TIEGCM modeling and 3D visualizations as tools for interpretation of Swarm (and other satellite) measurements

CBK & OBSEE

TIEGCM MODEL

Physics-based global model of the ionosphere: 100-700 km
(boundaries depend on atmosphere dynamics and solar-wind state or solar-cycle phase)

Inner boundary: atmospheric tides, GSWM model

Sun/solar-wind influence: solar irradiance and magnetosphere state as dependent on solar-cycle phase
- F107 (radio emissions correlated with ionizing UV emissions)
- CTPOTEN (cross-tail potential)
- POWER (hemispheric power, auroral precipitation)

TIEGCM AUTHORS SUGGEST:

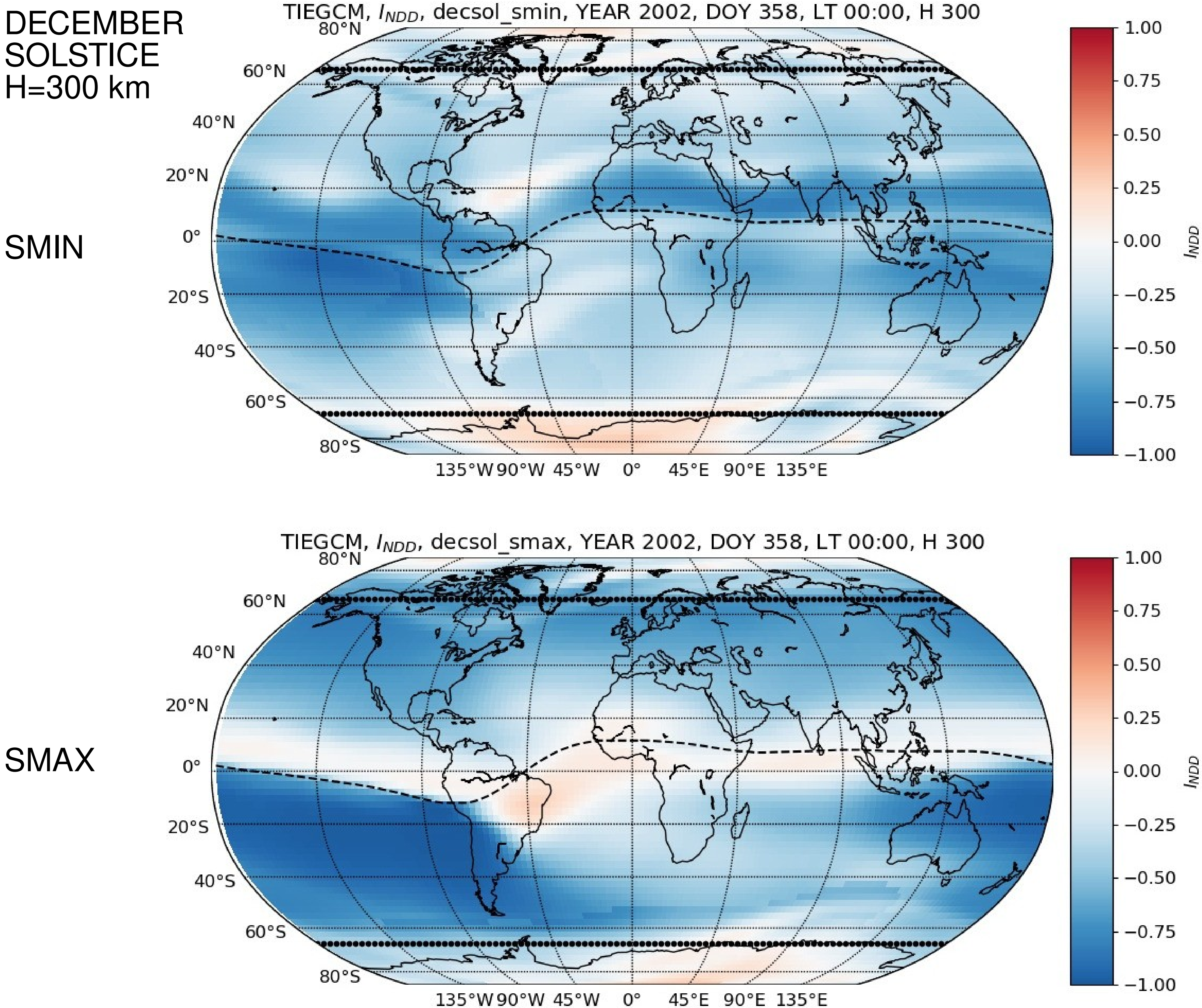
	F107	CTPOTEN	POWER
SMIN	70	30	18
SMAX	200	60	40

BENCHMARK CASES

TIEGCM simulations
Study focused on $I_{NDD}=(NE_t-NE_{t-12h})/(NE_t+NE_{t-12h})$

Four seasons: March equinox, June solstice, September equinox, December solstice
Two sets of solar conditions: solar min and max

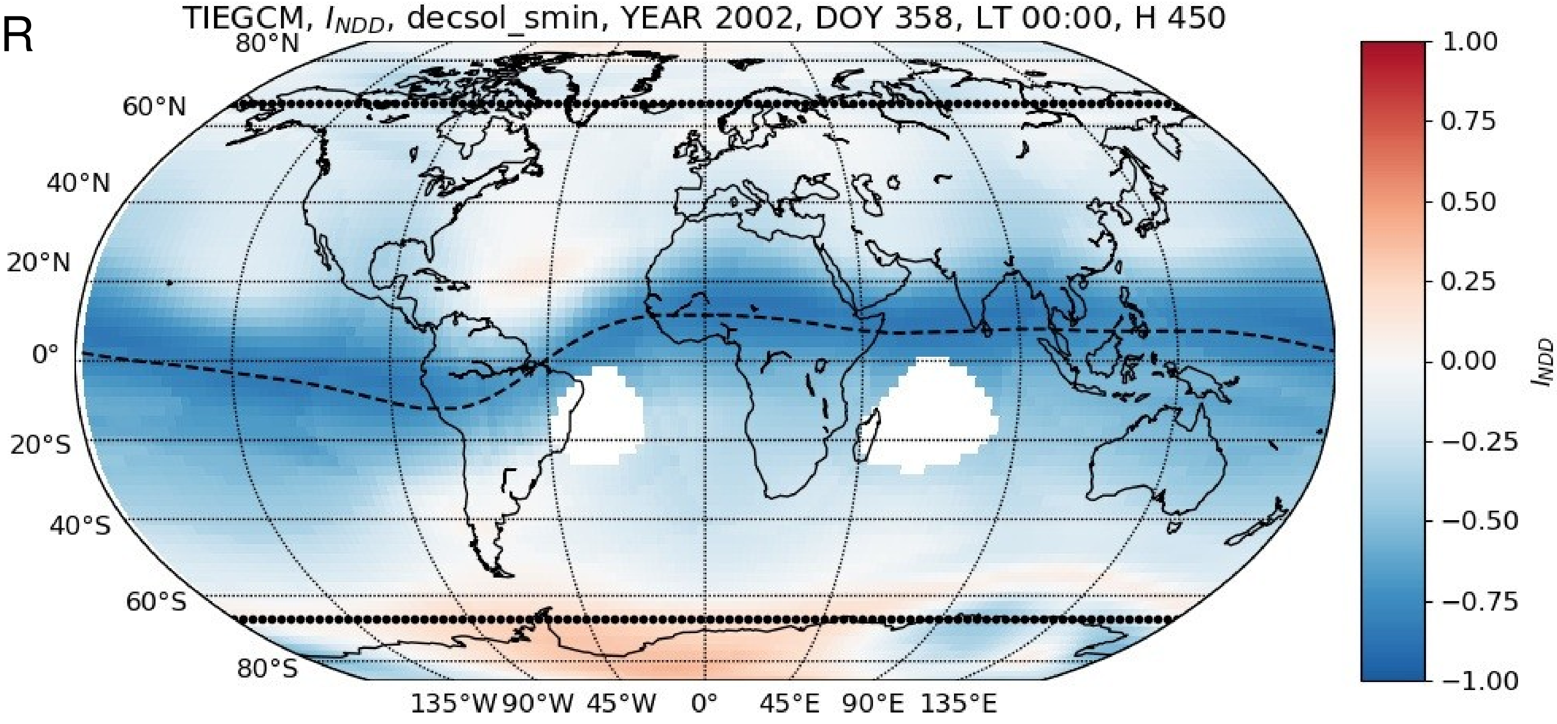
TIEGCM-benchmark cases are treated as sanctity: no change of parameters with respect to values recommended by code authors for simulated cases



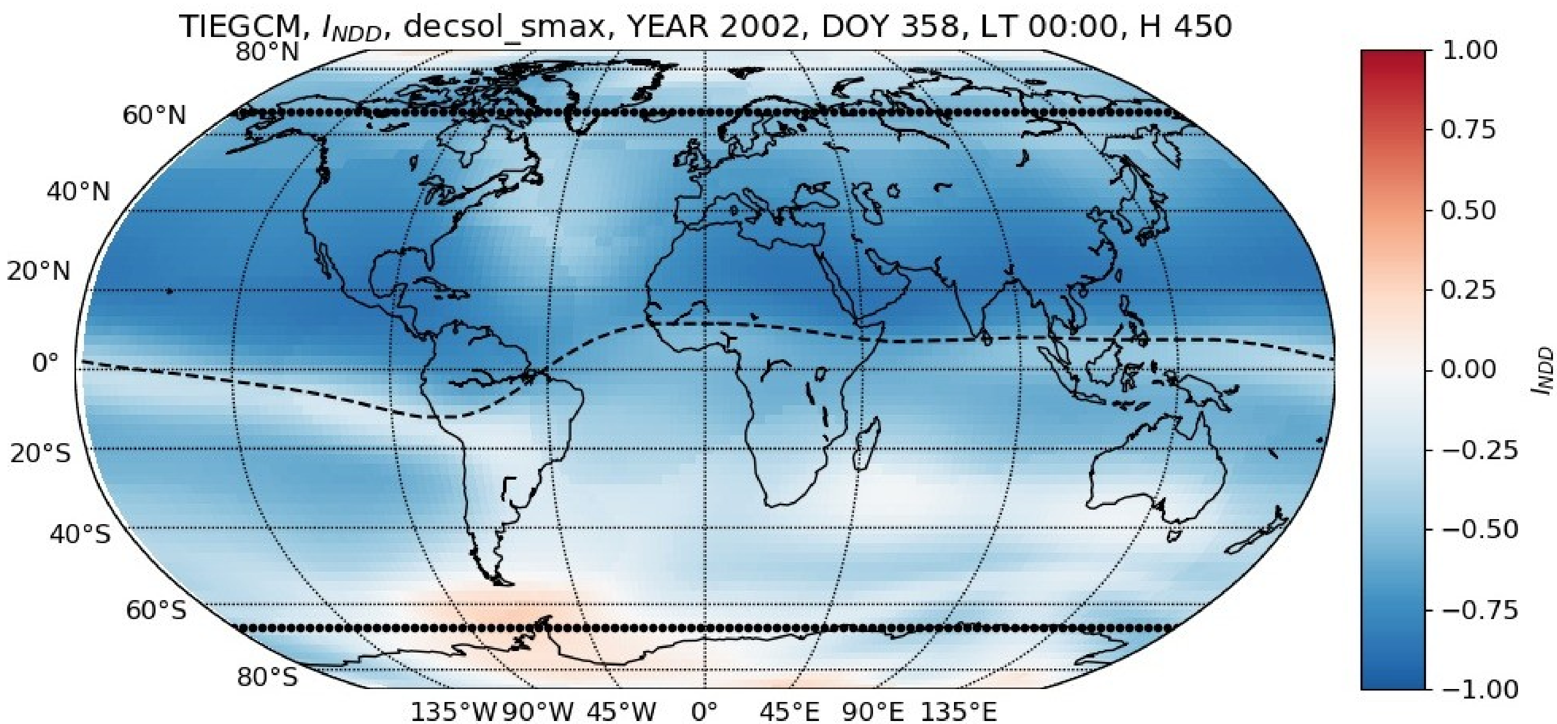
DECEMBER
SOLSTICE
H=300 km
SMIN
TIEGCM, I_{NDD}, decsol_smin, YEAR 2002, DOY 358, LT 00:00, H 300
80°N
60°N
40°N
20°N
0°
20°S
40°S
60°S
80°S
135°W 90°W 45°W 0° 45°E 90°E 135°E
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
I_{NDD}
SMAX
TIEGCM, I_{NDD}, decsol_smax, YEAR 2002, DOY 358, LT 00:00, H 300
80°N
60°N
40°N
20°N
0°
20°S
40°S
60°S
80°S
135°W 90°W 45°W 0° 45°E 90°E 135°E
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
I_{NDD}

