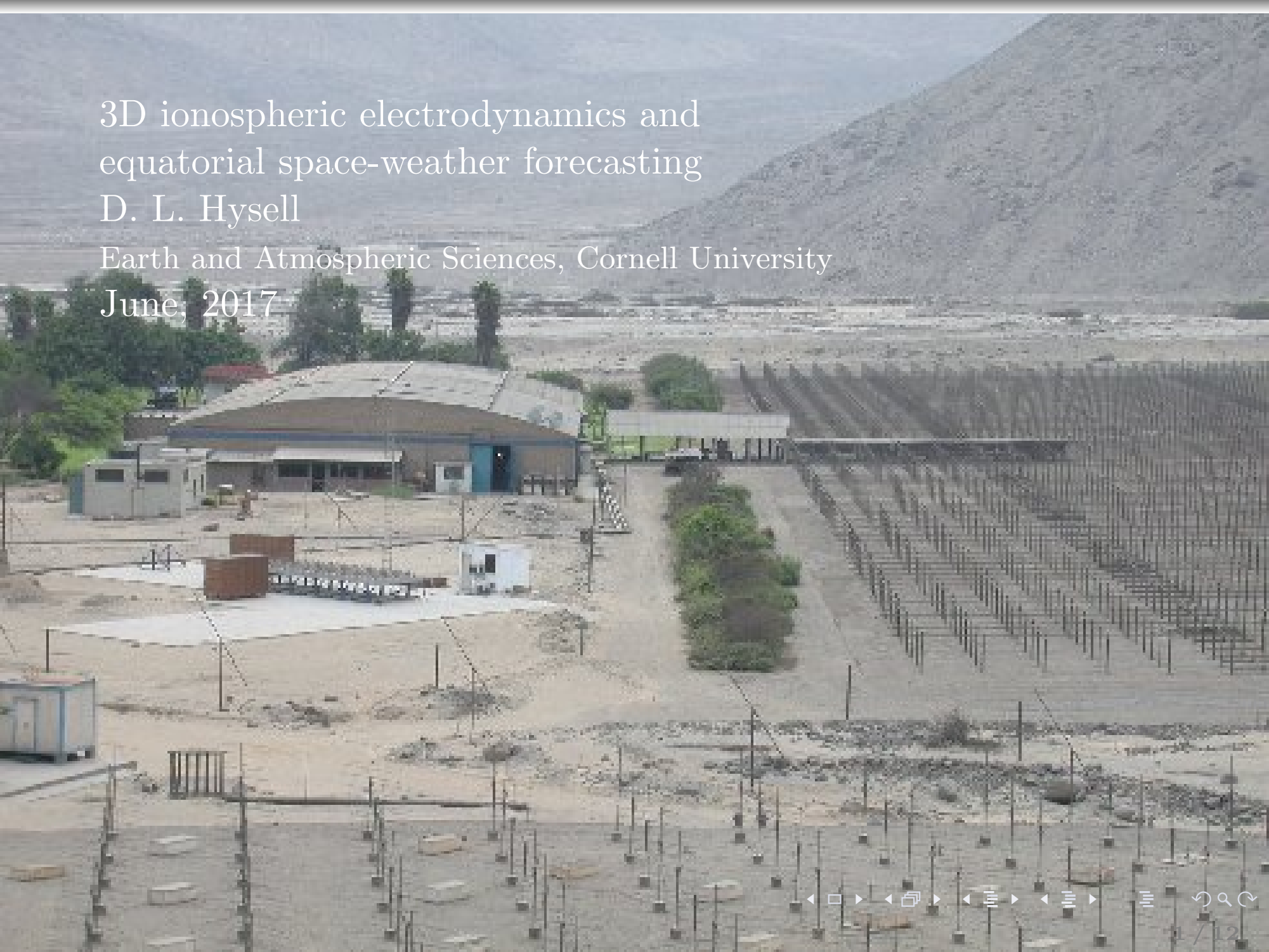


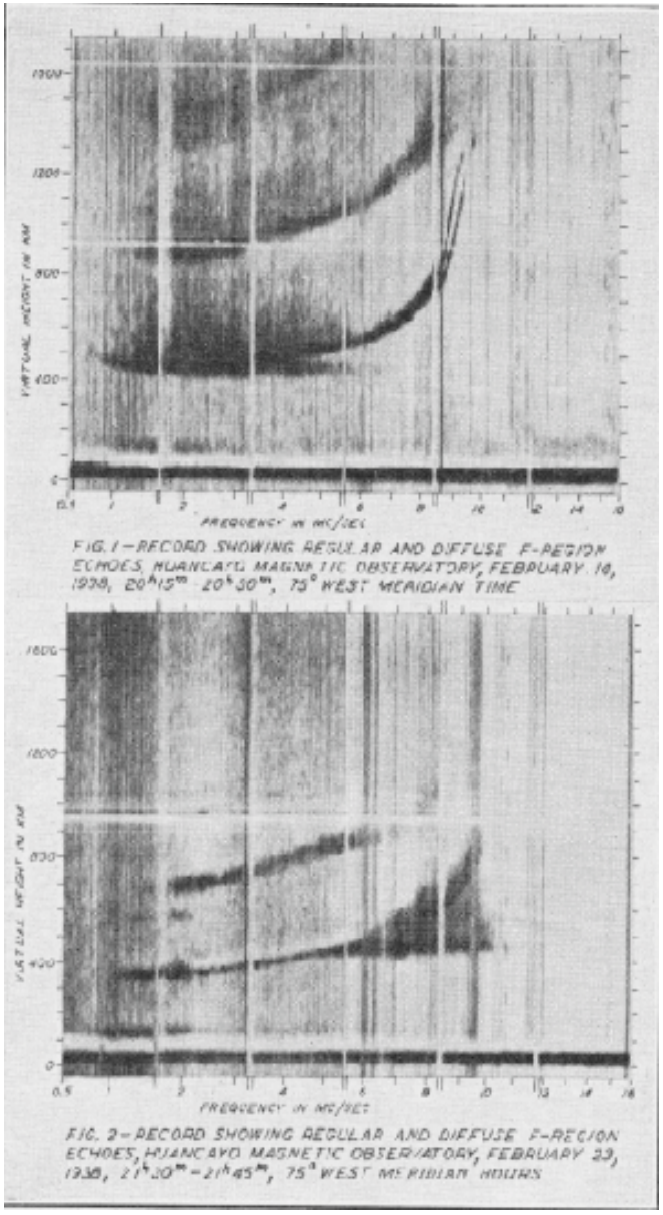
3D ionospheric electrodynamics and equatorial space-weather forecasting

D. L. Hysell

Earth and Atmospheric Sciences, Cornell University

June, 2017

80 years of equatorial spread F!



Booker and Wells, 1938; Woodman and La Hoz, 1976

outline

Jicamarca campaigns – http://jro.igp.gob.pe

Dec. 17–21, 2012 (N_e, T_e, T_i, $\mathbf{v}_\perp$ profiles + RTI)

Apr. 11–16, 2013 (added FPI winds)

Sep. 16–Oct. 3, 2013 (added widefield imaging)

May 5–9, 2014 (added HF beacons)

Nov. 24- 28, 2014 (C/NOFS)

Dec. 15–22, 2014

