UN/Russian Federation Workshop on the Aapplications of GNSS
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IONOSPHERE AND SPACE WEATHER

INVESTIGATIONS IN BOSNIA & HERZEGOVINA USING OS SOFTWARES

preliminary results

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2 SID Monitor SRJV_ION

3 OS software: gLAB and Vshell:

- GNSS coordinates accuracy by gLAB
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4 VTEC byVShell:

- GNSS SRJV variability analysis

5 Seismo-ionospheric pre-earthquake variations

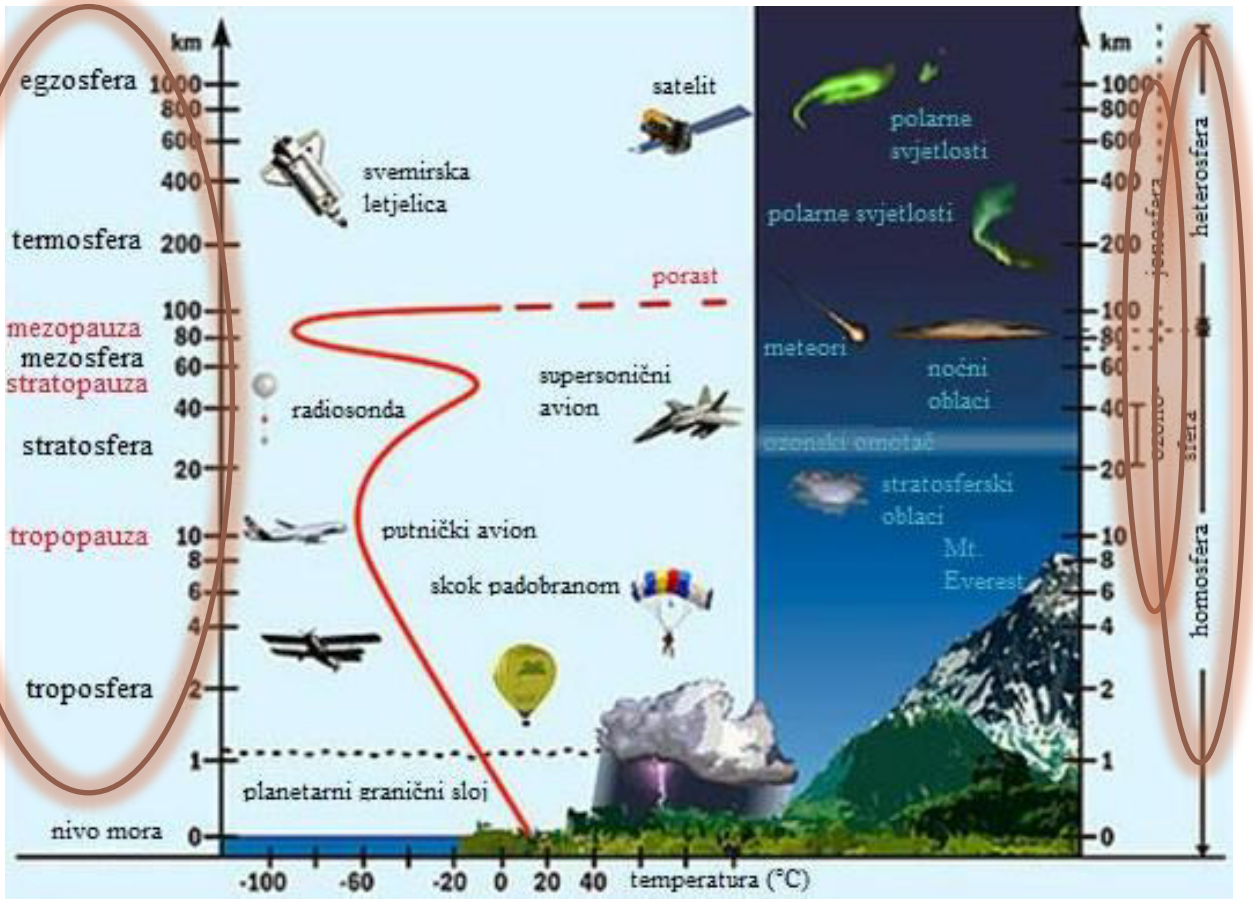
6 Conclusions

Introduction

1

- Ionospher is the part of atmospher from 50 up to 1000 km

1. Chemisty
2. Temperature
3. Conductivity of electricity



Vertical distribution of the Earth atmosphere

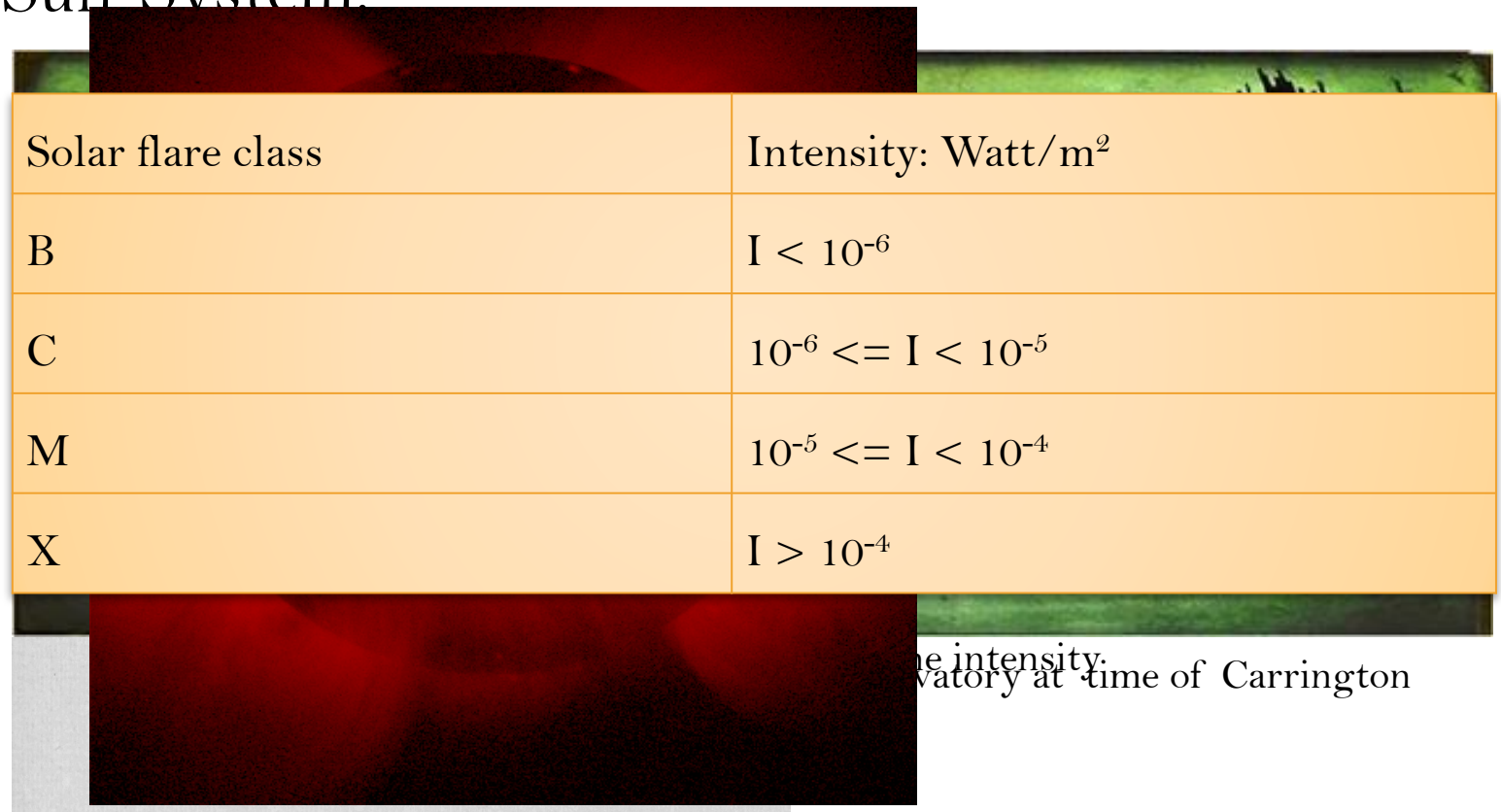
Introduction 2

- Variability in ionopher resulting as:
  - Anomalies in ionosphere:
    - Deily
    - Night
    - Polar
    - Annual, Seasonal, 11 year cycle,..
  - Ionospheric disturbances:
    - Traveling ionosphericdisturbances -TID
    - Ionospheric storms
    - Sudden ionospheric disturbances-SID
    - Ionospheric scintilation

1

- Space weather is set of physical and chemical processes releted to energy transport in Earth-Sun-System.

Solar flare class	Intensity: Watt/m^2
B	$I < 10^{-6}$
C	$10^{-6} <= I < 10^{-5}$
M	$10^{-5} <= I < 10^{-4}$
X	$I > 10^{-4}$



...e intensity
...vatory at time of Carrington

Solar spots as drawn by Galileo Galilei about 1610
Solar flares

SID Monitor SRJV_ION

SUDDEN IONOSPHERIC DISTURBANCE

VLF SID monitor SRJV_ION 0436

- Task: to receive and register VLF data from 6 SID stations
- Strategy: using SuperSID (Sudden Ionospheric Disturbance) software package
- Analyze of the first period of the observation 02/07/2014 -31/08/2014
- Objective: Prove of the abilities of monitor SRJV_ION 0436 to detect and register solar flares.

Assembling of SID monitor SJRV_ION 0436

2

Stanford University provided

Sarajevo University provided

Hardware components

- VLF signal reciever
- Coaxial cable
- Wire 120 m long

- Location with minumum interferece
- Power suplay
- PC
- Antenna wooden frame
- Internet conection

