PBMOD at CCMC

John Retterer, Pei Chen Lai, and Keith Groves
Institute for Scientific Research, Boston College

Min-Yang Chou and Jack Wang
Catholic Univ of America / CCMC

8 June 2022

PBMOD

PBMOD is a closed-field-line ionospheric model (for low and mid latitudes) that includes the evolution of plasma irregularities (bubbles) and the calculation of radio scintillation

It depends on input drivers including: neutral densities, temperatures, & winds, plus plasma temperatures & drifts and calculates the plasma density on both ambient and irregularity spatial scales

It was installed at CCMC about ten years ago for 'realtime' (daily) runs
https://ccmc.gsfc.nasa.gov/RoR_WWW/pbmod-rt/pbmodf_realtime.php (OLD)

and is being refreshed and set up for Runs on Request (see Min-Yang Chou)

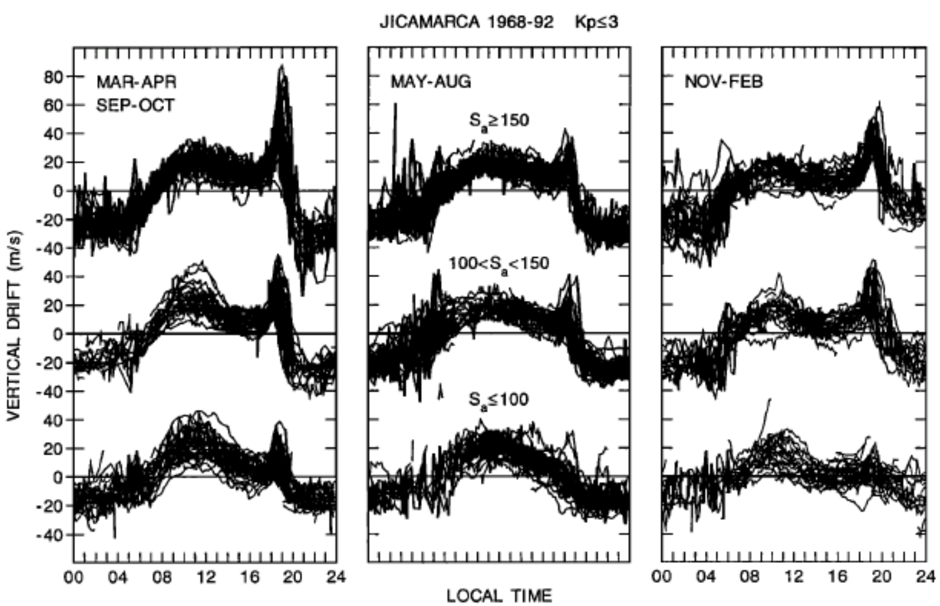
Because its results depend so heavily on the inputs it receives (GIGO), much of our attention has been devoted to better specifying its drivers

1) Statistical characterization of PRE plasma drift
2) Coupling with other models (e.g., WACCM-X)

Sensitivity to Nighttime Vertical Plasma Drift

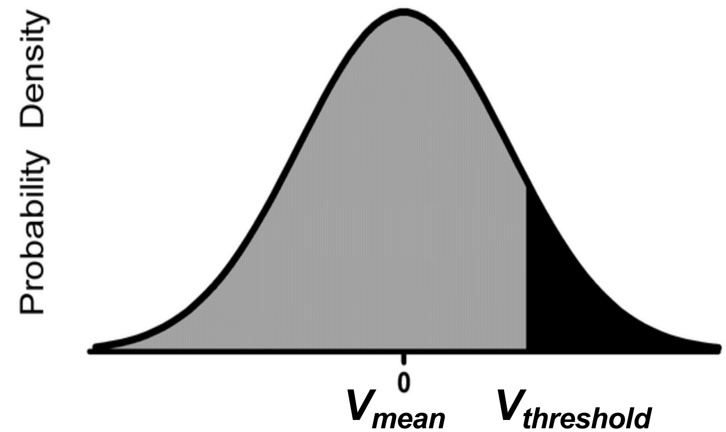
Plasma irregularity formation is very sensitive to the strength of the upward plasma drift at night, which unfortunately is one of the most variable plasma characteristics

One way to deal with this is statistically



Jicamarca ISR data
[Scherliess & Fejer, 1999]

