ALPHA v2.0 Status: Application of Machine Learning Technology

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Methods/PSO Summary

Used a “Particle Swarm Optimization” to optimize membership functions and weights

- Stochastic, supervised machine learning algorithm
- Tests sets of parameters for performance and automatically adjusts them to get progressively better performance
- Objective way to choose ALPHA membership functions and weights
- Works in any number of dimensions

Motivation for Applying Machine Learning Technology

Tuning param files and running ALPHA in playback mode is time consuming

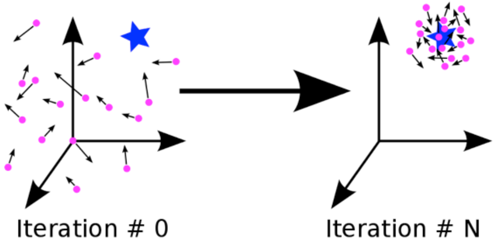
- No good way to objectively decide what to test
  - Lots of "eyeballing" histograms to come up with new membership functions
  - Best set of functions and weights might not be intuitive, so a human may never think to try them
- Functions and weights are not independent, so changing one often leads to a different optimal solution for another

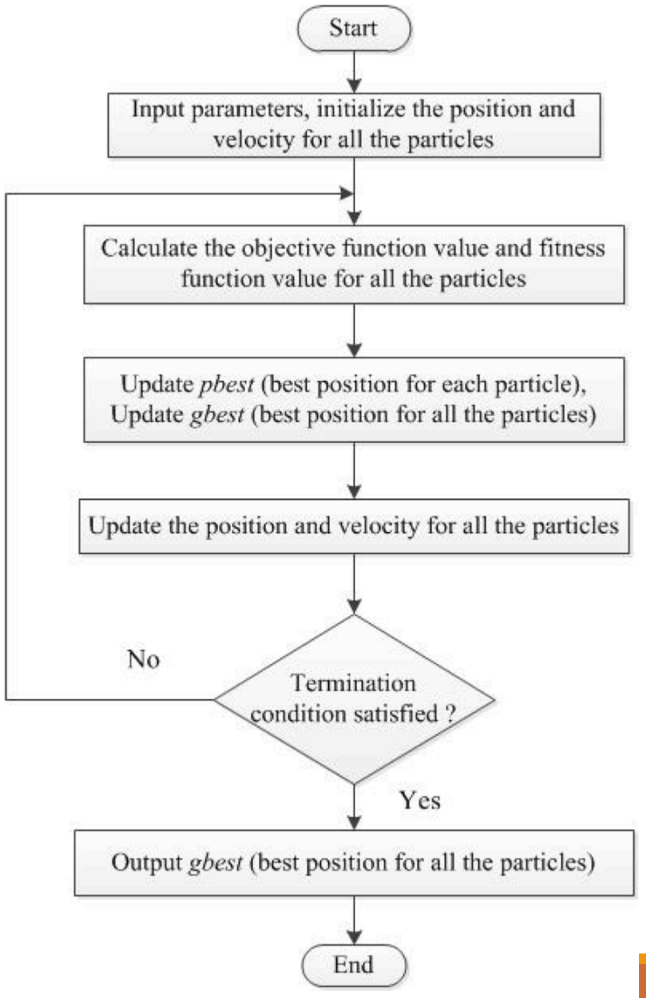
These obstacles lead to the development of a Particle Swarm Optimization (PSO)

- Automatically tunes the functions and weights
- Allows for all parameters to be adjusted together, rather than one at a time
  - Ideal since ALPHA parameters (membership functions and weights) are all interdependent

Particle Swarm Optimization (PSO)

- Supervised machine learning algorithm to find optima
- Easily to implement in any number of dimensions
- Each "particle" in the swarm "remembers" where it and its neighbors have been
  - The location of a particle represents a set of parameters by which we could compute HIWC interest
  - Particles move stochastically towards better solutions while searching the space around them
  - Eventually the particles converge on a local optimum
  - Running several times increases likelihood of finding the global optimum





PSO Implementation

3 degrees of freedom per input field
- Location of first inflection point
- Distance between inflection points (enforced to be positive)
- Weight (enforced to be positive and sum to 1)

Membership functions are piecewise linear with exactly 2 inflection points
- Sign of each membership function also determined by user

PSO can remove inputs by assigning zero weight, but cannot add new inputs

Radar, satellite, model, and temperature interests optimized separately
- Blended using weights from another PSO

Optimization Metrics Tested

The PSO algorithm needs to know how to score each location so that it can determine how the particles should move in each iteration. We tried several different metrics:

Correlation between IWC and interest

Histogram Error where we bin interest values, look at sum of squared difference from an “ideal” histogram where interest = fraction of MOG IWC measurements

