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IDS WORKSHOP

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Consistency of DORIS and GPS Assessments for the Real-time Global Ionospheric Maps

Ningbo Wang[1,2] and Zishen Li[1]

Academy of Opto-Electronics, Chinese Academy of Sciences
IAPG, Technical University of Munich

*wangningbo@aoe.ac.cn

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Outline

- Motivation and background
- RT-GIM generation with GNSS Technique
- RT-GIM validation with DORIS & GNSS Techniques
- Conclusions and future work

Motivation

- Validation of ionospheric electron content models
  - Data-driven IONO models within Geodetic community

    Using ground-based GNSS data to estimate the distribution of ionospheric total electron contents (TECs) in a thin-shell approximation

  - Performance validation of IONO models with GNSS technique
    - Comparison w.r.t GNSS absolute TECs

      Slant/vertical absolute TECs, using code leveled carrier phase, but affected *code biases*, *leveling errors*, *obs. noises*, *multipath effects* and *mapping errors* etc.

    - Comparison w.r.t GNSS relative TECs

      Relative TECs (rate of TECs), using dual-frequency carrier phase, concept of *dsTEC*

  - Performance validation of IONO models with altimeter satellites

    Vertical absolute TECs to altimeter orbit height, affected by bias calibration errors

Purposes

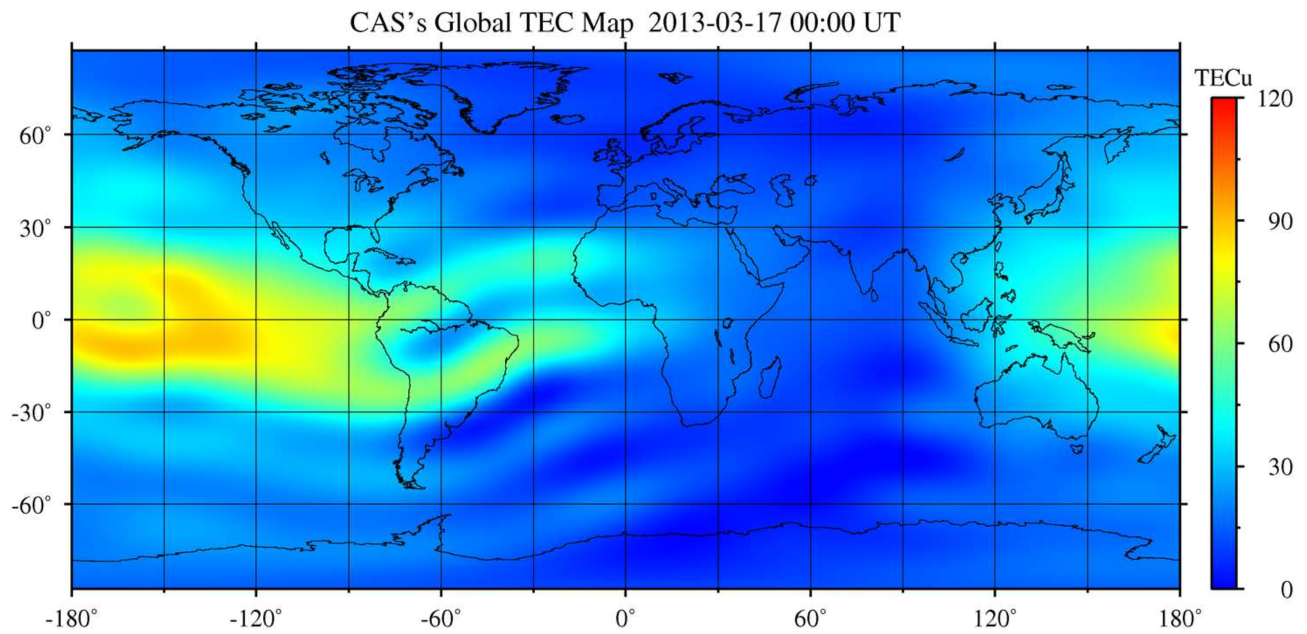
Comparison of diff. TEC sources for IONO model performance validation

	GNSS TEC	GNSS dsTEC	Altimeter vTEC	**DORIS dsTEC**
Obs.	GF comb.+ CLC	GF Comb.+ Phase	GF Comb.	**GF Comb.+ Phase**
TEC types	Absolute (V/S)	Relative	Absolute (V)	**Relative**
Data coverage	Mainly over continents		Only over oceans	**Globally uniform distribution**
Assessment types	Self- or external consistency		External consistency	**External consistency**