Feb. 9–15, 2015

Mar. 23–27, 2015

Aug. 25–28, 2015

Dec. 9–13, 2015

- 3D DNS simulations
  - Initialization and forcing
  - ESF event recovery
- HF beacons
  - Regional ionospheric specification
  - Forecast improvement

canpaign mode

North Quarter

4/2	4/2	5/3	5/3
4/2	5/3	5/3	2/4
5/3	5/3	2/4	2/4
5/3	2/4	2/4	5/3

East Quarter

2/2	5/2	3/3	A 2/3
3/5	2/5	B 4/2	C 3/2
D 4/5	3/3	5/4	4/4
5/2	4/2	2/3	5/3

West Quarter

2/4	5/4	3/5	2/5
3/3	2/3	4/4	3/4
4/5	3/5	5/2	4/2
F 5/4	4/4	G 2/5	5/5

South Quarter

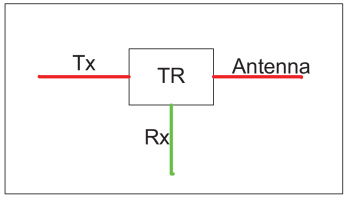
5/3	5/3	E 2/4	2/4
5/3	2/4	2/4	3/5
2/4	2/4	3/5	3/5
2/4	3/5	3/5	2/4

