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# CLOUD LAYER VERIFICATION AT THE AIR FORCE WEATHER AGENCY

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**AFWA, 16WS/WXN**



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# Overview



- **Cloud Model**
- **Ground Truth**
- **Verification Technique**
- **Results**



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# Cloud Model



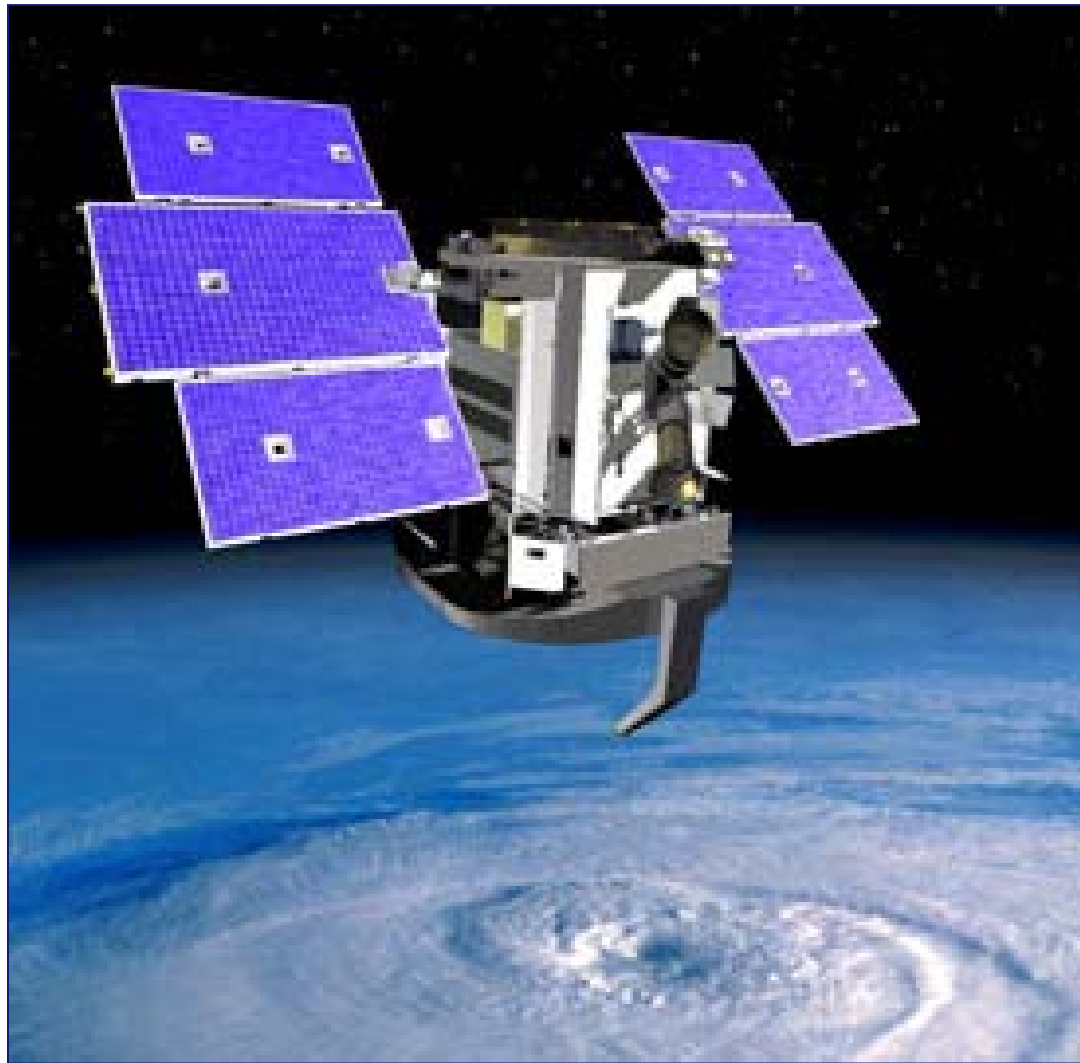
- **Diagnostic Cloud Forecast (DCF)**
  - **Statistical relation based on recent performance of mesoscale model**
  - **Run 4 times daily (00Z, 06Z, 12Z, 18Z)**
  - **3-hour forecast time step out to 72 hours**
  - **45 and 15 km grid spacing**
  - **Outputs include total cloud amount, layer bases and tops, and cloud type**
  - **5 vertical cloud layers**



# “Ground” Truth



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# CloudSat

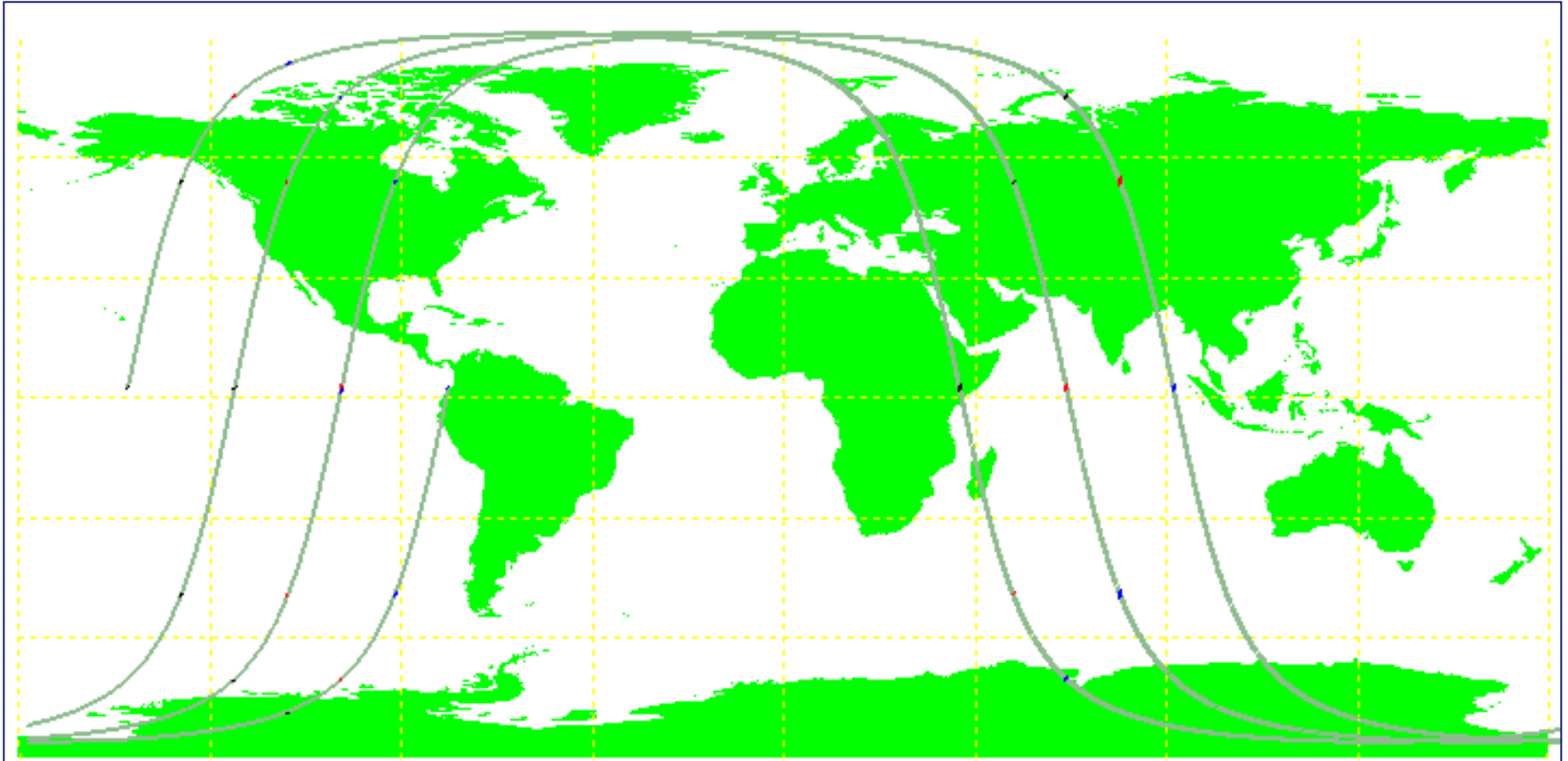


- **NASA Earth System Science Pathfinder satellite mission**
- **Launched 28 April 2006**
- **Sun-synchronous orbit**
- **One orbit ('granule') every ~99 minutes**



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# Sample Granules



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# CloudSat



- **First satellite-based millimeter-wavelength cloud radar**
  - “CPR” (Cloud Profiling Radar)
  - 1000 times more sensitive than existing weather radars
  - Developed jointly by NASA/JPL and the Canadian Space Agency (CSA)
  - Colorado State University provides scientific leadership and science data processing and distribution
  
- **<http://cloudsat.atmos.colostate.edu/overview>**

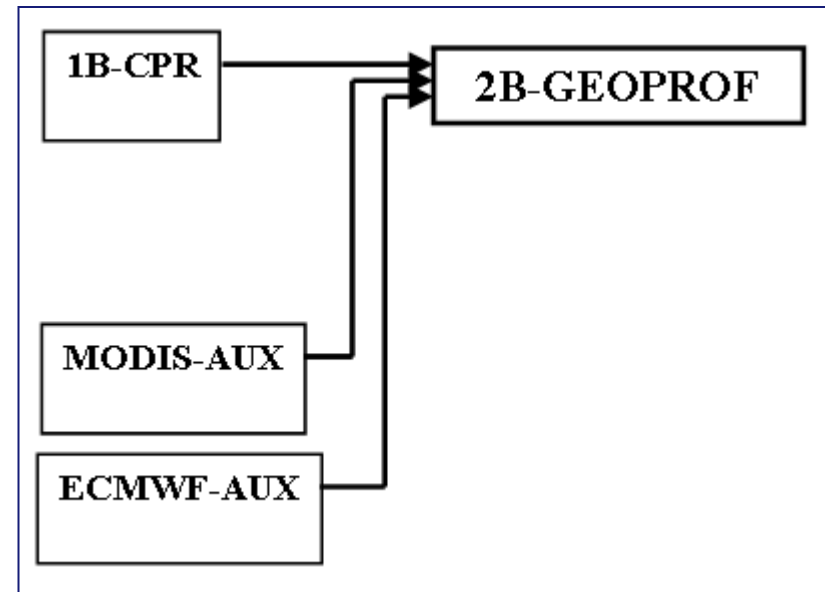


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# CloudSat



- 11 standard data products
- “2B-GEOPROF” (Cloud Geometrical Profile) contains the vertical cloud information
- Also includes ECMWF state variables and MODIS Cloud Mask and Radiance data (used for radar reflectivity factors)

