Longitudinal Variations in the Variability of Spread F Occurrence

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Outline

• Climatology of irregularities
• Occurrence and variability as a function of longitude
• Controlling physical factors
• Summary
Global Distribution of Irregularities

Climatology of occurrence frequency as a function of longitude and season is fairly well established

- ROCSAT in situ (600 km) observations indicate frequent F region irregularities
- DMSP observations show similar peak in bubble occurrence (Huang et al. 2004)
- C/NOFS & others

Adapted from S.Y. Su, 2005
Longitudinal Climatology

• Scintillation and irregularities are correlated but not the same
  – Possible to have irregularities without scintillation but not scintillation without irregularities
  – Scintillation provides information on strength of irregularities

• Gross occurrence climatology of irregularities as a function of longitude is relatively well established
  – Most complete statistical picture comes from satellite observations, BUT satellites miss activity below them

• Ground-based observations are rapidly improving our knowledge of the scintillation climatology
  – The only real source of scintillation information
Examine 250 MHz scintillation observations from three separate longitude sectors in 2011
Extreme Day-to-Day Variability?

- Occurrence dominated by seasonal factors
- Increase in solar flux evident in last quarter of the year

Cuiaba, Brazil VHF 2011
Terrestrial Weather Analogy: Monsoon Season in Mumbai

- Variability in precipitation in Mumbai, India shows predictable minima in Dec-May, maxima Jun-Sep
- Scintillation activity in the American sector shows similar predictability
Scintillation “Variability” in Cuiaba, Brazil

- Variability is mostly seasonal, not daily
- Apart from transition periods, persistence, climatology provides excellent forecast

![Probability of S4 > 0.6 for ≥ 1 hour](image-url)
Scintillation Occurrence in W. Africa

- Response looks pretty similar to Cuiaba
- Wet and Dry seasons
Cape Verde, West Africa

- Occurrence suggests dominant mechanism(s); not dependent on GWs, tides, phase of the moon, nighttime ionization rate, etc.
Scintillation Occurrence in E. Africa

• Region shows a lot of activity
• Fundamental shift in local time of onset during June/July
• Data appears to show more variability than American sector
Nairobi, Kenya Variability

- Variability exists throughout the year, even during the period of increased solar flux in the last quarter of 2011.
Variability exists throughout the year, but average severity is markedly less than in Nairobi.
Part of the difference in severity may be attributable to mag lat.
Kwajalein Variability

Probability of S4 > 0.3

Probability of S4 > 0.6
• Overall pattern similar to Kwajalein
• Decrease in severity may be magnetic latitude effect (1° vs 4°)
Christmas Island Variability

- Highly variable
- Severity further decreased on magnetic equator
Factors Contributing to Spread F
What about “seeds”?

Variability usually associated with “seeds” (e.g., gravity waves)

- Gravity wave activity cannot be a critical factor (no rationale for differences in AGW activity across such a range of longitudes/land mass/ocean environments)

- Non-migrating tides (i.e., classic 4-cell pattern) cannot be a critical factor since low variability region encompasses both maxima and minima

- Large-scale tropospheric systems, such as the inter-tropical convergence zone (ITCZ) cannot be factors since the low-variability region encompasses a range of +/- latitudes
Magnetic Field Factors

- Areas of low variability characterized by:
  1. Westward declination
  2. Relatively weak B-field strength
Ancon East & West 2002

- Ancon has a west link (55° el) and an east link (30° el)
- The links span the transition region between east and west declination
- The lower elevation angle to the east results in somewhat higher scintillation activity and intensity overall, but variability comparisons between E & W should be okay
Ancon East & West 2002

- More variable than Cuiaba in 2011.
- 2002 & 2011 were different solar environments, but this is an intriguing result; suggests declination is important.
- A lower threshold is applied at Ancon because it is on the magnetic equator.
Is it all about “B”?

• If seeds and tropospheric forcing are not critical, what’s left?
• Consider equation for RTI linear growth rate

\[ \gamma \approx \frac{\sum F}{\sum F + \sum E} \left[ \frac{E \times B}{B^2} + U^n + \frac{g}{\nu^{\text{eff}}} \right] \frac{1}{N} \frac{\partial N}{\partial h} \]

• At all seasons, small \(|B|\) suggests larger growth rate for an equivalent \(|E|\) (favorable to onset)
  – Small \(|B|\) implies higher vertical drift which reduces collision frequency and reinforces high growth rate
• Declination effect impacts E-region conductivity (angle between terminator and magnetic meridian)
Summary

- American longitude sector seems fairly predictable with respect to scintillation occurrence; suggests dominant driver(s) determined by terminator/B-field flux tube alignment
  - Can B-field really override all other factors related to Spread F variability?
- Predictability improves as solar flux increases and scintillation is most severe (and therefore of greatest space weather impact)
- Other longitude sectors show greater variability, most distressing is Africa which has the overall peak in activity!
- Physics-based approach is still the only viable long-term solution for a real global forecast

Understanding the longitudinal differences in scintillation activity may provide important insights into the critical processes controlling equatorial Spread F occurrence