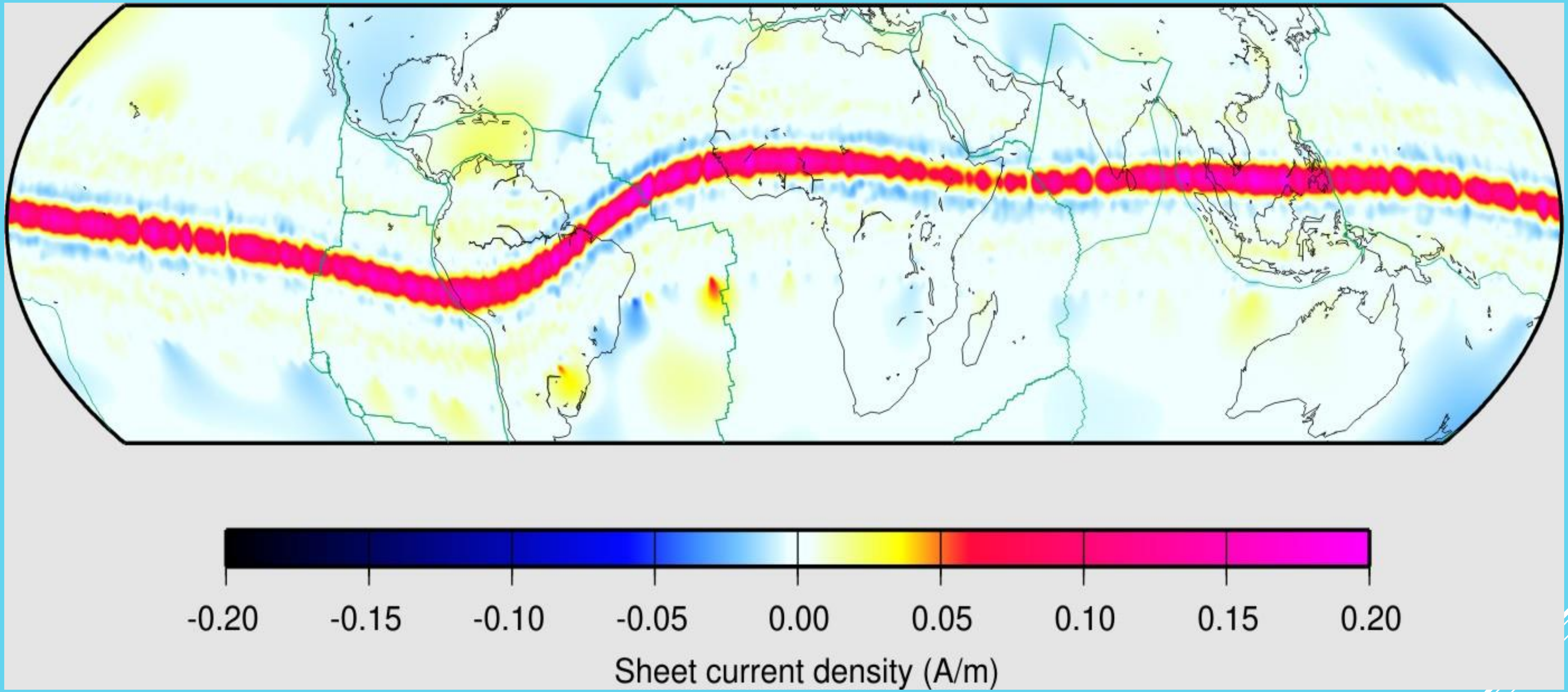
- The equatorial ionosphere is the region where the Earth's magnetic field lines are nearly horizontal.

- Owing to the unique configuration of mutually perpendicular nature of the electric field and the magnetic field, the equatorial ionosphere exhibits most important electro-dynamical phenomenon such as Equatorial Electrojet (EEJ), Counter Electrojet (CEJ) and Equatorial Ionization Anomaly (EIA), Equatorial Spread F (ESF)...

- These phenomena are strongly latitude, longitude, season, solar flux and geomagnetic activity dependent.

- We report our attempt to estimate the daytime equatorial vertical drift using magnetic data in the West African longitude sector.

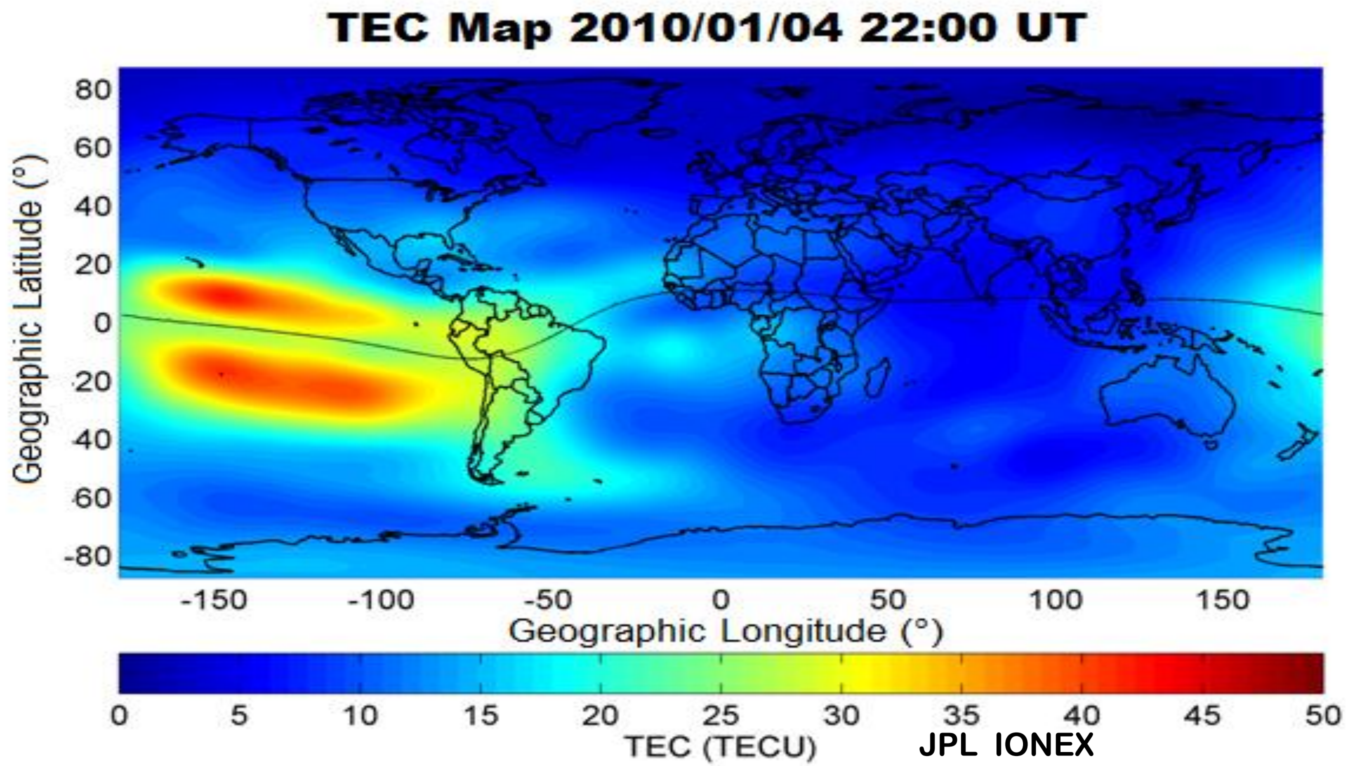
The Equatorial Electrojet (EEJ)