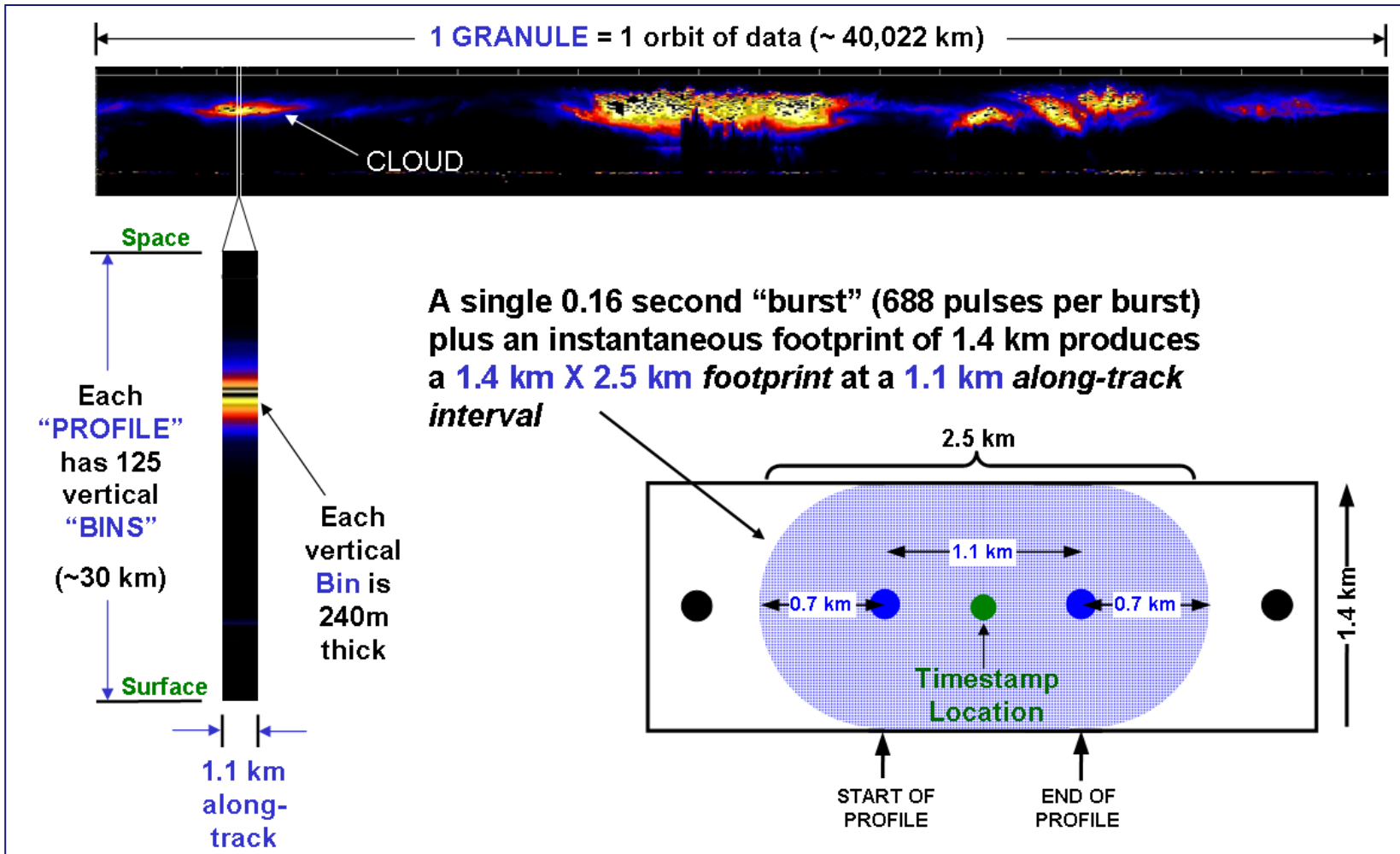




# CloudSat



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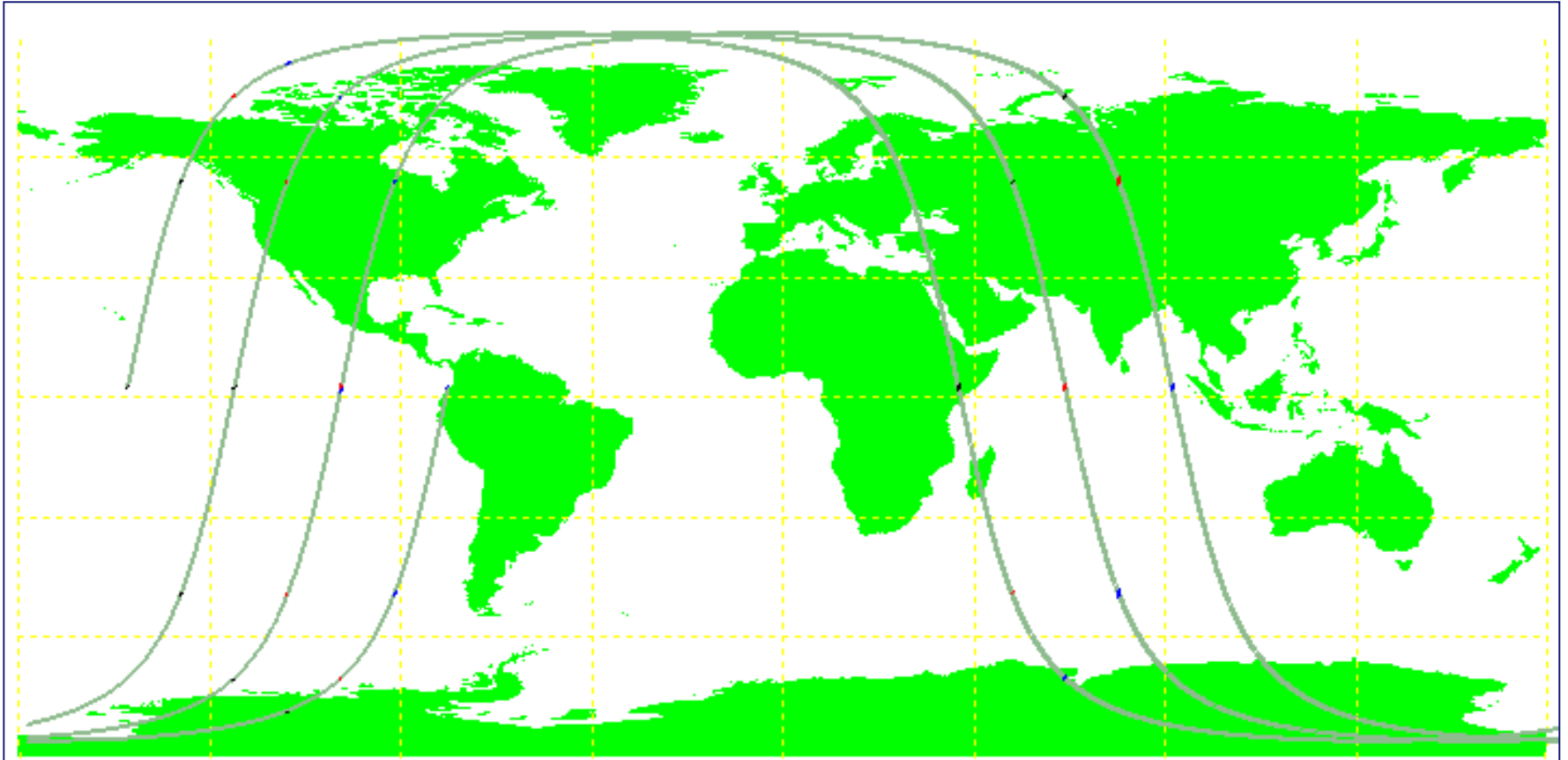


