Scintillation Modeling at CCMC

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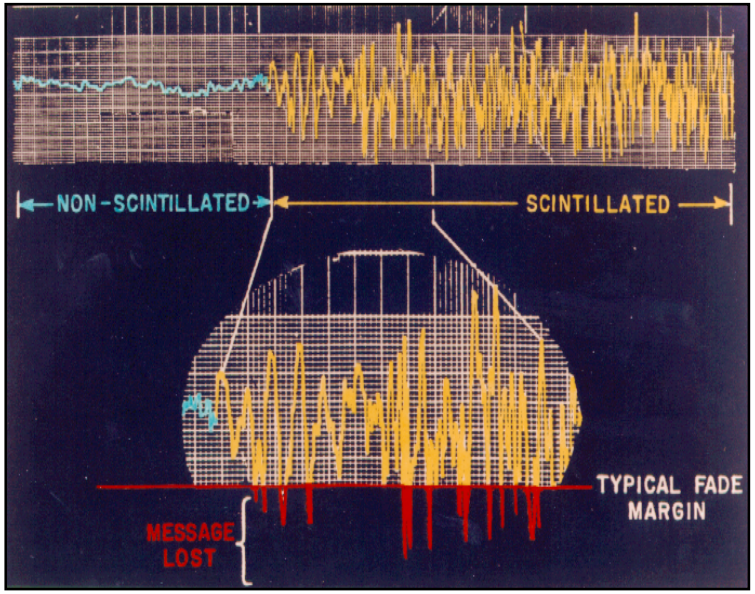
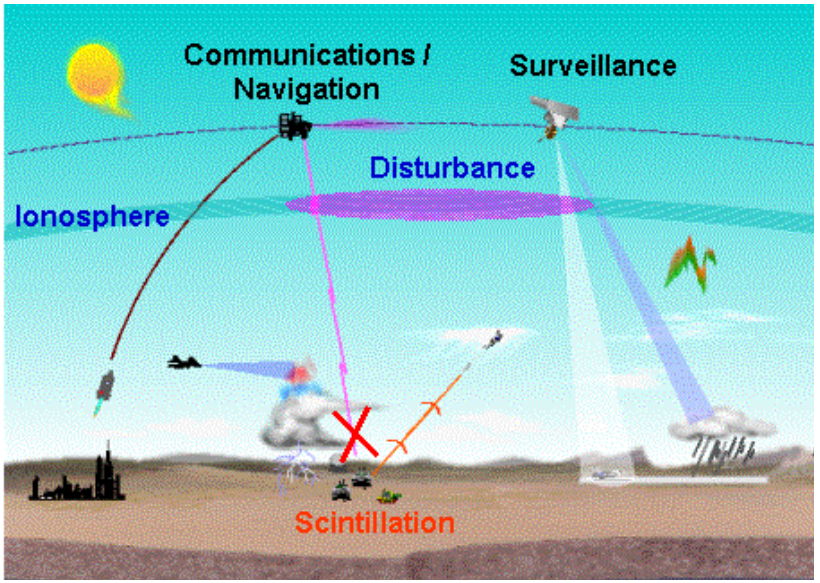
Scintillation Modeling at CCMC

- Radio Scintillation: importance and relevance
  - Space-weather impacts
  - Basic-science community
- The PBMOD Model for Scintillation
  - What's in it?
  - What can it do?
- Transition of model to CCMC
  - Interface for the community user

Scintillation

Scintillation: Rapid fluctuations of the amplitude & phase of radio signals from space due to ionospheric turbulence

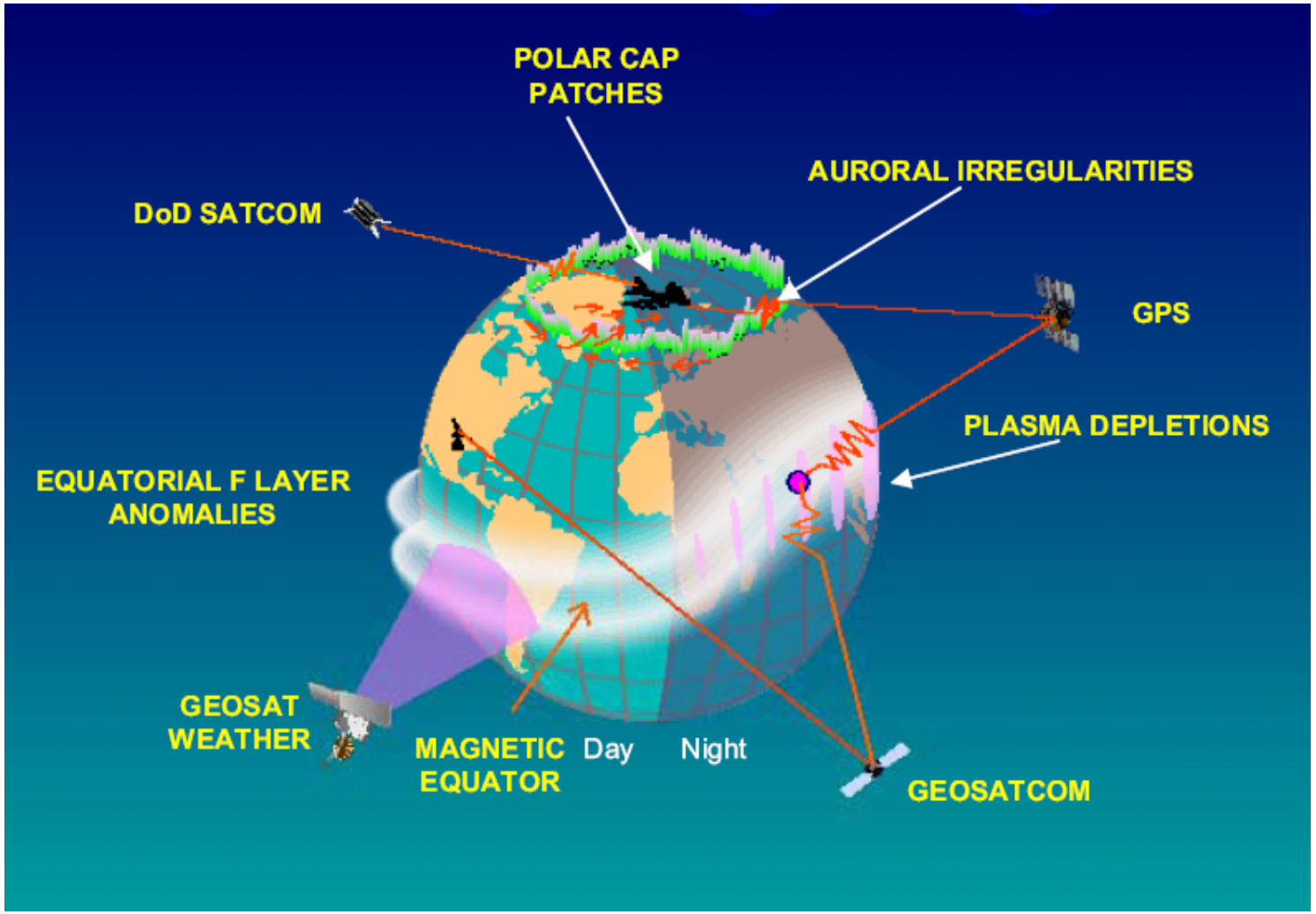




Scintillation causes outages of communication and navigation systems

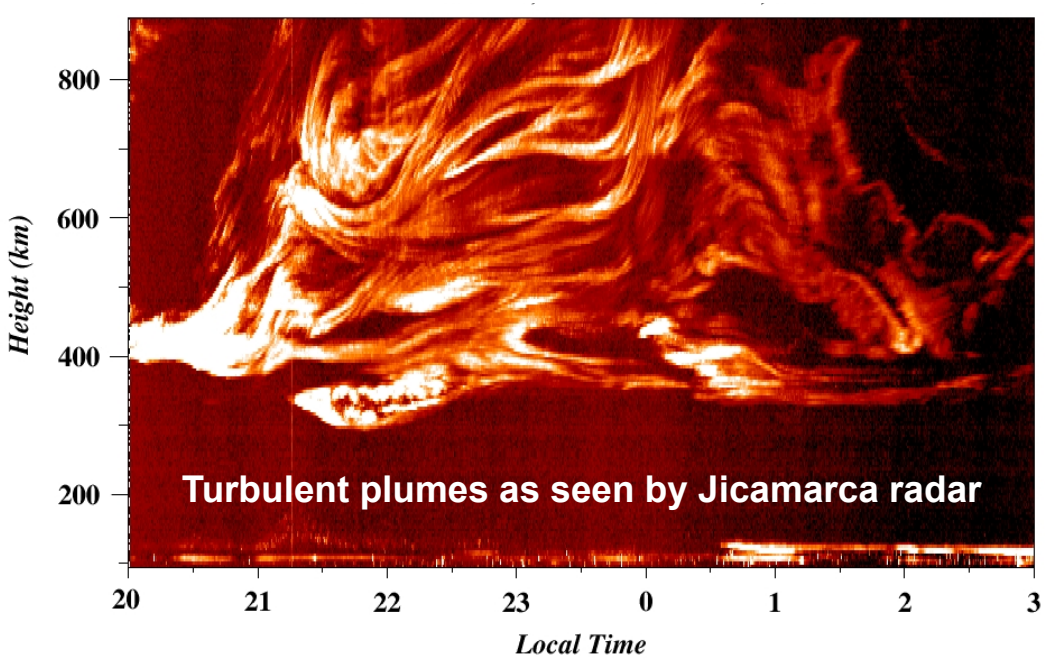
Scintillation Regions

polar and equatorial



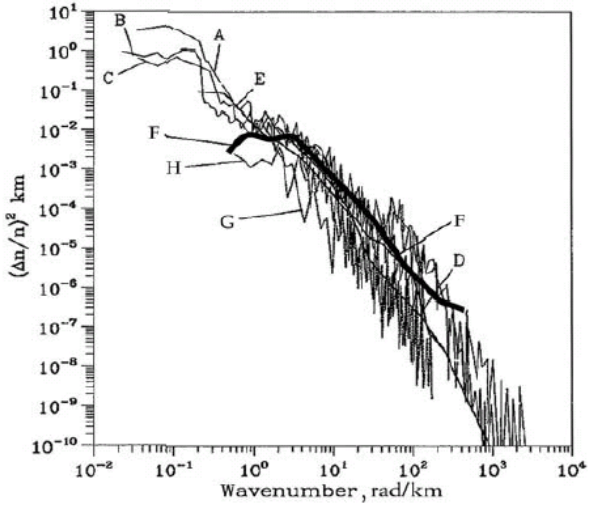
Low Latitude Scintillation

Scintillation at low magnetic latitudes is associated with the development of plasma turbulence within plumes of uplifting low-density plasma triggered by the Rayleigh-Taylor instability near the lower edge of the ionospheric F layer



