



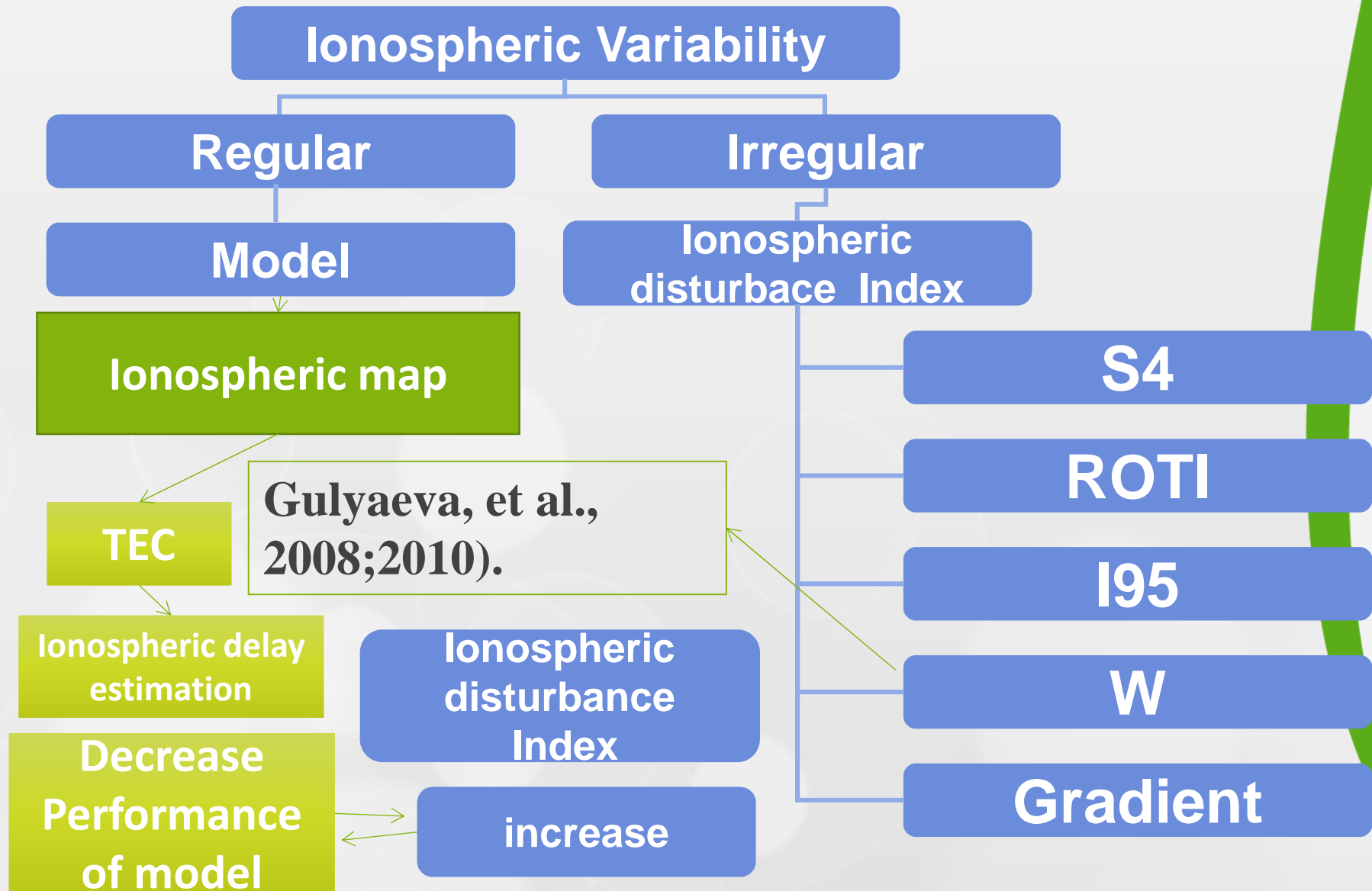
**BADAN INFORMASI
GEOSPASIAL**

Development of The New Ionospheric Disturbance Index for GNSS User

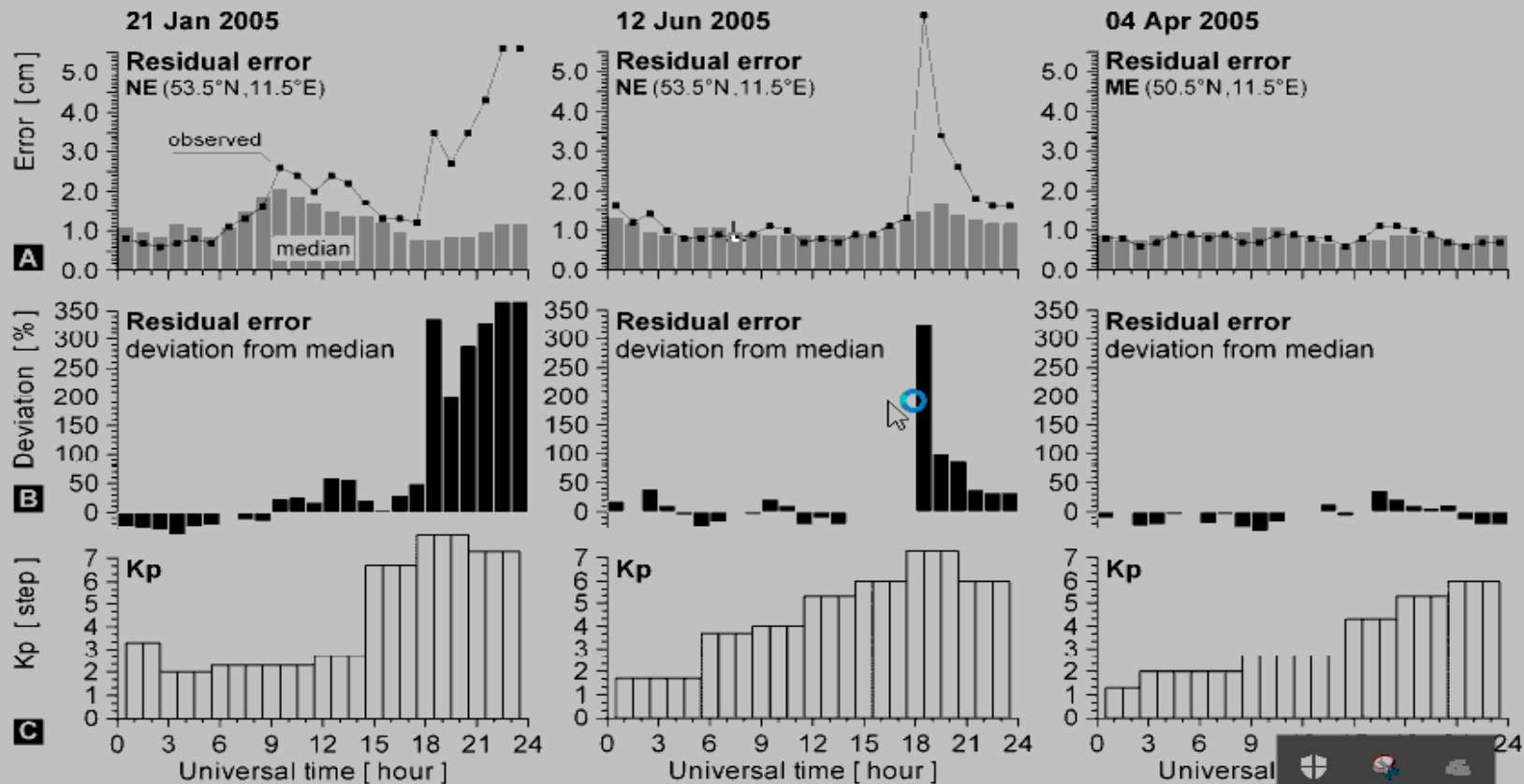
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**UN/Nepal Workshop on the Applications of Global Navigation Satellite
System, Kathmandu, Nepal, 12-16 Desember, 2016**

1. Introduction



Residual errors from median value of error increase to more than 300 %



Goal



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graph TD; A[Goal] --> B[Develop the ionospheric disturbance Index that can be used for space weather warning of Level Change in GPS Position Error];
```

Develop the ionospheric disturbance Index
that can be used
for space weather warning
of Level Change in GPS Position Error

Objectives :

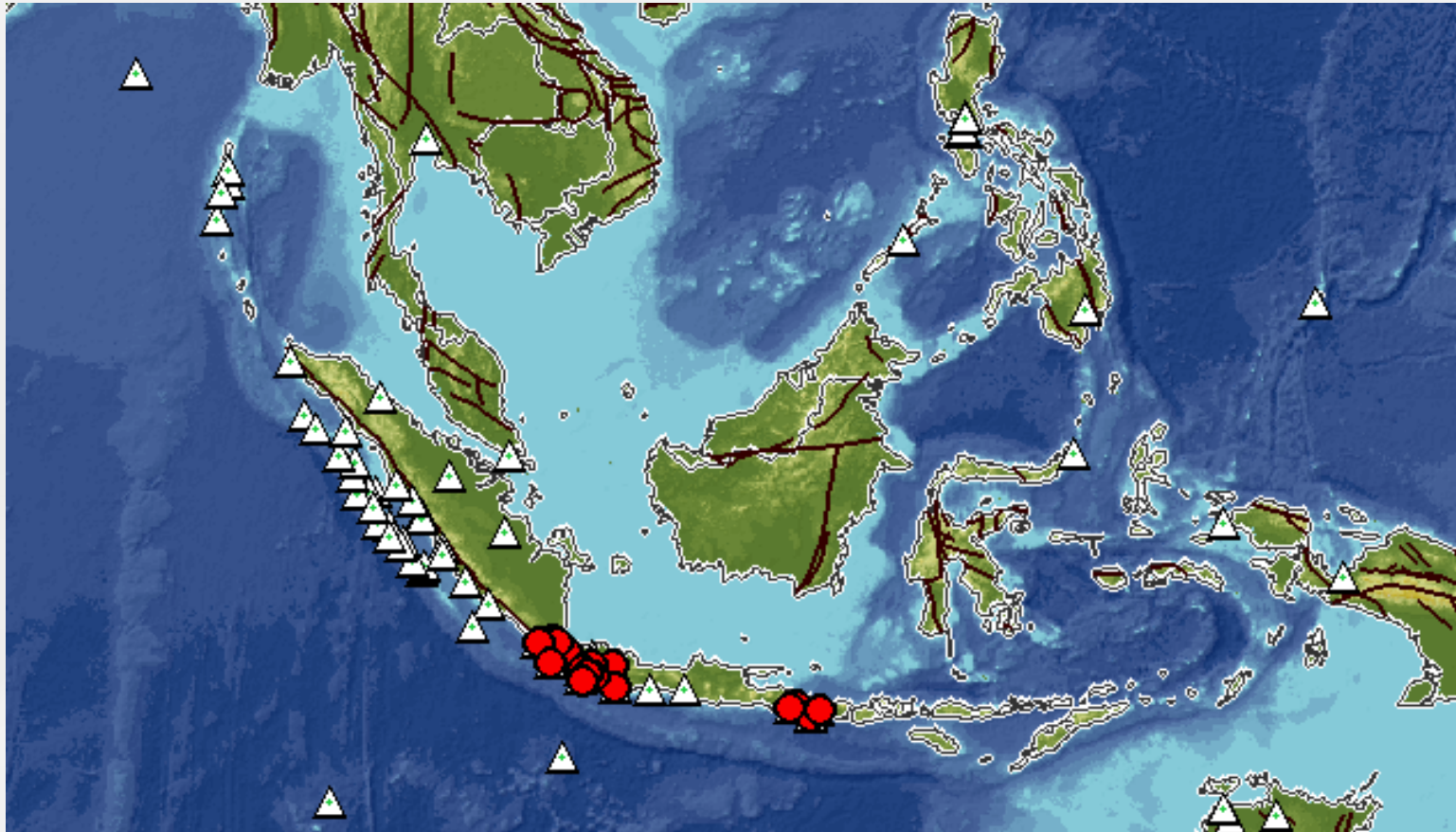
2016-2017

- A. To obtain the method and software for W ionospheric disturbance index estimation from TEC data**
- B. Verification of W index information for GPS position error change warning**
- C. Combine W index and DOP index to improve Level Change of Positioning Error (LCPE) warning**

Data and Methodology

- **GPS rinex data (BIG and IGS)**
- **Orbit data: GPS SP3, also broadcast data archived in ftp server, received by receiver**
- **Receiver Bias (for IGS GNSS data), DCB file**
- **GIM data**

