Contributions of DORIS to ionosphere modeling

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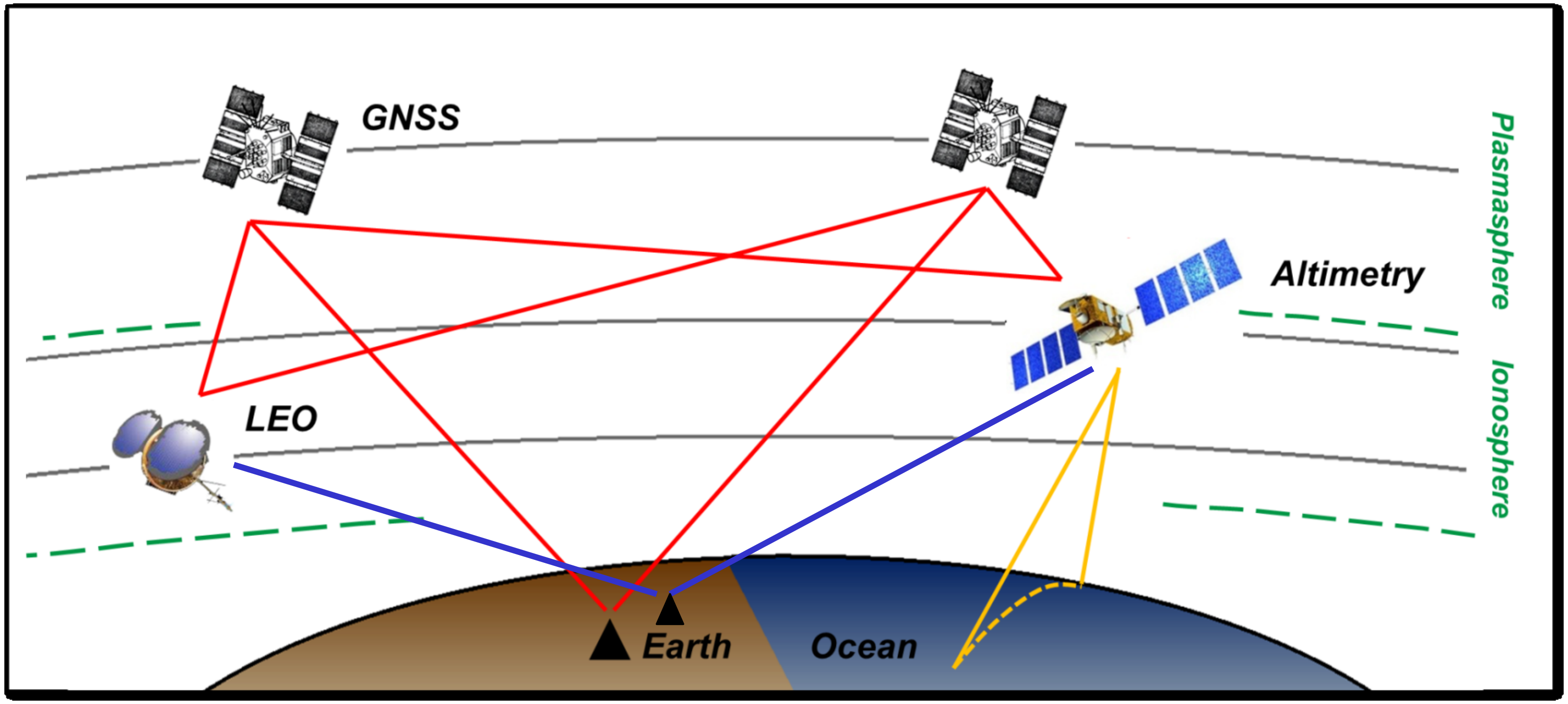
Space-geodetic observation techniques



- Terrestrial GNSS
- Space-based GNSS (radio occultation, RO)
- Satellite radar altimetry (RA)
- DORIS
- VLBI, GRACE K-band, …

DORIS data for ionospheric research

New DORIS instruments DGXX

RINEX 3 data

Phase measurements instead of Doppler measurement!

Similar to GNSS, but:

- high ratio between the two frequencies

$$f_1 = 2.03625 \text{ GHz} \qquad \lambda_1 = 14.7 \text{ cm}$$
$$f_2 = 0.40125 \text{ GHz} \qquad \lambda_2 = 74.7 \text{ cm}$$

=> factor 5.1 (GPS: 1.3)

- higher order effects significant

Processing chain

DORIS preprocessing

L_1/L_2 → $VTEC_{DORIS}$

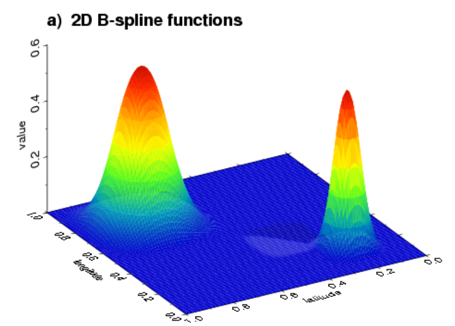
$VTEC_{GPS}$

$VTEC_{RO}$

$VTEC_{RA}$

⋮

DGFI VTEC model

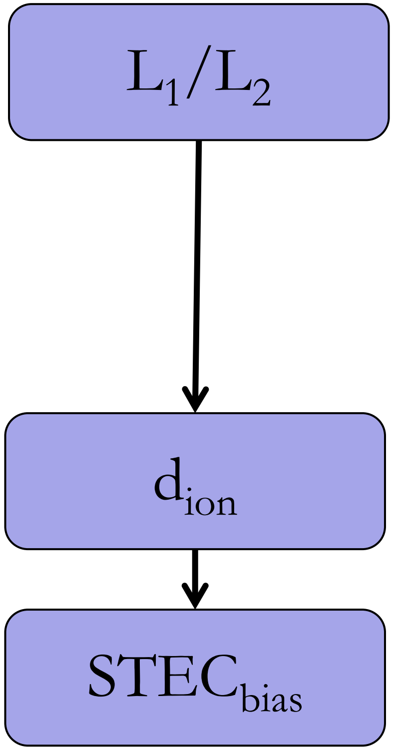


$$\Delta VTEC(\varphi,\lambda,t)=\sum_{k_1=0}^{K_1-1}\sum_{k_2=0}^{K_2-1}\sum_{k_3=0}^{K_3-1} d_{k1,k2,k3}\,\phi_{k_1}^{J_1}(\varphi)\phi_{k_2}^{J_2}(\lambda)\phi_{k_3}^{J_3}(t)$$