(Woodman and LaHoz 1976)

Spectrum of density irregularities from rocket fly-through density measurements

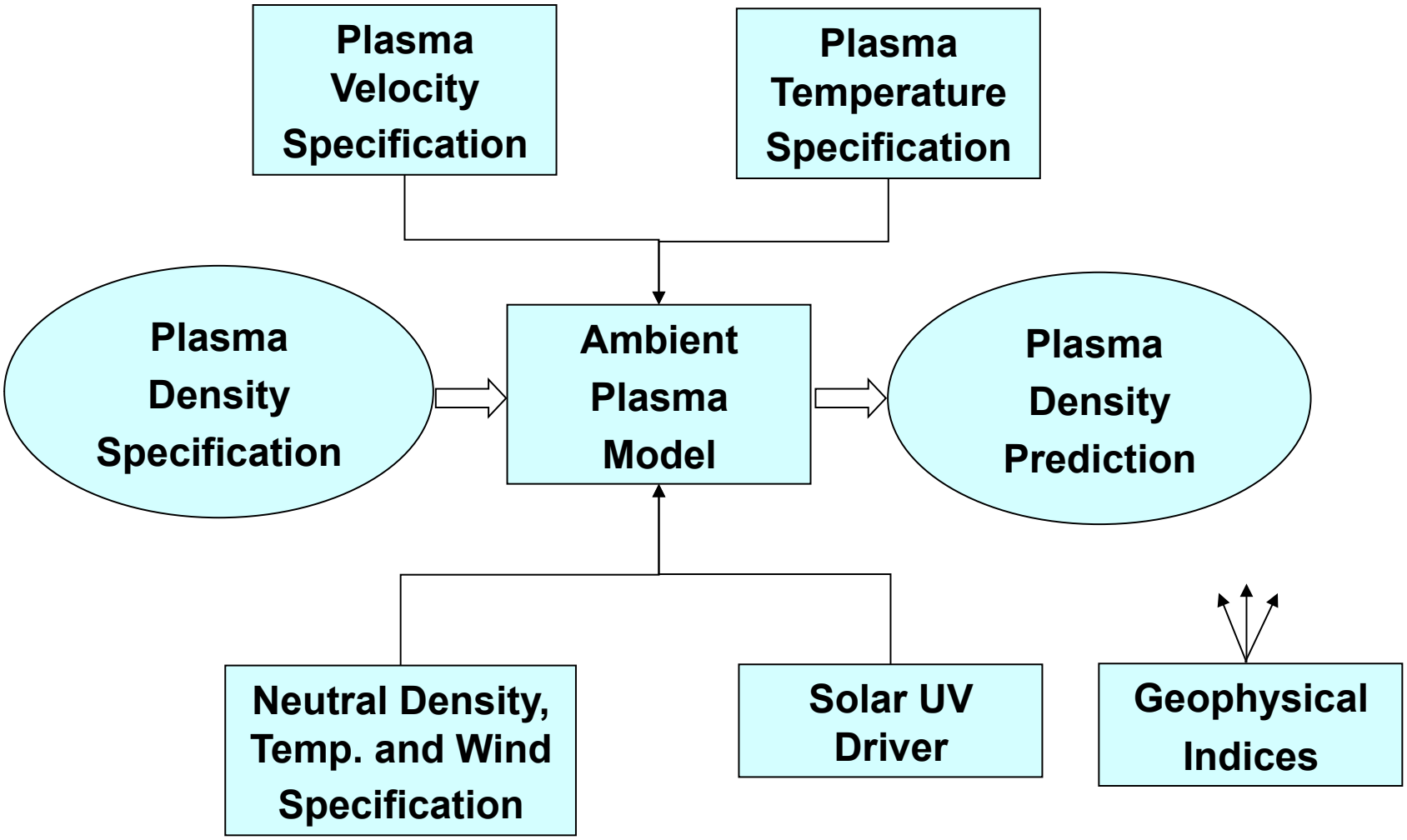


(Kelley and Livingston 2003)

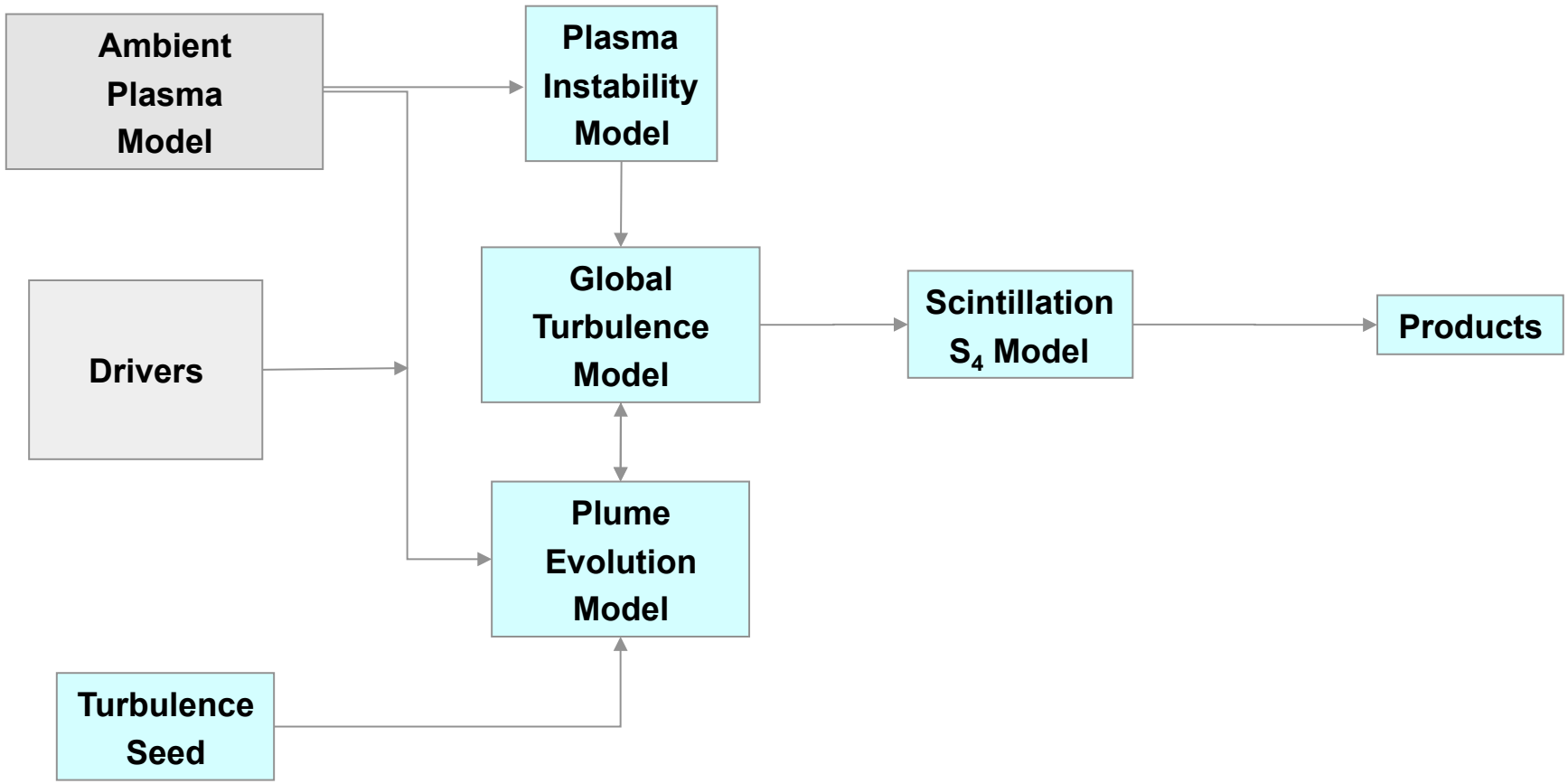
Scintillation Modeling at CCMC

- Radio scintillation calculations require a multi-scale chain of models of low-latitude ionospheric phenomena:
  - Ambient (global-scale) plasma-density modeling
  - Rayleigh-Taylor plasma-instability calculation
  - Plasma plume/bubble calculation
  - Scintillation calculation using resulting turbulence
- PBMOD is the system of models of these processes developed for the Air Force/NASA C/NOFS program by John Retterer (AFRL/BC)
- PBMOD is being installed at CCMC for community use