DECEMBER
SOLSTICE
H=450 km

SMIN

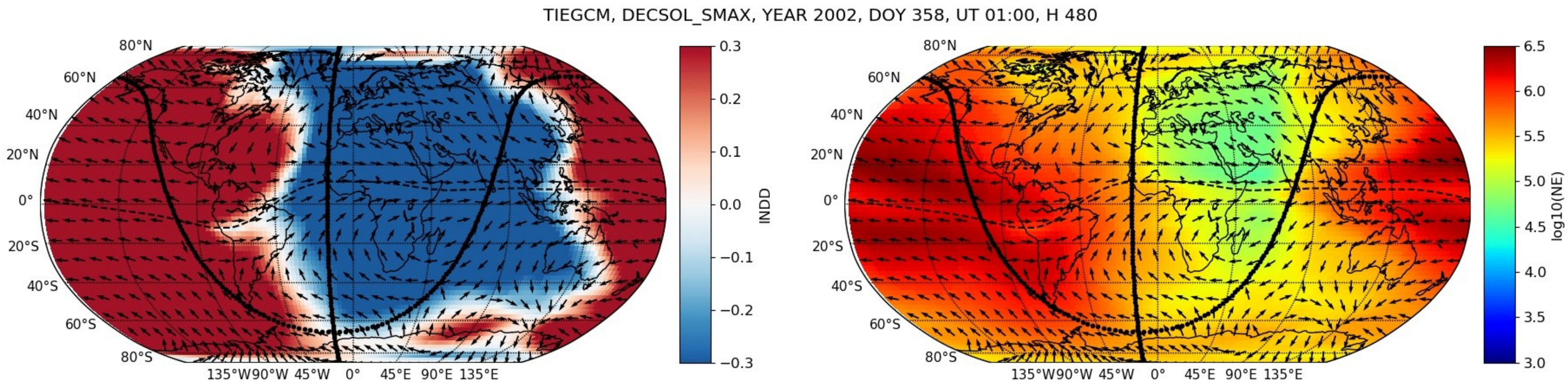


SMAX

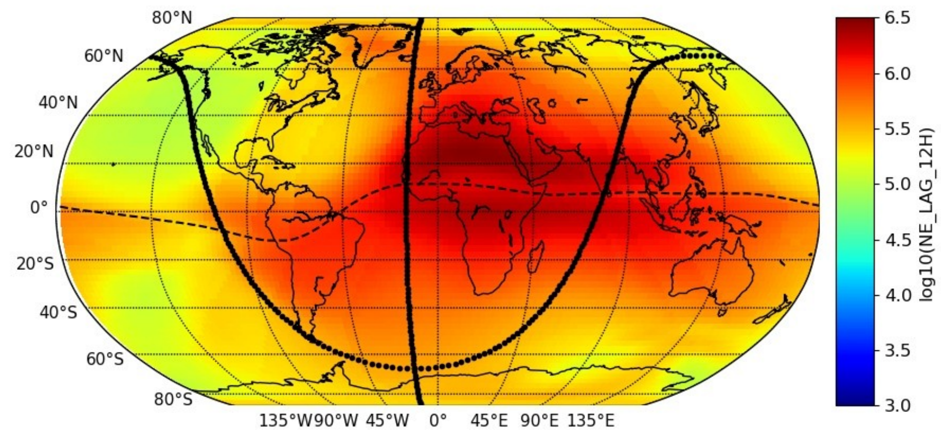


In solar max, nicely-formed Weddell Sea anomaly for H>420 km

Constant-UT maps

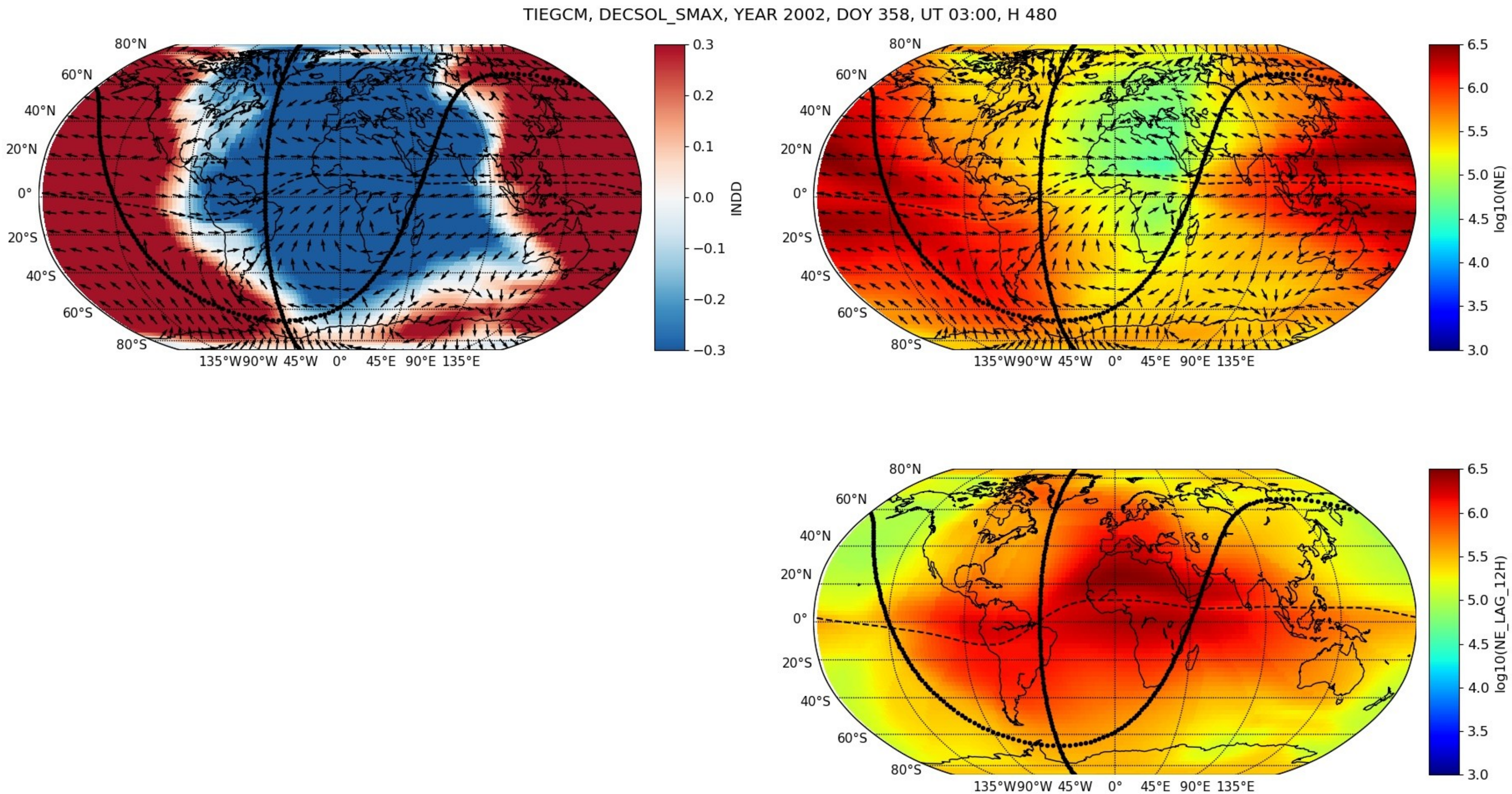


$I_{NDD}=(NE_t-NE_{t-12h})/(NE_t+NE_{t-12h})$

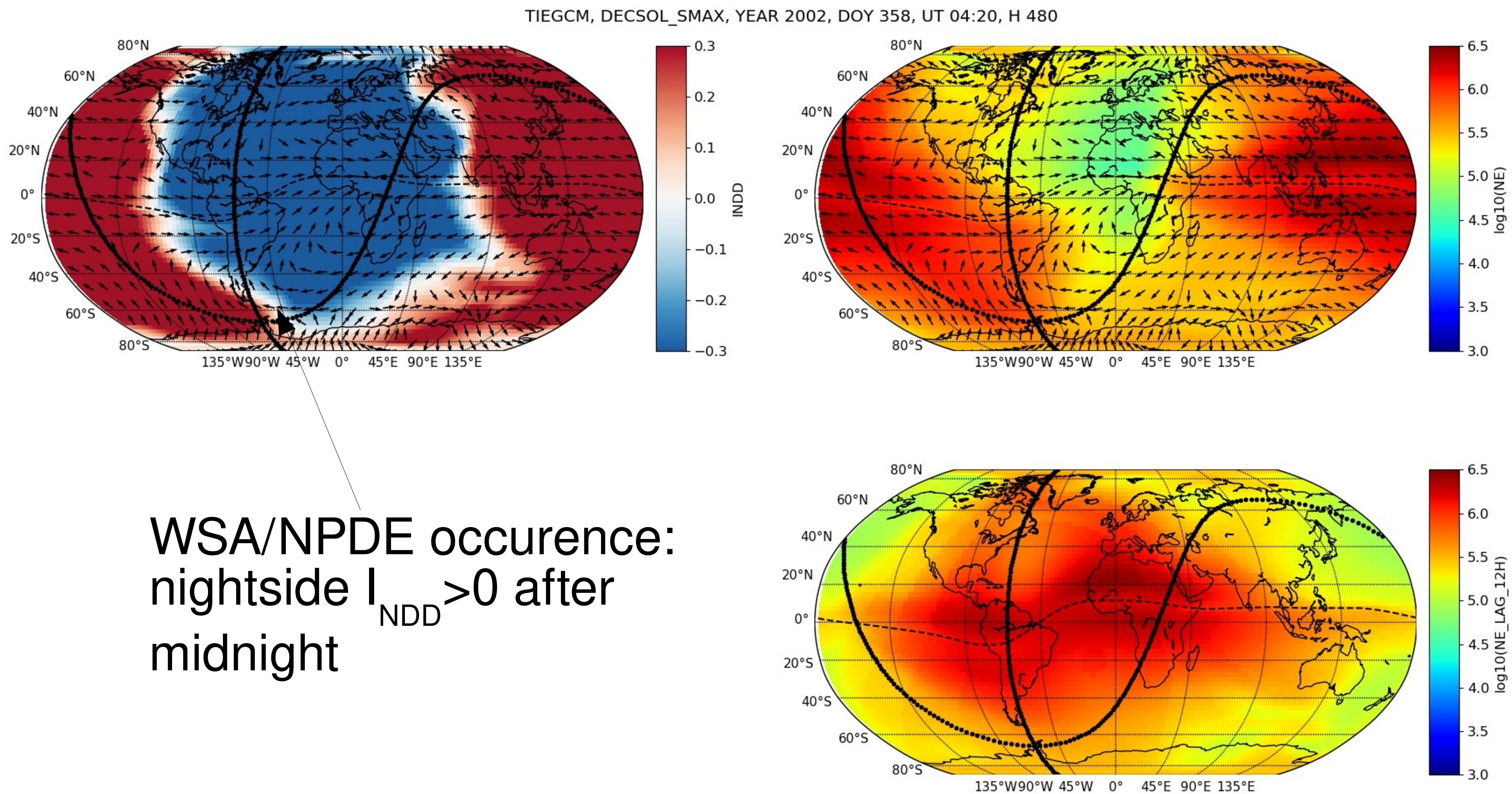


General pattern:
dayside $I_{NDD}>0$
nightside $I_{NDD}<0$
with some lag effects in post-dawn and post-dusk regions

Constant-UT maps

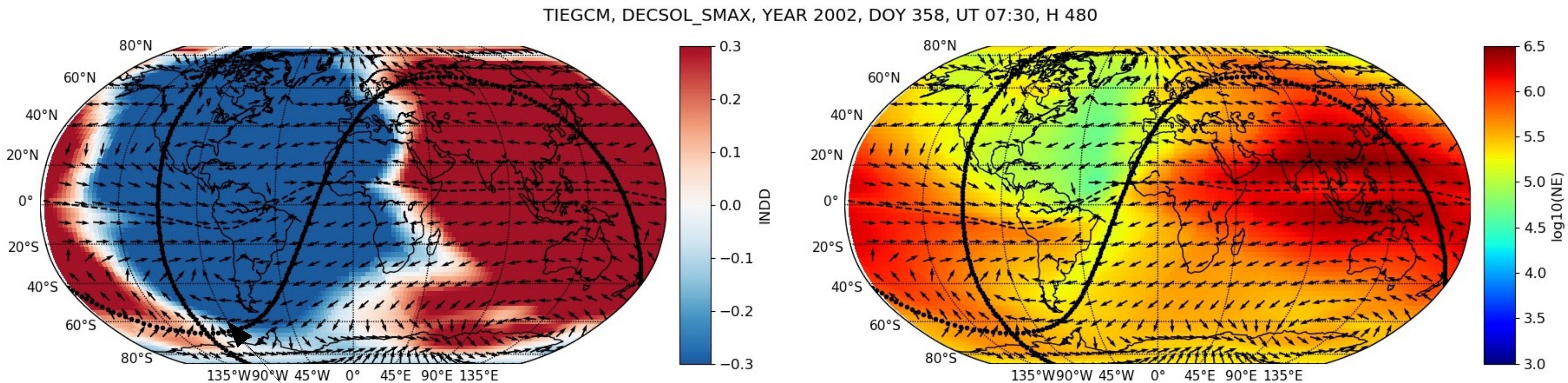


Constant-UT maps

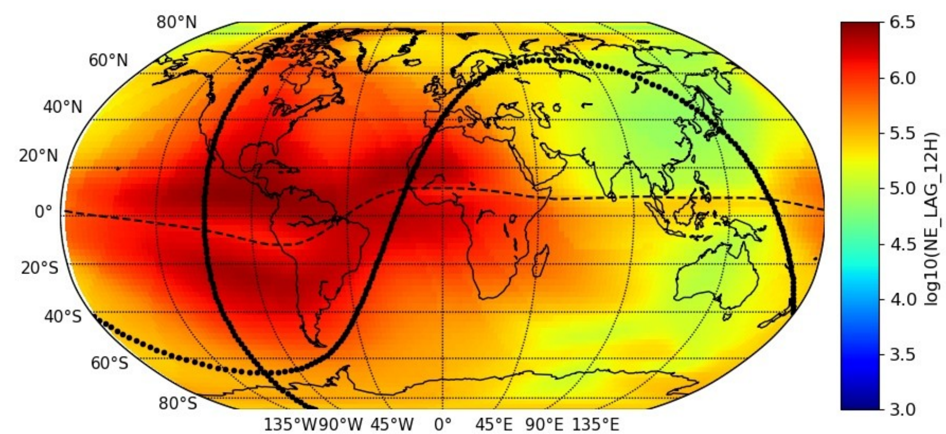


WSA/NPDE occurence: nightside I_{NDD}>0 after midnight

Constant-UT maps



WSA/NPDE occurence is a transient: after-midnight I_{NDD}>0 region disappears when we move west



WSA OCCURENCE IN TIEGCM MODEL (BENCHMARK CASES)
COMPARISON OF SEASONS
STUDY OF CONSTANT-LT MAPS AT DIFFERENT ALTITUDES
SUMMARY OF FINDINGS

