An update to the analysis of changes in the spatial distribution of the I_{NDD} index

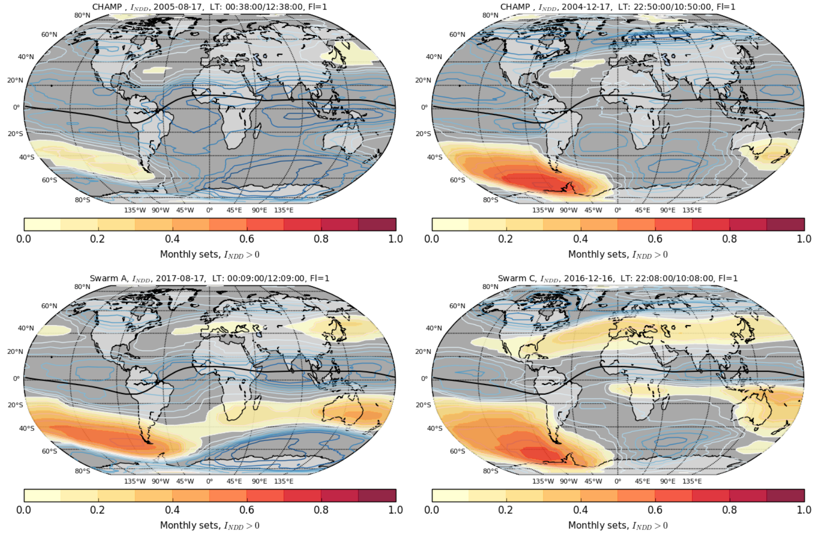
CBK & OBSEE

PM2
AGH

6/7.03.2019

Swarm vs CHAMP - Question from MS

What causes such significant difference in spatial distribution of NPDEs?

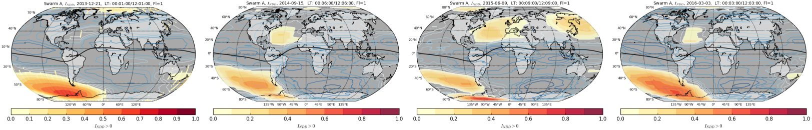


Main problem: Variations in B and I_{NDD}

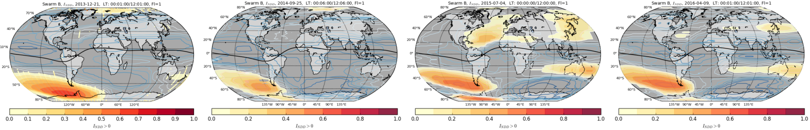
- Goal: **To show that on longer time-scale changes in B-field may have an impact on the WSA structure**
- Above the F-peak, reversed diurnal cycle is a permanent ionospheric feature
- Spatial patterns of I_{NDD} are mainly modulated by LT and seasonal changes - Well confirmed after 5 years of Swarm mission

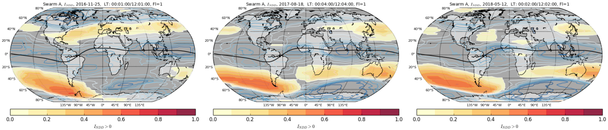
Spatial patterns of I_{NDD} - seasonal changes

Alpha:

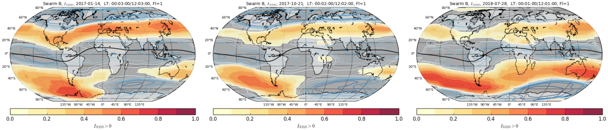


Bravo:



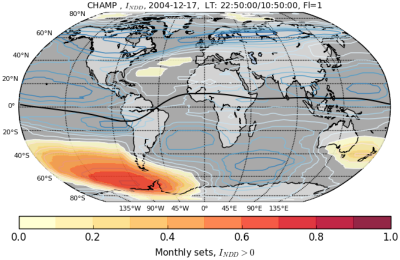


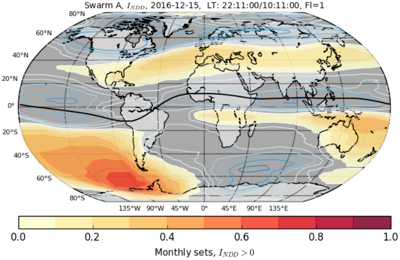
A: (2018-05-12)