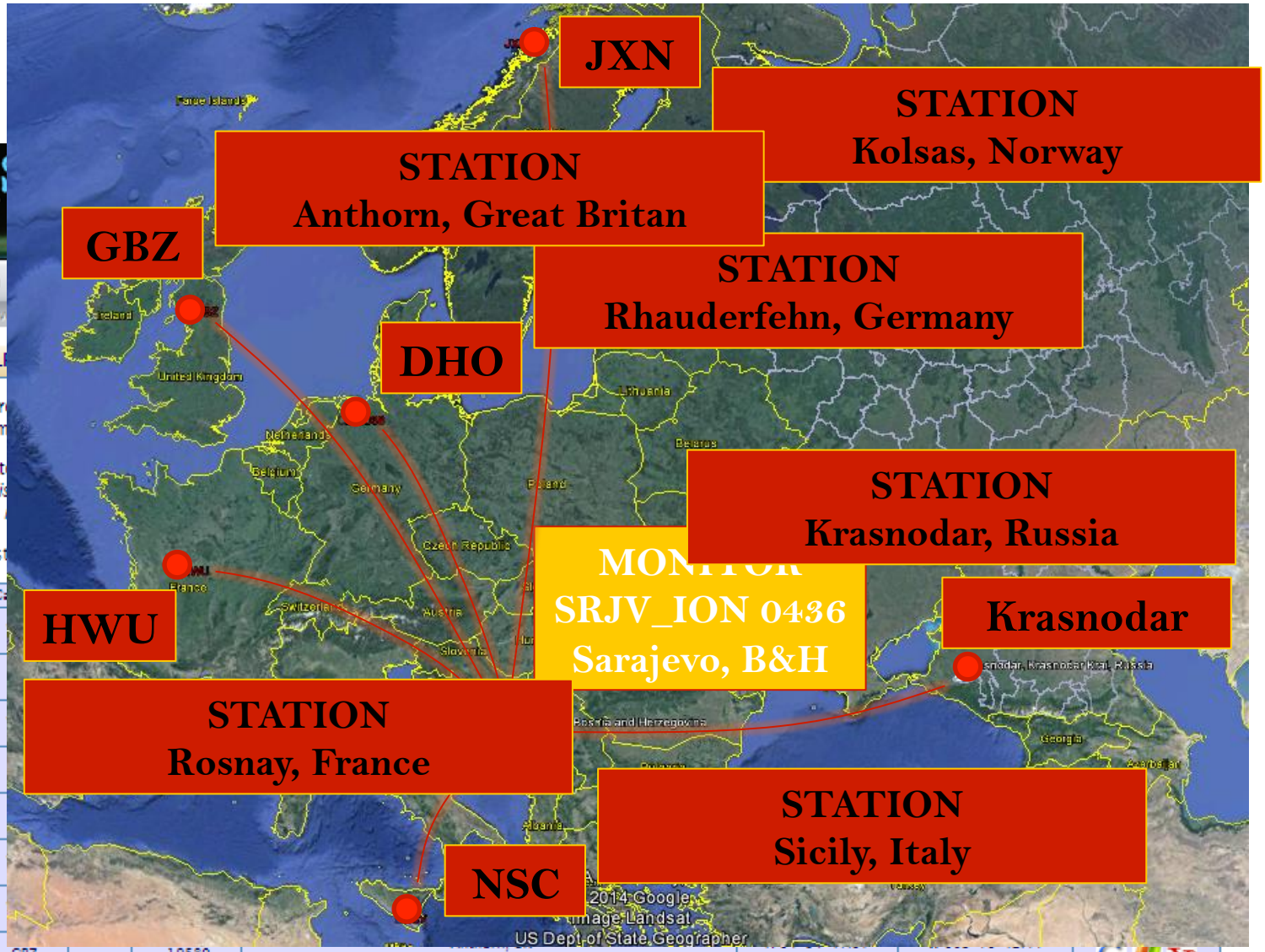
Software

- SuperSIDsoftware CD
- Manual

Establishing SID monitor SRJV_ION 0436

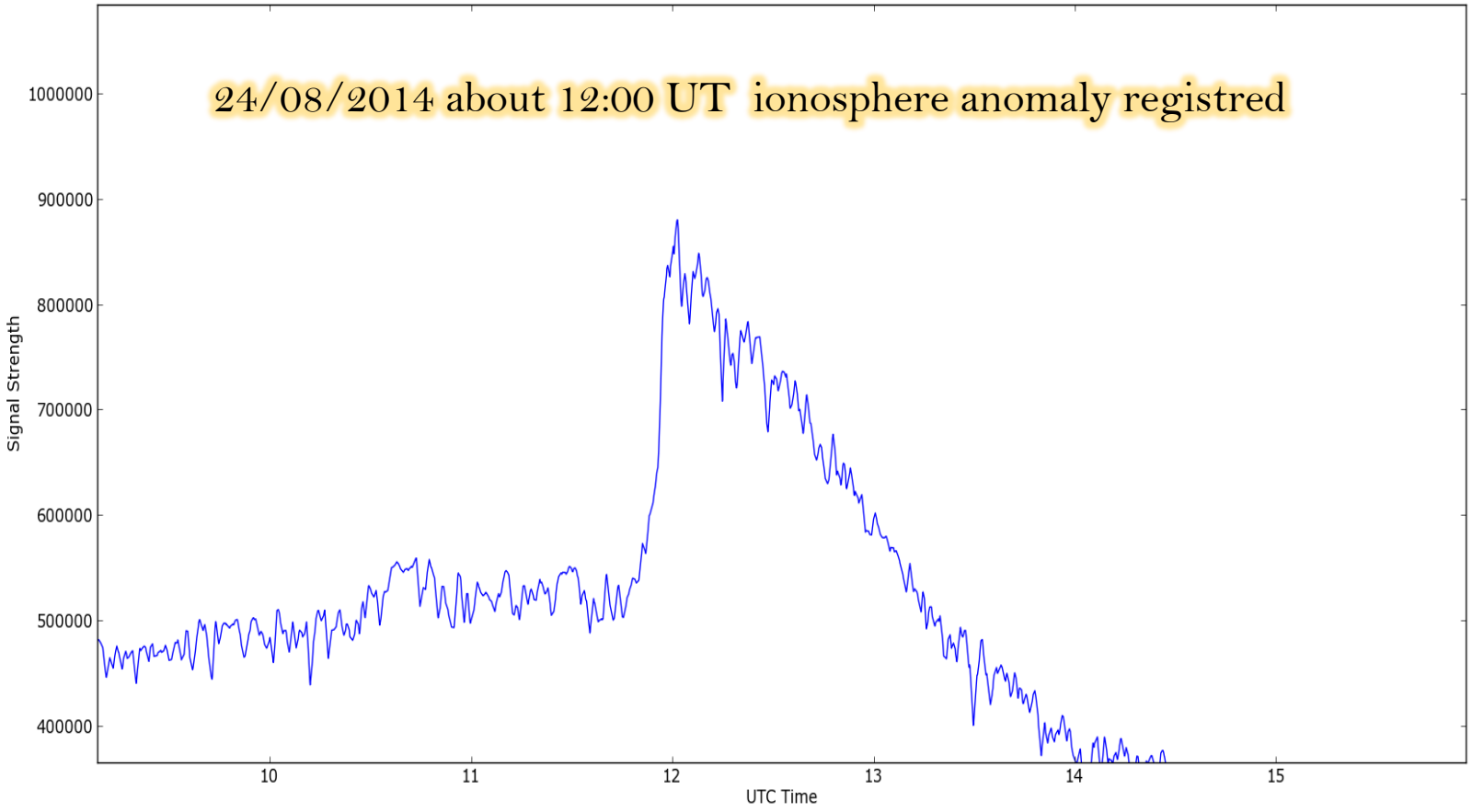
2

- Selection of VLF stations



First results: SID monitor SRJV_ION 0436

- **Interpretation of graphics**



Graphic shows variations in the signal strenght receiverd from station DHO, Rhauderfehn (Germany) in day 24/08/2014

Zoom to the jump in the signature of the observed signals

First results: SID monitor SRJV_ION 0436

- **Data analysis**

1. **Comparation of graphics data**
3. **Identification of registrsed solar flar**
   - **Graphics of three-days data (sampling rate of 5 minuts) from GOES satellites**
2. **Search of solar flare in the catalog of solar events**
   - **Catalog of solar events**

OS software gLAB

COODINATES ESTIMATION

TEC ESTIMATION AT

Coordinate of SRJV station by gLAB

3

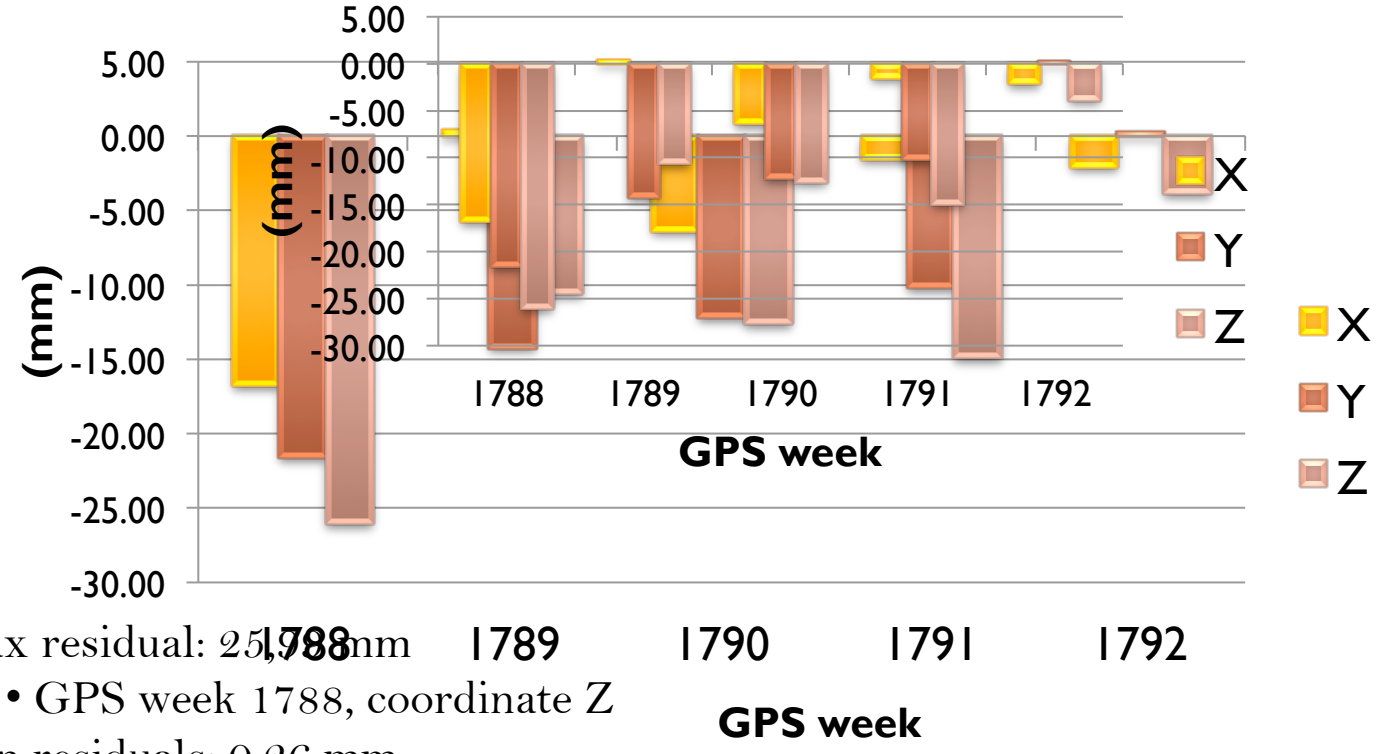
- **Task**: using gLAB software
- Analyse the accuracy of the GNSS station SRJV coordinates by PPP (Precise Point Positioning)
- Strategy: apply ionosphere free linear combination to eliminate 99,9% ionosphere refraction
- Analysis of the daily solutions for:
  - 15/04/2014 - 15/05/2014

Coordinate of SRJV station by gLAB

3

Analyse of the week coordinate solutions by gLAB referenced to EPN solution

- Weeks residals

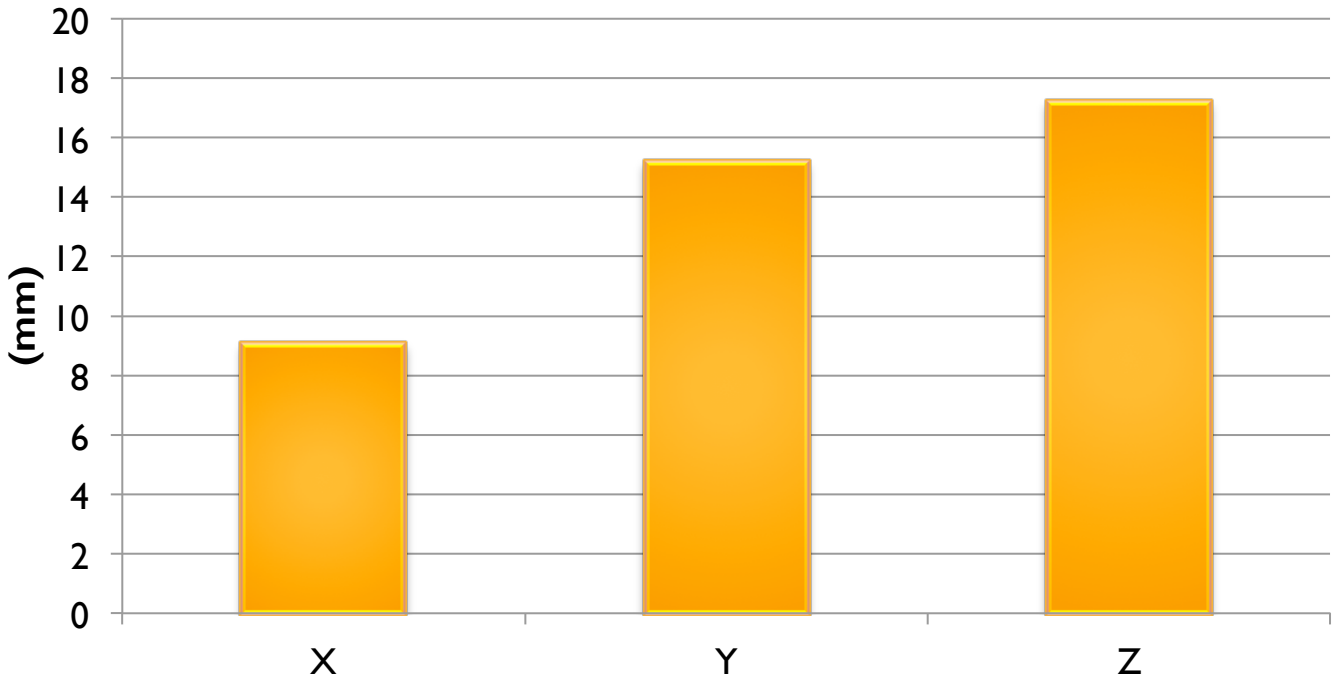


- Max residual: 25,78 mm
  - GPS week 1788, coordinate Z
- Min residuals: 0,26 mm
  - GPS week 1792, coordinate X