WSA occurence at H>330km in solar min: March and September equinoxes

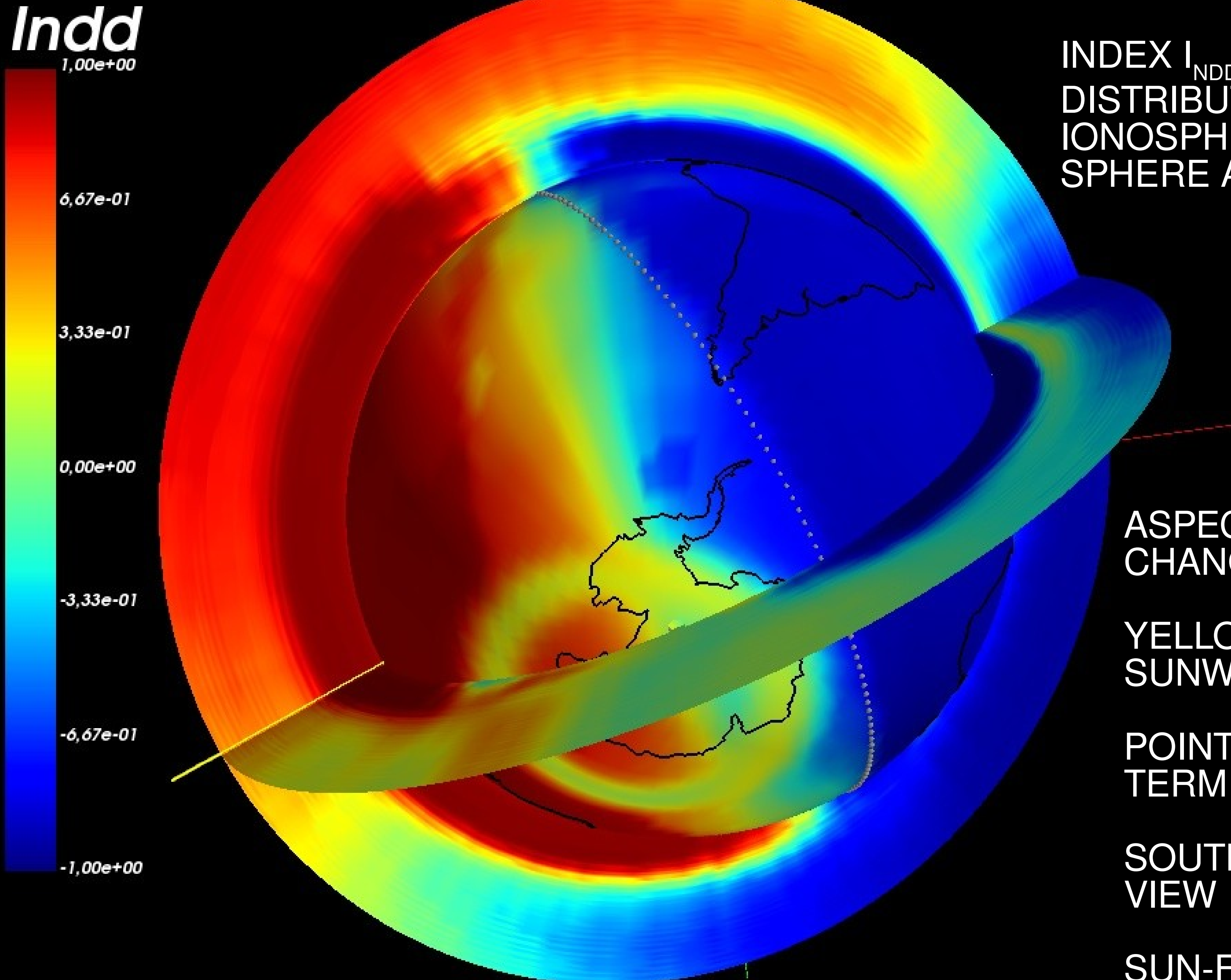
WSA occurence at H>400km in solar max: December solstice

December solstice in solar minimum is difficult to interpret, possible occurence of WSA at H>450 km