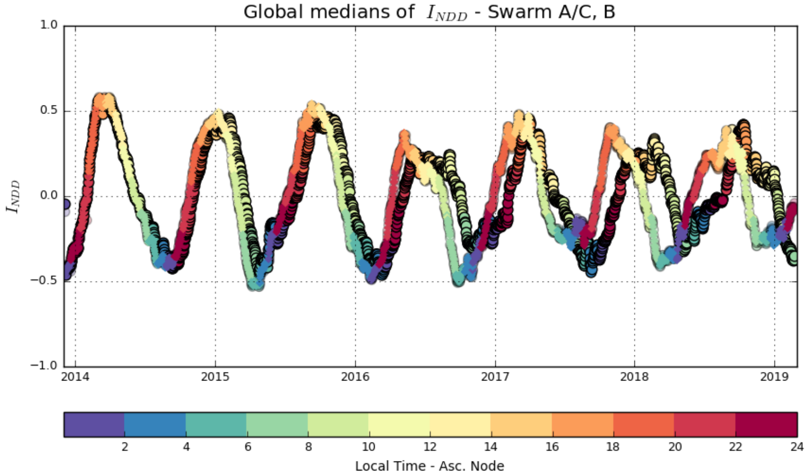
B: (2018-07-28)

Swarm A vs CHAMP - December solstice - 12 years difference





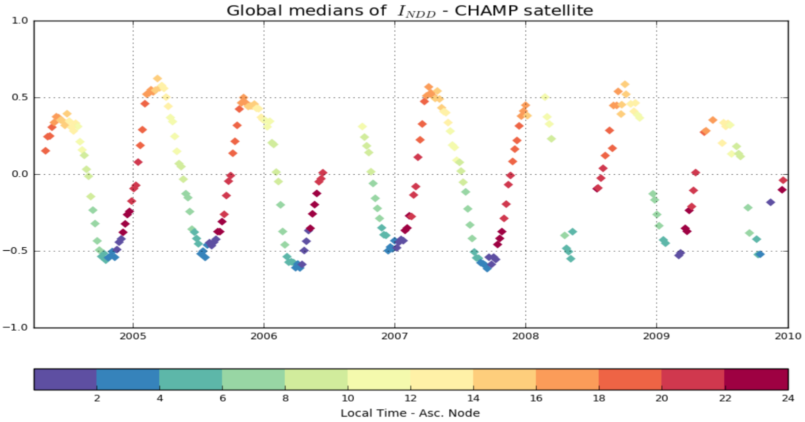
Discrepancies in I_{NDD} between Alpha/Charlie and Bravo are more related to the progressing differences in LTs rather than orbit's altitude



But, ... amplitude of the index is gradually decreasing in time

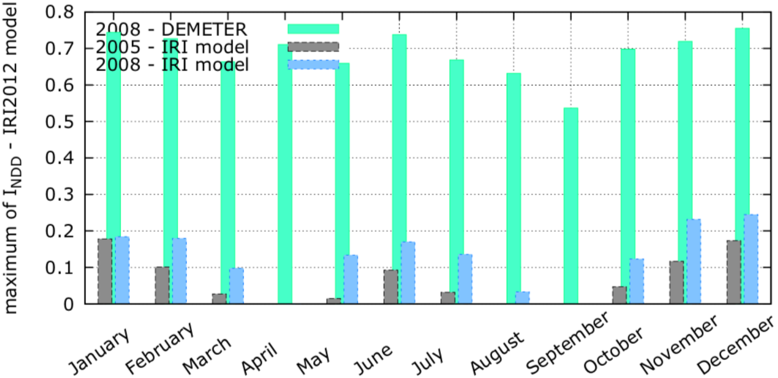
Decreasing amplitude of I_{NDD}

- Launch of Swarm mission - solar maximum
- As mission progresses solar activity is decreasing
- Currently, we are in solar min. - conditions similar to those in 2008/2009 - decreasing trend was less obvious for CHAMP