Purposes of the research

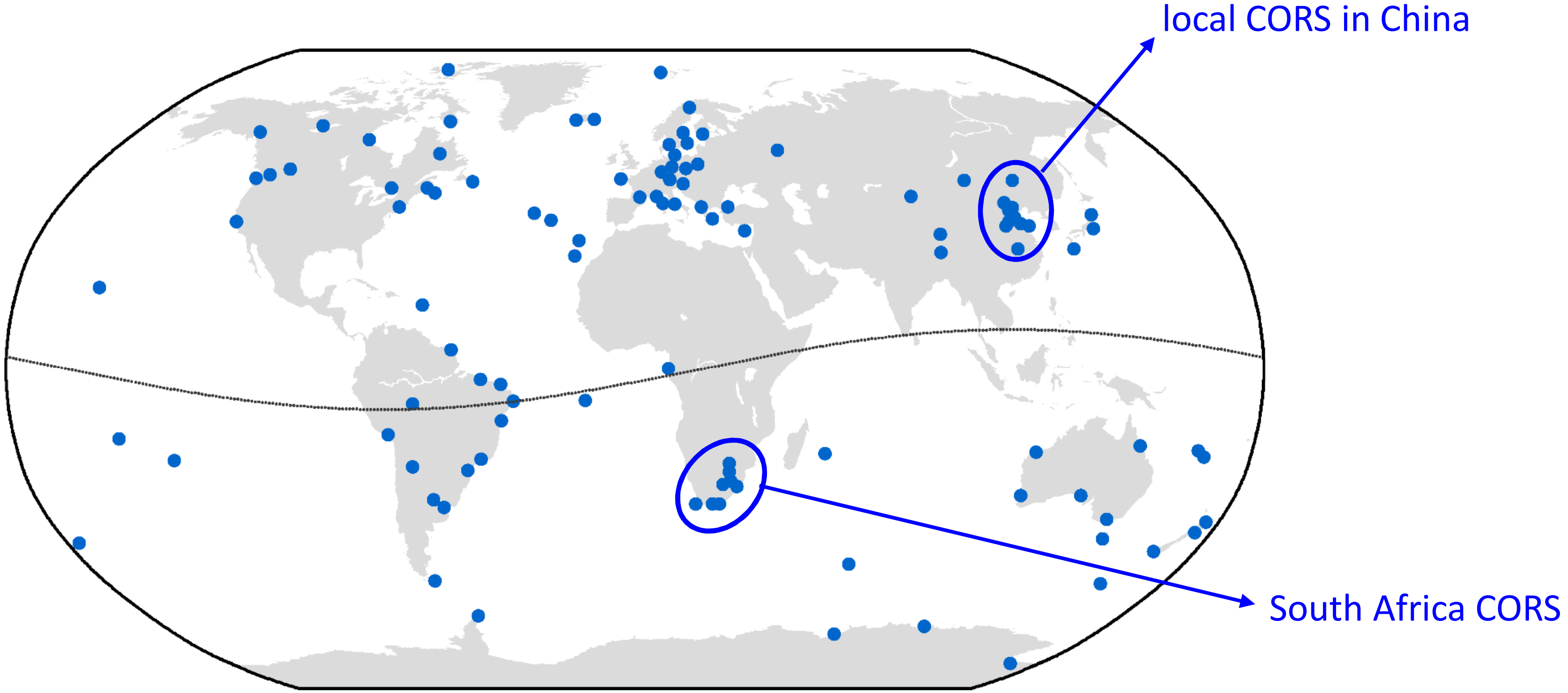
- Extend the current methods for the independent validation of IONO electron content models (GNSSs, Altimeters -> DORIS)
- Routine retrieval of **IONO info. from DORIS dual-freq. phase obs**.
- Extension of DORIS applications in GNSS community, and as the first step by **routine generation of DORIS relative TEC info.** for ionosphere sensing

- CAS Ionosphere Analysis Center of the IGS
  - Routine generation of rapid (carg) and final (casg) GIMs since 2014
  - New Ionosphere AC (1/7) of the IGS since 02/2016
  - Deliver to CDDIS on routine basis since 01/2017 (data: 1998-now)
  - Routine RT-GIM generation since 3rd quarter of 2017



- Tracking networks – IGS +MGEX (> 300 sites)
- Observations – GPS(L1+L2), GLONASS(L1+L2), BeiDou(B1+B3 since 2016)
- Global grids – ΔLon X ΔLat (5.0 X 2.5) Temporal resolution – 1 hour (30 mins since mid-2016)