Statistical Model

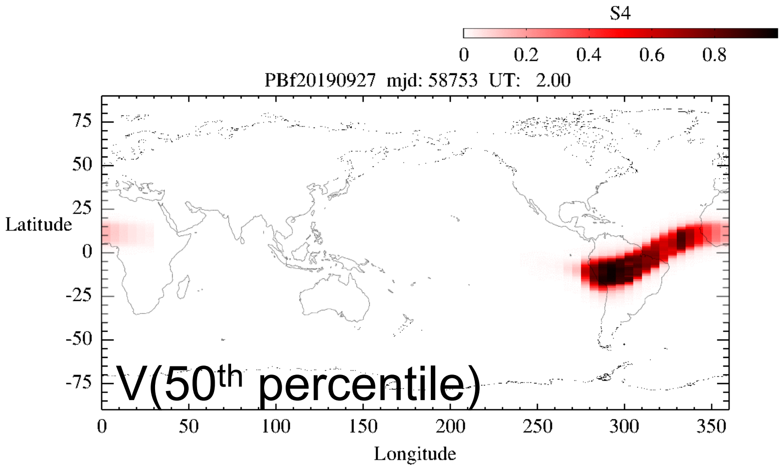


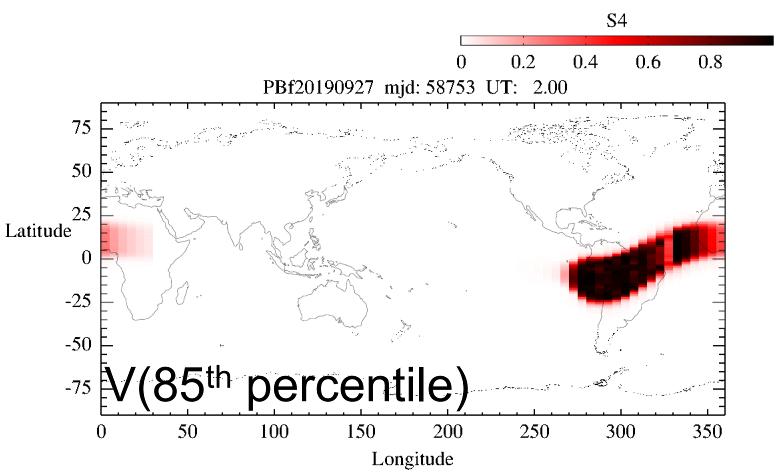
Climatological model specifies V_{mean}
Deviation of V from V_{mean} on any given day treated as a random variable with a gaussian probability distribution
Rough estimate of gaussian width: a uniform 5 m/s
$V_{threshold}$ defines minimum unstable V

[Retterer and Gentile, 2009]

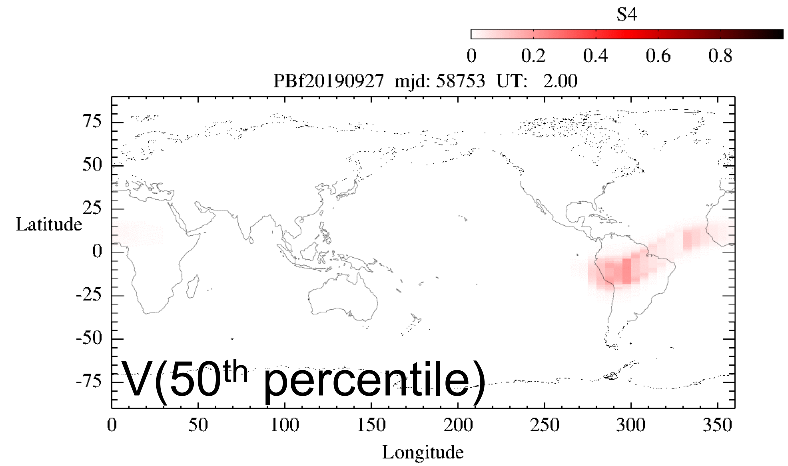
PBMOD Scintillation (from old CCMC page)

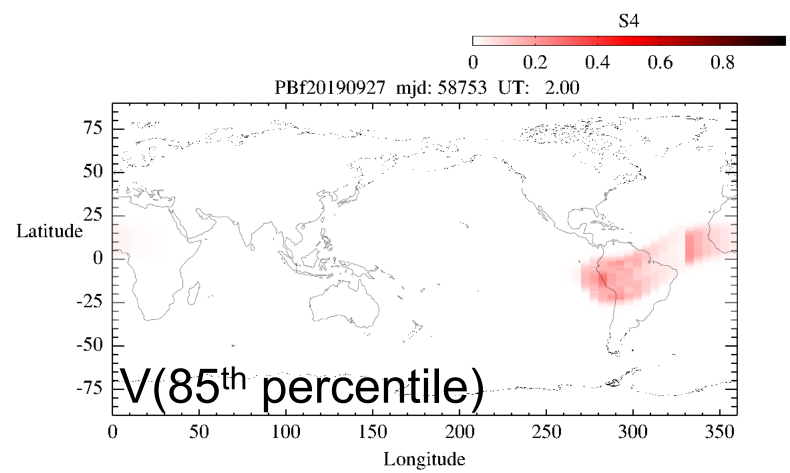
UHF Scintillation





L band Scintillation





Coupling to WACCM-X

Previously described results used the standard empirical models for the drivers: MSIS, HWM, Scherliess-Fejer