PBMOD Ambient Ionosphere Model



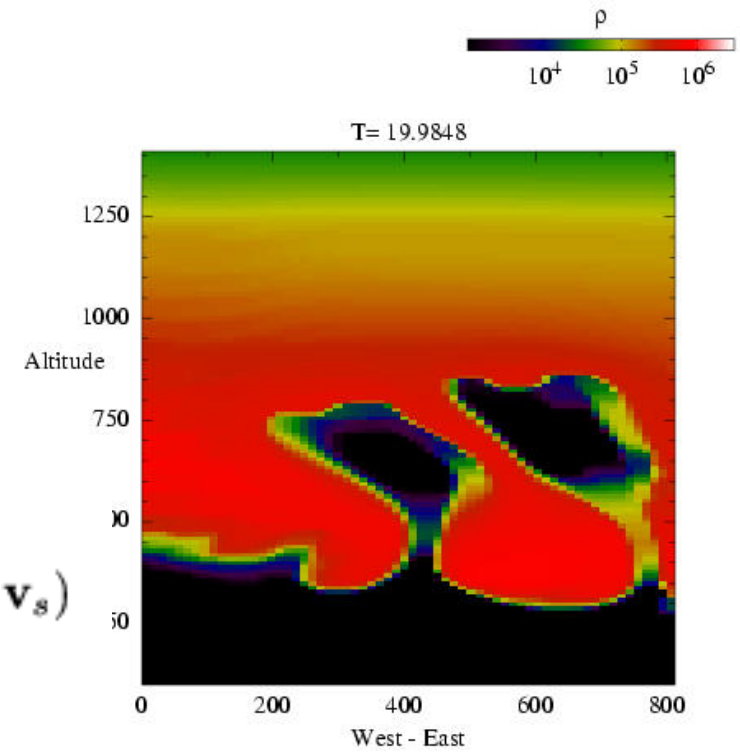
PBMOD Scintillation Forecast Model



Scintillation Forecast Model

Plume Evolution Model Algorithms

Model describes temporal development of mesoscale plasma structure & turbulence



Uses nonlinear continuity and momentum equations

$$\frac{\partial n}{\partial t} + \nabla_\perp \cdot (n\mathbf{v}_\perp) = 0$$

$$\frac{d\mathbf{v}_s}{dt} = \frac{q_s}{m_s}\mathbf{E} + \mathbf{g} + \Omega_s \mathbf{v}_s \times \hat{\mathbf{B}} - \frac{1}{n_s}\nabla_\perp P_s + \nu_s(\mathbf{U} - \mathbf{v}_s)$$

Perpendicular electric fields:

global-scale fields from ambient model +

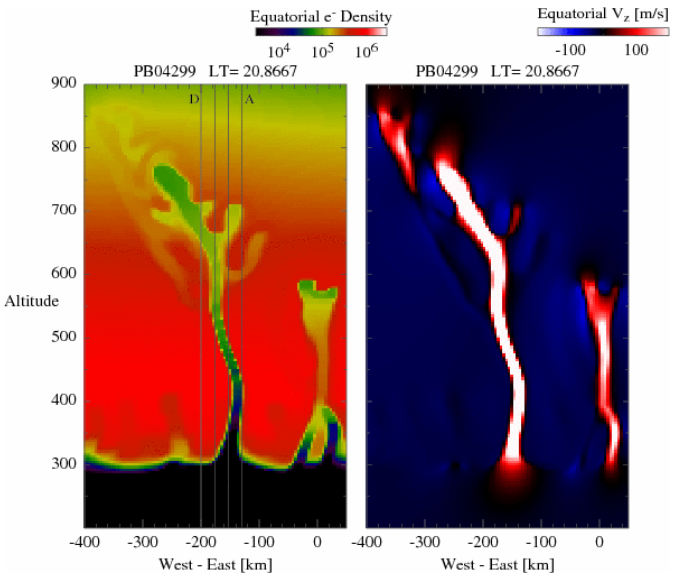
self-consistent fields determined by current-continuity condition

Start with small perturbation; if unstable plasma, perturbation will quickly grow

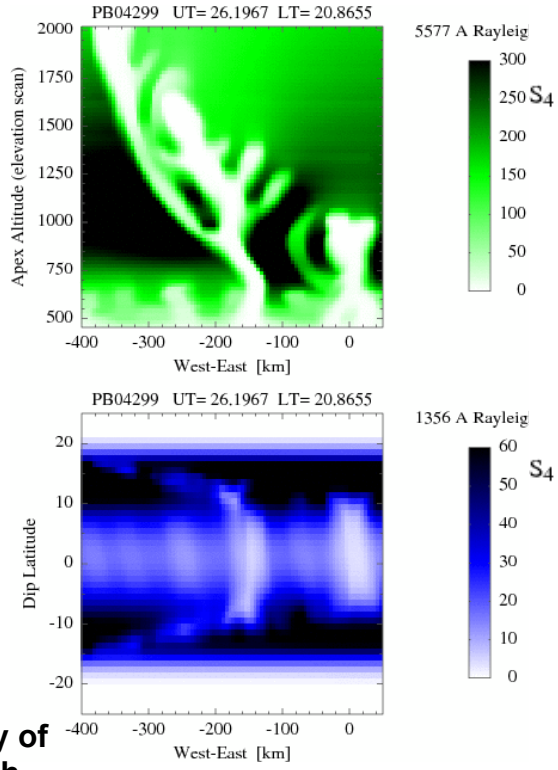
PBMOD includes two-dimensional and three-dimensional plume models

Scintillation Modeling by PBMOD

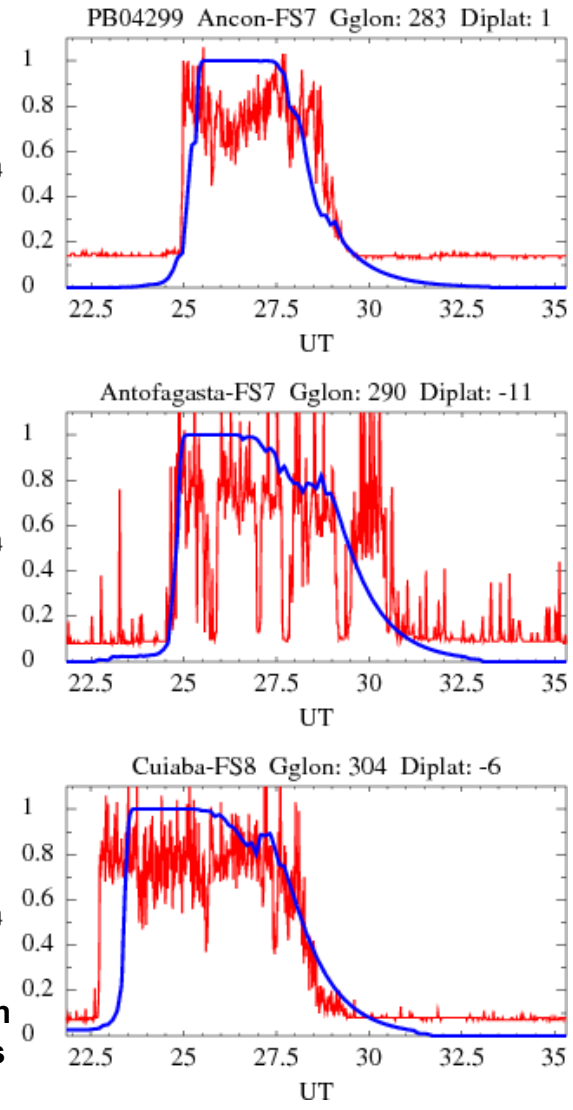
geomagnetically quiet conditions



Plume structure in density (left) and vertical velocity (right)



Airglow images of plumes: geometry of Cornell Hawaii camera (looking south toward plume) in 5577 A (top) and GUVI nadir sensing in 1356 A (bottom)



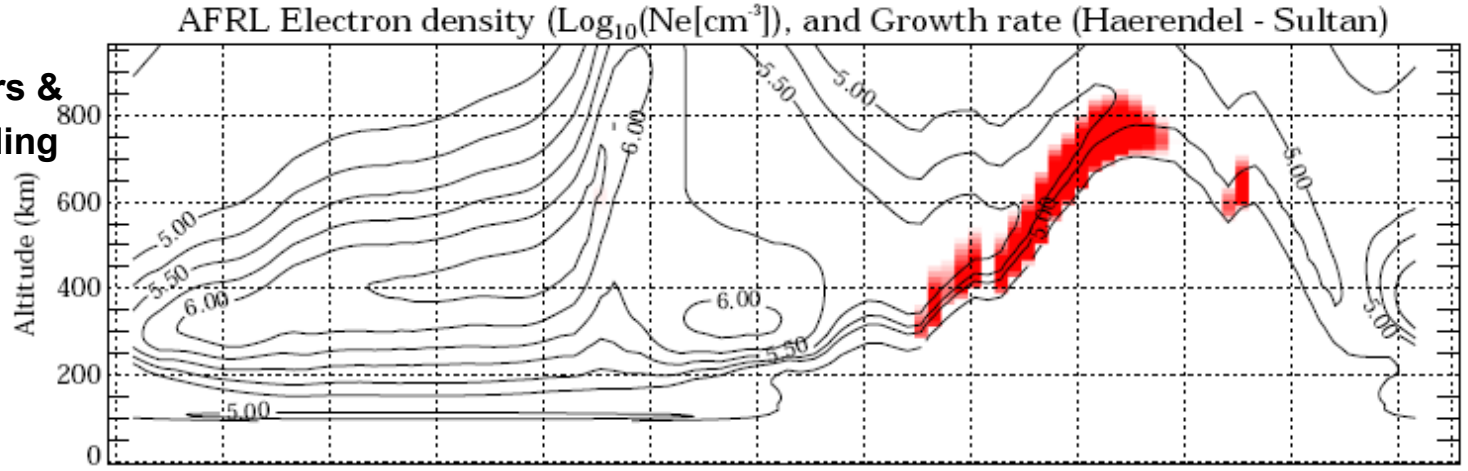
Scintillation observed at 3 SCINDA stations (red) compared with PBMOD predictions (blue)

