# ARTIST-5

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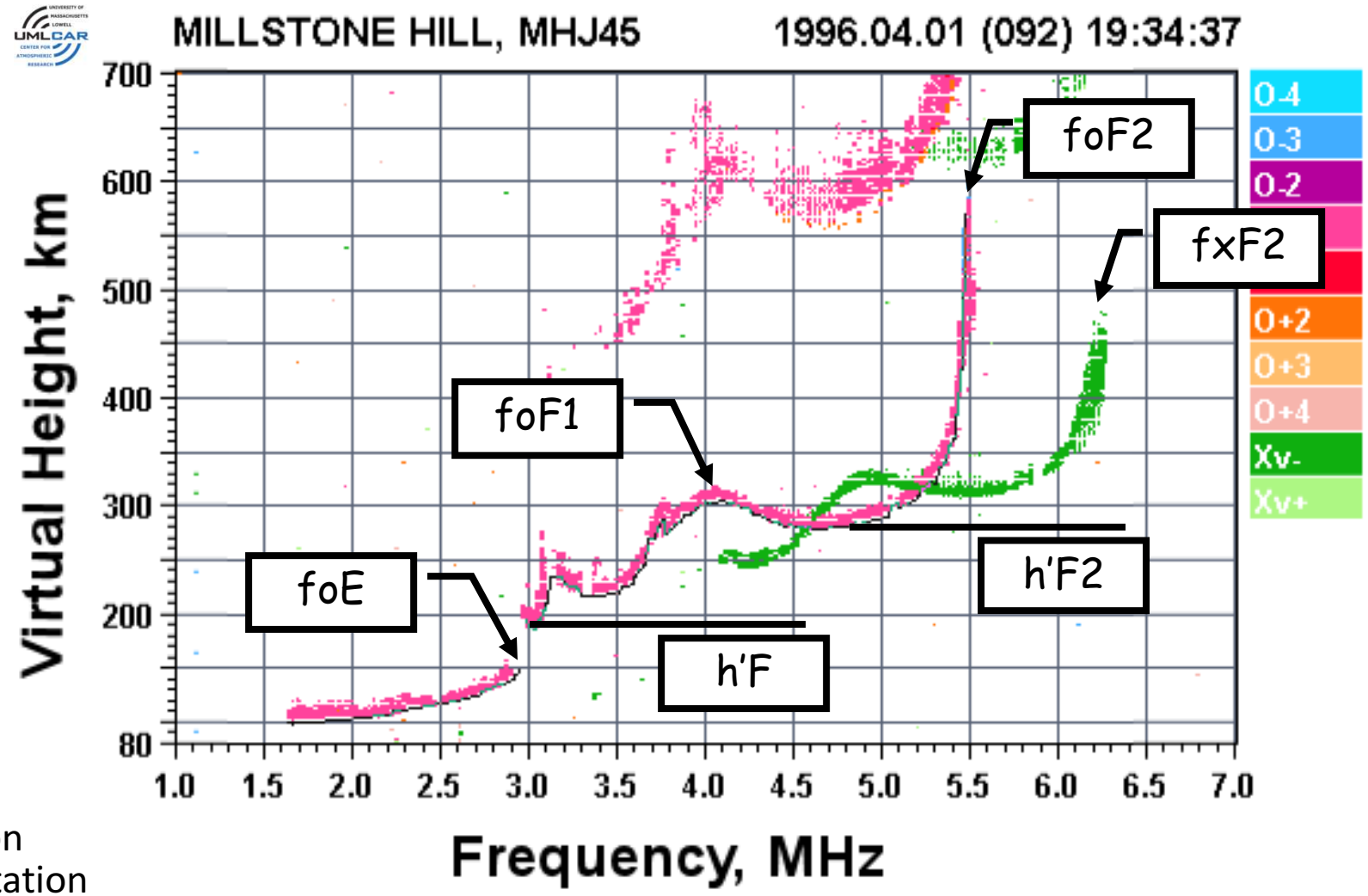
**Autoscaled:**

| | |
|---|---|
| foF2 | 5.49 |
| foF1 | 4.86 |
| foF1p | 4.56 |
| foE | 2.96 |
| foEp | 3.23 |
| fxI | 6.20 |
| foEs | 2.95 |
| MUF | 18.70 |
| M | 3.415 |
| D | 3000 |
| h'F | 185 |
| h'F2 | 285 |
| h'E | 98 |
| h'Es | 98 |
| zmF2 | 227 |
| zmF1 | 196 |
| zmE | 106 |
| yF2 | 67 |
| yF1 | 40 |
| yE | 30 |
| C-level | 1 |