First-principles models of the thermosphere and electrodynamics attempt to describe the natural variations with more detailed modeling on physical principles

We are interested in using one such promising model, WACCM-X, to provide the drivers and hopefully explain more of the natural variability in a less ad-hoc way

We are undertaking the simulation of a whole year (2011) with WACCM-X and PBMOD to establish the climatology of the Rayleigh-Taylor instability and the magnitude of the day-to-day variations in it predicted by WACCM-X

Baseline: 2011 Run with Climo Models

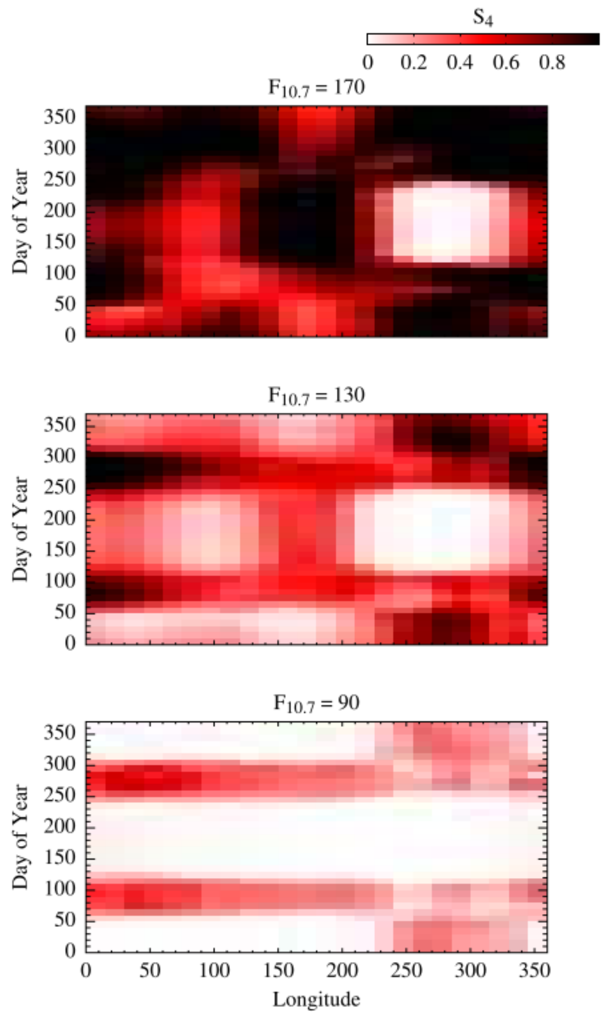
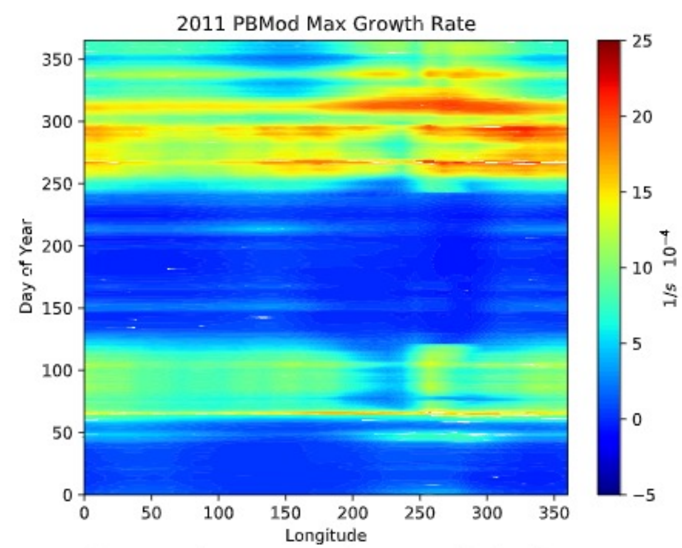


Figure 3. Climatology of scintillation strength: (top) solar $F_{10.7} = 170$, (middle) solar $F_{10.7} = 130$, and (bottom) solar $F_{10.7} = 90$.

