Flight Icing Threat Derived From Satellite Data

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Flight Icing Threat Inferred from Satellite

In-flight Aircraft Icing depends on

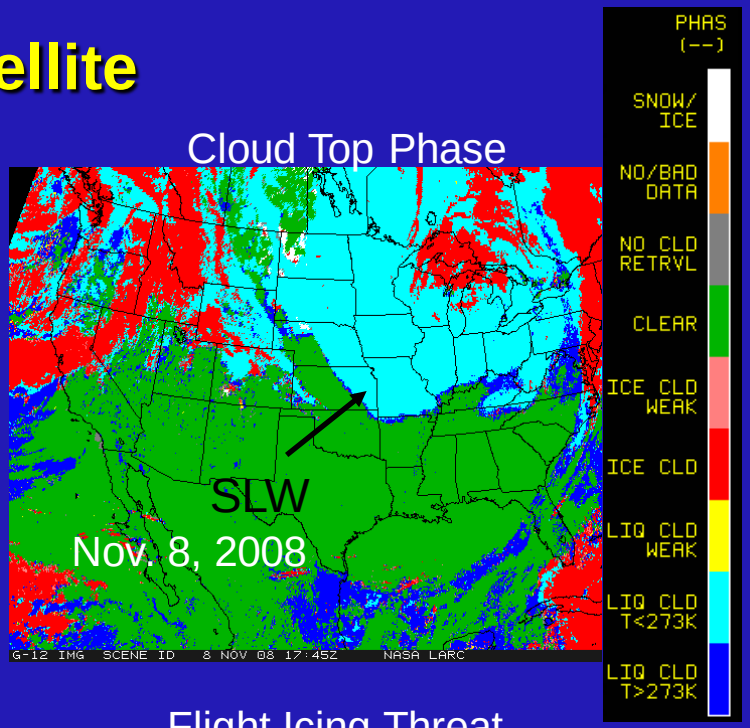
- presence of super-cooled liquid water (*SLW*)
- liquid water content, *LWC*
- Droplet size distribution, N(r)
- Temperature, T(z)

Satellite remote sensing can provide

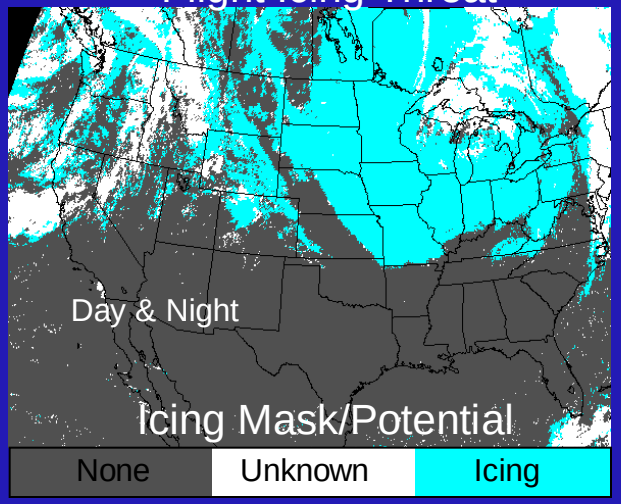
- Cloud top temperature and phase: SLW
- liquid water path: *LWP* = f(*LWC*)
- effective radius, r_e = f(*N(r)*)

- assumes satellite-derived cloud parameters are correlated with the parameters that determine icing (namely, LWP proxy for LWC; R_e proxy for N(r) at some level in the cloud)