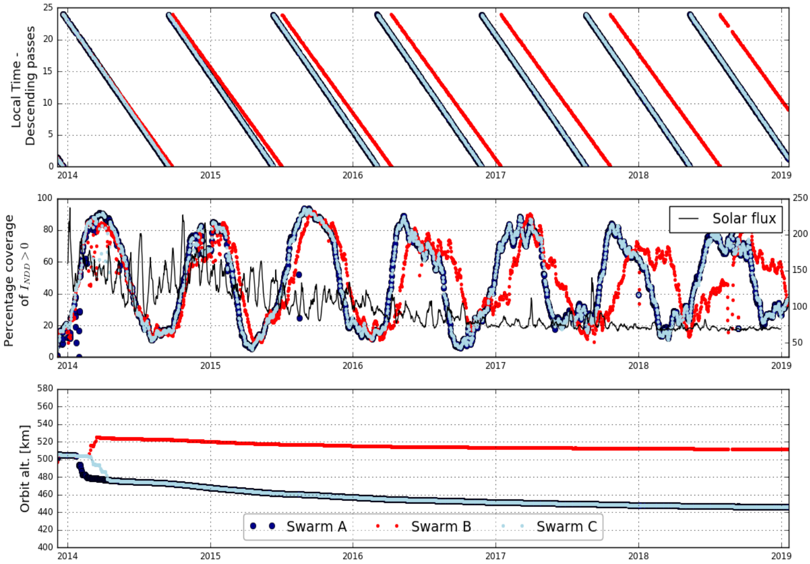


Solar activity dependence on DEMETER

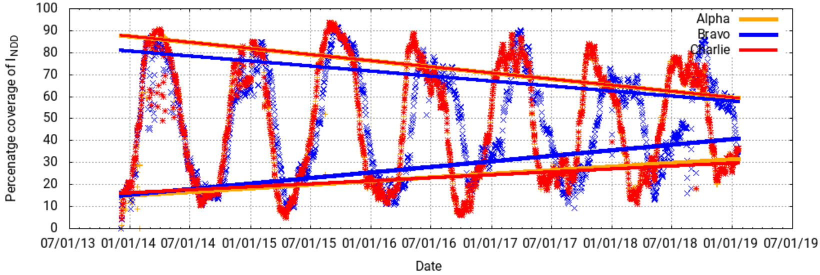
- Why it matters? The relationship between maximum concentration and solar indices is critical in ionospheric empirical models. A linear pattern is used in some models.
- IRI adopts a two-segment linear model to simulate the solar activity dependence of electron density - A threshold of the yearly moving-average F10.7 or R is empirically set - NmF2 increases linearly with the solar index before the threshold is reached, while it is constant afterward.



Percentage coverage of an anomaly

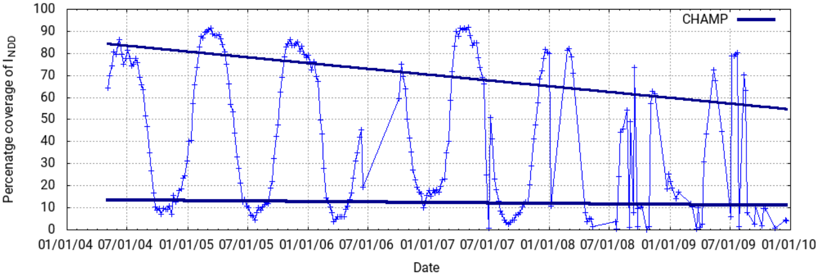


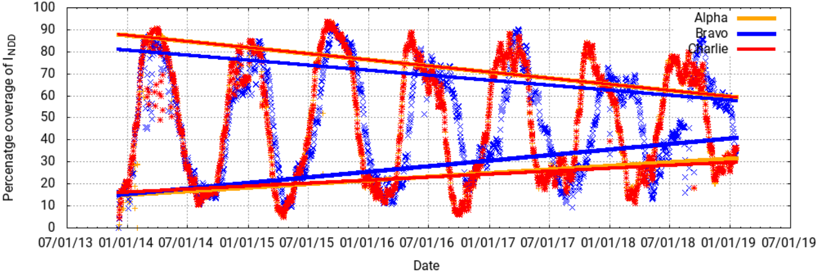
- Trend of percentage coverage of regions where $I_{NDD} > 0$ - proportional to the amplitude of the index

- $P_{cov}(I_{NDD} > 0)$ - time series of percentage coverage of regions $I_{NDD} > 0$
- Linear regression (f(t) =a*t+b) $P_{cov}(I_{NDD} > 0)$ @ LT
- 

For LTs corresponding to diurnal extrema (noon/midnight)

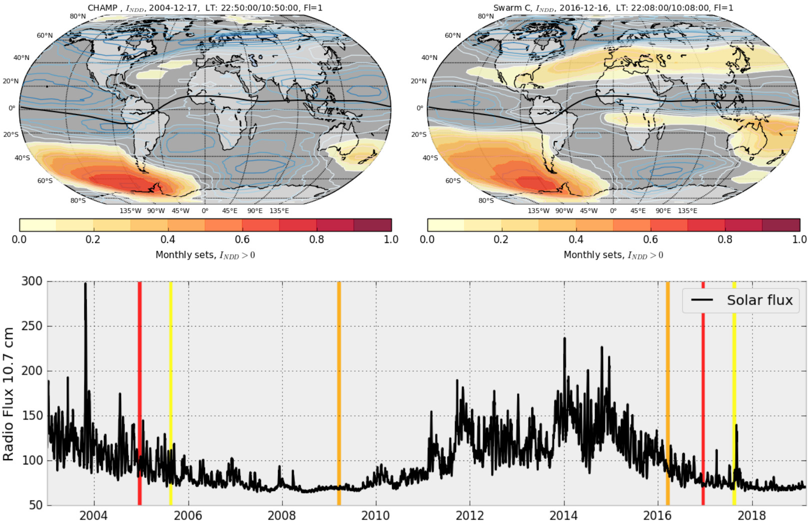
Swarm & CHAMP - Trends in $P_{cov}(I_{NDD} > 0)$ - noon/midnight