THIS ALTITUDE DEPENDENCE SUGGESTS THAT 3D VISUALIZATIONS MAY PROVIDE ADDITIONAL INSIGHT

TIEGCM SIMULATION

INDEX I_{NDD}, 3D DISTRIBUTION IN THE IONOSPHERE, SPHERE AND DISCS



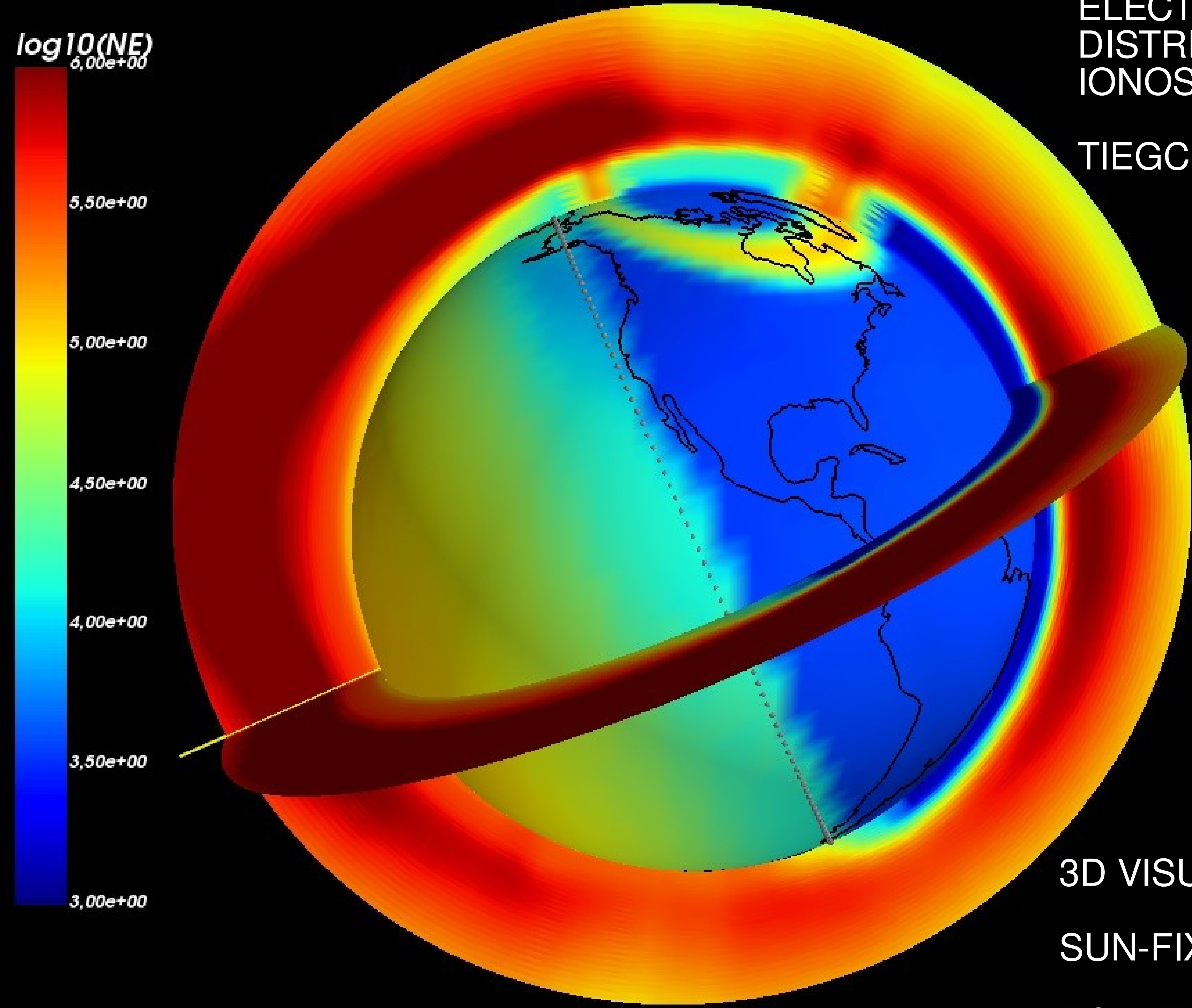
ASPECT RATIO CHANGED

YELLOW LINE SUNWARD

POINTS – SOLAR TERMINATOR

SOUTH-POLE VIEW

SUN-FIXED FRAME



ELECTRON DENSITY DISTRIBUTION IN THE IONOSPHERE

TIEGCM SIMULATION

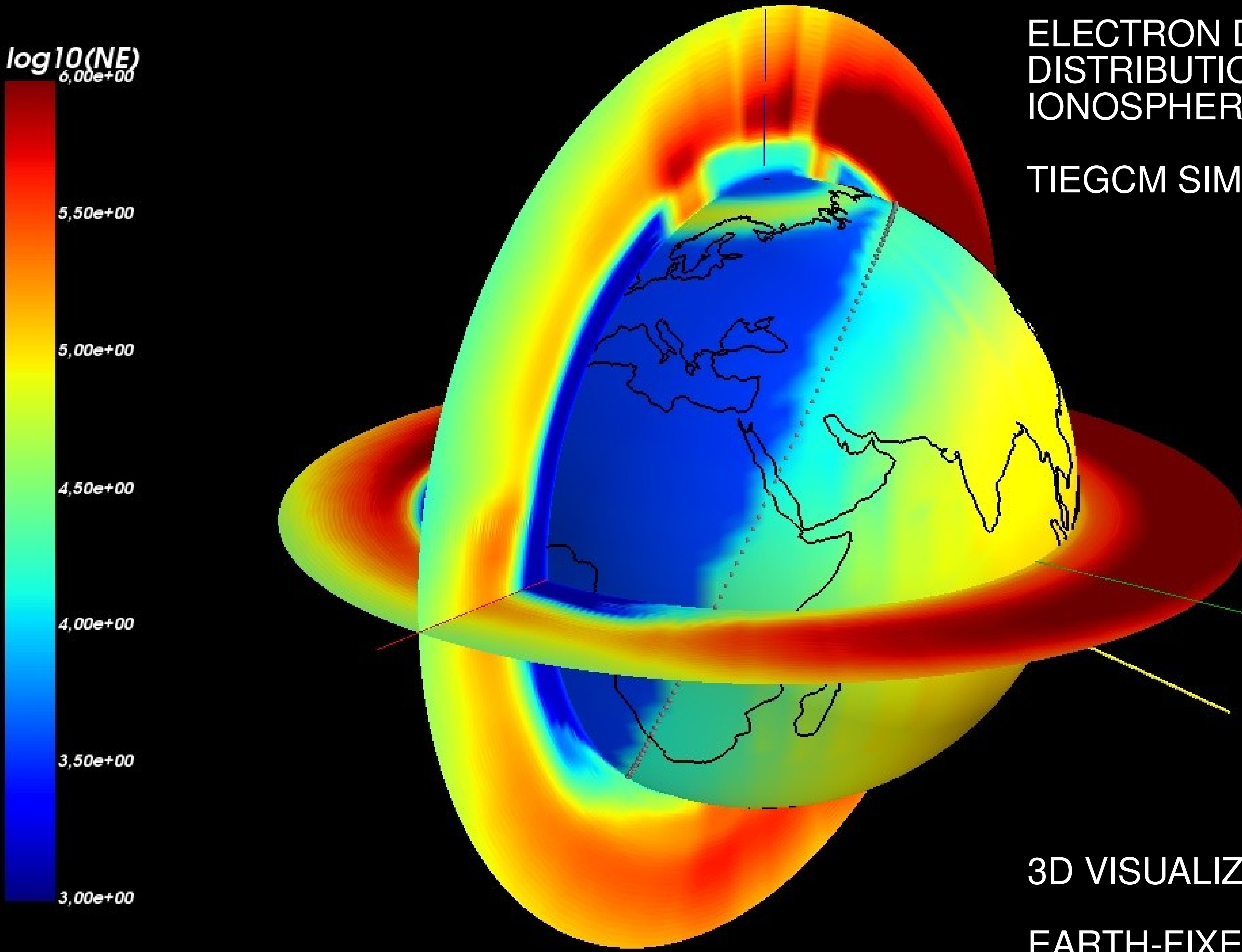
3D VISUALIZATION

SUN-FIXED FRAME

EQUATOR VIEW

ELECTRON DENSITY DISTRIBUTION IN THE IONOSPHERE

TIEGCM SIMULATION



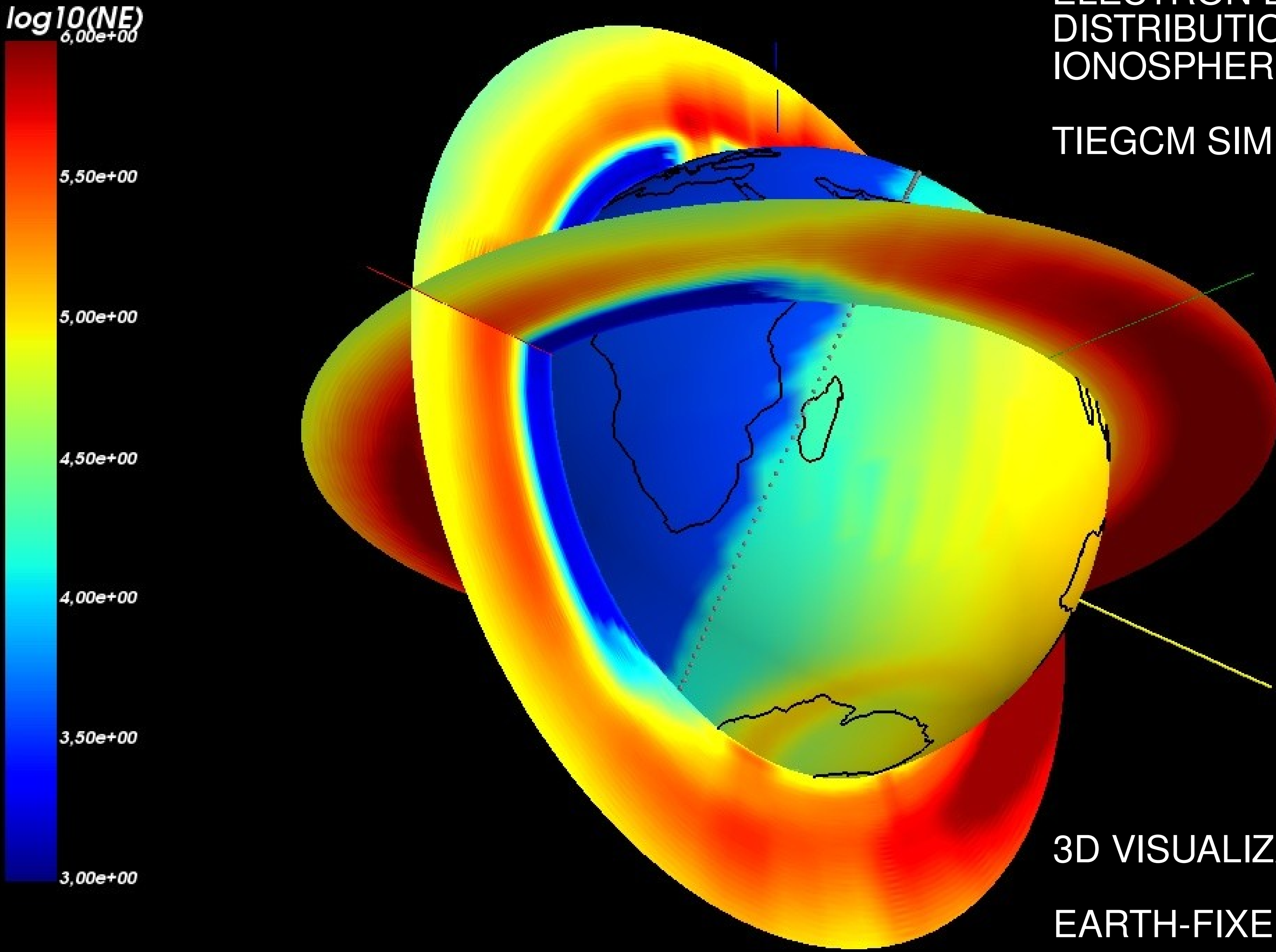
3D VISUALIZATION

EARTH-FIXED FRAME

NORTH VIEW

ELECTRON DENSITY DISTRIBUTION IN THE IONOSPHERE

TIEGCM SIMULATION



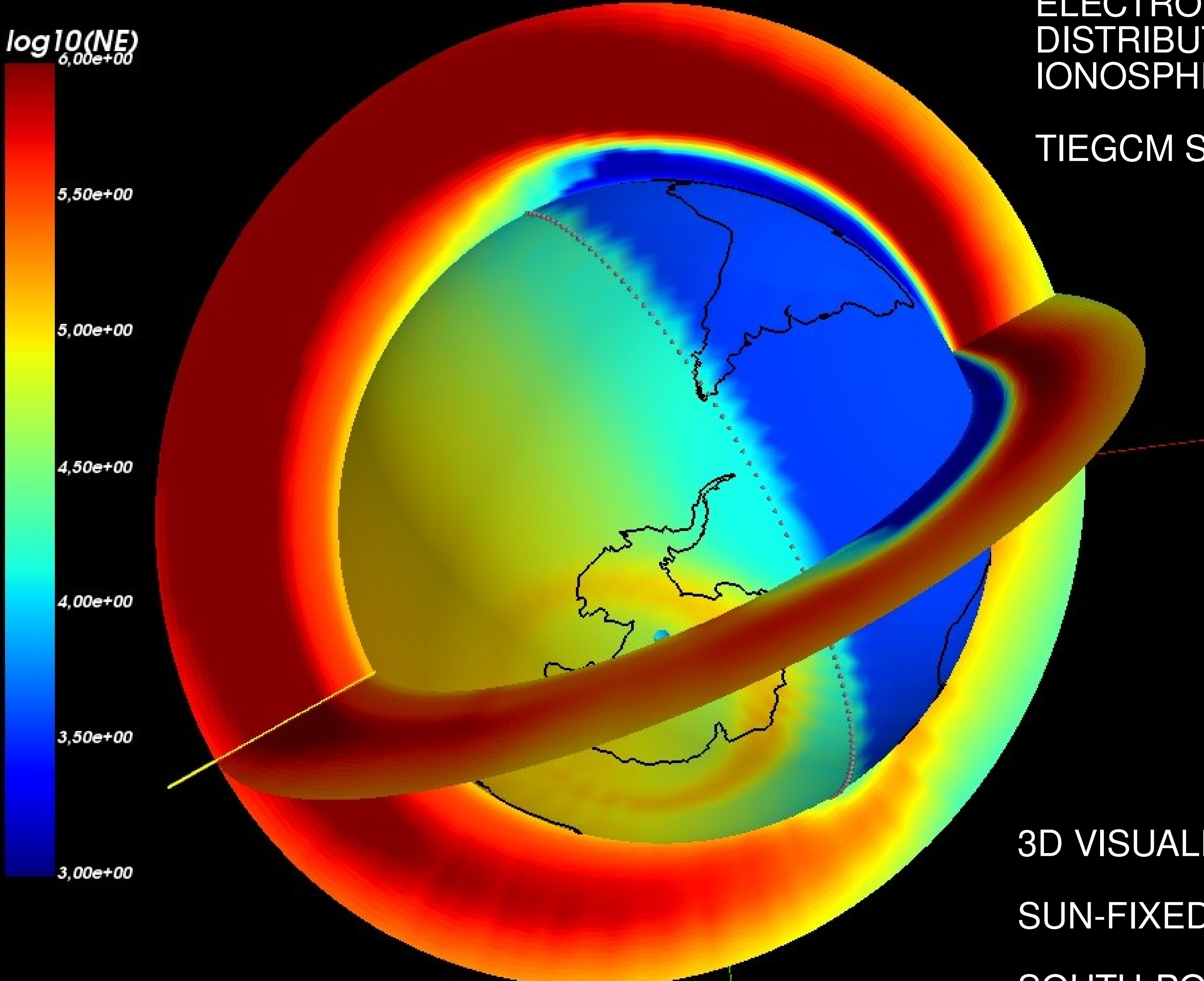
