Preliminary Evaluation of Loran for RNP 1.0

International Loran Association

October 24, 2006

Sherman Lo

This Talk …

- Background: What & Why
- Differences between RNP 0.3 and 1.0
- Assumptions
- RNP 1.0 Availability
- RNP 1.0 Accuracy
- Thoughts & Considerations

Loran for RNP 1.0: What, Why, How

- RNP 1.0 is for enroute navigation
  - Allows Loran to be used for all phases of flight
    - RNP 0.3 for approach
  - ADS-B back up
    - ADS-B key part of Next Gen Air Transport System
- Requirements
  - HAL of 1852 m (1 nm)

Differences in RNP 0.3 & 1.0 environment

- Aircraft on approach (RNP 0.3)
  - Close to airport and surveyed ASF/ECD location
  - At lower altitude (max 4000 ft AGL)
- Aircraft enroute (RNP 1.0)
  - Potentially far from known ASF/ECD location
  - At higher altitude (20 – 40,000 ft)

Assumptions on ASF/ECD

- Receiver may not calculate path integrals for bounding ASF & temporal variations
  - Will store grid of values
- Sources for ASF/ECD Grid
  - Airport & additional measurements
  - Model?
- Reference/Grid locations may be far away
  - ASF/ECD variations larger than RNP 0.3
  - Need to account in bounds
  - Implementation issue: How de we interpolate?

Loran RNP 1.0 Feasibility Assessment

- Integrity: Use basic integrity algorithm as RNP 0.3
- Continuity: Similar assessment as RNP 0.3
- Availability: Larger ASF/ECD values but larger HAL (1853 m)
  - Primarily determined by cycle integrity
- Accuracy

Availability Driven By Cycle Selection

- We always need cycle integrity
  - Probably cannot have a cycle slip
  - Integrity requirement is still $1e^{-7}$
- Cycle Selection & availability affected by
  - Bounds on ECD
  - Bounds on spatial, temporal correlated & uncorrelated ASF
- HPL is also affected by increased ASF bound
  - However, HAL is larger

- Hence we concentrate on ASF/ECD effects on Cycle Selection

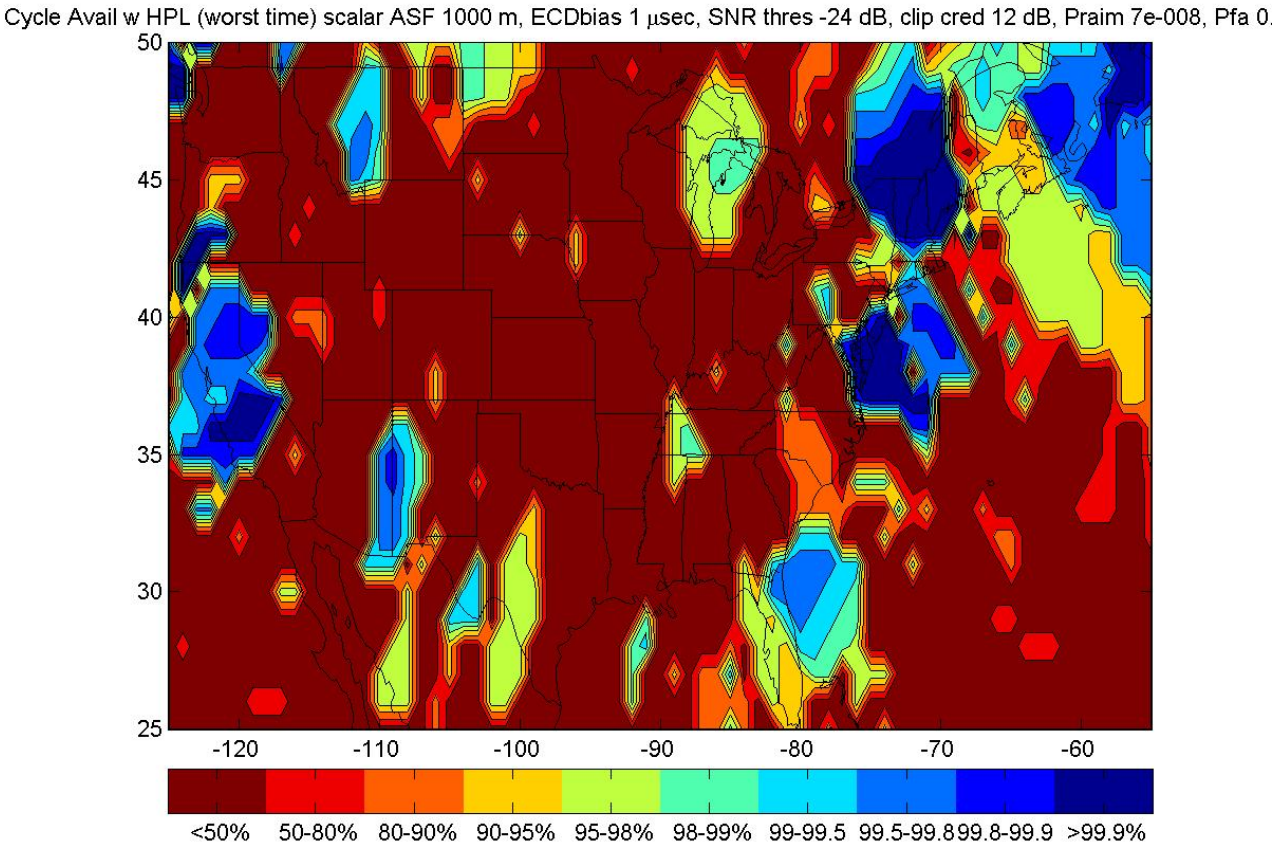
We examined Two Algorithms & Three Cases