Ionogram
Trace Extraction
Trace Interpretation


Dalu
감사합니다
Gracias
Danke
Ευχαριστίες
THANK YOU
Obrigado
Köszönöm
Grazie
Спасибо
Dank
Tack
谢谢
Merci
ありがとう
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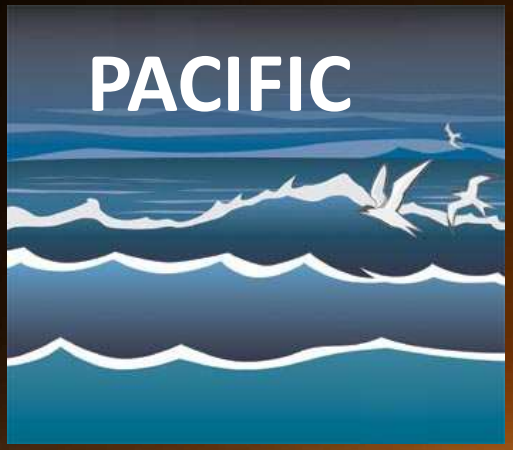
# Outline

- Review of ARTIST-5 innovations
- Autoscaling Confidence Level (ACL)
  - Prevent low confidence data from assimilation
- ARTIST-5 Uncertainty Study
  - Error Bounds for Characteristics
  - Error Boundaries for Electron Density Profile (EDP)
- Where do we go from here

# ARTIST Family

| | |
|---|---|
| APE (1974) | Automatic Parameter Evaluation, “Geomonitor” Intel 8080 microprocessor |
| BISA (1981) | Bottomside Ionogram Scaling Algorithm, Cyber 71 and CDC 6600 |
| ARTIST (1982) | Automatic Real Time Ionogram Scaler with True Height calculation, standalone unit based on Intel 8086 chip |
| ARTIST- II (1986) | based on PC |
| ARTIST- III (1991) | upgrade to ARTIST-II for Digisonde 256 |
| SARTIST (1991) | stand-alone version of ARTIST-III for DPS |
| ARTIST- B (1994) | Neural networks algorithm for tracing, separate analysis of O and X polarizations (inspired by PACIFIC) |
| ARTIST- 4 (1996) | Win32, stand-alone, AUX computer |
| ARTIST- 4.5 (2004) | Analysis of data in true height domain (trace gaps and truncation) |
| ARTIST- 5 (2002) | Fortran $\rightarrow$ Java, I/O and graphics unified with SAO-X, DIDB technology for testing, other improvements |

# ARTIST-5 Innovations





**A**rtificial
**N**eural
**N**etwork
pre-**A**ttentive
**E**ye



**P**rogram for
**A**utoscaling of
**C**onventional
**I**onograms with
**F**lexible
**I**nterpretation
**C**ontrol



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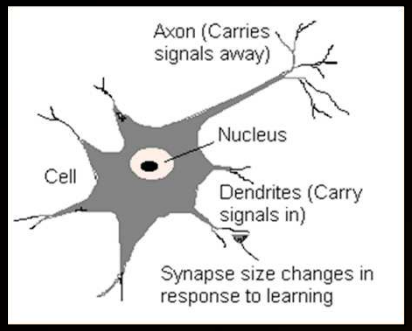
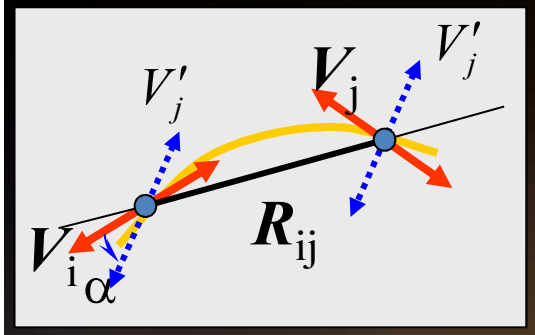
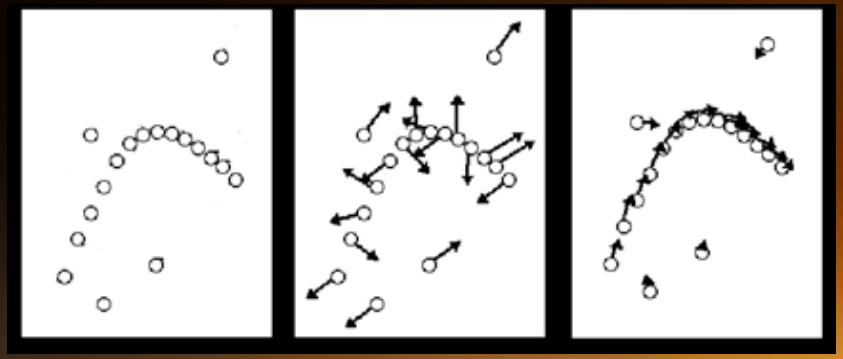
# Extraction of Traces