Coordinate of SRJV station by gLAB

3

- Analyse of the coordinate solutions
  - Standard deviations



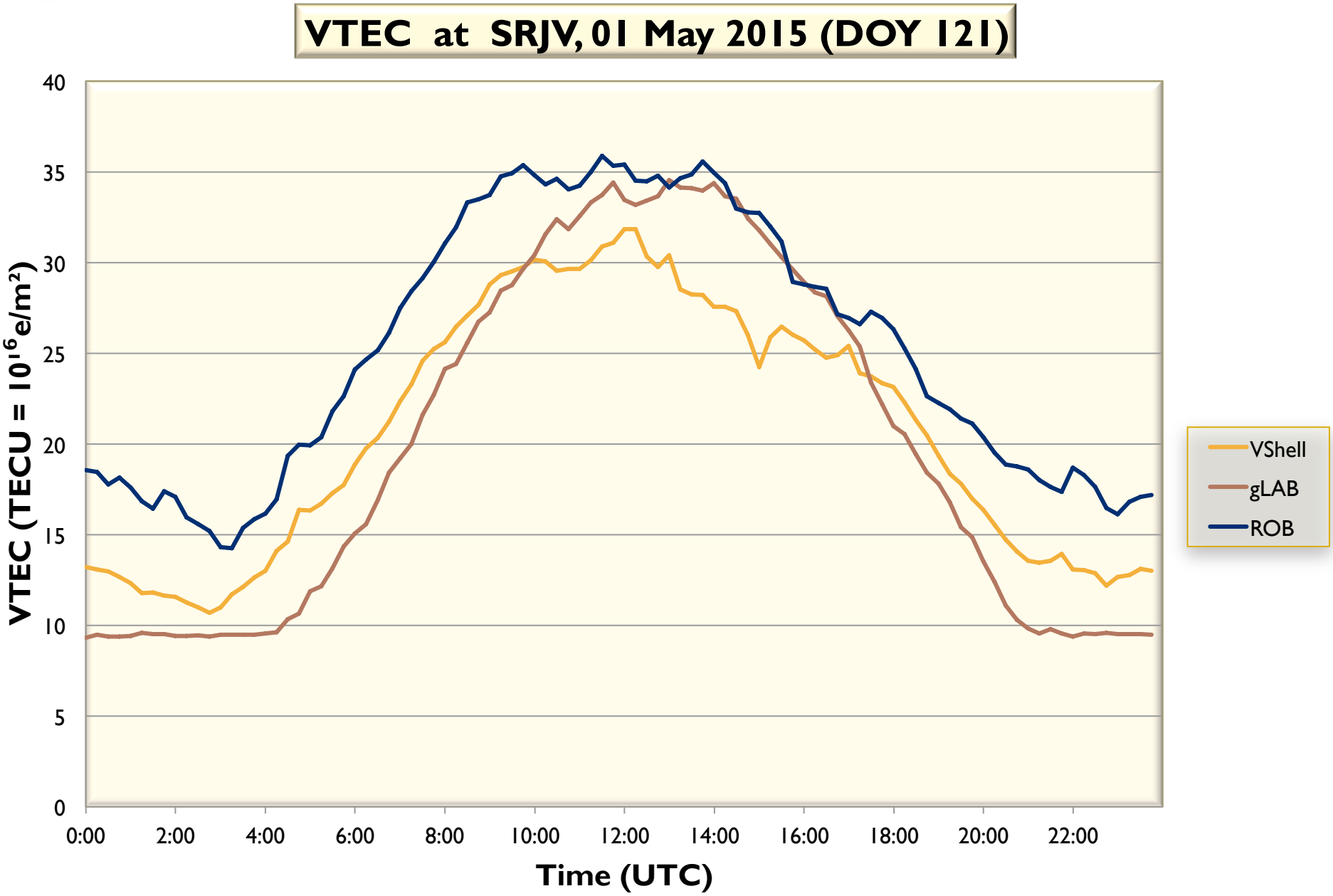
Standard deviations from the sample

VTEC from GNSS SRJV

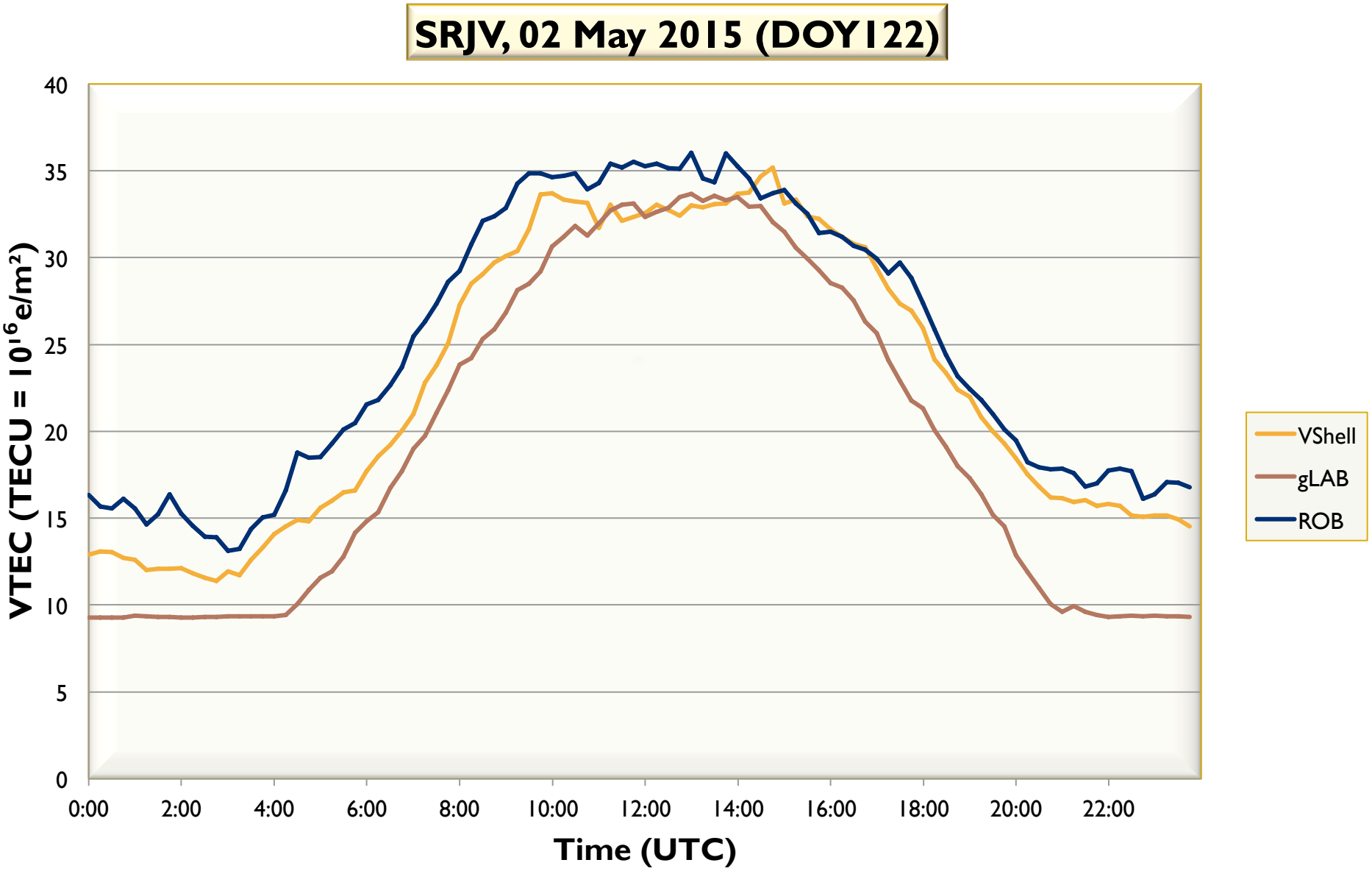
- **Using different OS software:**

  gLAB and VShell

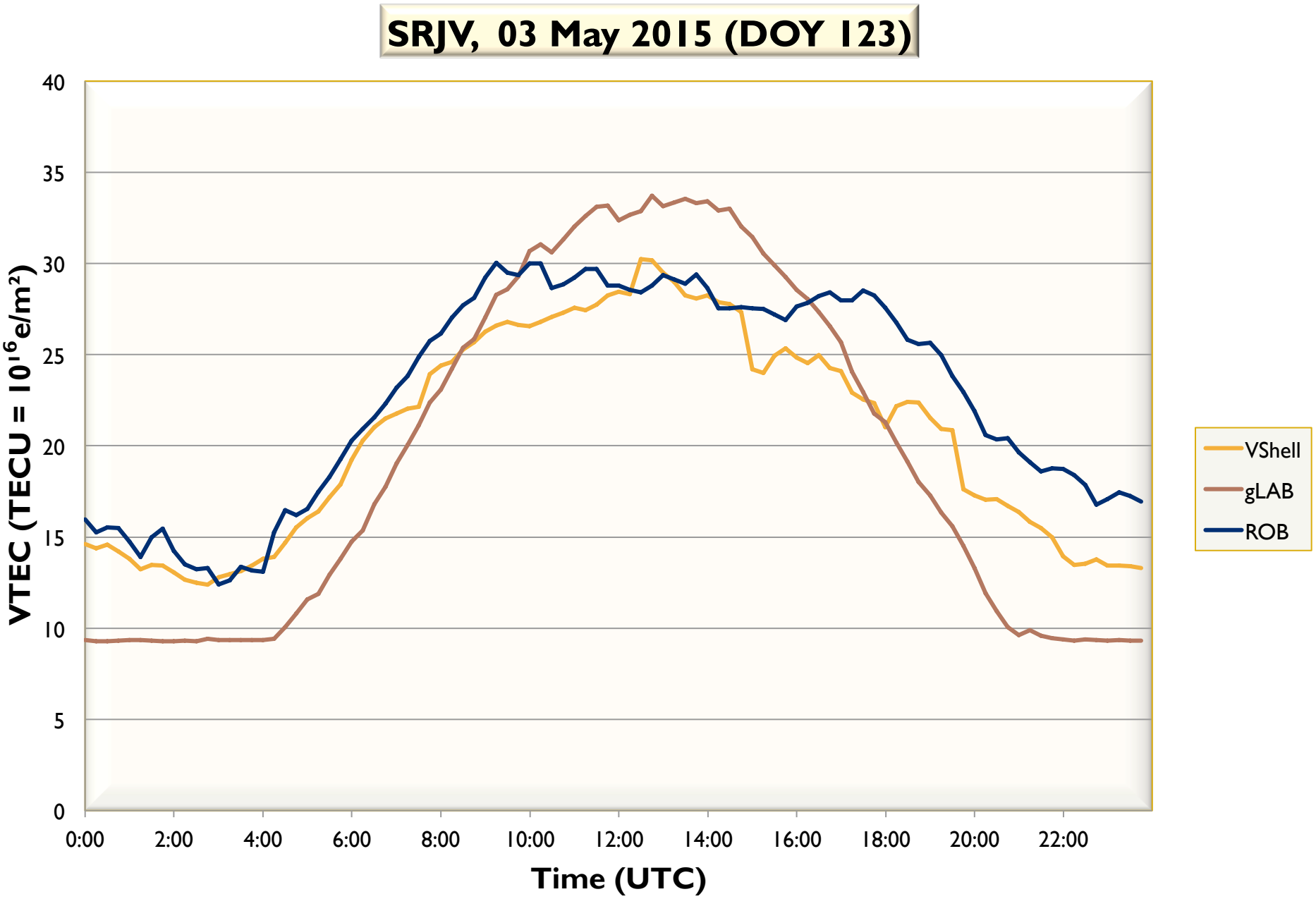
VTEC at GNSS SRJV



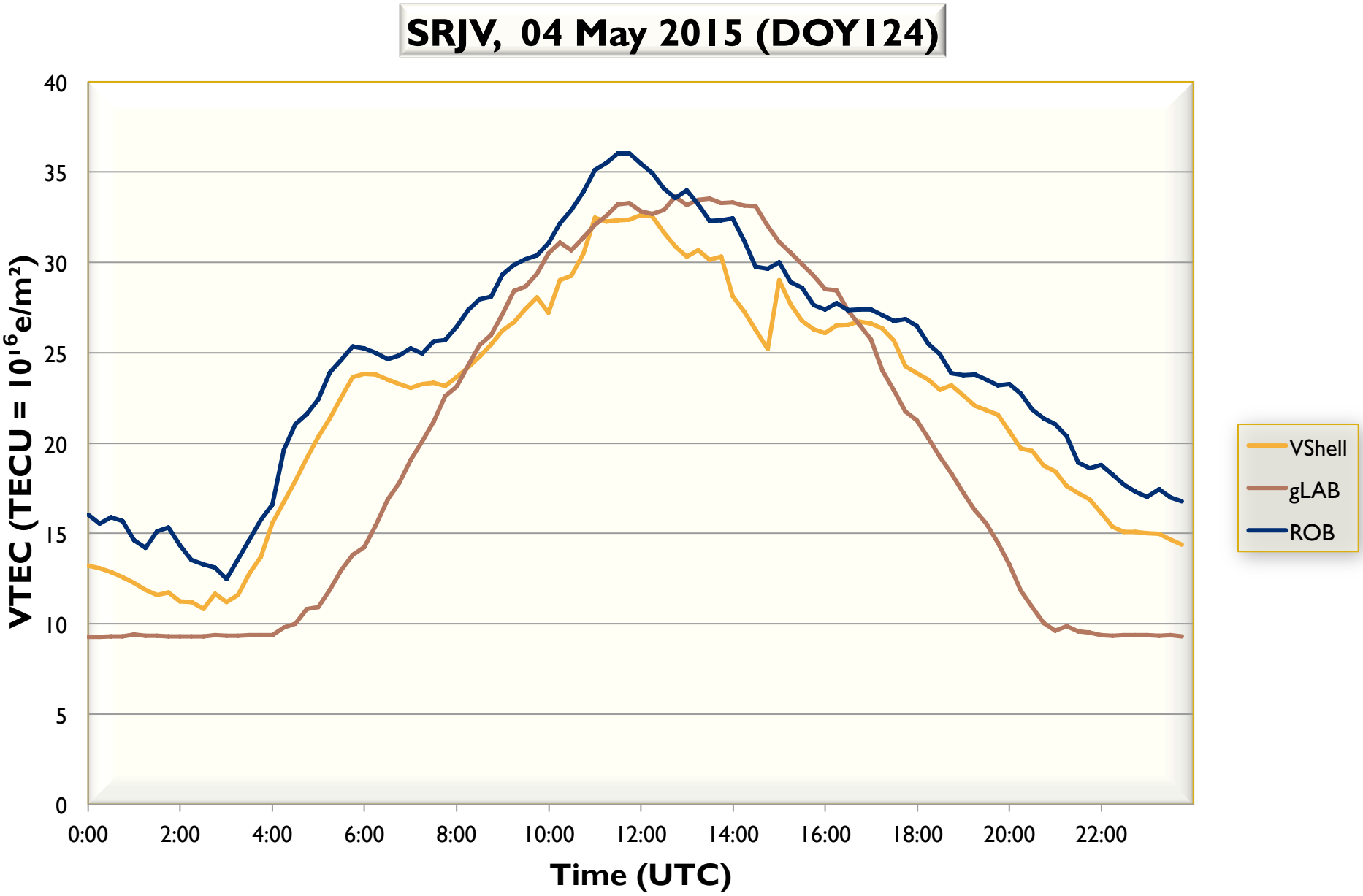
VTEC at GNSS SRJV
by different OS software