IGS GPS stations: XMIS, NTUS, and CRO1 Stations



GNSS receiver stations network operated by BIG (Survey Departement in Indonesia): BAKO



Product : Rinex file and RTCM by request and / or collaboration

Methodology: Classification of level change

Calculate position of IGS stations by using PPP method (RTKLIB)

Estimate the STD of PPP from coordinate of the station reference

Calculate the median value of STD every hour

Calculate deviation of STD every hour from Median of STD

High Change

Moderate Change

Slightly Change

Normal Change

Classify the Deviation of STD (from Median) into 4 level change

75 %

50 %

25 %

4

3

2

1

Methodology: W index calculation

TEC calculation
using GOPI SW

DTEC =
 $\text{TEC} / \text{Med}(\text{TEC})$

LOG (DTEC)

Classify the
ionospheric deviation
into 4 level

W index

4

INTENSE
STORMS

3

MODERATE
STORMS

2

ACTIVE

1

QUIET

W index

$$\text{DTEC} = \log(Y/Y_{\text{med27}})$$

$Y = \text{TEC}$ or foF2 , $Y_{\text{med27}} = 27$ days median, (*Gulyaeva et al., 2008; 2013*)

No	Ionospheric weather	DTEC	W
1	Quiet	$\text{DTEC} < + 0.046 / \text{DTEC} > -0,046$	+/- 1
2	Minor activity	$+ 0,046 < \text{DTEC} < + 0,155 /$ $-0,046 > \text{DTEC} > -0,15$	+/- 2
3	Moderate activity (ionospheric storm)	$+ 0,155 < \text{DTEC} < + 0,301 /$ $-0,155 > \text{DTEC} > -0,301$	+/- 3