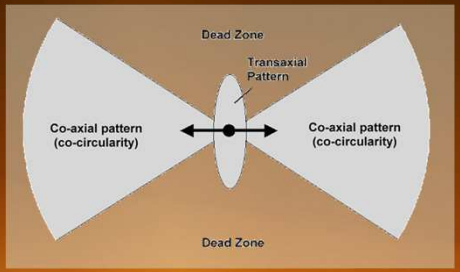

- Original design: 1993-1994
- Bio-plausible additions: 2003-2004
- New clustering algorithm: 2007

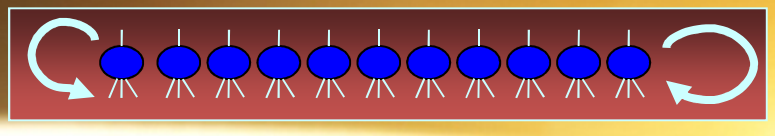




Rotor interaction
(co-circular model)



Initial state of NN  Final state of NN

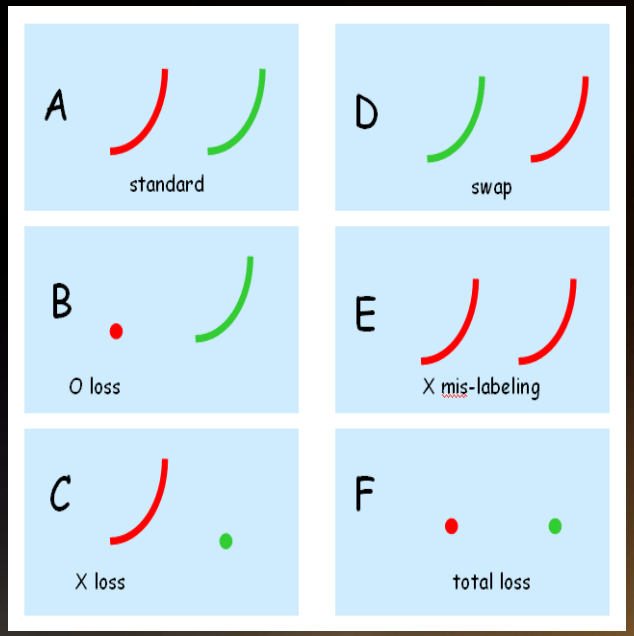


Hopfield Feed-back ANN

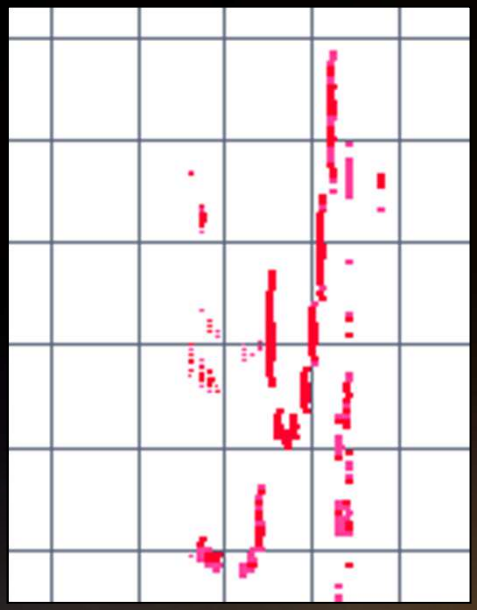
Honda ASIMO

# PACIFIC

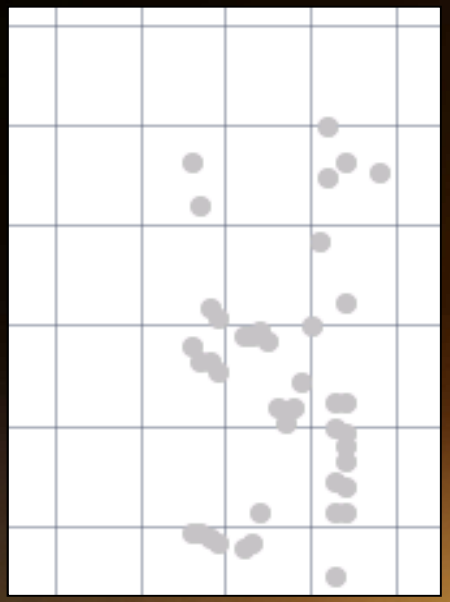



- Seeks trace segments pointing up
- Considers 6 configurations A-F
- Fits O- and X-cusps independently and refits if they do not match
- Allows down-grading to ionograms without polarization tagging or with swapped polarizations
  - Learmonth, Australia
  - Jicamarca, Peru