- Two different weighting:
  - Sigma (σ) noise, sigma+temporal bias+spatial bias (σ+b) asf
    - Only show results from sigma case, sigma + bias case results in very unacceptable availability
  - Another presentation on difference
- Examined Three cases
  - Max stations
  - Best combination of stations
  - Best combination allowing missed cycle on least weighted station
  - Result: Algorithm can be improved (some improvement from best station and allowing one miss)

Baseline Conditions for Results

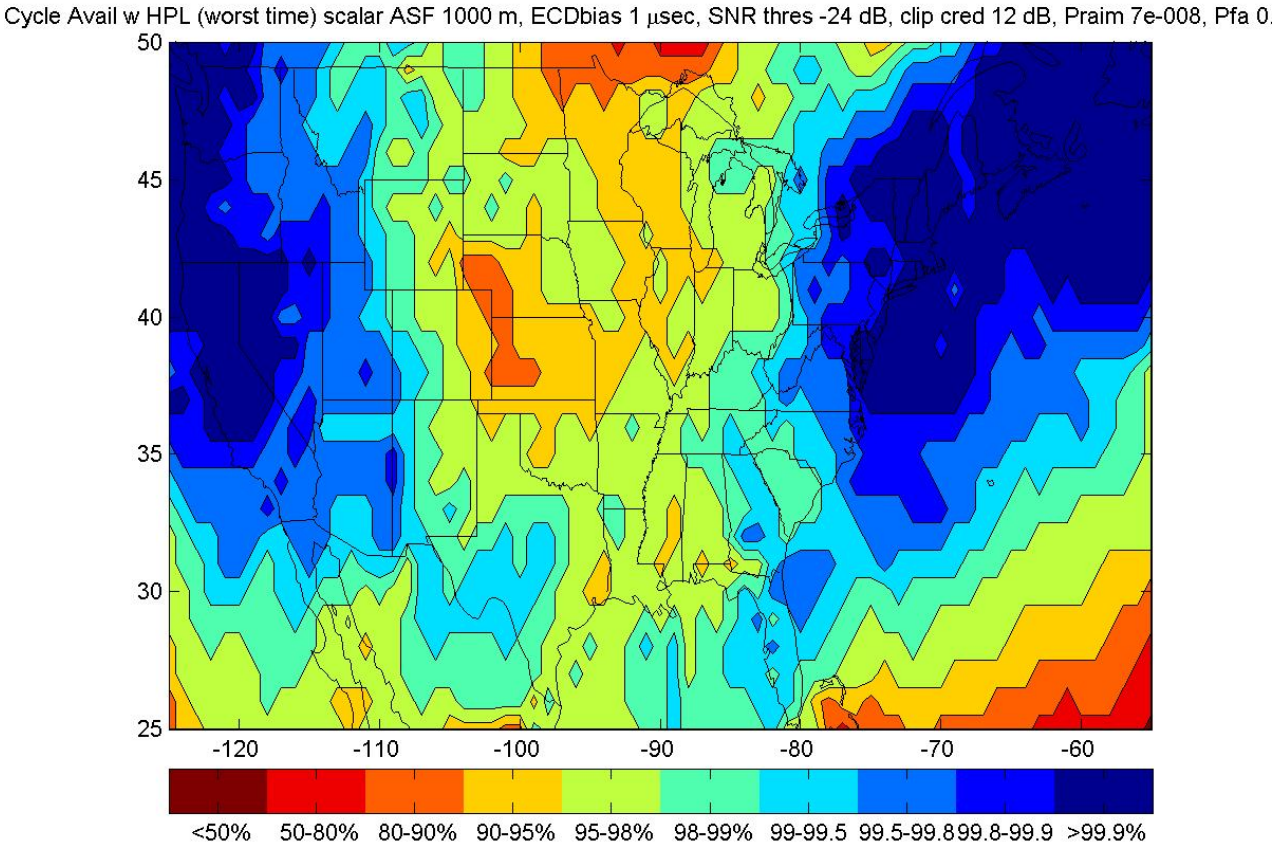
- Spatial ASF = 1000 m, Spatial ASF position domain = 240 m
- ECD bias = 1.0 microsecond
  - Increased value to test sensitivity
- Temporal ASF (correlated/uncorrelated) unchanged from RNP 0.3