Variance Components

VTEC maps

DORIS data preprocessing



$$\lambda_1 L_1 = D_1 + \lambda_1 d_w - dion_1 + h_{rec} - h_{emi} + A_1$$
$$\lambda_2 L_2 = D_2 + \lambda_2 d_w - dion_2 + h_{rec} - h_{emi} + A_2$$

phase windup

$$\lambda_1 L_1 - \lambda_2 L_2 = (dion_2 - dion_1) + (D_1 - D_2) + (\lambda_1 - \lambda_2) d_w + A$$
$$\lambda_1 L_1 - \lambda_2 L_2 \approx (dion_2 - dion_1) + \Delta_{geom} + A$$

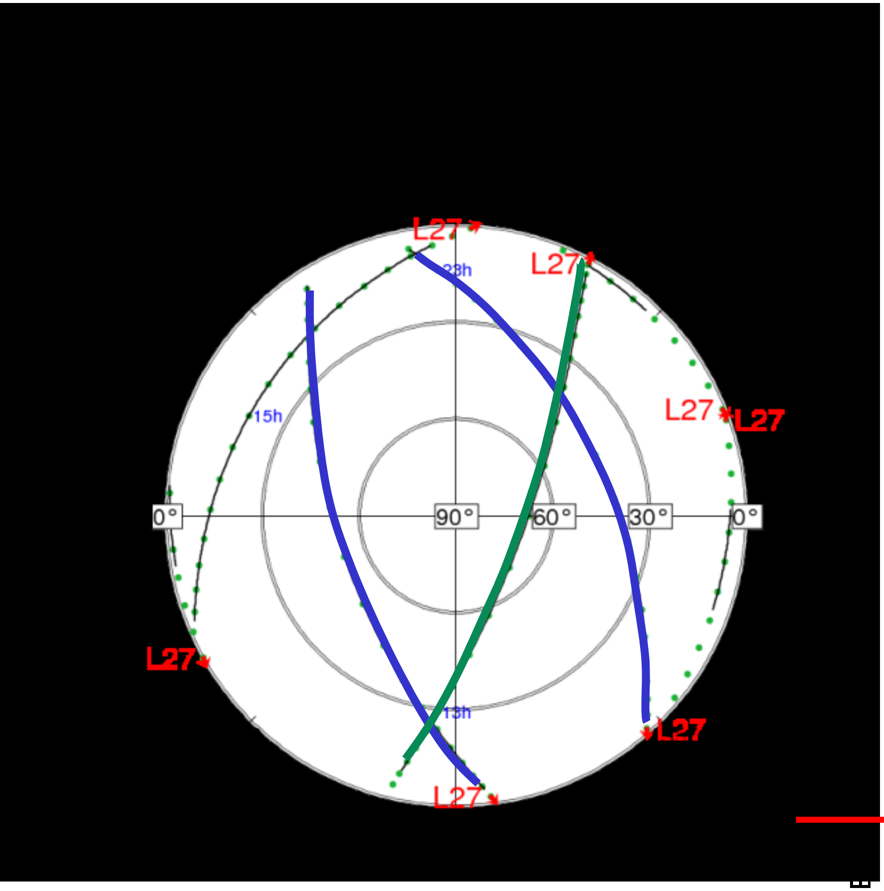
geometry correction

$$d_{ion1} = k \cdot (\lambda_1 L_1 - \lambda_2 L_2) - k \cdot \Delta_{geom} + A \qquad \text{with} \quad k = \frac{f_2^{\,2}}{f_1^{\,2} - f_2^{\,2}}$$

$$STEC_{bias} = -\frac{f_1^{\,2}}{40.3} \cdot d_{ion1}$$

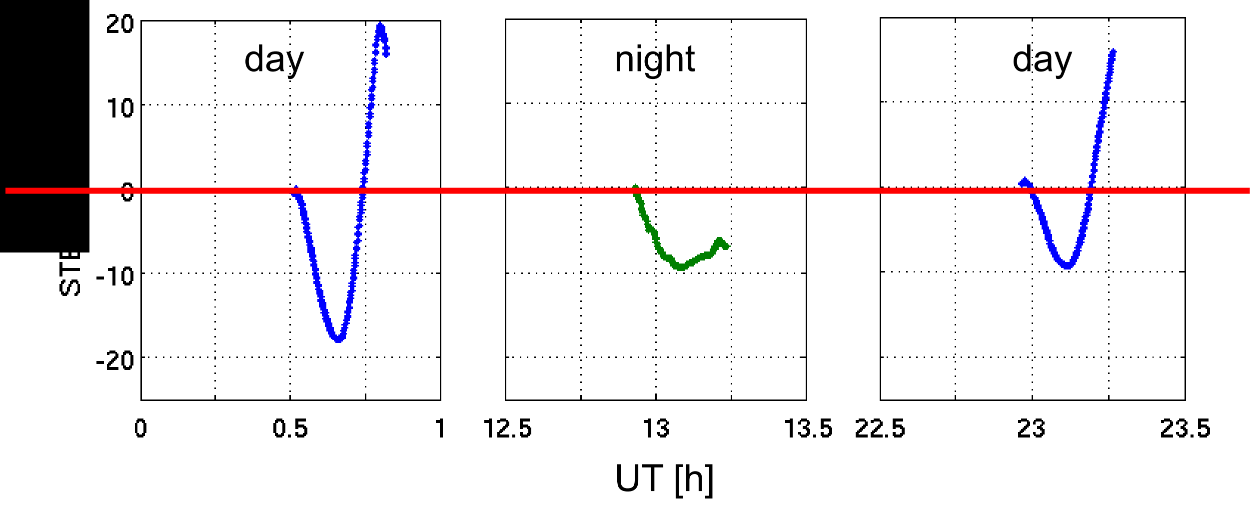
higher order ionospheric effect is neglected!