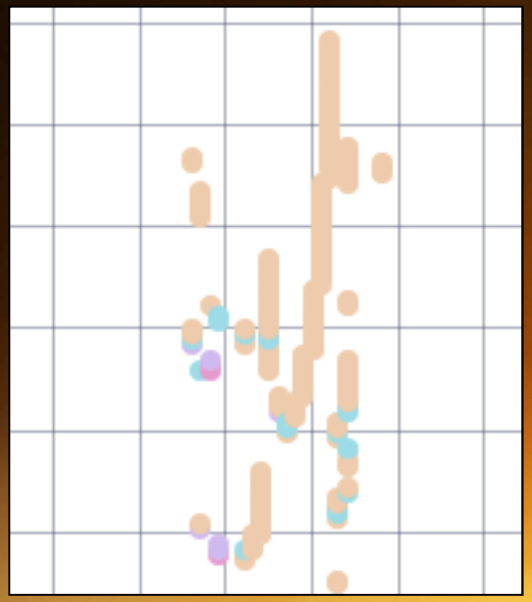
# A45: Edgel Extraction

IONOGRAM
thresholded



Classic edgel detection



"Dual" A45 edgel detection

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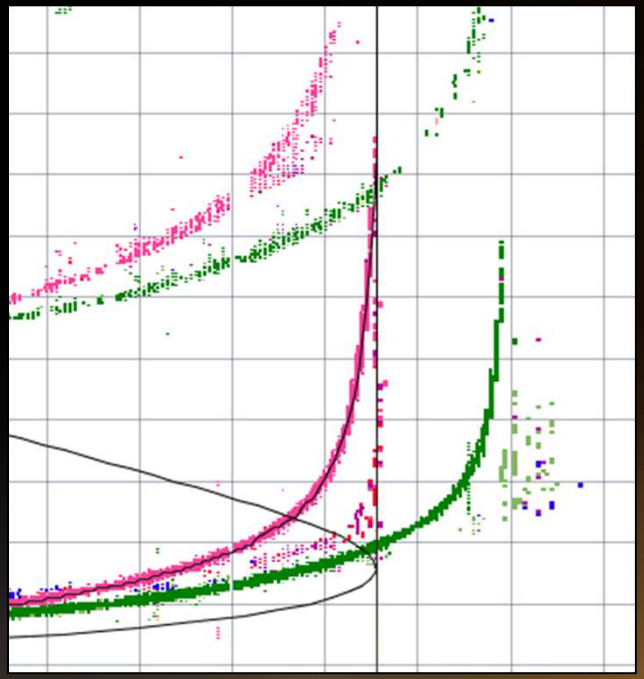
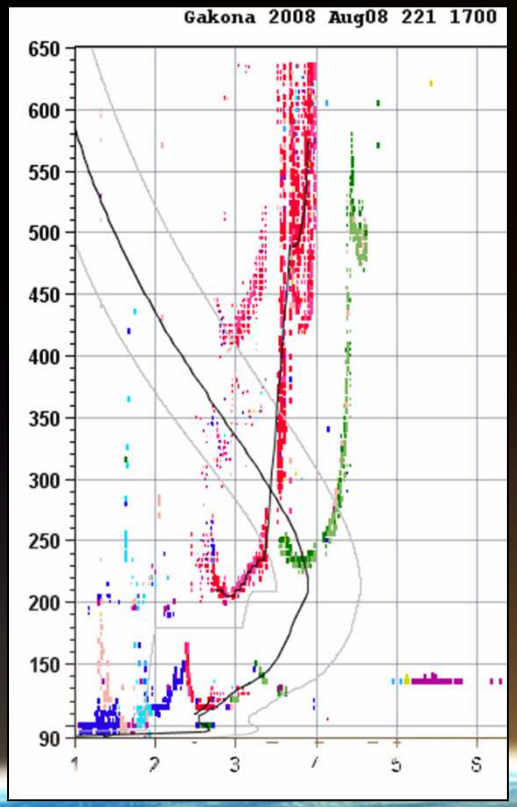
# ARTIST-5 Lessons Learned



- Accurate foF2 cusp processing is most important
  - Careful with cusp extrapolation above last trace point
- Imperfections in trace extraction are not important
  - Small effect on Ne density profile
- NHPC Profile inversion works as trace gap interpolator