Coverage Sigma + All ASF bias



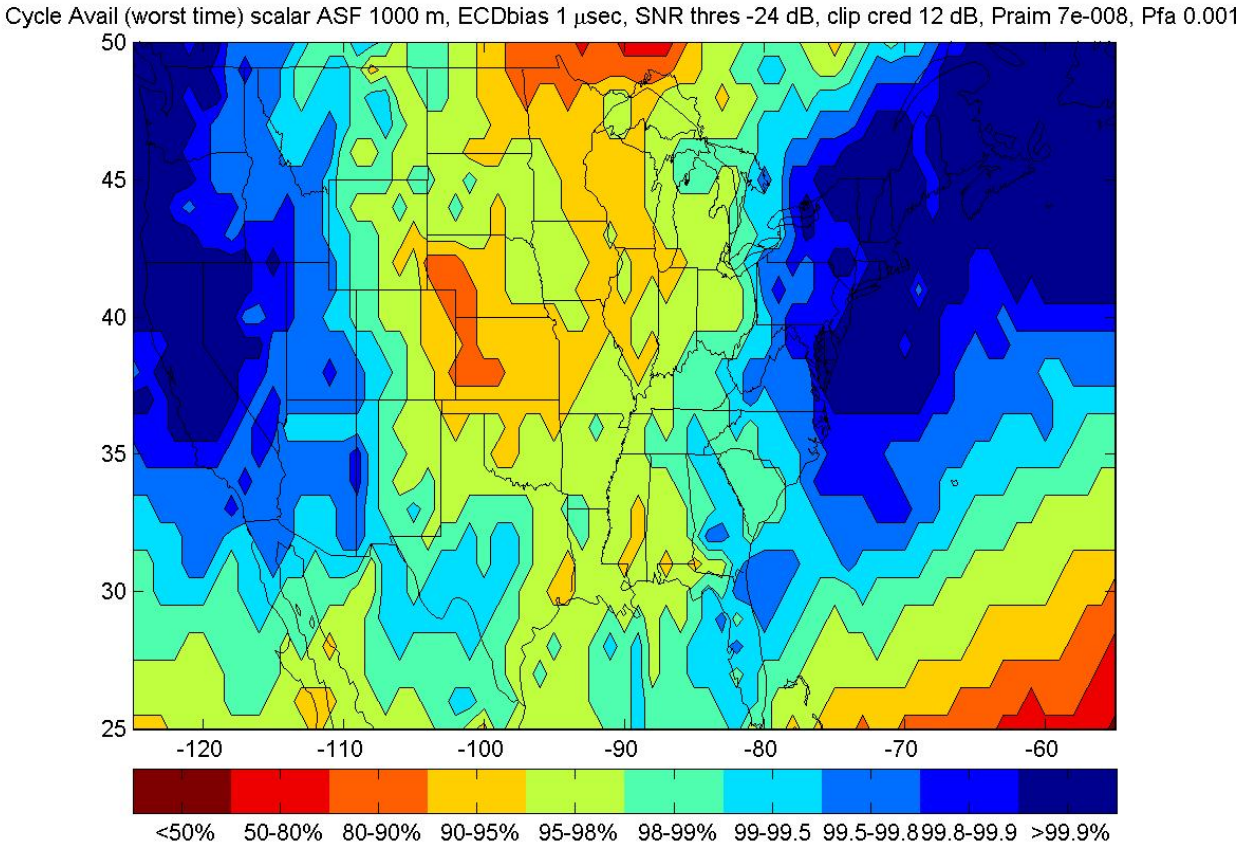
σ+b

Coverage Sigma