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# Sample Granules

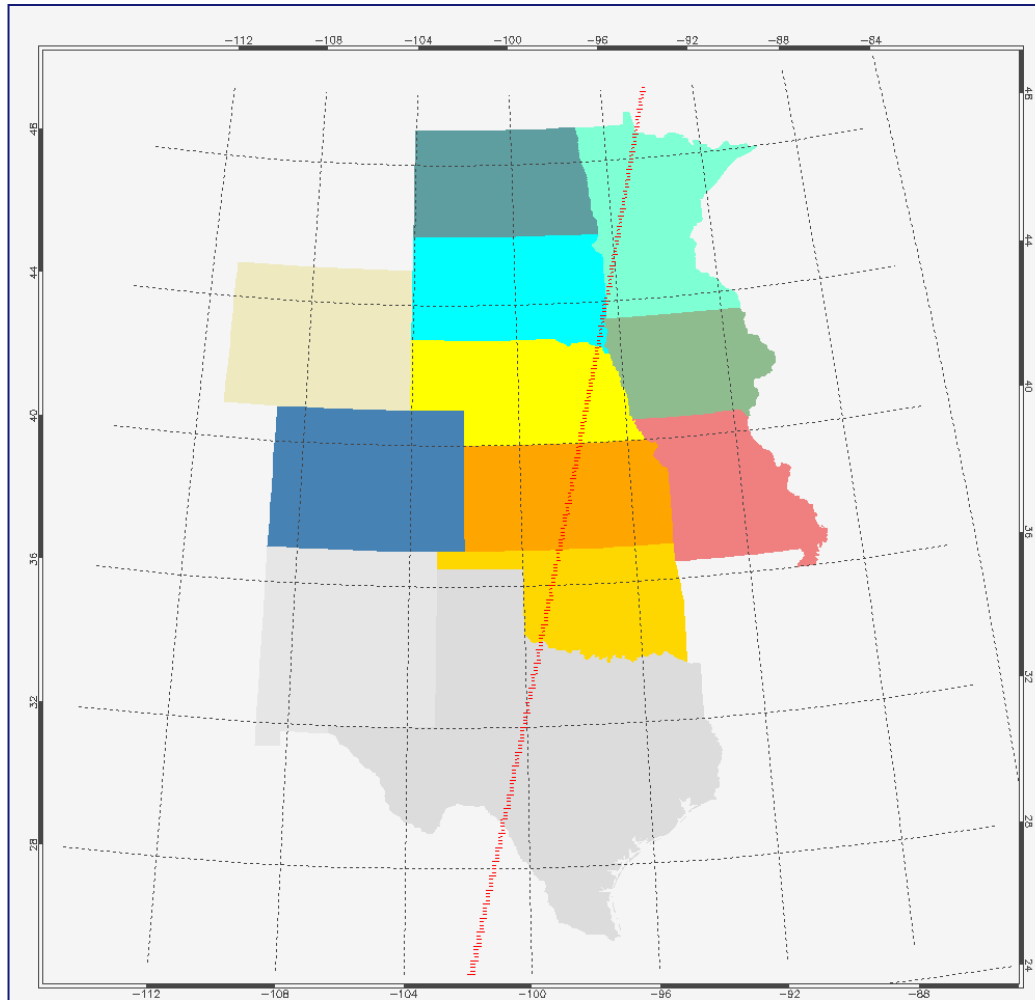


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# Granule Close-Up

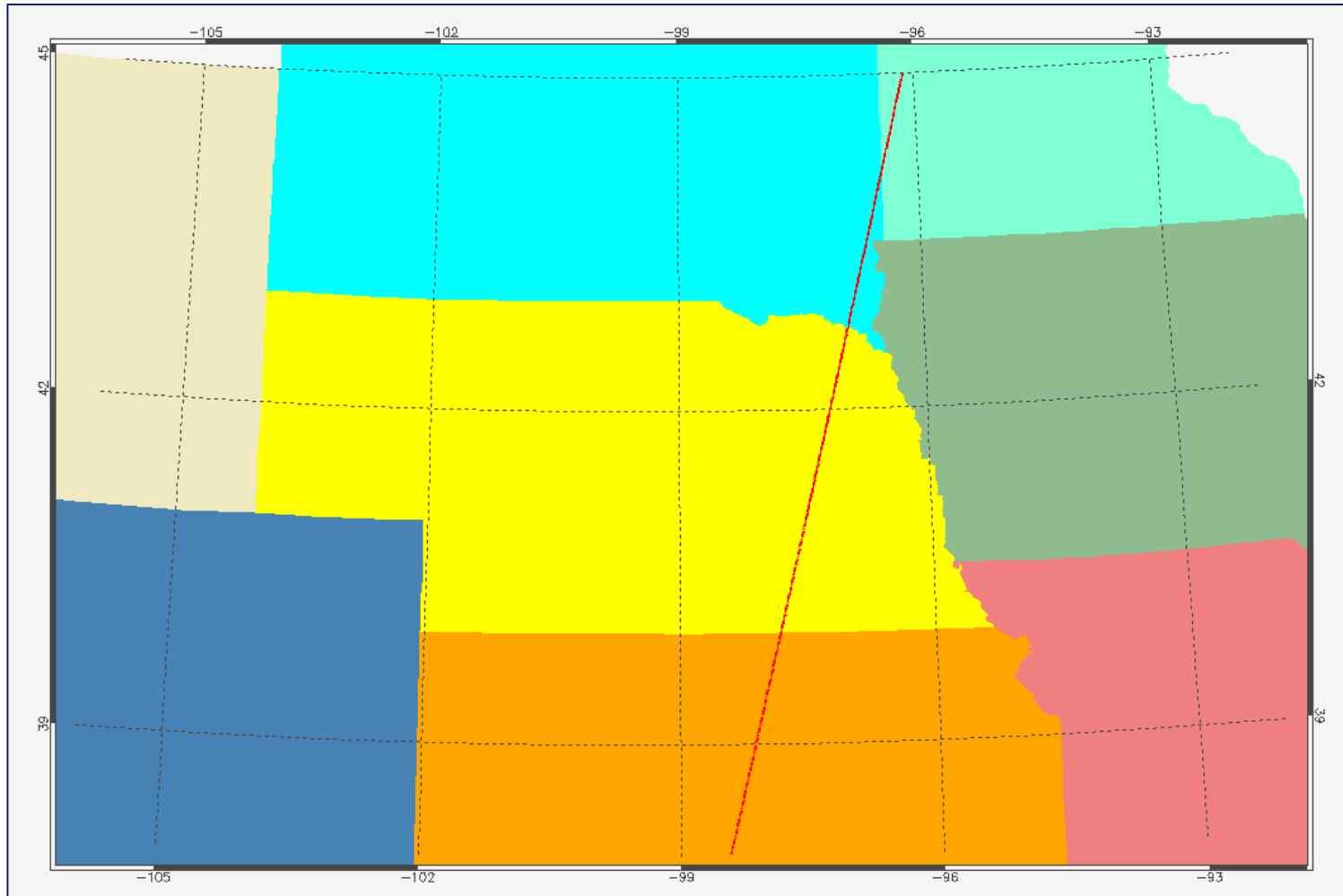


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# Granule Close-Up

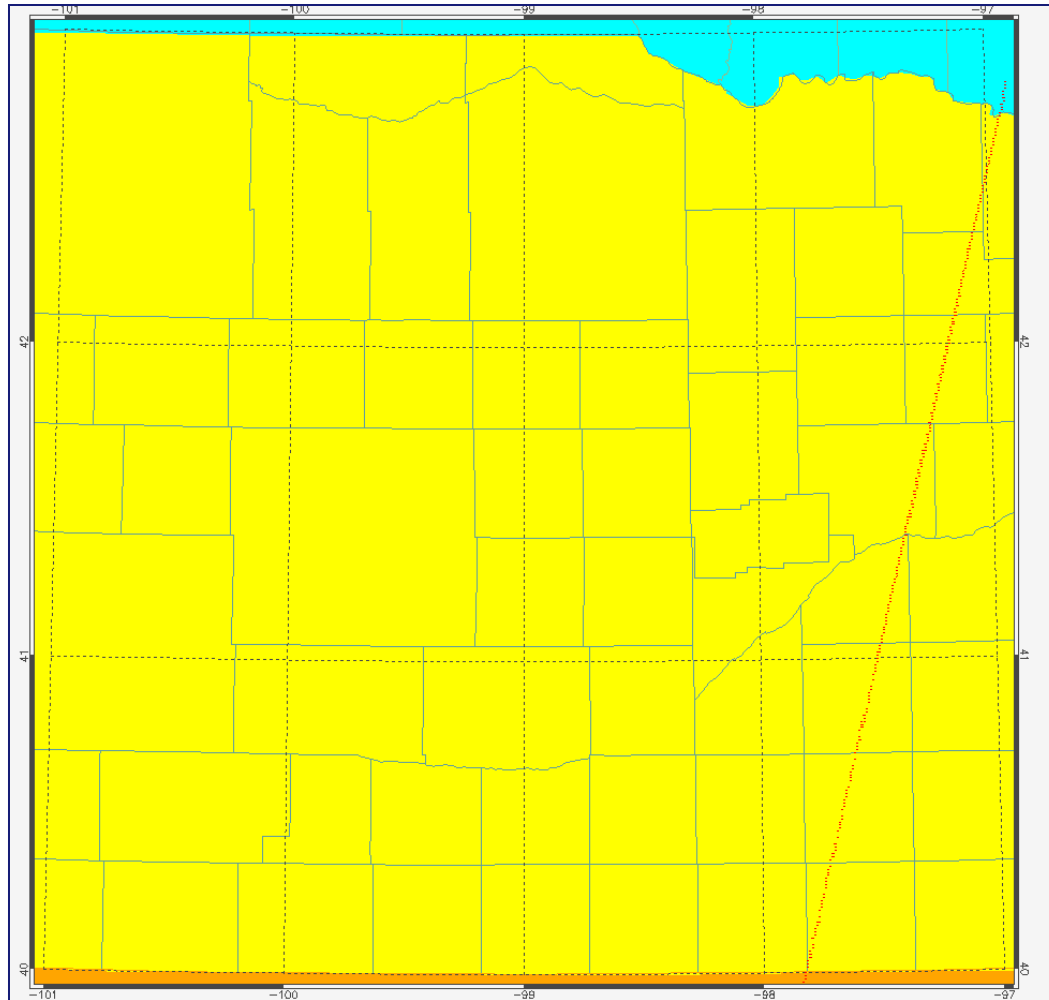


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# Granule Close-Up



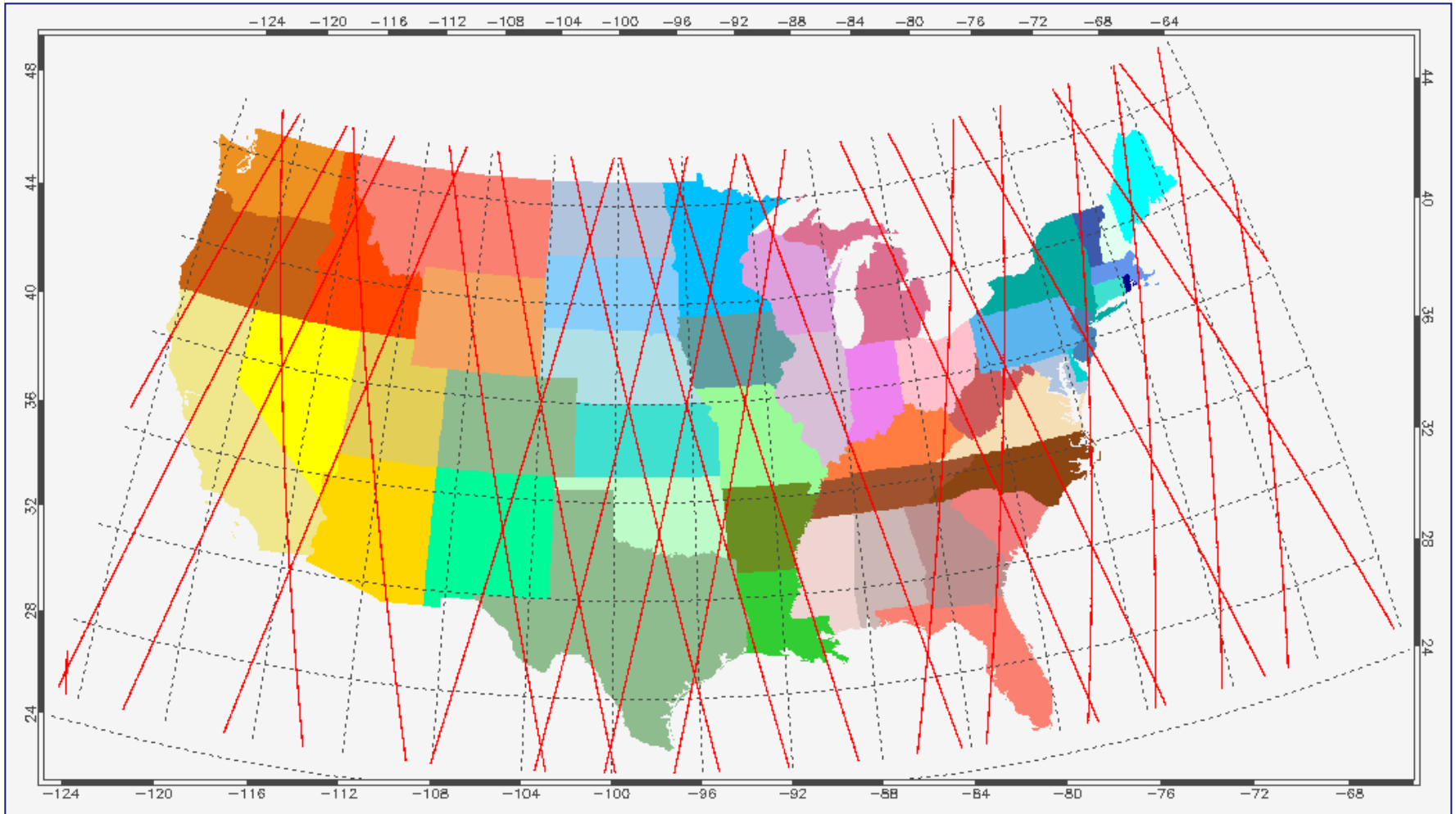
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# 7 Days of Granules



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# CloudSat Issues



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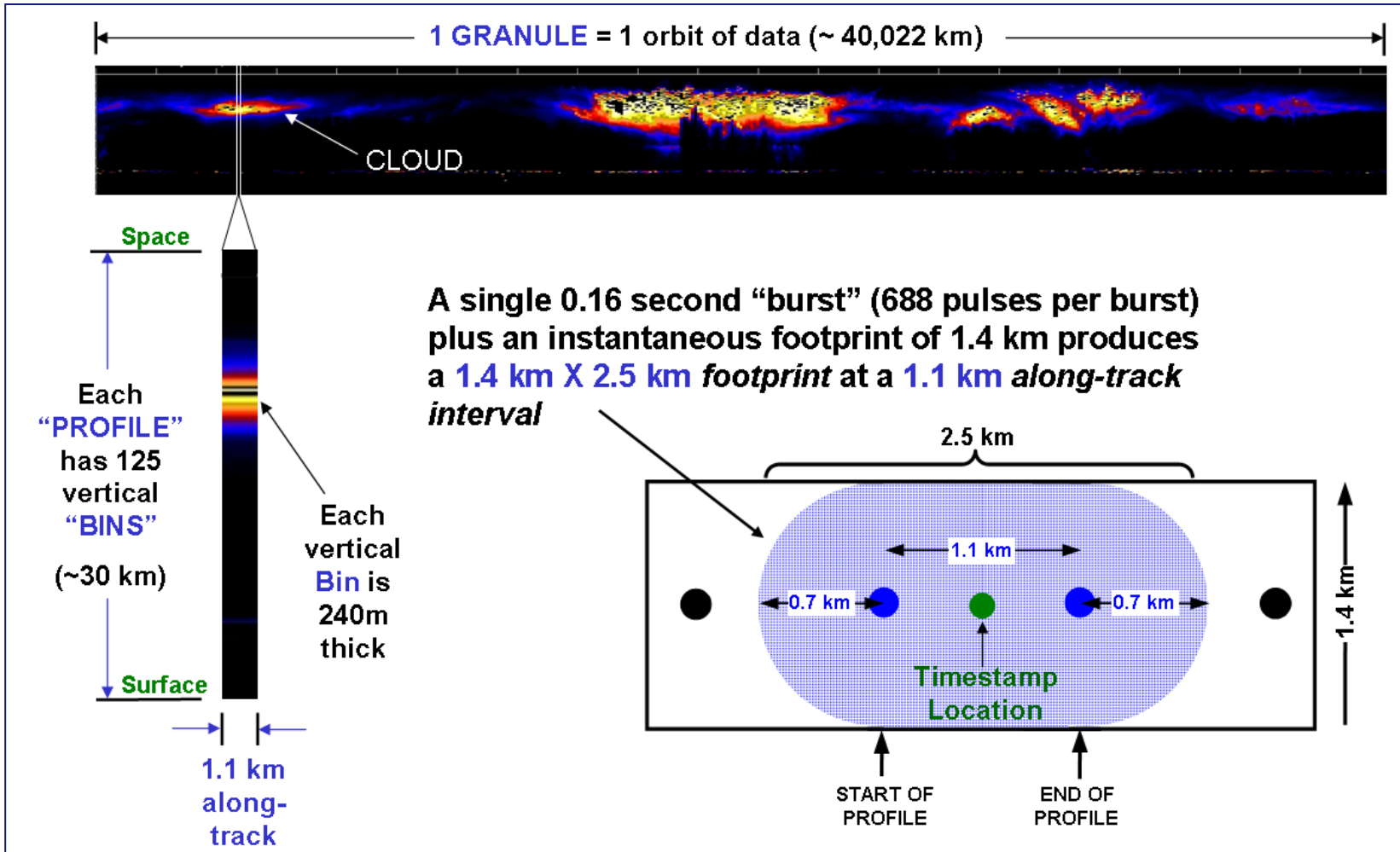
- **Narrow View → “Occasional Coverage”**
- **Data Receipt**
  - **Research Product = No Guarantees...**
  - **Indirect FTP ( AFWA → NRL → CSU )**
  - **Data lag in availability can be 2-3 weeks!**
- **Case Studies Only**
  - **Verification impossible in ‘real time’**
  - **Insufficient data retention on AFWA server**
  - **Communications Issues**
    - **Empty files**



# CloudSat



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# ***CloudSat Layer Determination***



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- **Each vertical bin has a yes/no flag for the presence of clouds**
- **Each cloud layer is bounded by the highest and lowest ‘yes’ bins when a consecutive stretch of one or more ‘yes’ bins is found**