[Retterer, 2005]

Min-Yang Chou performed 365-day run of climo PBMOD at CCMC

Pei Chen Lai (BC) presented the RT growth rates:



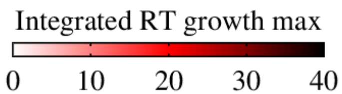
Notes: Scherliess-Fejer V model parameterized by solar F10.7, which increases through the year 2011
Stripes with 30-day period connected to variation of F10.7 with solar rotation

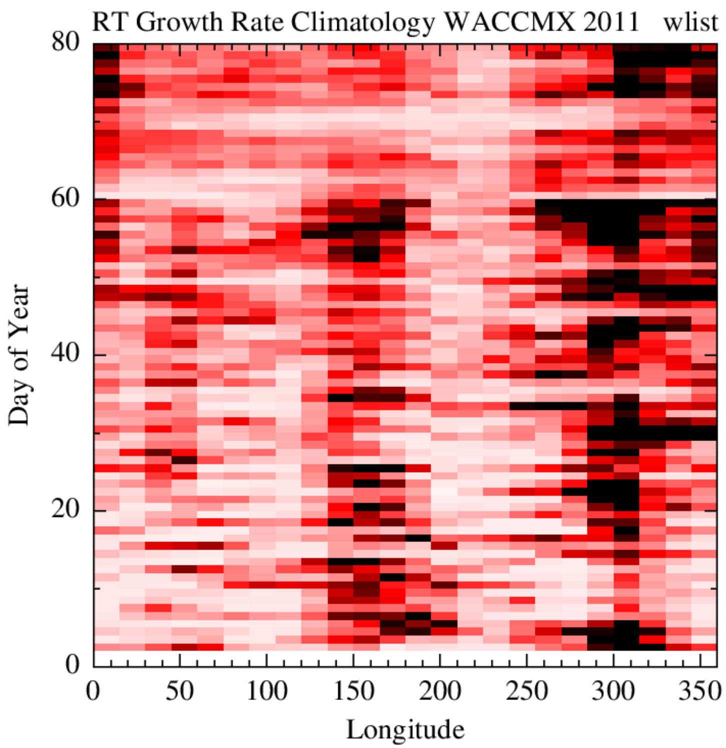
PBMOD run with WACCM-X Drivers

The story so far (with 80 days calculated) …

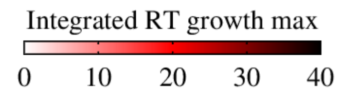
The quantity of interest is the RT growth rate integrated through time