$N_e, T_e, T_i, \mathbf{v}_\perp +$ imaging

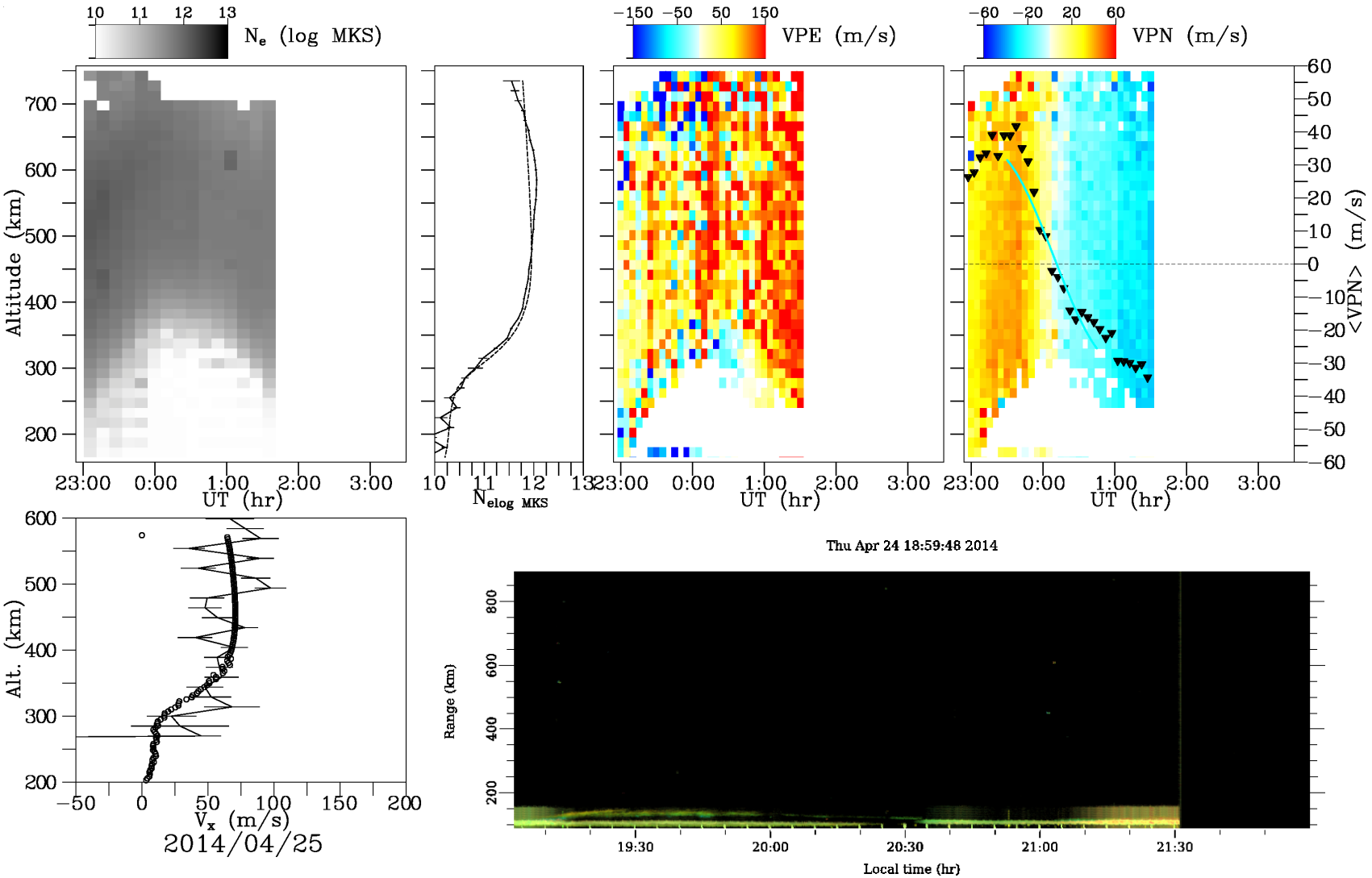
- 3 modes
- 4 beams
- 4 transmitters
- 16 receivers
- + FPI, HF