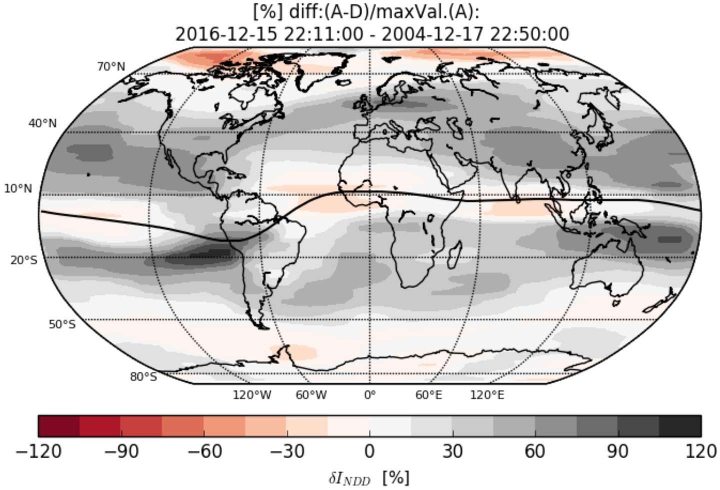
- For ground-based observations: TEC and N_mF2 linearly increase with solar proxies at low and moderate solar activity levels, but the linearity breaks down at a higher activity level at all stations.
- At the current stage of the mission, Swarm covers similar part of solar cycle, as CHAMP did.
- Common feature for both missions: when solar activity decreases, larger variations in the global averaged value of the index occur - Which suggests that definition of "nighttime" and "daytime" ionosphere is not exact for low levels of solar ionization

Swarm C vs CHAMP - December solstice - 12 years difference

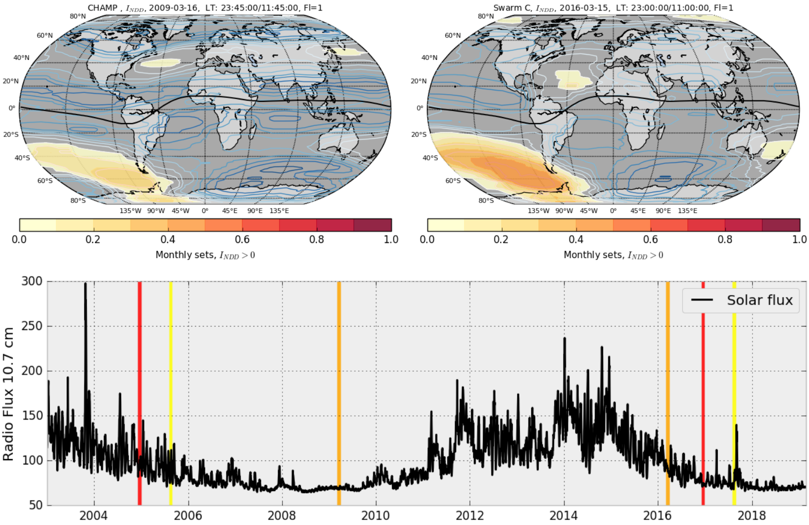


CHAMP and Swarm Alpha - δI_{NDD}

$$\delta_{INDD} = \frac{(I_{NDD}(T1) - I_{NDD}(T2))}{maxVal(I_{NDD}(T1))} * 100\%$$