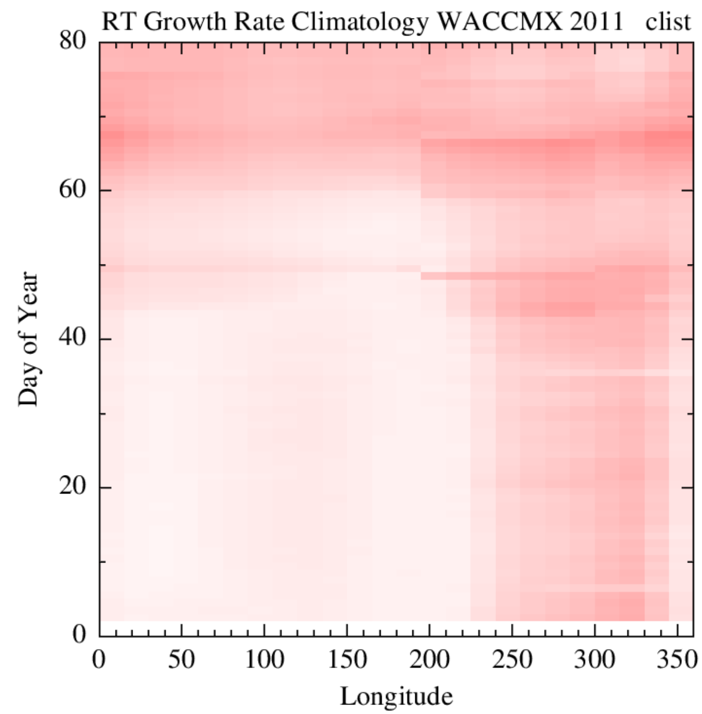
WACCM-X Drivers





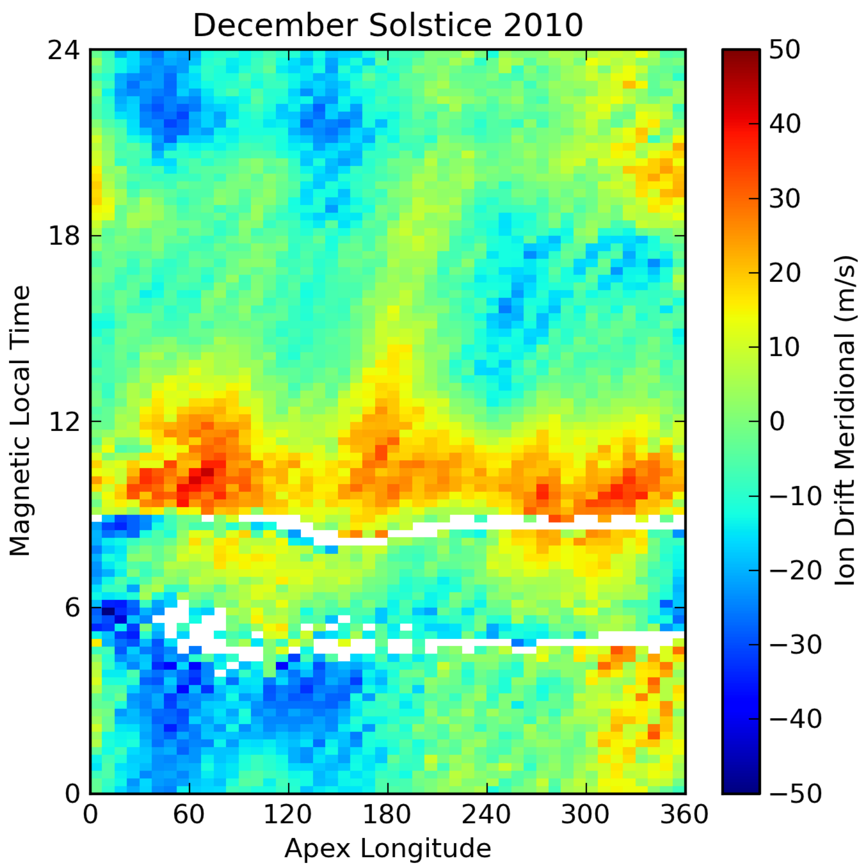
Scherliess-Fejer Drifts





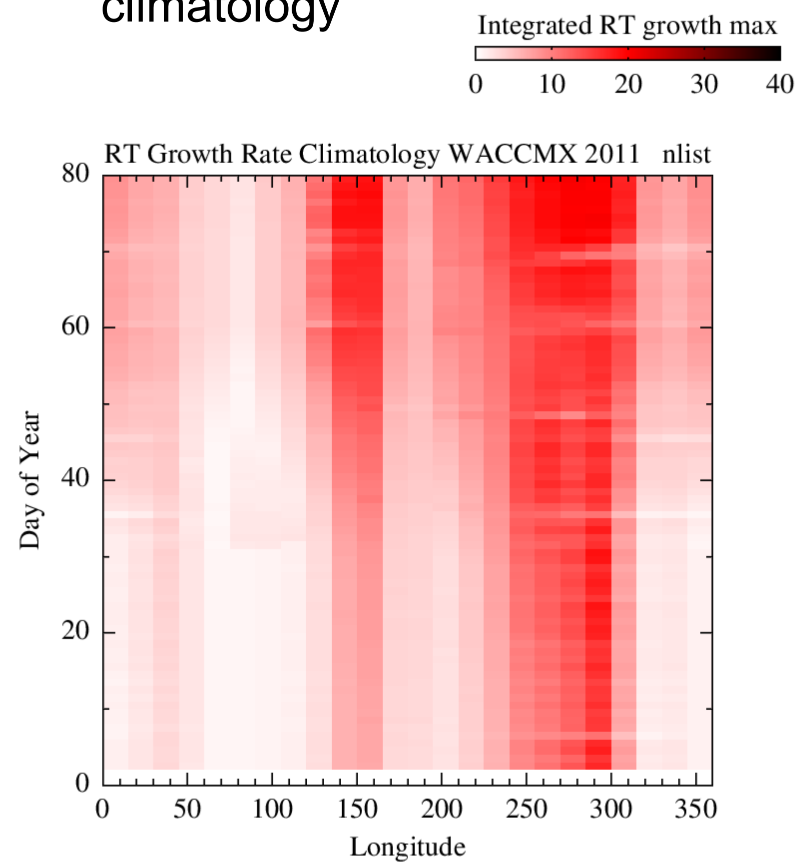
Check with C/NOFS IVM Climatology

Empirical model of meridional plasma drift measured by IVM instrument on C/NOFS satellite