H — Hysell Module

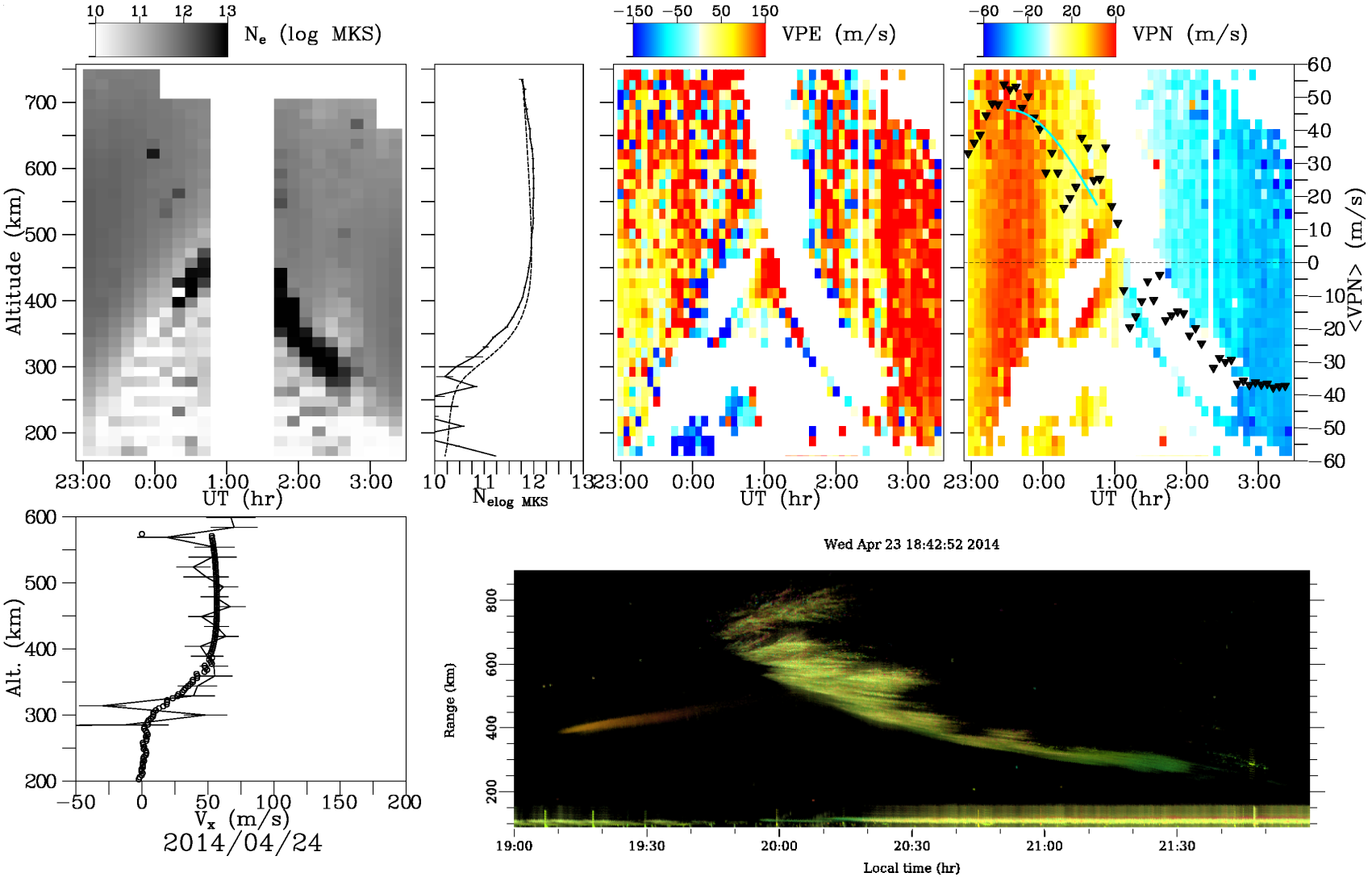
Imaging modules (Up polarization)