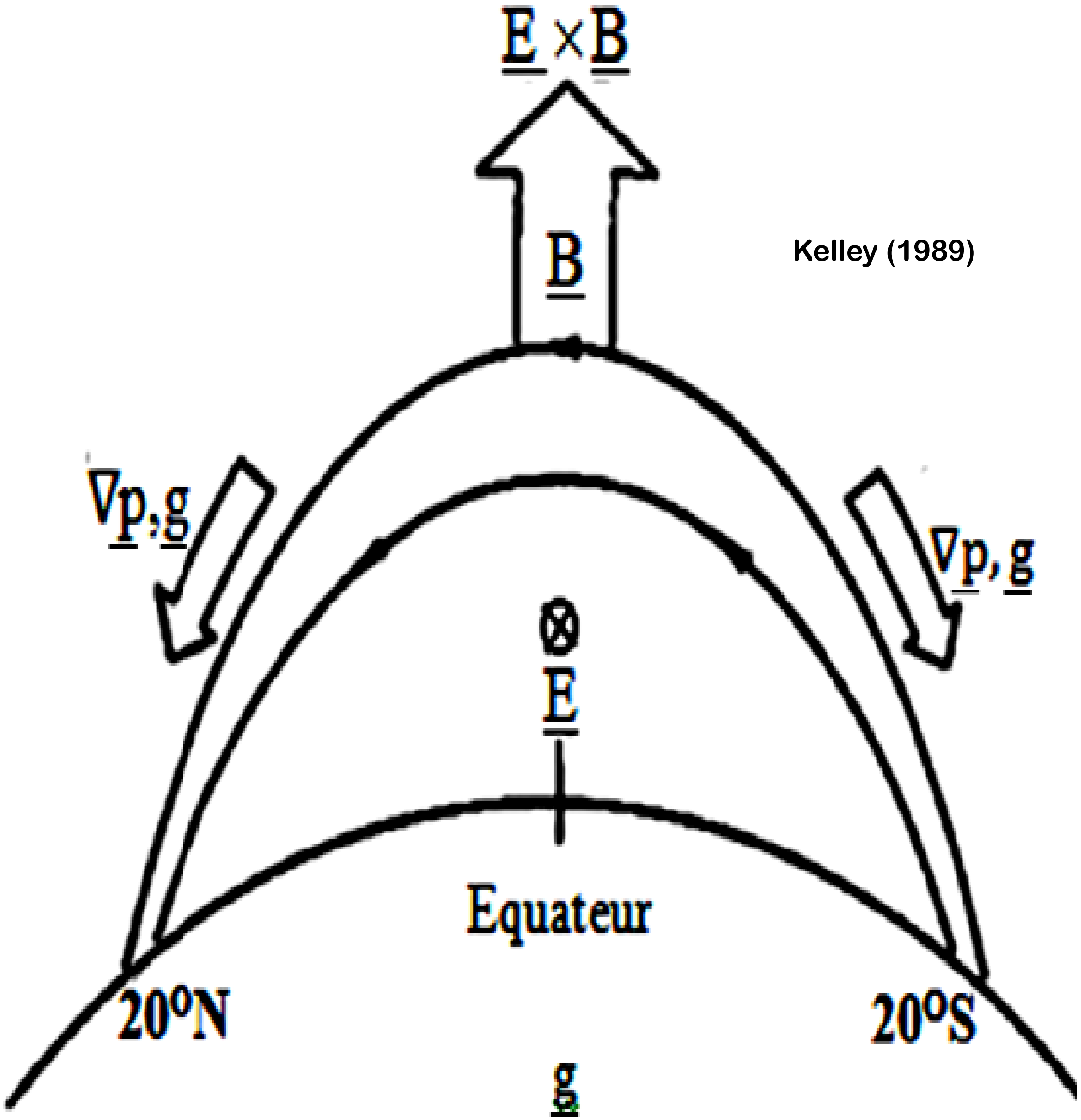


- The EEJ is considered as a band of non-uniform intense eastward ionospheric current flowing within a latitudinal extent of ±2° on either side of the dip equator at lower altitude E region centered between 100-120 km.
- The flowing currents in the ionosphere induce magnetic perturbations on the ground.

The Equatorial Ionization Anomaly-EIA (Appleton Anomaly)

At low / equatorial magnetic latitudes, ionosphere presents the Equatorial Ionization Anomaly that consists of two crests of high electron densities (and TEC) around 20 degrees (North and South) of magnetic latitude.





Kelley (1989)

Previous works

Various instruments have been used to study the $\mathrm{E} \times \mathrm{B}$ vertical drift:

- ✓ Incoherent Scatter Radar (e.g. Woodman, 1970; Fejer et al.,1979, 1991, 2008)

- ✓ Satellites such as Atmospheric Explorer-E(AE-E), Republic of China Satellite (ROCSAT) and Communications and Navigation Outage Forecasting System (C/NOFS) satellite (e.g. Fejer et al., 1995, 2008; Stoneback et al., 2011)

- ✓ Ground-based instruments, such as Jicamarca Unattended Long-term Ionosphere and Atmosphere System (JULIA) and pairs of low latitude magnetometers also provide vertical $\vec{\mathrm{E}} \times \vec{\mathrm{B}}$ measurements comparable with those from ISR (e.g. Woodman and Villanueva, 1995; Anderson et al., 2002, 2004; Chau and Woodman, 2004)

- ✓ Despite the importance of vertical $\vec{\mathrm{E}} \times \vec{\mathrm{B}}$ drift in affecting electrodynamics and plasma density distribution in the low latitude ionosphere there is a general lack of instruments that are capable of directly measuring vertical drifts over the African region which motivates the development of an empirical model

The method of Anderson et al. (2004)

- The H field measurements from a pair of magnetometer stations near dip equator and another located at 6–9° off dip equator provide an estimate of EEJ and thus daytime $\vec{E} \times \vec{B}$ drift (e.g. Rastogi and Klobuchar, 1990; Anderson et al., 2004)

- In Anderson et al. (2004), the relationship between $\vec{E} \times \vec{B}$ and ΔH was developed based on JULIA observations and magnetic field data for the period 2001–2003 over the Peruvian longitude sector.