- **Vast majority of points in a granule have 3 or less cloud layers**
- **Limit layer data to first 10 layers ‘seen’ (from above)**
- **Only verify layers in the lowest 15 km above the surface**



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# Verification Technique



- Determine model-observation pairs
- Pair nearest DCF point to each CloudSat data point
- Calculate basic yes/no contingency table data for cloud/no cloud regions within each 'column' of paired CloudSat/DCF data
  - Each 1 meter (15,000 per column) is examined-perfect forecast would be \*if\* all 15,000 points agreed on cloud or no cloud
  - Discretization of CloudSat layers makes this unlikely
  - 240 meters an approximation; appears to vary such that it is not a constant location



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# Results



- **Total cloud forecasts**
- **CONUS domain**
- **06Z and 18Z model runs**
- **23 day totals: September 1-23, 2010**
- **2x2 contingency table data**



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# Results



## ■ Six metrics:

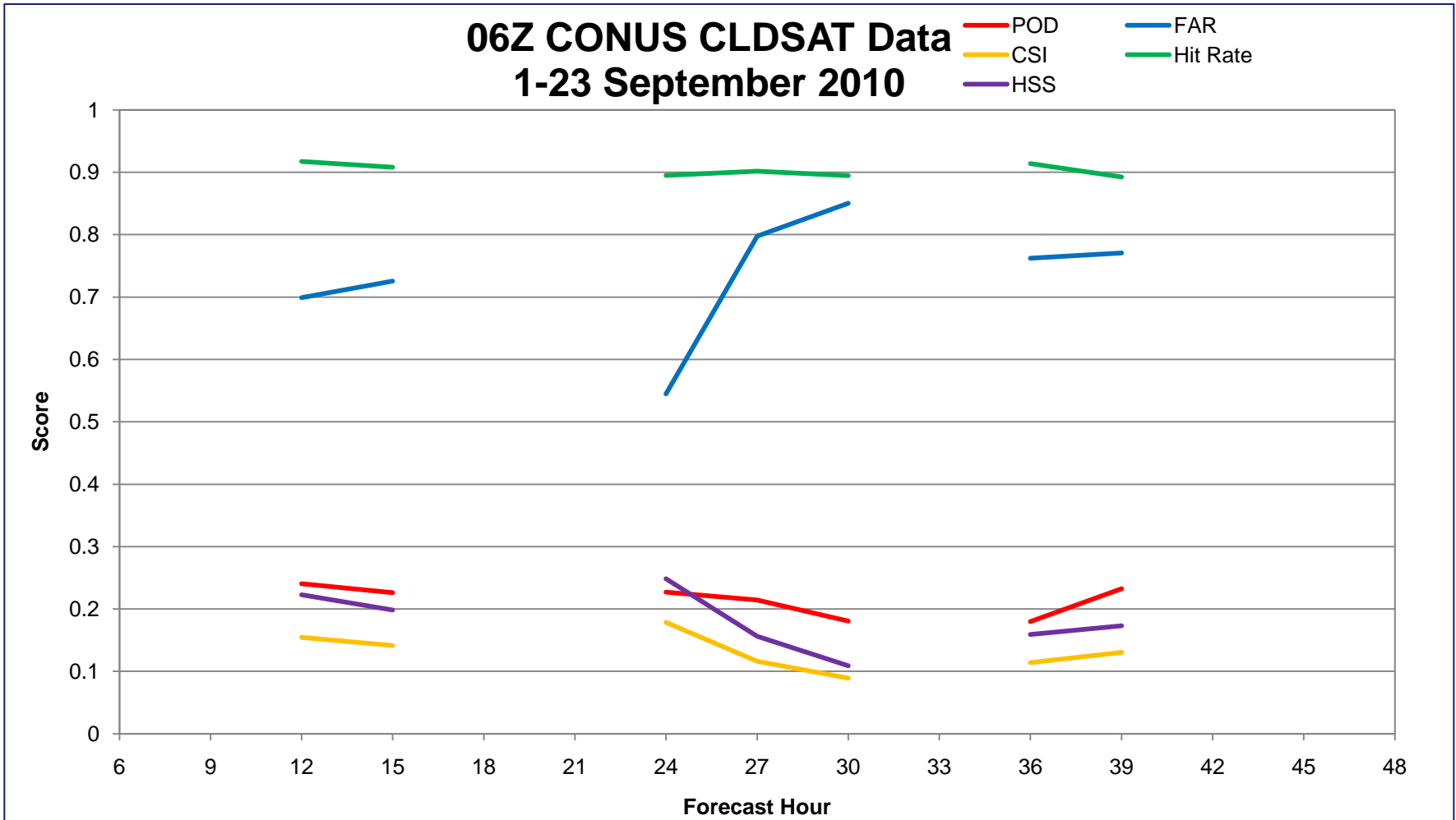
- Probability of Detection (POD):  $a/(a+c)$
- False Alarm Rate (FAR):  $b/(a+b)$
- Critical Success Index (CSI):  $a/(a+b+c)$
- Hit Rate:  $(a+d)/(a+b+c+d)$
- Heidke Skill Score (HSS):  $2(ad-bc)/((a+c)(c+d)+(a+b)(b+d))$
- Bias:  $(a+b)/(a+c)$