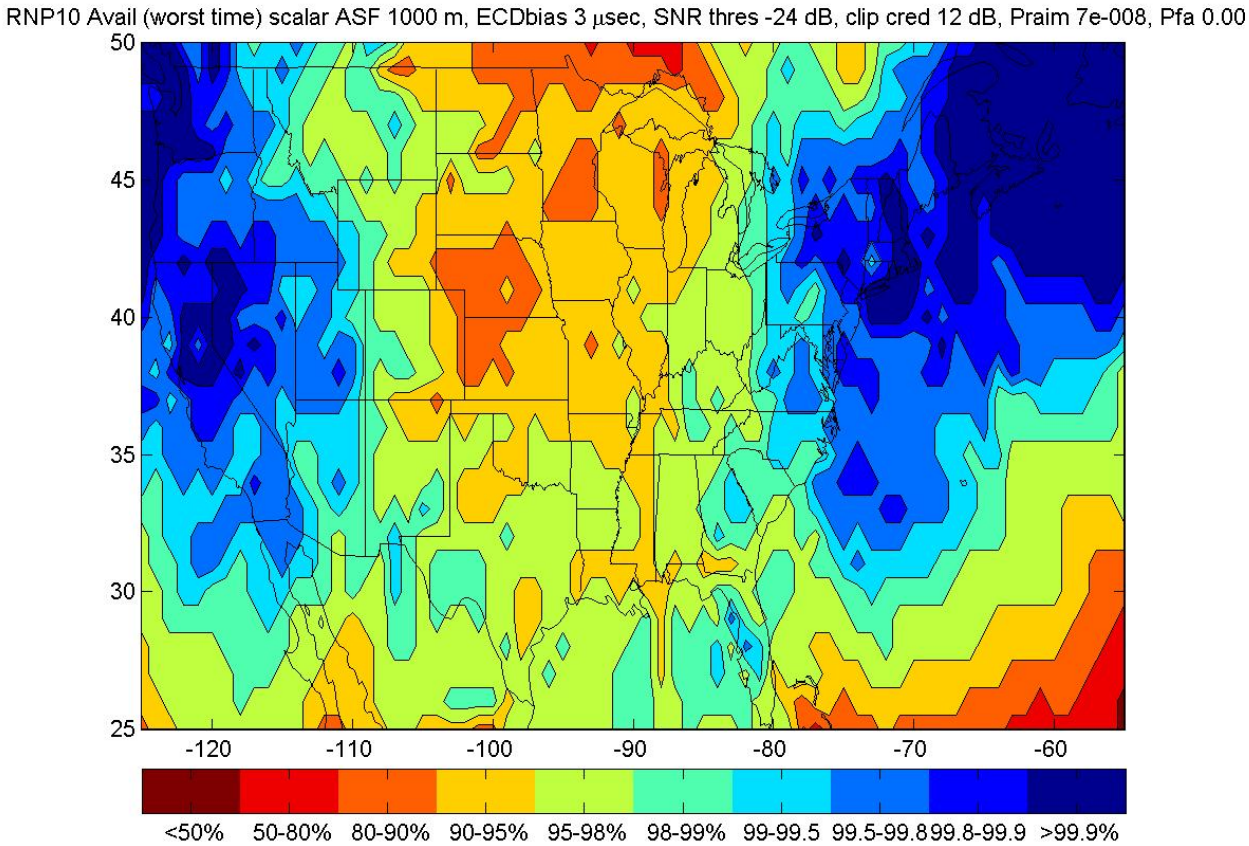
σ

Cycle Only Sigma

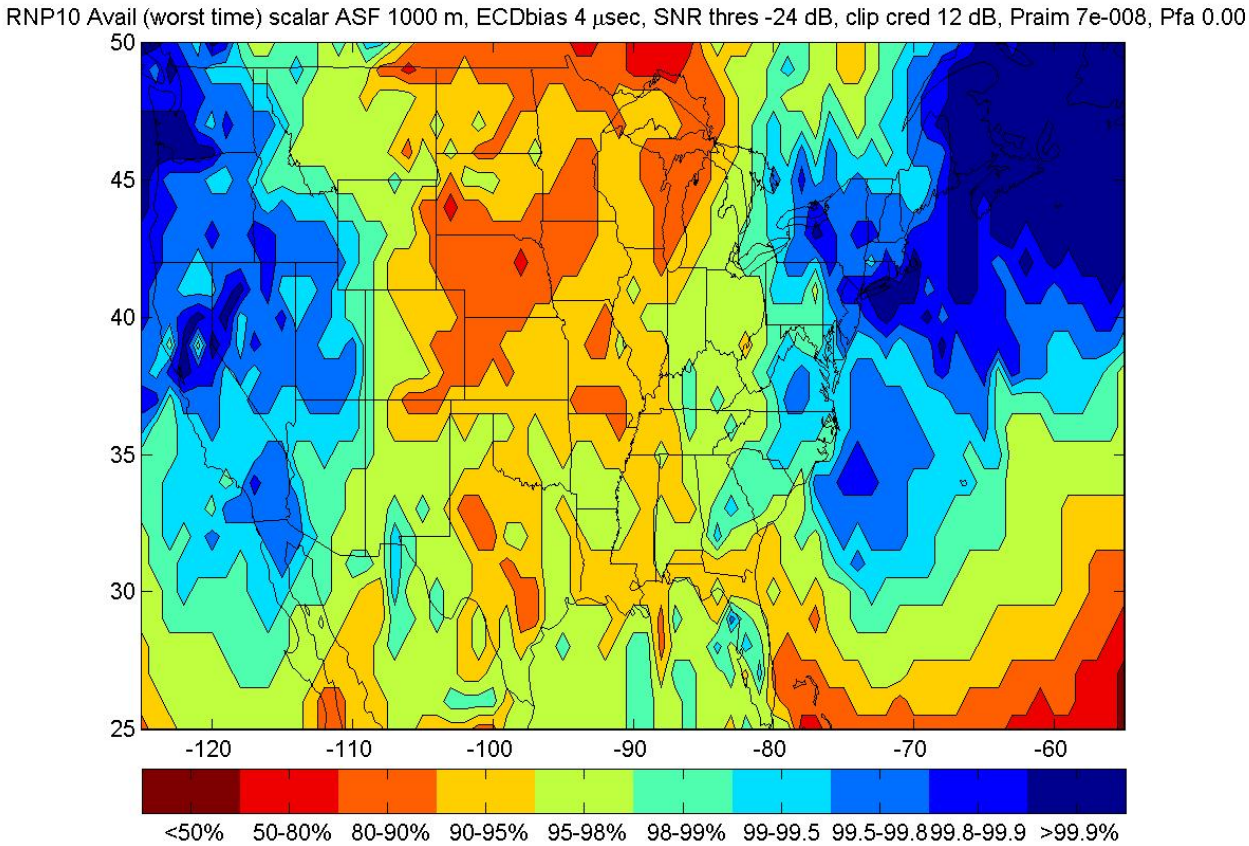


σ