(Retterer 2010a,b)

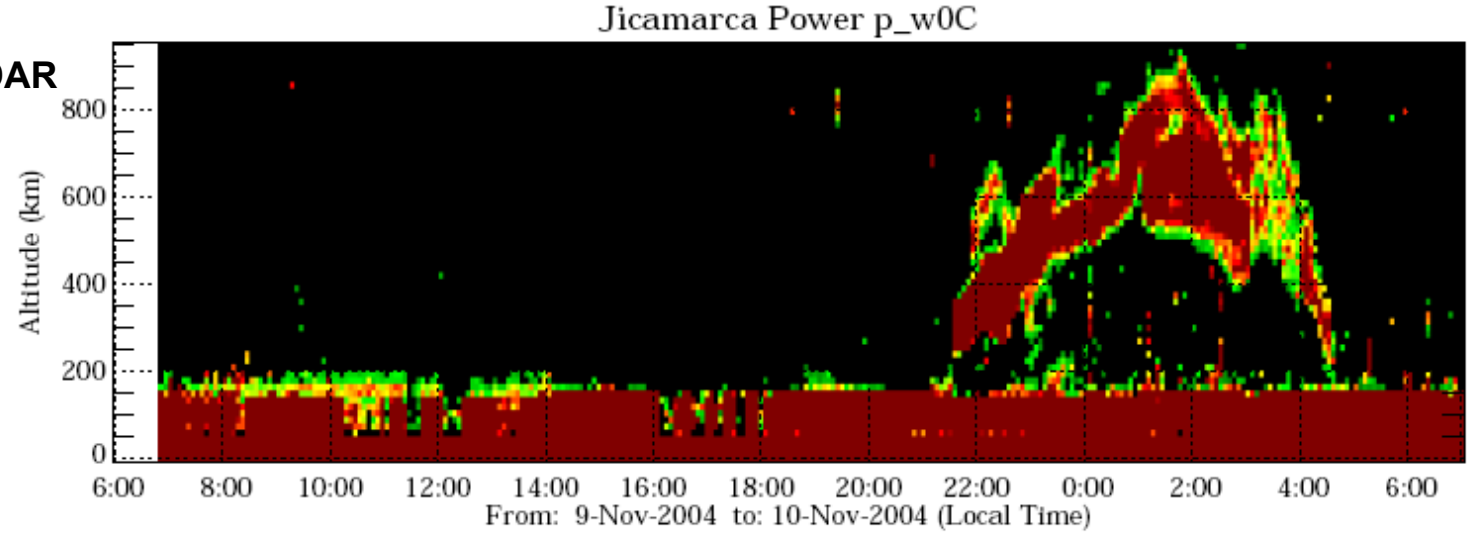
Scintillation Modeling

geomagnetic storm conditions (November 2004)

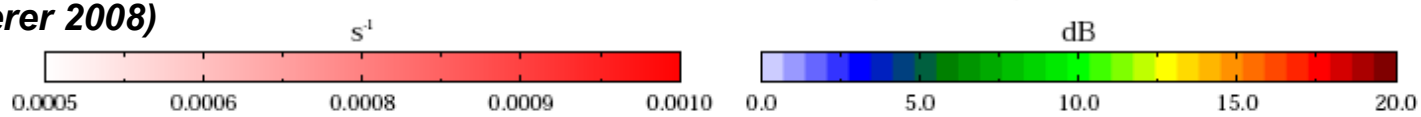
Density contours & RT growth shading from PBMOD using plasma drifts from Jicamarca



Jicamarca RADAR coherent returns - indicating presence of turbulence

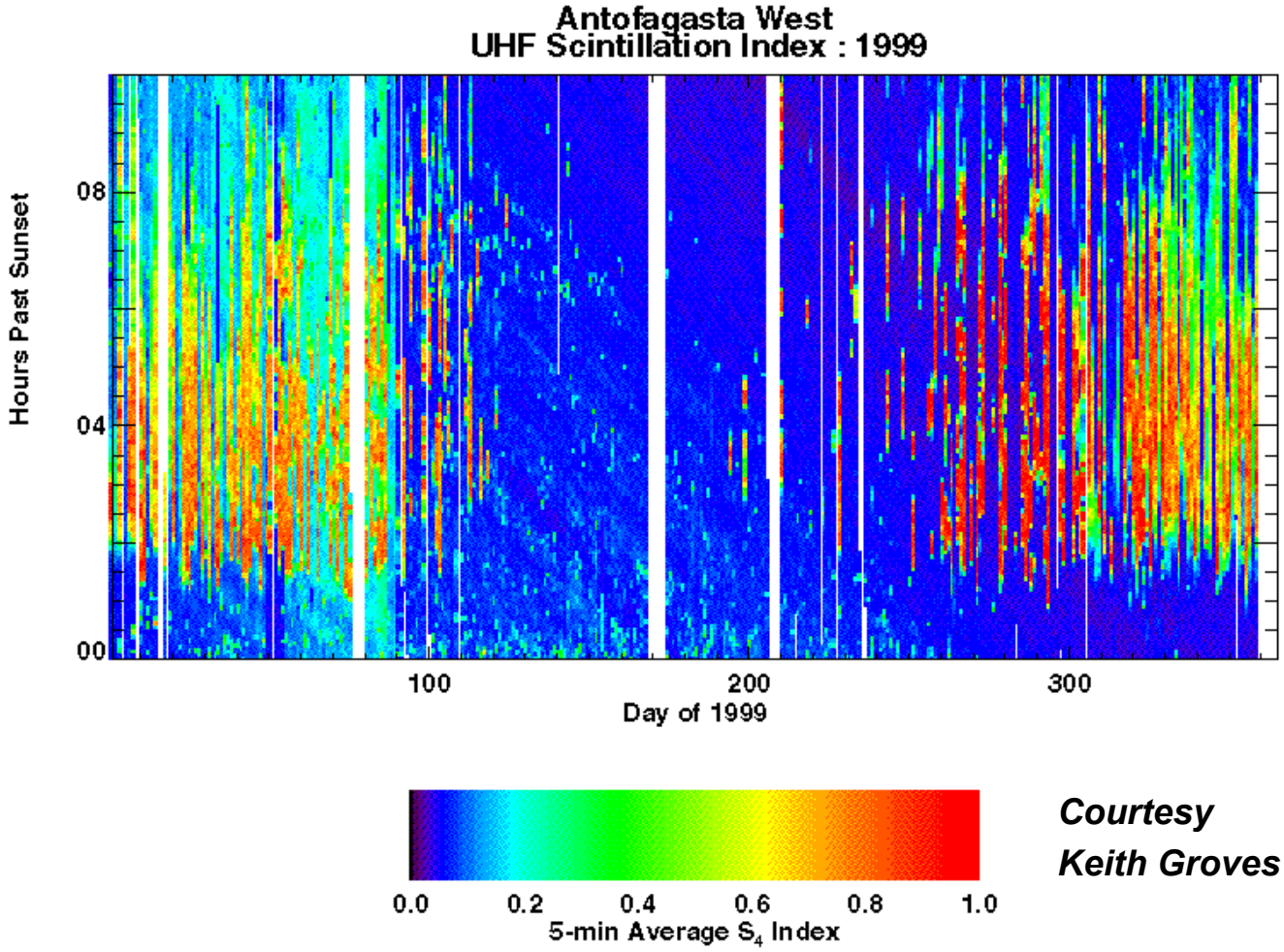


(Kelley and Retterer 2008)



Scintillation Statistics

SCINDA Station, Antofagasta, Peru



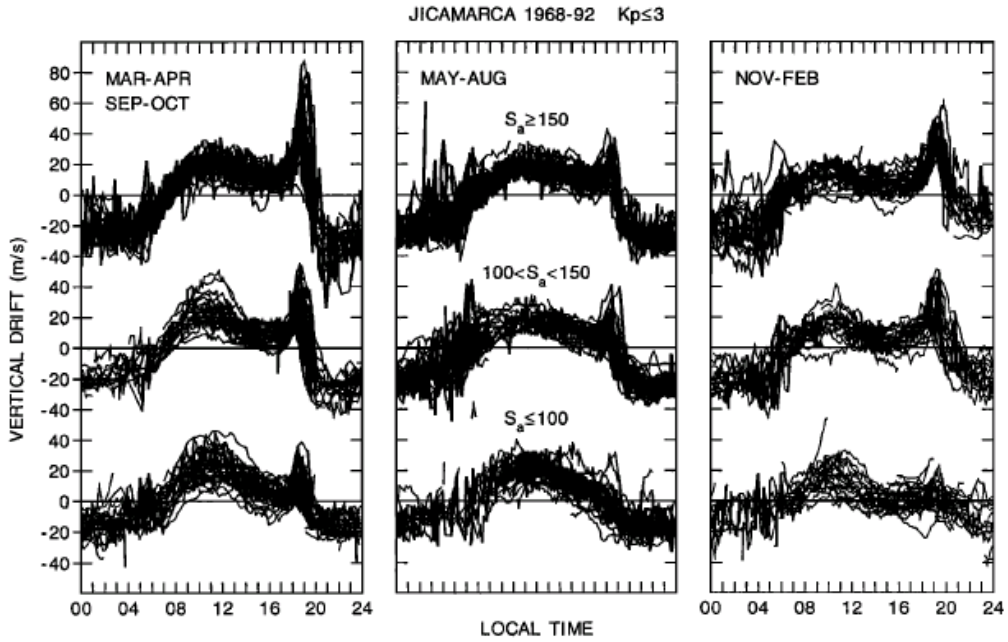
Courtesy
Keith Groves

Definite seasons of occurrence, but high day-to-day variability

Natural Geophysical Variation

The natural variability in scintillation is caused by the variability of geophysical conditions controlling the instability of the ionosphere