# 06Z Results



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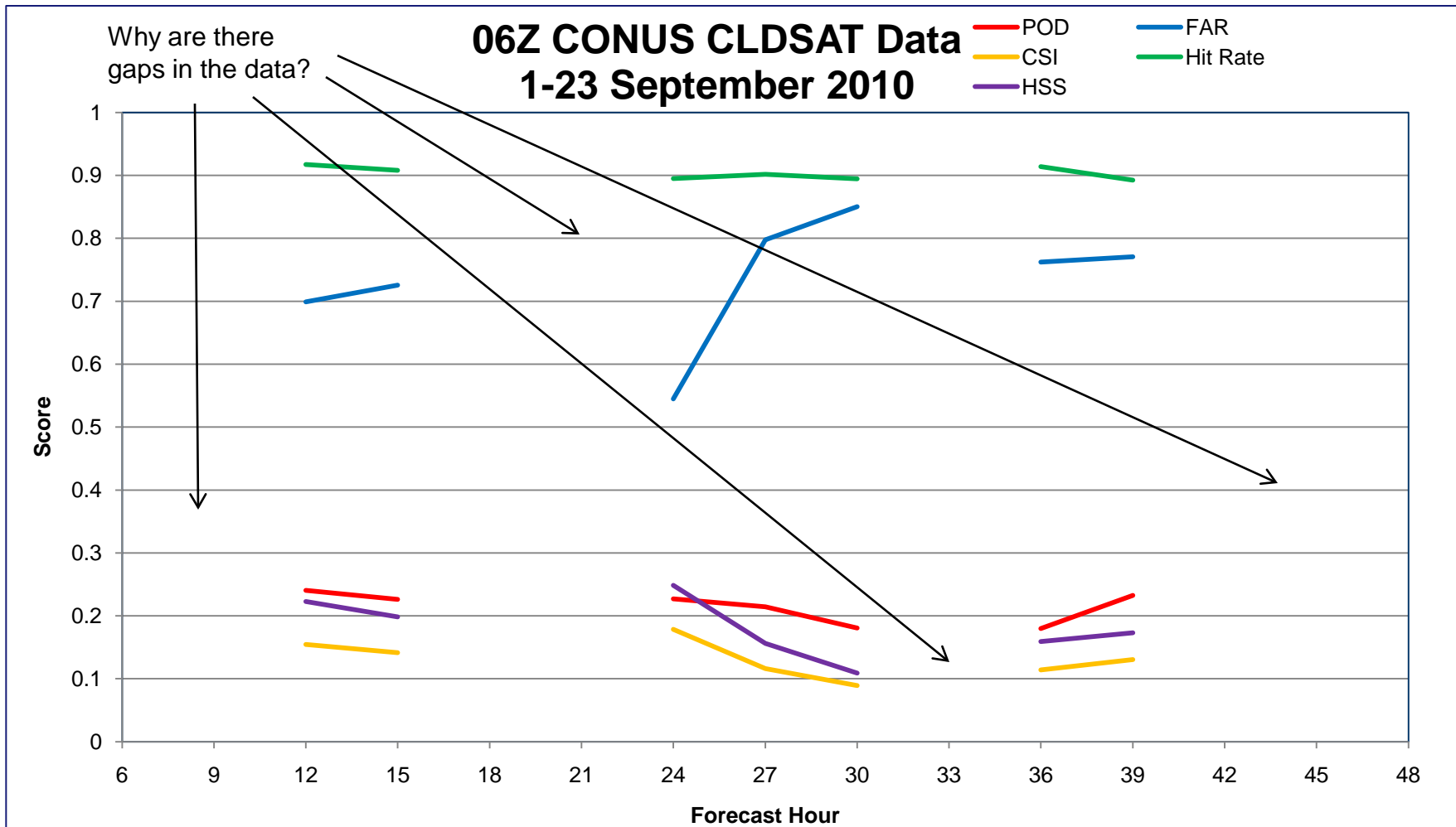
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# 06Z Results



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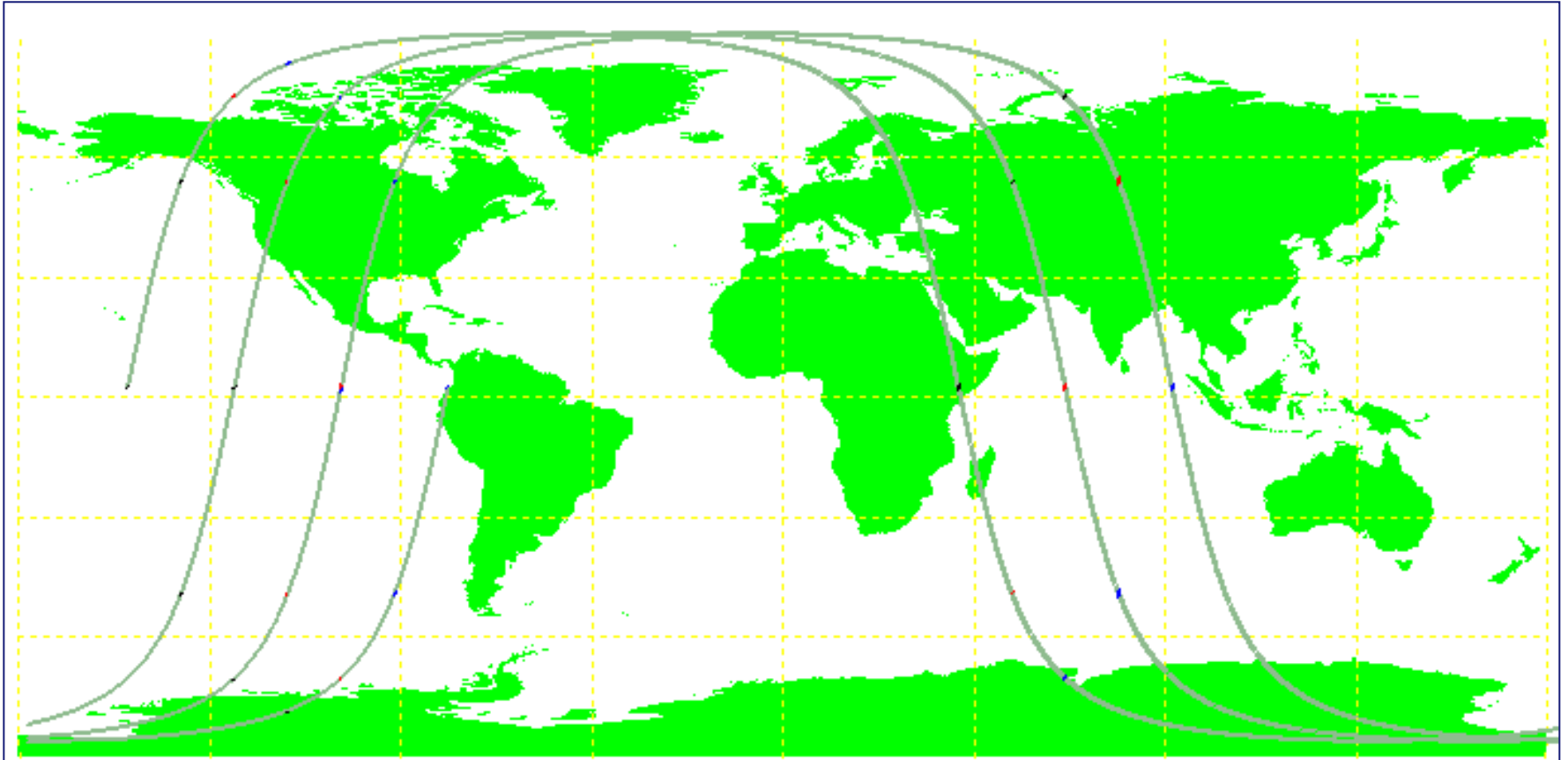