Fraction of Correct assignments using a 0.5 IWC and 0.5 interest thresholds

Sum of PoDno and PoDyes using 0.5 IWC and 0.5 interest thresholds

Products developed to try to balance two or more of the other metrics at once

- (1 – correlation)*(histogram error)*(fraction of wrong assignments)
- (1 – correlation)*(histogram error)*(2 – PoDyes - PoDno)

Choice of Metric

We decided that the **correlation** between IWC and interest was the preferred metric

- Utilized the most information
  - No need to bin or categorize the IWC or the interest
  - All of the other metrics relied on defining bins or thresholds for IWC and/or interest, so some information is lost in the process of doing this
  - Many other metrics put a lot of weight on just a handful of inputs
- Can still look at histogram shape and PoD statistics after running PSO for further verification

ALPHA 2.0 Summary

All membership functions and weights adjusted based on “training” with IWC data from IKP2

Satellite Interest

- Incorporate two new brightness temperature difference fields
- Replace total water path with optical depth

Radar Interest

- Remove 30 dbz height
- Add new VAHIRR field (volume averaged height integrated radar reflectivity)

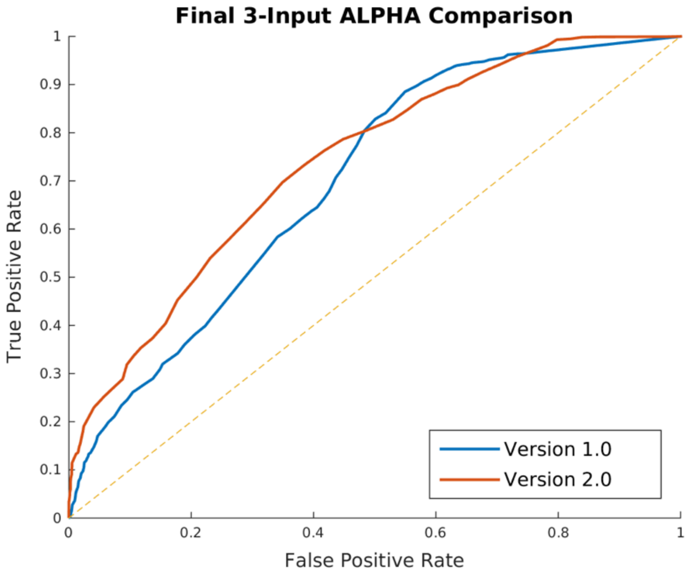
Model Interest

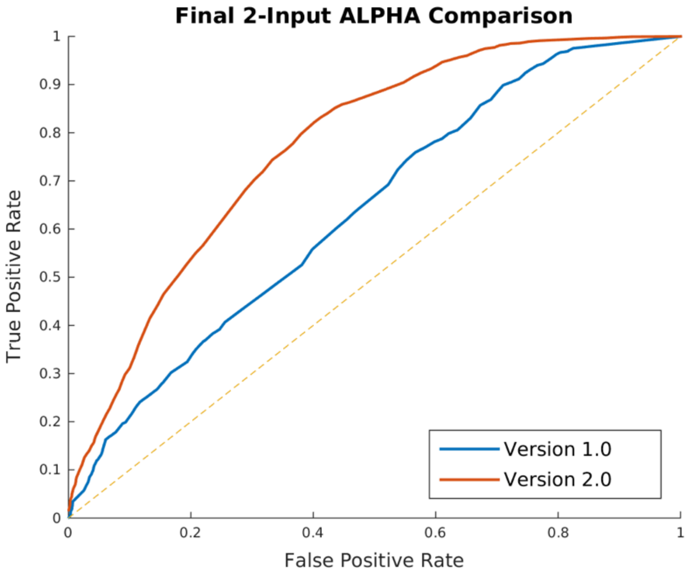
- Remove total water path and precipitation
- Add surface wind curl and divergence
- Only permitted to increase final interest