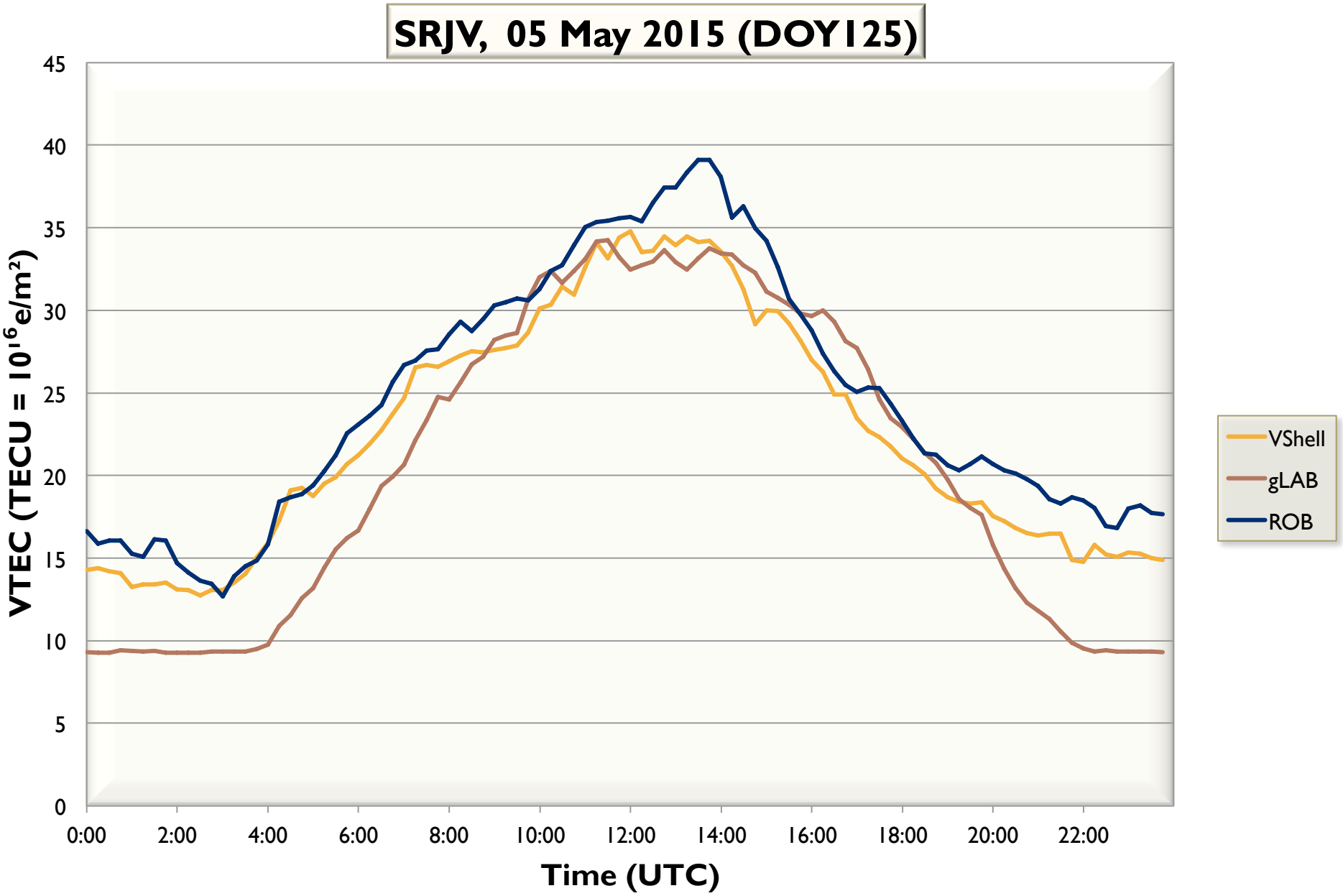
VTEC at GNSS SRJV



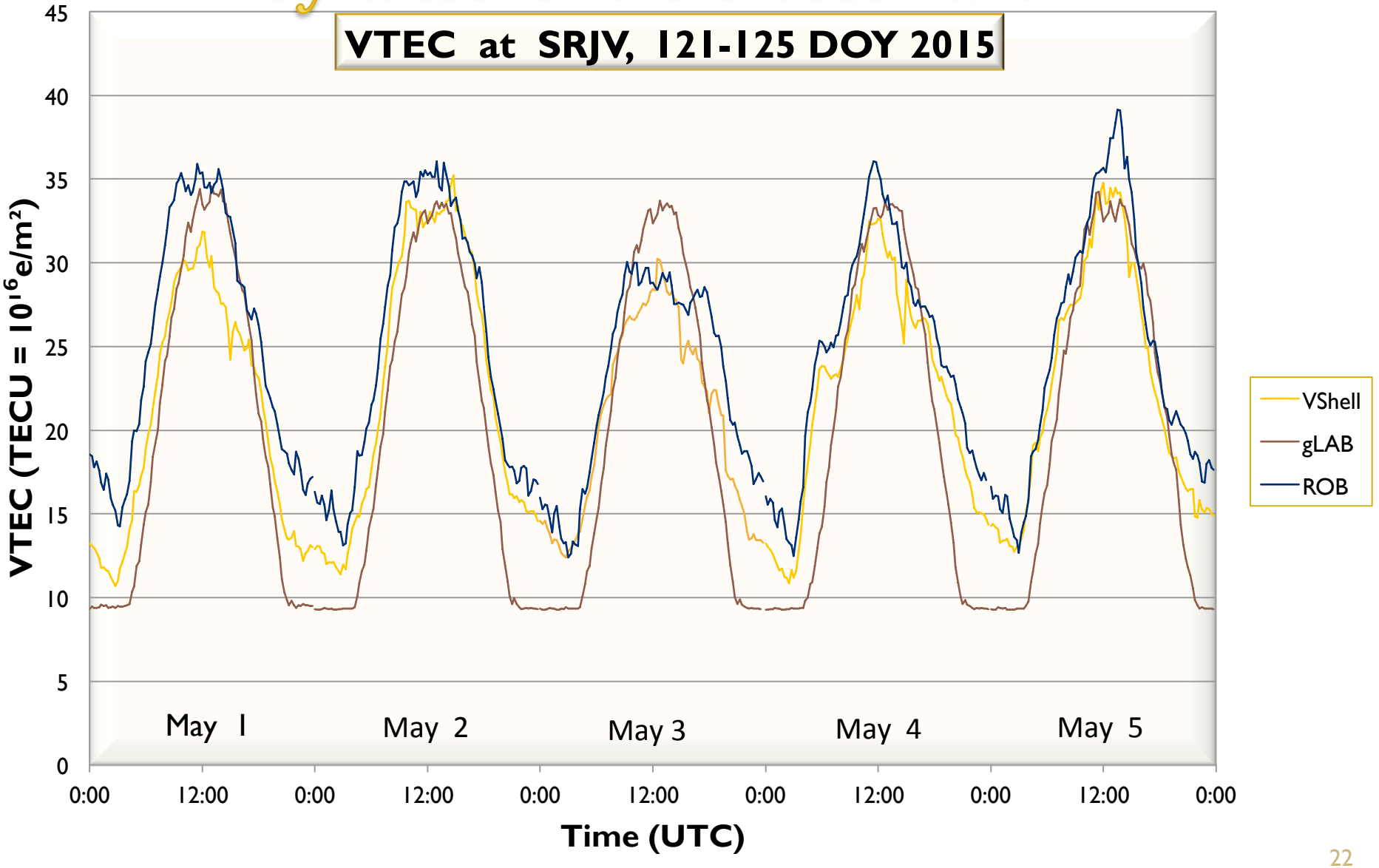
VTEC at GNSS SRJV



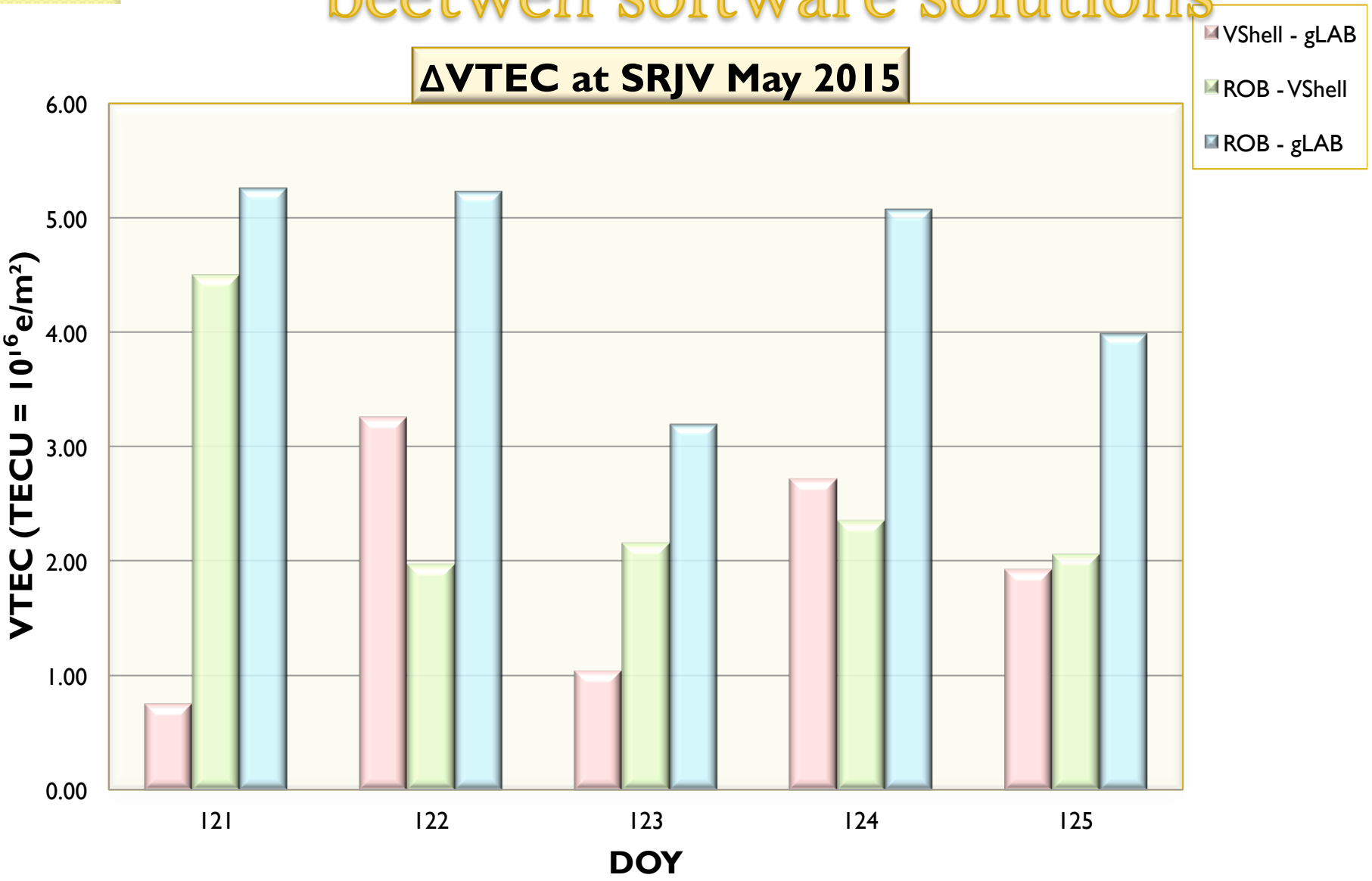
VTEC at GNSS SRJV



VTEC at GNSS SRJV by different OS software



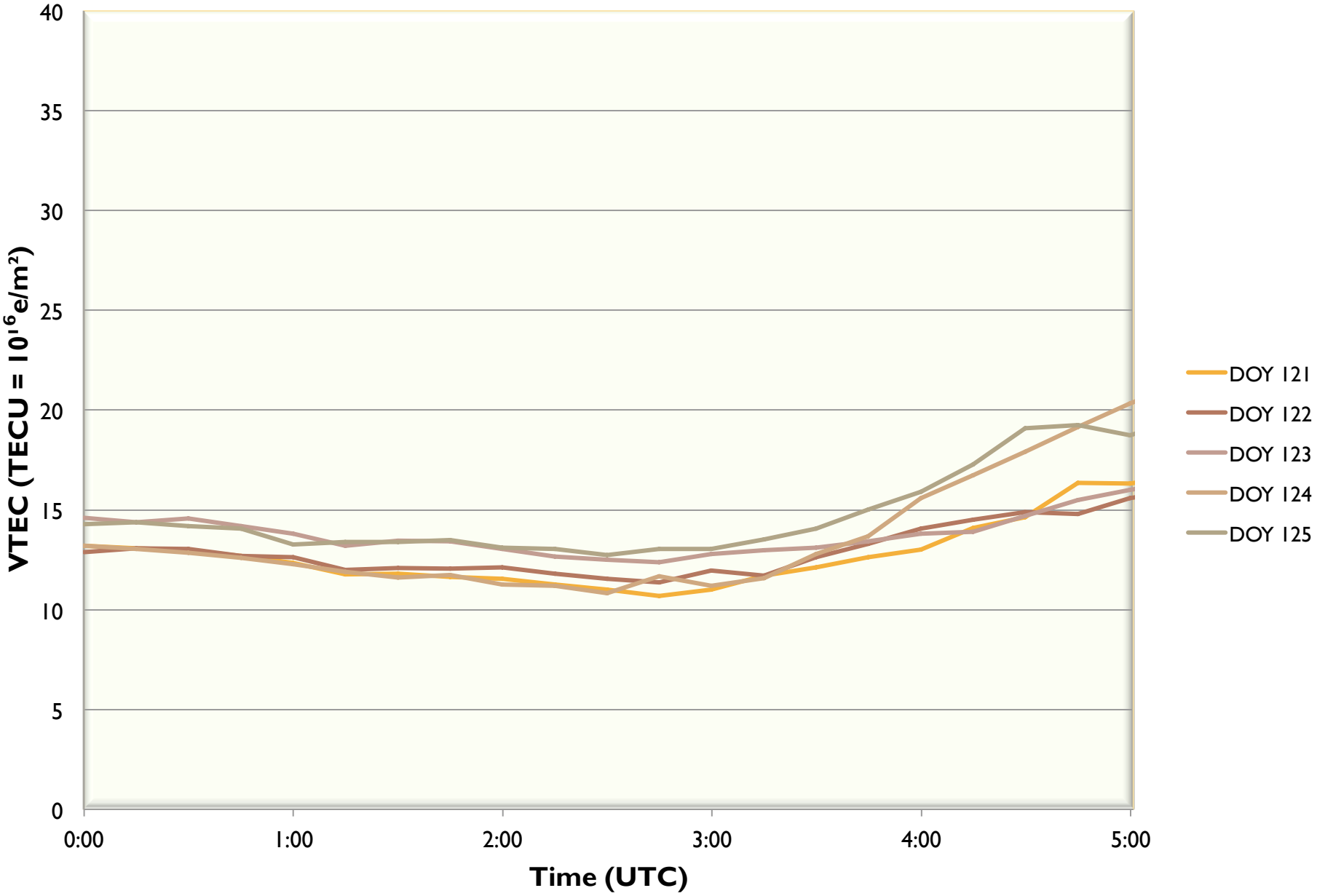