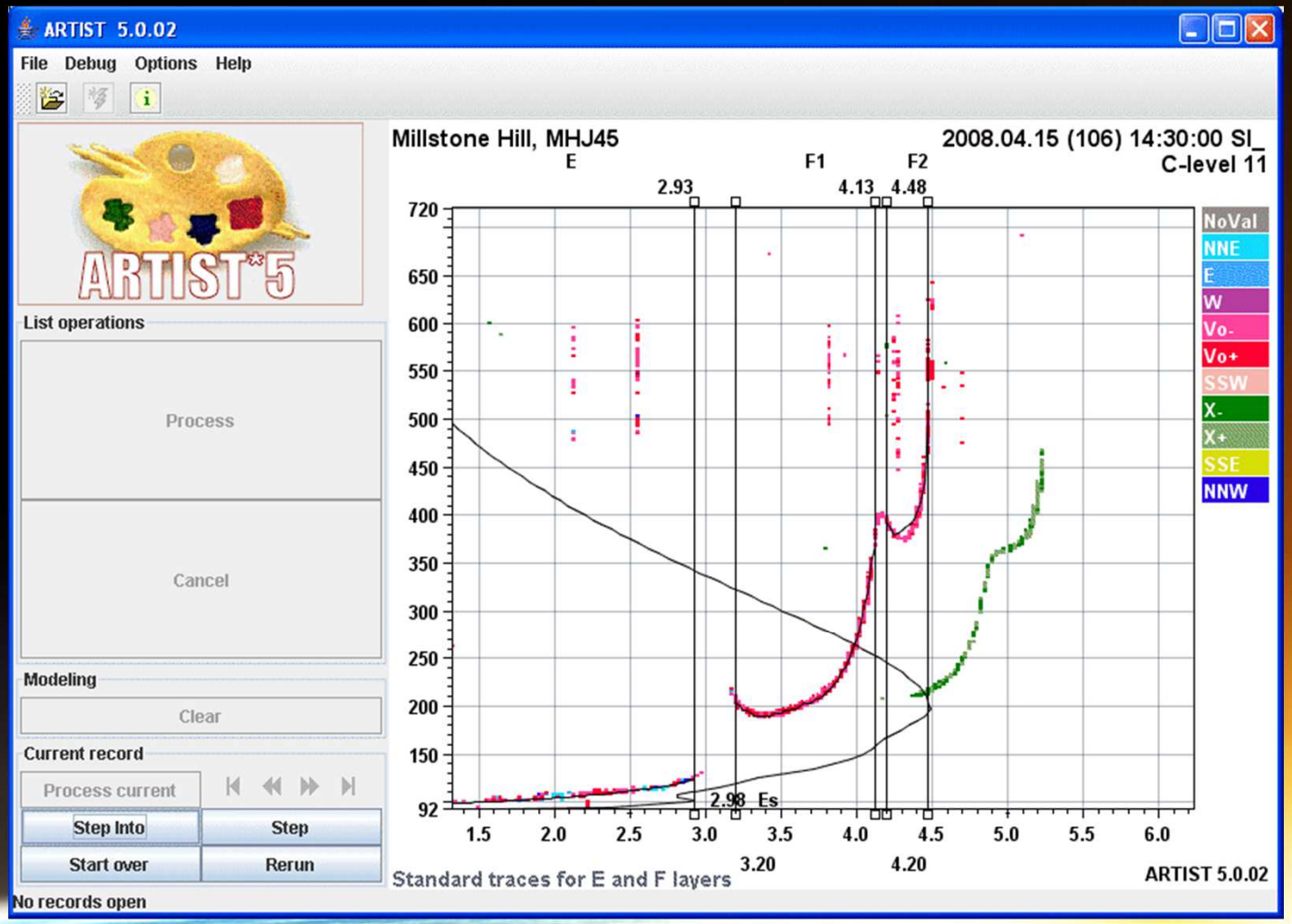
# ARTIST-5 Lessons Learned (2)




- Short steep high traces are most difficult
  - Summer
  - Low solar activity
  - Storm time / F3 layer
- Second hop traces are difficult
  - from sporadic E layer
  - stronger than 1st hop trace
  - Not removed by multi-hop analysis
  - Dourbes Digisonde 4D is prone to this
- Ionograms taken during spread F conditions shall be processed differently

# Ionogram Optimization for ARTIST-5

- Use smallest frequency step possible under measurement time restrictions
- Use Precision Ranging mode
  - Subject to PR quality verification
- 5 km may be better than 2.5 km
- Reliable polarization tagging is important
  - Special considerations apply for equatorial locations


ARTIST 5.0.02
File Debug Options Help
ARTIST 5
List operations
Process
Cancel
Modeling
Clear
Current record
Process current
Step Into
Step
Start over
Rerun
No records open
Millstone Hill, MHJ45
2008.04.15 (106) 14:30:00 Sl_
C-level 11
E
F1
F2
2.93
4.13
4.48
NoVal
NNE
E
W
Vo-
Vo+
SSW
X-
X+
SSE
NNW
720
650
600
550
500
450
400
350
300
250
200
150
92
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
2.98 Es
3.20
4.20
Standard traces for E and F layers
ARTIST 5.0.02

# ARTIST Quality Assessment

- Autoscaling Confidence Level (ACL)
  - Detect severe errors to disqualify such ionograms
- Uncertainty of autoscaled ionograms
  - Bounds for characteristics
  - Boundaries on Ne profile
  - Components of uncertainty:
    - Autoscaling errors: statistics of manual vs autoscaled
    - Profile inversion uncertainty: compare NHPC to POLAN, add difference to the uncertainty