DORIS station KOLB – mission Jason-2



DOY 255, 2008
3 passes (2 desc, 1 asc)

negative STEC > biased!

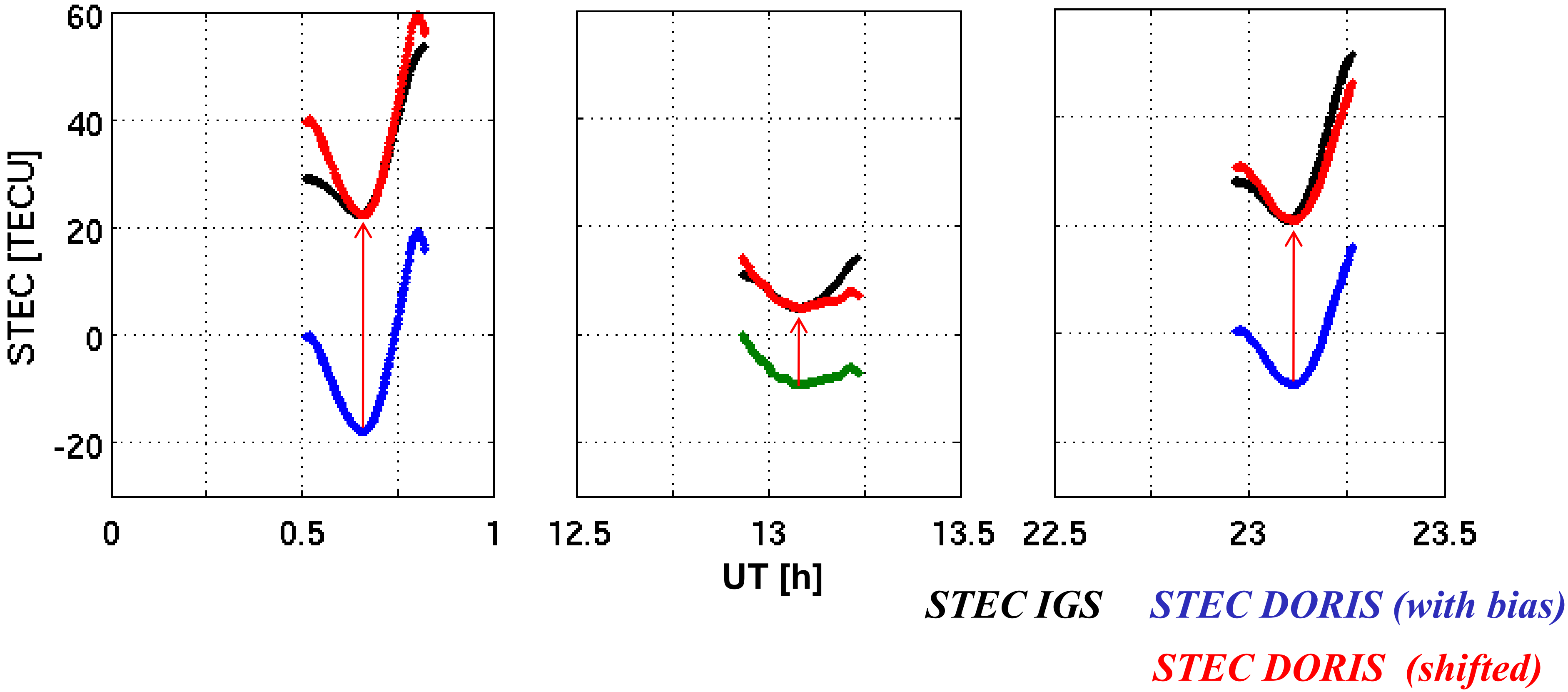


STEC bias estimation

- Pseudo-range observations not usable for „ambiguity fixing“
- Knowledge of bias important for mapping from STEC to VTEC
- Ambiguity is adjusted for each pass using an external ionosphere model
    - Model: IGS GIM
    - Factor for height reduction to J2 orbit height (f = 0.925)
    - Mapping to STEC with MSLM (CODE)