3D VISUALIZATION

EARTH-FIXED FRAME

SOUTH VIEW

ELECTRON DENSITY DISTRIBUTION IN THE IONOSPHERE

TIEGCM SIMULATION



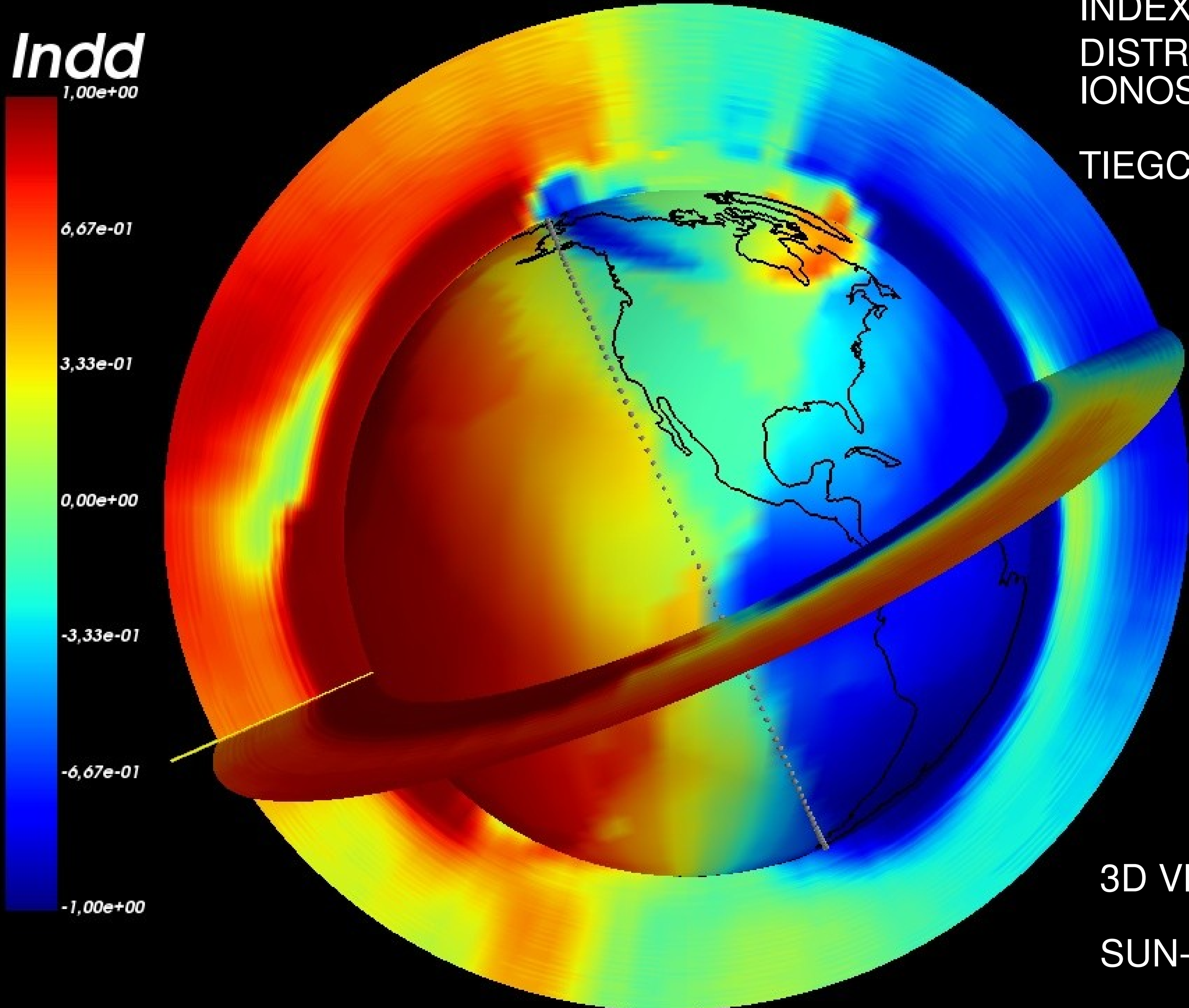
3D VISUALIZATION

SUN-FIXED FRAME

SOUTH-POLE VIEW

INDEX I_{NDD} DISTRIBUTION IN THE IONOSPHERE

TIEGCM SIMULATION

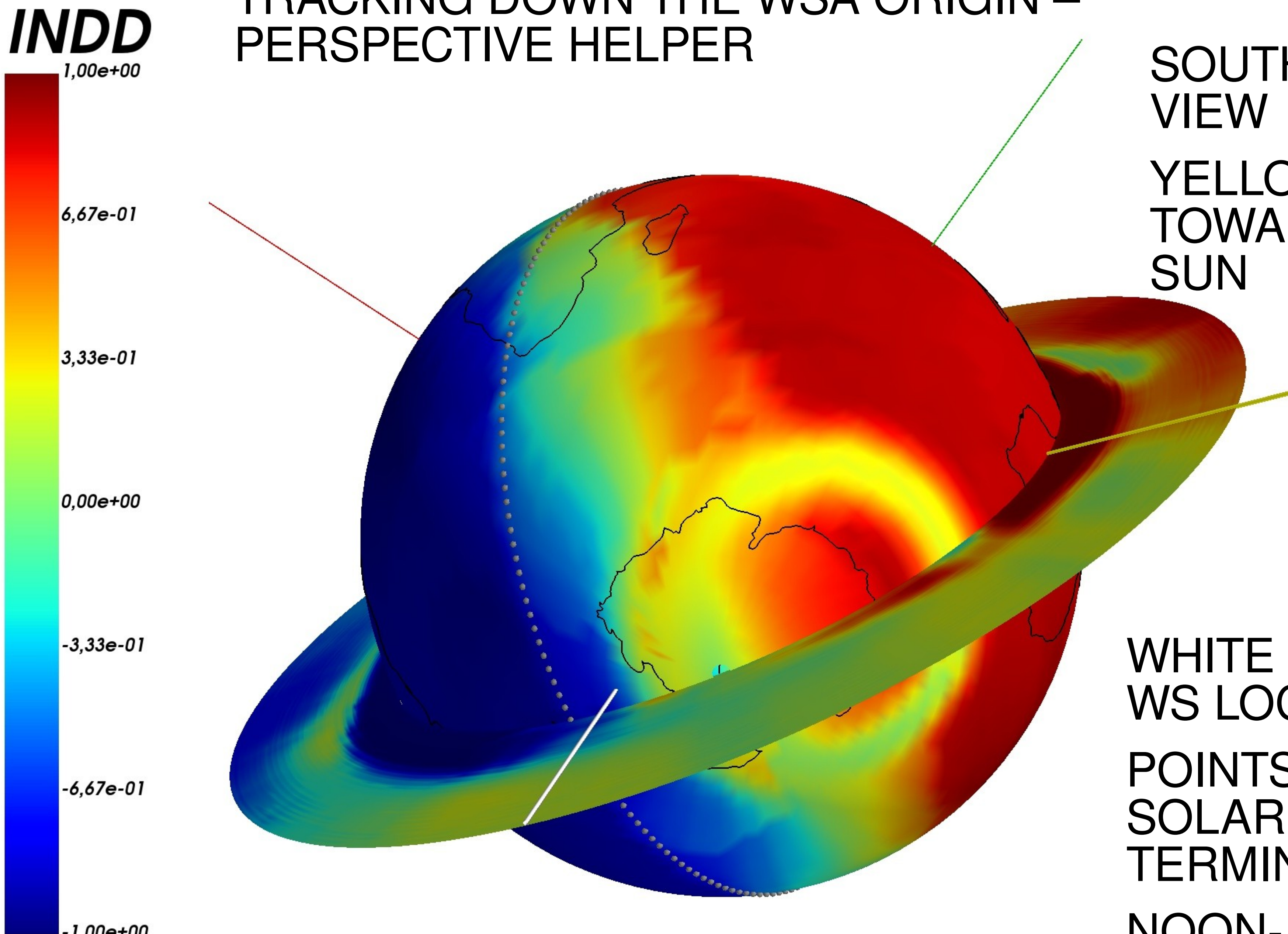


3D VISUALIZATION

SUN-FIXED FRAME

EQUATOR VIEW

TRACKING DOWN THE WSA ORIGIN – PERSPECTIVE HELPER



SOUTH-POLE VIEW

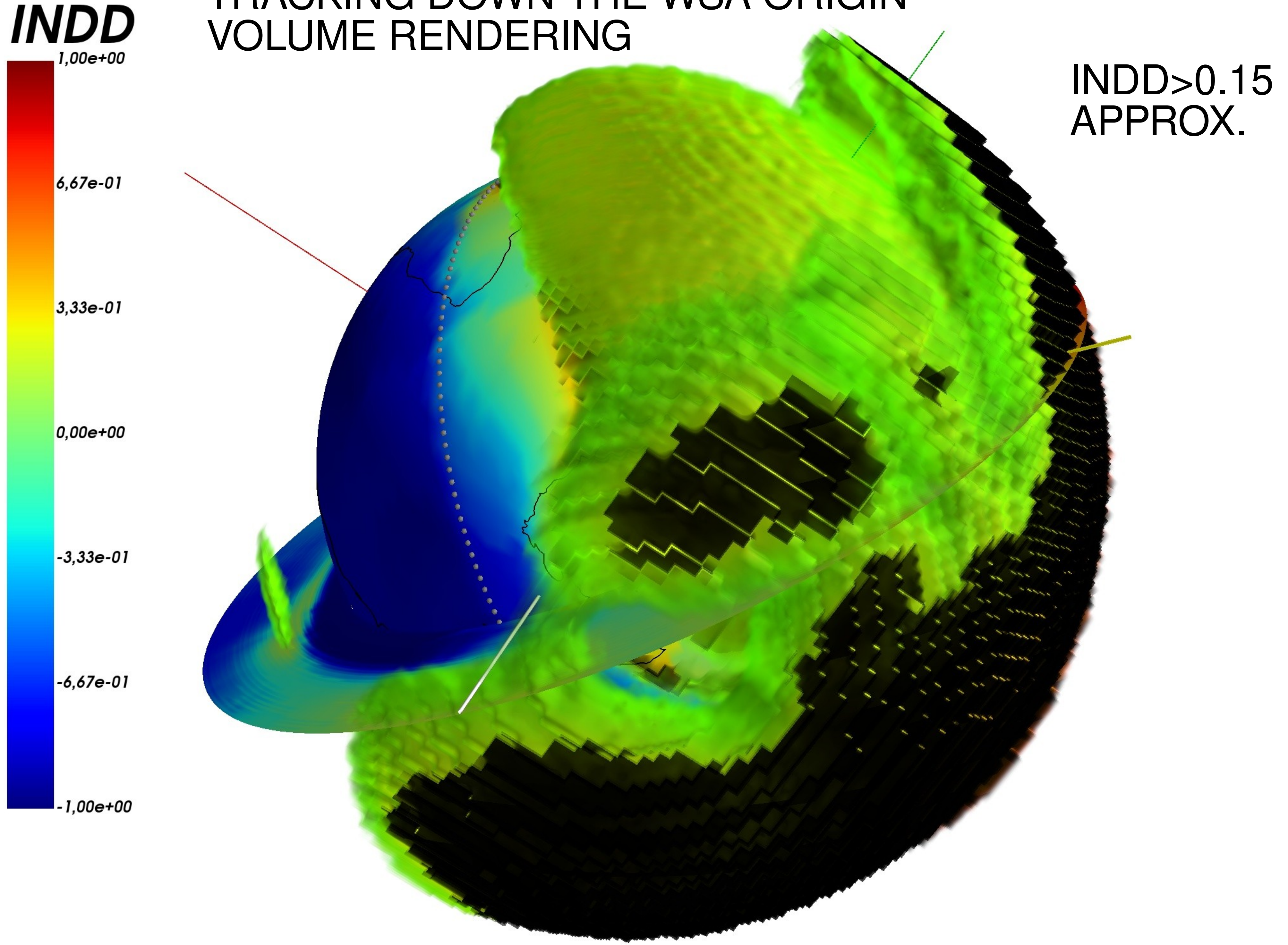
YELLOW LINE TOWARDS THE SUN

WHITE LINE – WS LOCATION

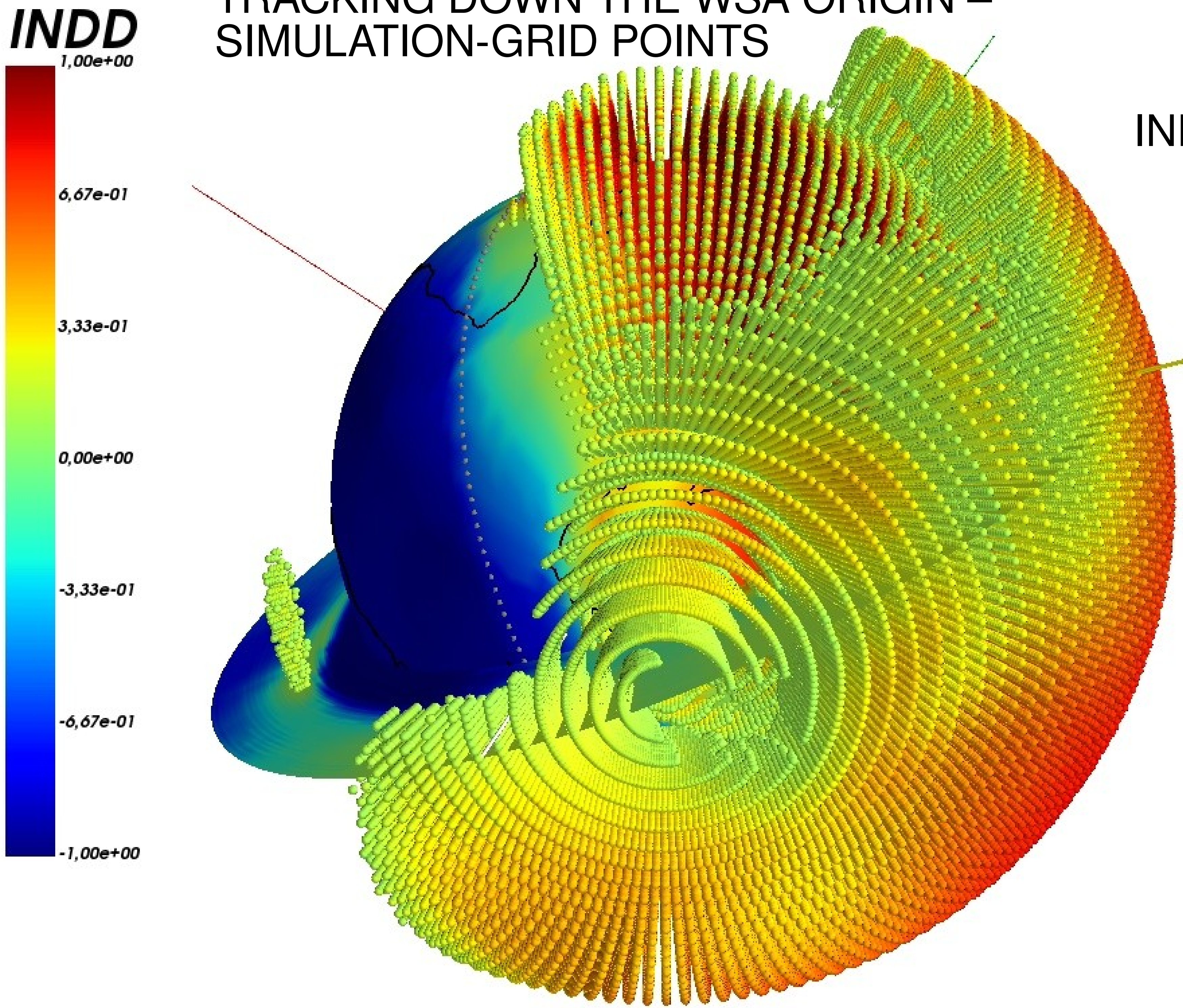
POINTS - SOLAR TERMINATOR

NOON-MIDNIGHT PLANE

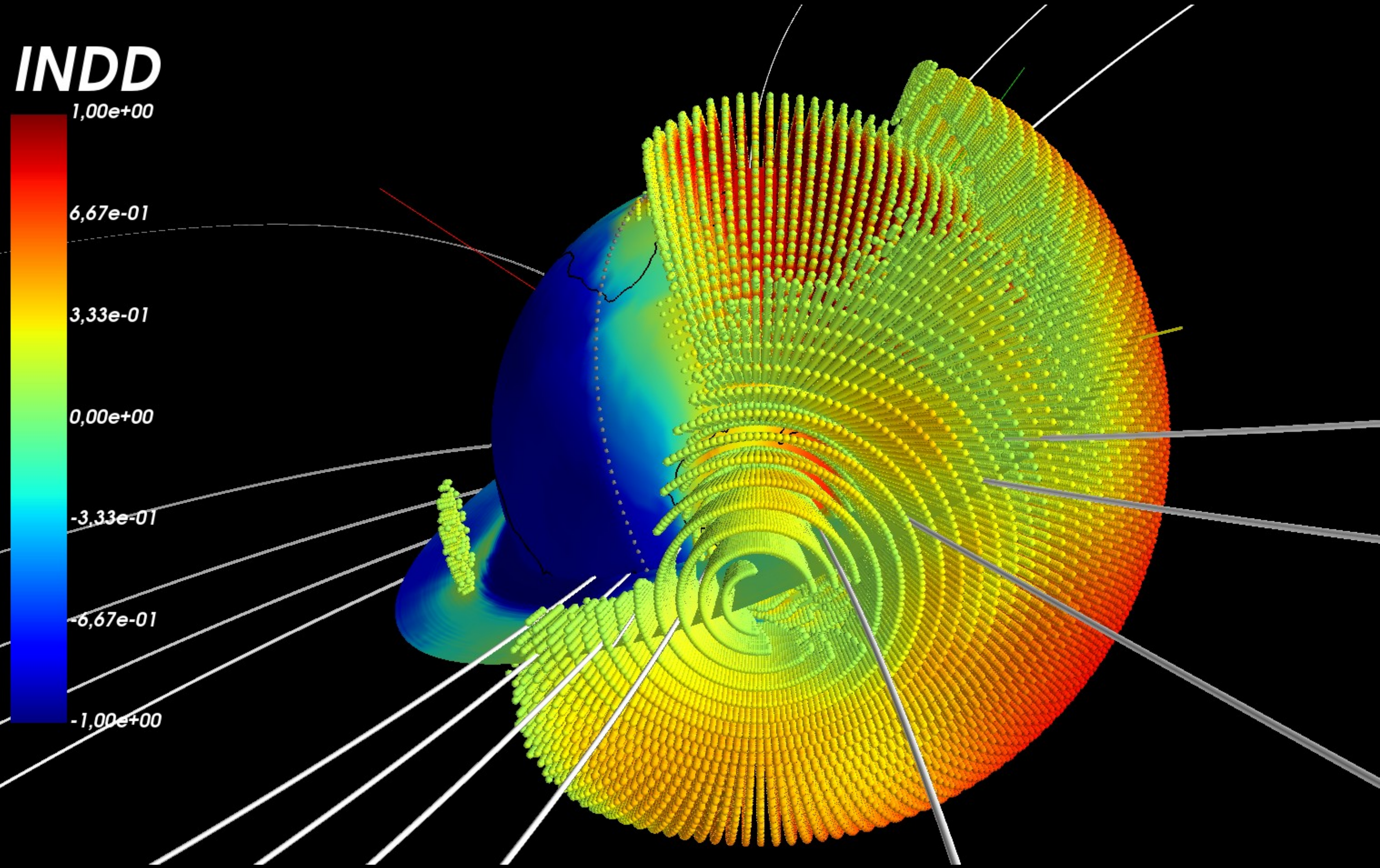
TRACKING DOWN THE WSA ORIGIN – VOLUME RENDERING