Average daily differences of VTEC beetwen software solutions



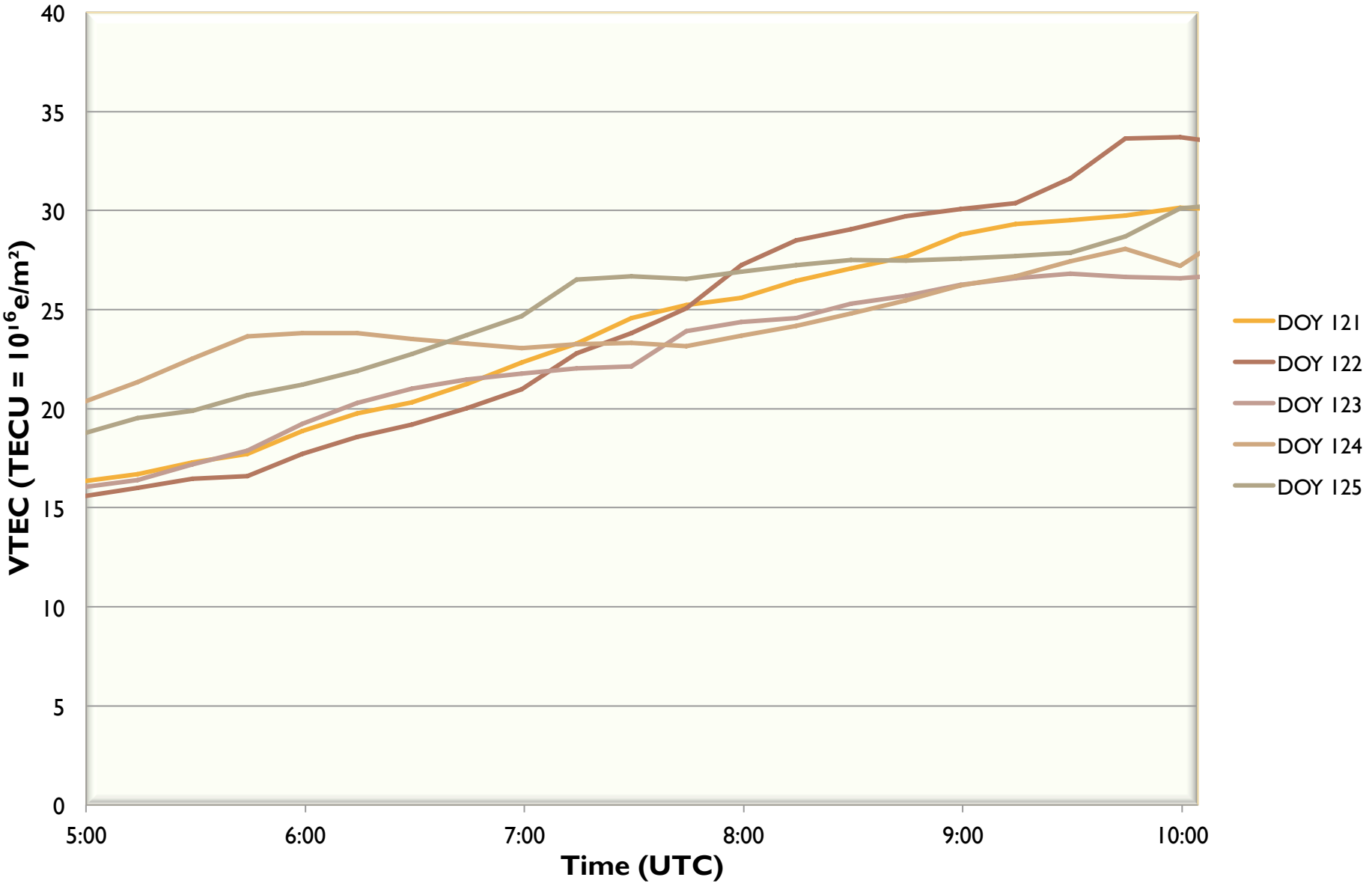
VTEC Data analysis: **Year 2015**

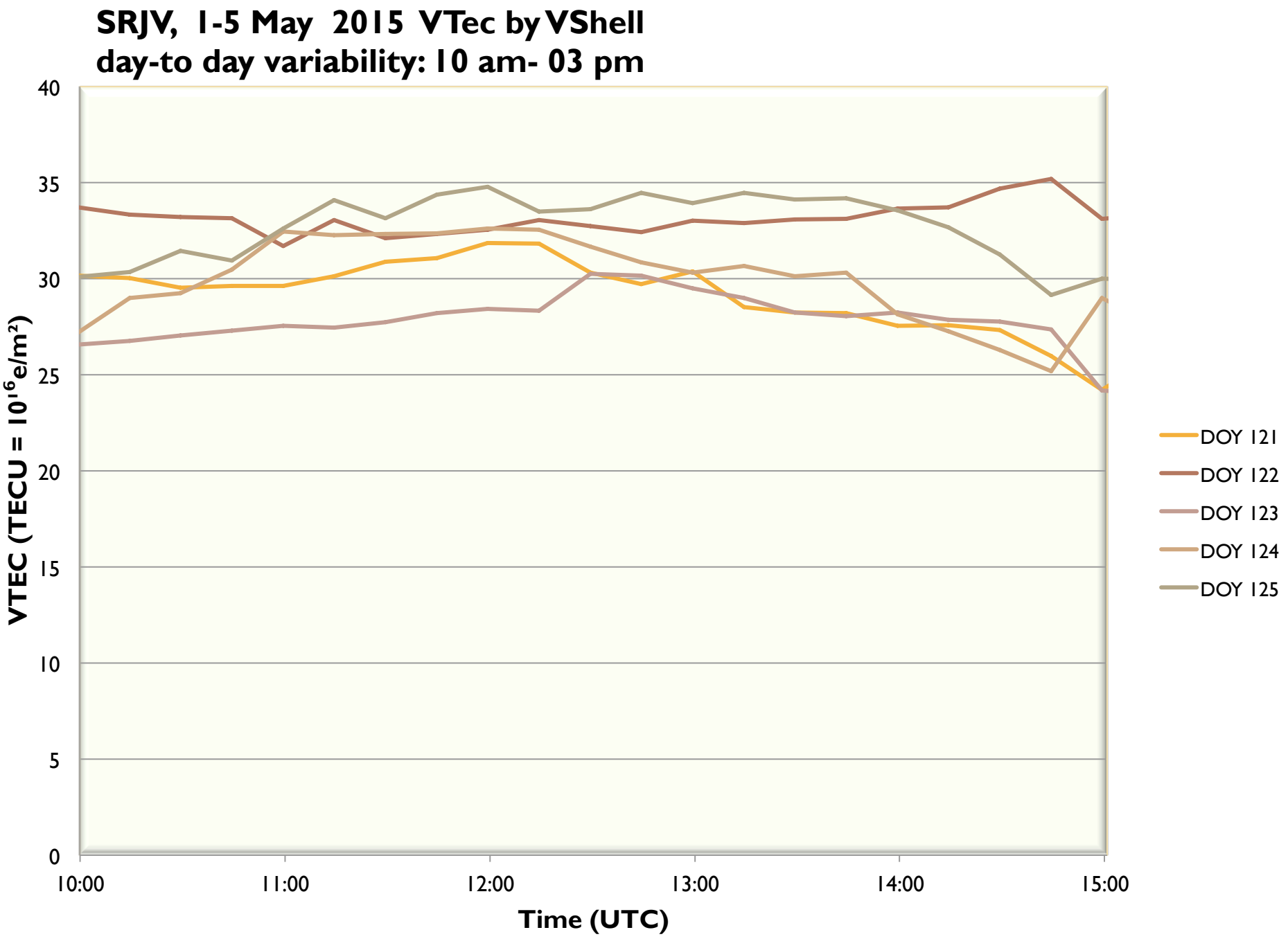
VShell only

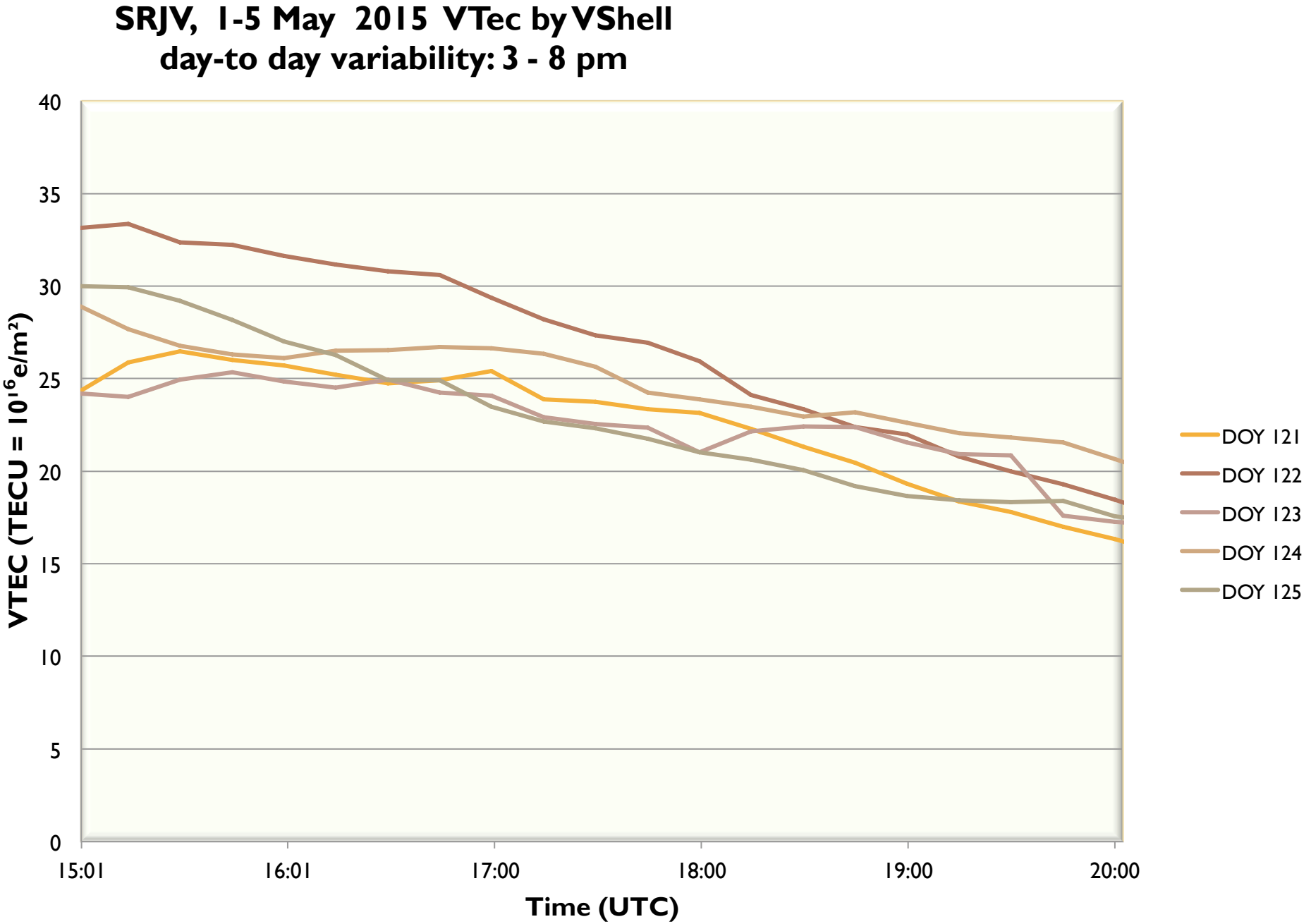
SRJV, 1-5 May 2015 VTec by VShell
day-to day variability: 0-5 pm