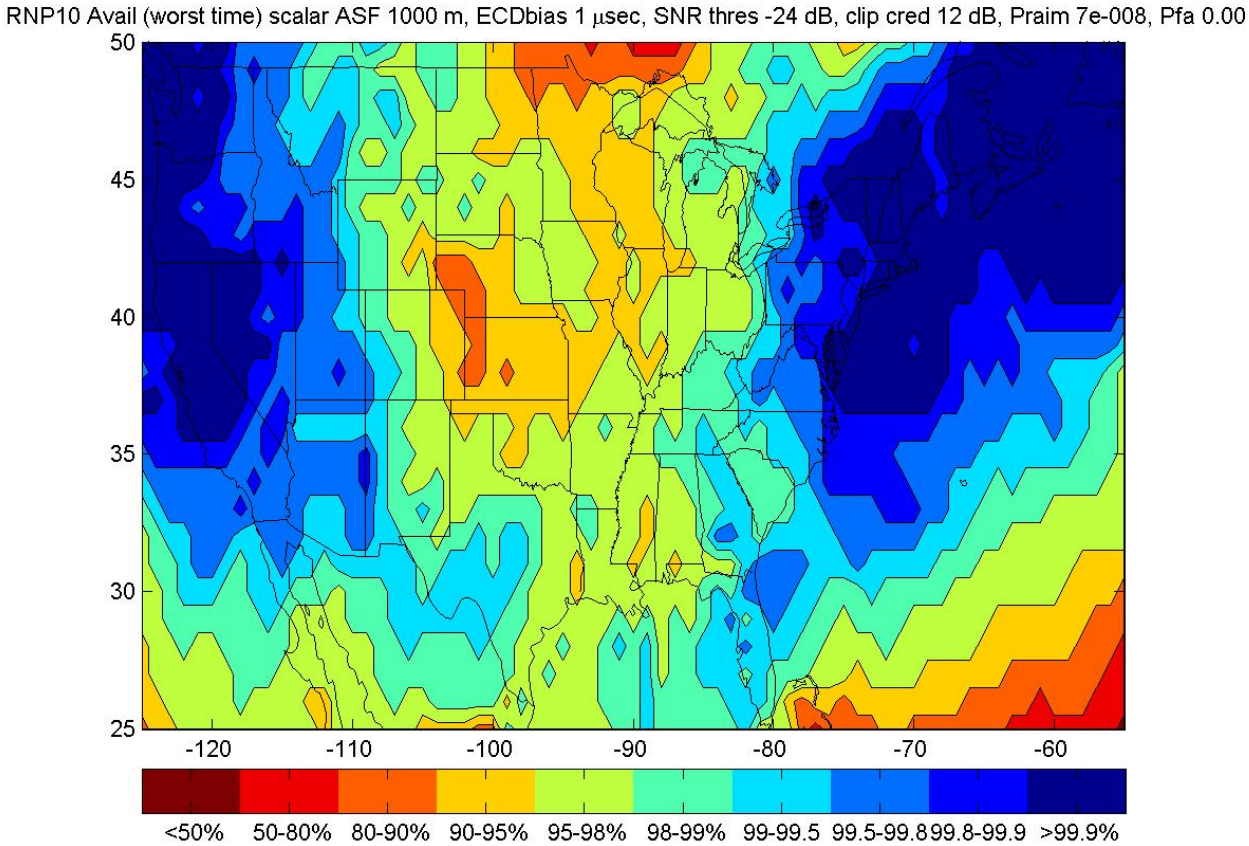
Coverage: Sigma (ECD = 3.0, Best Station)



Coverage: Sigma (ECD = 4.0, Best Station)