Russell Stoneback

Integrated RT growth rate calculated using C/NOFS climatology

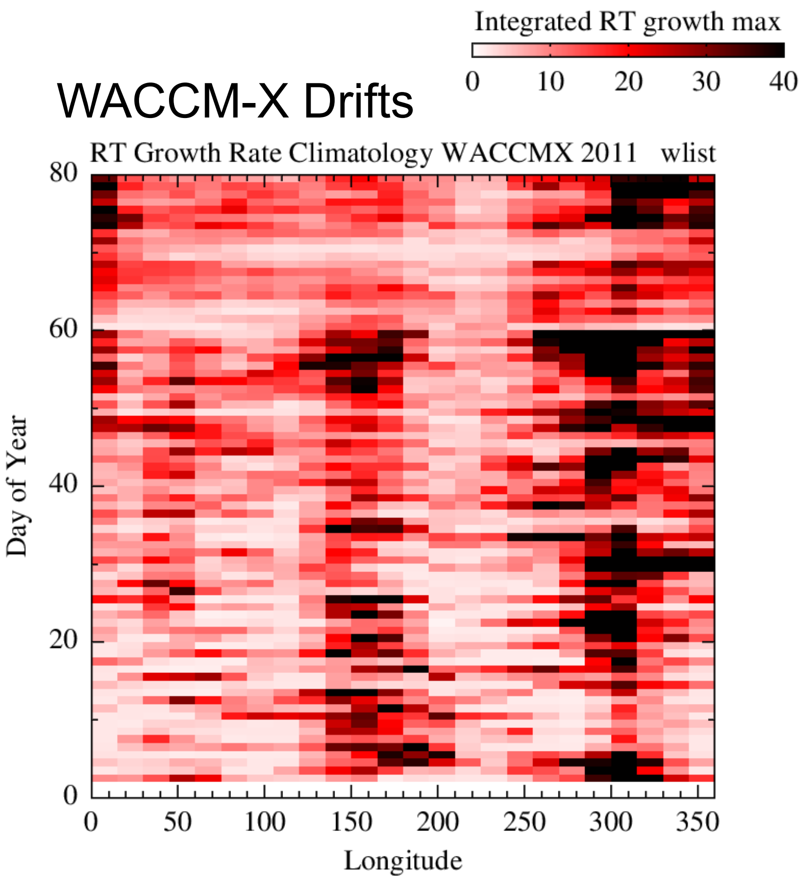


(The short reductions in growth are times of geomagnetic activity)