4	Major activity (Intense ionospheric storm)	$\text{DTEC} > + 0,301 /$ $\text{DTEC} < -0,301$	+/- 4

Methodology: Correlation analysis

W index

LEVEL CHANGE PE
INDEX

CORRELATION
ANALYSIS

```
graph TD; A[W index] --> C[CORRELATION ANALYSIS]; B[LEVEL CHANGE PE INDEX] --> C;
```

Methodology: PDOP index

Calculation PDOP
using RTKLIB

Classification of PDOP

≥ 9 . Poor (4)

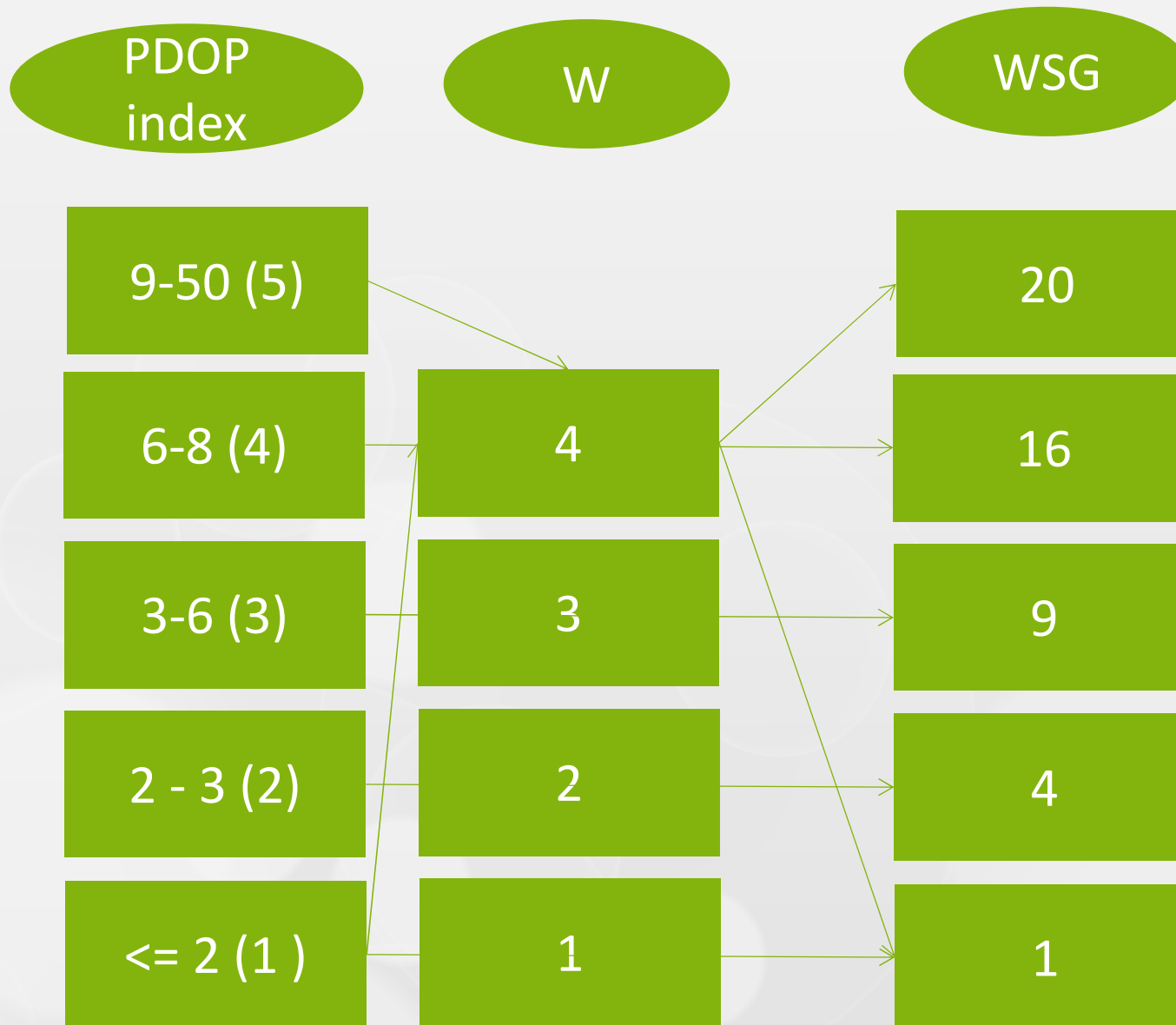
7-8 . Moderate (3)

4-6. Good (3)

2 - 4. Exelent (2)

< 2 . Ideal (1)

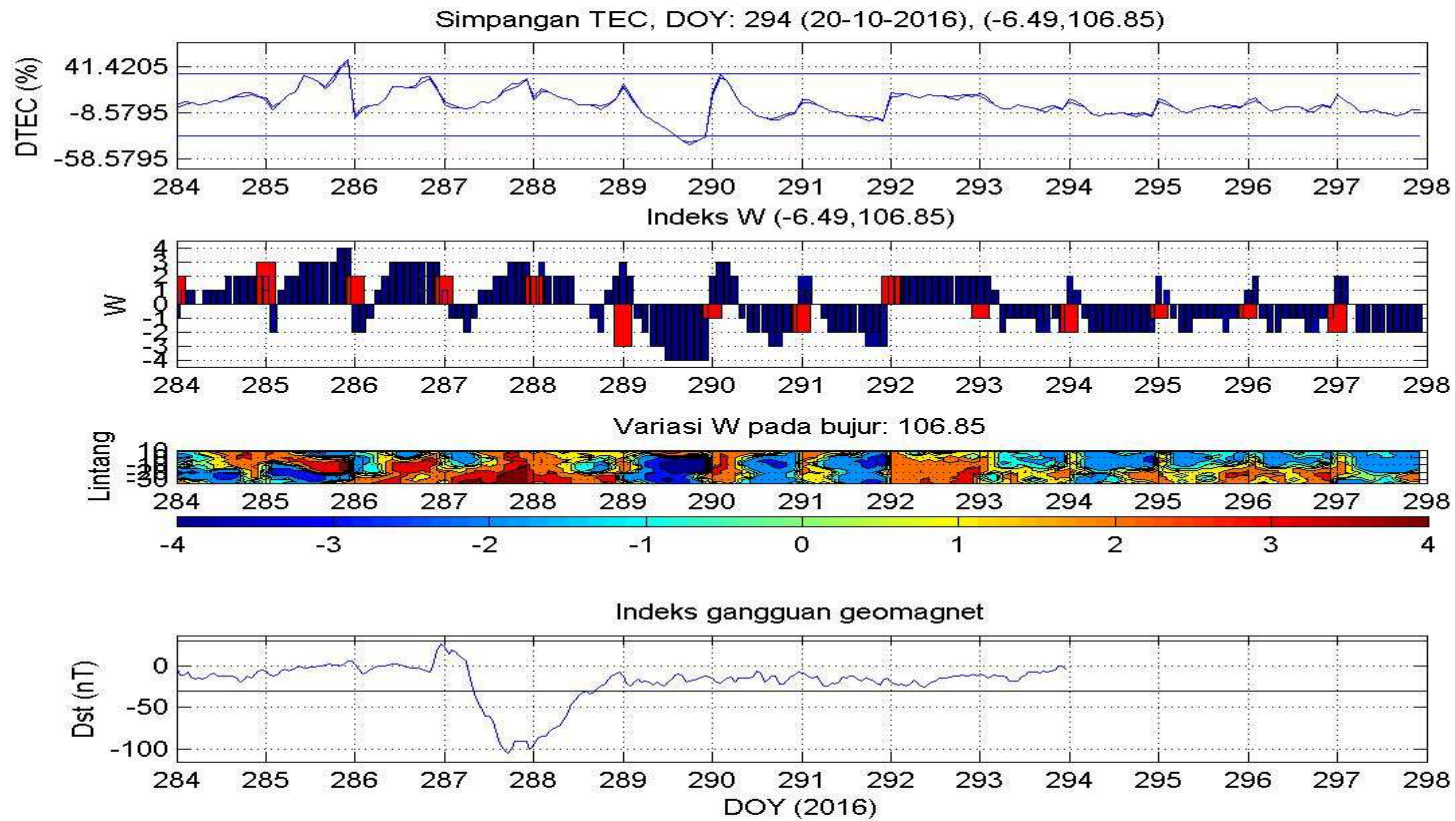
Methodology: WSG index determination



Results and Discussions:

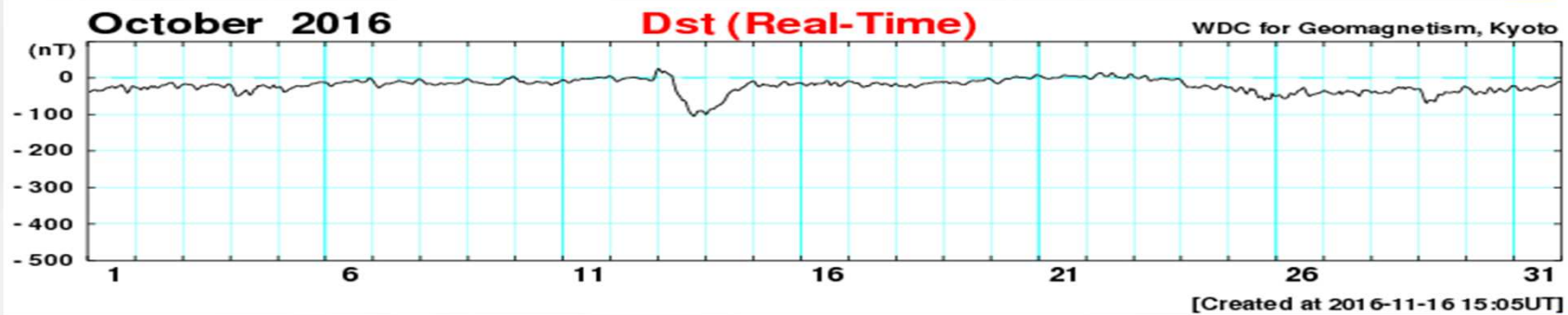
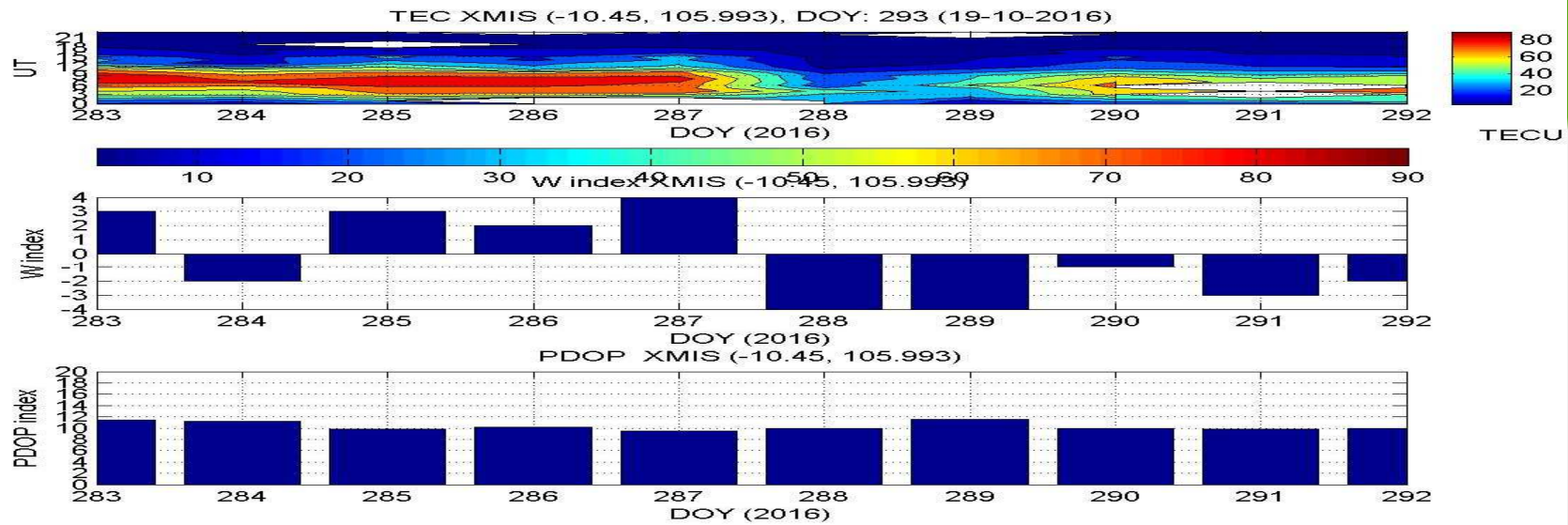
- **W.exe to produce W index from GIM data**
- **W index from XMIS station (GPSIONMAP.EXE)**
- **W index correlation with level change of GPS error**
- **WSG index correlation with level change of GPS error**

W index during geomagnetic storm in October 13, 2016



W index rose to 4, 1 day after geomagnetic storms finished

W Index XMIS station



W index +4 in day of geomagnetic storm but -4 for 2 days after geomagnetic storm

W index – LCPE correlation

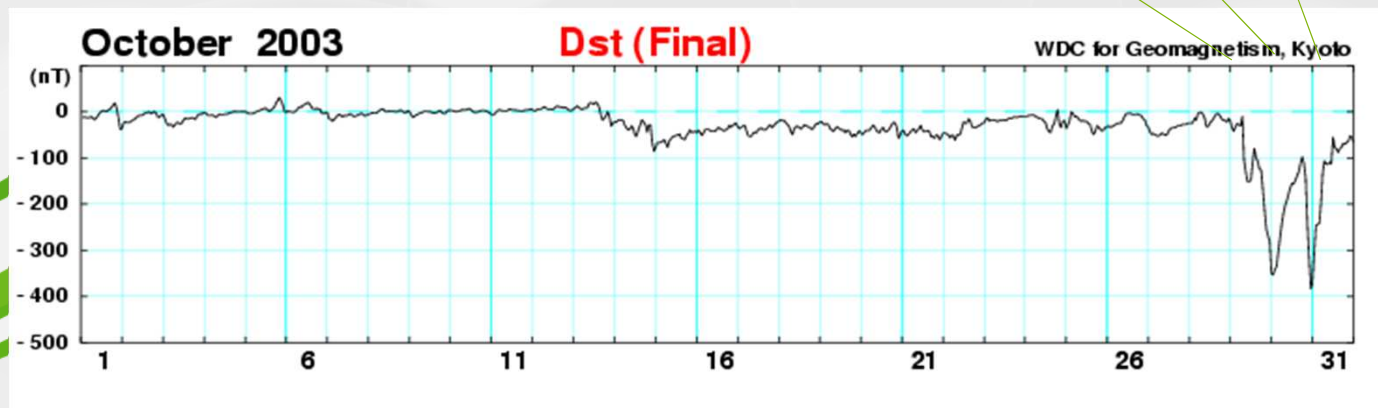
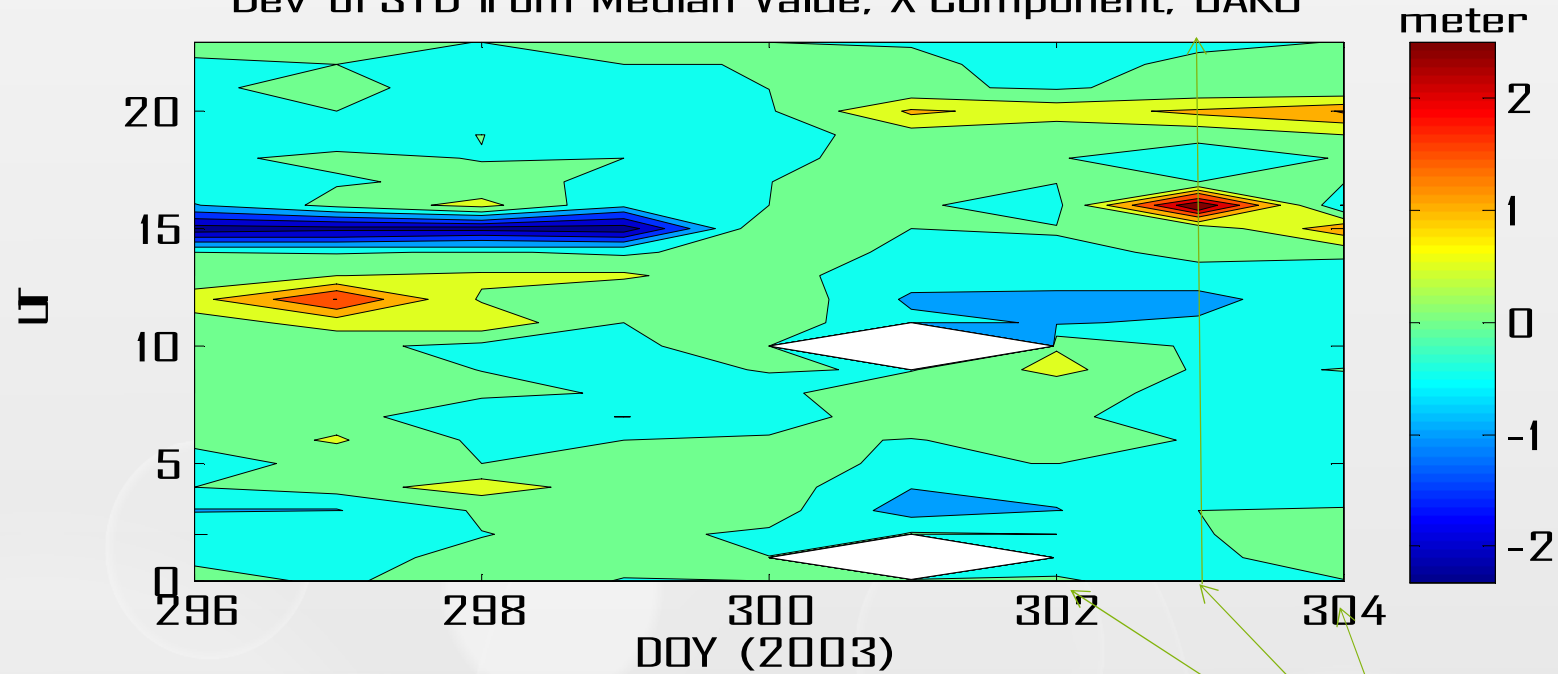
WSG index – LCPE correlation

WSG performance <, >, = W performance

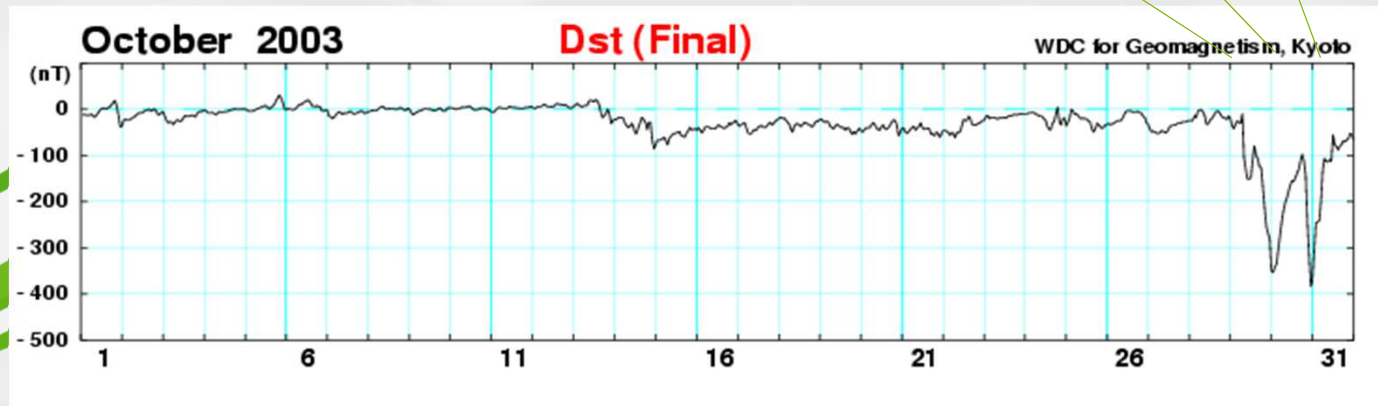
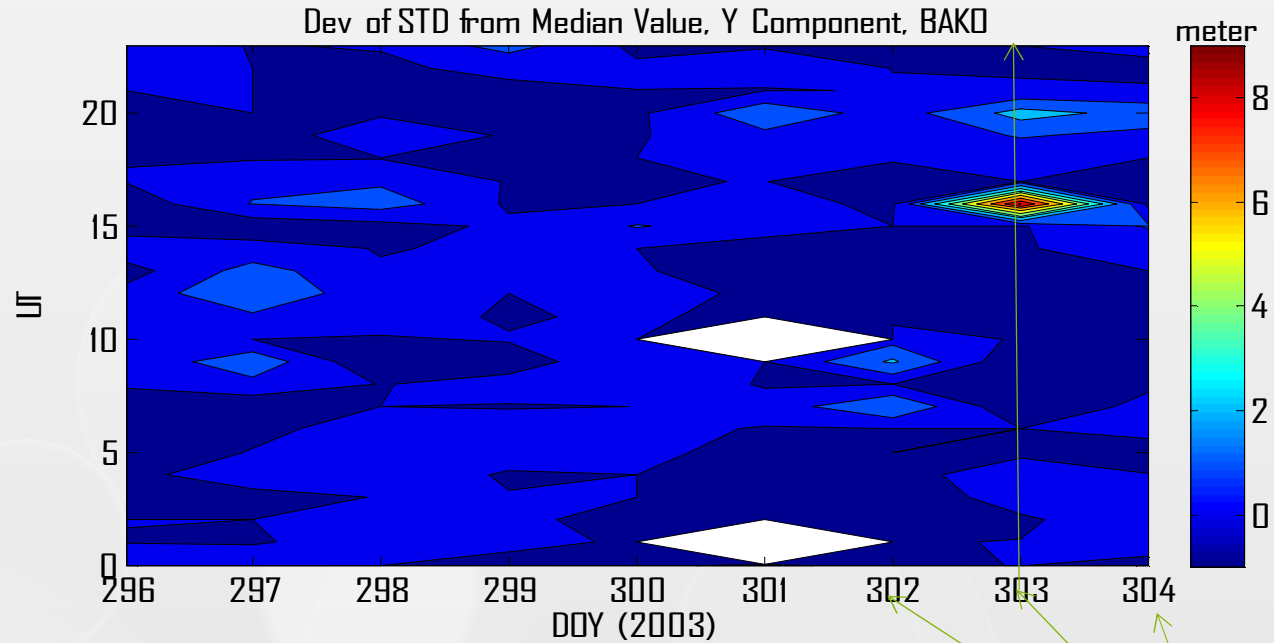
?