The major variable factor is the vertical plasma drift (Fejer et al., 1999)



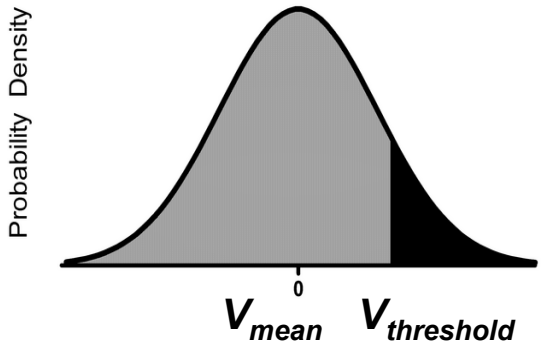
Jicamarca ISR data

(Scherliess & Fejer) suggest that the natural scatter of velocities: is +/- 10 m/s

Plasma Bubble Probability

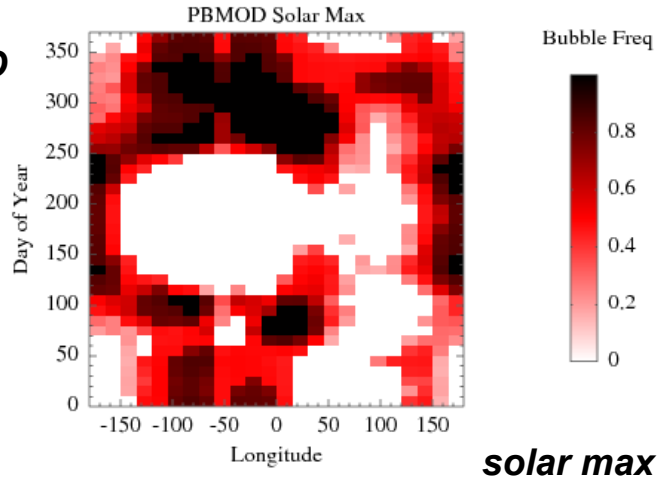
To test the idea that the statistics of bubble/scintillation formation can be described using the statistics of the vertical plasma drift, we estimated the bubble frequency at DMSP altitude from the ensemble statistics of several PBMOD runs with different plasma velocities to determine the threshold. The probability is then determined from the fraction of the population exceeding the threshold.

We found general agreement in the patterns of occurrence (the differences in detail could be fixed by adjusting other parameters).



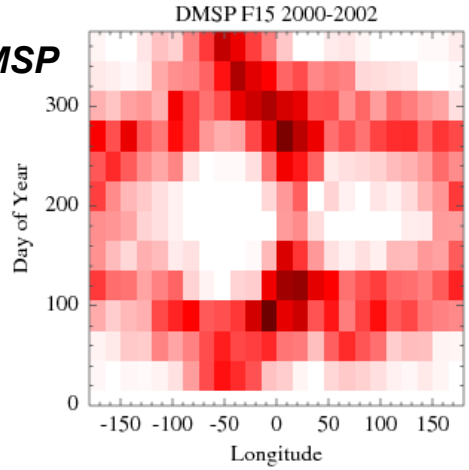
Plasma Bubble Probability

PBMOD



solar max

DMSP

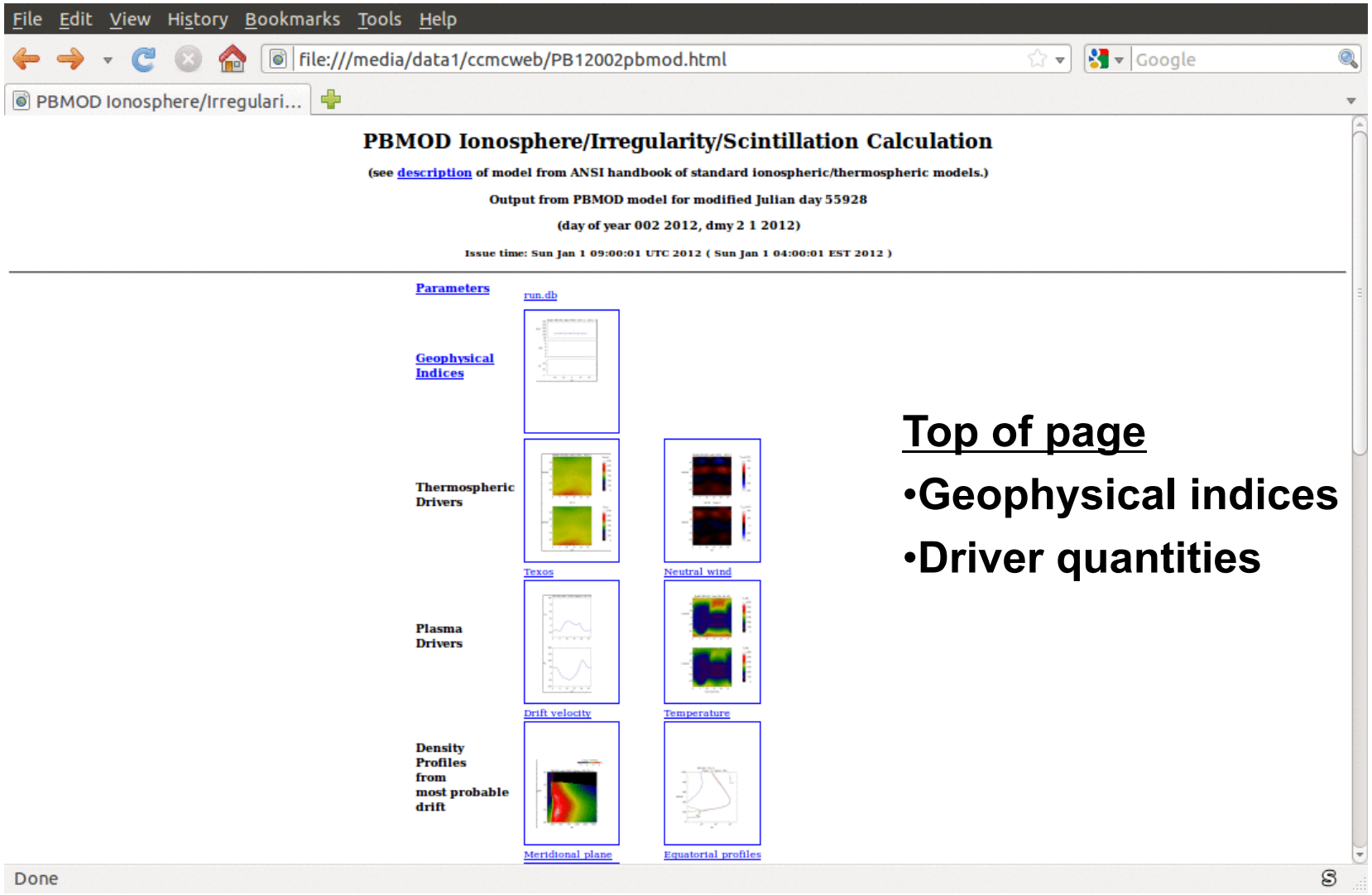


Retterer and Gentile 2010

PBMOD Daily Run at CCMC

- Daily run of PBMOD currently being performed at CCMC
- Execution start timed so that scintillation calculation can serve as a forecast
- Calculation done with two drift-velocity histories
  - Expected drift (50th percentile) for plasma densities
  - 85th percentile drift envelope to find near-worst-case scintillation strength
- Output webpage
  - Wide variety of output quantities, described in links
  - Model documentation included for reference