Temperature Interest

- Include warmer temperatures

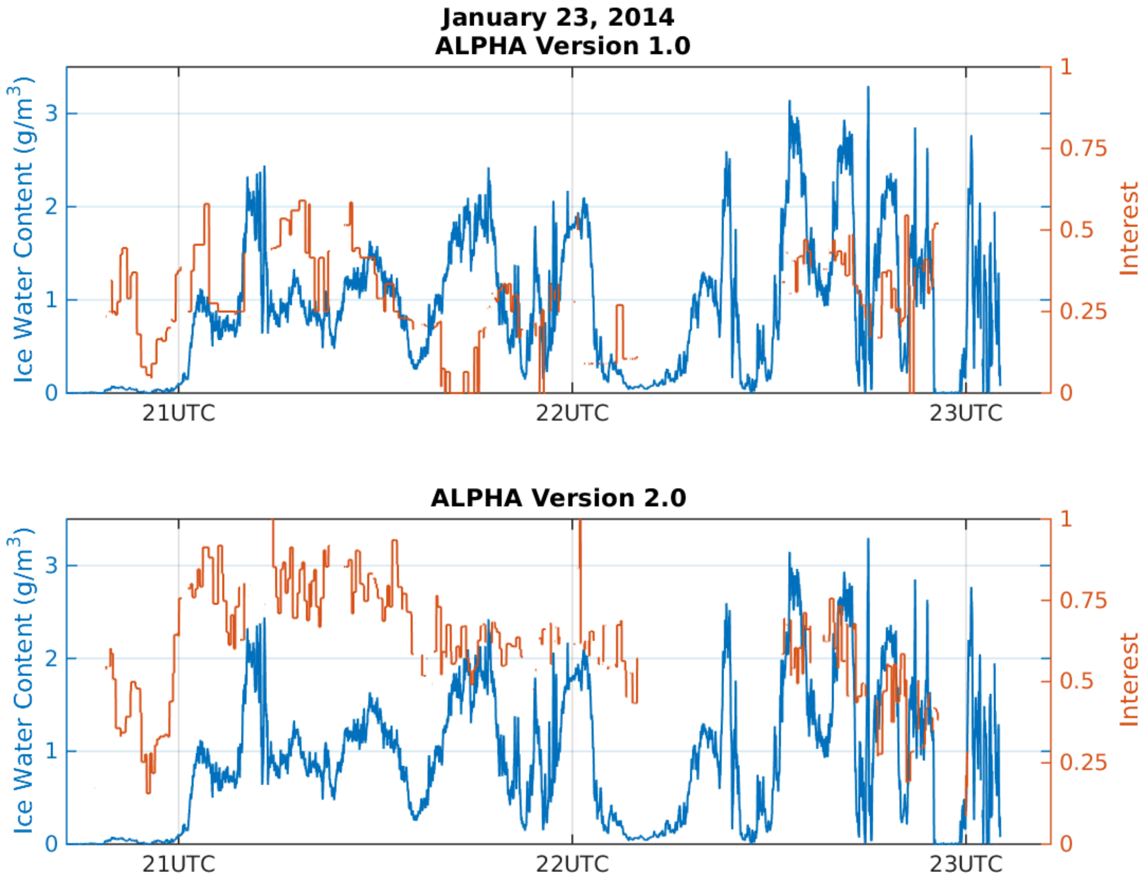
Performance Comparison



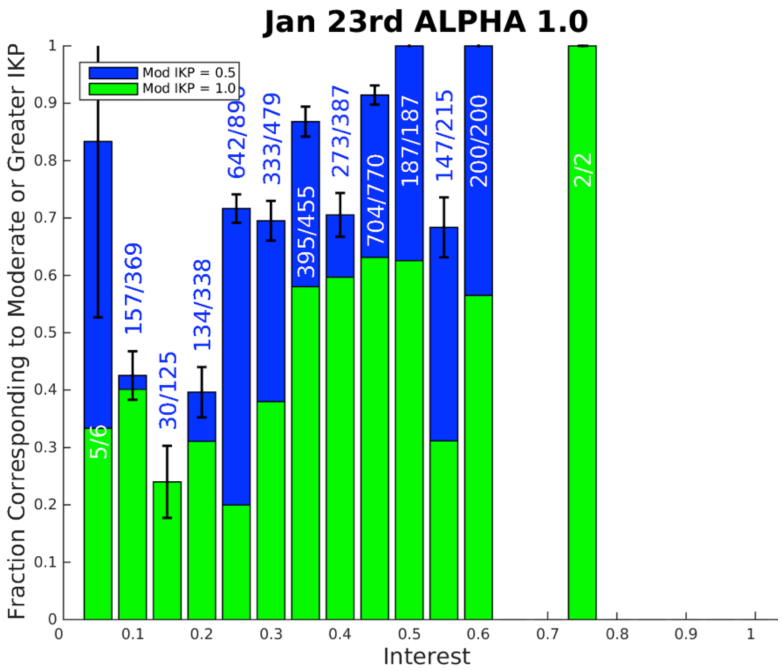


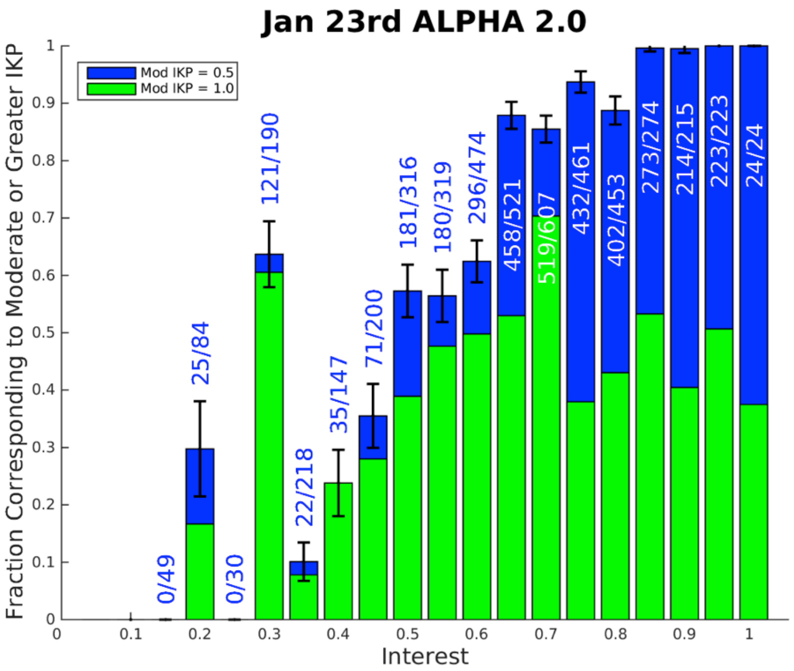
These ROC curves are created by setting a constant HIWC threshold of 0.5 g/m^3 and letting the HIWC interest threshold vary between 0 and 1

Note: The 3-Input interest has a much smaller sample size than the 2-Input. If we only consider point where both interests are available, the 3-Input performs better than the 2-Input interest.


January 23, 2014
ALPHA Version 1.0
Ice Water Content (g/m^3)
Interest
0
1
2
3
0
0.25
0.5
0.75
1
21UTC
22UTC
23UTC
ALPHA Version 2.0
Ice Water Content (g/m^3)
Interest
0
1
2
3
0
0.25
0.5
0.75
1
21UTC
22UTC
23UTC