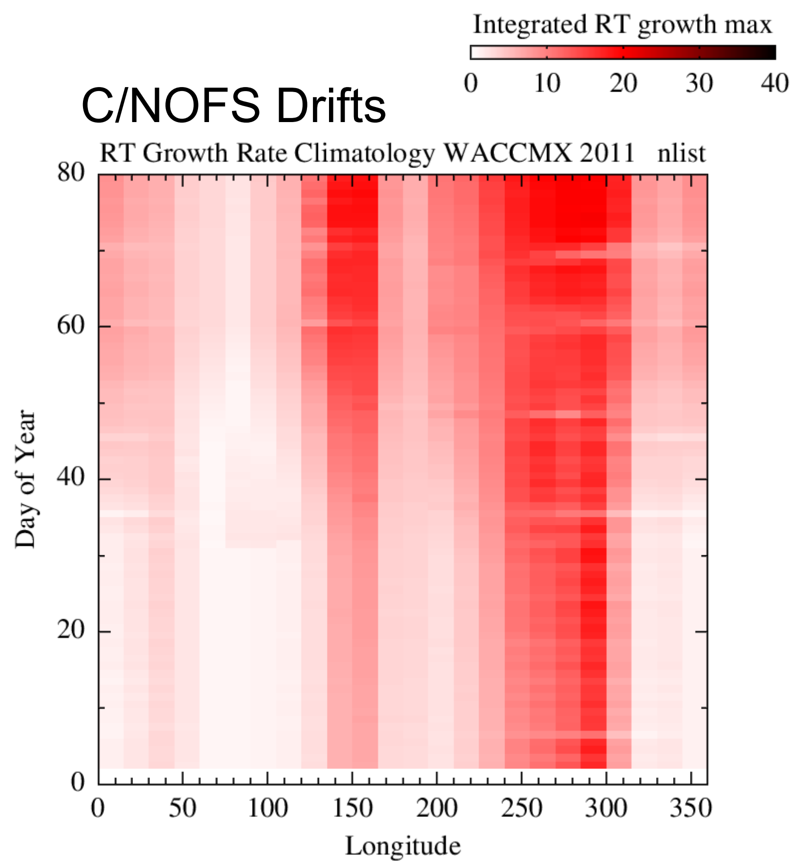
Check with C/NOFS IVM Climatology

The RT growth rate integrated through time

WACCM-X Drifts



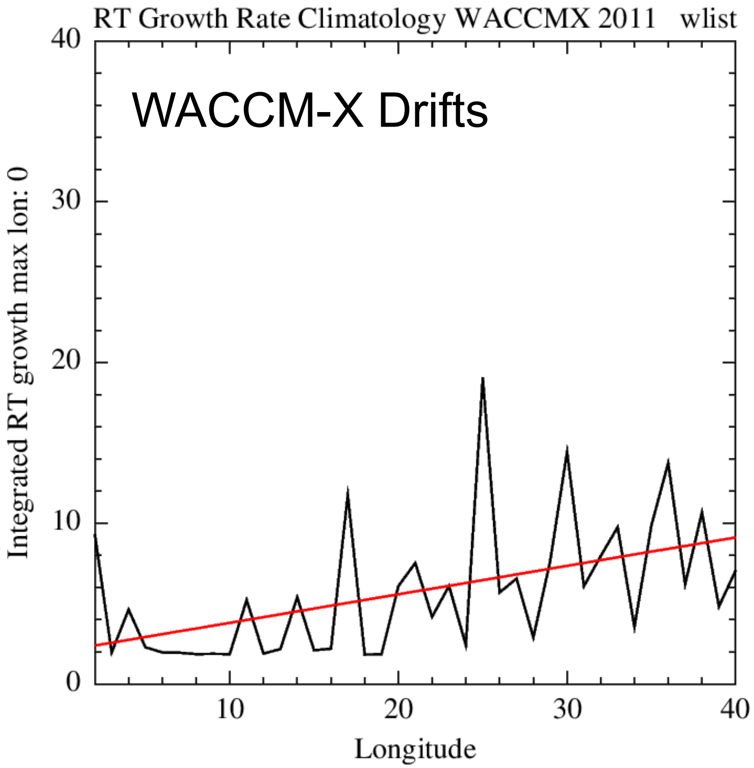
C/NOFS Drifts

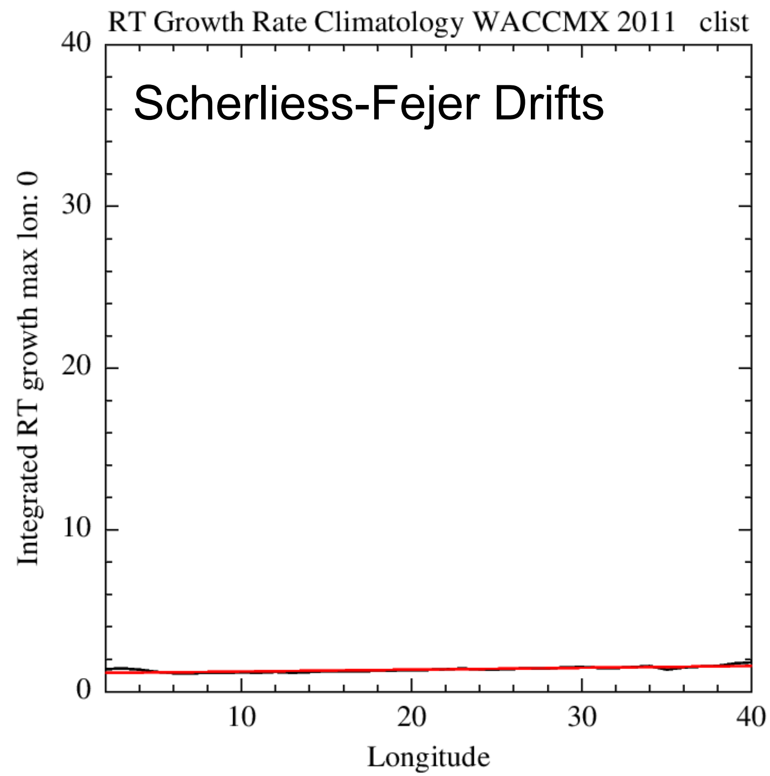


WACCM-X predicts the longitudinal structure of the growth rate
If this structure (which was not captured by earlier climatological models) is due to nonmigrating tides and similar phenomena, then it’s clear that WACCM-X is doing a good job estimating their structure