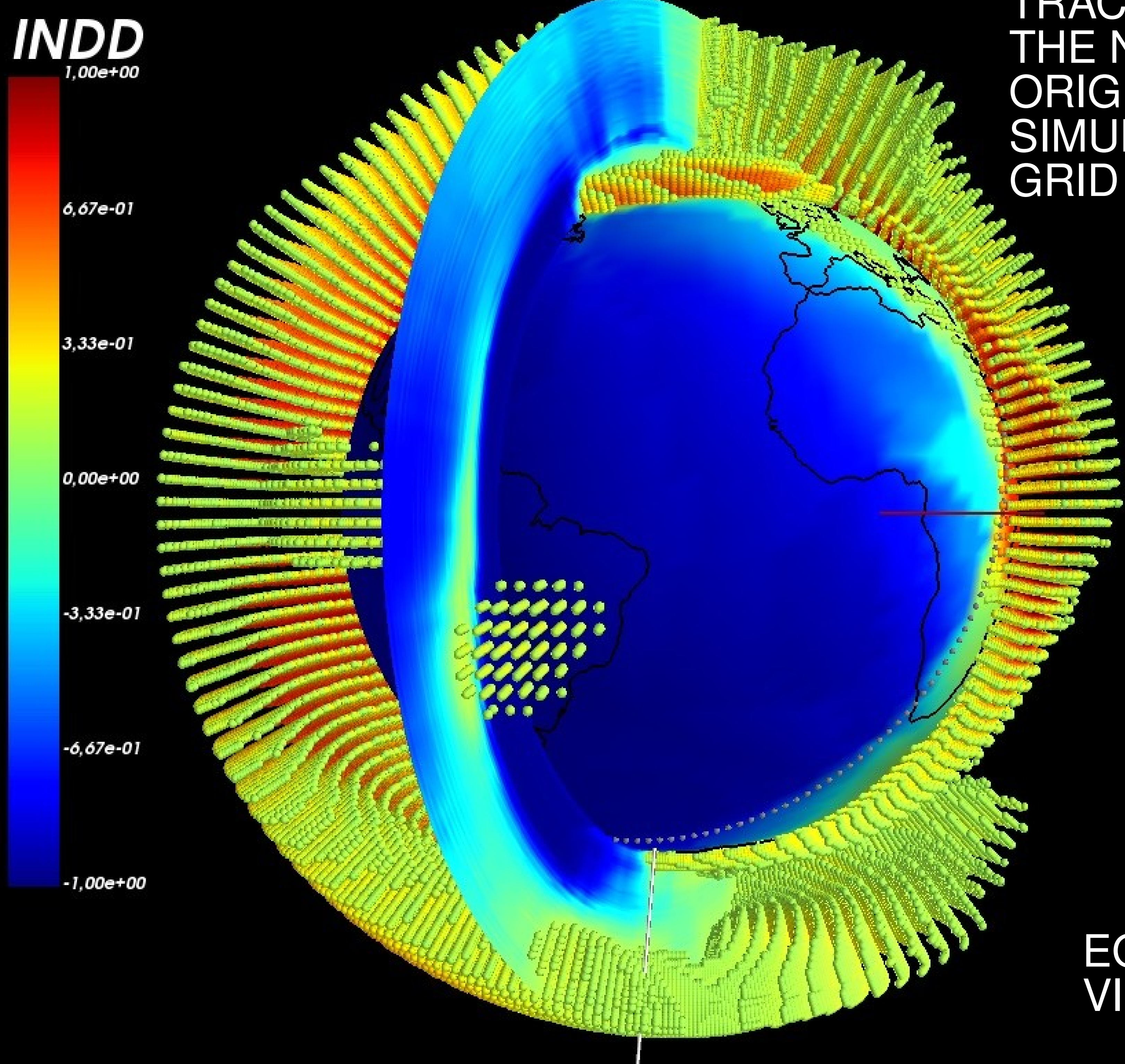
TRACKING DOWN THE WSA ORIGIN – SIMULATION-GRID POINTS



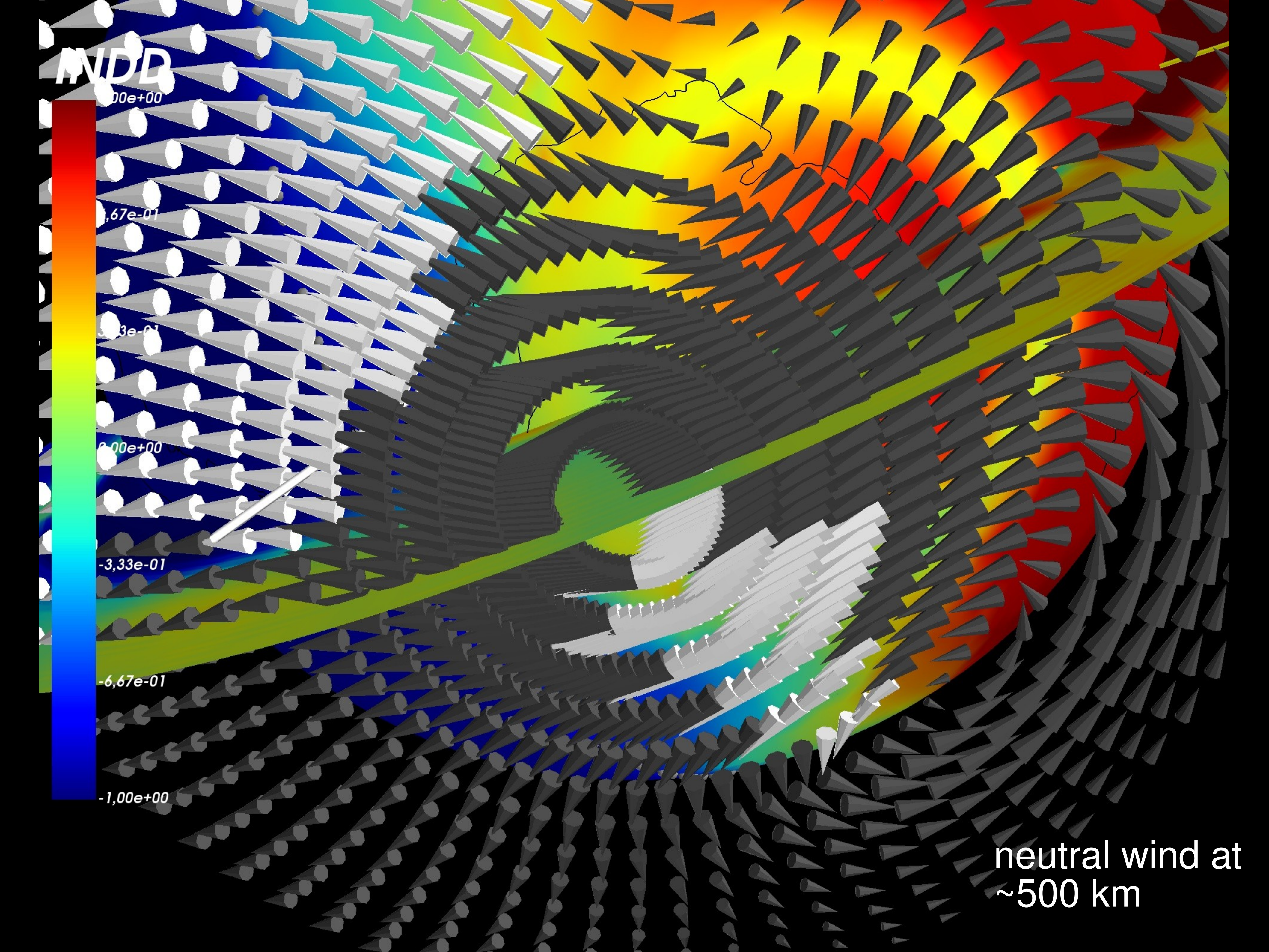
INDD>0.1

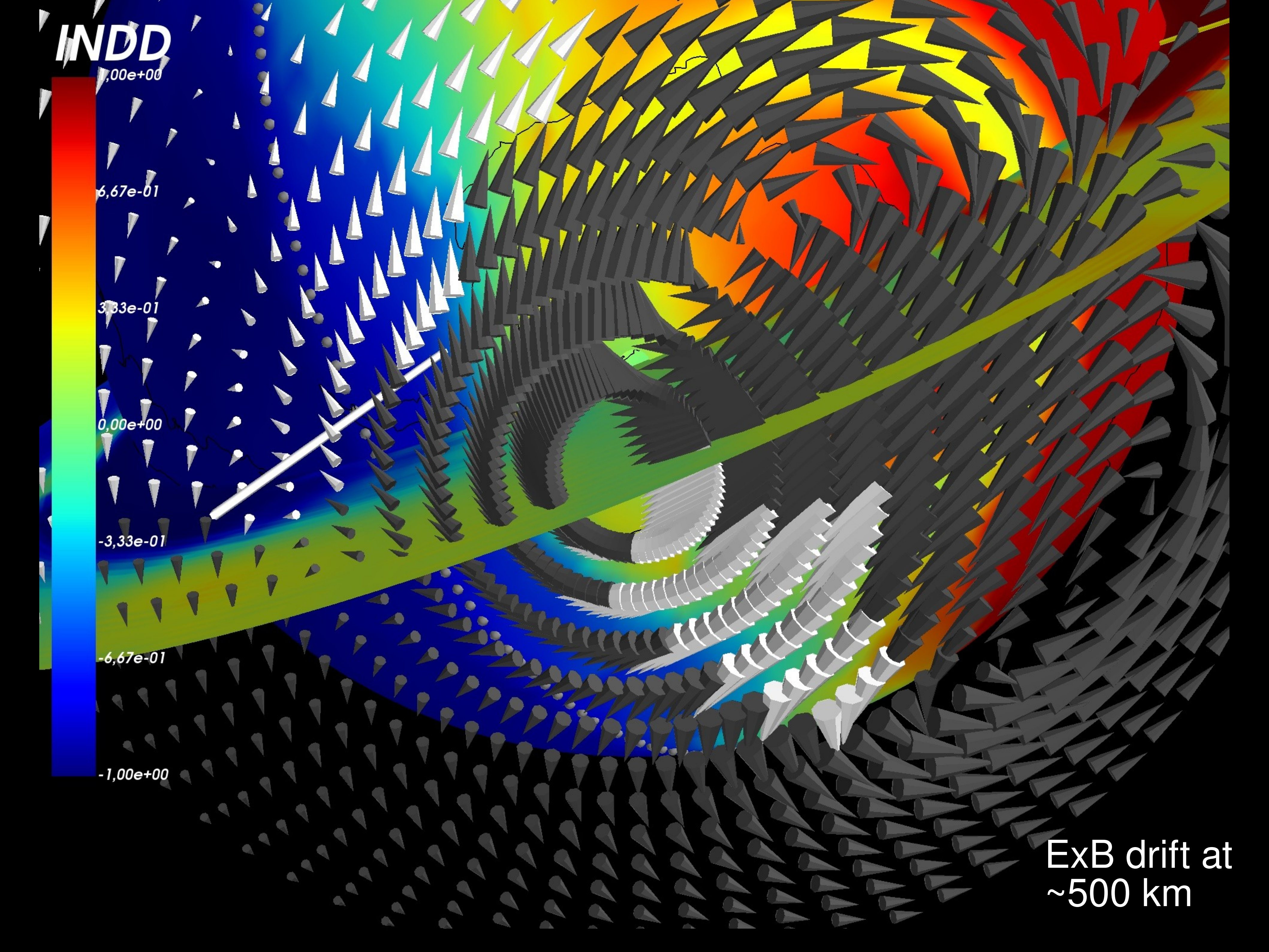

INDD
1,00e+00
6,67e-01
3,33e-01
0,00e+00
-3,33e-01
-6,67e-01
-1,00e+00

TRACKING DOWN THE NPDE ORIGIN – SIMULATION-GRID POINTS

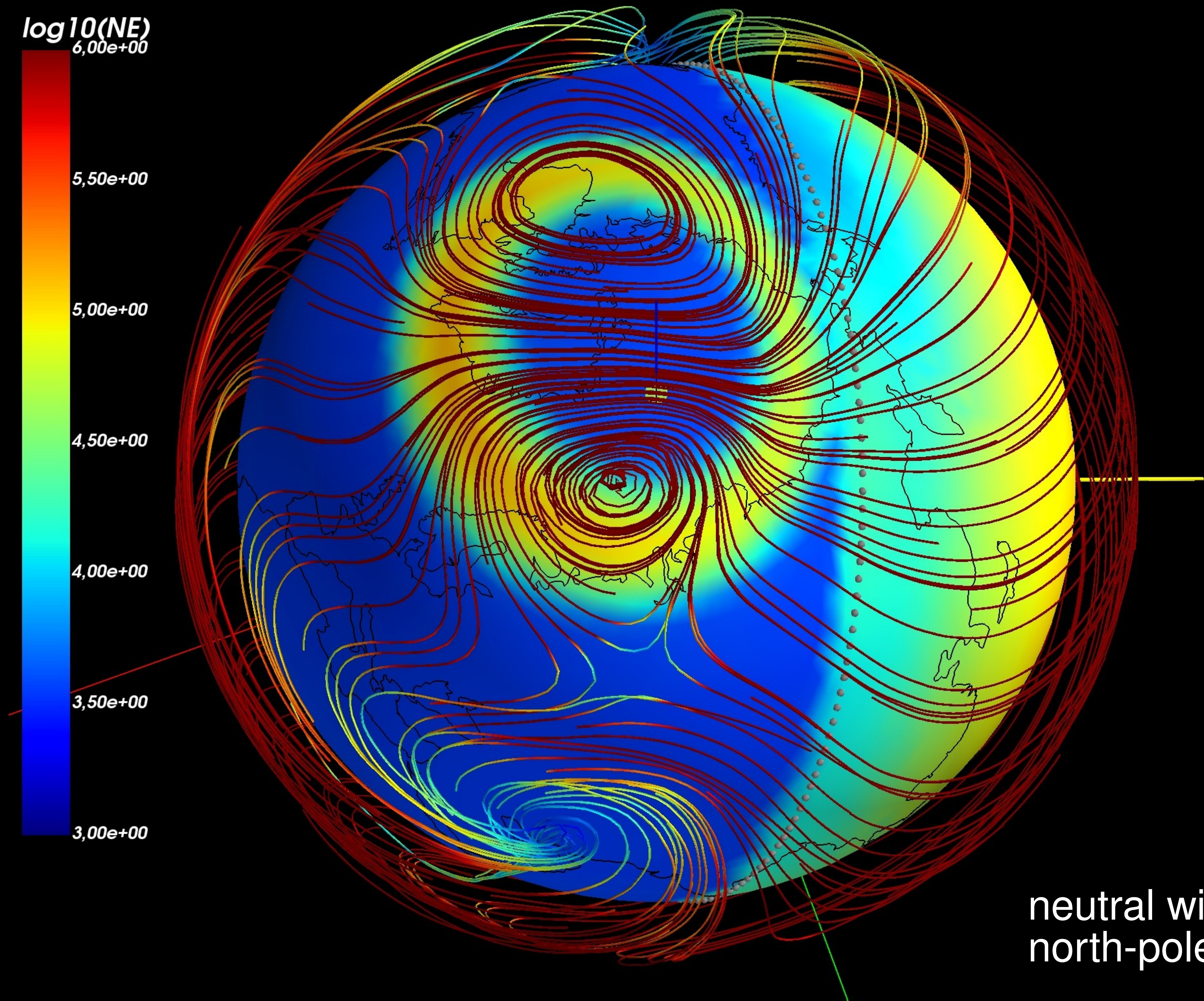


EQUATORIAL VIEW

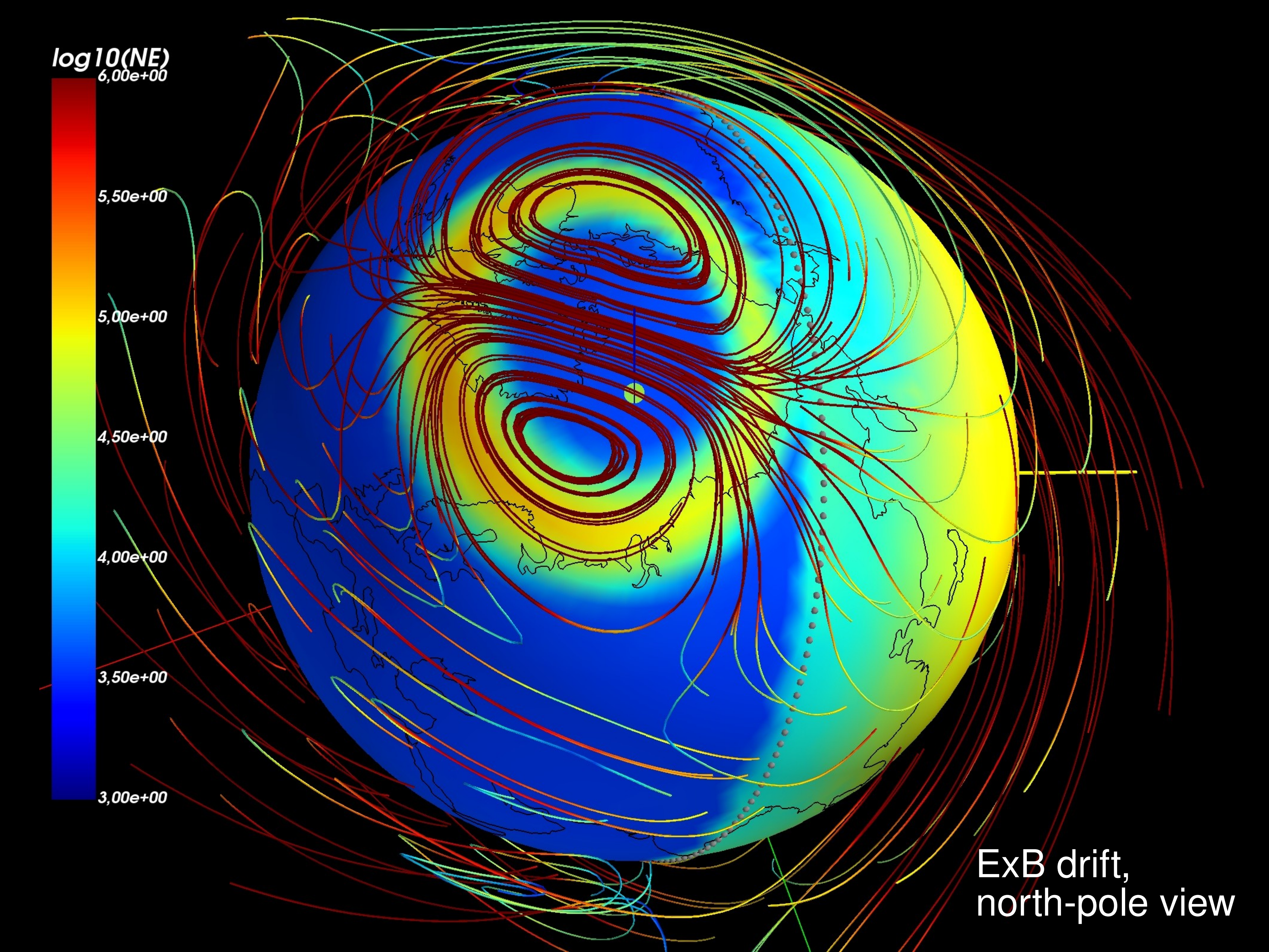