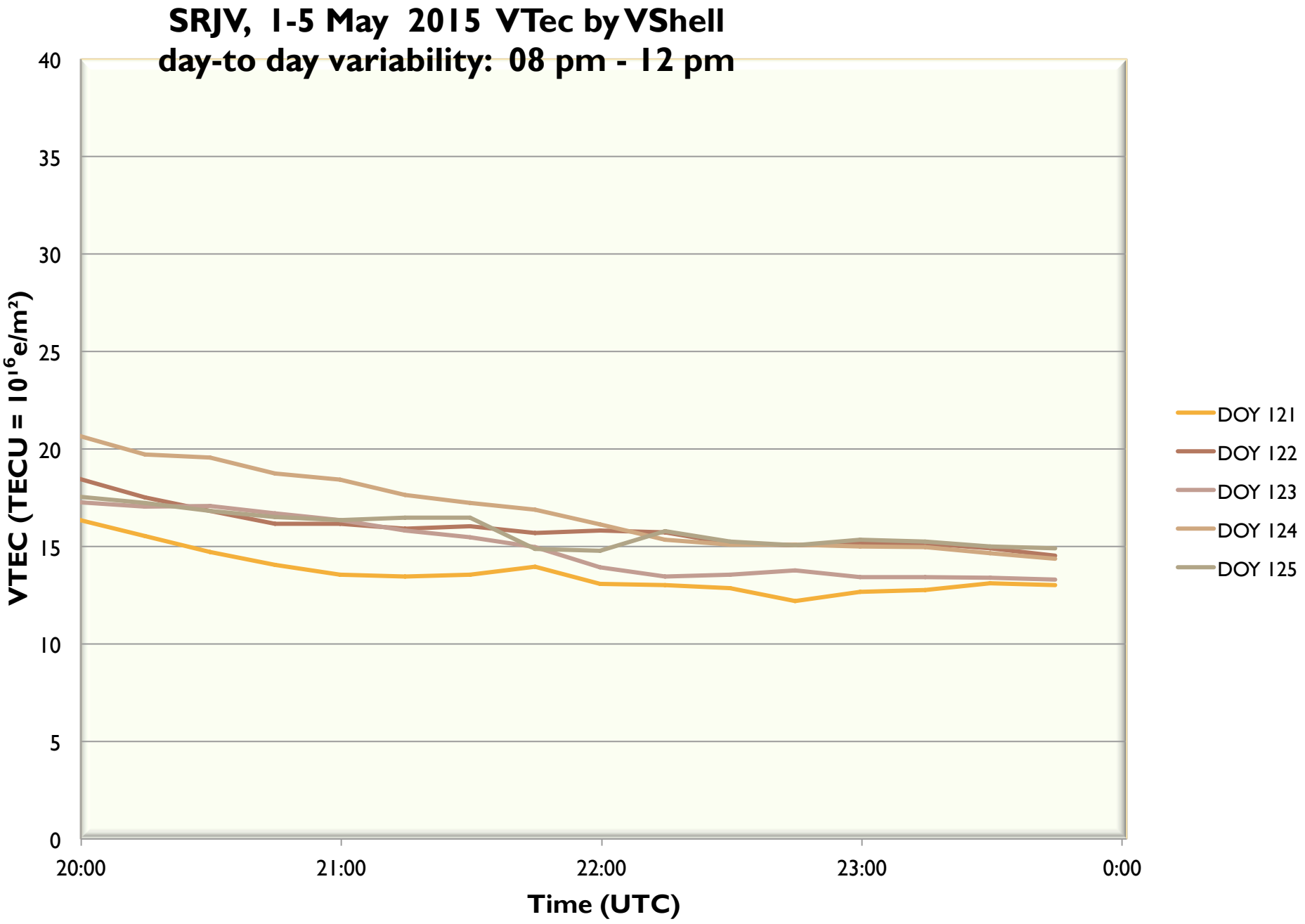


SRJV, 1-5 May 2015 VTec by VShell
day-to day variability: 5-10 am

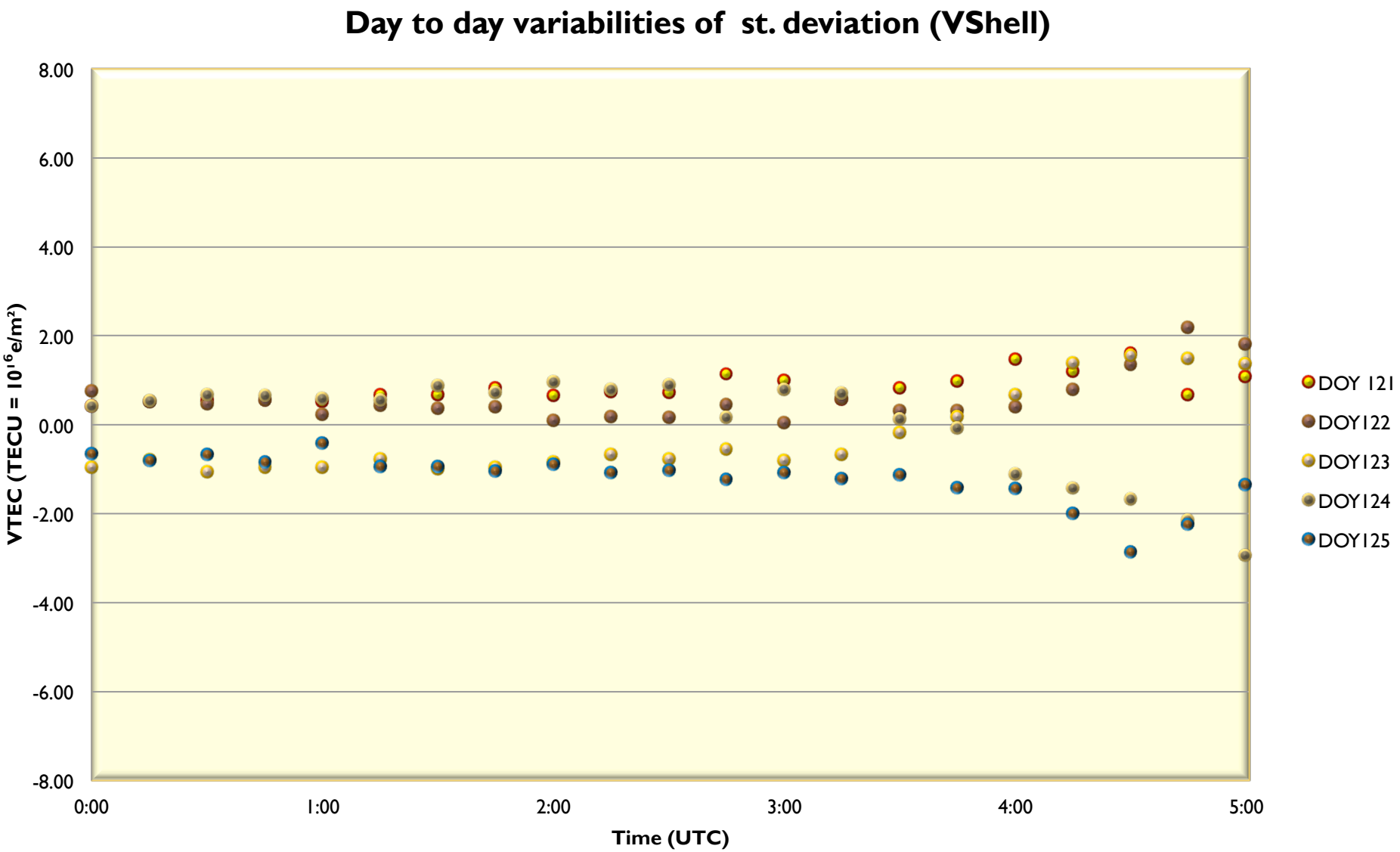



SRJV, 1-5 May 2015 VTec by VShell
day-to day variability: 10 am- 03 pm
VTEC (TECU = 10^16 e/m^2)
40
35
30
25
20
15
10
5
0
10:00
11:00
12:00
13:00
14:00
15:00
Time (UTC)
DOY 121
DOY 122
DOY 123
DOY 124
DOY 125

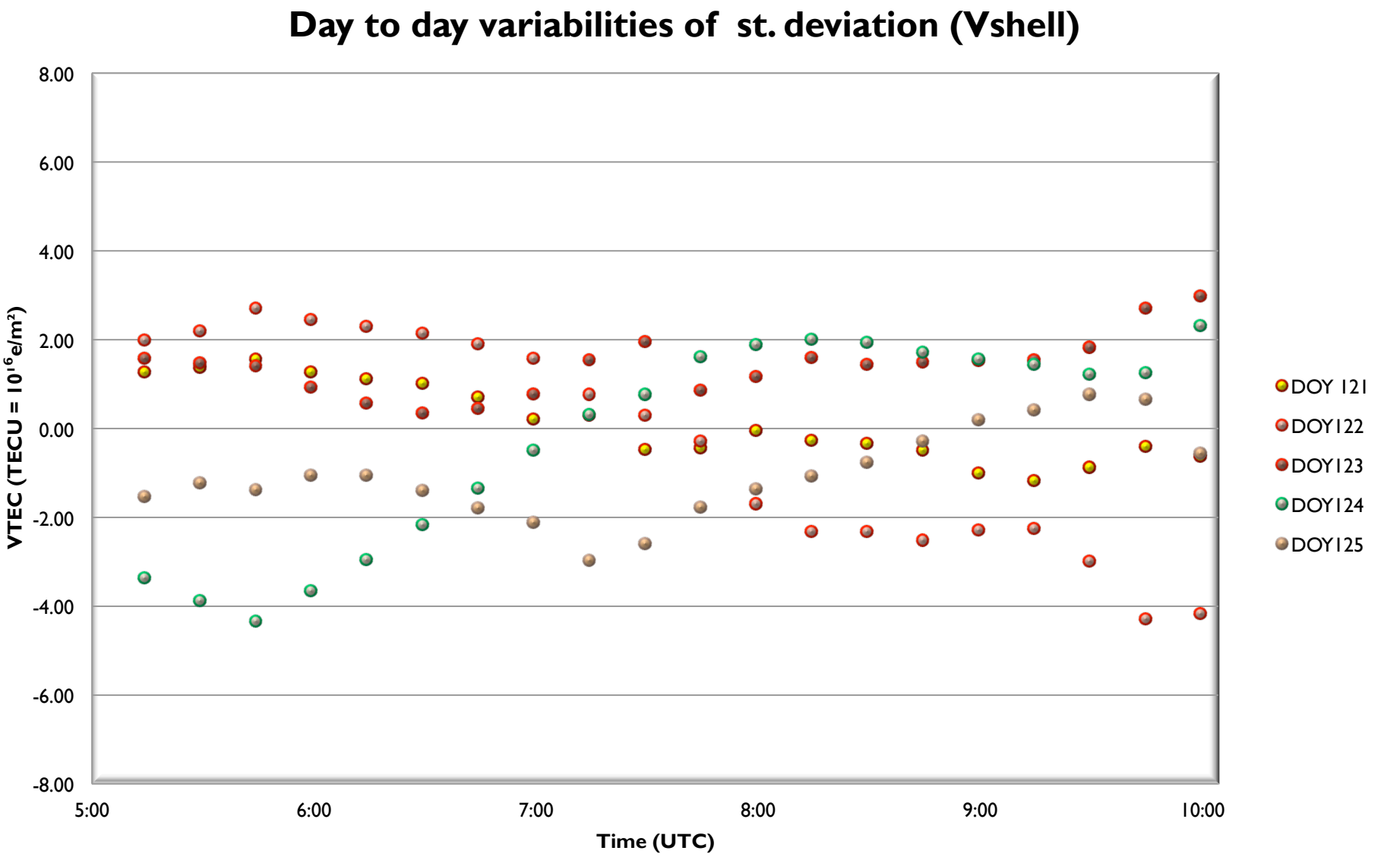

SRJV, 1-5 May 2015 VTec by VShell
day-to day variability: 3 - 8 pm
VTEC (TECU = 10^16 e/m^2)
40
35
30
25
20
15
10
5
0
15:01
16:01
17:00
18:00
19:00
20:00
Time (UTC)
DOY 121
DOY 122
DOY 123
DOY 124
DOY 125