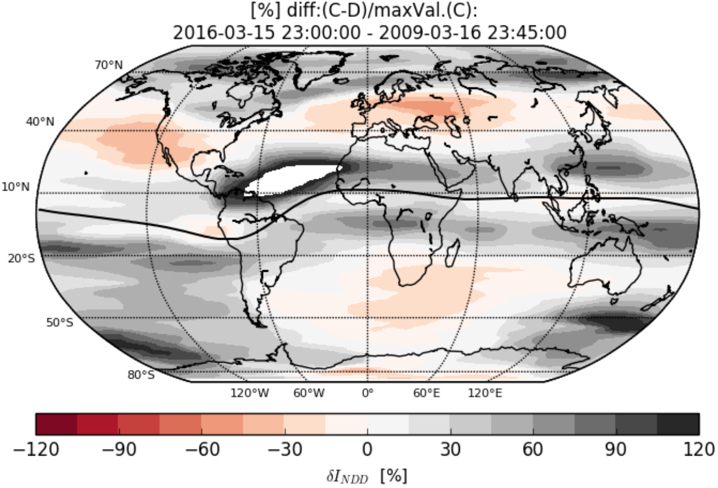


Swarm vs CHAMP - March equinox - 7 years apart

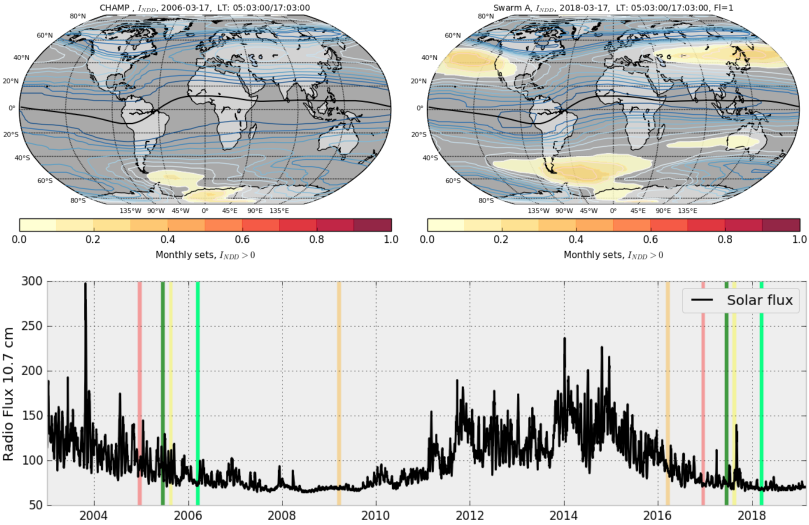


CHAMP and Swarm Charlie - δI_{NDD} - March equinox

$$\delta_{INDD} = \frac{(I_{NDD}(T1) - I_{NDD}(T2))}{maxVal(I_{NDD}(T1))} * 100\%$$

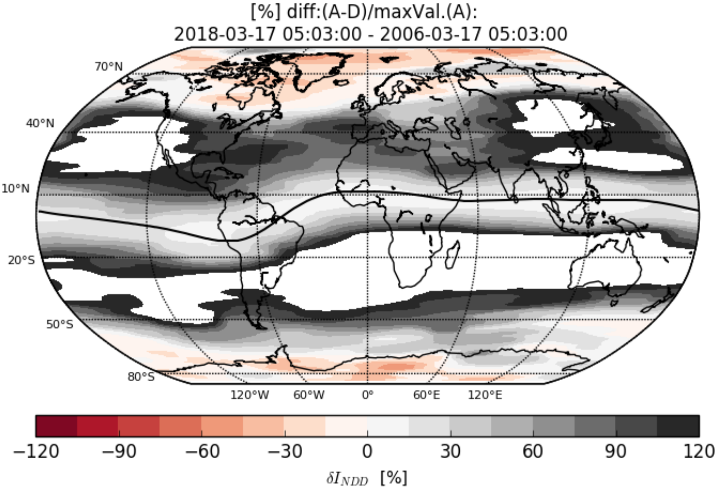


Morning sector - March equinox - CHAMP - Swarm A



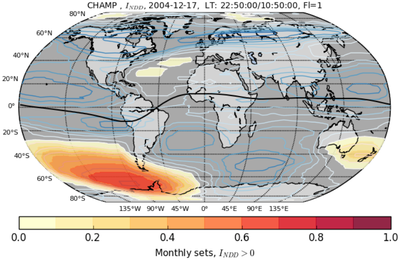
CHAMP and Swarm A - δI_{NDD} - Morning sector - March equinox

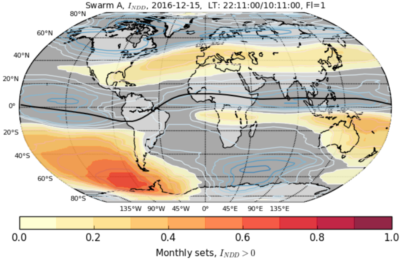
$$\delta_{INDD} = \frac{(I_{NDD}(T1) - I_{NDD}(T2))}{maxVal(I_{NDD}(T1))} * 100\%$$