# ARTIST 5 Confidence Score

- Determined automatically by inspecting both individual steps of interpretation process and its outcome for anomalies
- Confidence Score ranges from 0 to 100
- Starting score is 100
- Confidence score is lowered each time a quality criterion is violated
- If final score gets below 50, the scaling is flagged as low confidence
- **Do not use low-confidence autoscaled data for IRI validation/verification**
  - ARTIST Flag #10 in SAO and SAO.XML records

# Error vs Uncertainty

Error bars vs Uncertainty bounds

## ERROR BAR

- Error: difference between ARTIST value and the true value known from manual scaling
- Error histograms can be built and used to derive the error bars

## PRECISION

- Repeating value in multiple takes

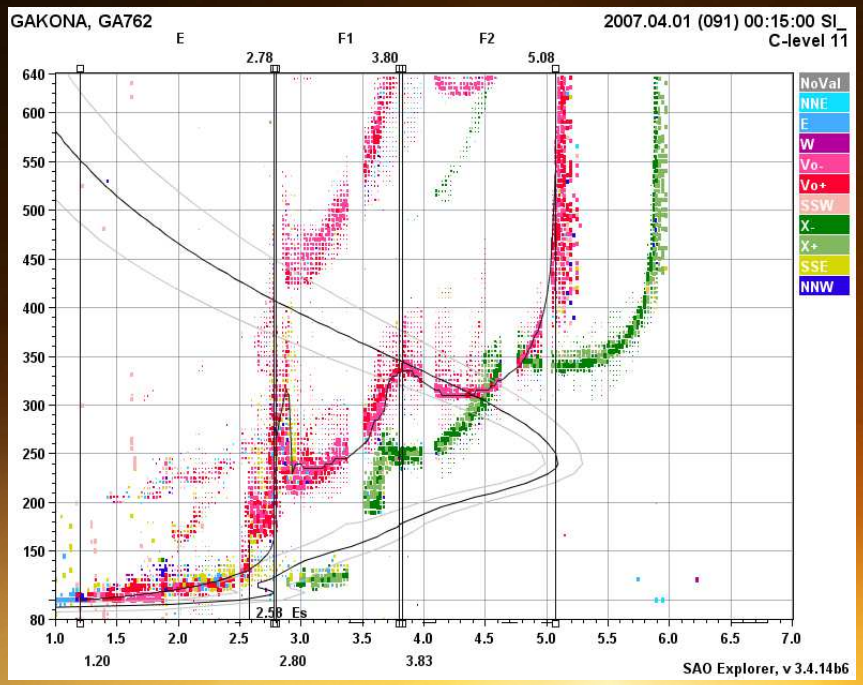
## UNCERTAINTY BOUNDS

- Uncertainty: expected difference between ARTIST value and unknown true value
- The error bar from previous statistical analysis is attributed to ARTIST value as uncertainty bound

Uncertainty: expected difference between ARTIST value and unknown true value
The error bar from previous statistical analysis is attributed to ARTIST value as uncertainty bound

# Error Bar → Uncertainty Bounds

- For example, foF2:
  - Manual vs. automatic comparison produces the ERROR BAR for foF2
  - Then, when ARTIST scales a new ionogram, foF2 value is attributed the UNCERTAINTY BAR