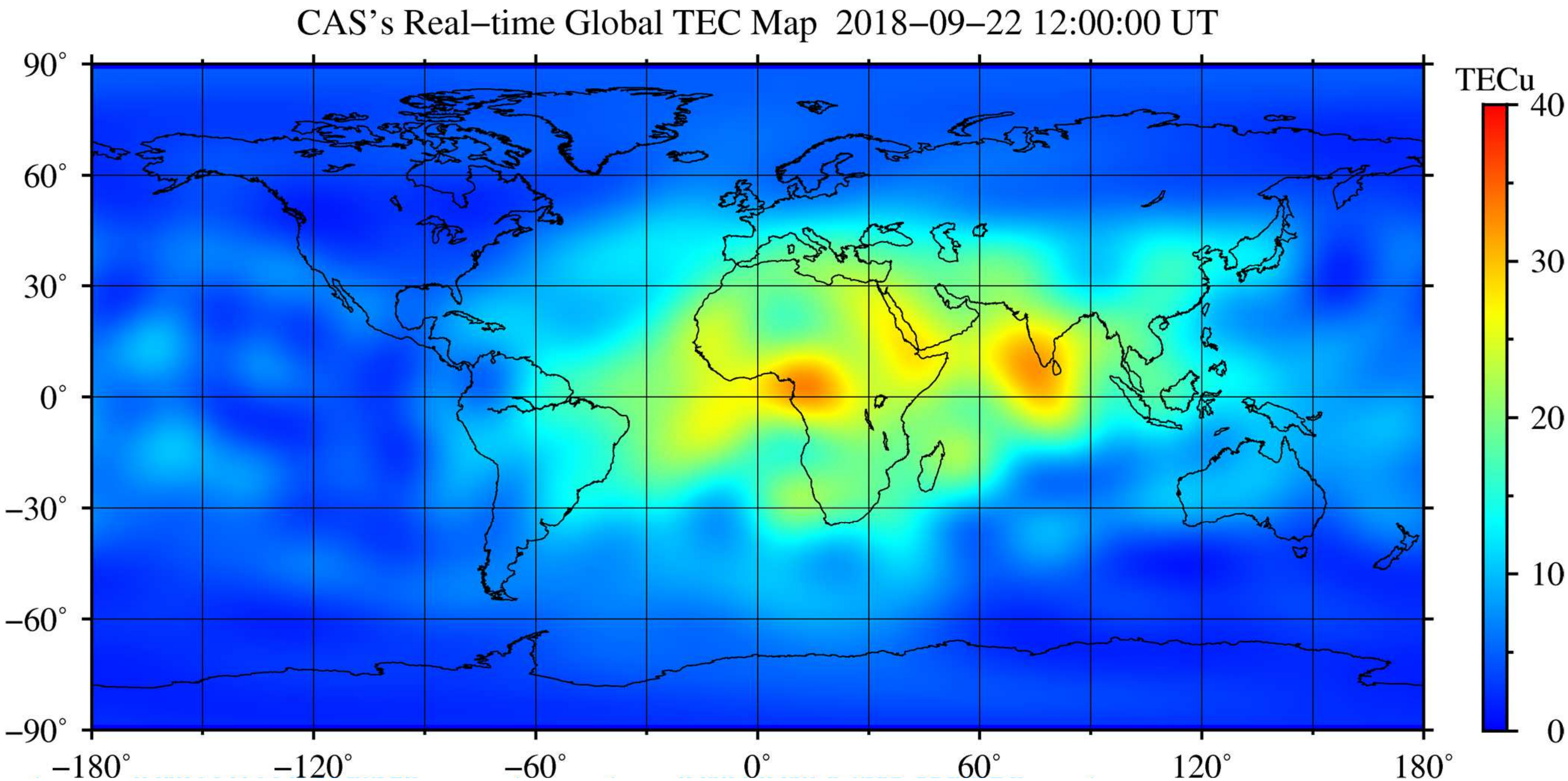
- Real-time GNSS data processing at CAS
  - IGS+MGEX (mainly) RT data streams
  - ~120 stations
  - supporting GPS+GLO+GAL+BDS
  - SW — **IGGNtrip** (modified BNC, Win+Linux)



Distribution of RT GNSS stations processed at CAS (UT 13:05, 30/10/2017)

RT-GIM Generation

- RT-IONO SW developed at CAS



Mount point (Account required): products.gipp.org.cn/CAS01
Data archive: ftp://ftp.gipp.org.cn/product/ionex/

RT-GIM validation

- DORIS and GNSS dsTEC assessment
  - Input data: dual-frequency phase obs.
  - Retravel of IONO info: geometry-free combination
  - $L_I(t_k)$ denotes phase derived TEC at epoch t_k
  - $L_I(t_{ref})$ denotes phase derived TEC with highest satellite elevation of the arc
  - dsTEC is calculated from

$$dsTEC(t_k) = L_I(t_k) - L_I(t_{ref})$$

  - Accuracy of dsTEC is much higher than that of the TECs derived from code leveled carrier phase technique