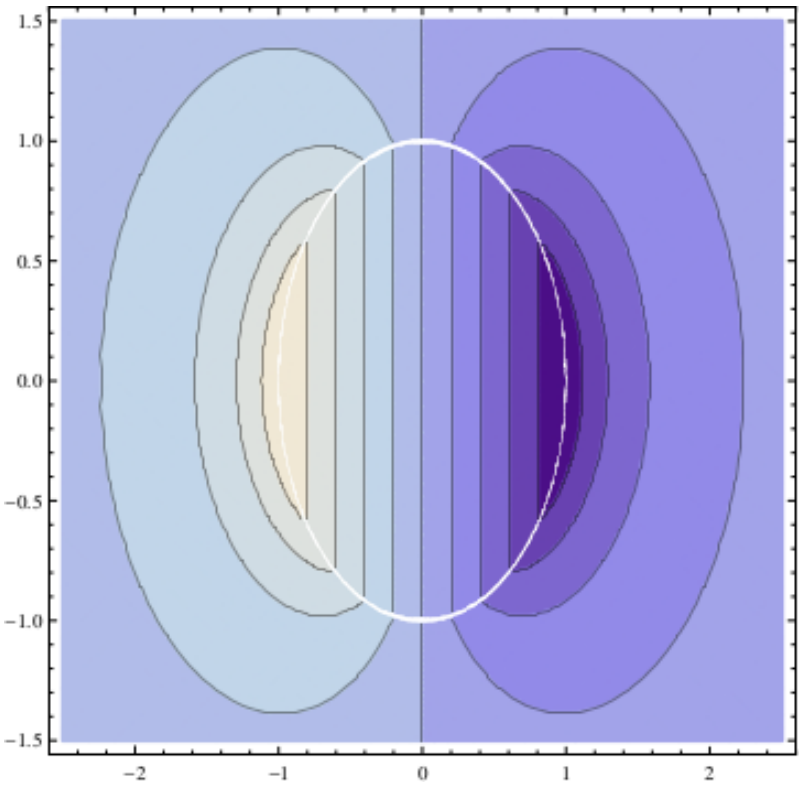
Apr. 24, 2014


10 11 12 13
N_e (log MKS)
−150 −50 50 150
VPE (m/s)
−60 −20 20 60
VPN (m/s)
Altitude (km)
700
600
500
400
300
200
23:00 0:00 1:00 2:00 3:00
UT (hr)
10 11 12 13
$N_{elog\ MKS}$
<VPN> (m/s)
60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60
Alt. (km)
600
500
400
300
200
−50 0 50 100 150 200
V_x (m/s)
2014/04/25
Thu Apr 24 18:59:48 2014
Range (km)
800
600
400
200
19:30 20:00 20:30 21:00 21:30
Local time (hr)

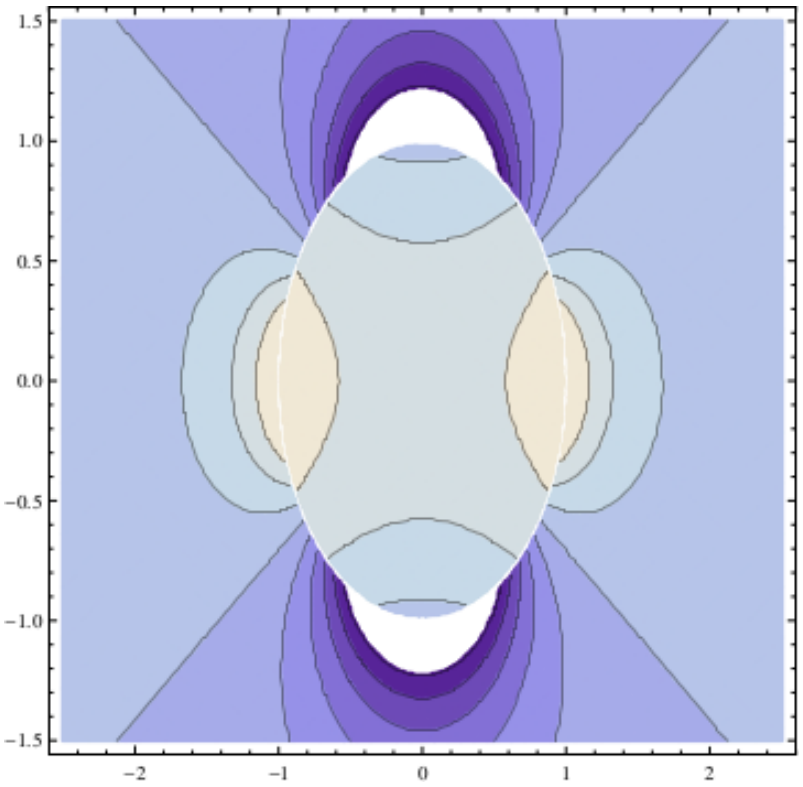
Apr. 23, 2014


10 11 12 13
N_e (log MKS)
−150 −50 50 150
VPE (m/s)
−60 −20 20 60
VPN (m/s)
Altitude (km)
700
600
500
400
300
200
23:00 0:00 1:00 2:00 3:00
UT (hr)
10 11 12 13
$N_{elog\ MKS}$
<VPN> (m/s)
60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60
Alt. (km)
−50 0 50 100 150 200
V_x (m/s)
2014/04/24
Wed Apr 23 18:42:52 2014
Range (km)
800
600
400
200
19:00 19:30 20:00 20:30 21:00 21:30
Local time (hr)