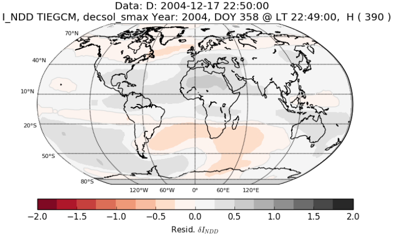


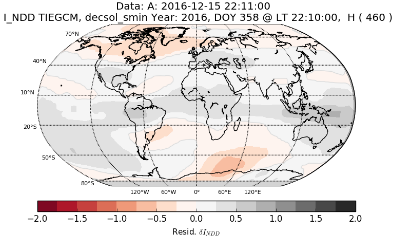
CHAMP, Swarm and TIEGCM - I_{NDD} Residuals

$$Resid = I_{NDD}(Obs_{Monthly\ Com.}) - I_{NDD}(Model_{Ref.\ Day})$$



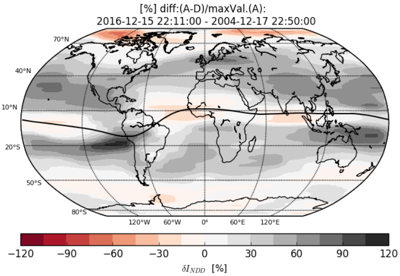






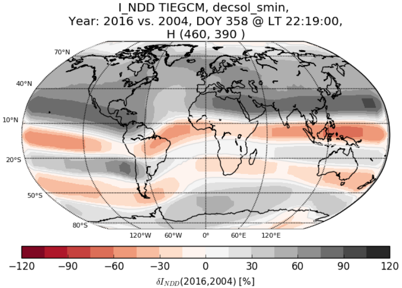
$$\delta_{INDD} = \frac{(I_{NDD}(T1) - I_{NDD}(T2))}{maxVal(I_{NDD}(T1))} * 100\%$$

Alpha and CHAMP



Comparison between Swarm A ("A") and CHAMP (denoted as "D")

TIEGCM



Solar min.(2016) and max(2004) - 12 years difference

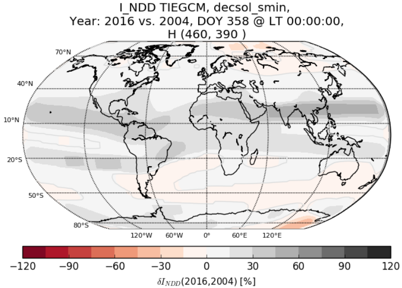
Combination of two main factors, which can contribute to observed changes:

- different levels of solar flux;
- changes in the magnetic field strength and configuration;
- different settings for magnetic activity - (more important for short term variations)

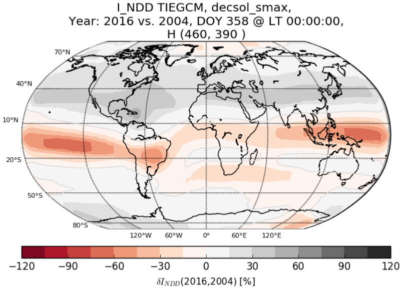
Examine simplified cases:

- Scenrio #1: **Fixed solar flux: for both periods 2016 and 2004**
- Scenario #2: Same year - different levels of solar activity

Solar min for both decmeber solstices (2016/2004)

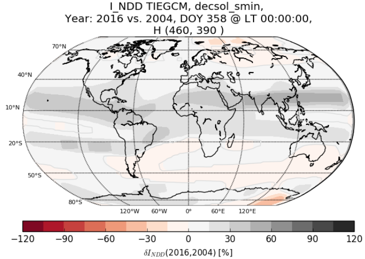


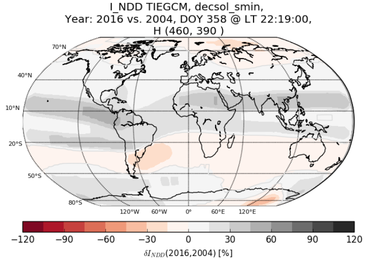
Solar max. for both decmeber solstices (2016/2004)



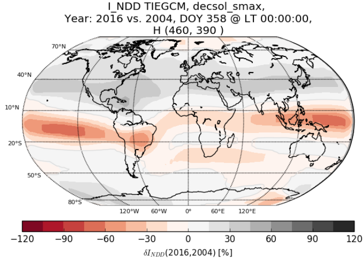
Scenario #1 - Towards understanding of δI_{NDD} - LT dependence

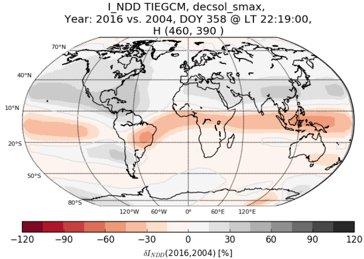
Sol. Min.