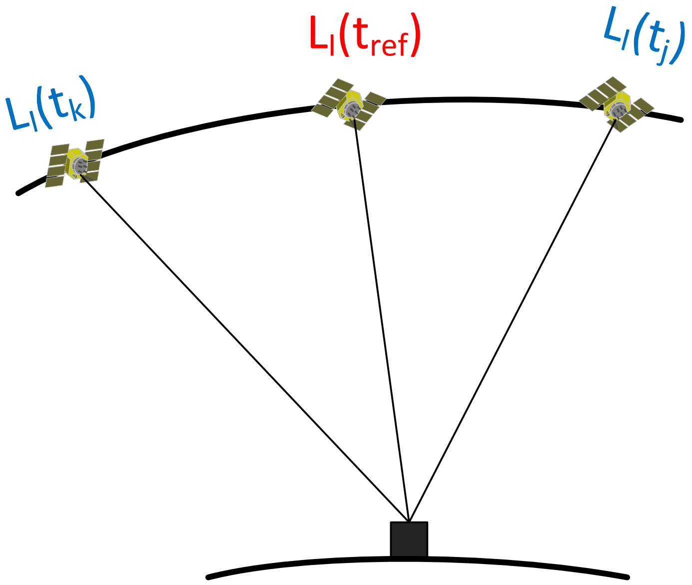


illustration of dsTEC concept in a continuous arc of carries phase observations

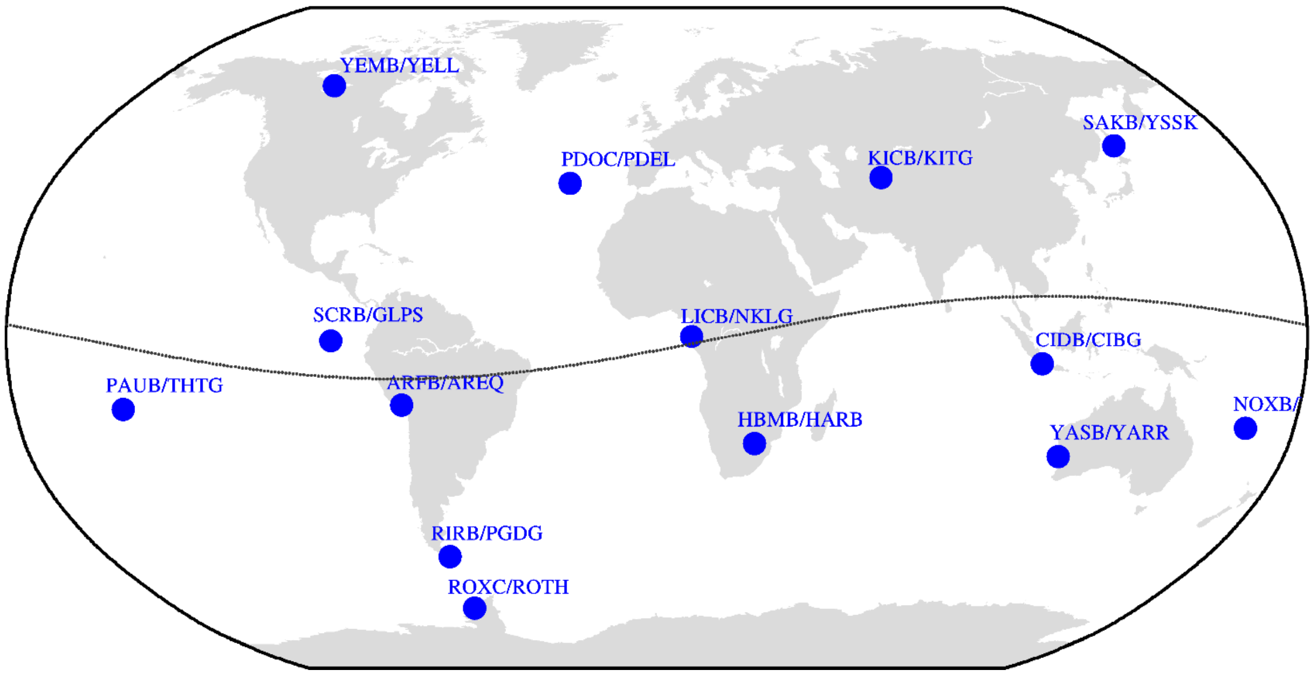
RT-GIM validation

Details in calculating GNSS (GPS) and DORIS (Jason-3) dsTEC

Terms	GPS dsTEC	Jason-3 DORIS dsTEC
Obs. Comb.	L4 (geometry-free comb. of dual-freq. phases)	
Obs. interval	30 s	10 s
Cycle slip detection	IONO residual algorithm + MW comb.	IONO residual algorithm + 3σ criterion
Cycle slip repair	NO	
Obs. noise	ignored	
Satellite elevation cut-off	10º	
Max satellite elevation within each arc	No detection	20º
Remarks for Jason-3 DORIS data processing	* Geometry corrections in satellite and receiver parts are applied ** Jason-3 TECs NOT converted to GPS orbit height	