Day to Day Variability

Integrated RT Growth rate at longitude = 0



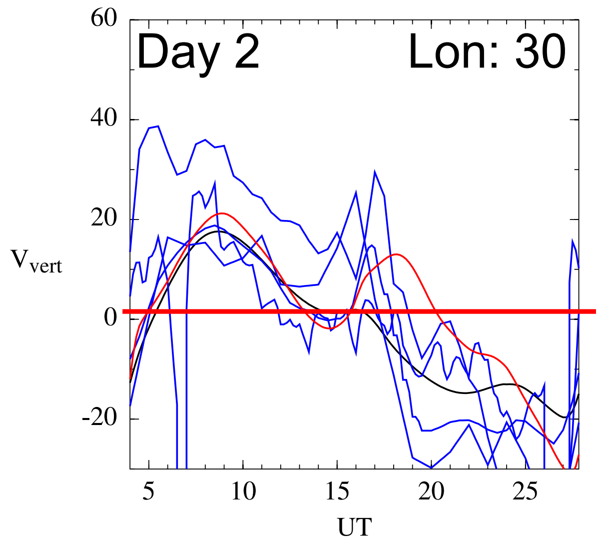


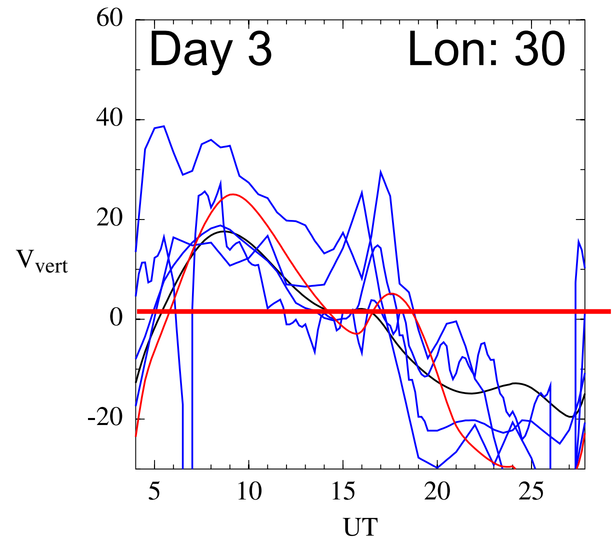
Black: actual history of integrated RT growth rate
Red: linear fit to integrated RT growth rate across first 40 days

Not Everything is Perfect

At some longitudes, PRE seems delayed and extended in time

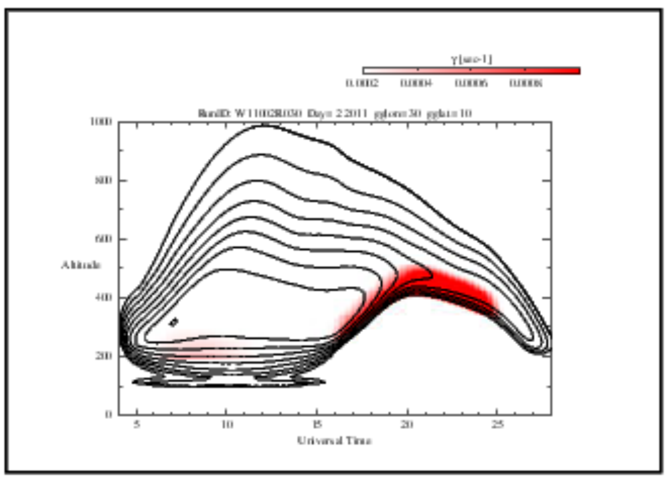
Vertical velocity
Black: Scherliess-Fejer
Red: WACCM-X
Blue: Satellite Empirical models (ROCSAT and C/NOFS)

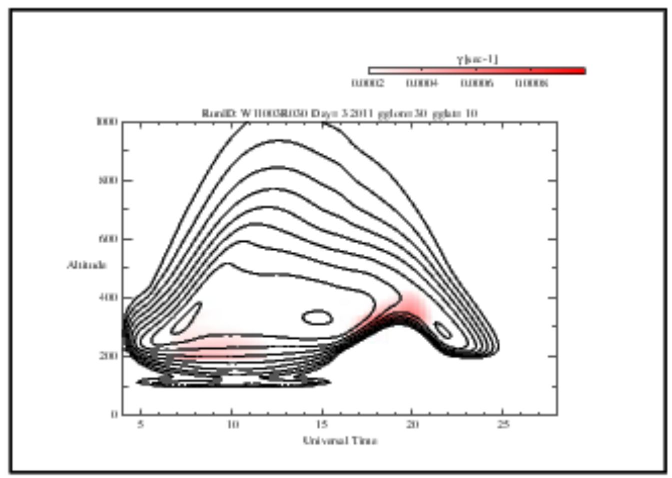




Contours: plasma density in equatorial plane

Shading: RT growth rate





Summary

We are conducting an extended run of PBMOD globally for the year 2011 using driving parameters (neutral winds, plasma drifts, etc) from WACCM-X run at CCMC to study the climatology of the strength of the RT plasma instability predicted by that model

The preliminary results:

1) The WACCM-X drivers correctly reproduce longitudinal features seen in C/NOFS measurements

2) The day-to-day variability of the RT growth is certainly enhanced over that predicted by standard climatological models

For CCMC, we recommend:
Introducing the velocity percentile parameter for Runs on Request using standard climatological models, to at least recognize the problem of parameter variability

Encourage models to be transitioned to CCMC to be built to permit interoperation and facilitate model coupling activities such as ours

Backup Slide: Geophysical Indices 2011