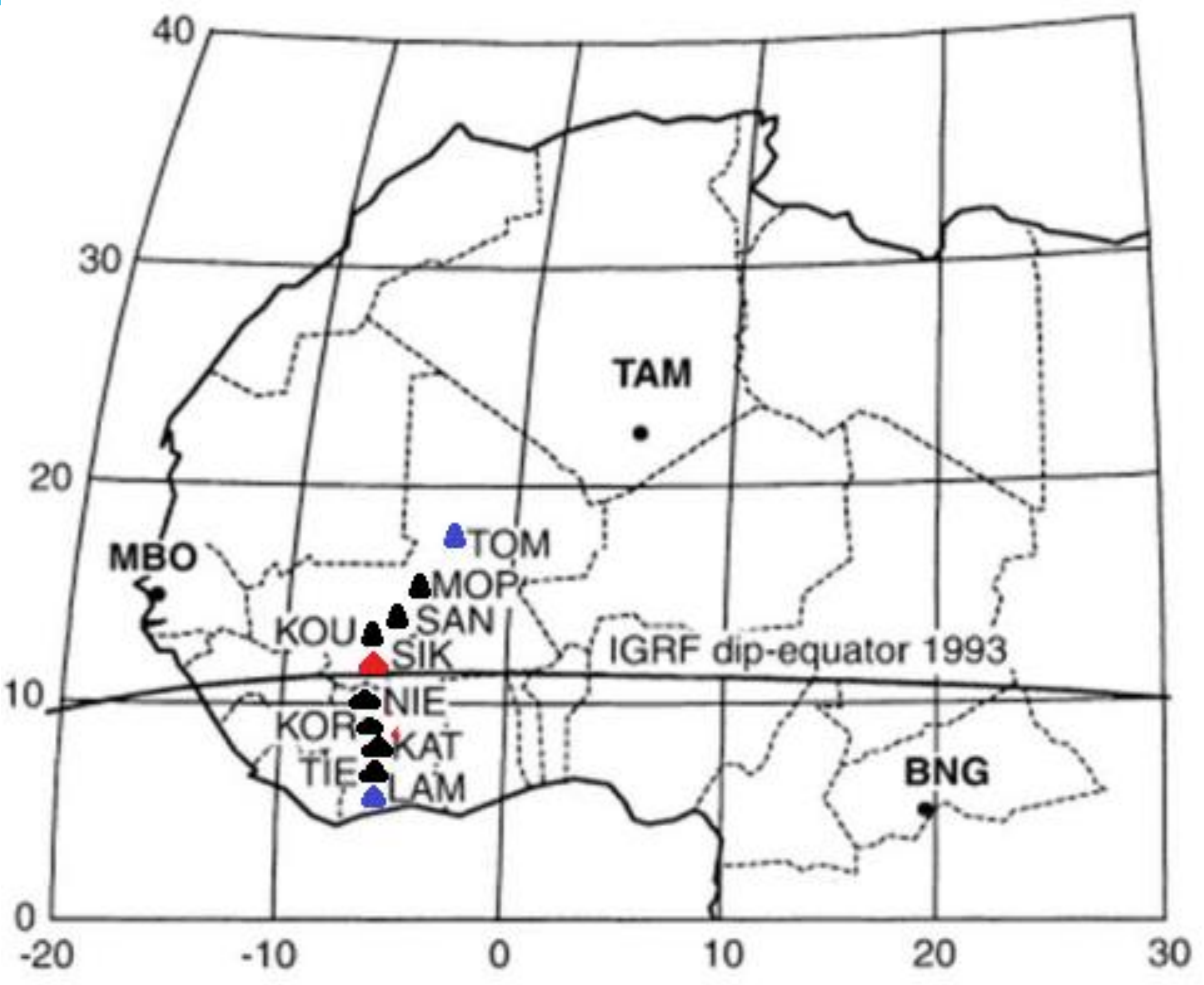
$$V_z = -1989{,}51 + 1{,}002 \times Year - 0{,}00022 \times DOY - 0{,}0222 \times F10.7 - 0{,}0282 \times F10.7A - 0{,}0229 \times Ap + 0{,}0589 \times Kp - 0{,}3661 \times LT + 0{,}1865 \times \Delta H + 0{,}00028 \times \Delta H^2 - 0{,}0000023 \times \Delta H^3$$

- Due to the similarity of climatological daytime vertical drifts (Scherliess and Fejer, 1999) at all longitudes, this relationship was suggested to be applicable at all equatorial latitudes as has been demonstrated in Peruvian, Philippine, Indian and African sectors (e.g. Anderson et al., 2004, 2006; Anghel et al., 2007; Yizengaw et al., 2012)

The International Equatorial Electrojet Year (IEEY)

Data used

Stations	Code	Geo. Coor.		Dip-Latitudes (°)
		Lat.(°)	Lon.(°)	
Tombouctou	TOM	16.733	3.000	6.76
Mopti	MOP	14.508	4.087	4.03
San	SAN	13.237	4.879	2.50
Koutiala	KOU	12.356	5.448	1.41
Sikasso	SIK	11.344	5.706	0.12
Nielle	NIE	10.203	5.636	-1.20
Korhogo	KOR	9.336	5.427	-2.30
Katiola	KAT	8.183	5.044	-3.82
Tiebissou	TIE	7.218	5.241	-4.99
Lamto	LAM	6.233	5.017	-6. 27



Geographic and geomagnetic coordinates of the magnetic stations installed along the meridian 5°W in West Africa during the International Equatorial Electrojet Year

The AMBER Magnetometer Station

Data used

Conakry
Latitude: 0.46°S
Longitude: 60.37°E

Abidjan
Latitude: 6°S
Longitude: 65.85°E

http://magnetometers.bc.edu/index.php/amber

Data processing

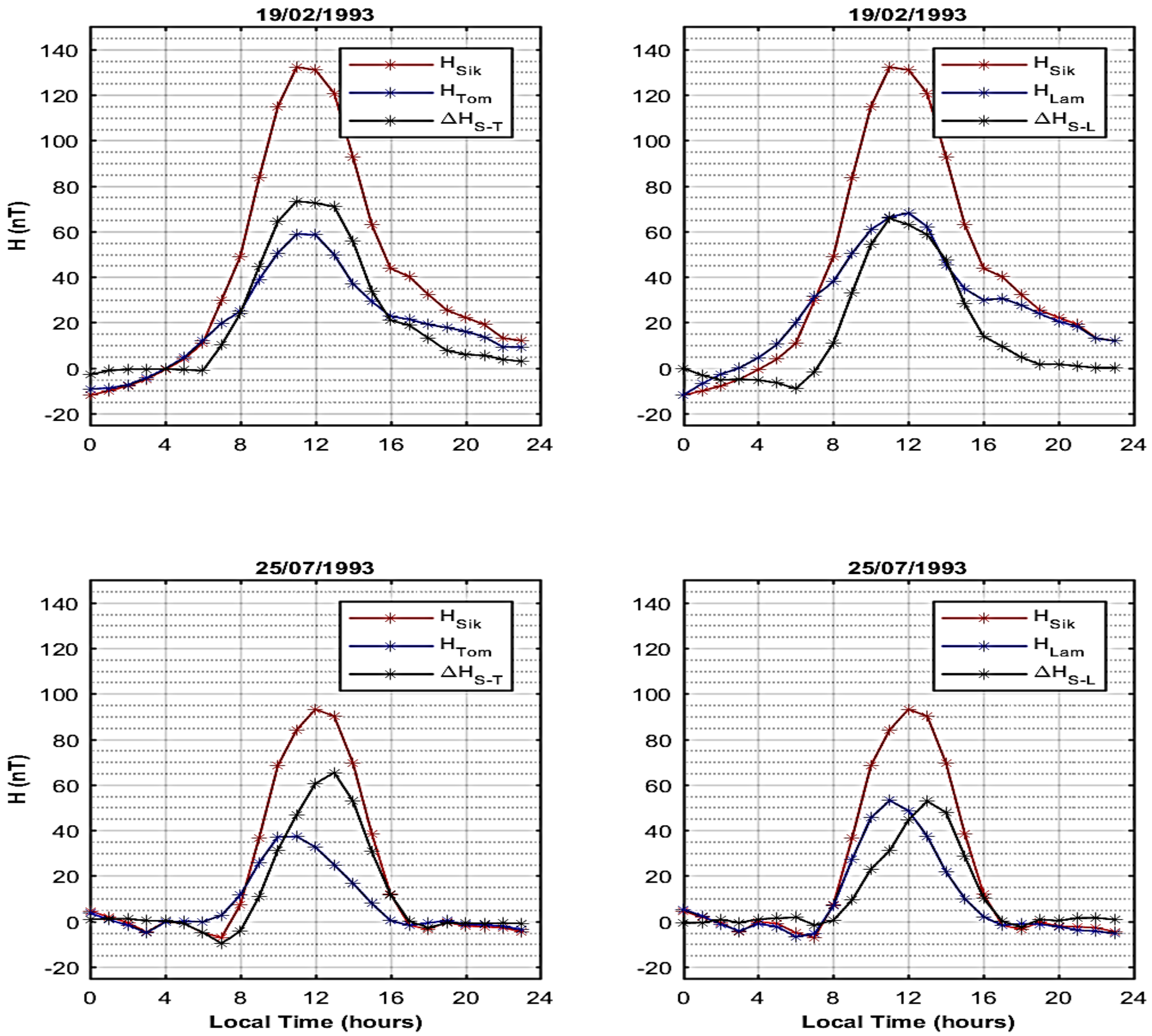
- The H component magnetic field includes the contributions from the main field, the magnetic effect of the EEJ, the field of magnetospheric currents (e.g. ring current) and the field of large-scale ionospheric currents. To calculate the intensity of the magnetic field that is only due to the effect of the electrojet, we need to eliminate the three other contributions. Since the night level represents an estimate for the main field, removing it eliminate the main field effects (Siddiqui et al., 2015a).
- For the two sets of data, the night time value is considered as the baseline of the daily variations, which corresponds to the average midnight values (H0) of the H component.