Deviation of STD

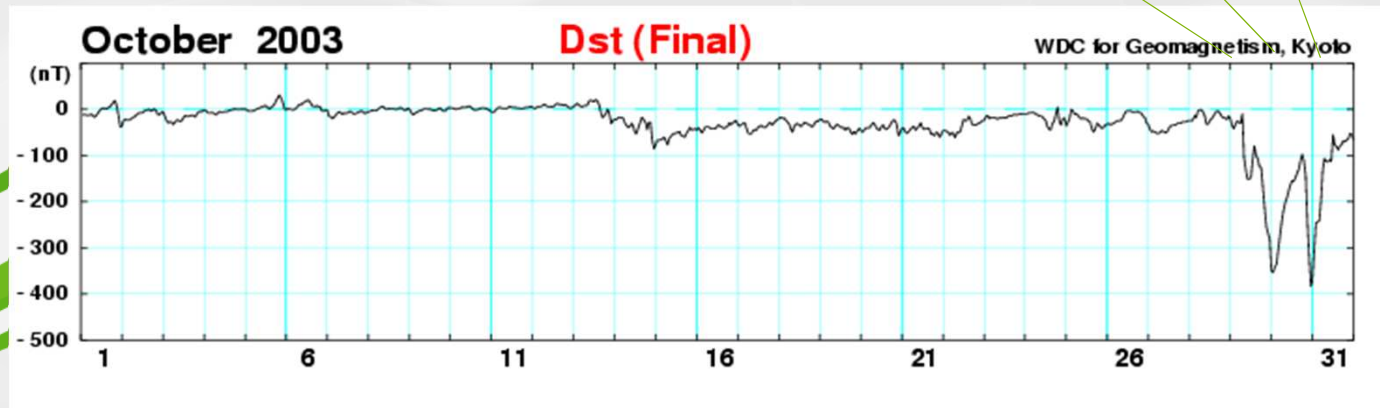
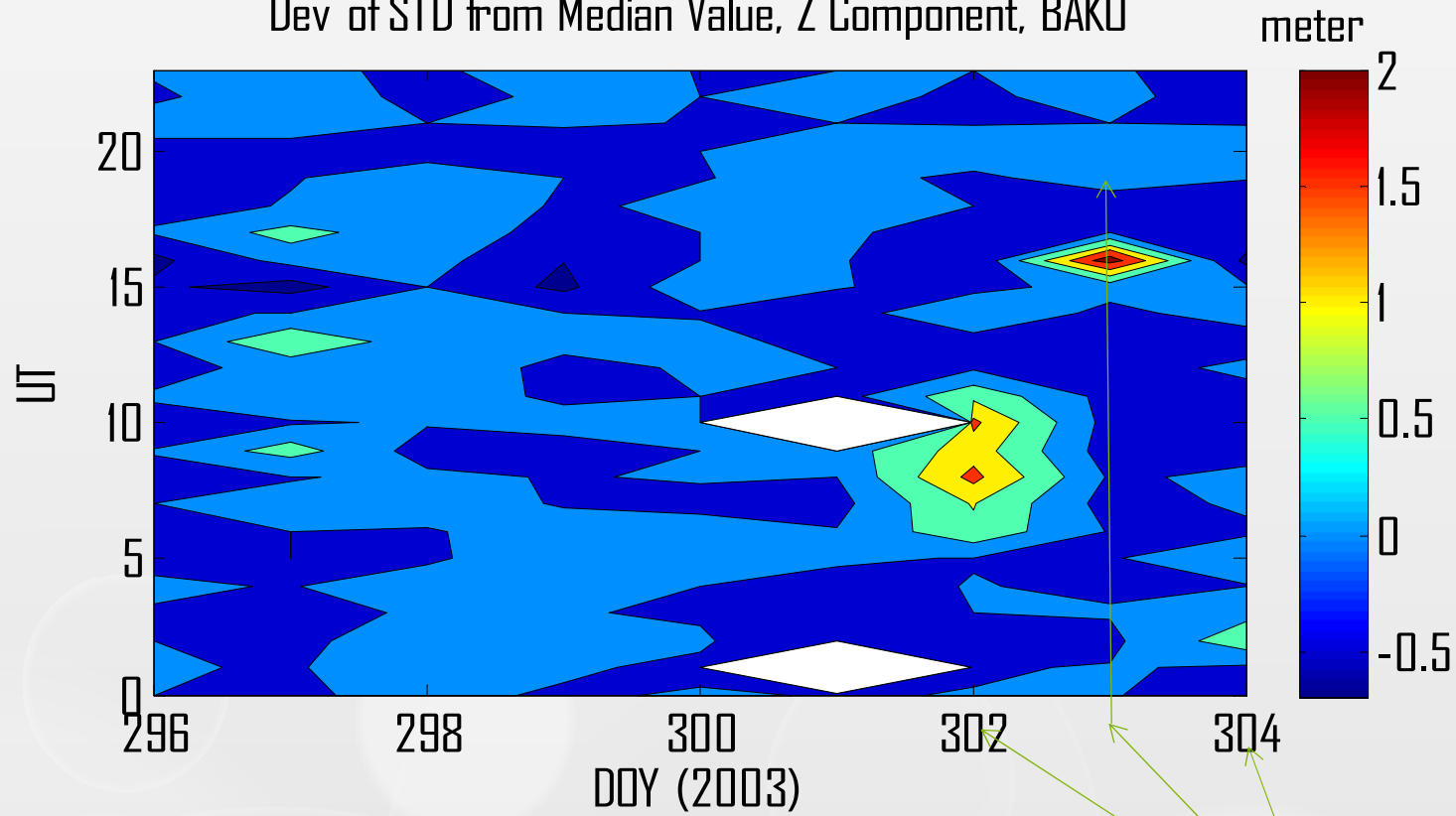
Dev of STD from Median Value, X Component, BAKO



Deviation of STD Y Component

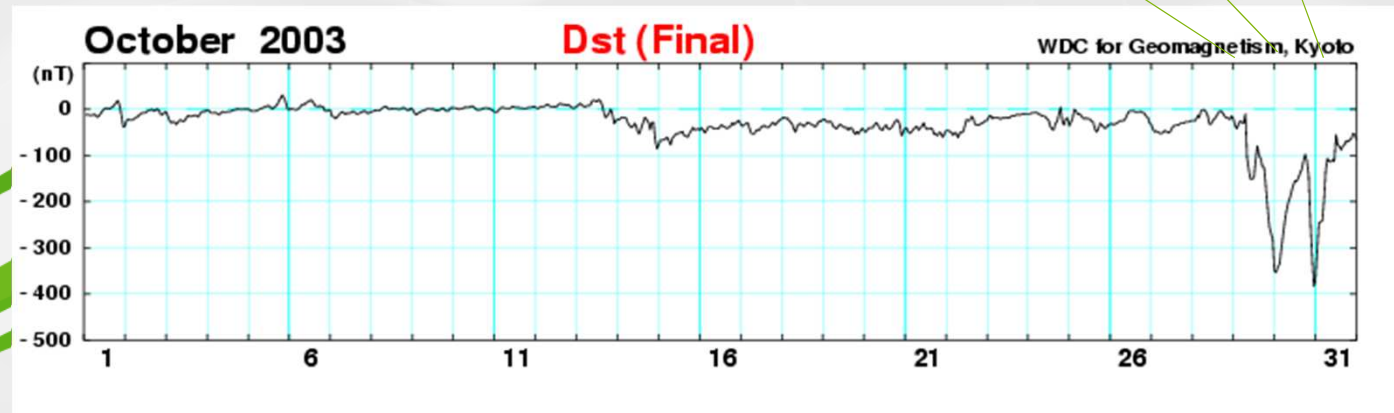
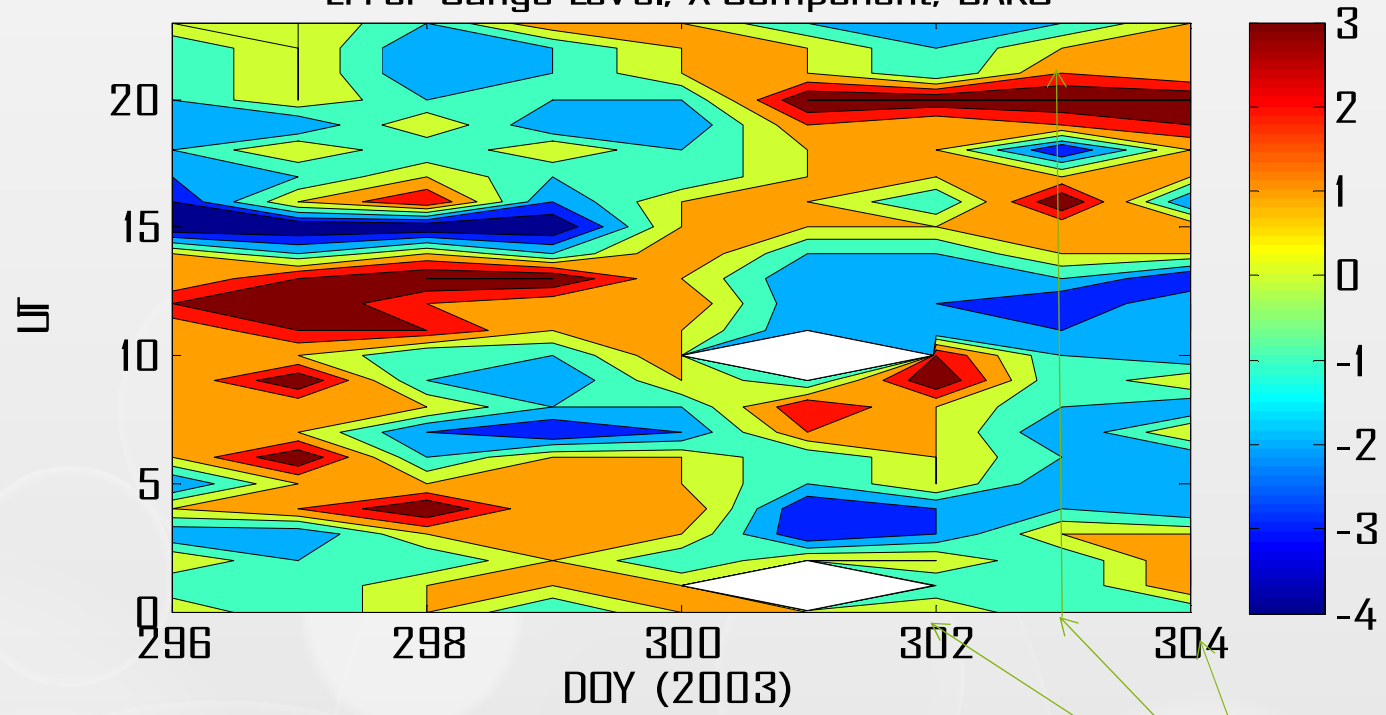


Dev of STD from Median Value, Z Component, BAKO



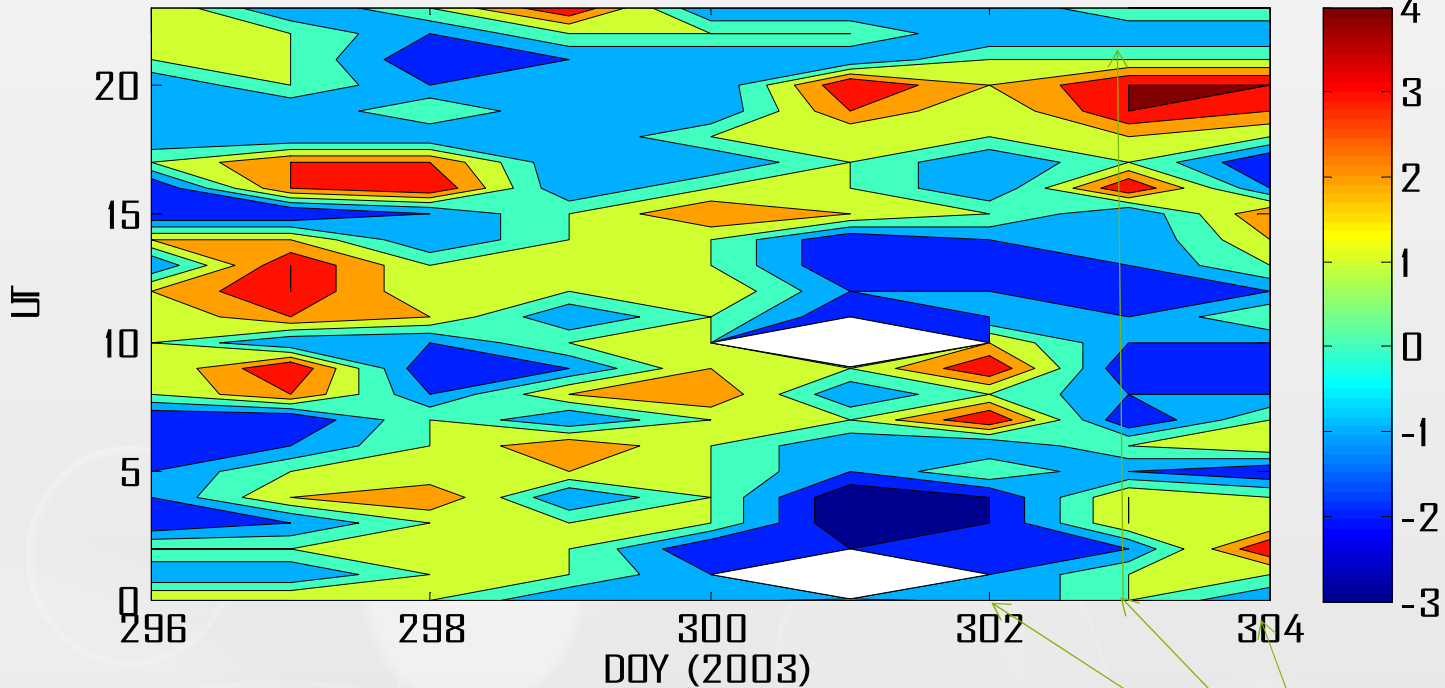
Level Change of Position Error

Error Cange Level, X Component, BAKO



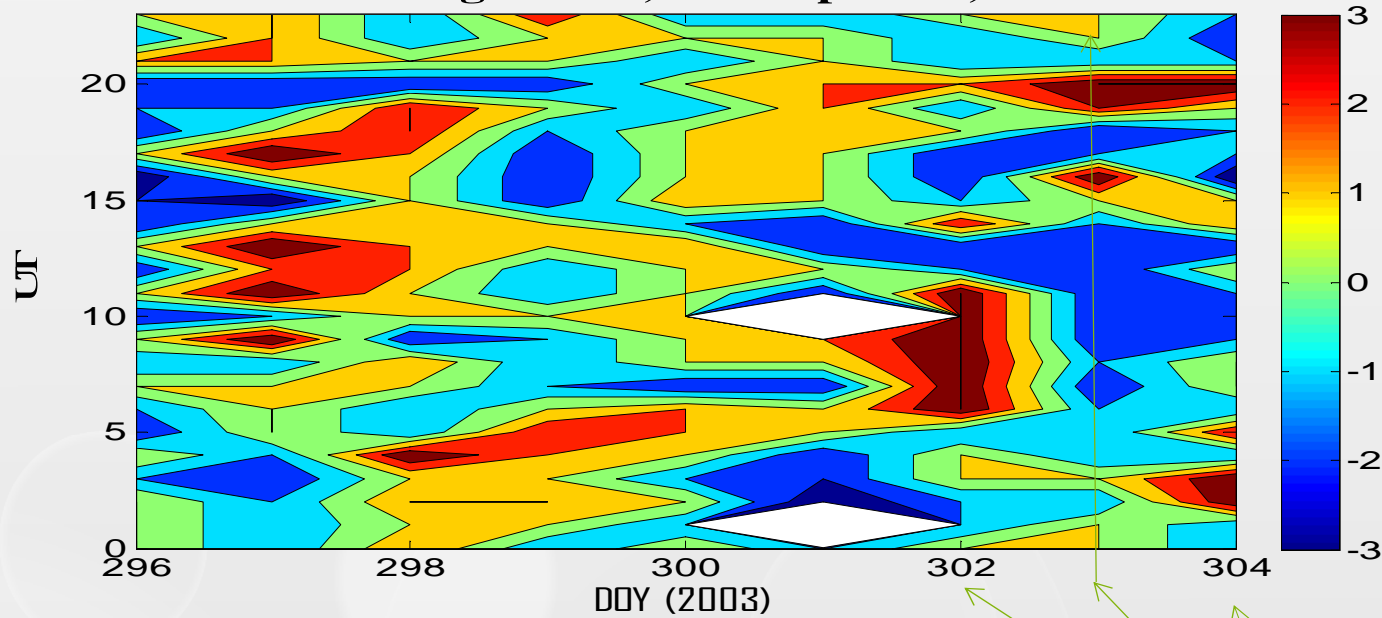
Level Change of Position Error

Error Gange Level, Y Component, BAKO