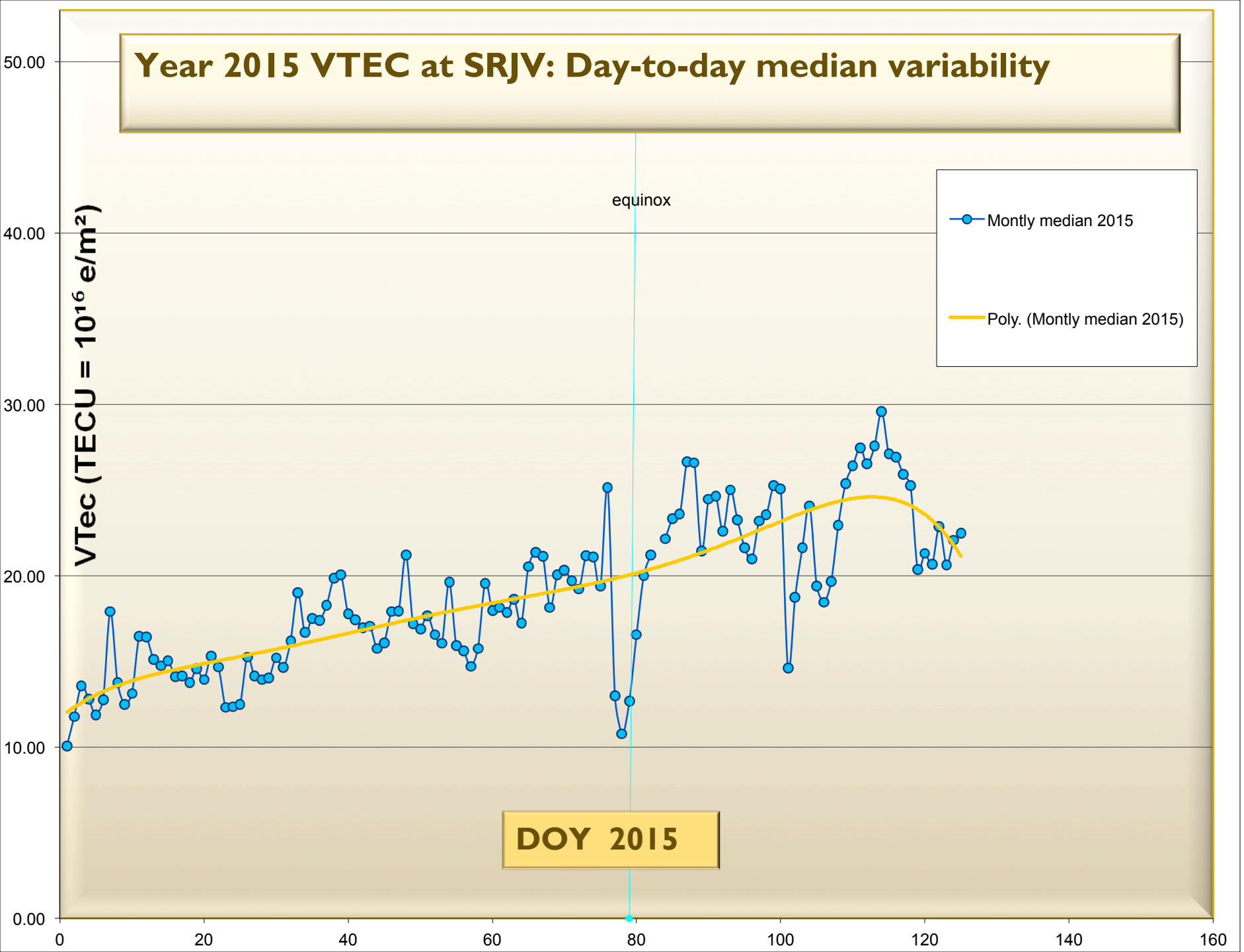

SRJV, 1-5 May 2015 VTec by VShell
day-to day variability: 08 pm - 12 pm
VTEC (TECU = 10^16 e/m^2)
40
35
30
25
20
15
10
5
0
20:00
21:00
22:00
23:00
0:00
Time (UTC)
DOY 121
DOY 122
DOY 123
DOY 124
DOY 125

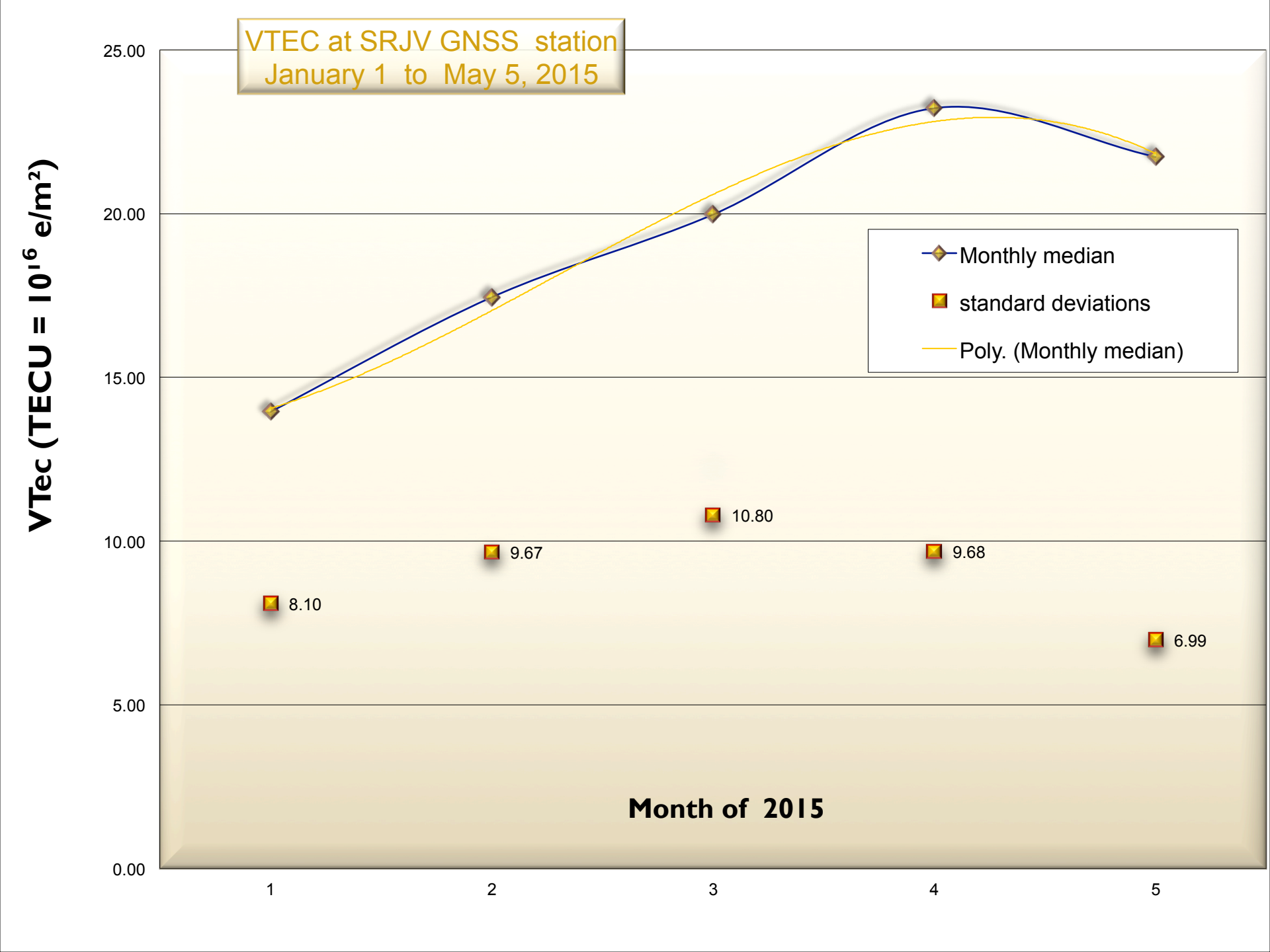
1-5 May of 2015: Comparation of data from 0 - 5 am