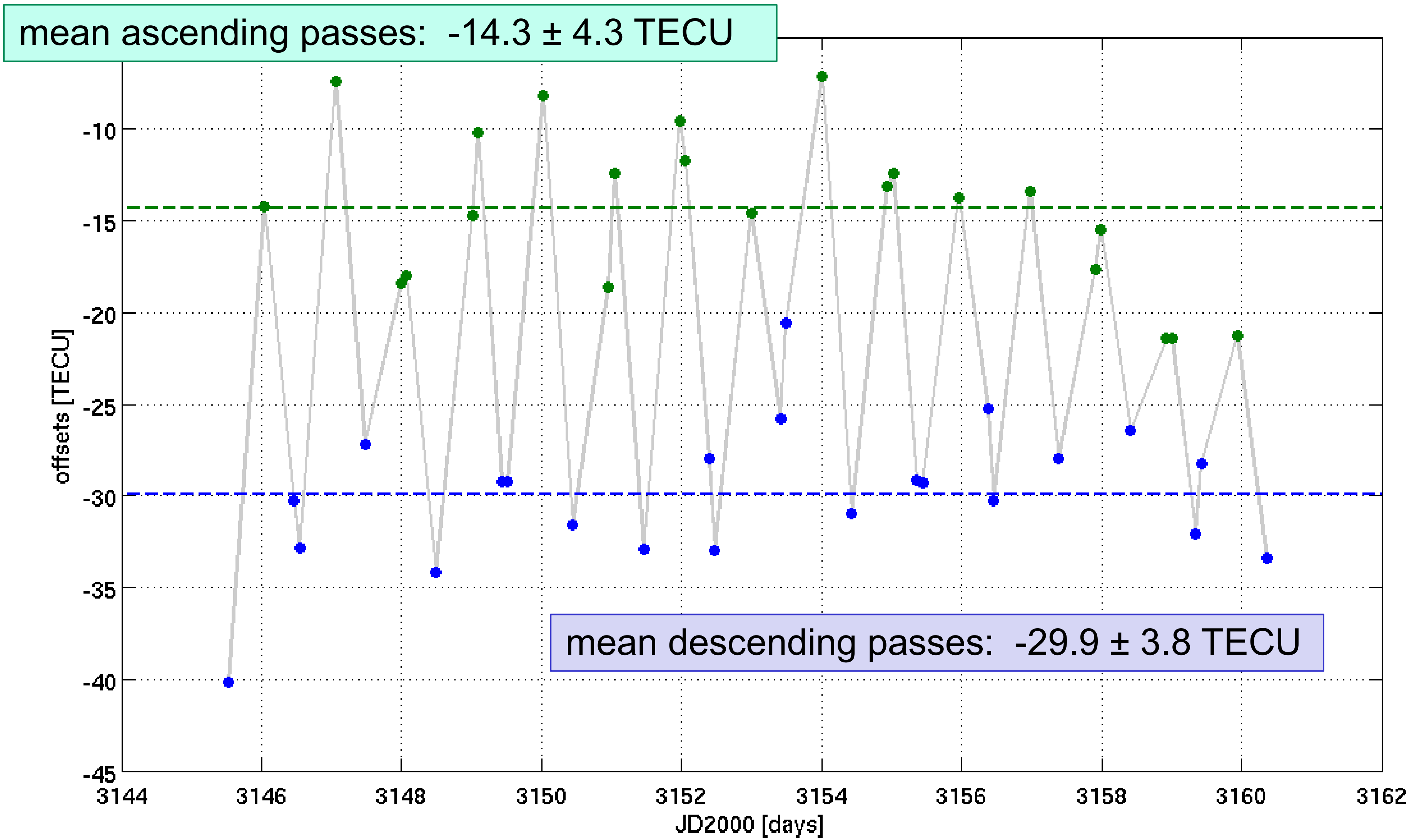
- Only passes with max. elevation of at least 20°, new pass after data gap or cycle slip => 2…4 passes per day

DORIS STEC (DOY 225)



offsets:	-40.2 TECU	-14.2 TECU	-30.3 TECU

DORIS STEC bias (per pass)



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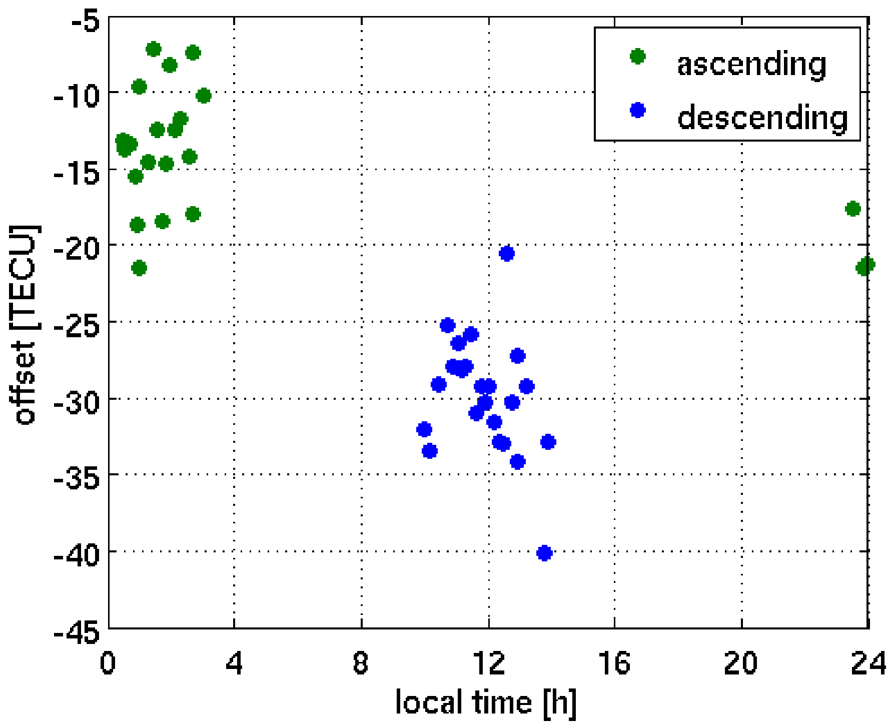
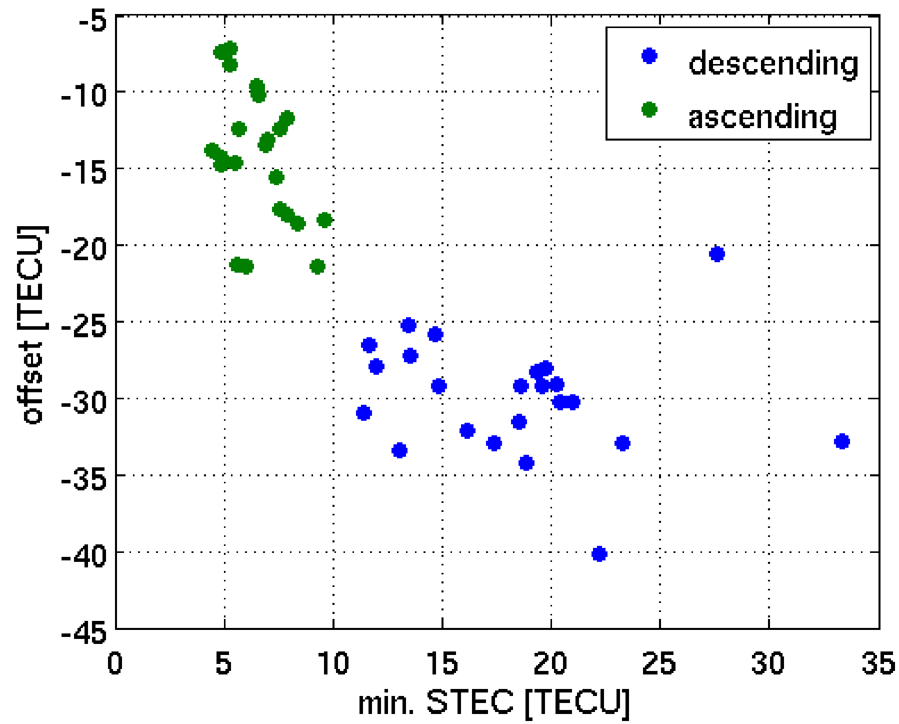
DORIS STEC bias