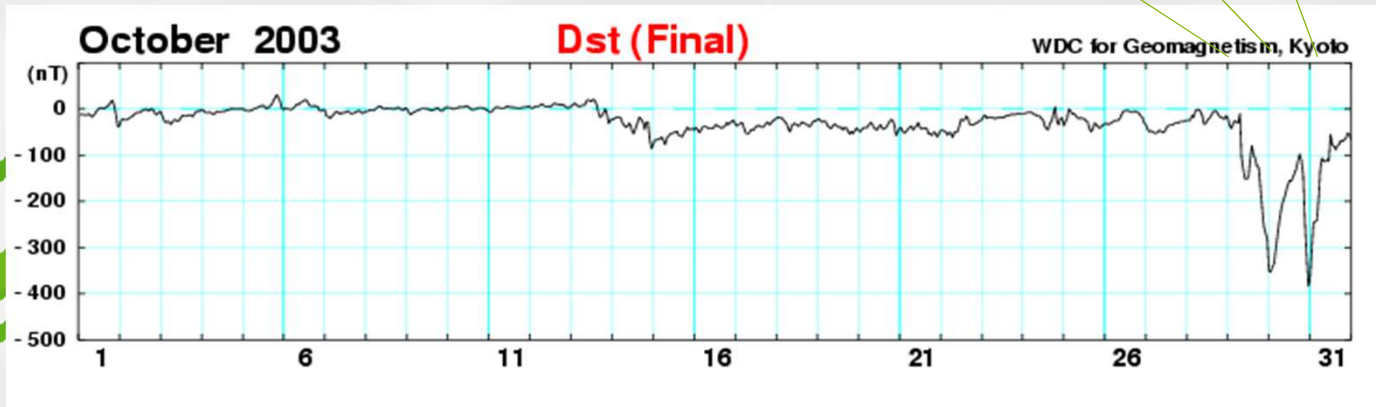
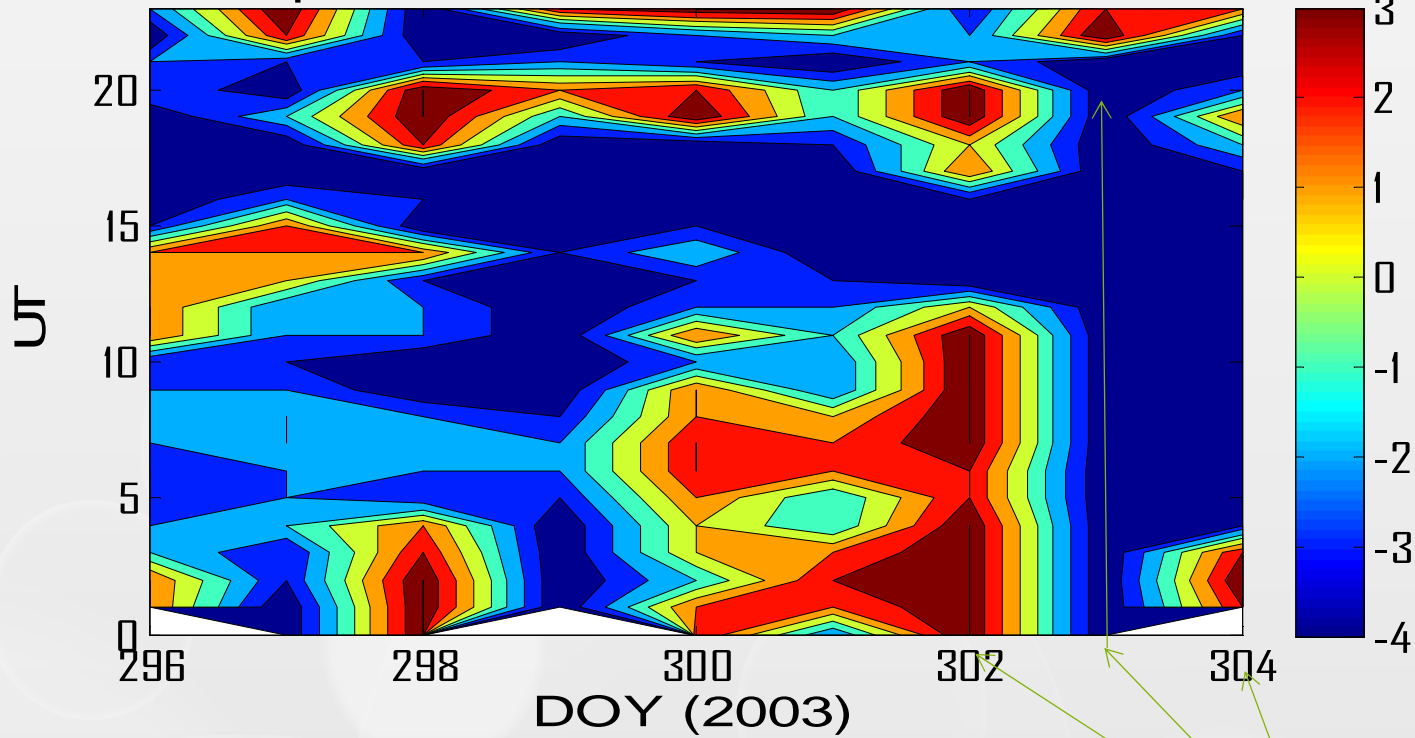


Level Change of Position Error

Error Change Level, Z Component, BAKO

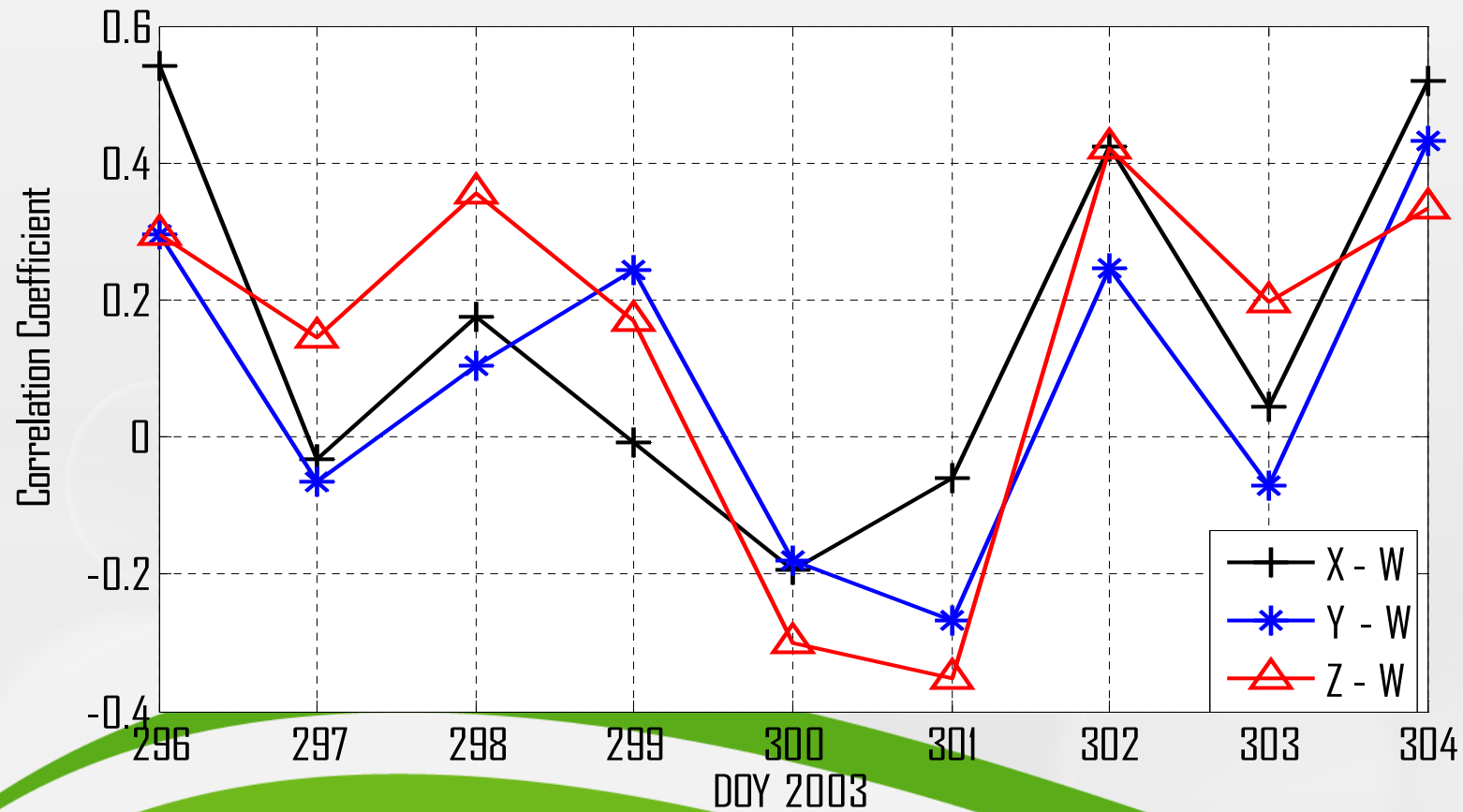


Ionospheric Disturbance Index, W, BAKO



W and LCPE correlation

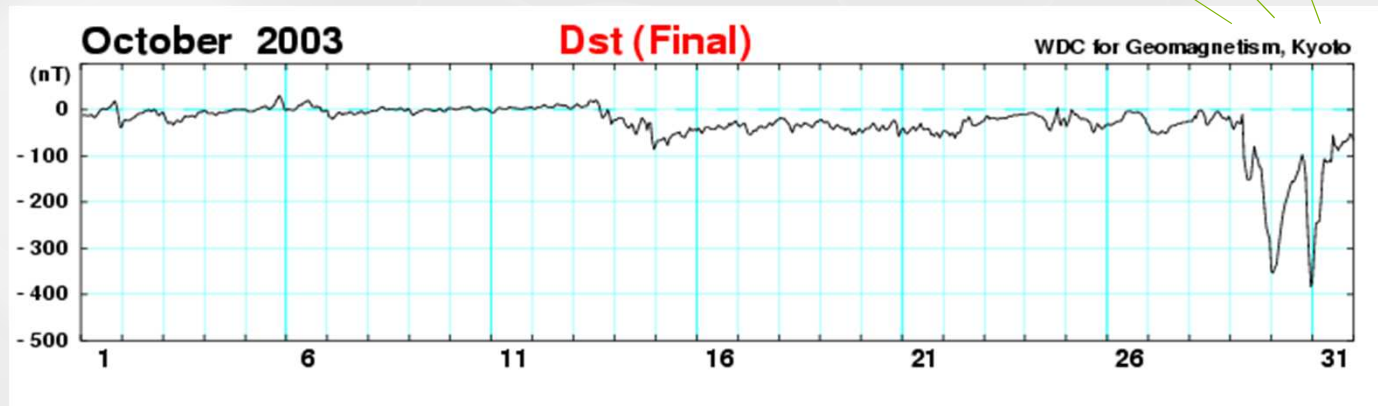
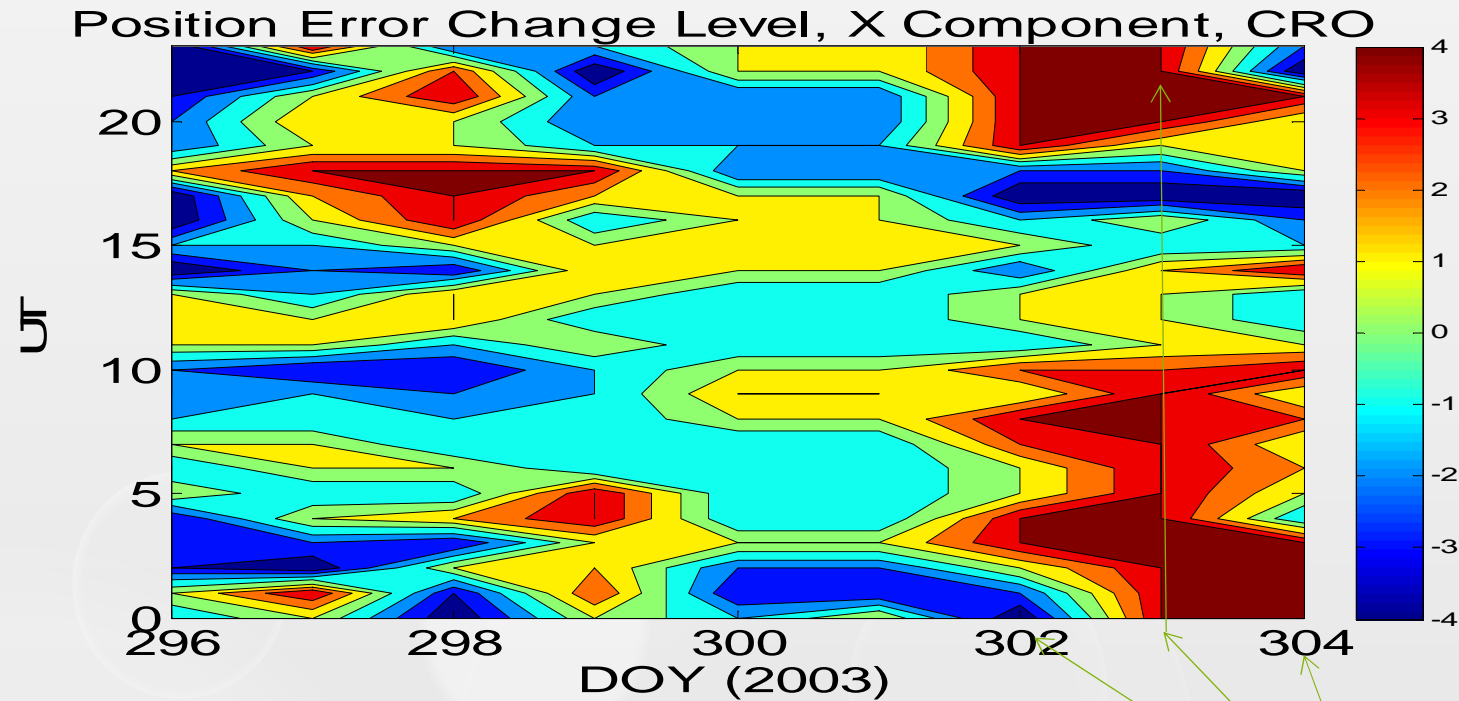
BAKO Station



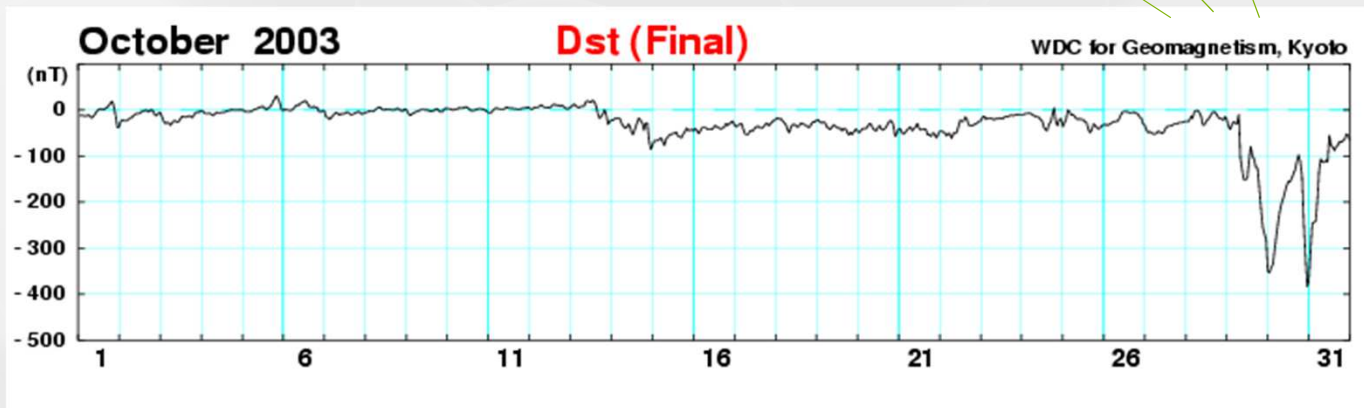
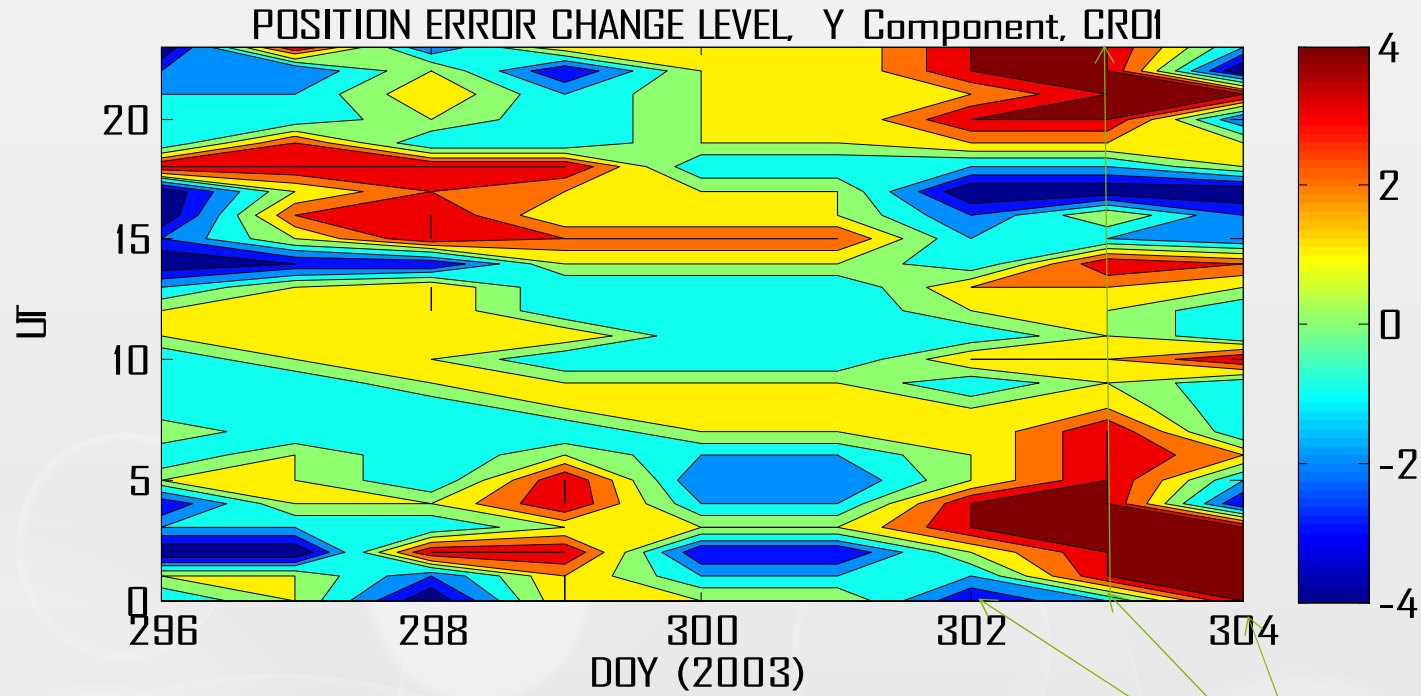
WSG (Ionospheric Disturbance Index W and Satellite Geometry)

PDOP index	W	WSG
9-50 (5)		20
6-8 (4)	4	16