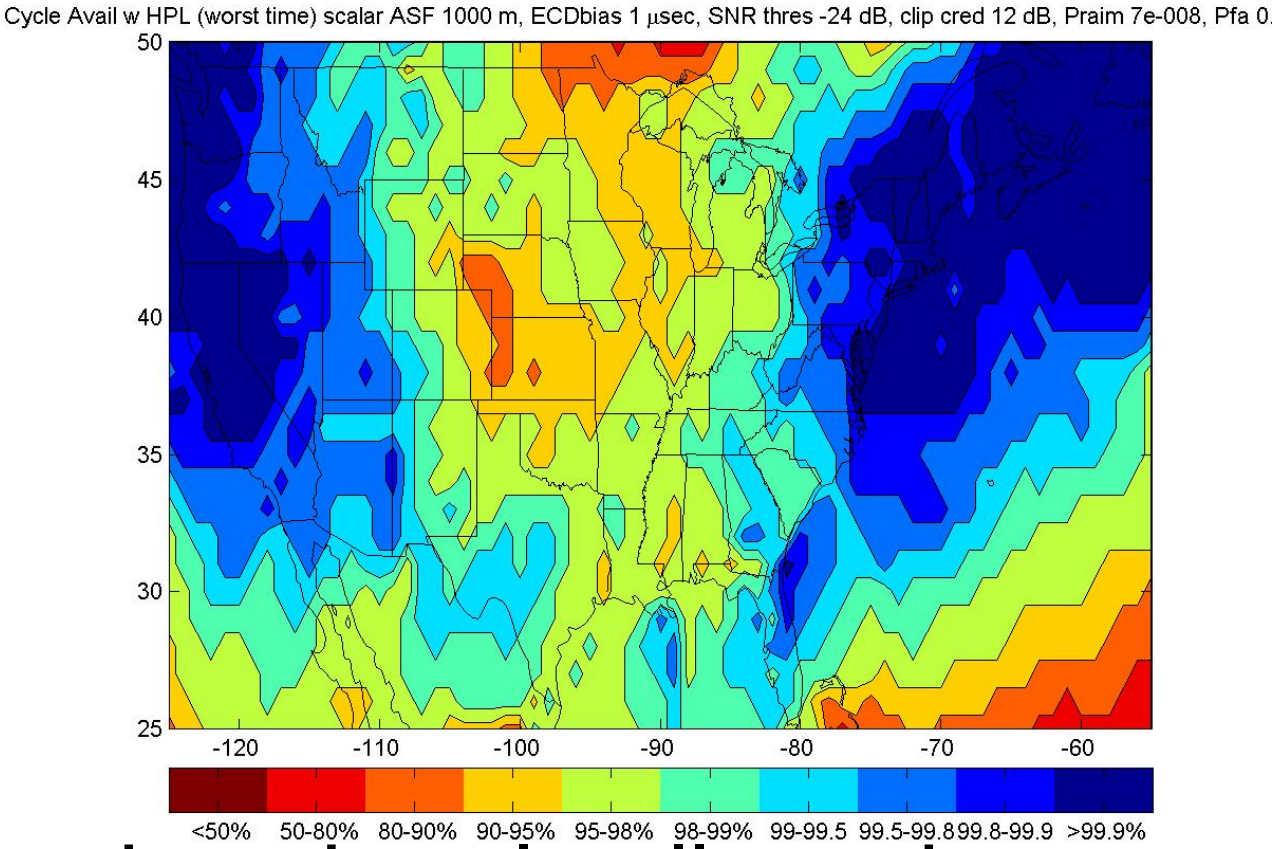


Coverage Sigma (Best Station Set)



σ, best set

Coverage Sigma (Best Station Set + Miss)