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# Sample Granules



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# Data Gaps



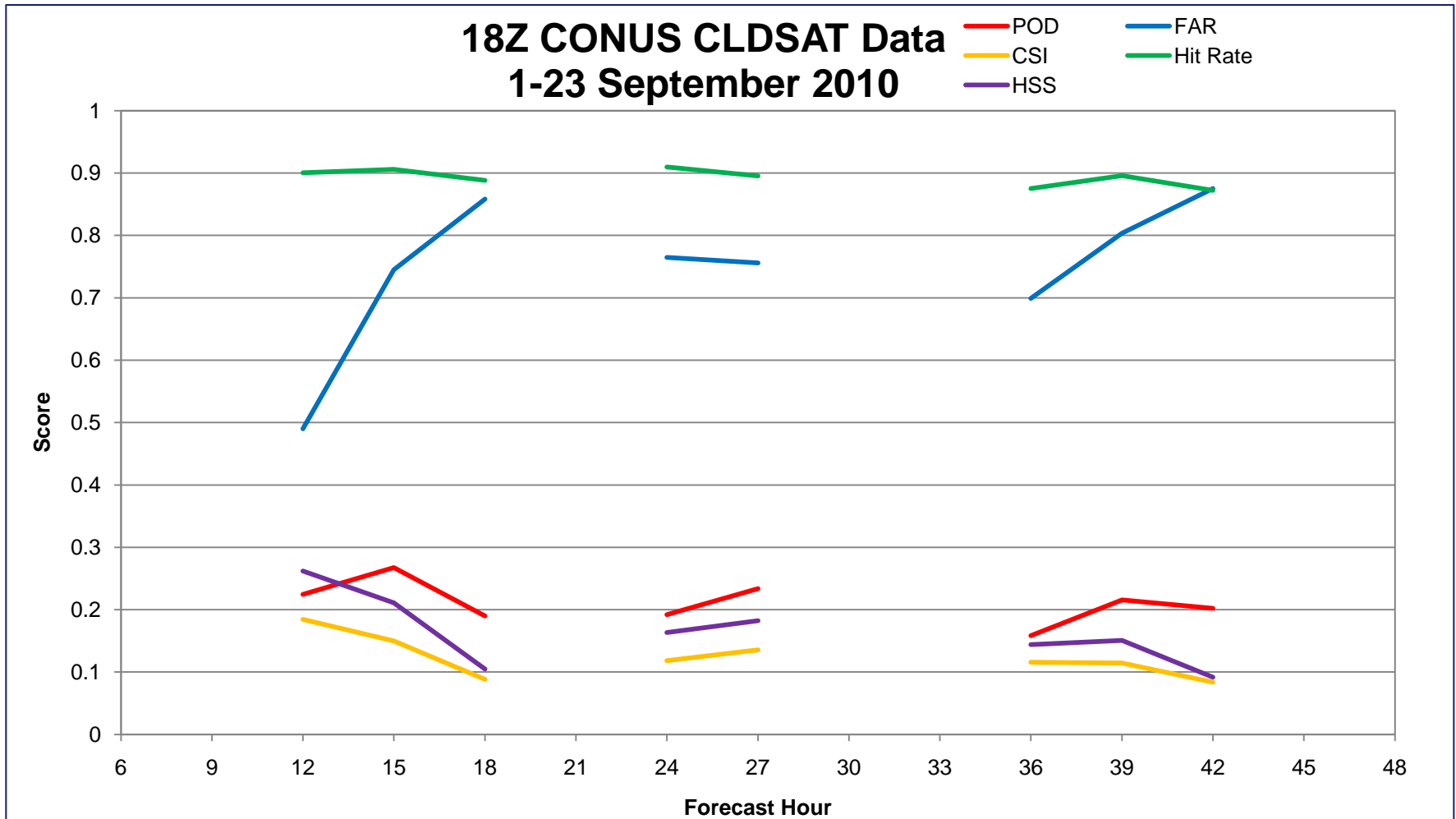
- **CLDSAT granules are such that:**
  - **CONUS is not covered by all granules**
  - **Sun-synchronous orbit → passes occur at similar times each day**
  - **Spatial and temporal data coverage are far from ideal**
  - **06Z, 09Z, 12Z, 18Z, 21Z are the only available ground truth times**



# 18Z Results



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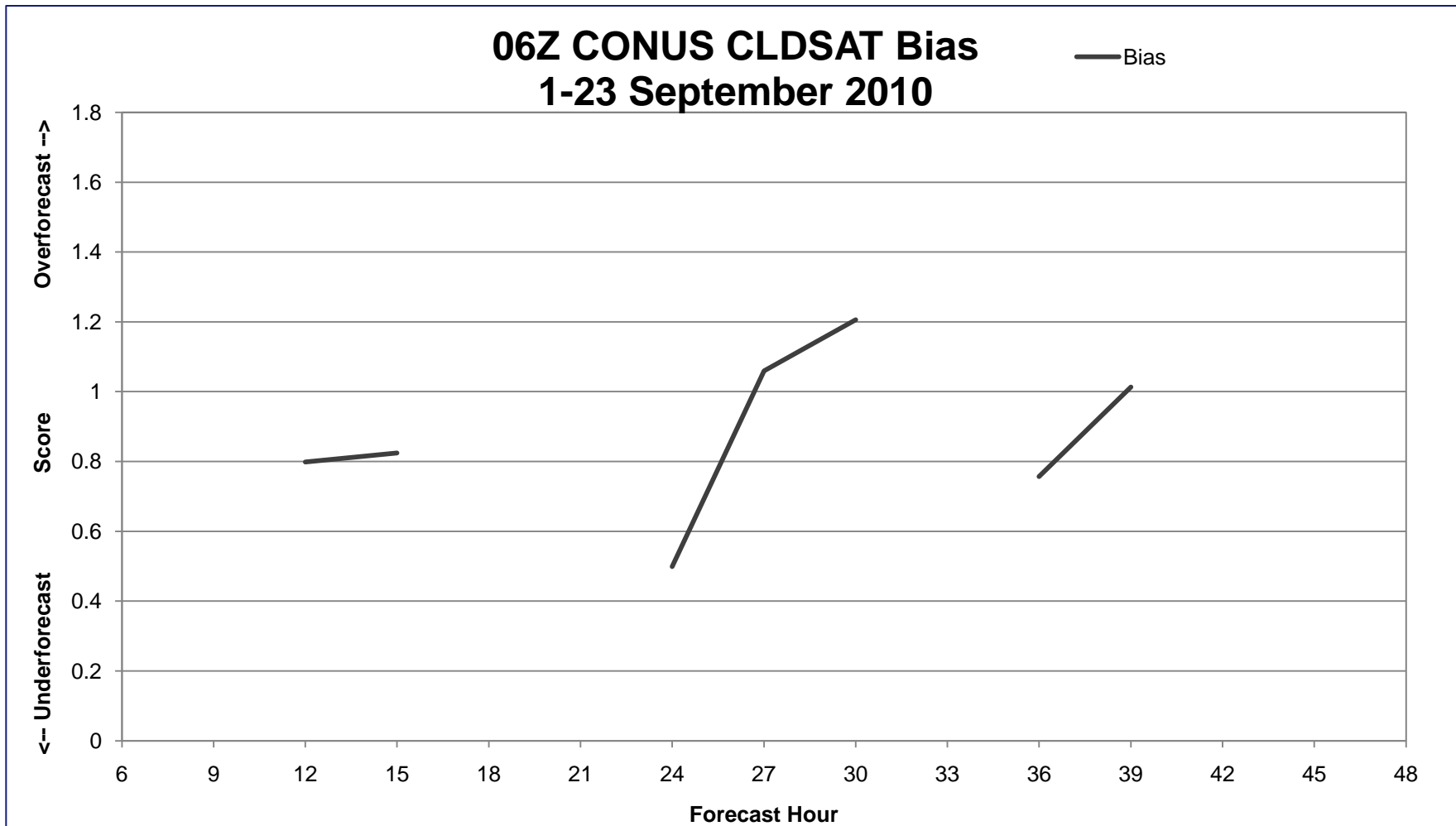
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# 06Z Bias



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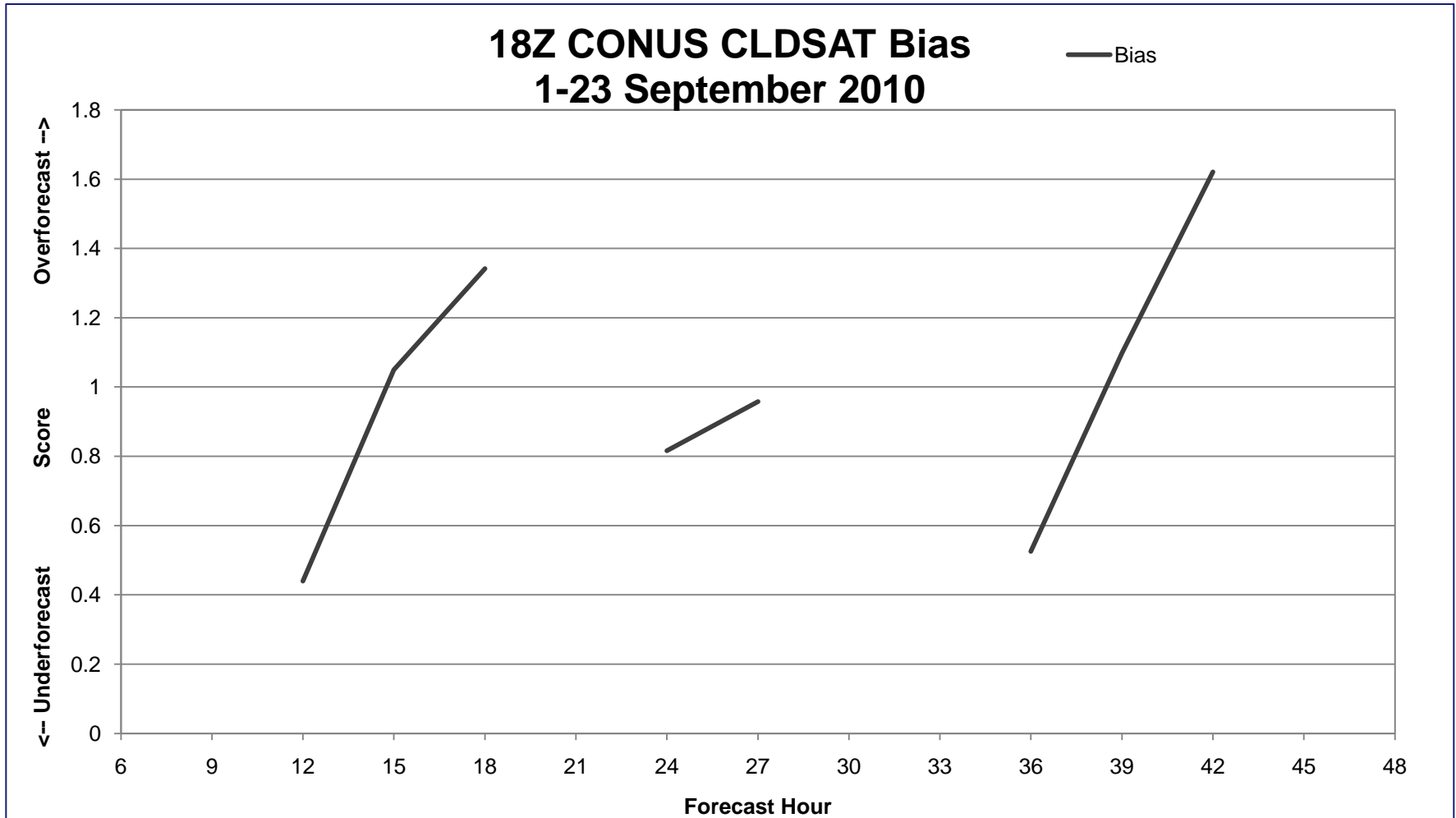
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# 18Z Bias