3-6 (3)	3	9
2 - 3 (2)	2	4
≤ 2 (1)	1	1

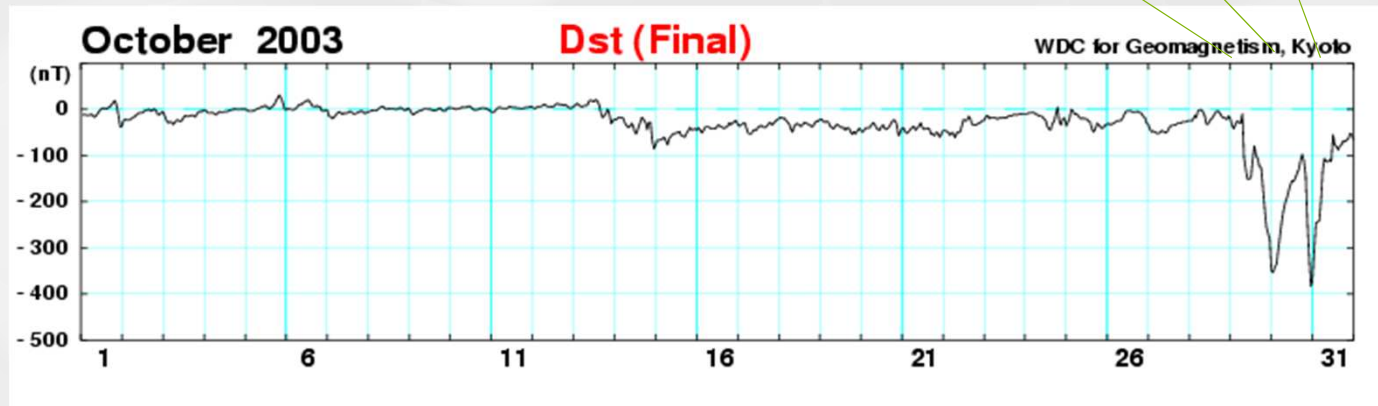
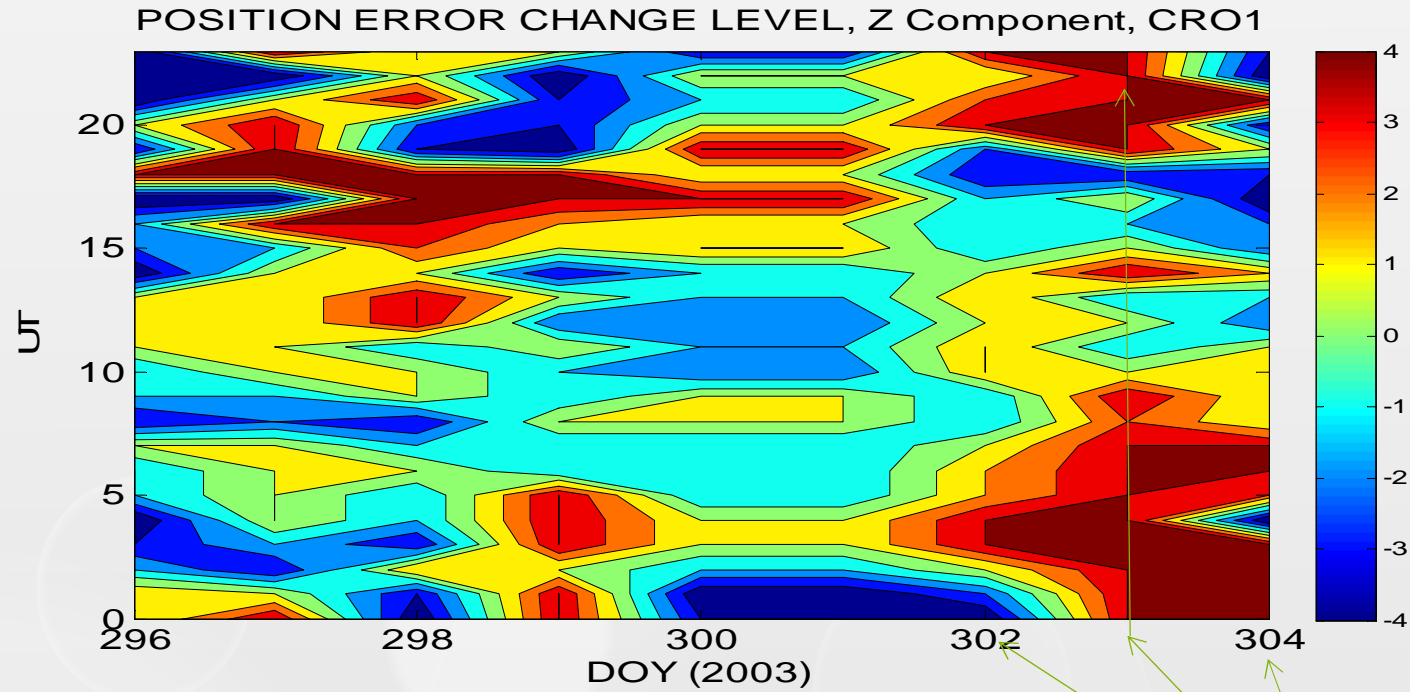
Level Change of Position Error X Comp



LCPE, Y Comp, CRO1

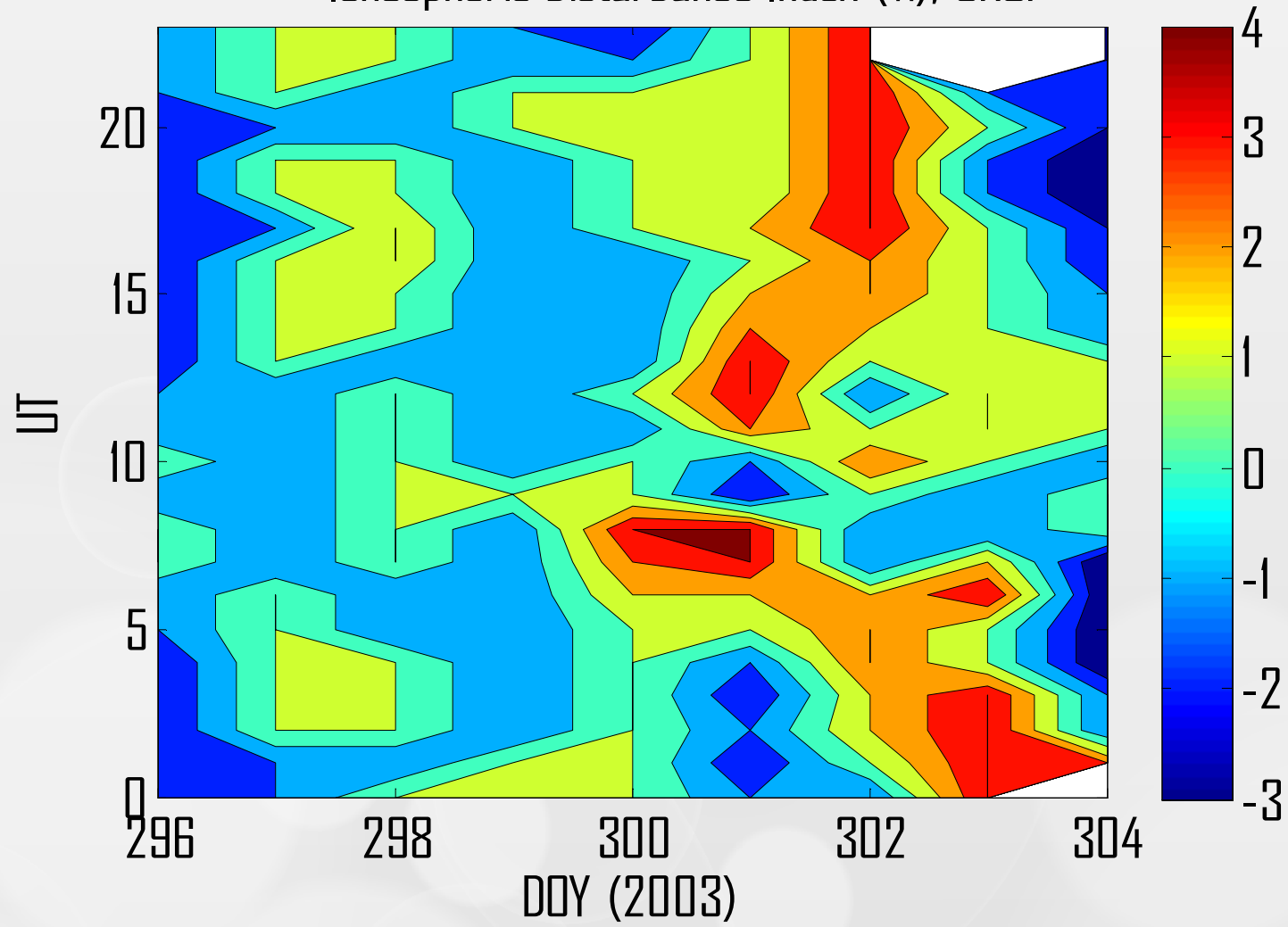


LCPE Z Comp, CRO1

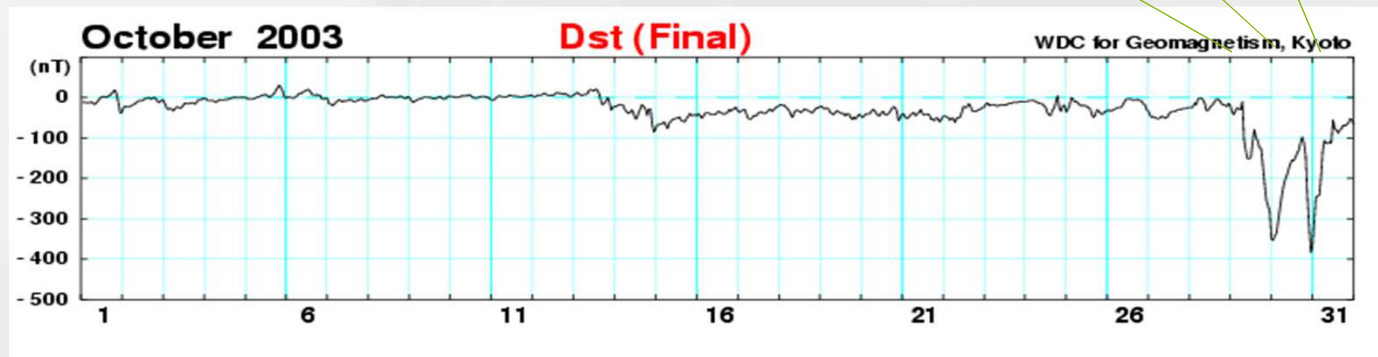
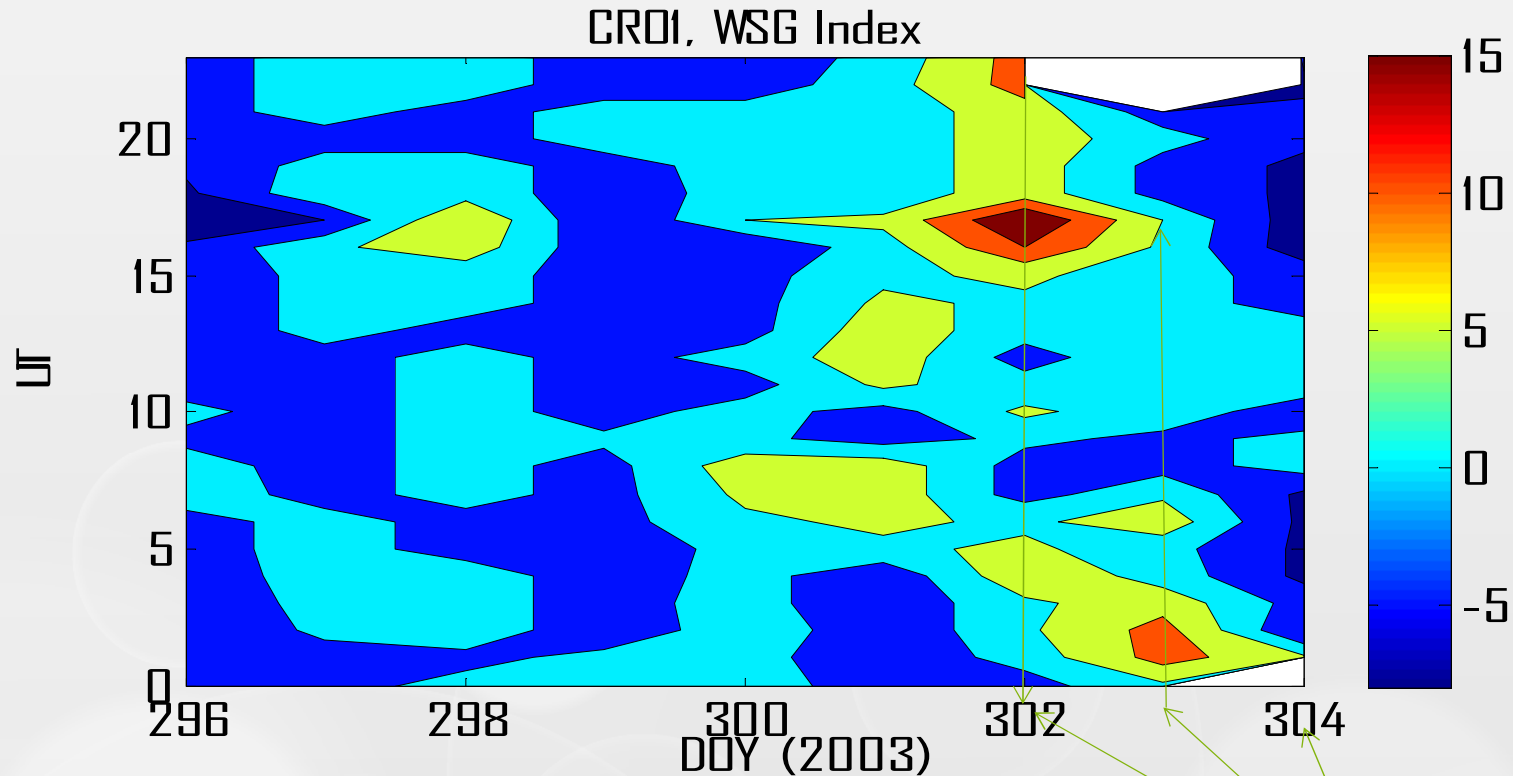


W

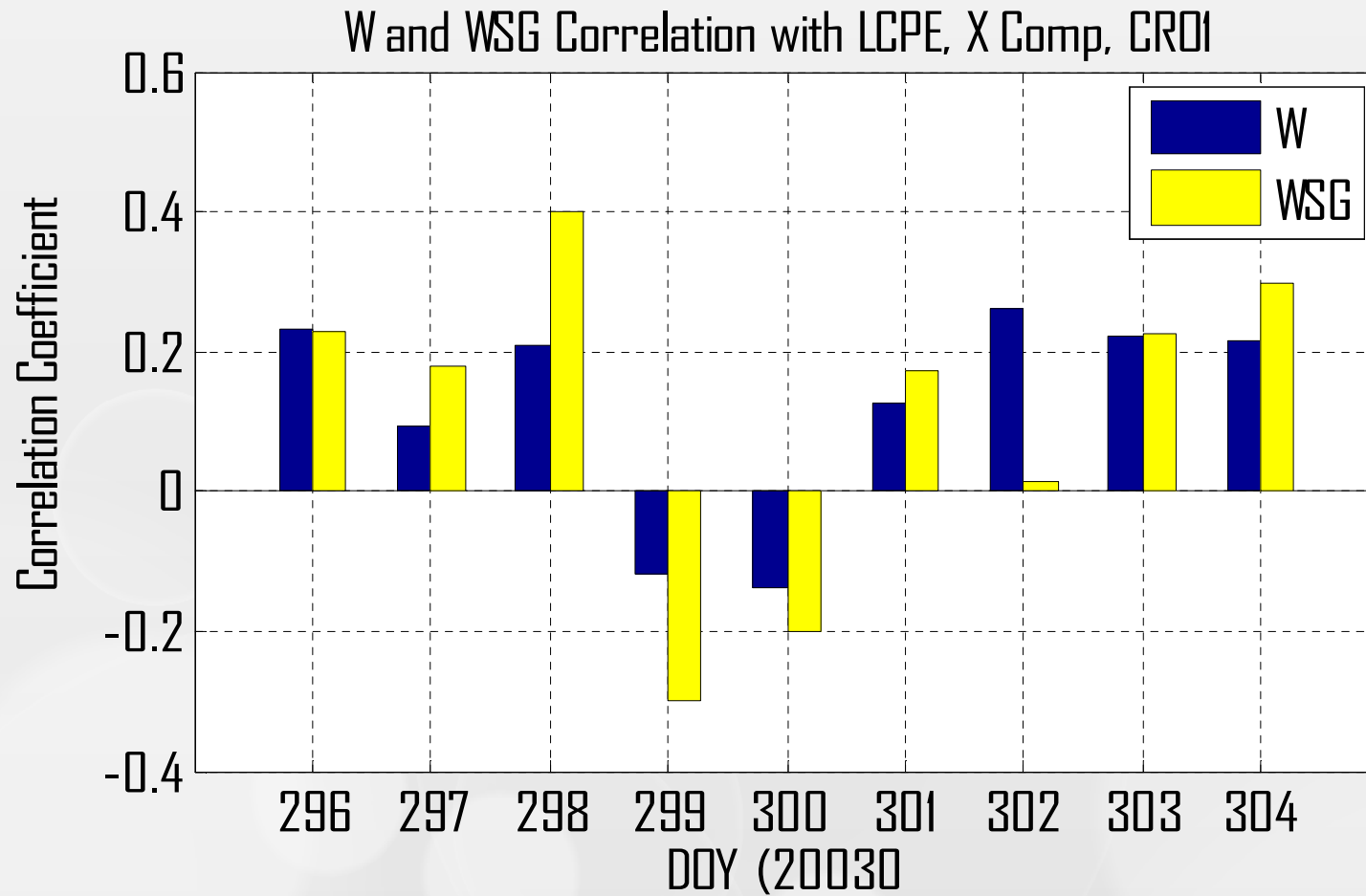
Ionospheric Disturbance Index (W), CRO1



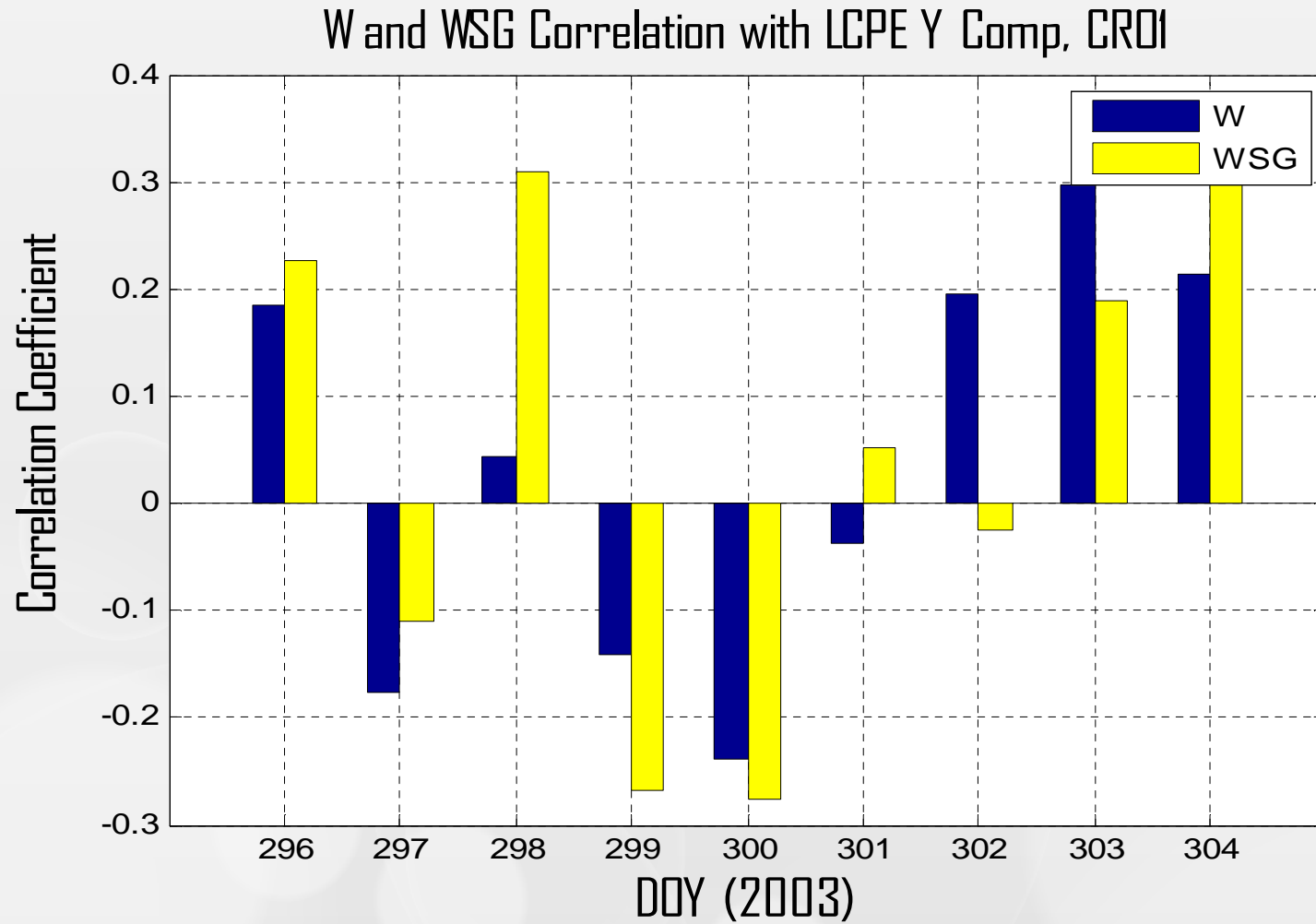
WSG Index, 29-30 Oct 2003 Ionospheric Storm



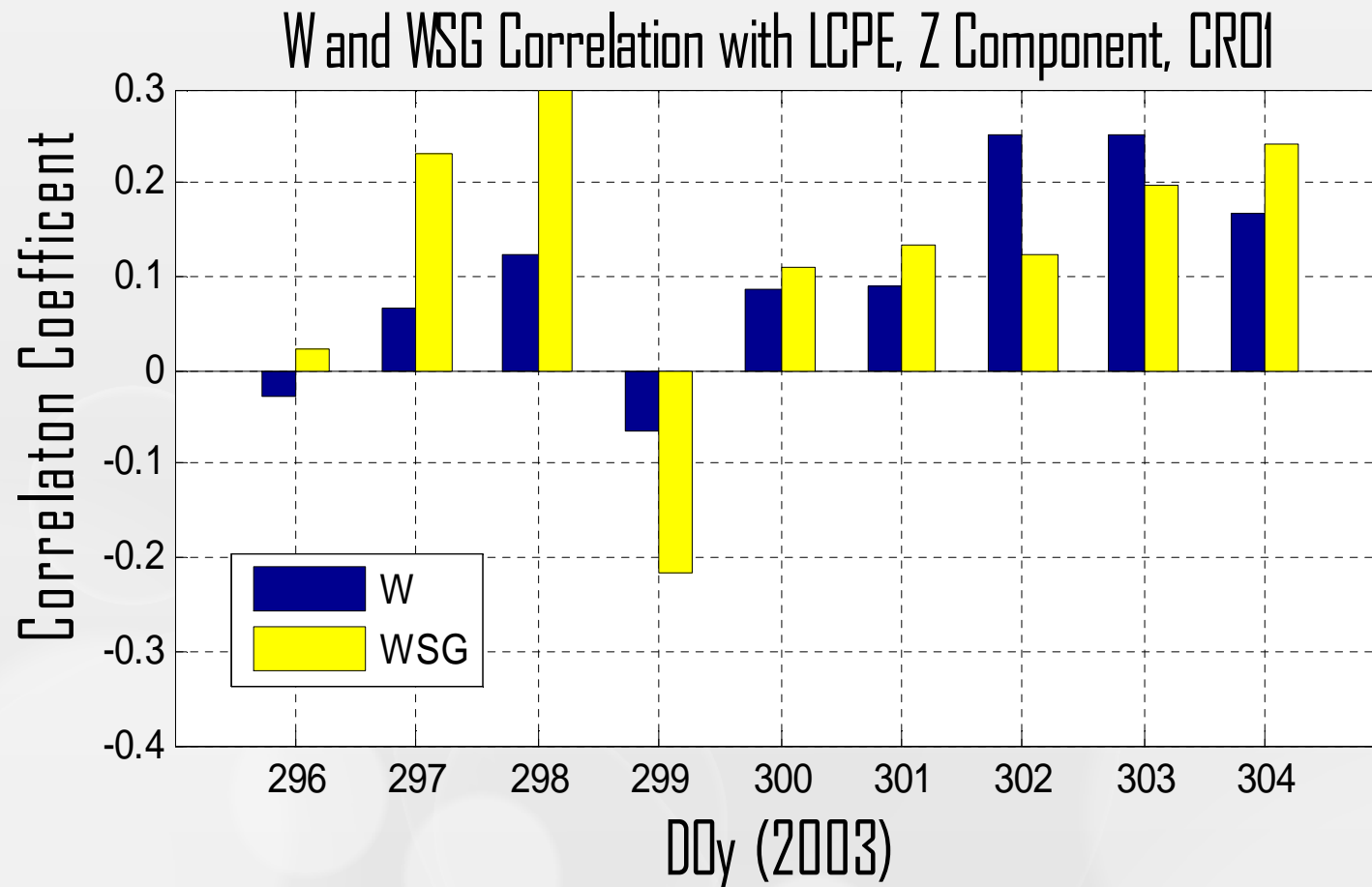
W and WSG performances



W and WSG performances



W and WSG performances



Conclusions and Future works

- The automatic software has been developed to estimate the ionospheric disturbance index, W, to upload W index to SWIFTS website (www.swifts.sains.lapan.go.id), for low latitude region of Indonesia
- W index has low correlation with level change of GPS position error .
- We have investigated the new ionospheric index as combination of W index and satellite geometry index, WSG
- The early results of the new ionospheric index, WSG, has slightly improvement over W except during phase of geomagnetic storms

Future works (2017):

The WSG index will be optimized to obtain high correlation with the level change GPS positioning error required by GNSS user

The WSG index will be estimated from GPS stations networks (local, national, regional and international)

Acknowledgment

- 1. Geospatial Information Agency (Indonesian Survey and Mapping Agency)
- 2. CODE (Center of Orbit Determination in Europe)
- 3. The Crustal Dynamics Data Information System (CDDIS) NASA
- 4. GOPI
- 5. RTKLIB