-3,33e-01
-6,67e-01
-1,00e+00
neutral wind at
~500 km

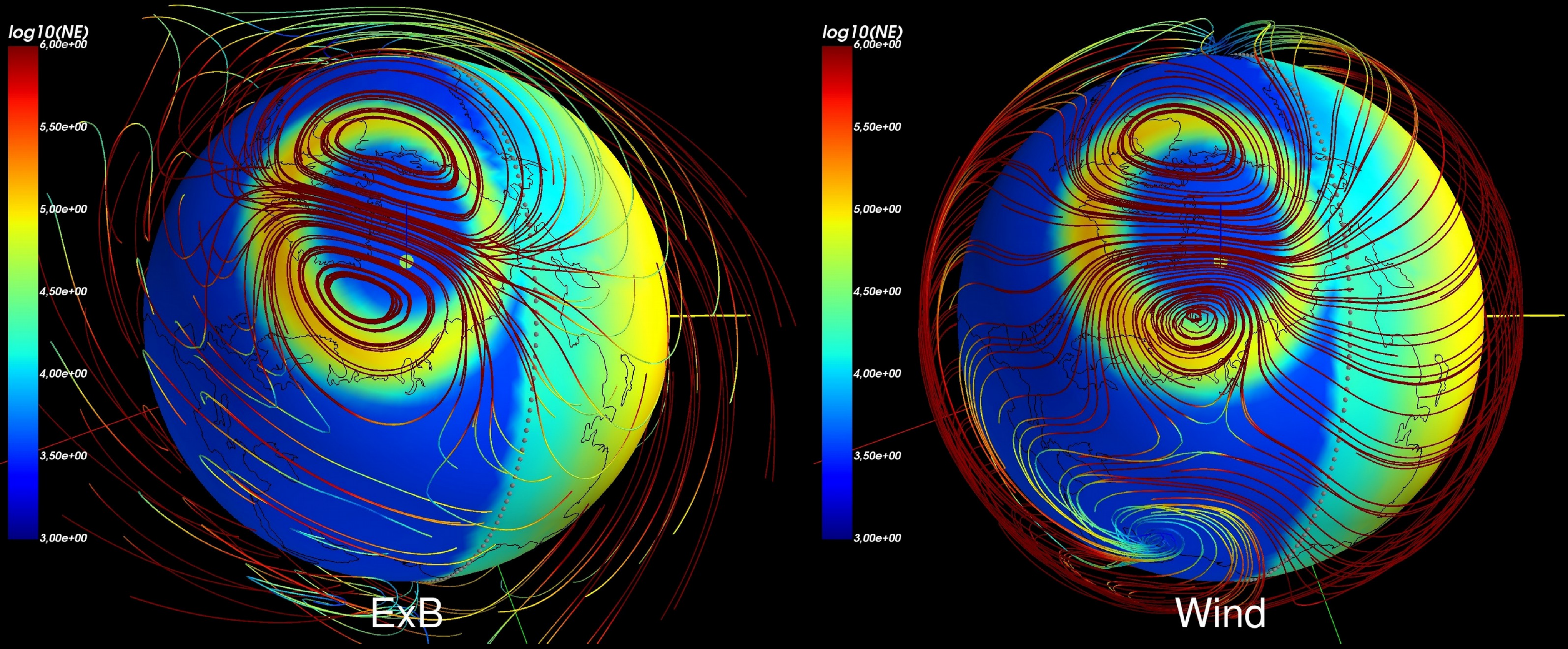


INDD
1,00e+00
6,67e-01
3,33e-01
0,00e+00
-3,33e-01
-6,67e-01
-1,00e+00
ExB drift at
~500 km

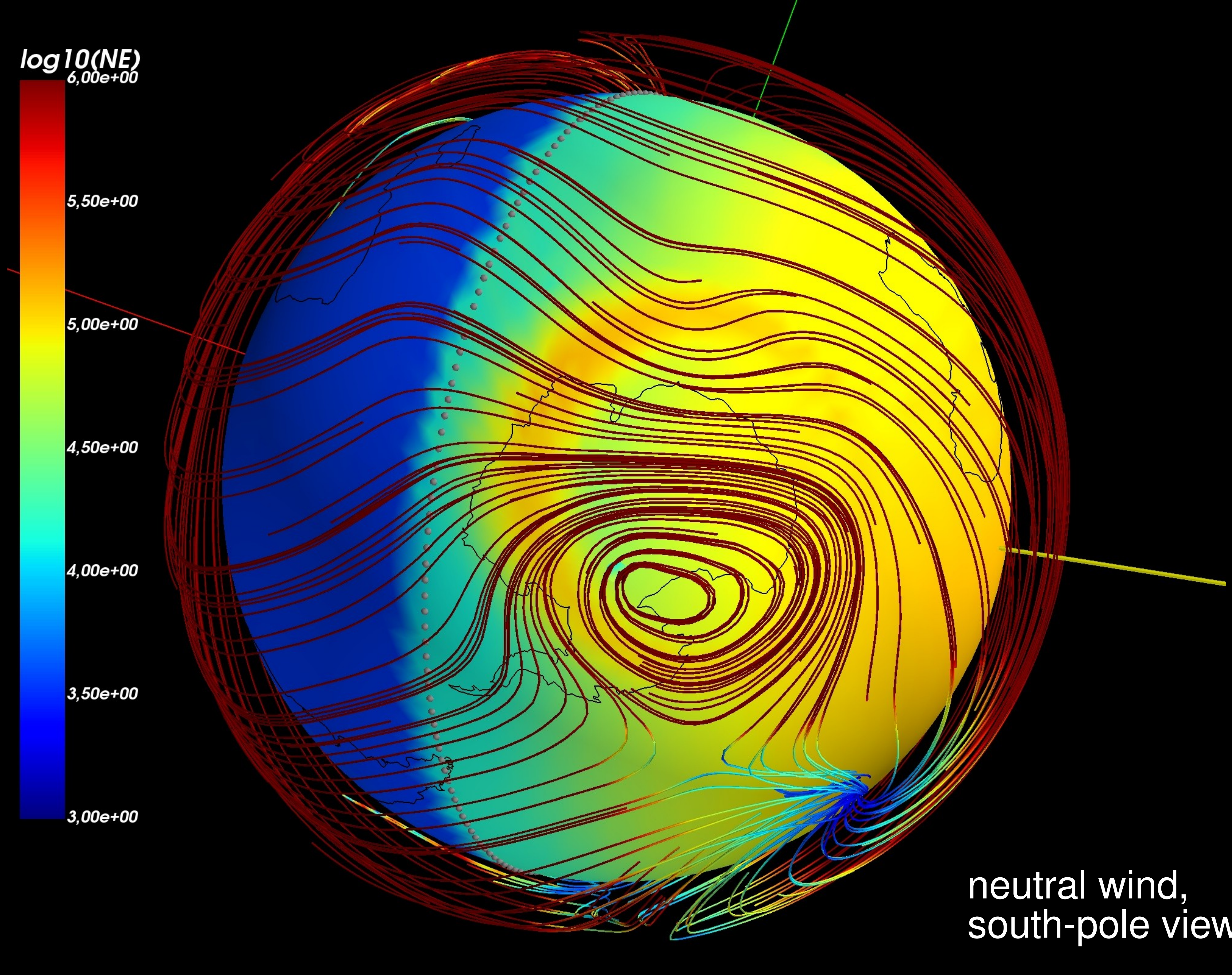


neutral wind,
north-pole view

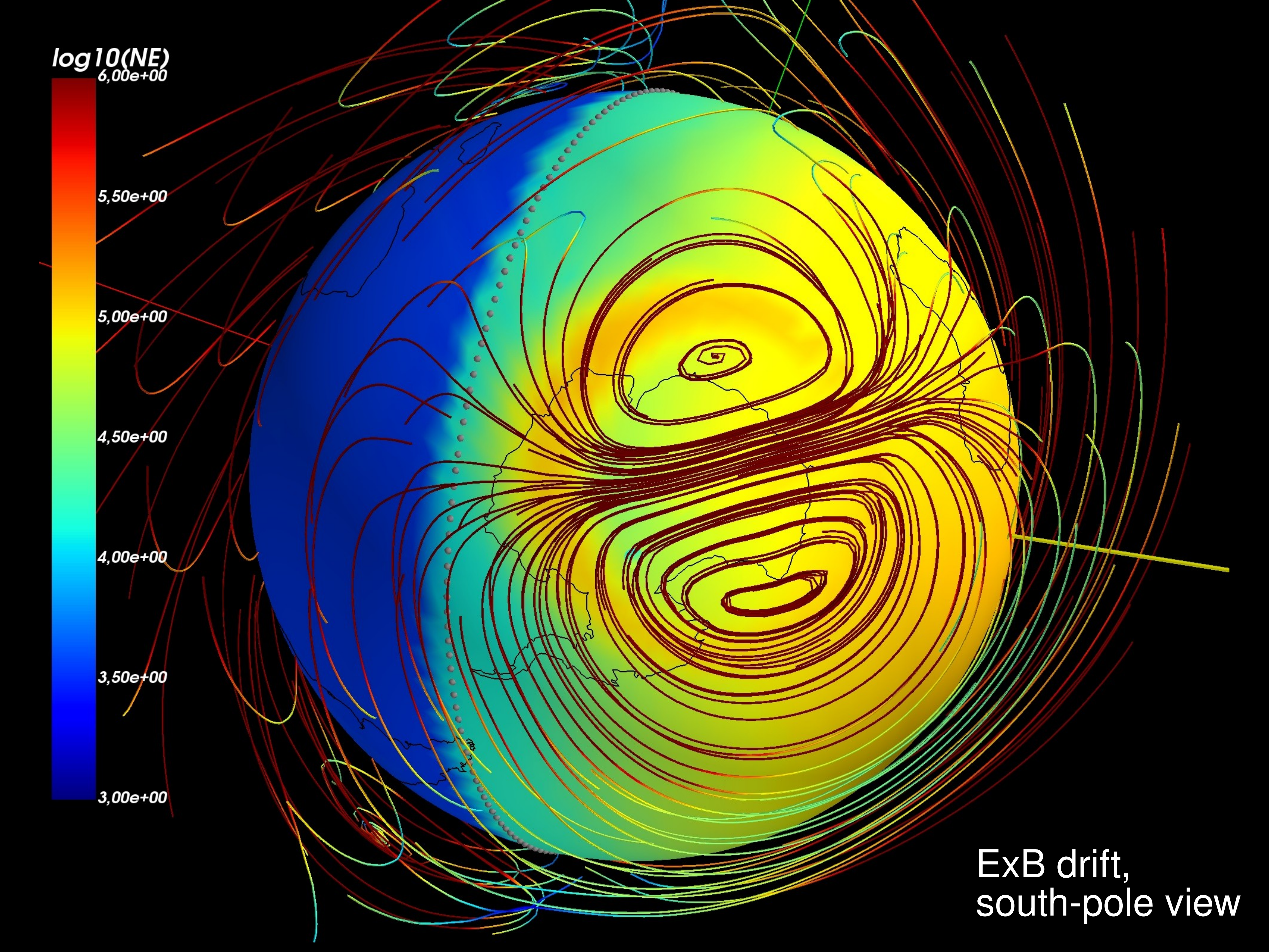

log10(NE)
6,00e+00
5,50e+00
5,00e+00
4,50e+00
4,00e+00
3,50e+00
3,00e+00
ExB drift,
north-pole view