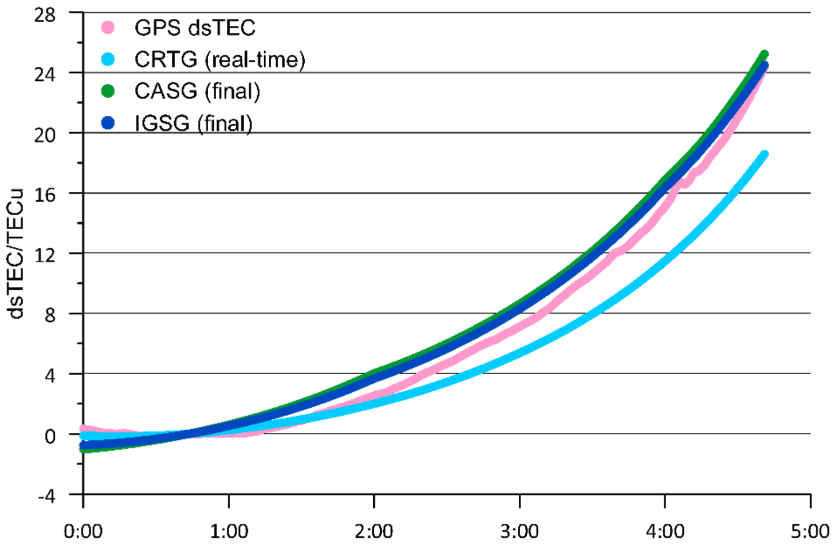
RT-GIM validation

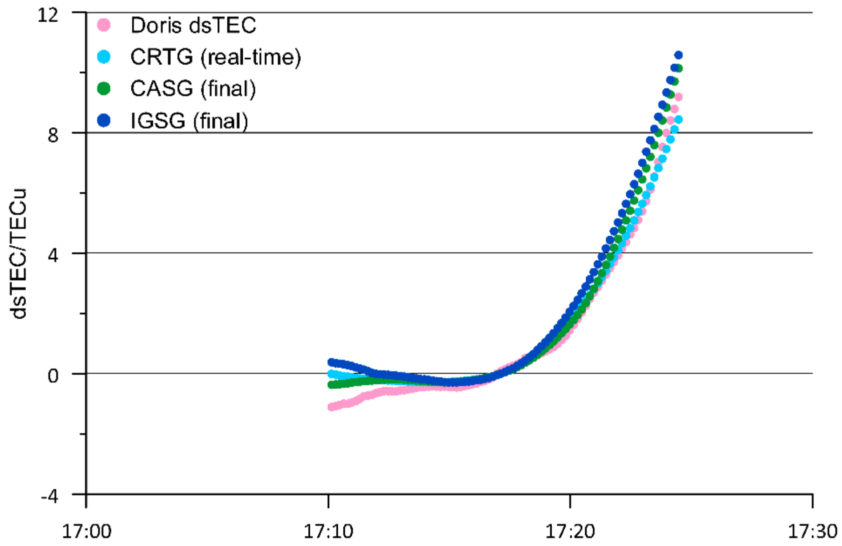
- Experimental setup
  - Time span: 001/2018-060/2018
  - Selected sites: 14, globally distributed
  - GIMs: CRTG (real-time, 5 mins), CASG (final, 30 mins) & IGSG (final, 2 hours)
  - TEC references: GPS & **Jason-3 DORIS** dsTEC, GPS vTEC (bias-free)



Distribution of selected sites for GIM validation (DORIS/GPS)