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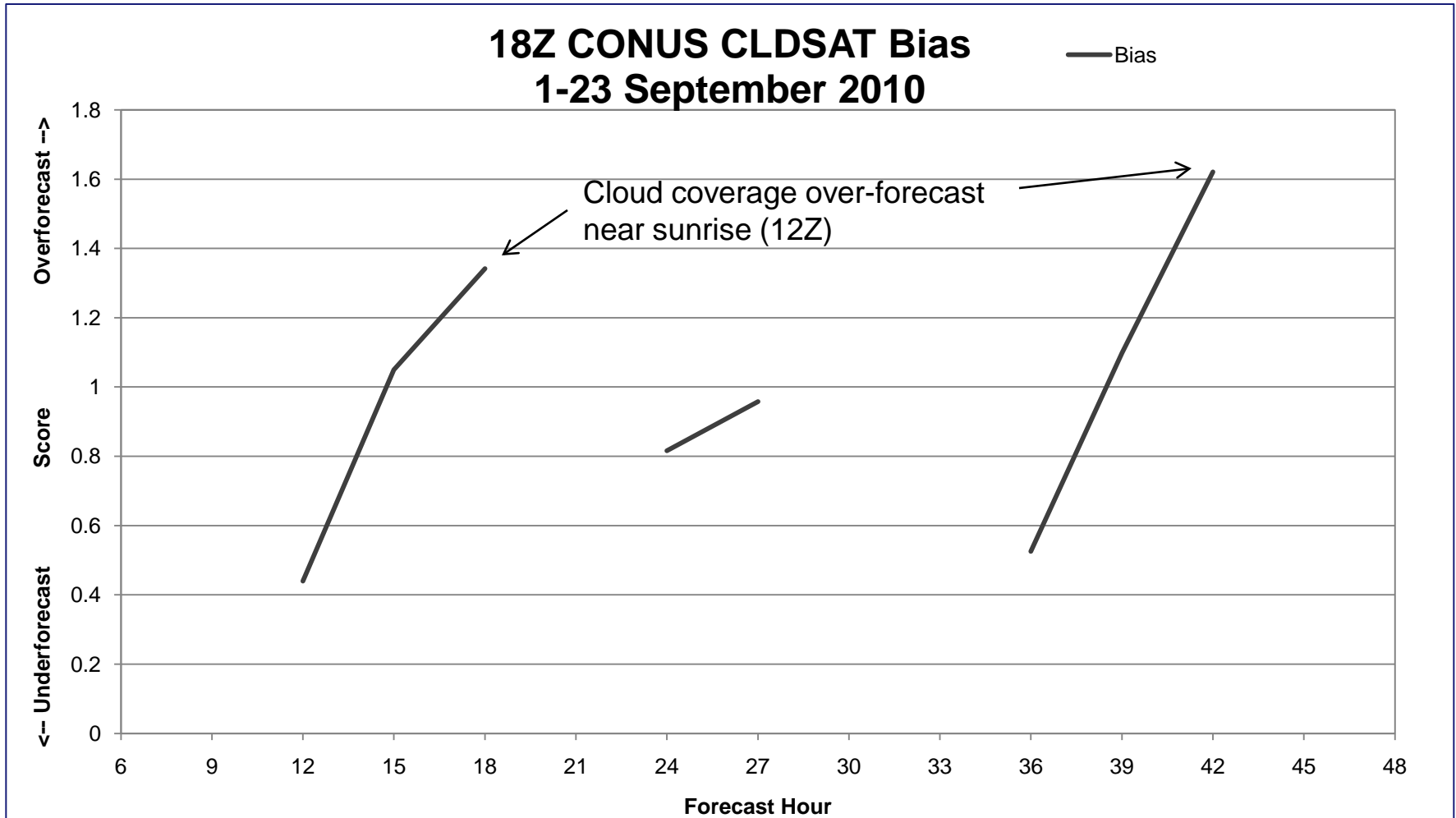
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# 18Z Bias



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# *Height Classification*



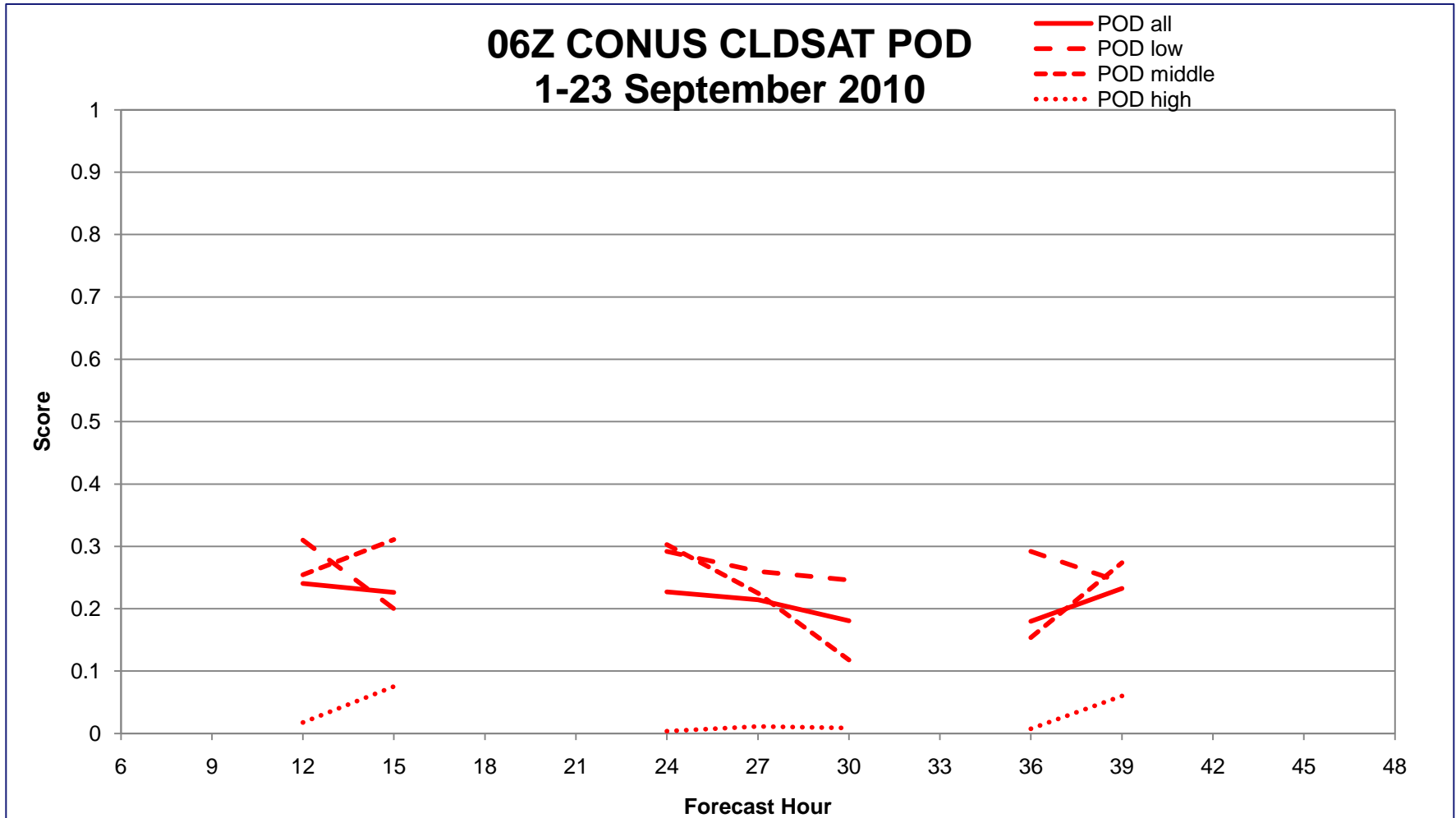
- How do the statistics vary if the full 15,000 meter vertical column is separated into 5,000 meter sections?
  - “Low”, “Middle”, “High”
  - Same 23-day period