1-5 May of 2015: Comparation of data from 5-10 am

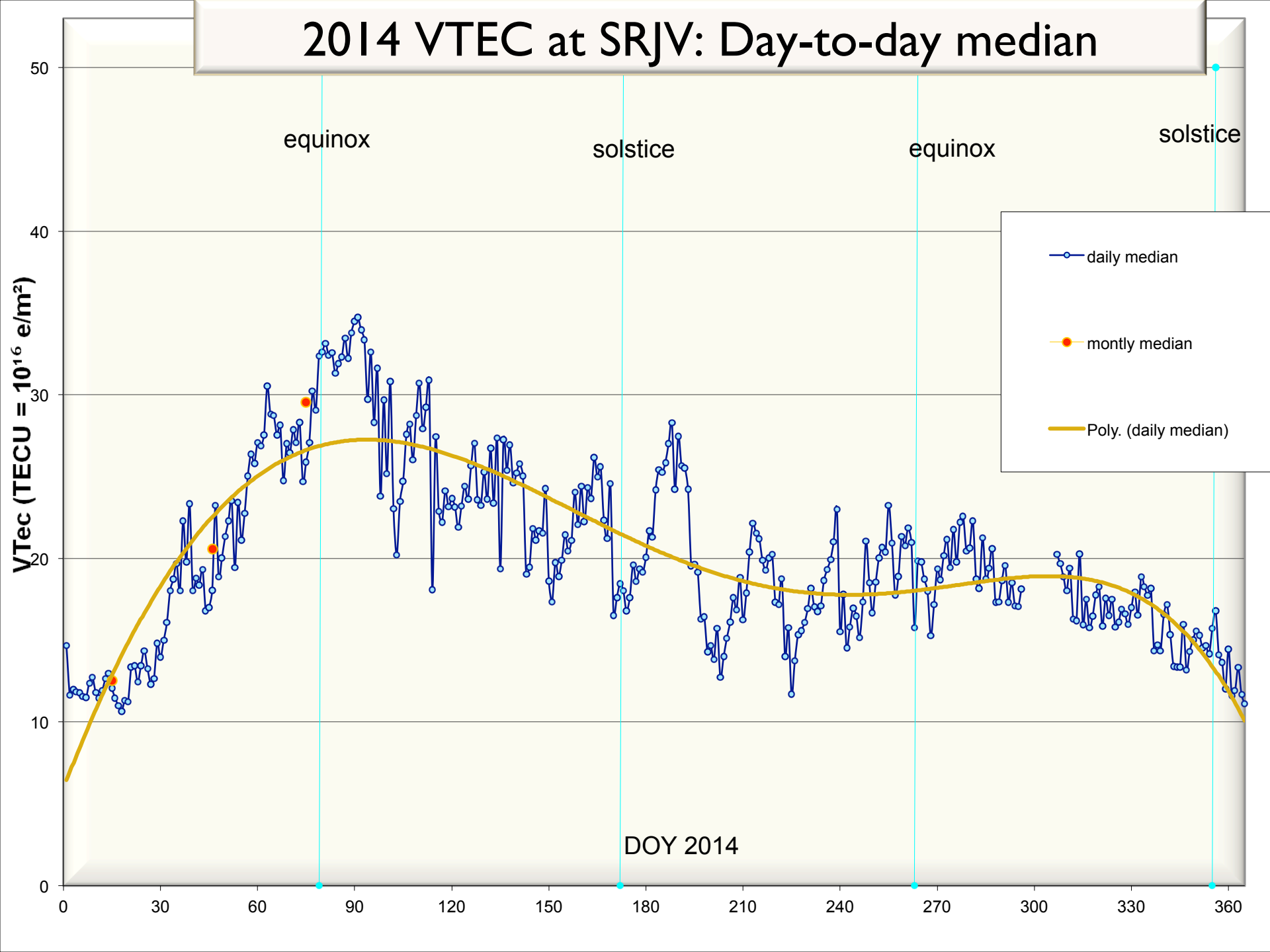


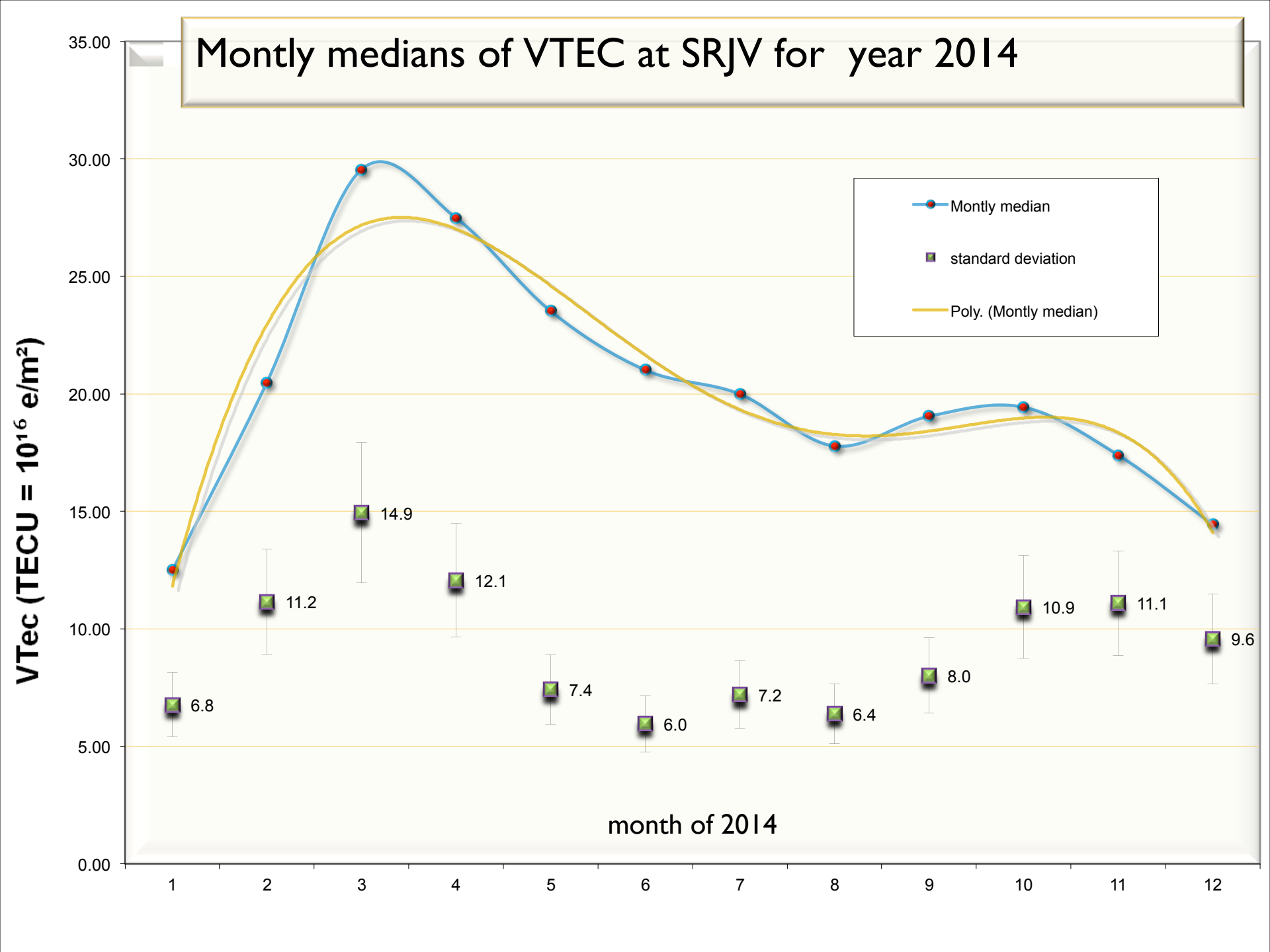

Year 2015 VTEC at SRJV: Day-to-day median variability
equinox
Montly median 2015
Poly. (Montly median 2015)
VTec (TECU = 10¹⁶ e/m²)
50.00
40.00
30.00
20.00
10.00
0.00
0
20
40
60
80
100
120
140
160
DOY 2015


VTEC at SRJV GNSS station
January 1 to May 5, 2015
VTec (TECU = 10^16 e/m²)
25.00
20.00
15.00
10.00
5.00
0.00
1
2
3
4
5
Month of 2015
Monthly median
standard deviations
Poly. (Monthly median)
8.10
9.67
10.80
9.68
6.99

VTEC data analysis : **Year 2014**

VSell only

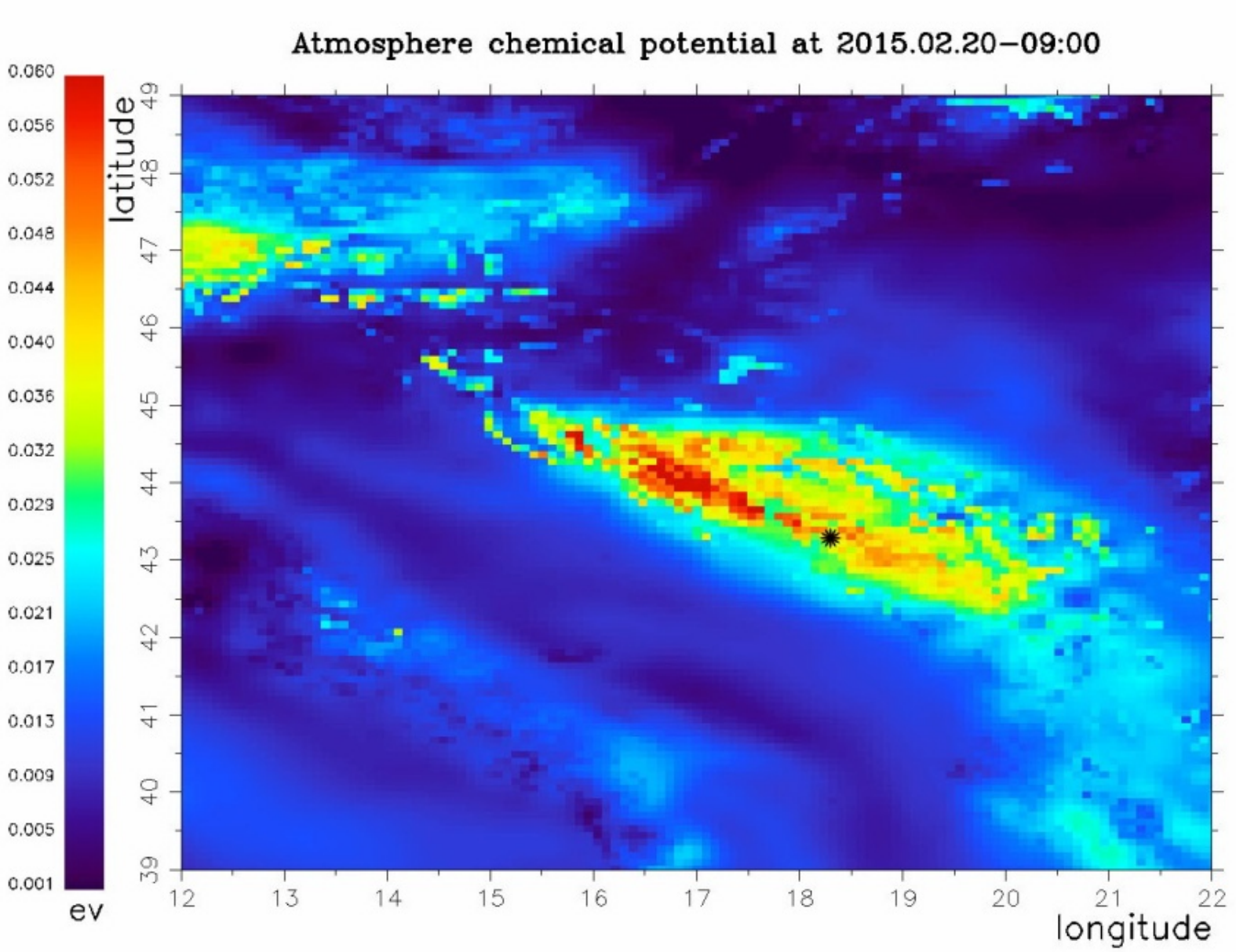

2014 VTEC at SRJV: Day-to-day median
equinox
solstice
equinox
solstice
daily median
montly median
Poly. (daily median)
VTec (TECU = 10¹⁶ e/m²)
DOY 2014
0
10
20
30
40
50
0
30
60
90
120
150
180
210
240
270
300
330
360

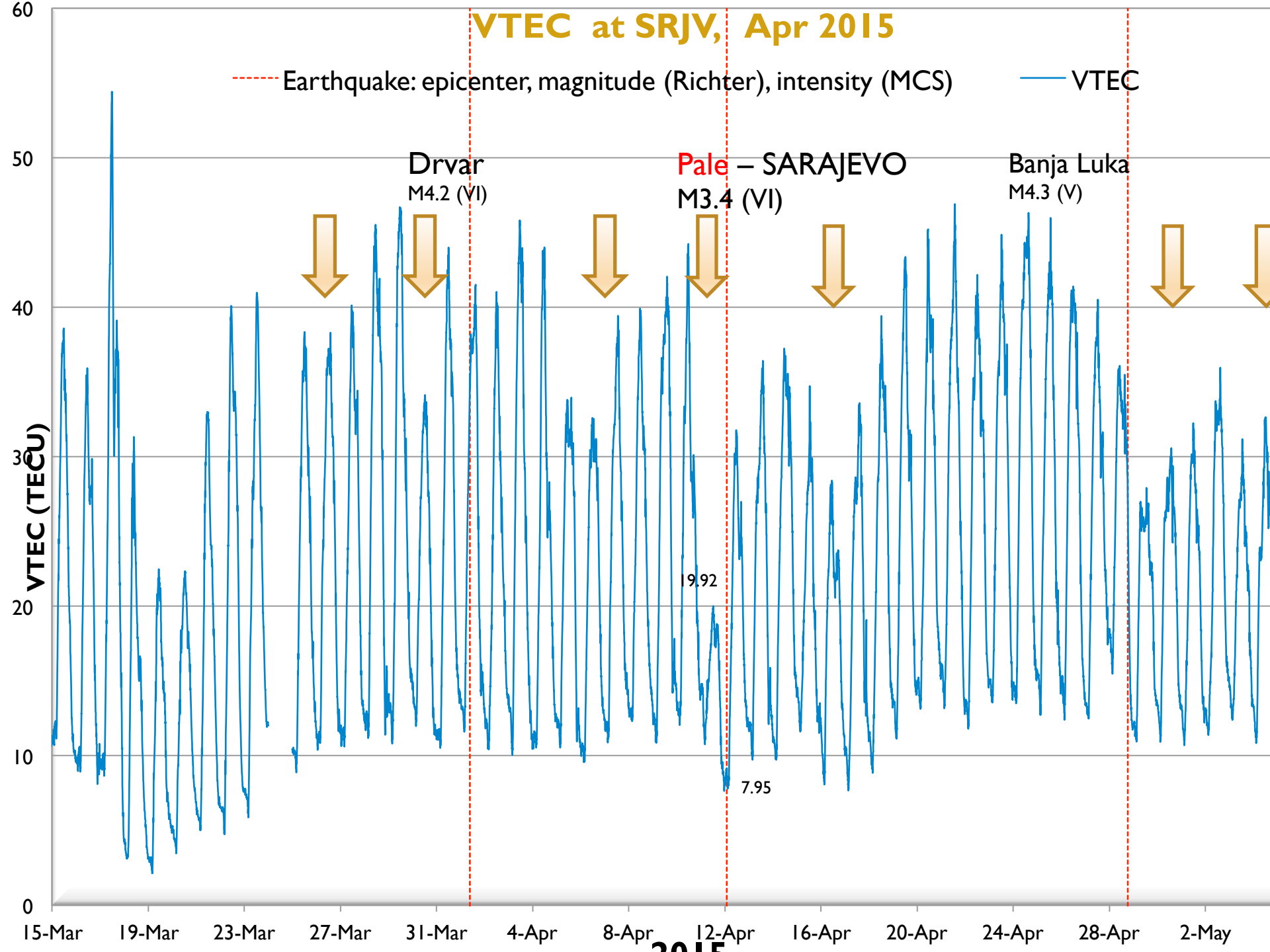

Montly medians of VTEC at SRJV for year 2014
VTec (TECU = 10¹⁶ e/m²)
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Montly median
standard deviation
Poly. (Montly median)
6.8
11.2
14.9
12.1
7.4
6.0
7.2
6.4
8.0
10.9
11.1
9.6
month of 2014
1
2
3
4
5
6
7
8
9
10
11
12

IONOSPHERE-EARTHQUAKE COUPLING

2015 Erthqueks in Bosnia and Herzegovina

Date	Time	Epicenter	Magnitude (Richter)	Intensity (MCS)
Feb. 28 2015	09:24 am	Sarajevo (Treskavica mounten)	M 4.3	V
Feb. 28 2015		Sarajevo (Treskavica mounten)		
April 12,				


Atmosphere chemical potential at 2015.02.20−09:00
0.060
0.056
0.052
0.048
0.044
0.040
0.036
0.032
0.029
0.025
0.021
0.017
0.013
0.009
0.005
0.001
ev
latitude
49
48
47
46
45
44
43
42
41
40
39
12
13
14
15
16
17
18
19
20
21
22
longitude


VTEC at SRJV, Apr 2015
Earthquake: epicenter, magnitude (Richter), intensity (MCS)
VTEC
Drvar
M4.2 (VI)
Pale – SARAJEVO
M3.4 (VI)
Banja Luka
M4.3 (V)
19.92
7.95
VTEC (TECU)
60
50
40
30
20
10
0
15-Mar
19-Mar
23-Mar
27-Mar
31-Mar
4-Apr
8-Apr
12-Apr
16-Apr
20-Apr
24-Apr
28-Apr
2-May
2015

6 CONCLUSIONS

- SRJV_IONO SID monitor station enables space weather monitoring: sloar flares M+
- OS software gLAB and VShell enable to estimate VTEC GNSS.
- gLAB capable to estimate coordinates to 1 cm for horizontal and 2 cm for vertical component of positions, for a month period GNSS observations.
- Day to day variability of TEC from SRJV GNSS data show seasonal, monthly and daily variations.
- Methodes presented that have potentials for the investigation of ionophere and space weather.
- Could be applied in developing counrties.
- Research must be continued, extended to other BIHPOS stations.
- Particular attention should be given to further investigation of the statistical methods and parameters suitable to analise GNSS TEC.

Acknowledgements

I owe gratitude to:

- Stanford University for SID monitor
- ESA for gLAB softver
- ICTP and Dr. Luigy Ciraolo for Vshell
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