Comparison of GIMs w.r.t GPS (left) and DORIS (right) dsTEC

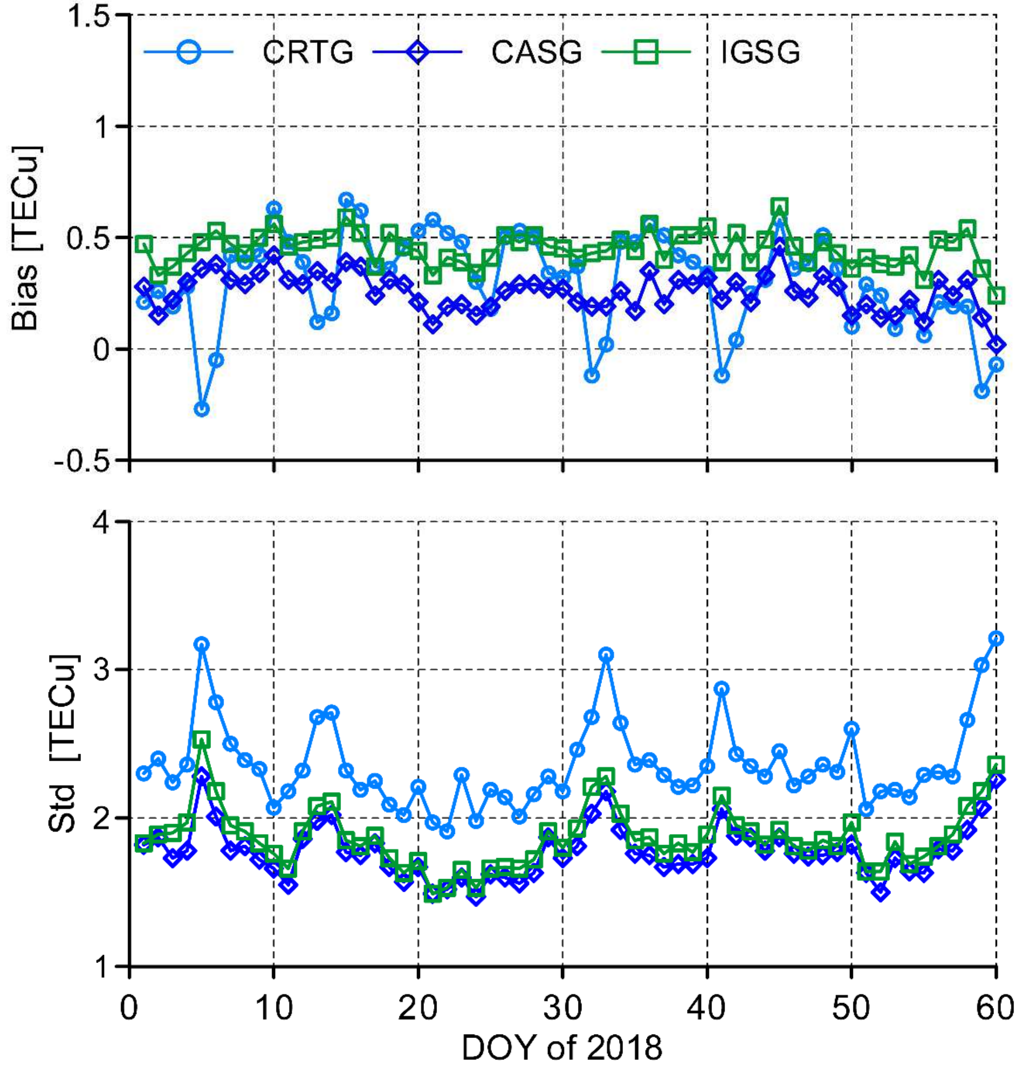




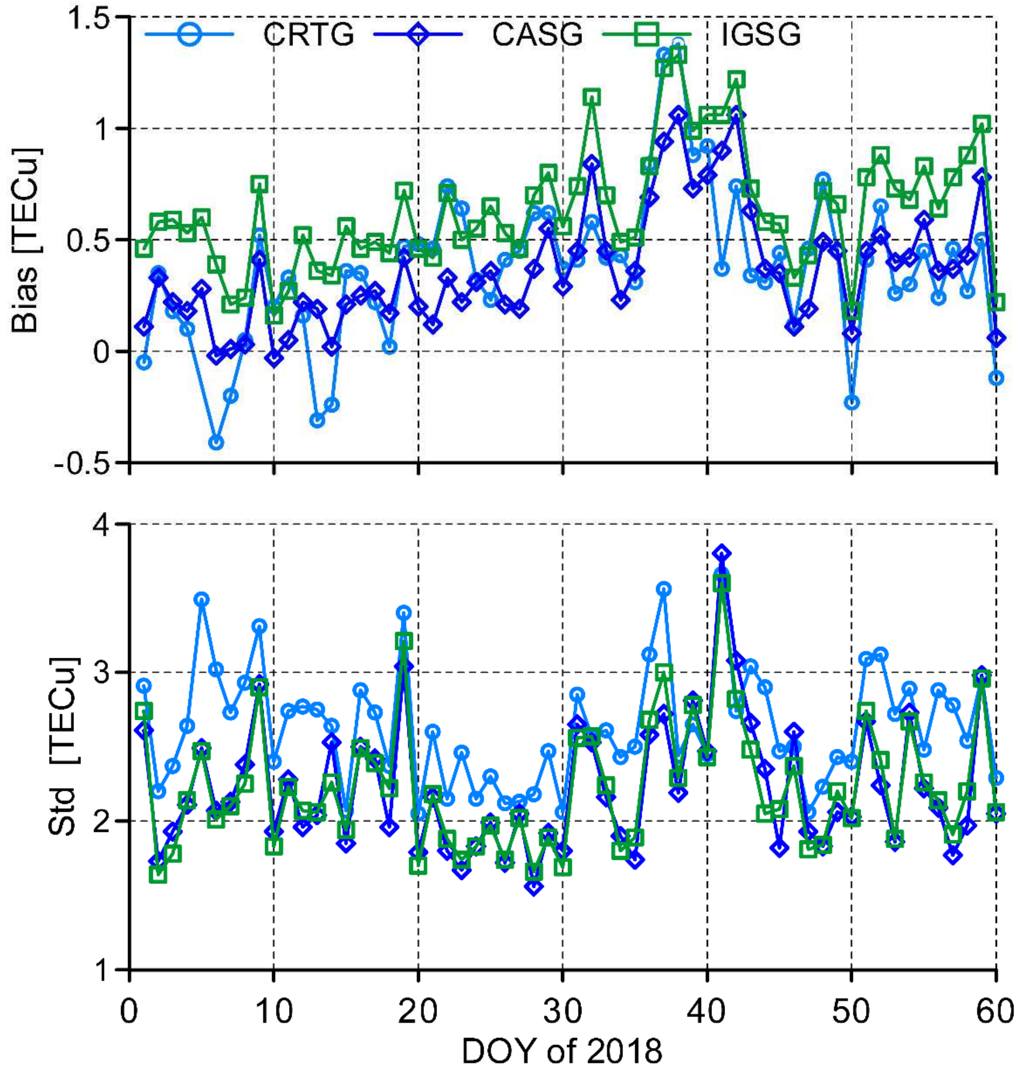
- TEC sources: GPS dsTEC
- Time: UT 0:00-04:40, 001/2018
- Data interval: 30 s
- GPS satellite: G23