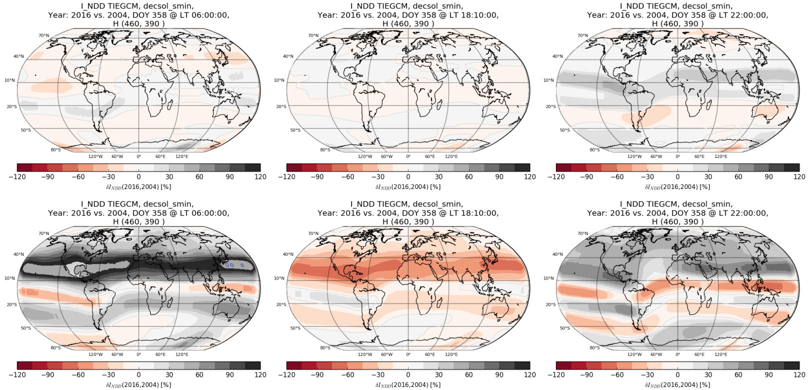


Sol. Max.





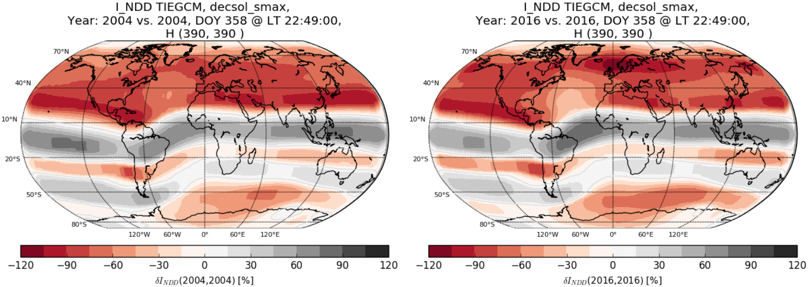
Scenario #1 - Towards understanding of δI_{NDD} - LT dependence