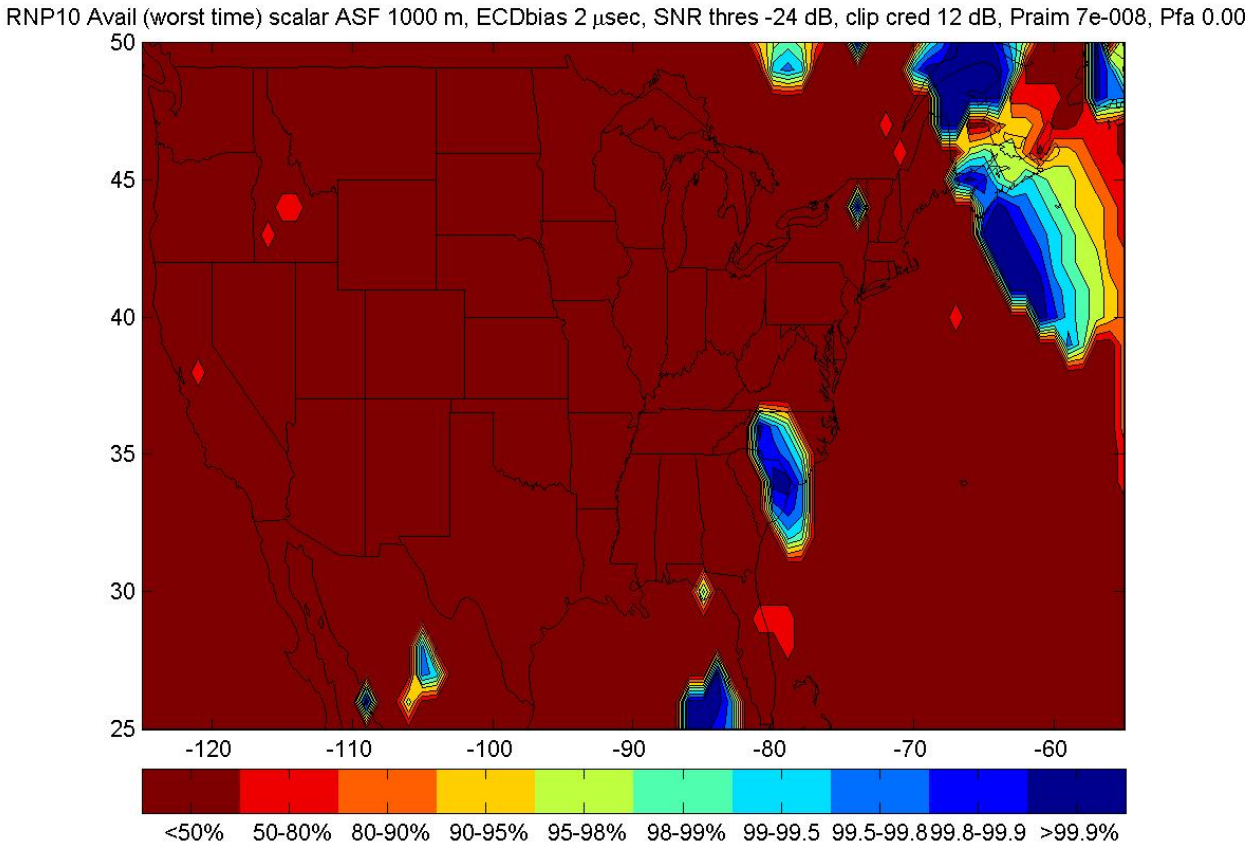


σ, best, missed cycle allowed

Improving Performance

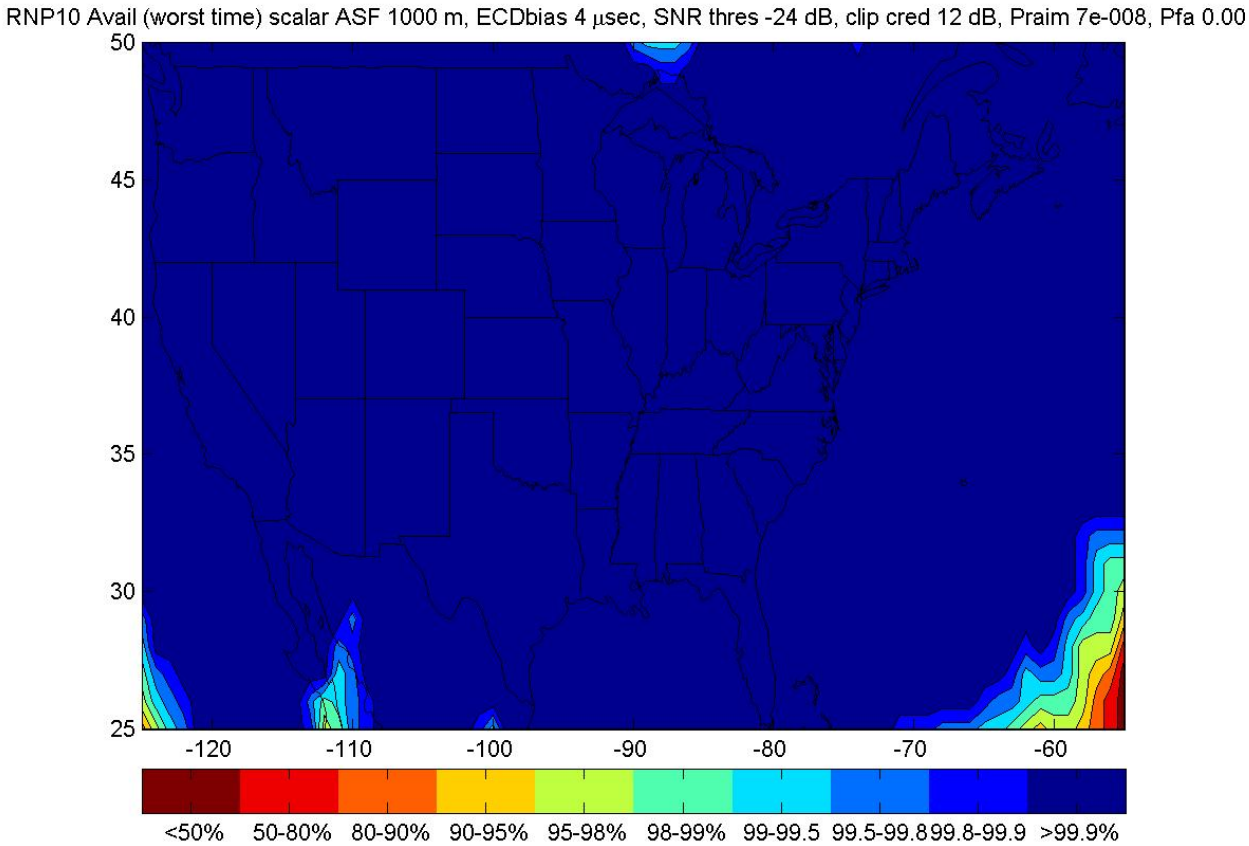
- Examine Boyce's Noise Model
  - Discussed at ION-GNSS 2006
  - See paper tomorrow for additional information