- TEC sources: DORIS dsTEC
- Time: UT 17:00-17:25, 001/2018
- Data interval: 10 s
- Altimeter satellite: Jason-3

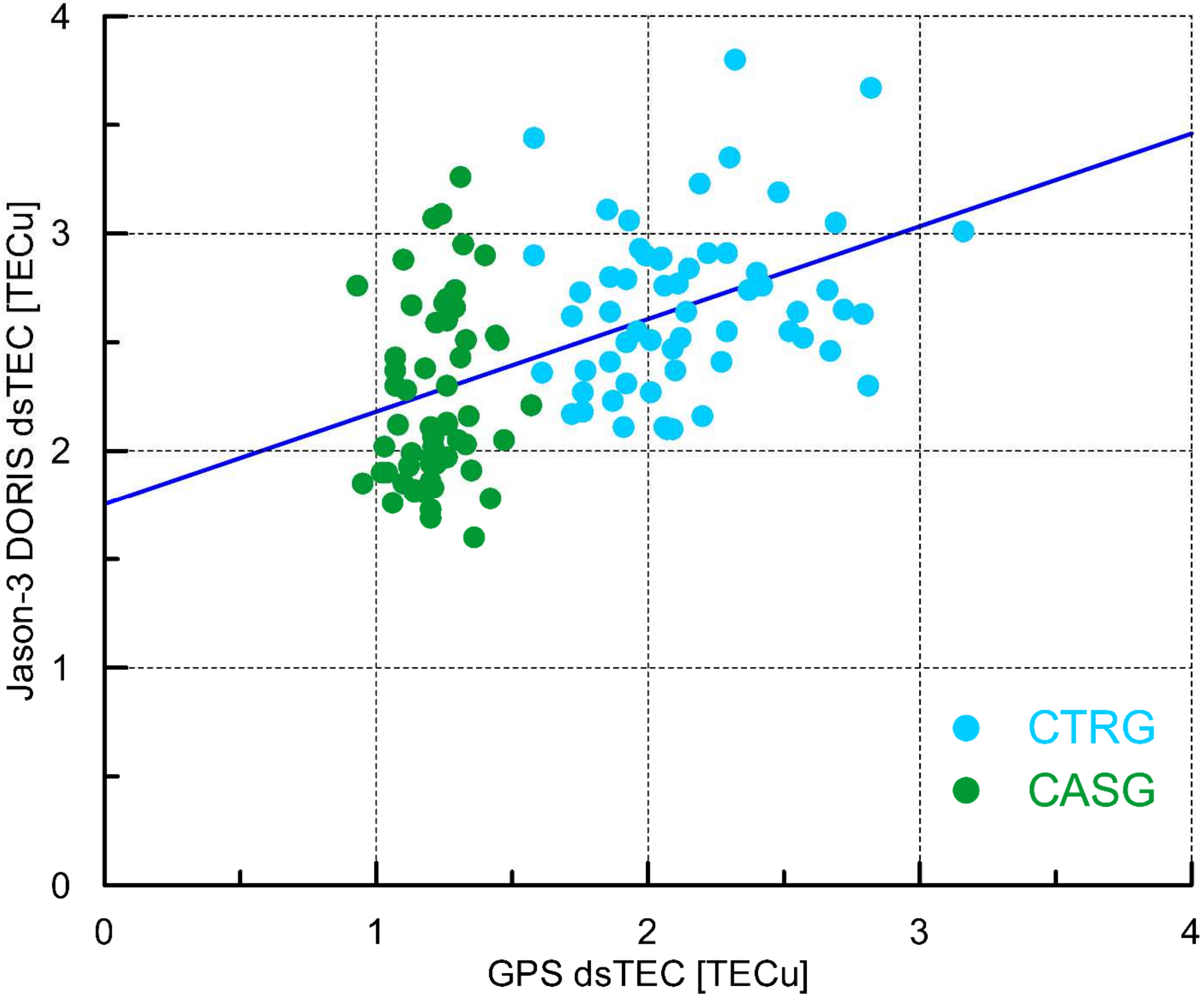
- Comparison w.r.t GPS dsTEC



- Comparison w.r.t Jason-3 DORIS dsTEC



- Relationship between GPS and Jason-3 DORIS dsTEC errors



Comparison of RT and final GIMs w.r.t diff TEC sources (001-060, 2018)

		CRTG*	CASG*	IGSG*
w.r.t GPS vTEC	Bias	-0.11	-0.09	0.64
	Std	1.68	0.83	1.03
	Rms	2.17	1.22	1.51
w.r.t GPS dsTEC	Bias	0.31	0.26	0.45
	Std	2.36	1.77	1.86
	Rms	2.45	1.86	1.97
w.r.t DORIS dsTEC	Bias	0.37	0.34	0.63
(Jason-3)	Std	2.64	2.20	2.22
	Rms	2.69	2.26	2.34

(*Unit: TECu)