3D warm plasmas



polarization



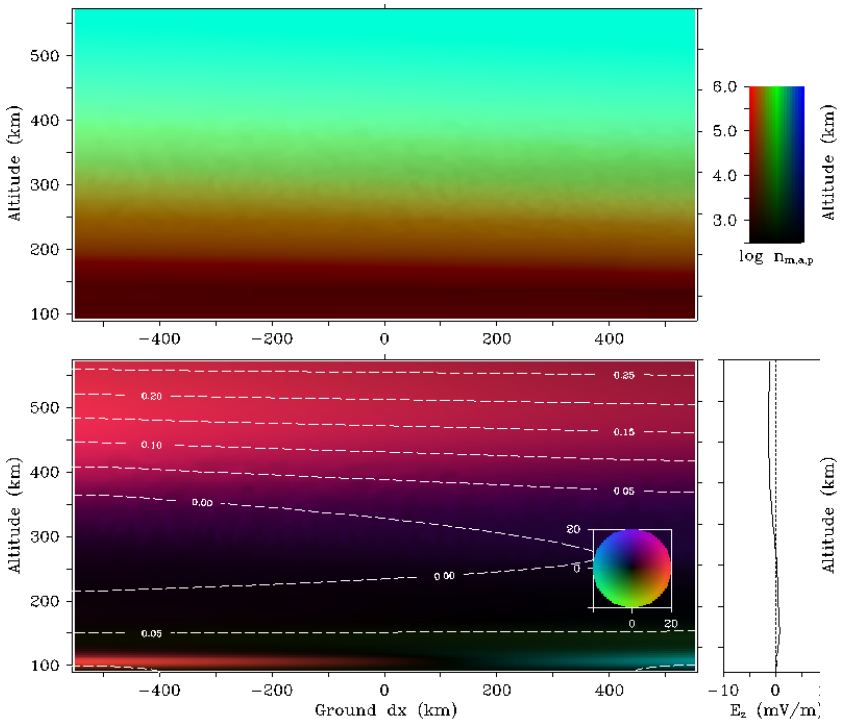
ambipolar diffusion

Drake, J. F., and J. D. Huba, *Phys. Rev. Lett.*, 58, 1987.