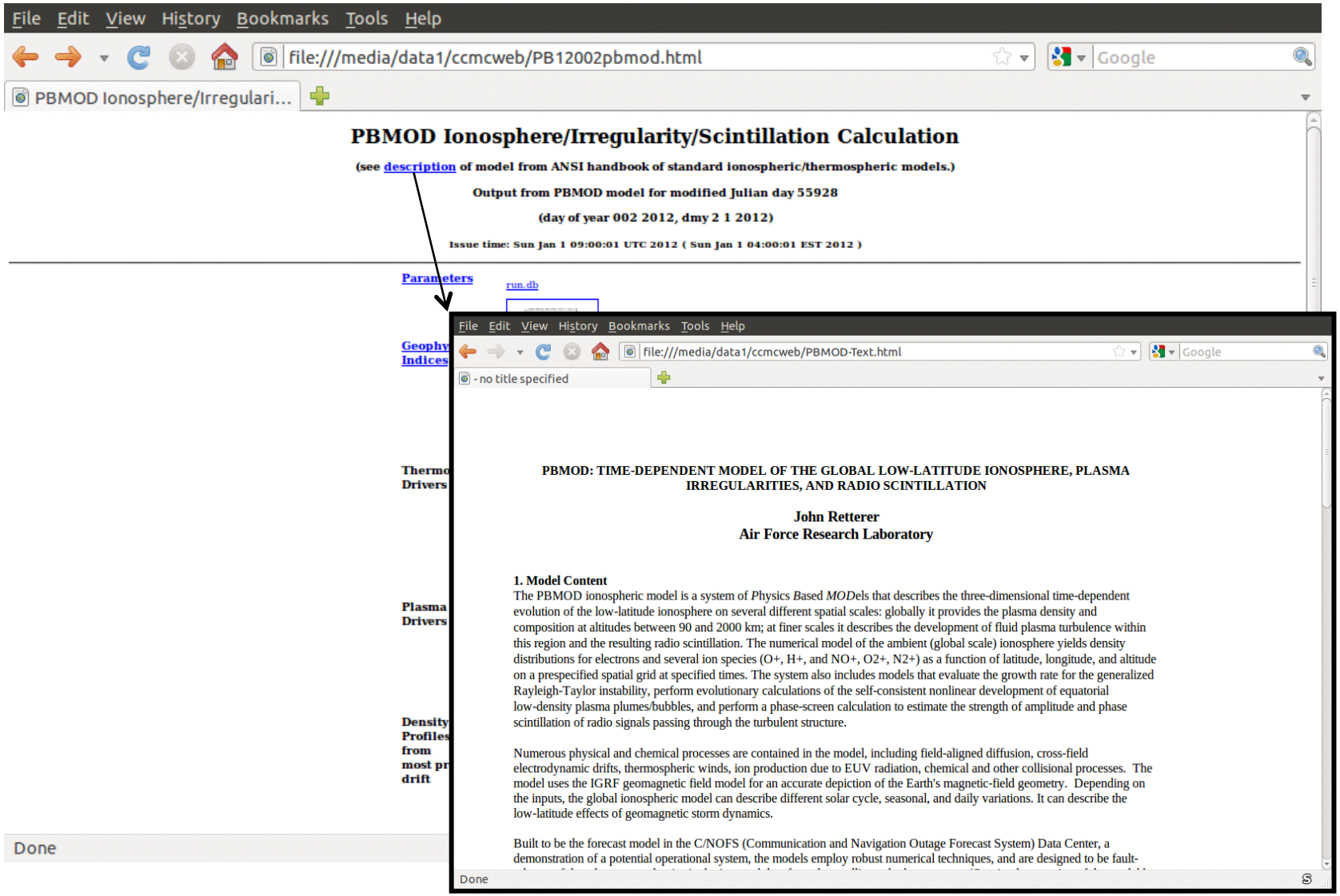
PBMOD Daily Run Webpage



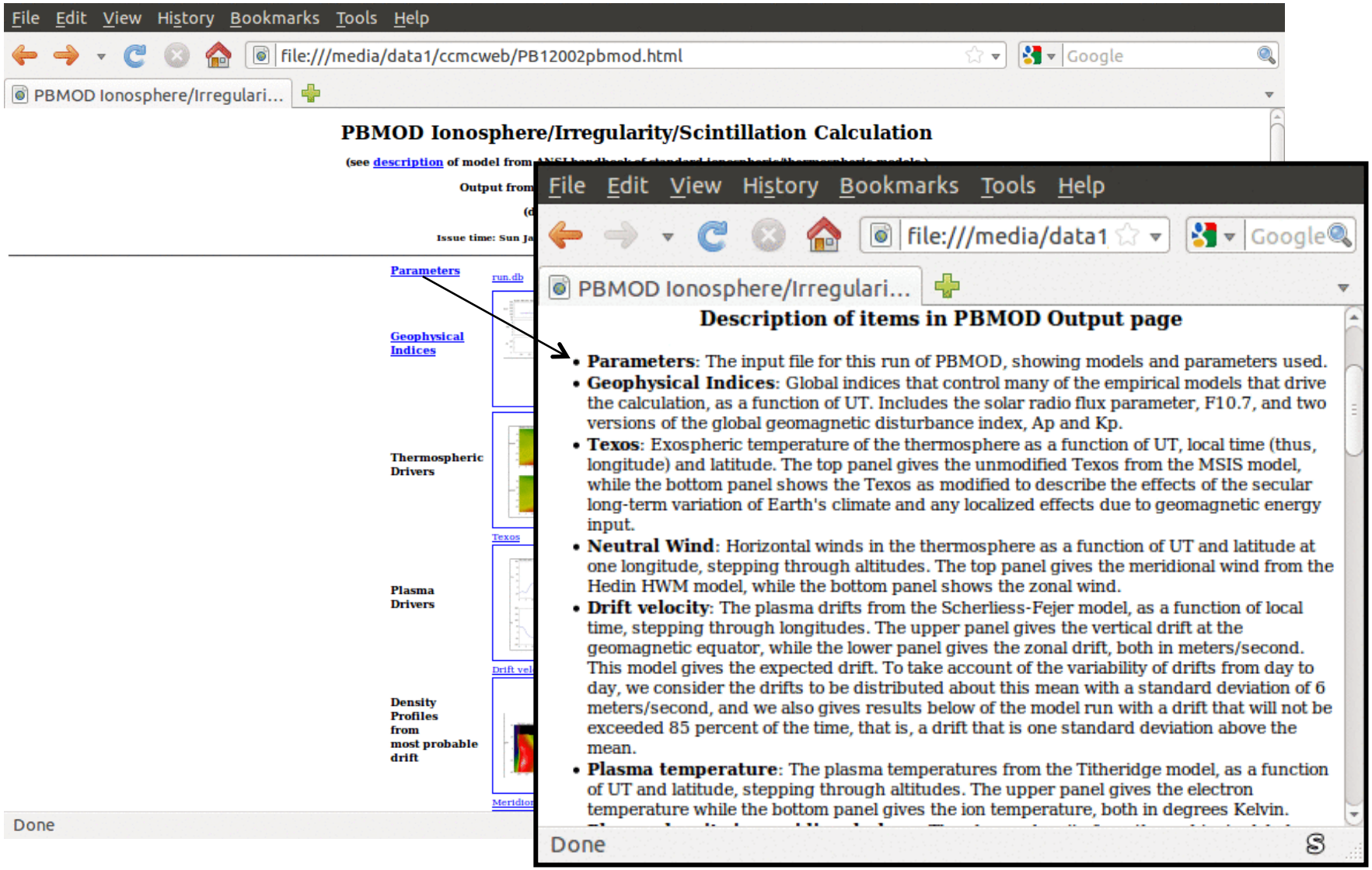
Top of page

- Geophysical indices
- Driver quantities

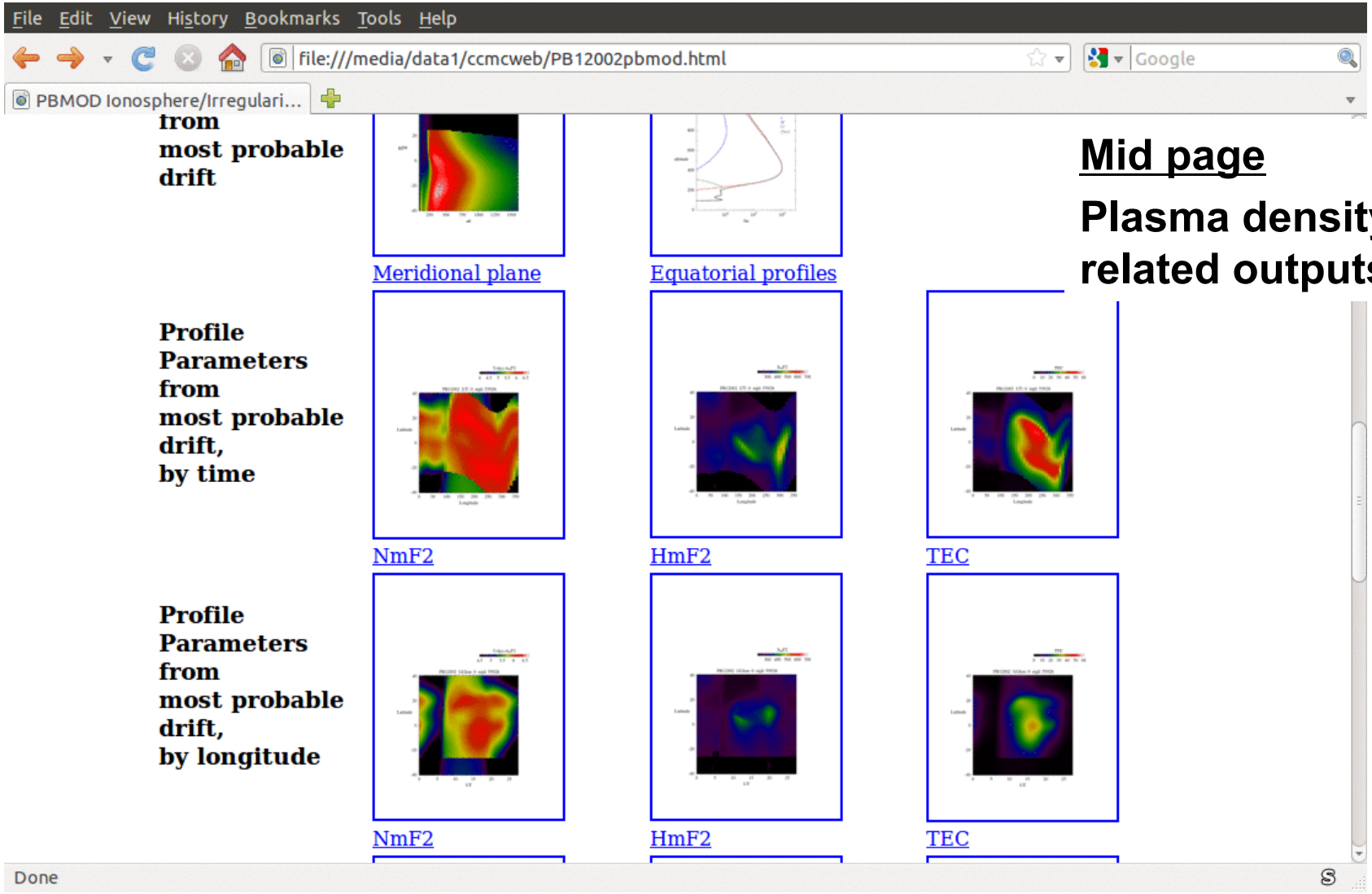
PBMOD Daily Run Webpage



PBMOD Daily Run Webpage



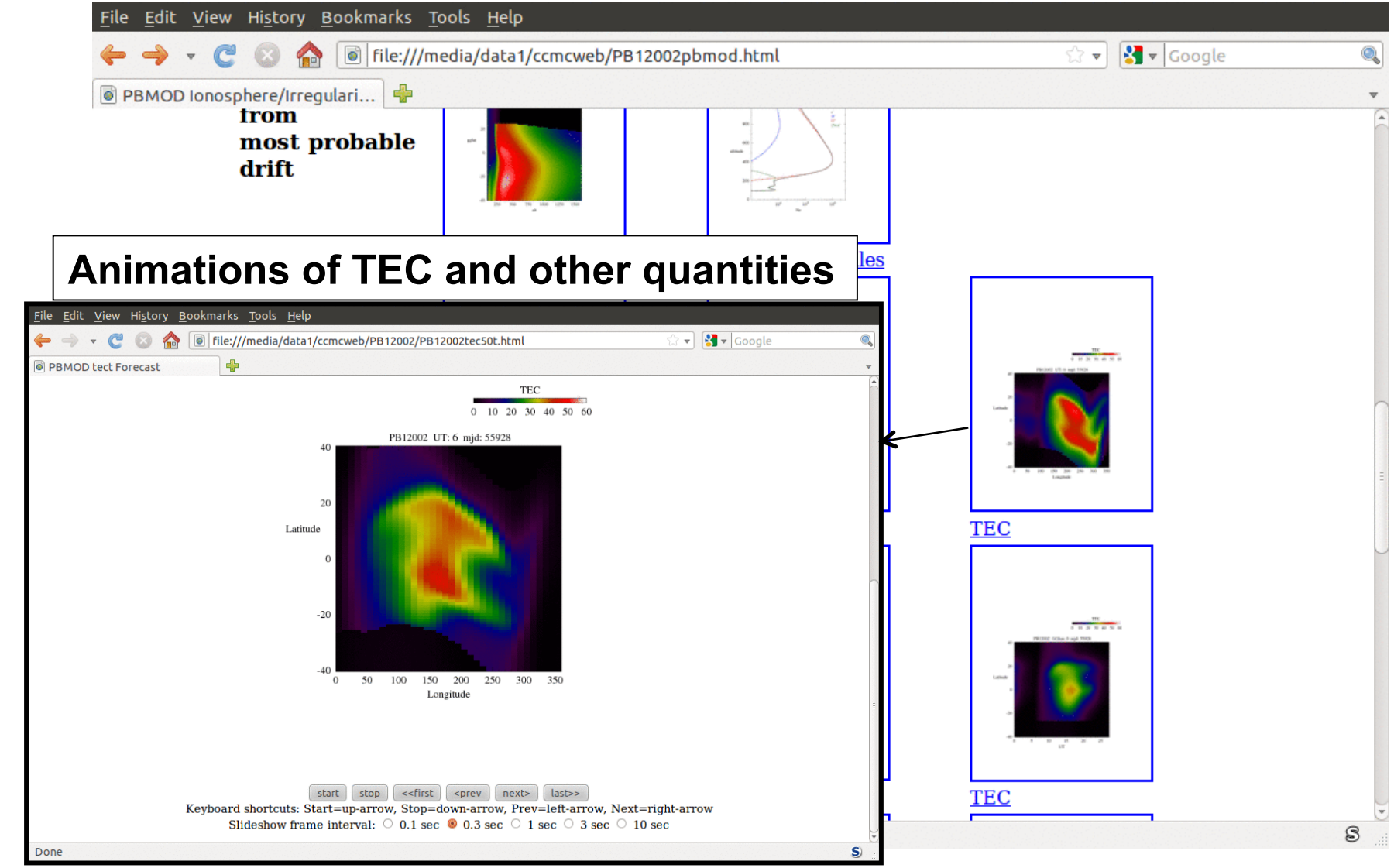
PBMOD Daily Run Webpage



Mid page

Plasma density related outputs

PBMOD Daily Run Webpage



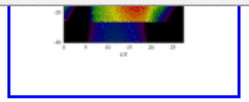
PBMOD Daily Run Webpage

File Edit View History Bookmarks Tools Help

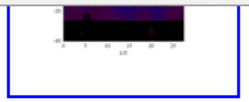
file:///media/data1/ccmcweb/PB12002pbmod.html