Coverage: Sigma + All Bias (Most Conservative Revised Noise)

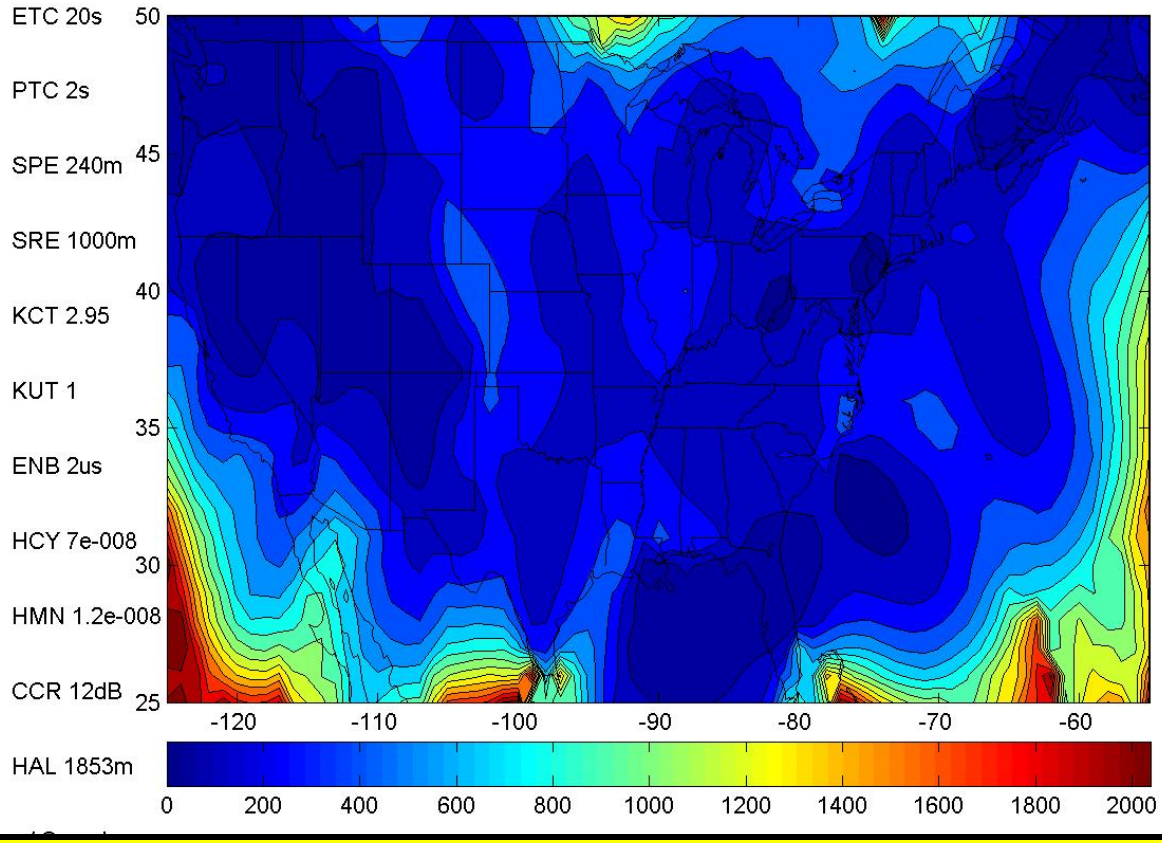


•Even with Boyce's Noise Model, Cycle Confidence is not adequate using σ+b weighting

Coverage: Sigma, ECD = 4 (Nominal, Most Conservative Revised Noise)



HPL Sigma (Most Conservative Revised Noise)



- Cycle Confidence, not HPL, is the key driver
- Position Domain Spatial ASF error can be significantly increased (from 240 m to > 1000m)

Accuracy & Modeling

- USCGA/JJMA Flight Test
  - Test to assess long baseline calculations of ASF
  - Compares collected ASF with those calculated by different models
- Implementation of models in receiver may be difficult
- Results it suggest we can generate the grid points using a model

Thoughts & Considerations

- Availability targets are achievable
  - Need to σ weighting availability
    - Can be achieved without compromise to integrity
    - Integrity can be demonstrated! (another presentation)
    - WSSE should follow χ^2
    - Still working out details of algorithm
  - Boyce's values for noise & clipping credit, availability using σ approaches 99% +
- Flight test suggests that models may be used to generate ASF grid
  - Potentially some improvement in availability
  - Improve accuracy

Acknowledgements

- Federal Aviation Administration
  - Mitch Narins – Program Manager
- The views expressed herein are those of the presenter and are not to be construed as official or reflecting the views of the U.S. Coast Guard, Federal Aviation Administration, or Department of Transportation .