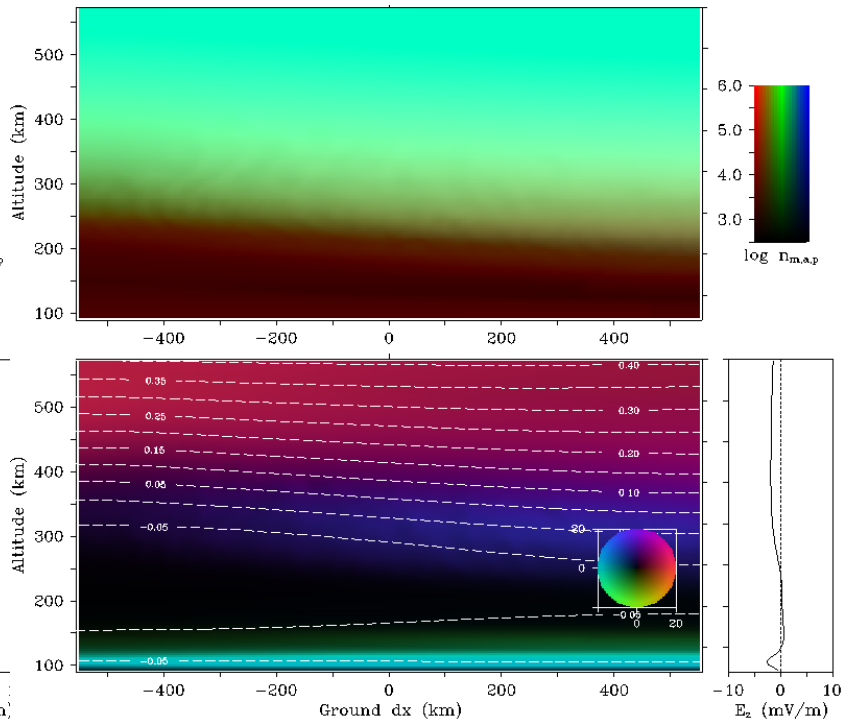
simulation code

- cast in 3D tilted magnetic dipole coordinates
- complete 3D potential solve (PBiCGStab)
- NO^+, O_2^+, O^+, and H^+ plus electrons
- MUSCLs
- MSISE90 + IRI2016 + PIM + HWM014(*) + E-field(*)
- longitude $\sim$ local time for all independent variables
- recently ported to F90, parallelized, moved to small cluster (10x speed improvement)