ΔH_{S-T} = Hsik-Htom

ΔH_{S-L} = Hsik-Hlam

ΔH_{C-A} = HAban-HCnky

$H0 = (H_{23} + H_{00} + H_{01})\ /3$

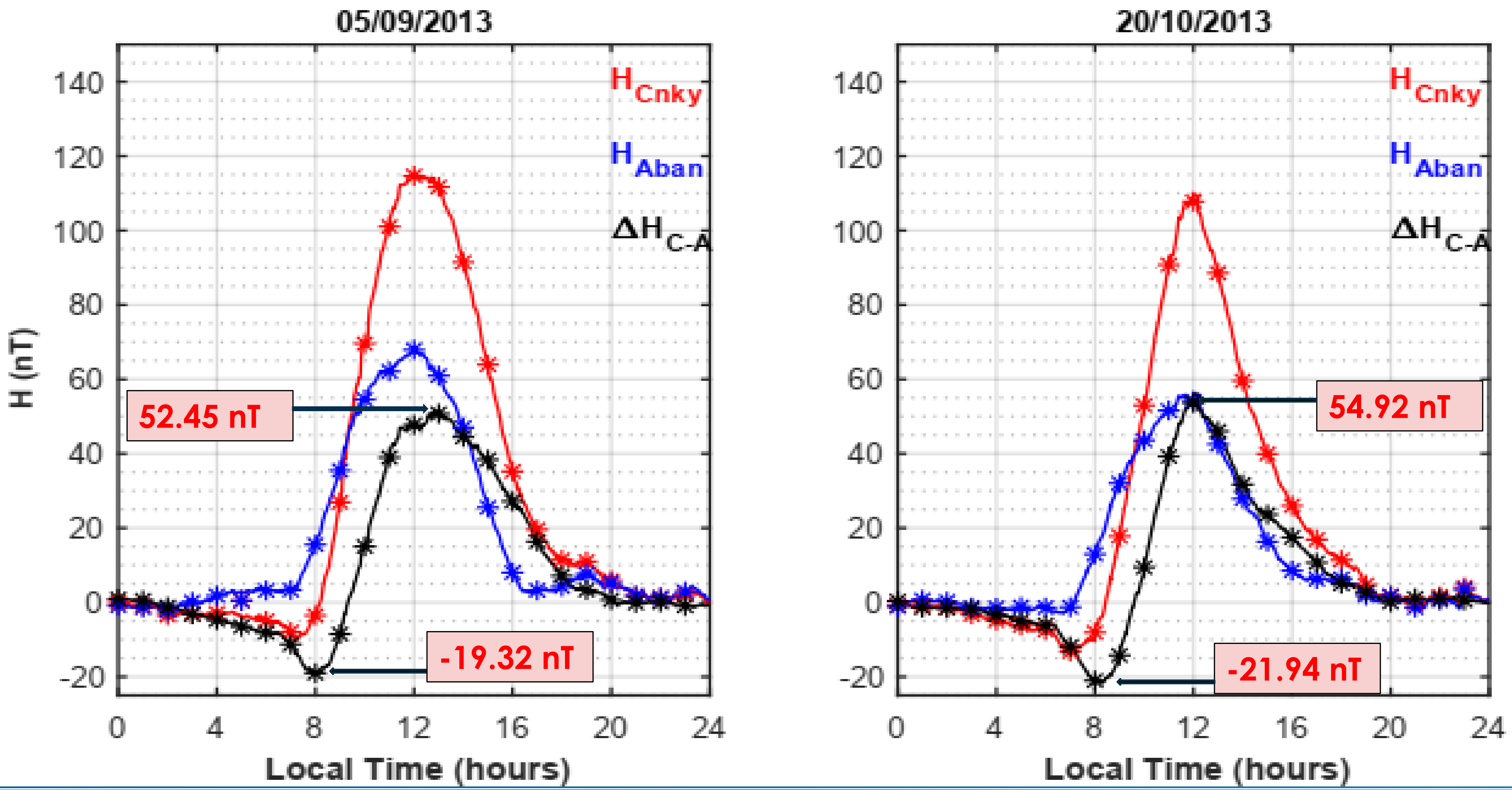


19/02/1993 noon peak values
ΔH_{S-T}= 73.35 nT
ΔH_{S-L}= 65.8 nT

25/07/1993 noon peak values
ΔH_{S-T}= 65.25 nT
ΔH_{S-L}= 52.75 nT

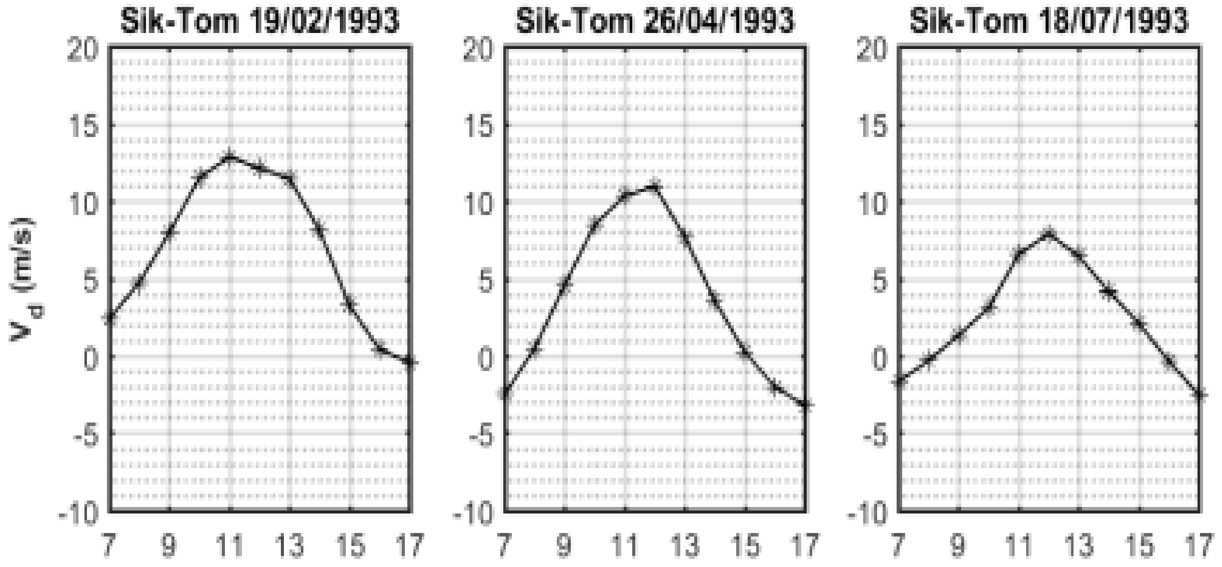
SIK-LAM latitudinal separation is about 6.18° latitudes while SIK-TOM is 6.64° latitudes.