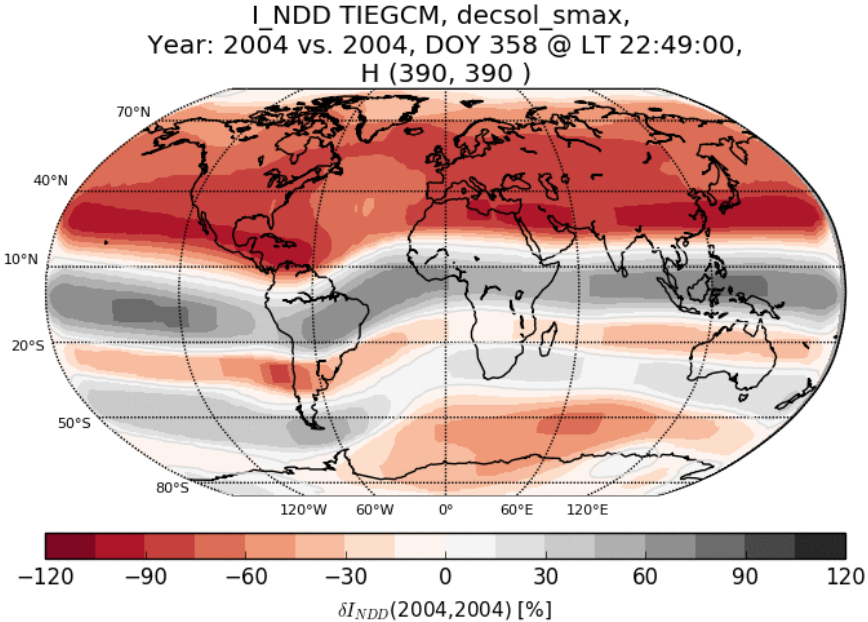


Towards understanding of δI_{NDD} - LT dependence

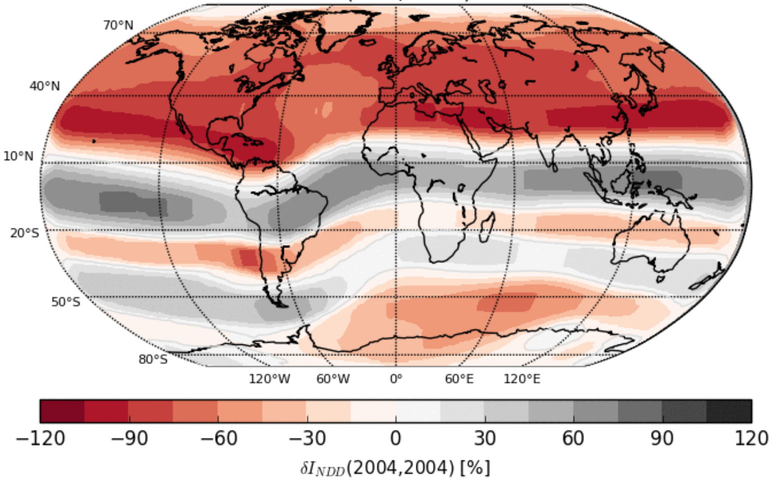
How LT changes δI_{NDD}

- Examine two cases for fixed year - difference between varying solar conditions for the same day - single altitude and LT - $\delta(s.min, s.max)$
-

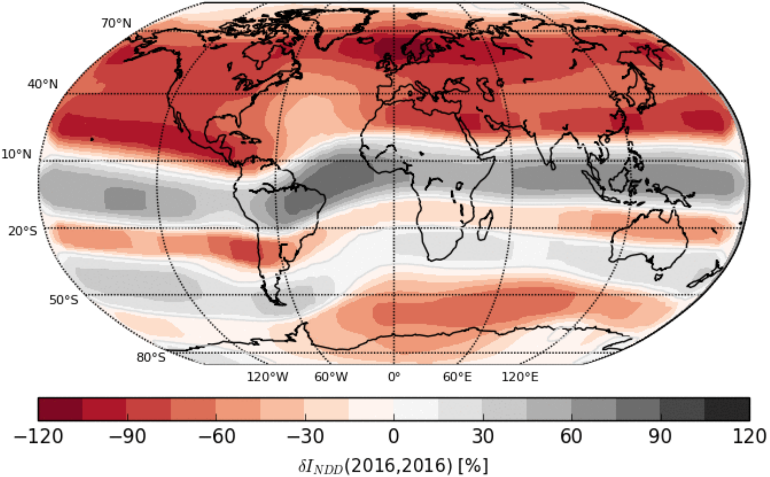



I_NDD TIEGCM, decsol_smax,
Year: 2004 vs. 2004, DOY 358 @ LT 22:49:00,
H (390, 390)
70°N
40°N
10°N
20°S
50°S
80°S
120°W
60°W
0°
60°E
120°E
−120
−90
−60
−30
0
30
60
90
120
δI_{NDD}(2004,2004) [%]

I_NDD TIEGCM, decsol_smax,
Year: 2004 vs. 2004, DOY 358 @ LT 22:49:00,
H (390, 390)



I_NDD TIEGCM, decsol_smax,
Year: 2016 vs. 2016, DOY 358 @ LT 22:49:00,
H (390, 390)

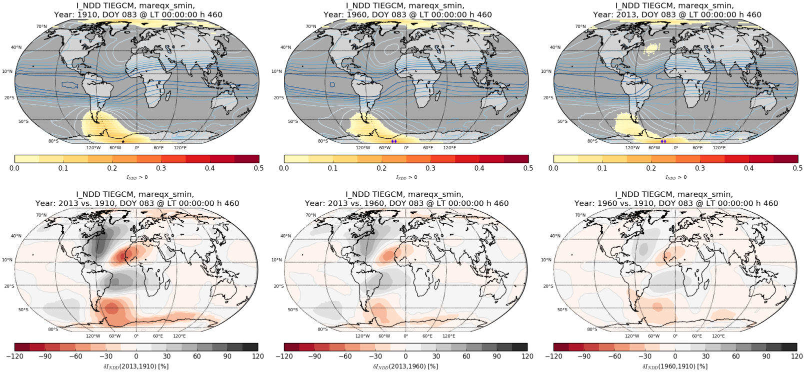


Scenario #2 - Results

- For higher values of solar fluxesFor solar min. NPDEs last longer

Magnetic field secular variations and the WSA - theoretical analysis

- March equinox for years: 1910, 1960, 2013 (&2016!!)
- Solar conditions corresponding to solar. min.
- Fixed altitude of 460 km



Summary

- According to the model, the WSA shows slight tendency to drift westward.
- For periods corresponding to decades: for LTs suitable for observations of the phenomenon, the amplitude of the index decreases in the region above the Weddel Sea and builds up more in the southern sectors of the Pacific Ocean.
- It is probable that occurrence of NPDEs (corresponding WSA-like features) in the northern hemisphere (especially in the Atlantic sector) could be contributed to long-term variations in the magnetic field