Conclusions

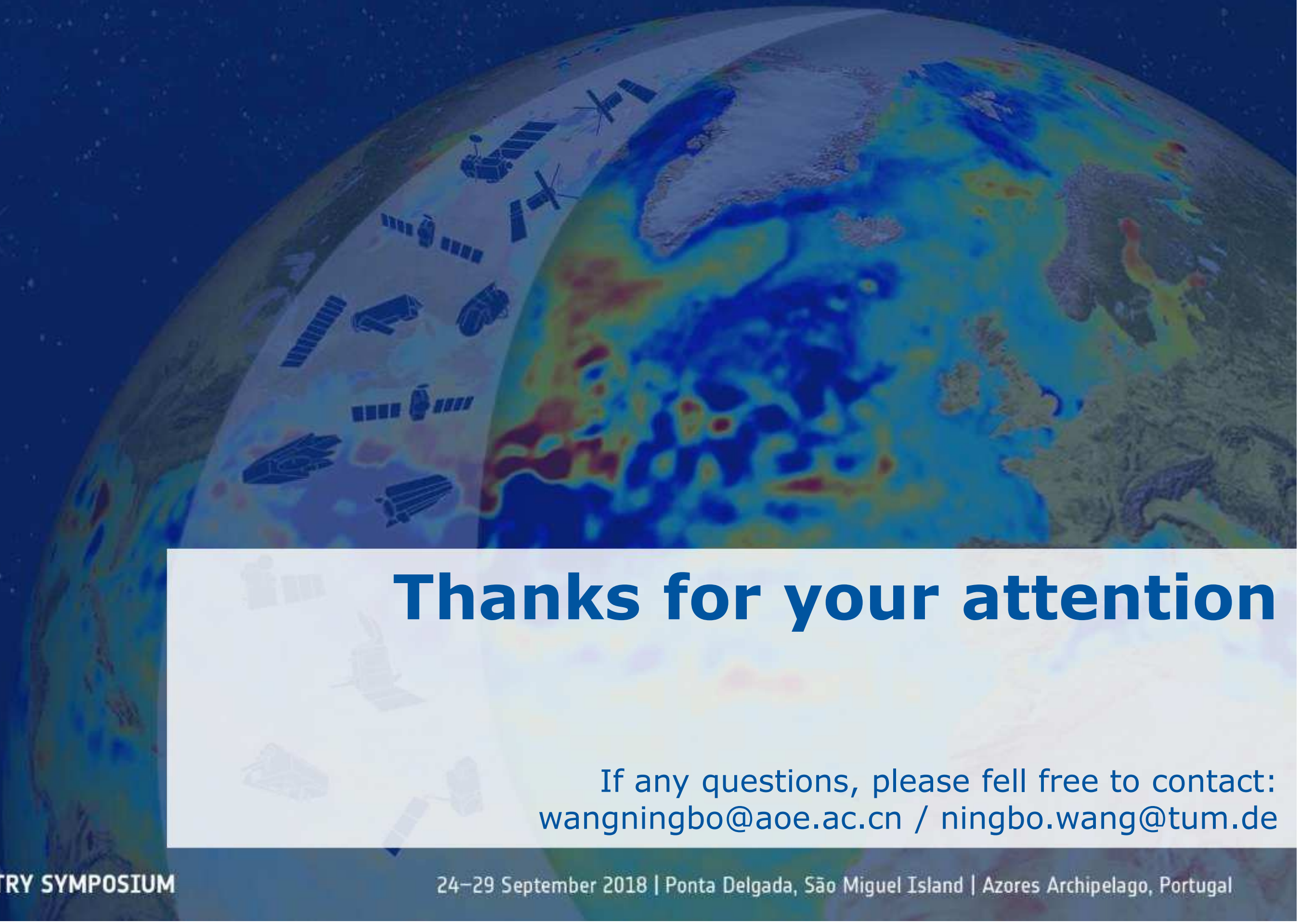
- Extension of current method to validate the performance of IONO electron content models using DORIS data (in addition to GNSS techniques)
- Easy handling of DORIS carrier phase measurements compared to that of GNSS
- Quality of DORIS-derived dsTEC info comparable to that of GPS
- Validation of CAS's real-time (URTG) and final (CASG) GIMs w.r.t dsTEC sources derived from GPS and Jason-3 DORIS phase observations
- RMS of URTG compared to GPS and DORIS dsTEC are 2.45 and 2.69 TECu, respectively
- Advantages of DORIS technique (site distribution, frequencies, independent assessment)

Future work

- **Routine generation** of relative IONO TECs using dual-frequency phase observations of DORIS-series missions

- Definition of **DIRIS TEC file format (internal)**, and make them available to users who are interested via CAS FTP archive

- **Application** of DORIS data in ionosphere sensing
  - Ionospheric irregularity monitoring (RT or NRT)
  - Global ionospheric map generation (TEC modeling)



Thanks for your attention

If any questions, please fell free to contact:
wangningbo@aoe.ac.cn / ningbo.wang@tum.de