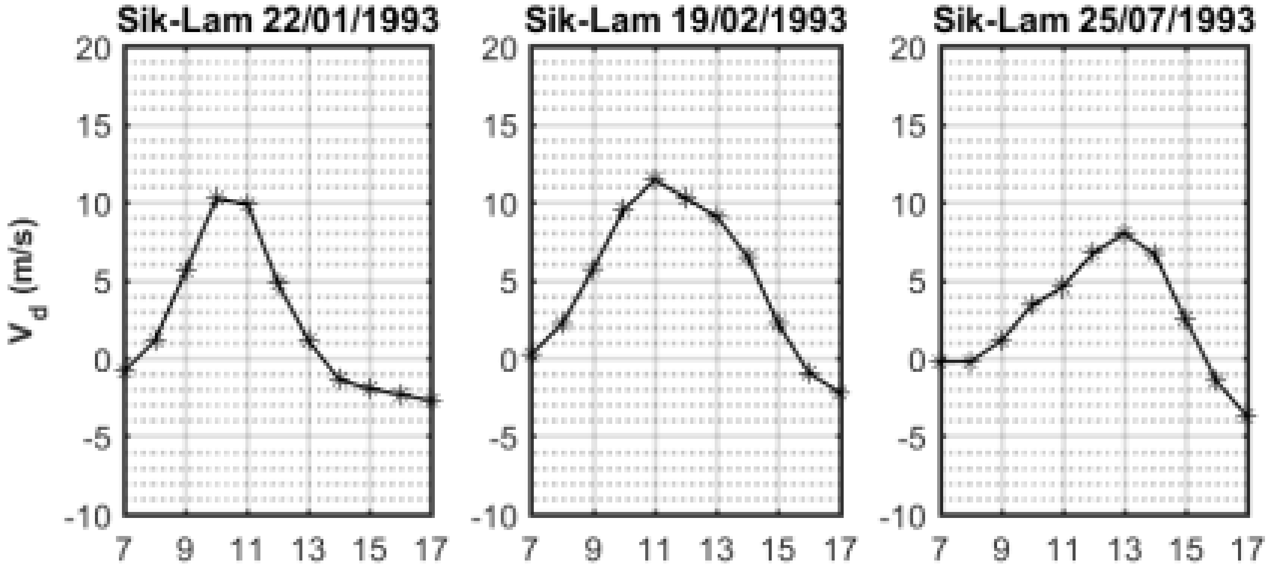
Daily variations of the EEJ magnetic effect



Daily variations of the EEJ magnetic effect

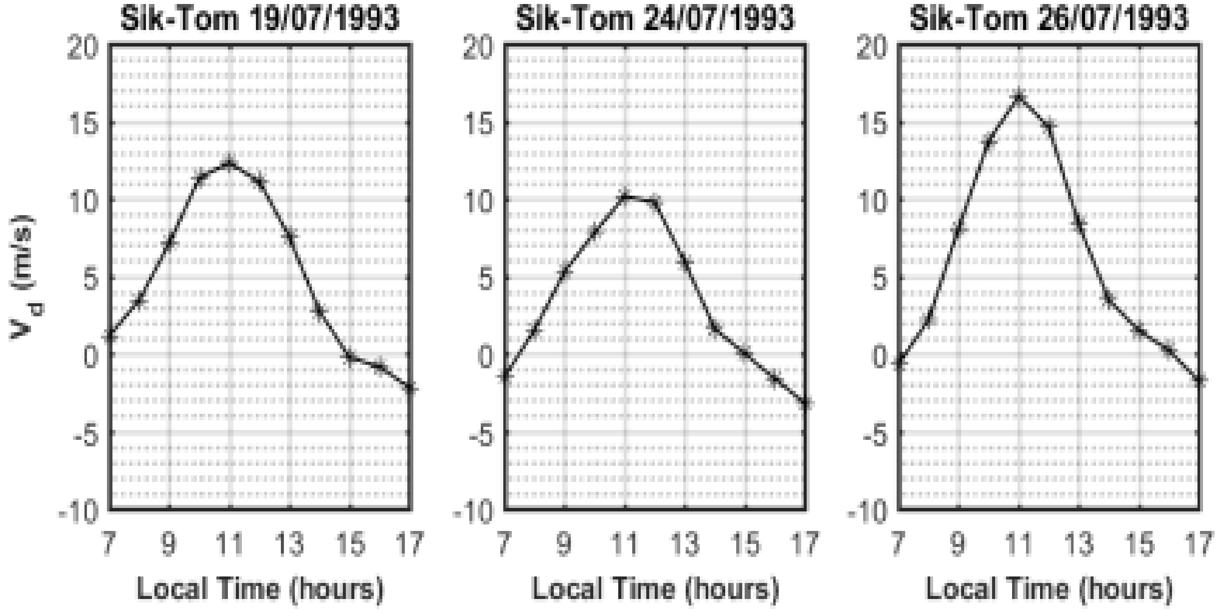
Day-to-day variation of the quiet time F-region plasma vertical drift velocity