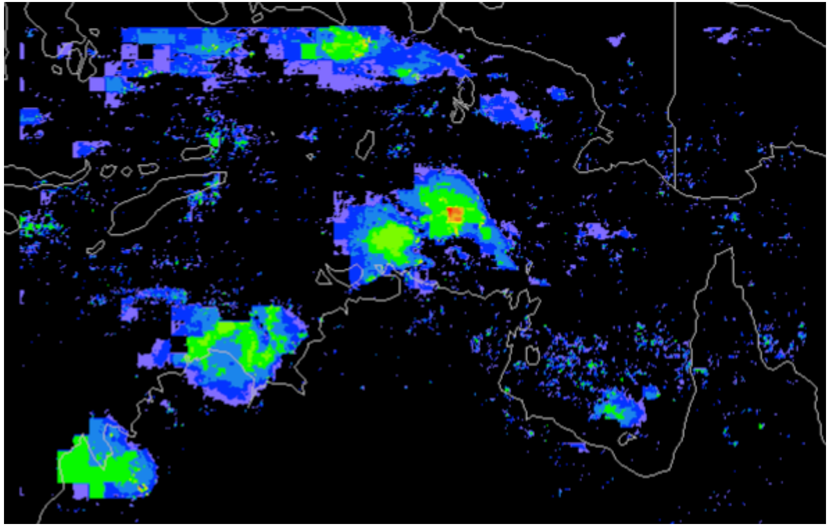
Case Study: Jan 23rd Darwin Flight



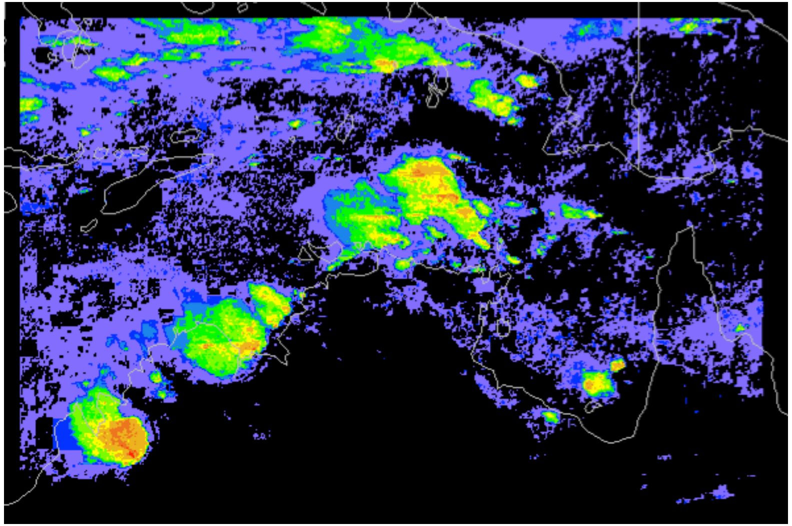


Case Study: Jan 23rd 2015, 22:45 UTC

ALPHA 1.0



ALPHA 2.0



Additional Slides

ALPHA 2.0: Temperature Interest

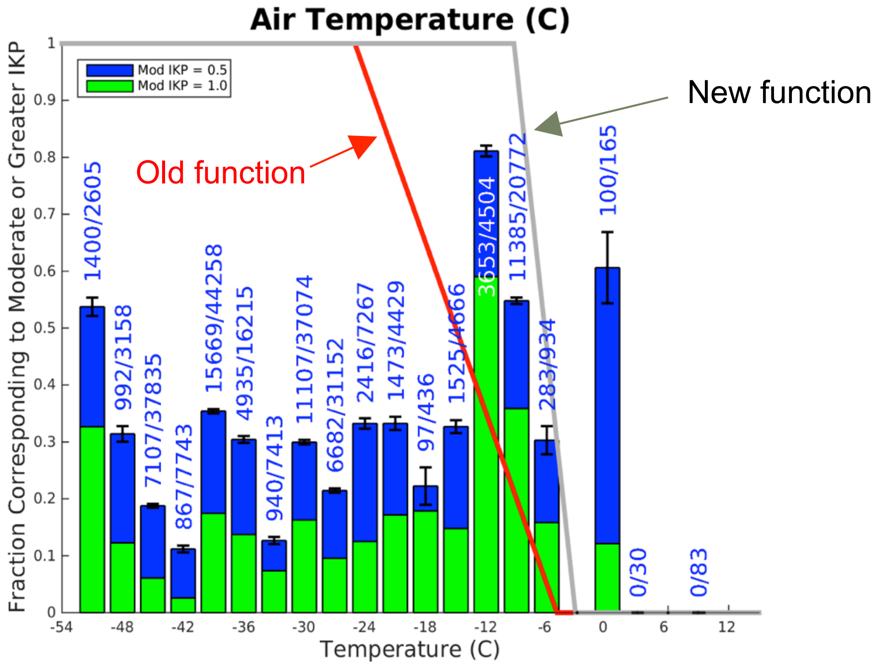
The blended interest is multiplied by the temperature interest to mask out areas too warm for HIWC

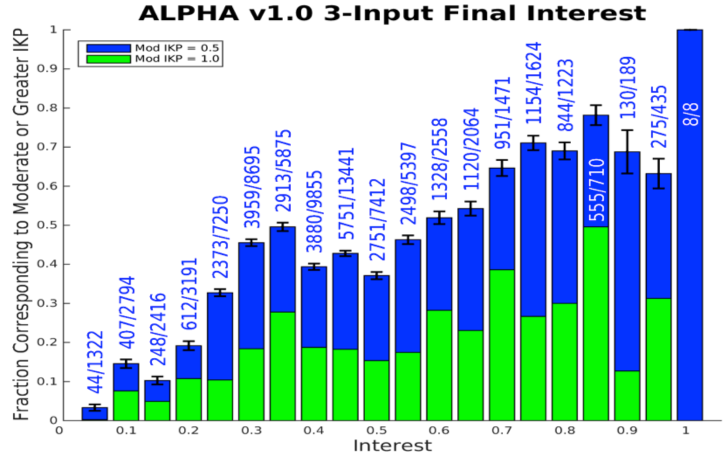
PSO runs resulted in a membership function that includes warmer temperatures

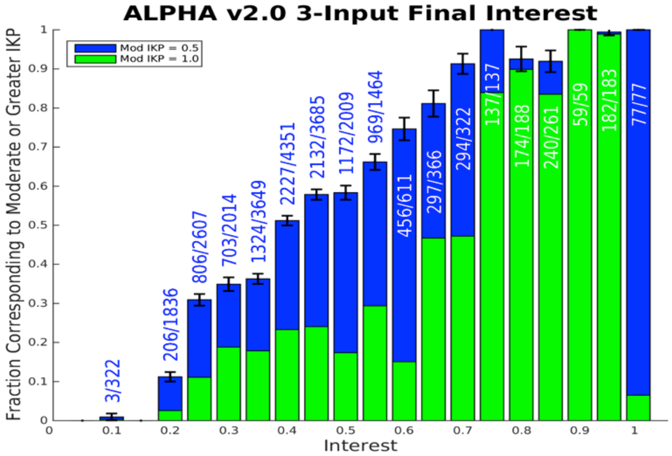
Big improvement in final ALPHA performance between old and new membership functions