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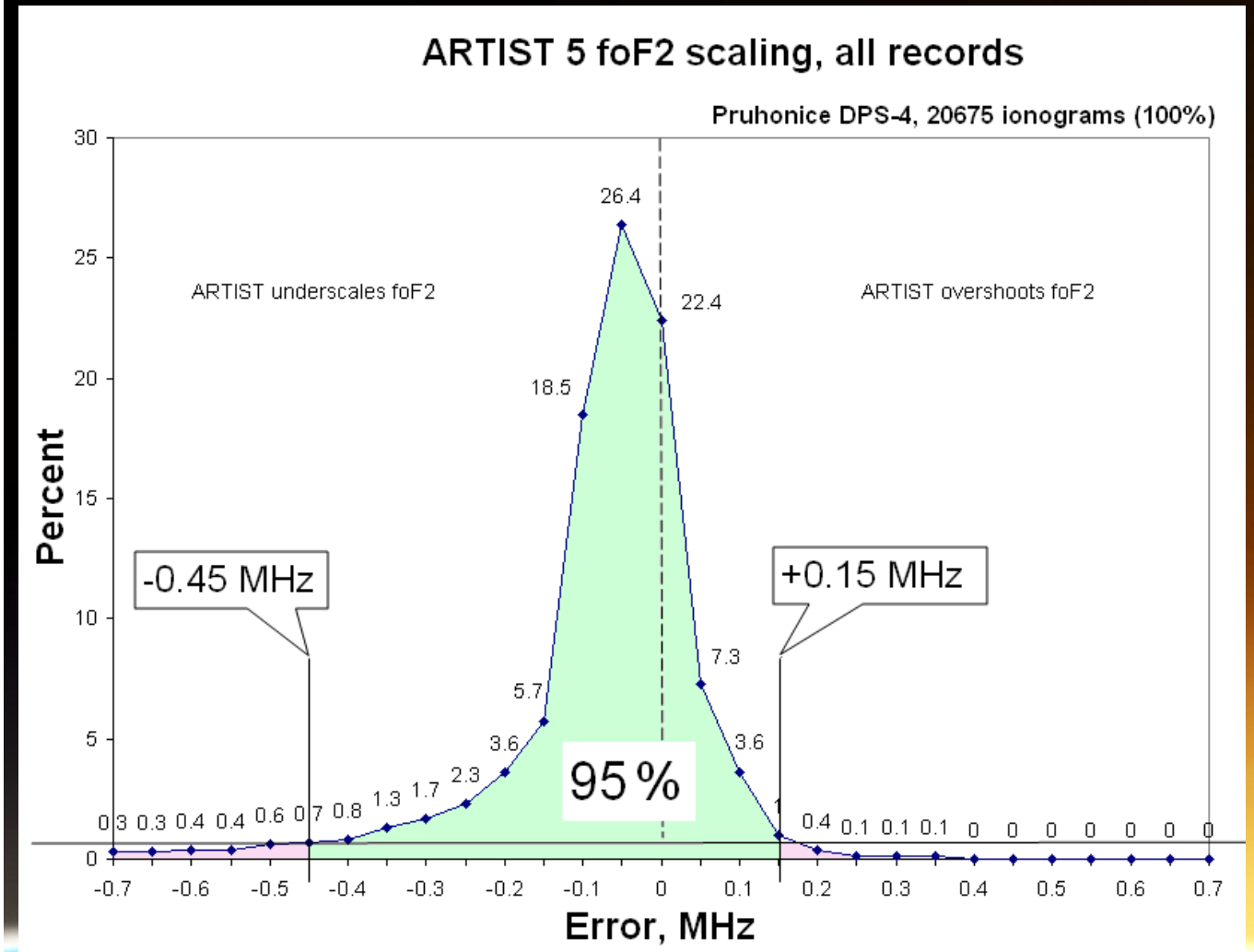


# ARTIST vs Manual foF2

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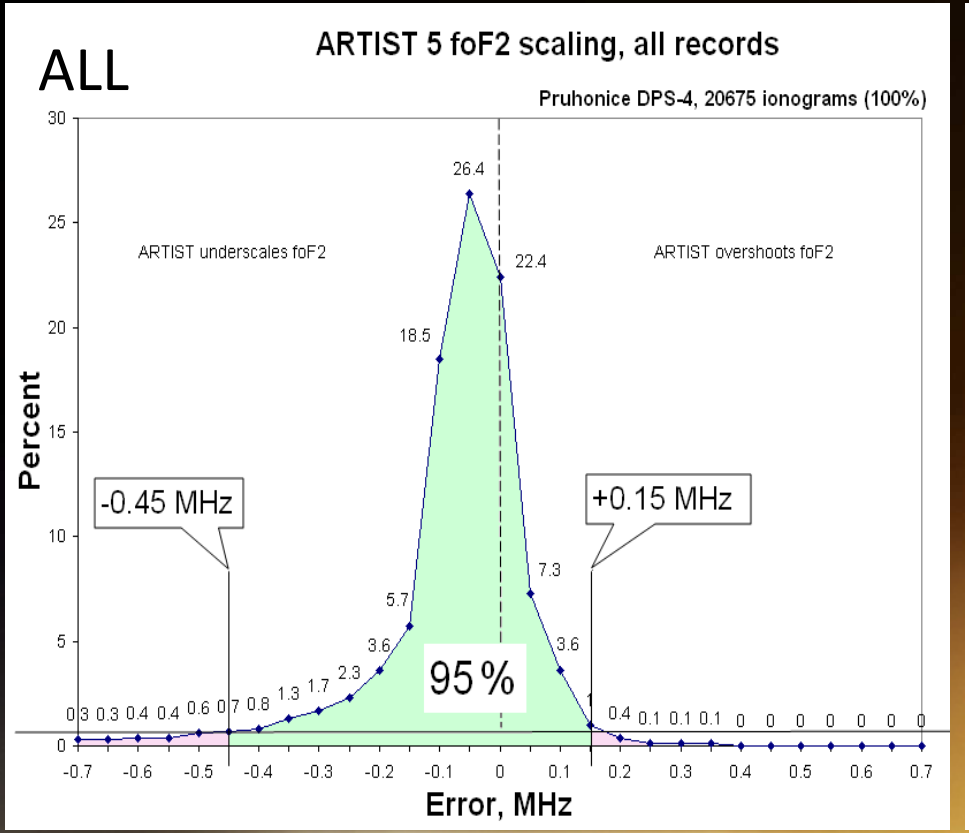
# Automatic Ionogram Classification