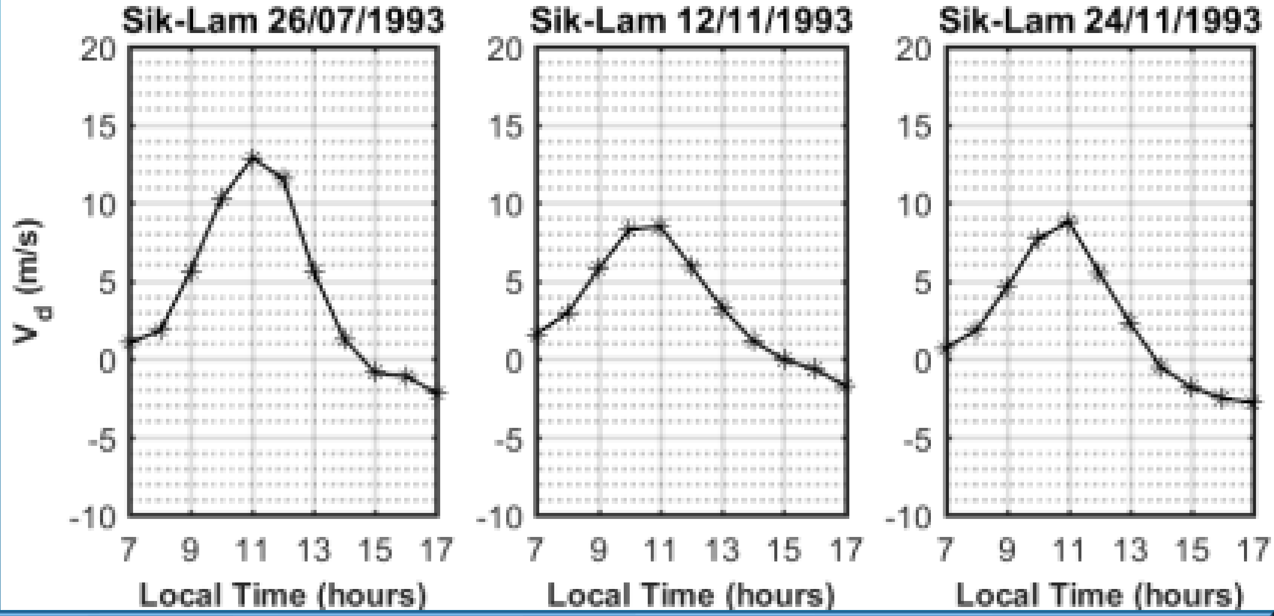




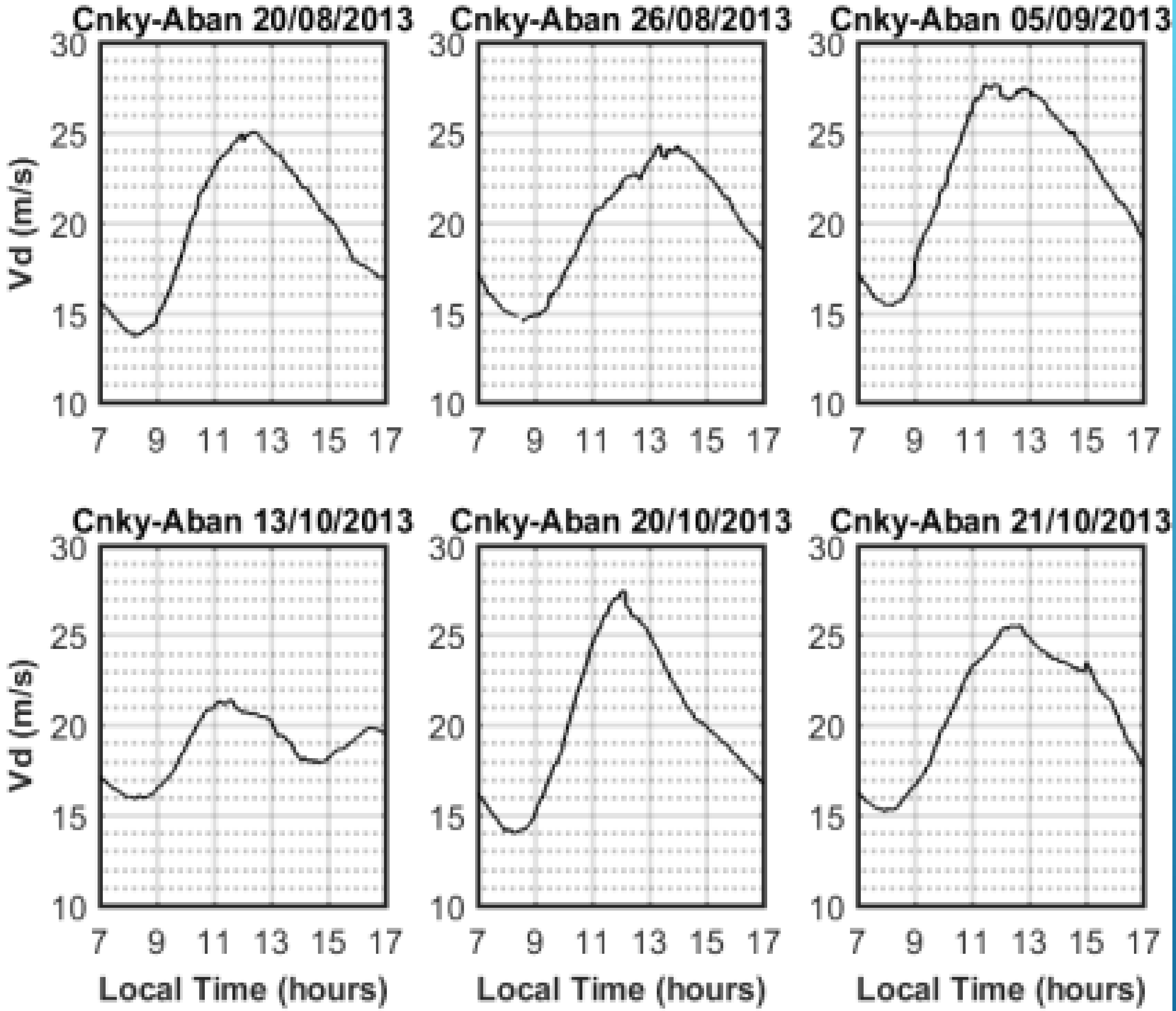
Noon peak values range V_d= 08.12-16.62 m/s