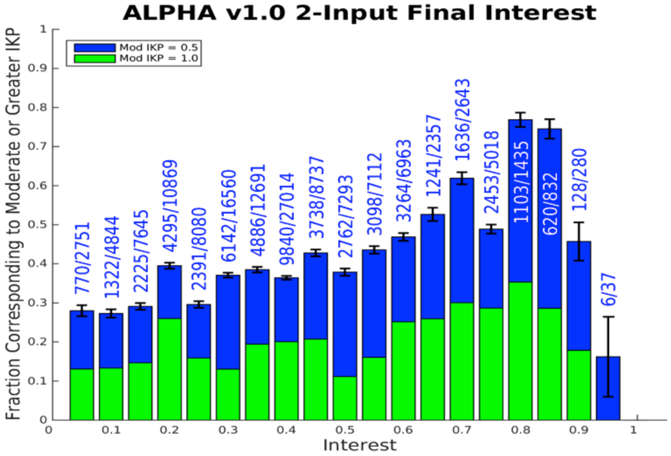
Little difference in performance between new algorithm and using no temperature masking

- Sampling bias
- Likely prevents over-forecasting in above freezing temperatures




ALPHA v1.0 3-Input Final Interest
Mod IKP = 0.5
Mod IKP = 1.0
Fraction Corresponding to Moderate or Greater IKP
Interest
44/1322
407/2794
248/2416
612/3191
2373/7250
3959/8695
2913/5875
3880/9855
5751/13441
2751/7412
2498/5397
1328/2558
1120/2064
951/1471
1154/1624
844/1223
555/710
130/189
275/435
8/8


ALPHA v2.0 3-Input Final Interest
Mod IKP = 0.5
Mod IKP = 1.0
Fraction Corresponding to Moderate or Greater IKP
Interest
3/322
206/1836
806/2607
703/2014
1324/3649
2227/4351
2132/3685
1172/2009
969/1464
456/611
297/366
294/322
137/137
174/188
240/261
59/59
182/183
77/77


ALPHA v1.0 2-Input Final Interest
Mod IKP = 0.5
Mod IKP = 1.0
Fraction Corresponding to Moderate or Greater IKP
Interest
770/2751
1322/4844
2225/7645
4295/10869
2391/8080
6142/16560
4886/12691
9840/27014
3738/8737
2762/7293
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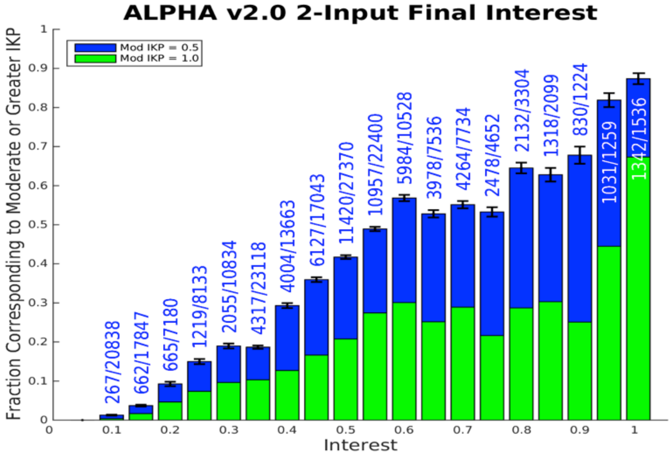
620/832
128/280
6/37