DORIS STEC bias depending on

- pass direction (asc/desc)
- mean local time
- absolute STEC (pass minimum)

Main reason:

- First STEC value per pass is always set to ZERO

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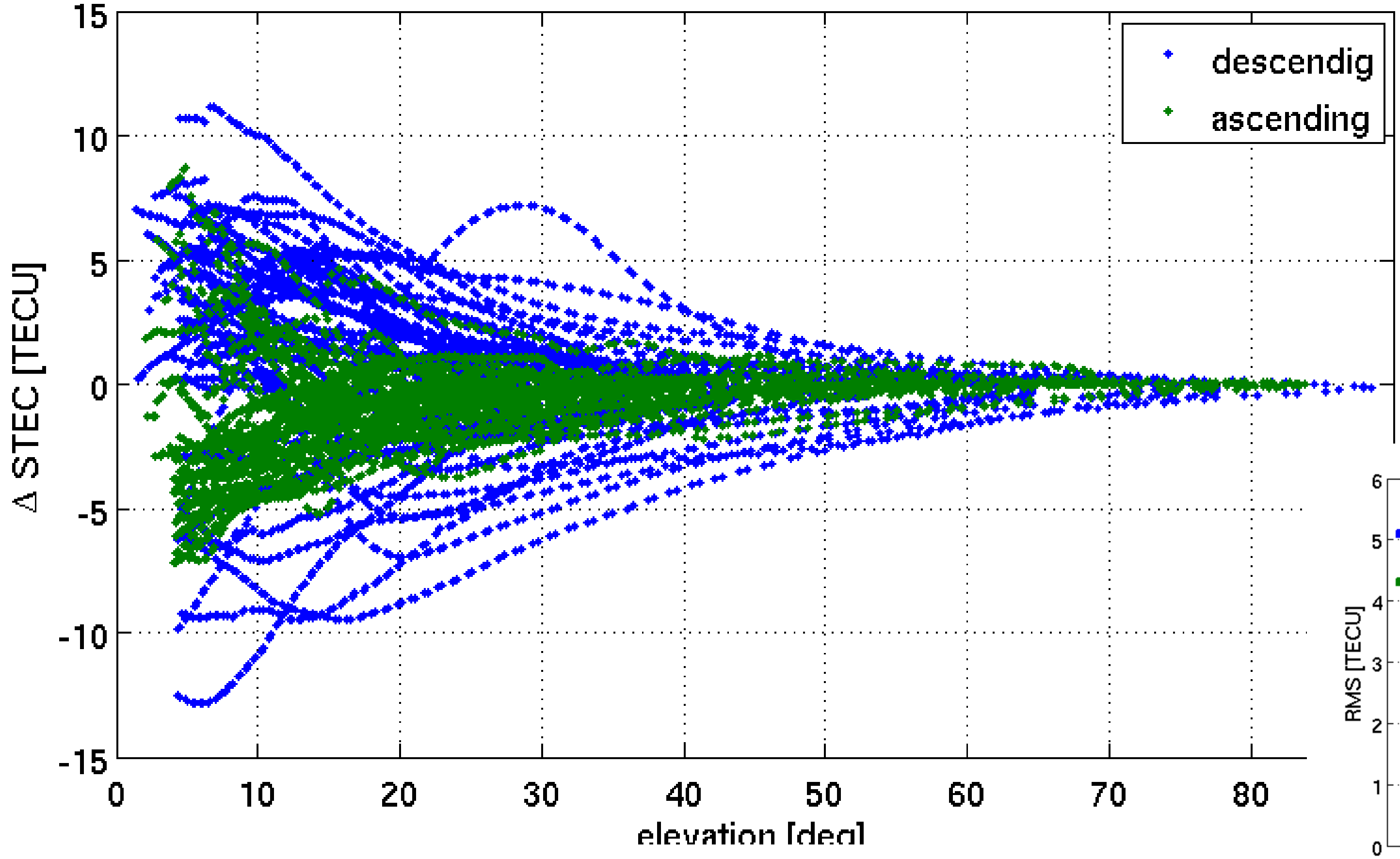
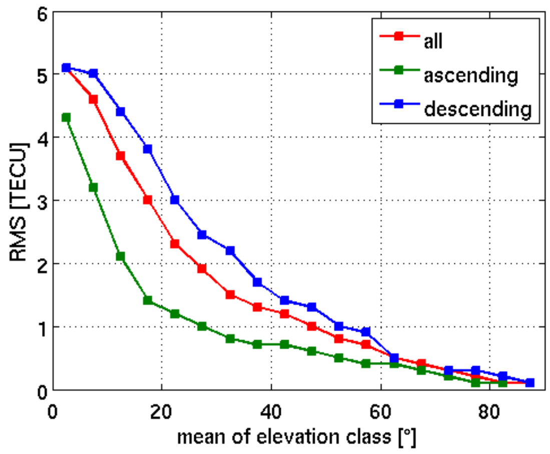
Differences DORIS$_{shifted}$-IGS