Noon peak values range V_d= 08-12.85 m/s



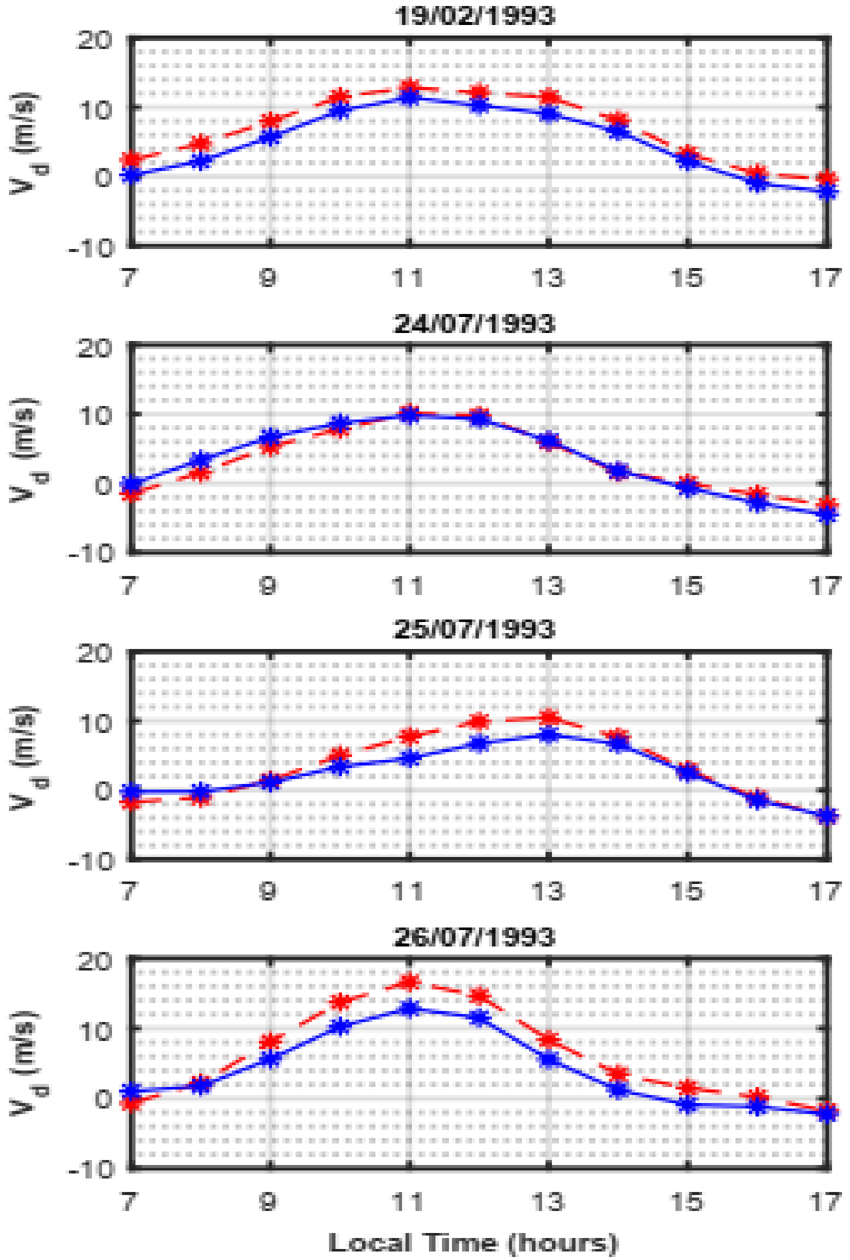


Day-to-day variation of the vertical drift velocity estimated from ΔH_{C-A}



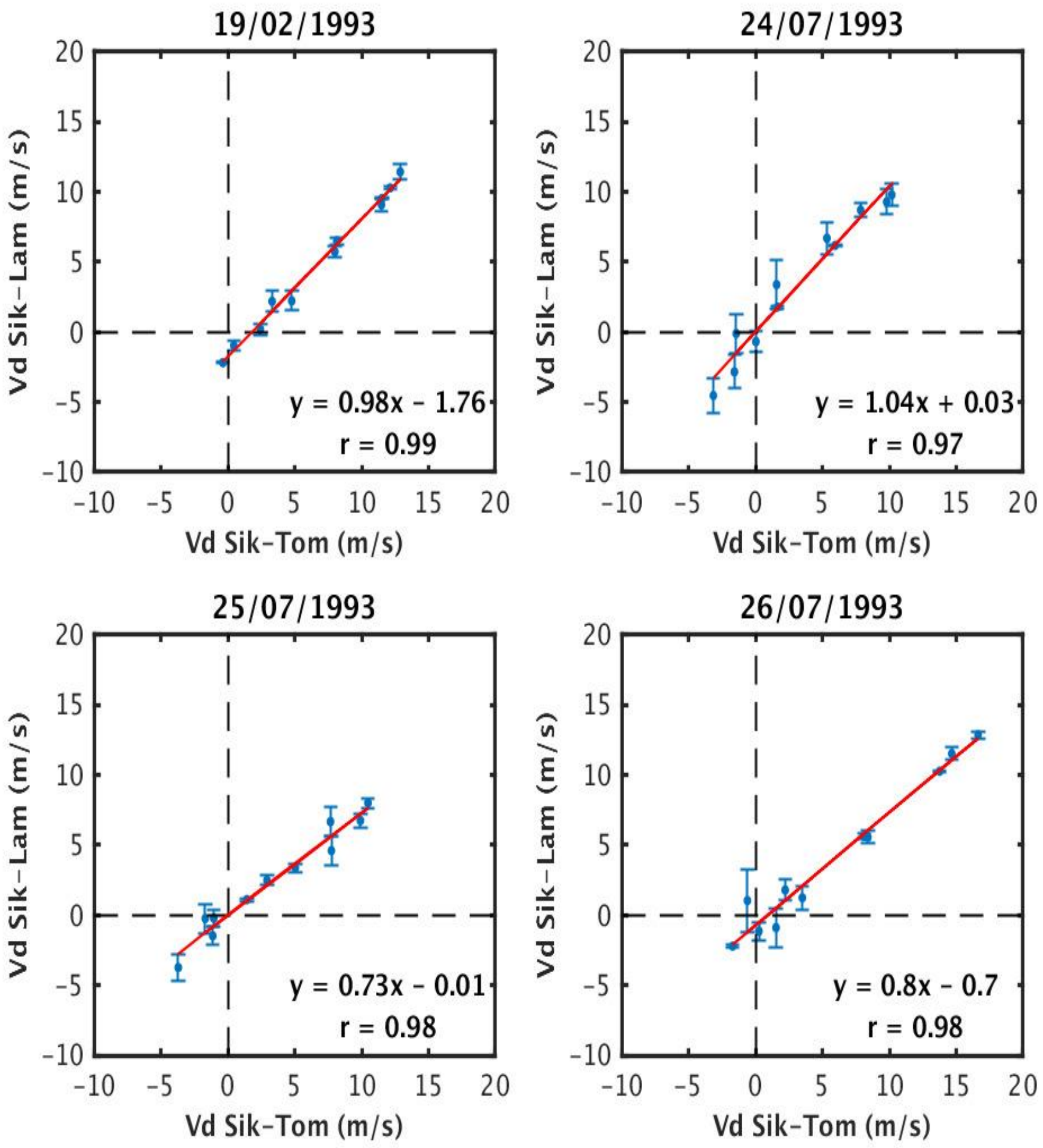
- In response to the morning CEJ observed in ΔH_{C-A}, the drift velocities drop down between 0700 LT to 0800 LT to minimums of 14 m/s to 16 m/s.
- After this morning depression, the drift velocity increases and attains its maximum 21.57 m/s to 27.66 m/s around local noon, then decreases during the afternoon.