ALPHA v2.0 2-Input Final Interest
Mod IKP = 0.5
Mod IKP = 1.0
Fraction Corresponding to Moderate or Greater IKP
Interest
267/20838
662/17847
665/7180
1219/8133
2055/10834
4317/23118
4004/13663
6127/17043
11420/27370
10957/22400
5984/10528
3978/7536
4264/7734
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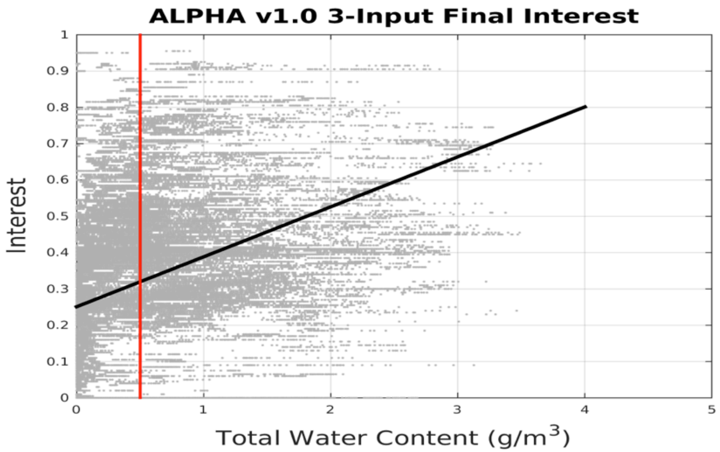
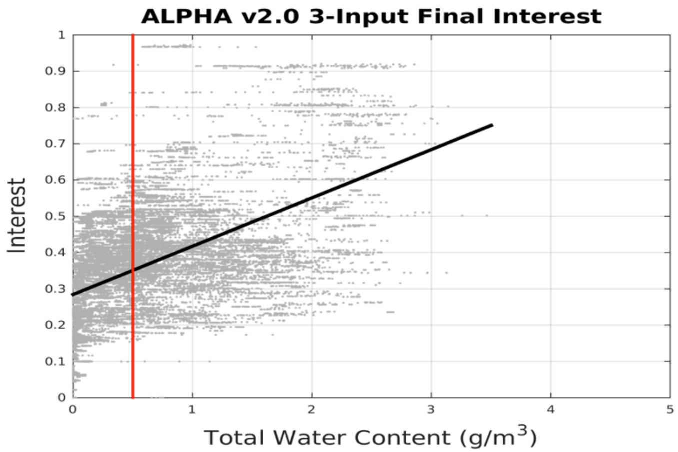
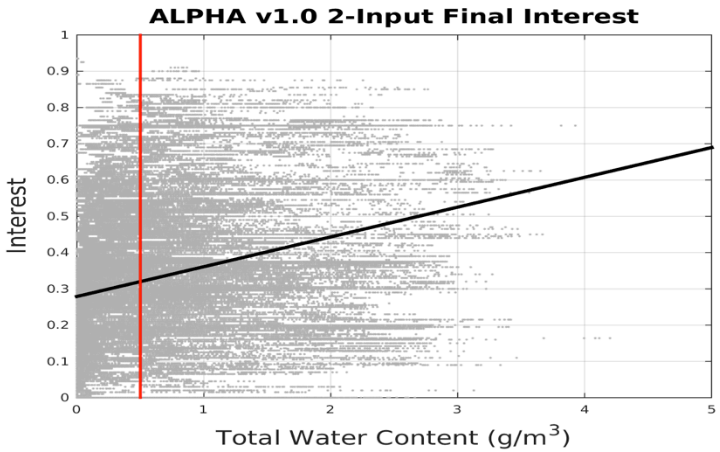
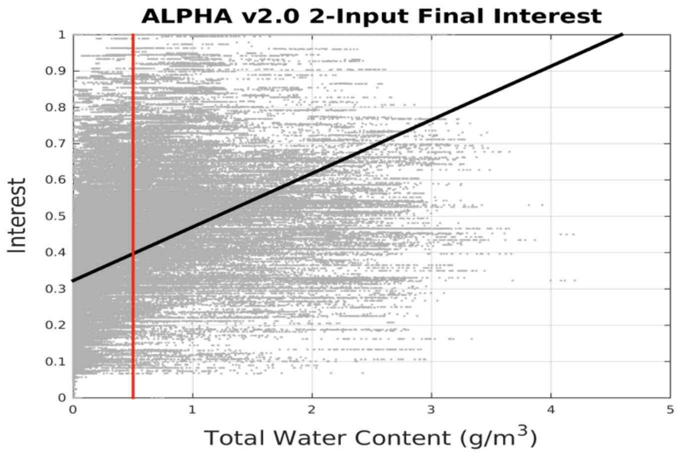
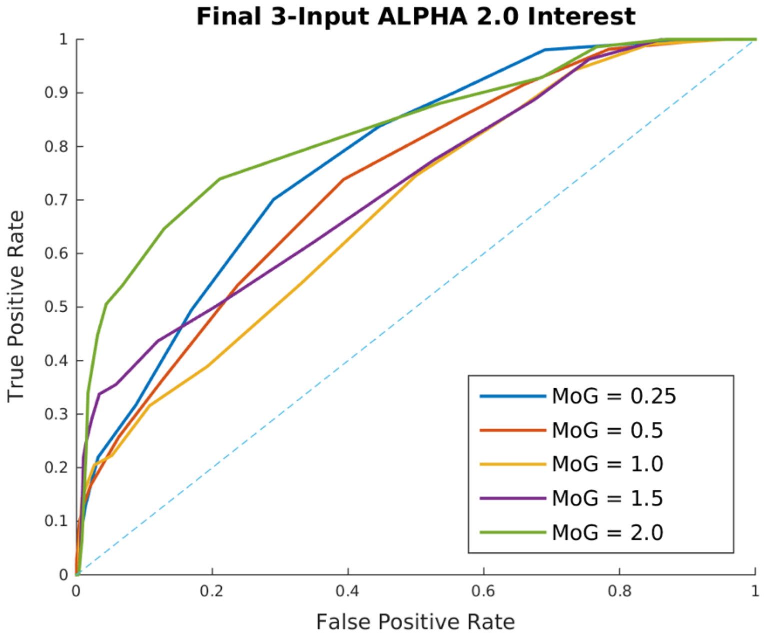
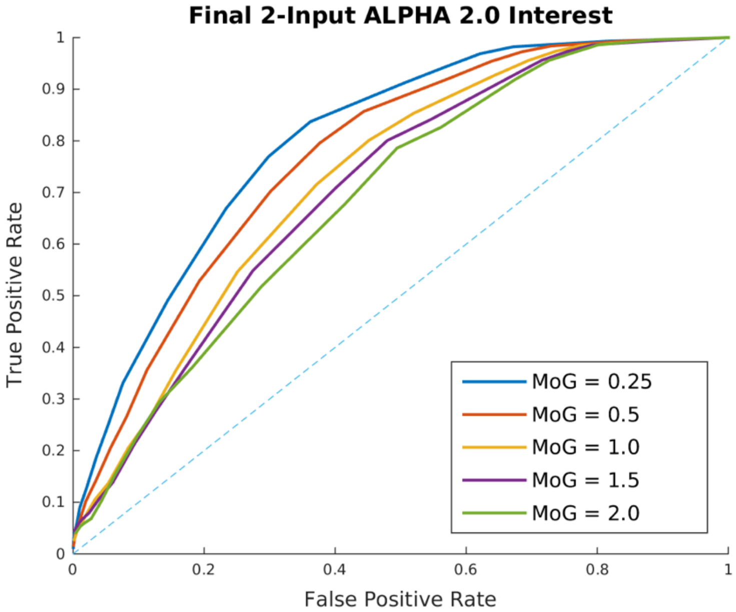
1031/1259
1342/1536