CONT08 time period (15 days) => 45 passes, 9185 observations (4380 asc / 4805 D)





Possible reasons:

- DORIS measurement errors
- IGS model and mapping ?
- Higher order ionosperic effects ?
- …

DORIS data preprocessing

L_1/L_2

Dual frequency synchronous phase measurement

- Outlier detection
- Geometry correction
- Phase windup (neglected)
- Higher order ionospheric effects (neglected)

d_{ion}

Ionospheric path delay

$STEC_{bias}$

Slant total electron content (with ambiguity)

- Bias for each path

STEC

Slant total electron content

- Mapping
- Single layer model

VTEC

Vertical total electron content

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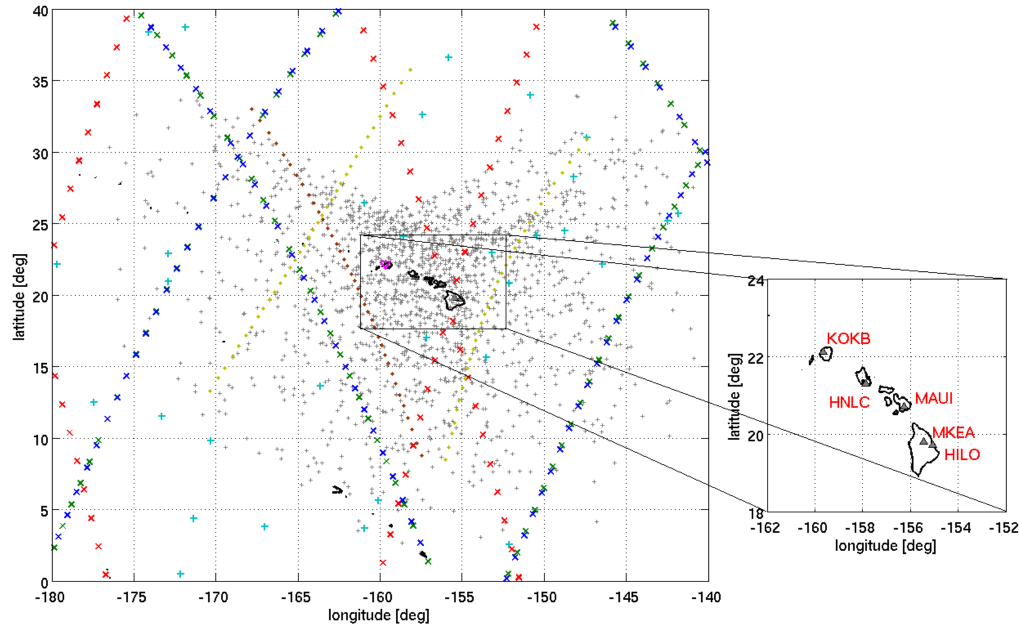
DGFI Ionosphere model

Model approach:

- VTEC modeling with respect to a background model (IRI2007)
- 3-dimensional B-splines for latitude, longitude and time (level 3,3,5)
- variance component estimation for rel.weighting of different observation types

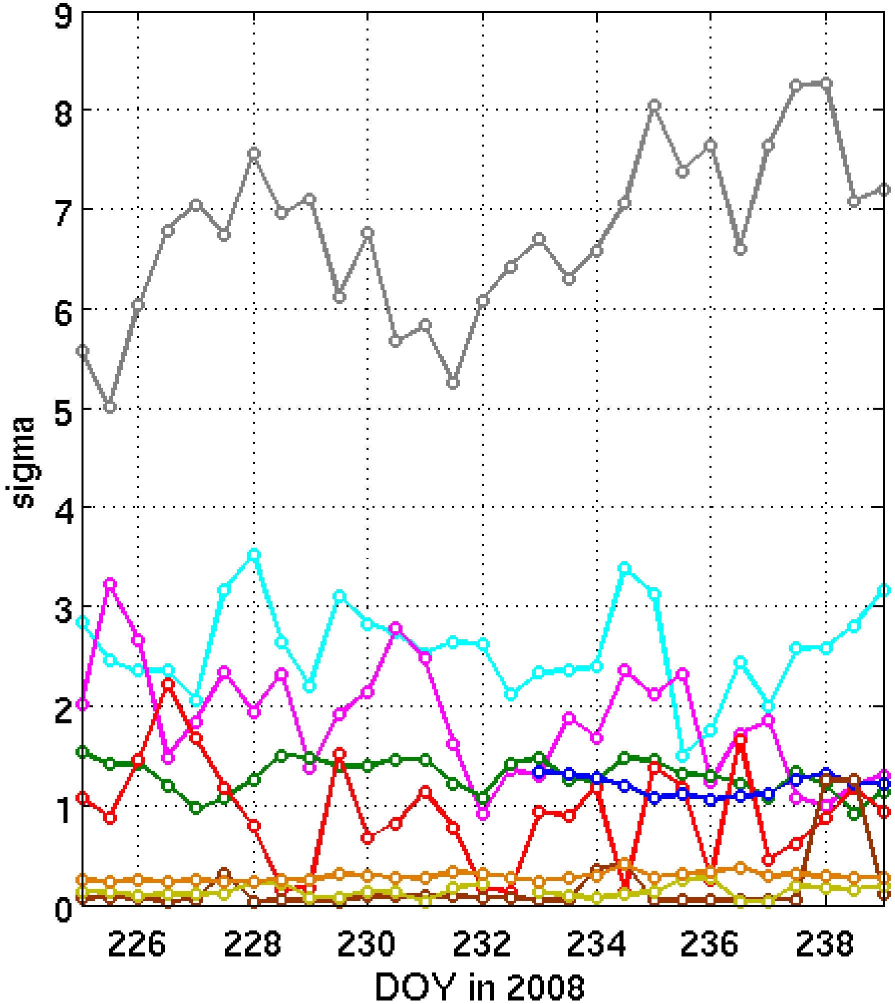
Area under investigation: Hawaii
Time period: CONT08 (Aug. 15-29, 2008)
Input data: VTEC up to 2000 km height
Input observation types:

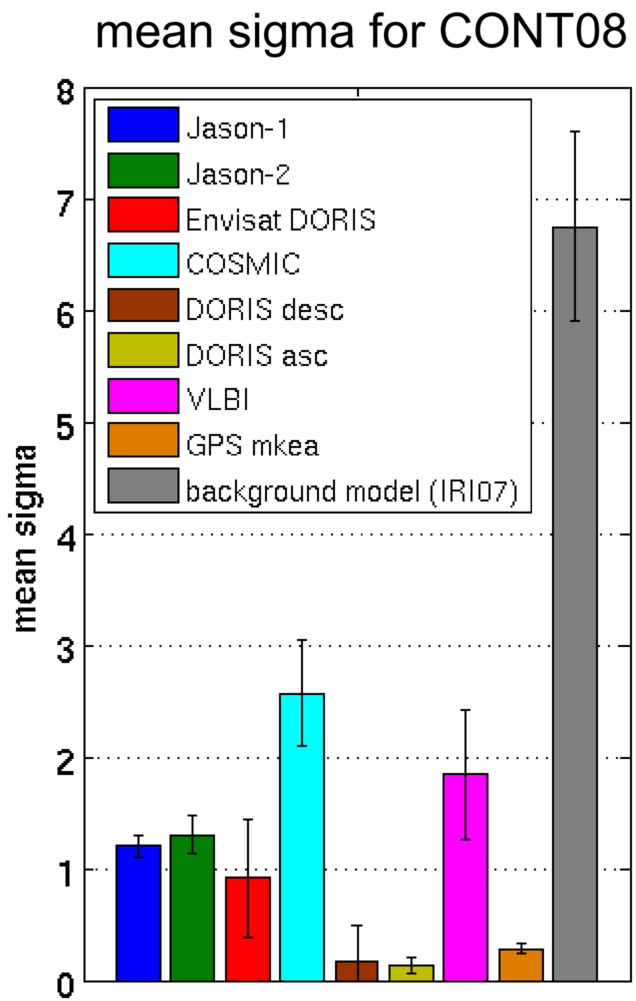
terrestrial GPS (5 stations),
RO (COSMIC),
RA (Jason-1, Jason-2)
VLBI
Envisat DORIS
DORIS VTEC (asc + desc)



Reference:
Dettmering D. et al, 2011: Systematic differences between VTEC obtained by different space-geodetic techniques during CONT08. Journal of Geodesy 85(7), 443-451, doi 10.1007/s00190-011-0473-z