PBMOD Ionosphere/Irregulari...

by longitude



NmF2



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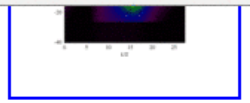
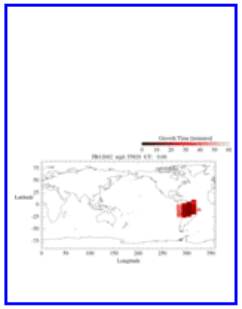
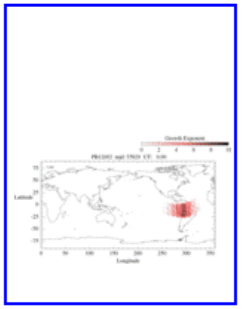


TEC

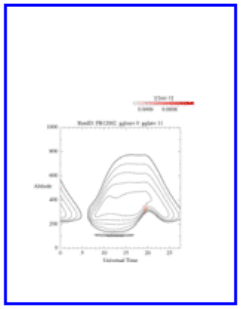
Rayleigh-Taylor Growth Rate from most probable drift



RT growth rate

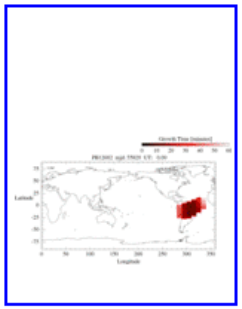


Time-integrated RT growth rate

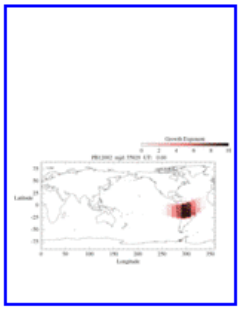


RT growth and density contours

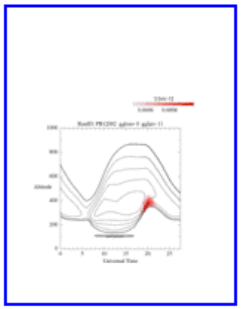
Rayleigh-Taylor Growth Rate from 85th-percentile drift