ALPHA v1.0 3-Input Final Interest
Interest
Total Water Content (g/m3)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
1
2
3
4
5

ALPHA v2.0 3-Input Final Interest
Interest
Total Water Content (g/m3)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
1
2
3
4
5

ALPHA v1.0 2-Input Final Interest
Interest
Total Water Content (g/m3)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
1
2
3
4
5

ALPHA v2.0 2-Input Final Interest
Interest
Total Water Content (g/m3)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
1
2
3
4
5

V2.0 Performance by IWC Threshold

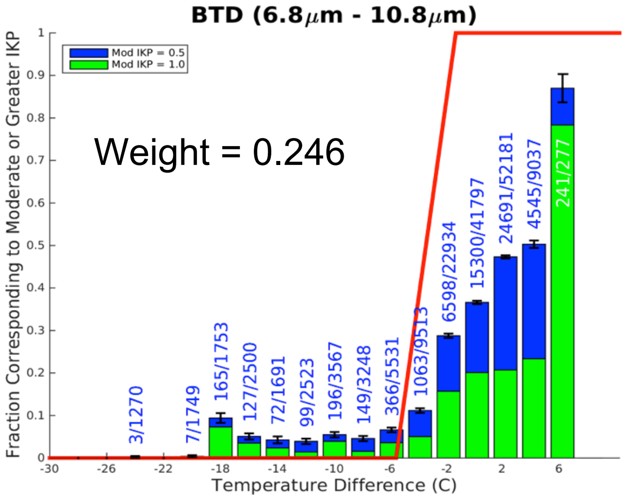


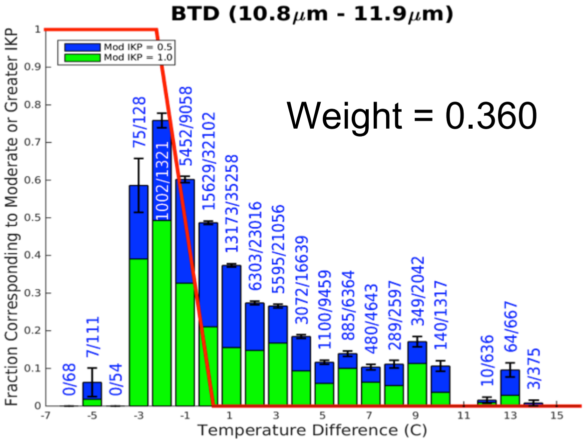


Remember sample size for 3-Input Interest is much smaller than for the 2-Input

Brightness Temperature Differences

- Assigned high weight in ALPHA 2.0 satellite interests
  - Over 60% combined
- Water vapor minus infrared (right)
  - Indicates moist stratosphere
  - Associated with overshooting tops
- Two different infrared channels (below)





Schmetz, J., S. A. Tjemkes, M. Gube, and L. Van De Berg. "Monitoring Deep Convection and Convective Overshooting with Meteosat." *Adv. Space Res.* 19.3 (1997): 433-441.

Next Steps with ALPHA v2.0

- Continue with comparison of ALPHA product with IKP2 IWC measurements from HIWC-Florida experiment
  - Independent assessment
- Update ALPHA-CONUS real-time product with ALPHA v2.0; implement a version in Australia
- Use ALPHA v2.0 to characterize horizontal variation and time duration of HIWC features in ALPHA products
- Airborne cloud radar (RASTA) IWC retrievals for comparison with ALPHA vertical variation
- Advection of HIWC features using TITAN (Thunderstorm Identification Tracking and Nowcasting)