- Qualification is tailored to each digisonde station individually
- THREE CLASSES:
  - Quiet ionosphere (no spread)
  - Moderately disturbed ionosphere
  - Heavily disturbed ionosphere
- TWO SUB-CLASSES in each class based on Autoscaling Confidence Level (ACL)
  - Confidently scaled ionograms (ACL=1)
  - Not confidently scaled ionograms (ACL=0)
    - Only confident (ACL=1) records are sent to assimilation

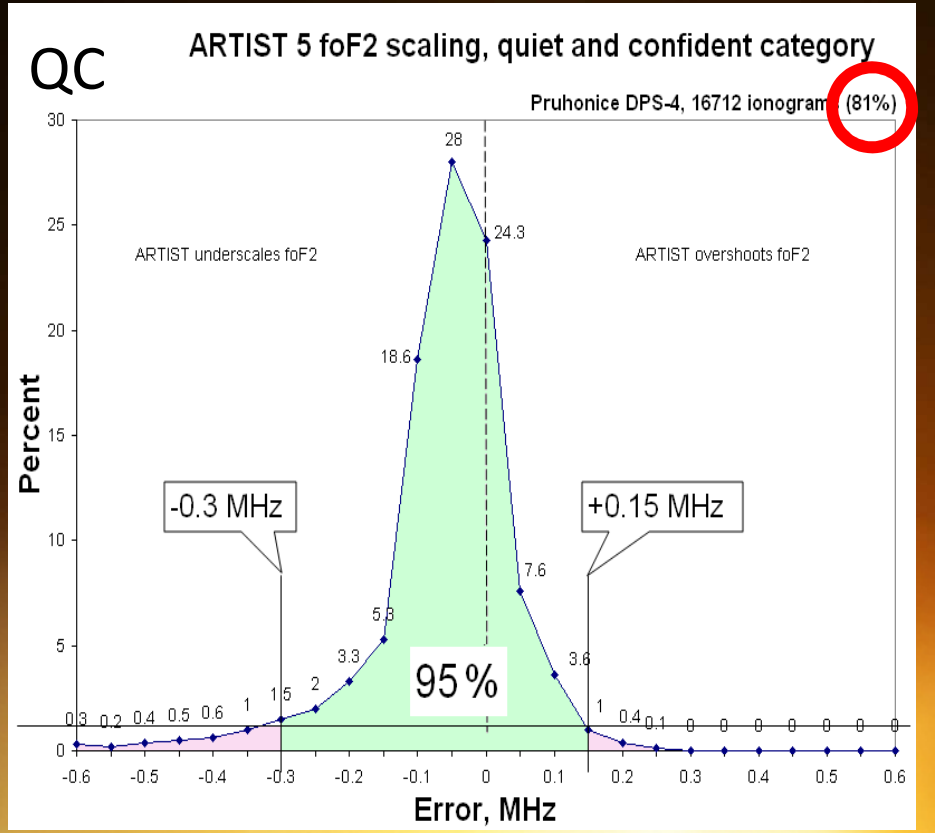
# Quiet-Confident Category

ALL




Lower bound = -0.45 MHz

QC




Lower bound = -0.3 MHz

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# Typical ARTIST-5 Error Bars

Digisonde 4D, mid-latitude station

| Para meter | % ionograms with perfect match to manual value | | | Error bounds encompassing 95% of all cases (2σ) High ARTIST confidence | | |
|---|---|---|---|---|---|---|
| | QC | MC | HC | Quiet (23%) | Moderate (41%) | Heavy (23%) |
| foF2 | 69% | 60% | 52% | -0.15 to +0.05 MHz | -0.25 to +0.25 MHz | -0.45 to +0.40 MHz |
| foF1 | 46% | 31% | - | -0.05 to +0.10 MHz | -0.1 to +0.1 MHz | insufficient statistics |
| foE | 40% | 20% | - | -0.30 to +0.05 MHz | -0.45 to +0.25 MHz | insufficient statistics |

# Future Work

- ARTIST 5.1
  - Baseline construction
  - E-F transition area
  - Clustering in spread F conditions
- ARTIST 6
  - Attention-driven techniques
    - Based on a model of expected traces
    - Fitting a joint set of O, X, and 2nd hop traces
  - Added contribution from a medium scale wave-like irregularity
  - Multi-scale analysis instead of Spread-F detector


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Gracias
Danke
Ευχαριστίες
THANK YOU
Obrigado
Köszönöm
Grazie
Спасибо
Dank
Tack
谢谢
Merci
ありがとう
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