Comparison daytime vertical drift velocity estimated from ΔH_{S-T} and ΔH_{S-L}

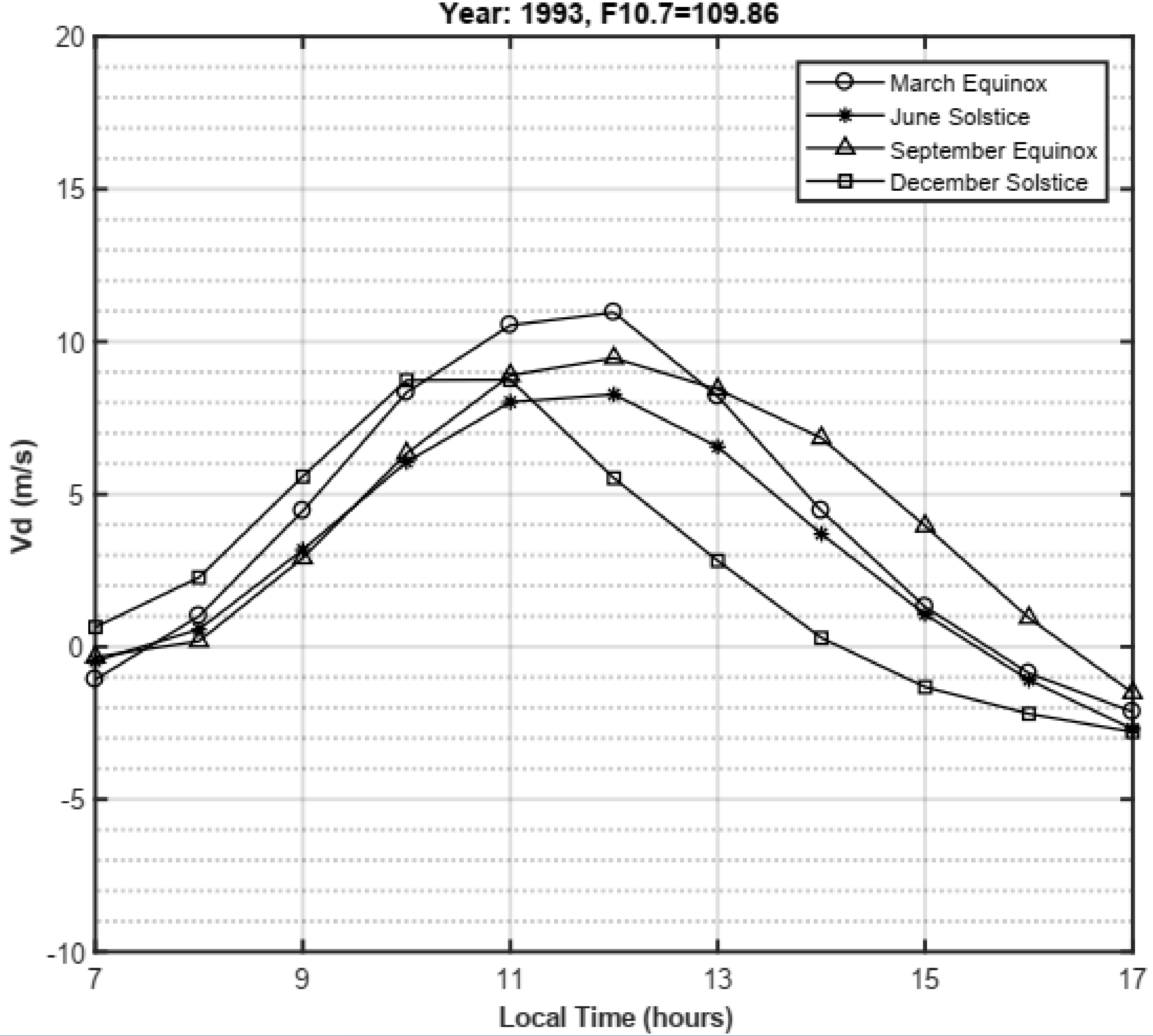


R=0.97
Slope about 0.89 on average showing that Vd from ΔH_{S-T} slightly greater than Vd from ΔH_{S-L}.

Lines overlap the error-bars, showing that their slopes range within the error-bars, which makes it possible to consider as approximately equal on both sides

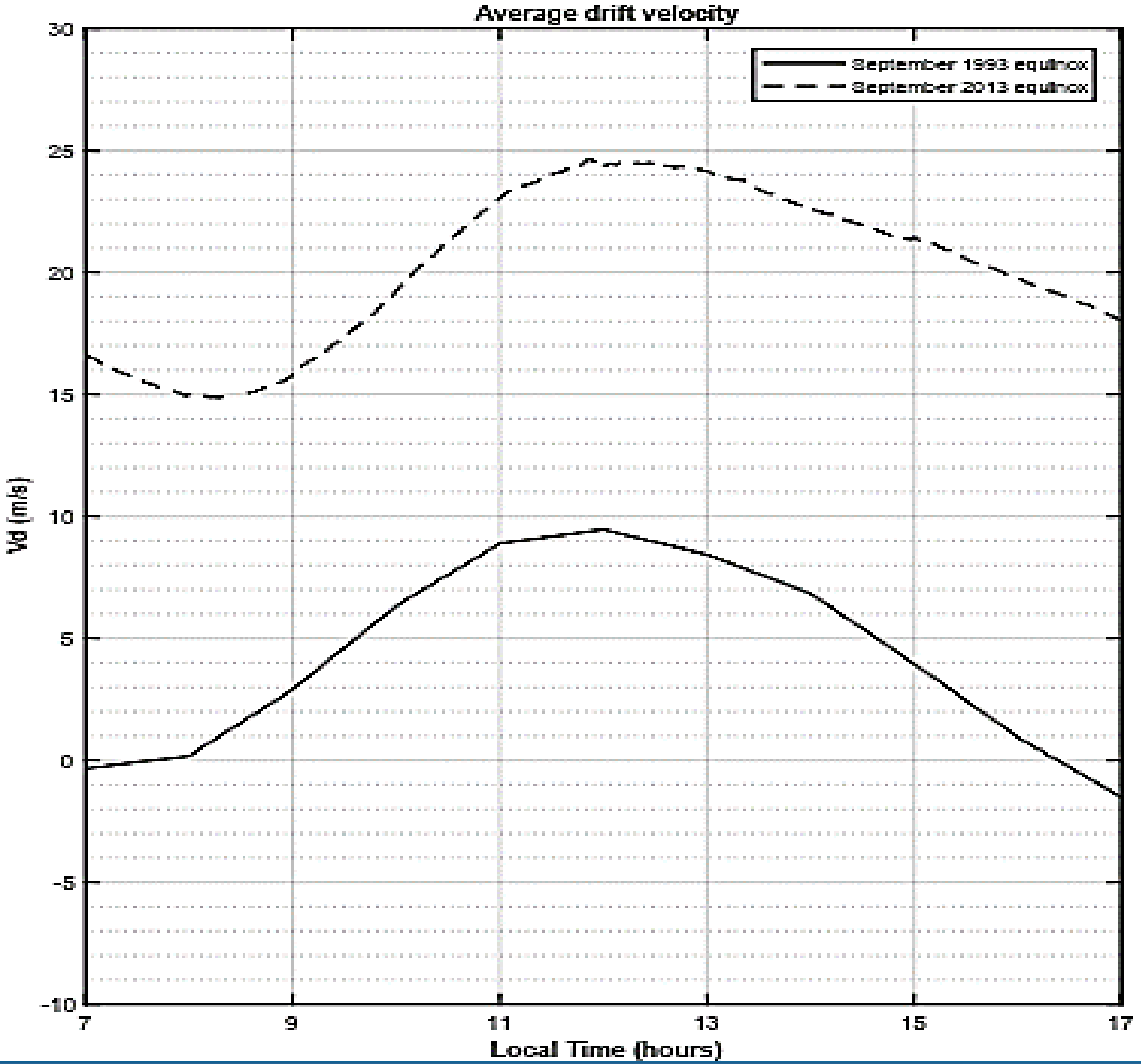


Dependence of the F-region plasma vertical drift velocity on seasons



- The patterns of Vd are roughly similar for the March equinox, June solstice, September equinox, with noontime maxima at 1200LT. In December solstice the maximum Vd is attained around 1100LT and the decreasing phase in the afternoon starts earlier and faster than the other seasons.
- Highest noontime amplitudes of Vd are observed in equinoxes, being higher in March equinox than in September equinox
- Vd amplitude is weaker in June Solstice than in December solstice.

Dependence of the F-region plasma vertical drift velocity on solar cycle



- Vertical drift velocity is significantly higher in 2013 (cycle 24) than in 1993 (cycle 22)
- Noontime values of the drift velocity are respectively about 9.5 m/s in 1993 and 24.5m/s in 2013
- The difference between the values of Vd could be interpreted as possible solar cycle effect

Conclusion

- The values of ΔH_{S-T} and its corresponding Vd are slightly higher than those of ΔH_{S-L} and its related Vd.
- The pair with the largest latitudinal separation exhibits the strongest EEJ while, the one with the smallest latitudinal separation presents the weakest EEJ.
- The amplitudes of Vd are higher in equinoxes, with strongest values during the March equinox. The maximum in the December solstice is stronger than in June solstice.
- It appears that the values of the daytime vertical drift velocity in 2013 are significantly larger than those obtained in 1993.

Thank you