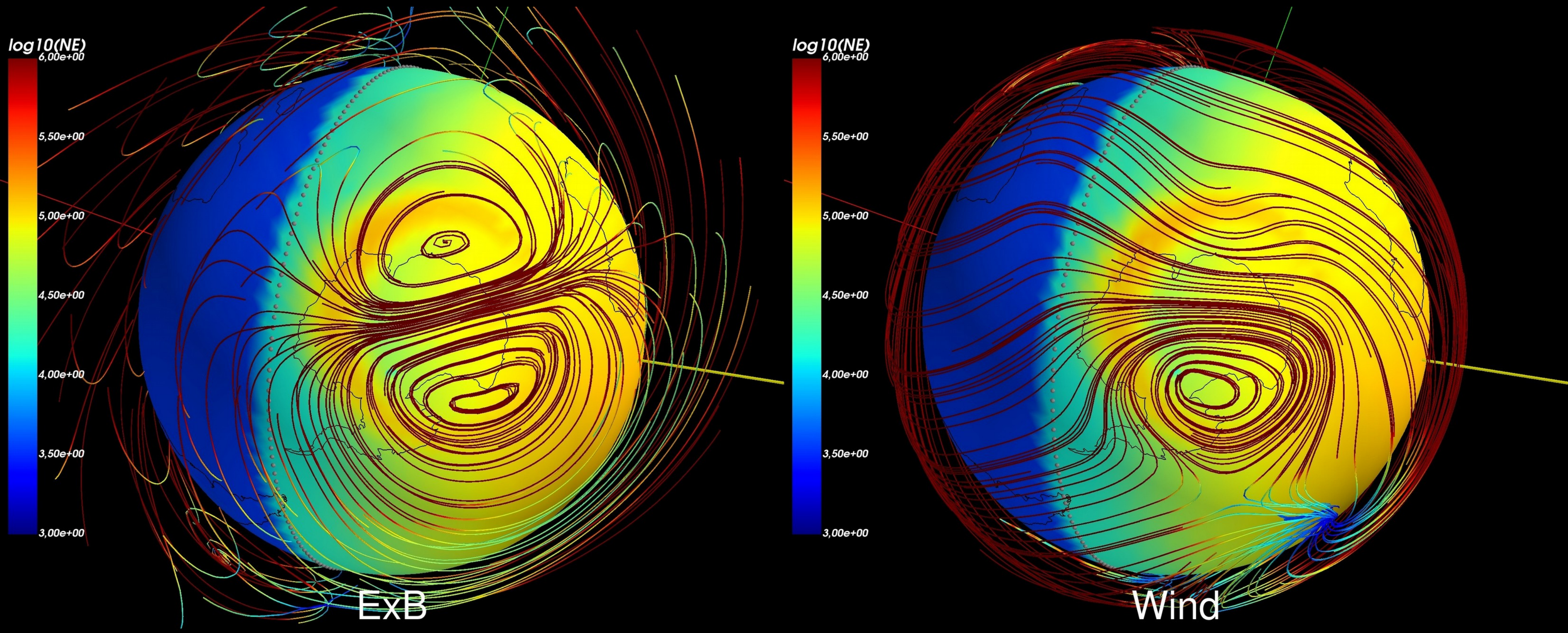


north-pole view,
fully consistent with
classical textbook
pictures

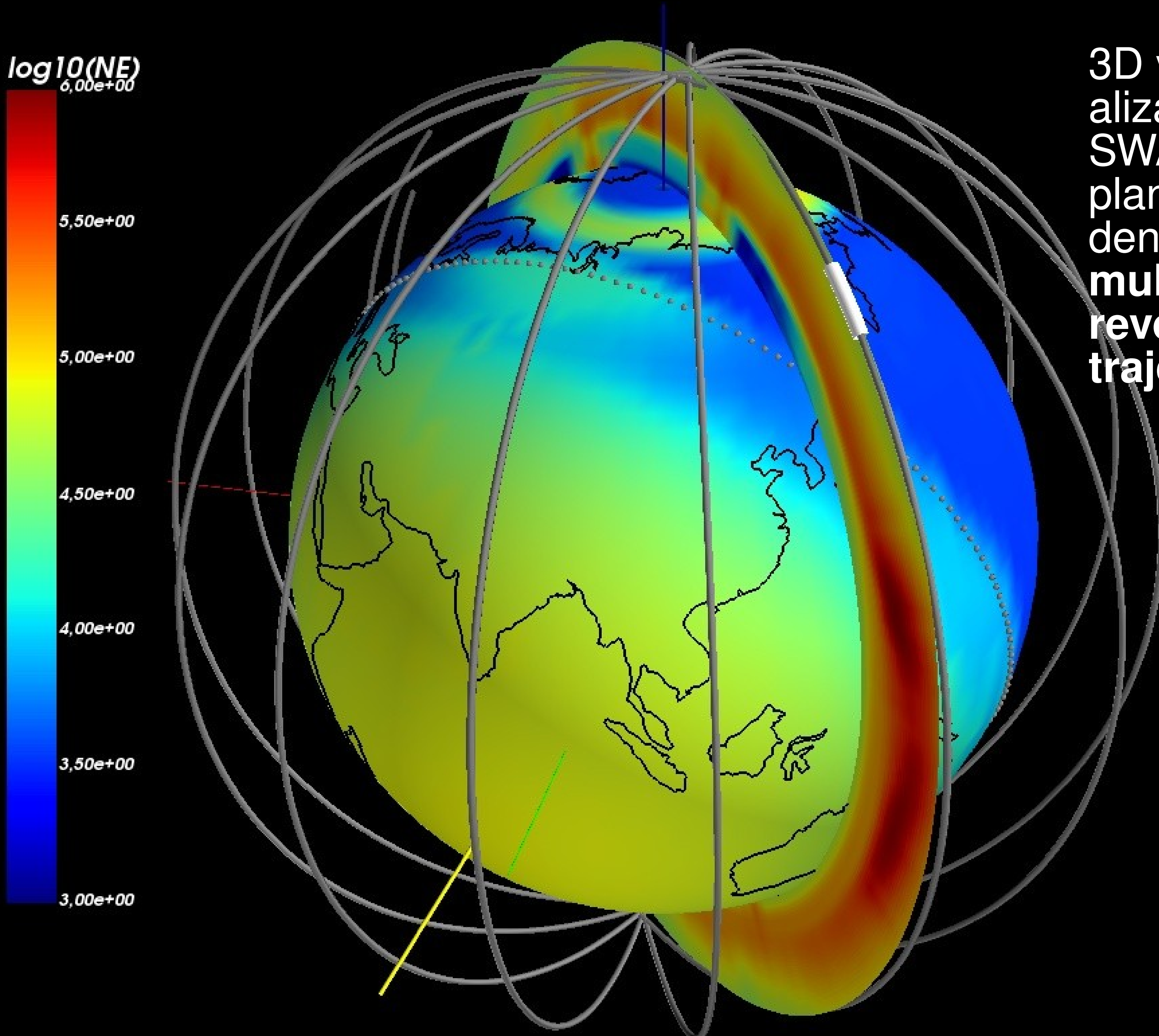


neutral wind,
south-pole view


log10(NE)
6,00e+00
5,50e+00
5,00e+00
4,50e+00
4,00e+00
3,50e+00
3,00e+00
ExB drift,
south-pole view

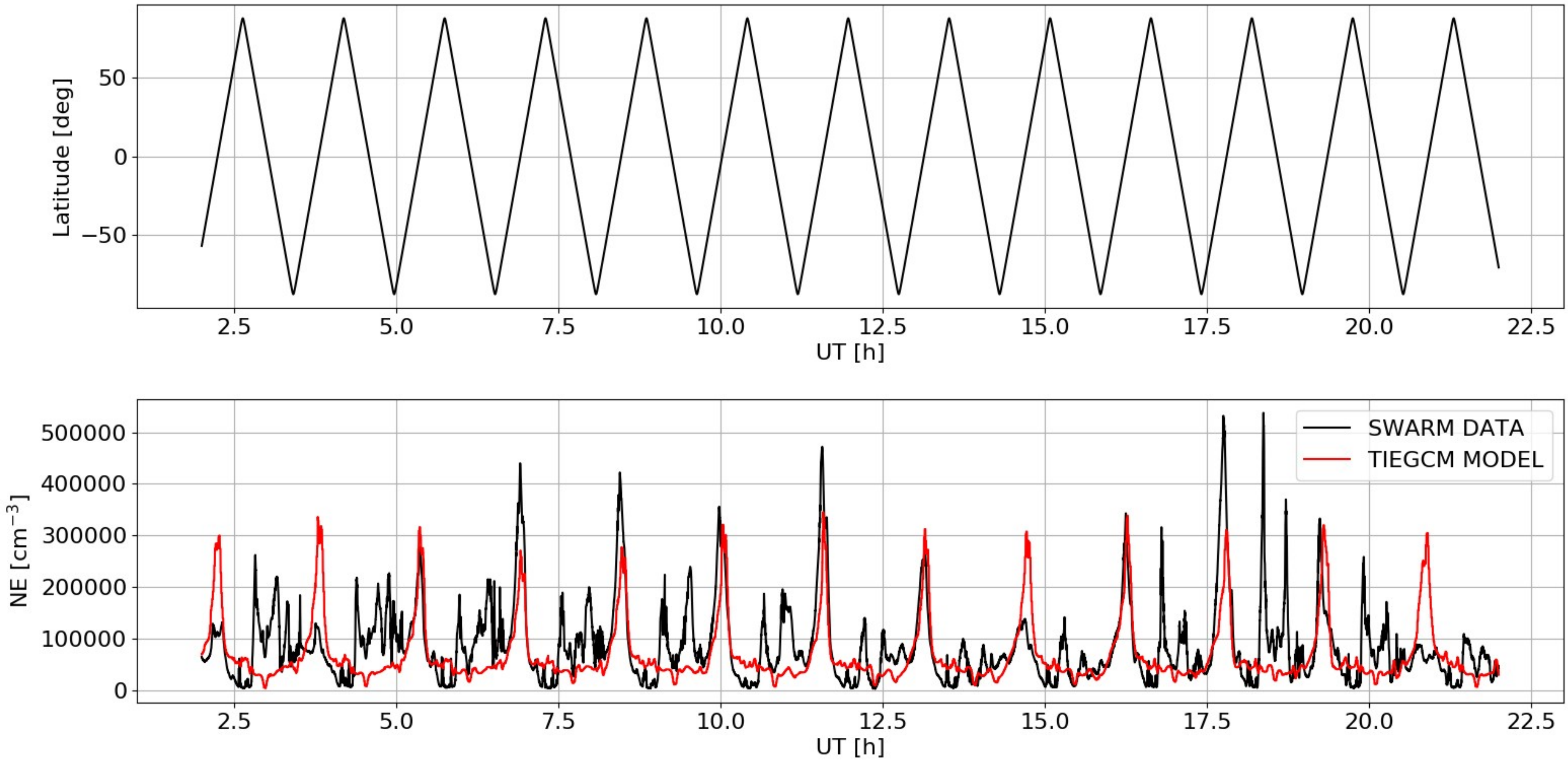


south-pole view, different convection pattern in ExB and neutral wind



3D visu-
alizations in
SWARM-orbit
plane, plasma
density,
**multiple-
revolutions
trajectory**

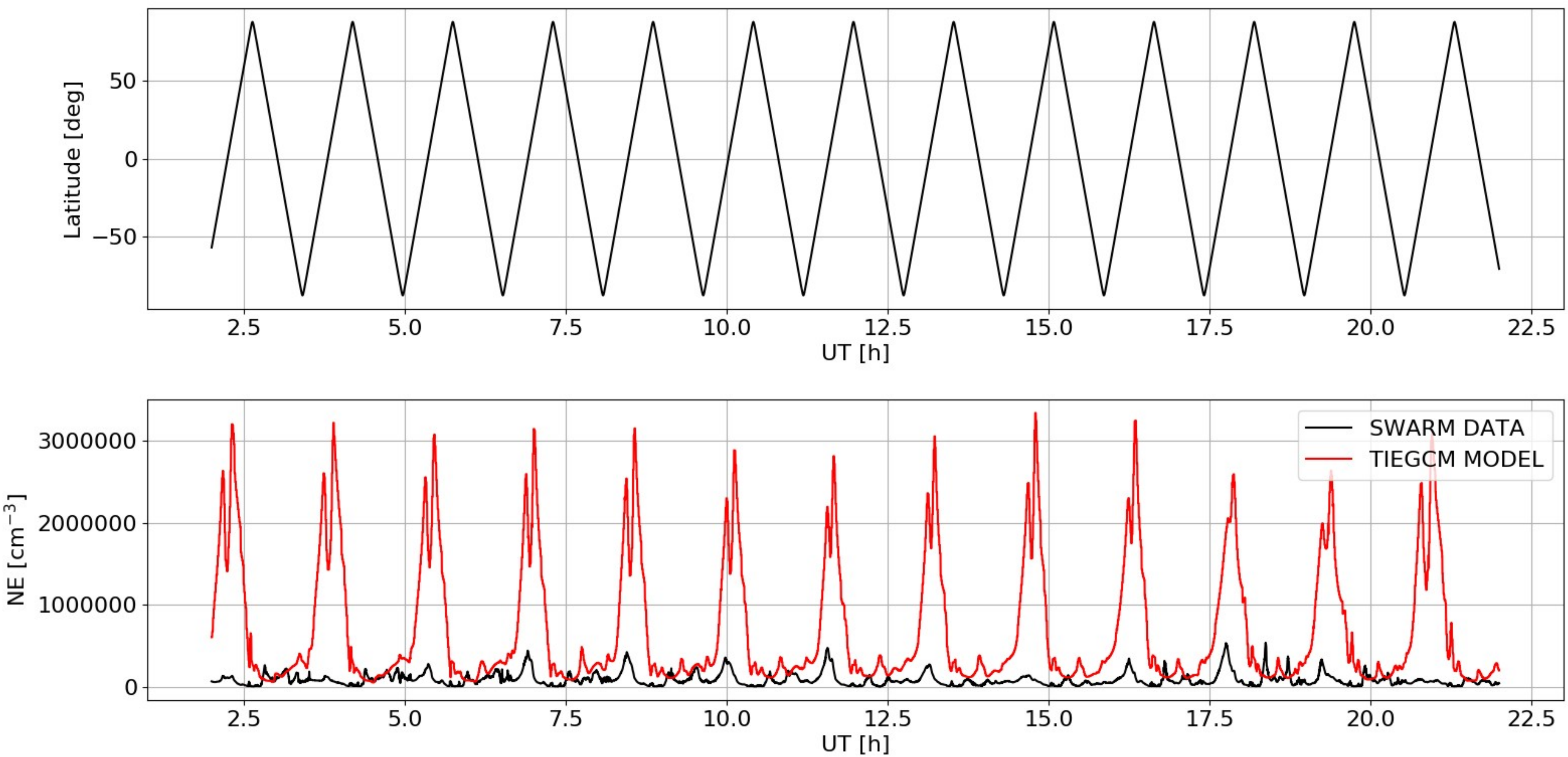
SWARM vs TIEGCM: direct comparison of the electron density



SWARM A DATA: 2018-12-24

TIEGCM MODEL: 2002-12-24
(BENCHMARK CASE: DECEMBER SOLSTICE, **SOLAR MIN**)

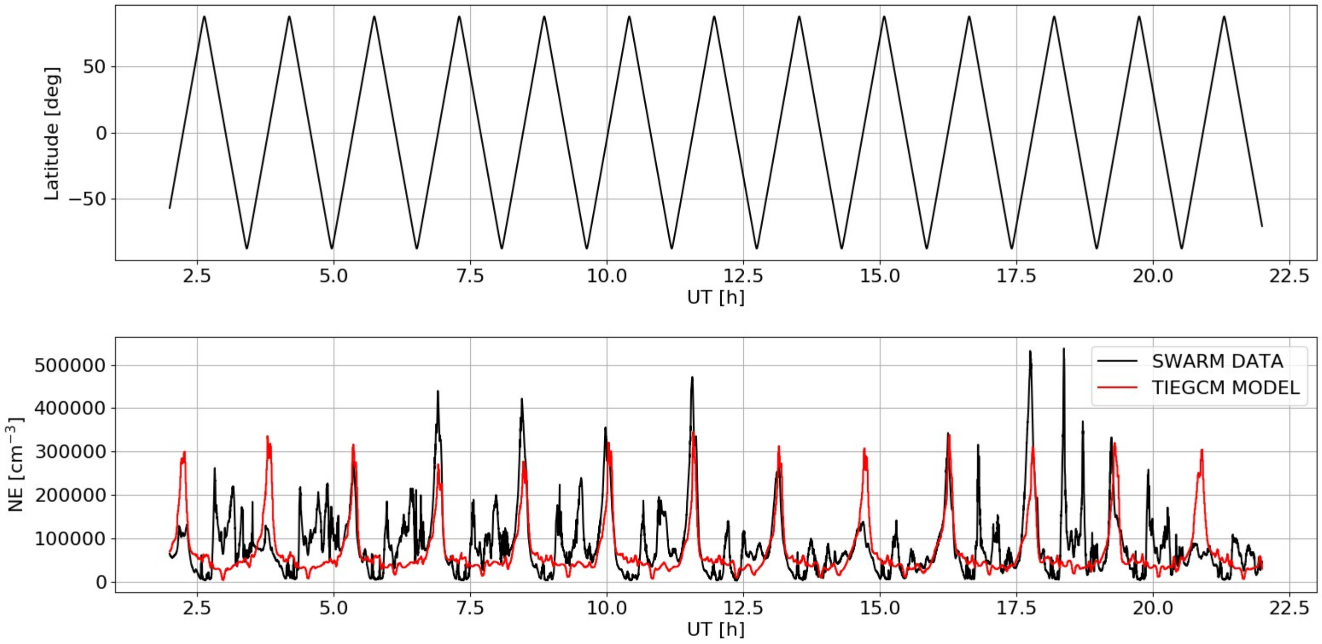
SWARM vs TIEGCM: direct comparison of the electron density



SWARM A DATA: 2018-12-24

TIEGCM MODEL: 2002-12-24
(BENCHMARK CASE: DECEMBER SOLSTICE, **SOLAR MAX**)

SWARM-TIEGCM discrepancies



TIEGCM curve (red) is very periodic as compared with measurements

Discrepancies can result from numerical dissipation and the lack of all necessary physical effects in the model, but they may also be related to fixed Sun/solar-wind conditions as a driver in modeling

TIEGCM seems to offer feeding the simulation with observed time-dependent F107 and solar wind data from OMNI database (instead of setting constant CTPOTEN and POWER)

Long-run from 2002 to 2019 with time-dependent Sun/solar-wind influence?

Thank you for your attention