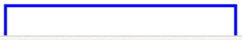
RT growth rate



Time-integrated RT growth rate



RT growth and density contours



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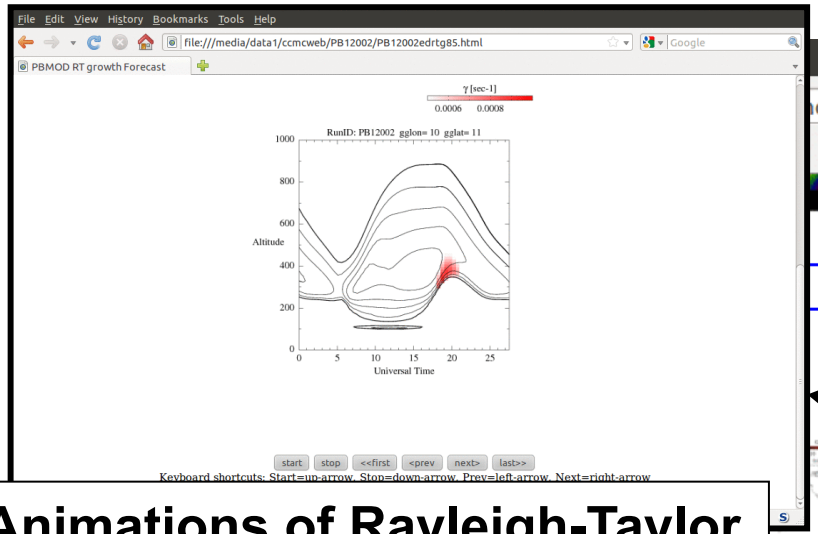
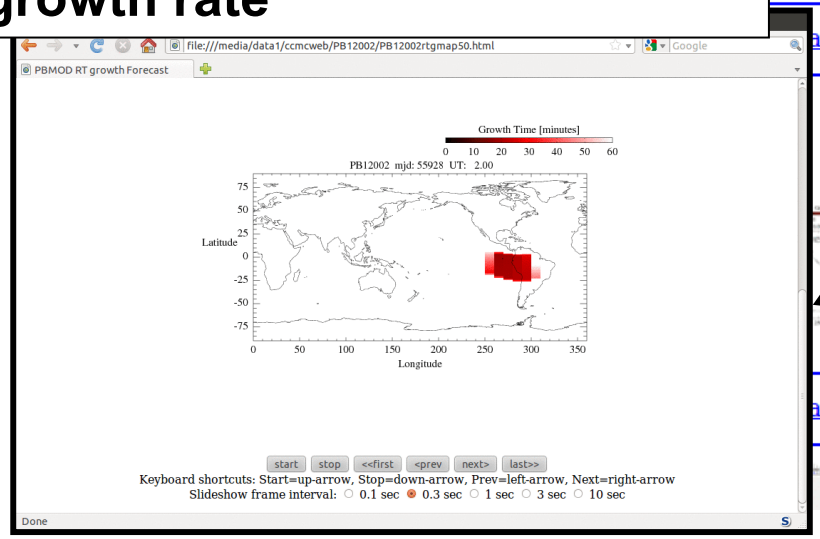
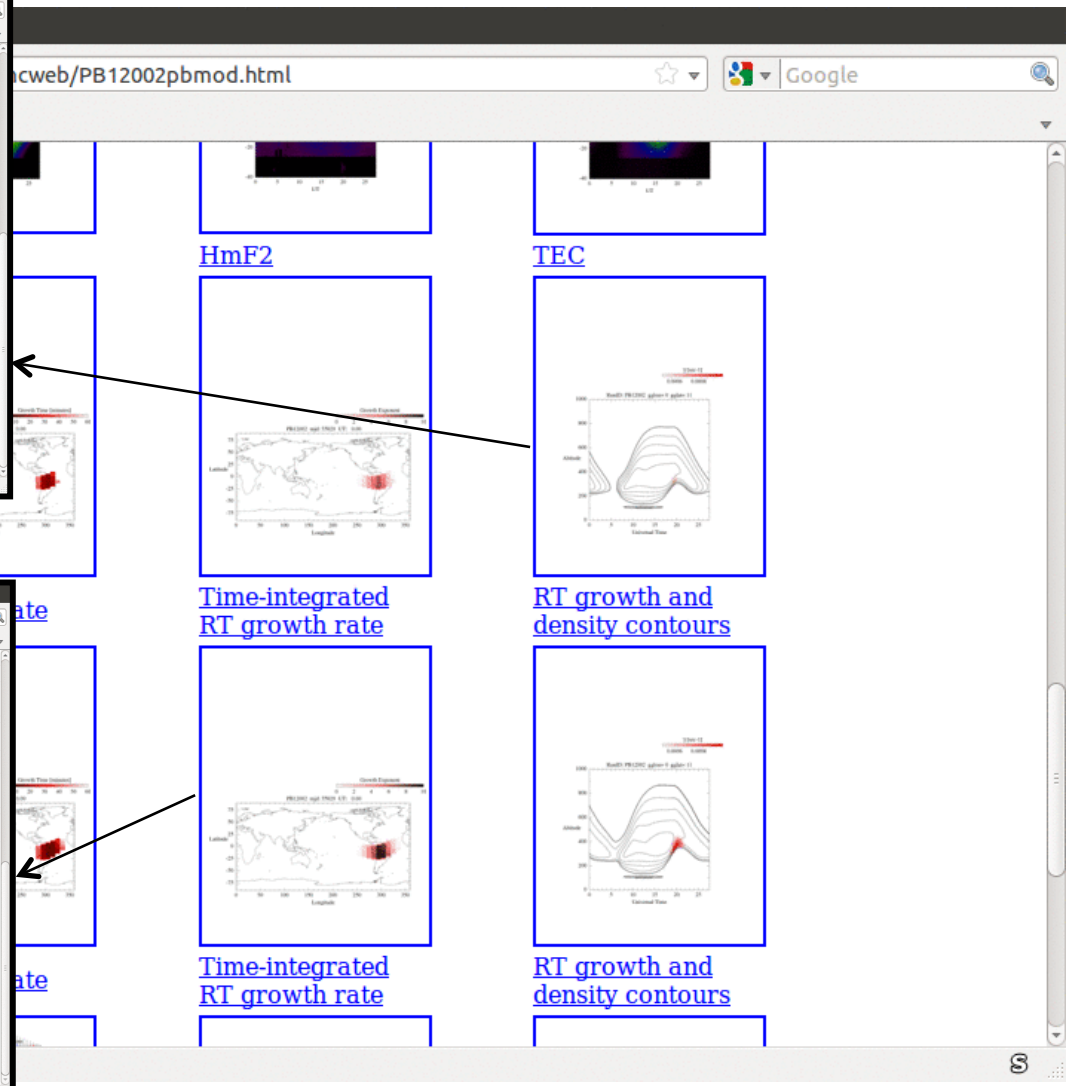
PBMOD Daily Run Webpage

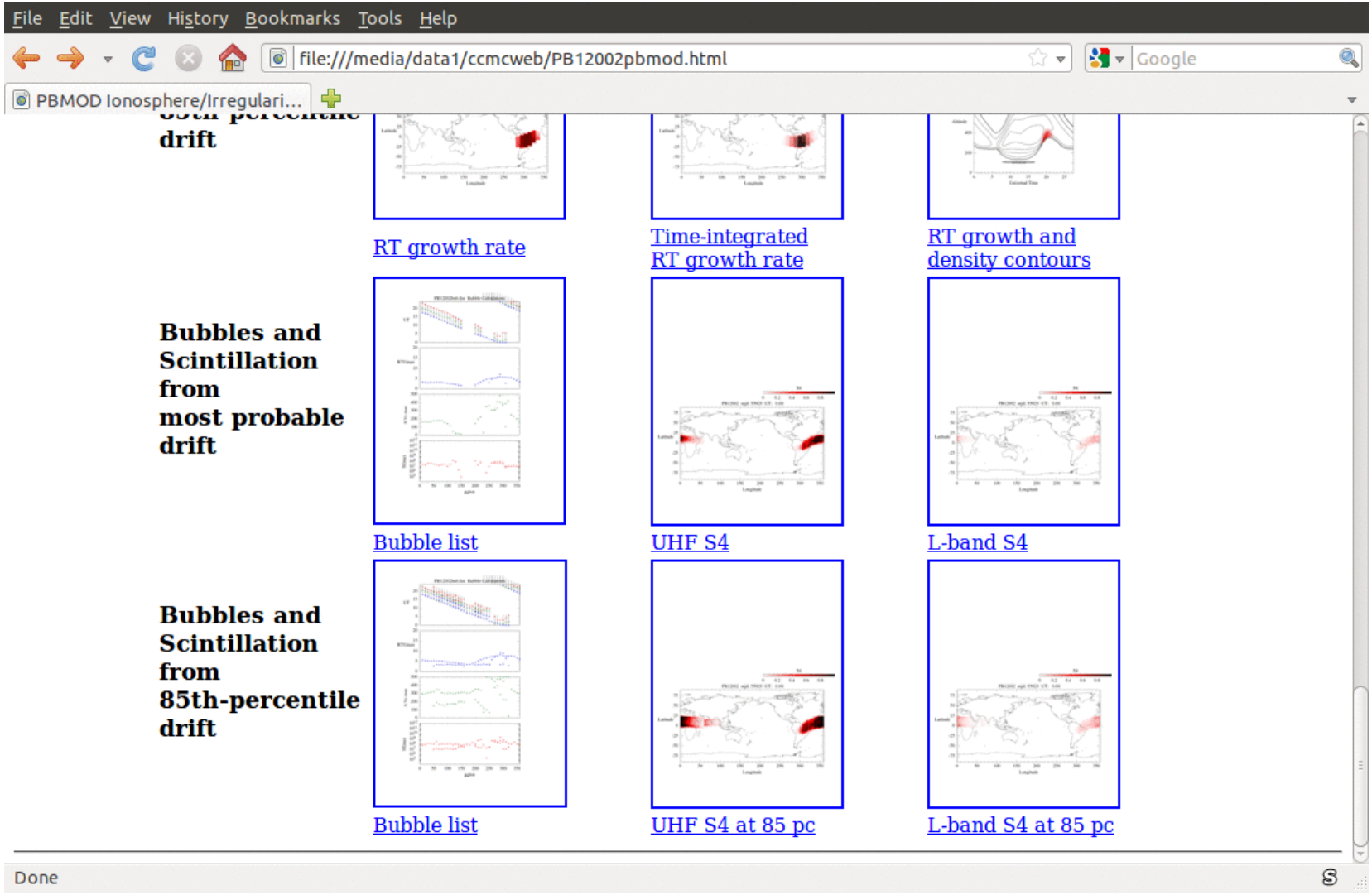


Animations of Rayleigh-Taylor growth rate



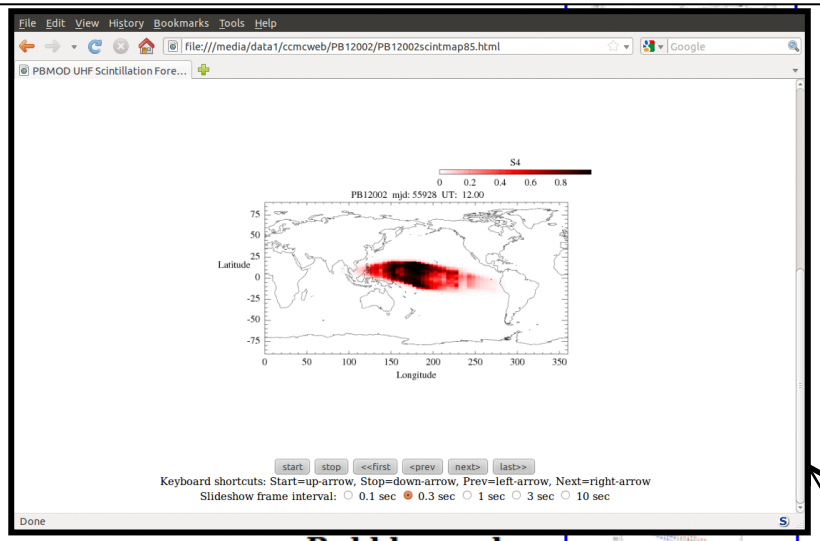


PBMOD Daily Run Webpage



PBMOD Daily Run Webpage

Animations of scintillation strength



Animations of bubble quantities

To Be Added

- Run PBMOD on Demand
  - User entry of plasma drift (local mode – one longitude sector)
- Couple PBMOD with other models at CCMC
  - TIEGCM for winds
  - Penetration fields and other storm effects

Summary

- Radio scintillation is a space-weather phenomenon with important implications for the basic science of the ionosphere and consequences for operational systems
- PBMOD is a model of the chain of phenomena that lead to scintillation that was developed for the Air Force/NASA C/NOFS program, which has been tested and refined under a variety of circumstances
- Good reason to implement PBMOD at CCMC: there are a number of meaningful aspects of the scintillation phenomena that the community user will be able to explore using the model with the web interface