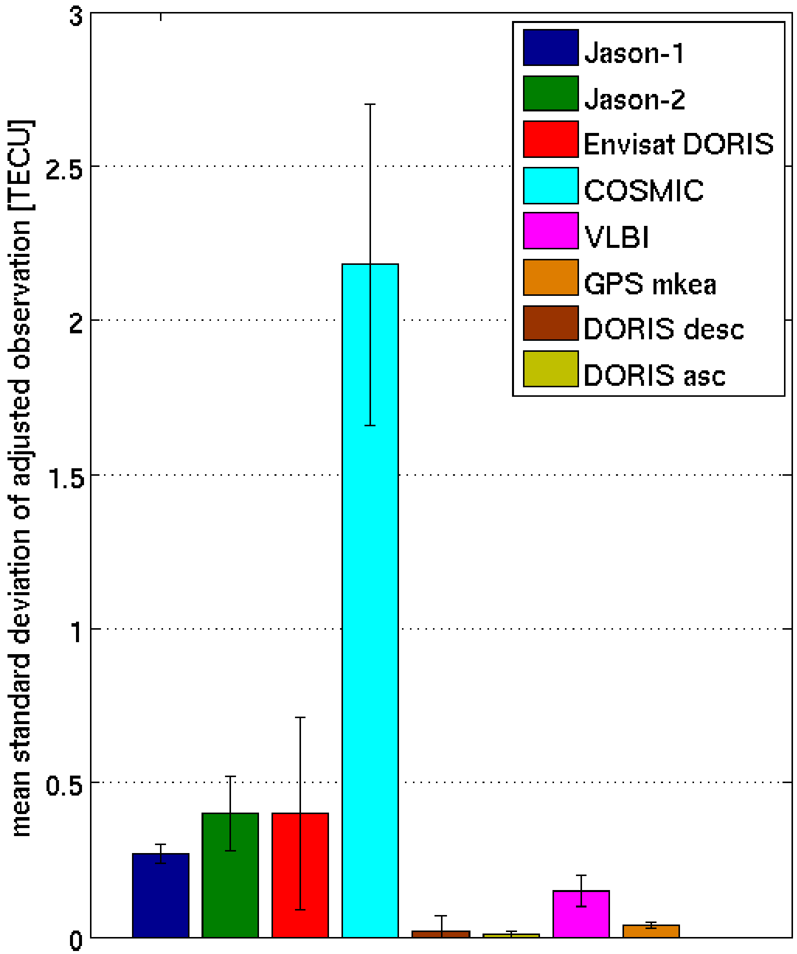
Variance Components





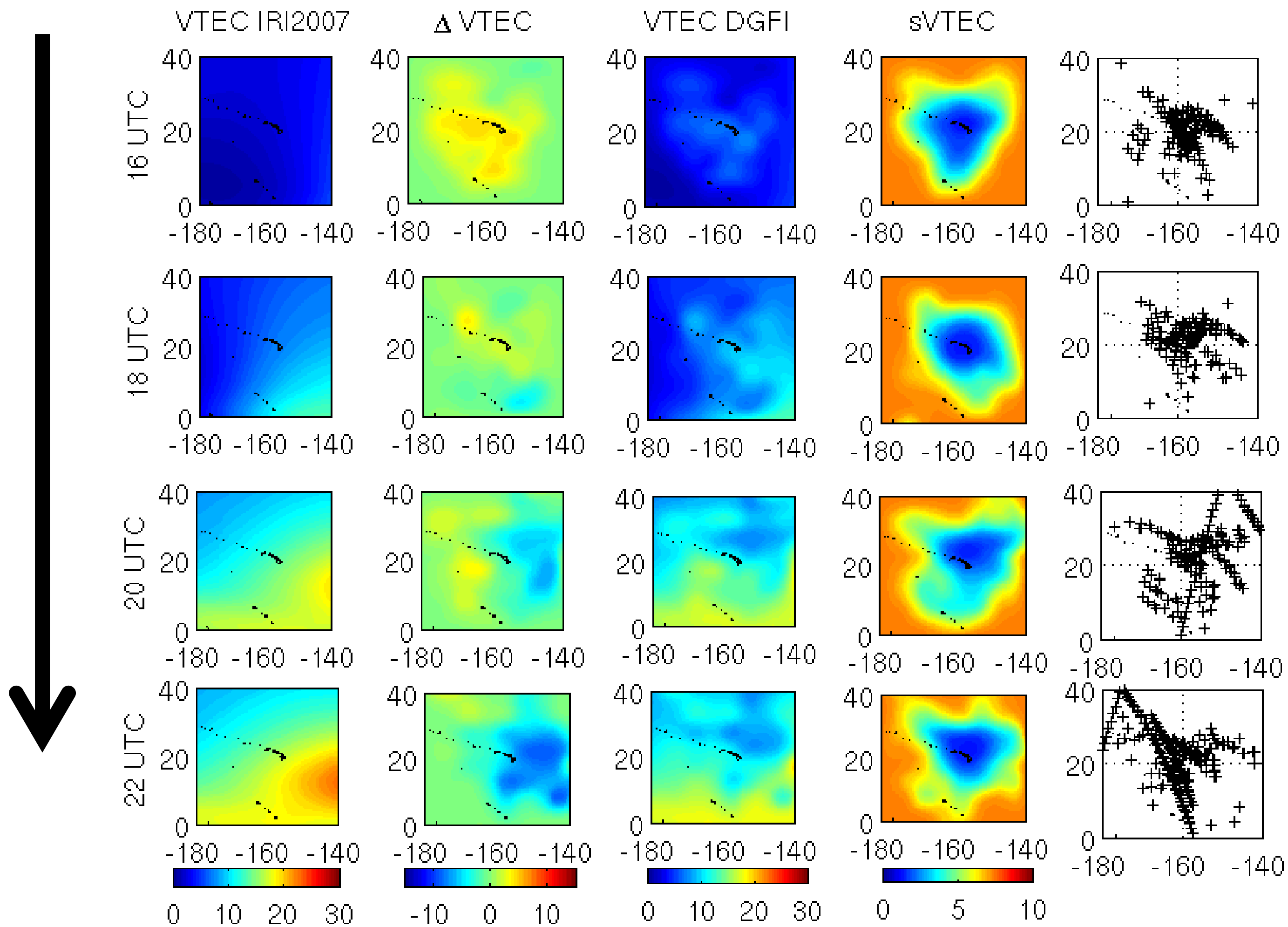
DORIS VTEC:
- smallest sigma
- highest weights

Accuracy of adjusted observations



- DORIS data standard deviation (mean) < 0.1 TECU
- Too optimistic due to high correlation between consecutive measurements
- More accurate than GPS
- DORIS Envisat product less accurate and less homogeneous

VTEC model (August, 24 2008)



- Estimated differences to IRI2007: up to 15 TECU
- Model precision: ~ 1TECU (optimal data coverage) … ~5 TECU (few or no data input)

Conclusions and Outlook

- DORIS can contribute significantly to ionosphere modeling
- High frequency factor ensure high sensitivity
- Data distribution promising (good global coverage, many missions)
- DGXX receivers provide measurements which are easy to handle
  more problems when using „old“ iono-products (not successfull yet)

- Ambiguity fixing needs external information
- Higher order ionospheric effects need to be investigated in detail

- Variance components for DORIS VTEC are better than for other observation techniques used in the study
- Quality of DORIS VTEC is better for ascending passes than for descending passes

Future work:
- Investigate large differences between DORIS STEC and IGS GIM for lower elevations
- Extend model area and use more DORIS missions and ground beacons
- Use of DORIS for 4-dimensional modeling of electron density