# 06Z POD



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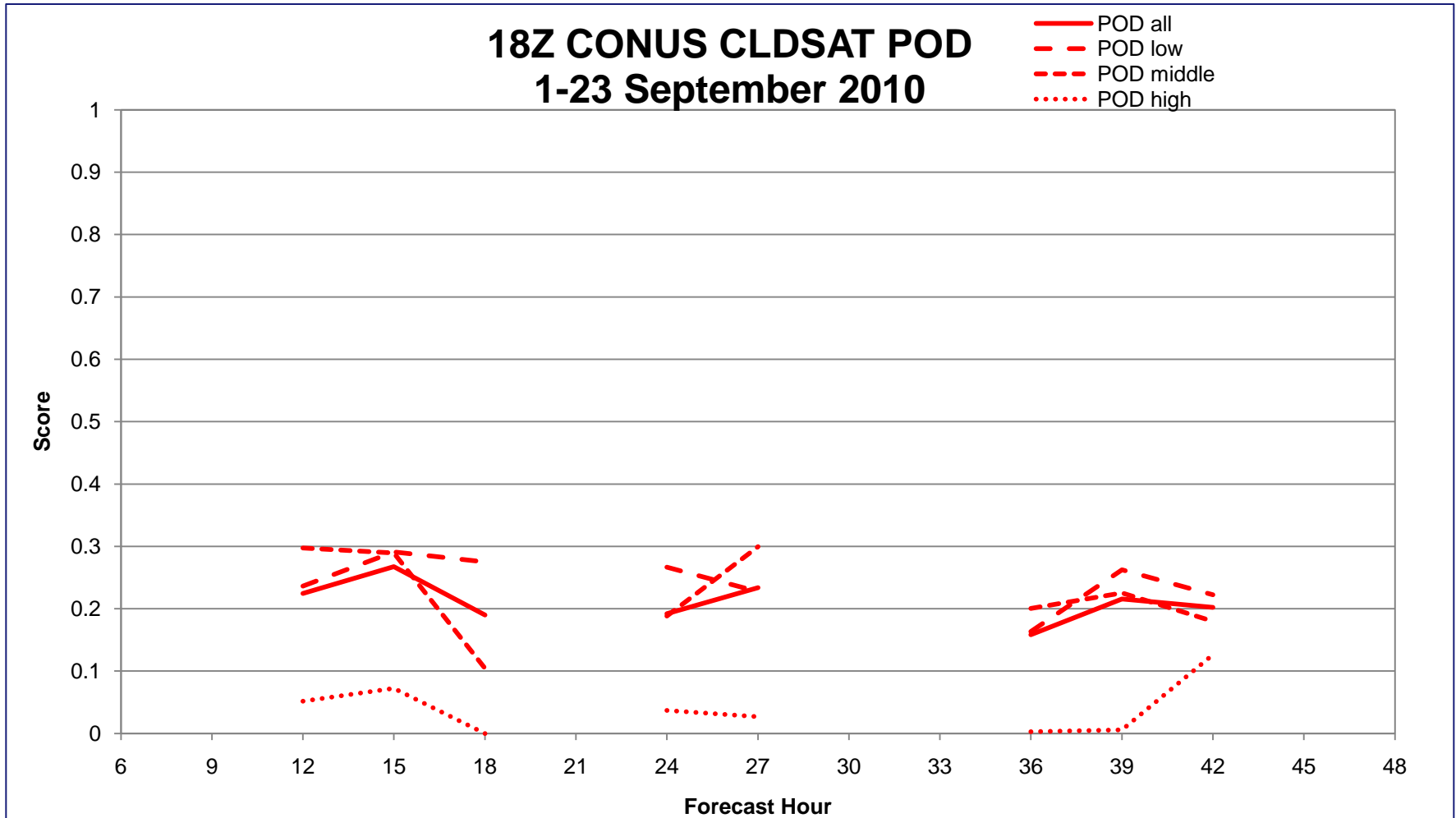
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# 18Z POD



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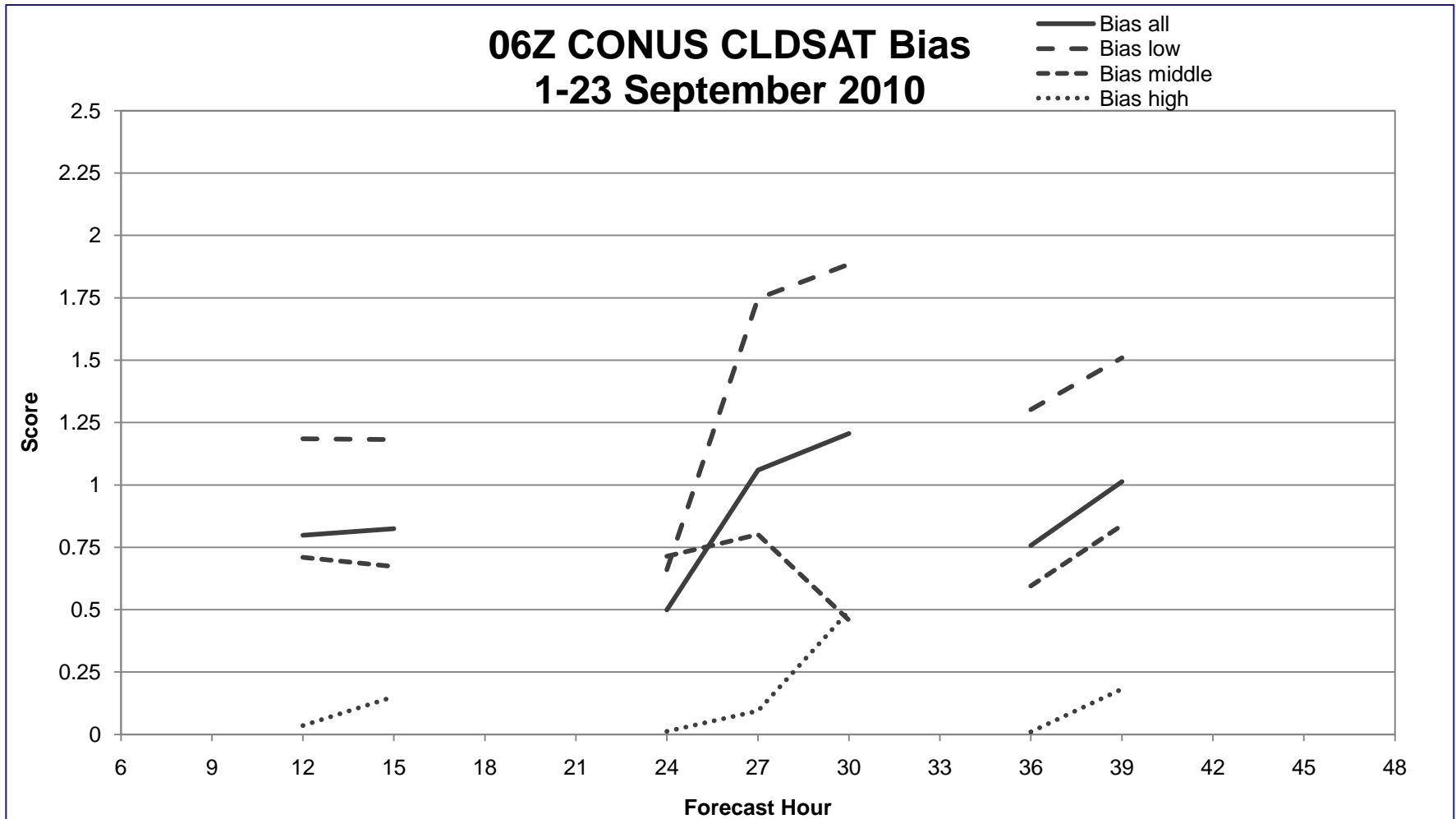
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# 06Z Bias



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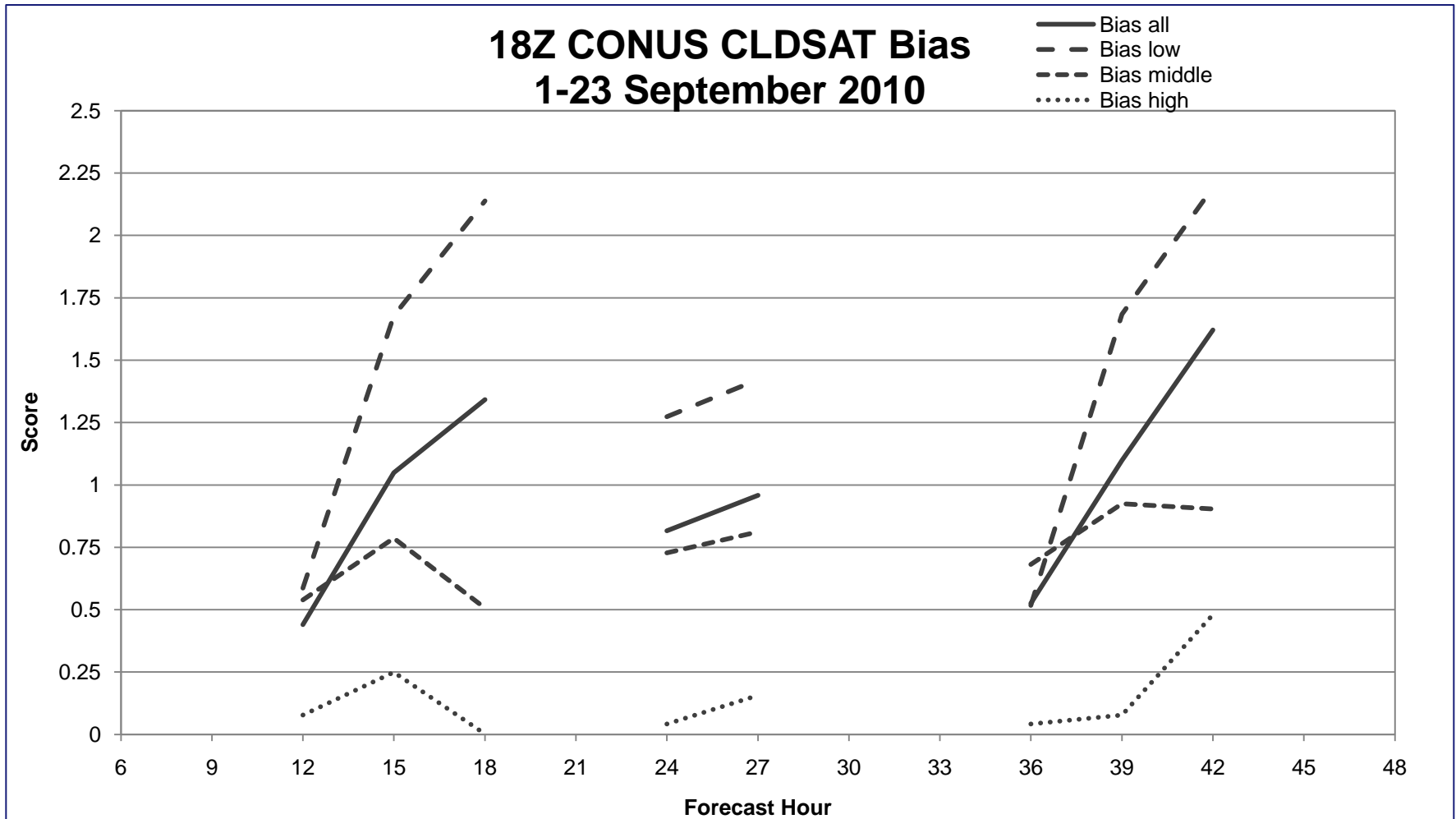
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# 18Z Bias



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# Conclusions



- **CLDSAT's limitations are many**
  - **Narrow spatial paths**
  - **Temporal gaps**
  - **Communications issues**
  - **Long delay in receipt**
- **Results suggest:**
  - **Cyclical pattern to metrics**
  - **Over-forecast near local sunrise, esp. low and middle layers**



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# Questions/Comments?



- **Contact the author:**
  - **Matthew.Sittel@offutt.af.mil**