simulation: low activity

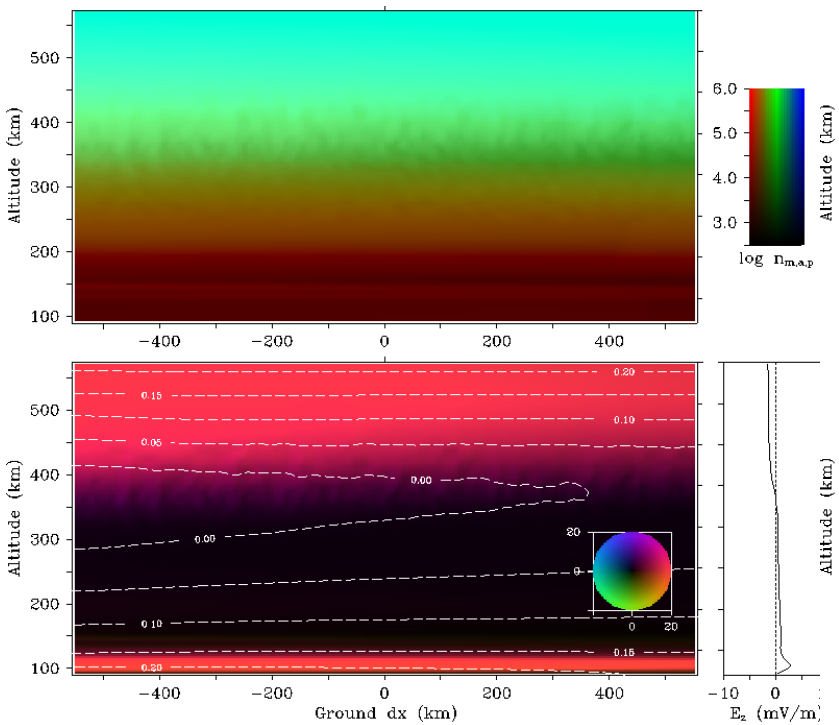


2345 UT + 25 min.

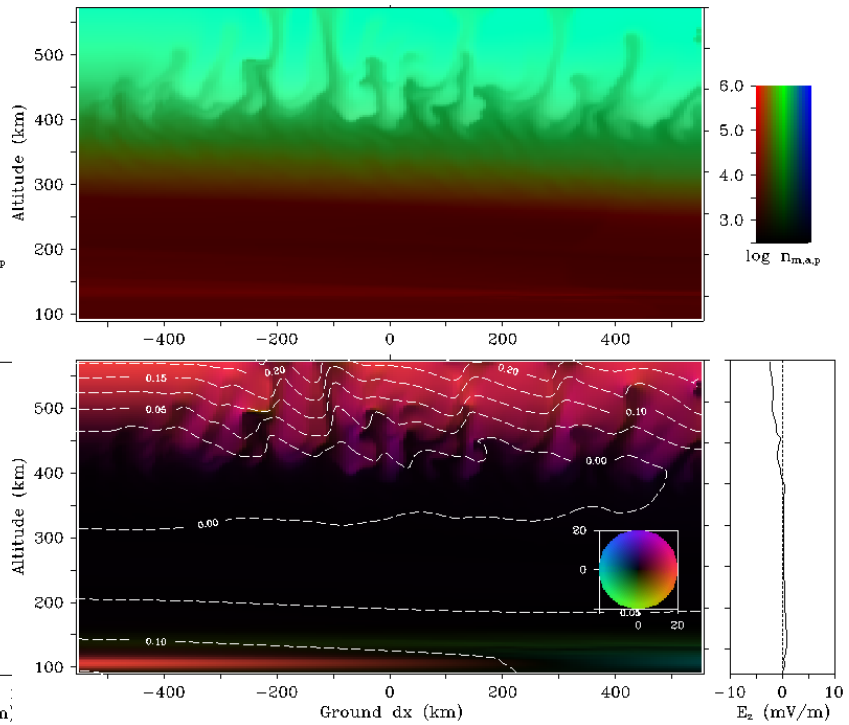


2345 UT + 75 min.

simulation: high activity

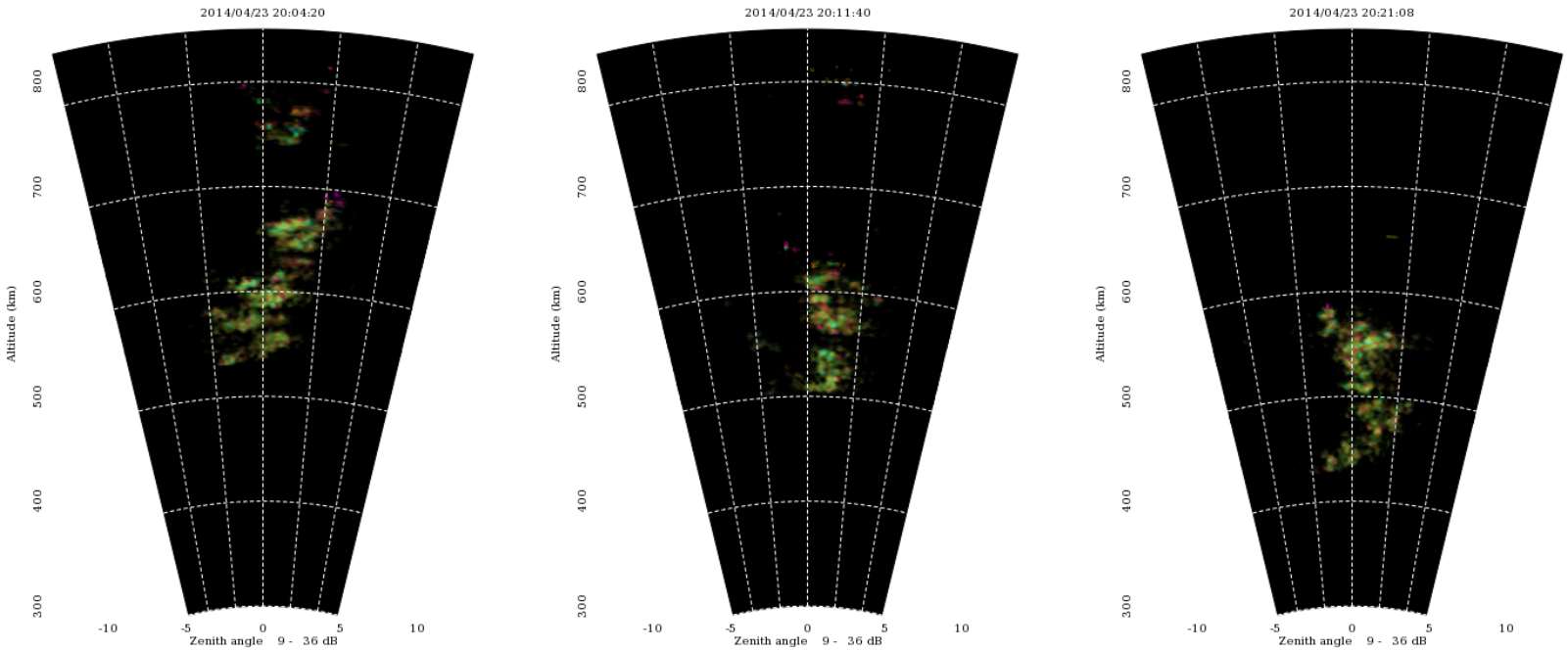


2345 UT + 25 min.



2345 UT + 75 min.

radar images



animation

summary

- ESF driven by variants on simple E×B instability. Most important nonlinearity in convective derivative in continuity equation, giving rise to plasma steepening.
- Details are critical; inclusion of shear flow, vertical currents, and non-equipotential magnetic field lines essential for accurate modeling.
- No false alarms!
- A few missed detections: occasional rogue plumes suggest nonlocal origins.
- Use beacon network to identify depletions arriving from different longitudes, latitudes.