Cloud Top Phase



Flight Icing Threat



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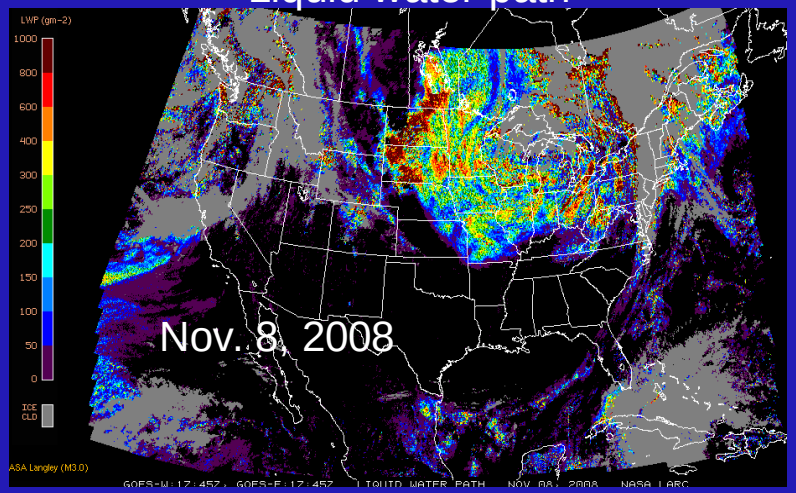
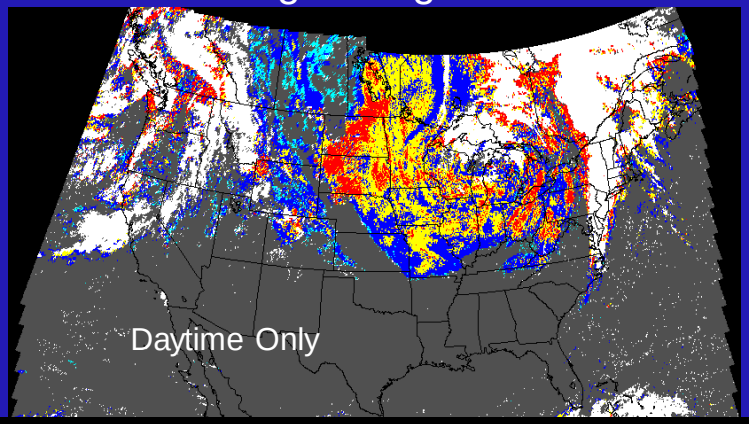
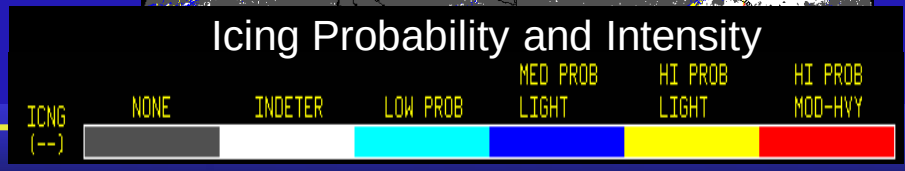
Liquid water path



Flight Icing Threat





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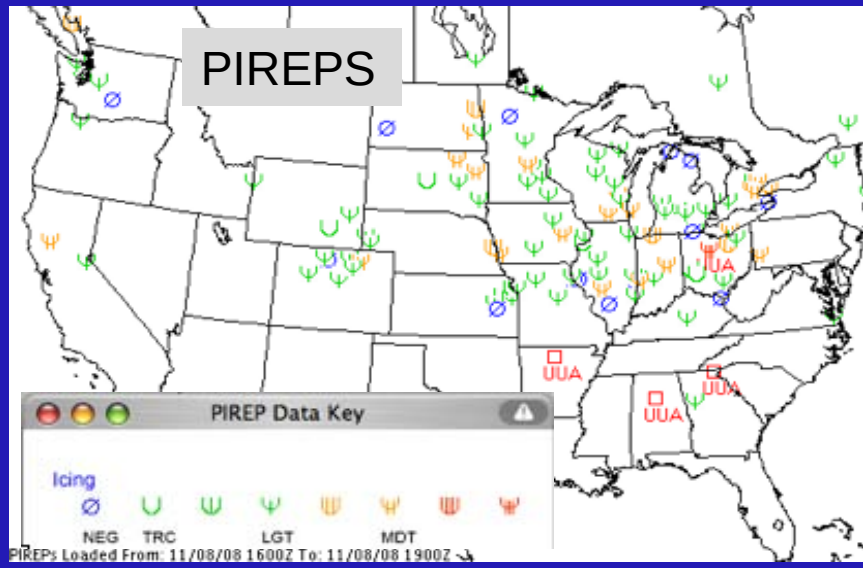

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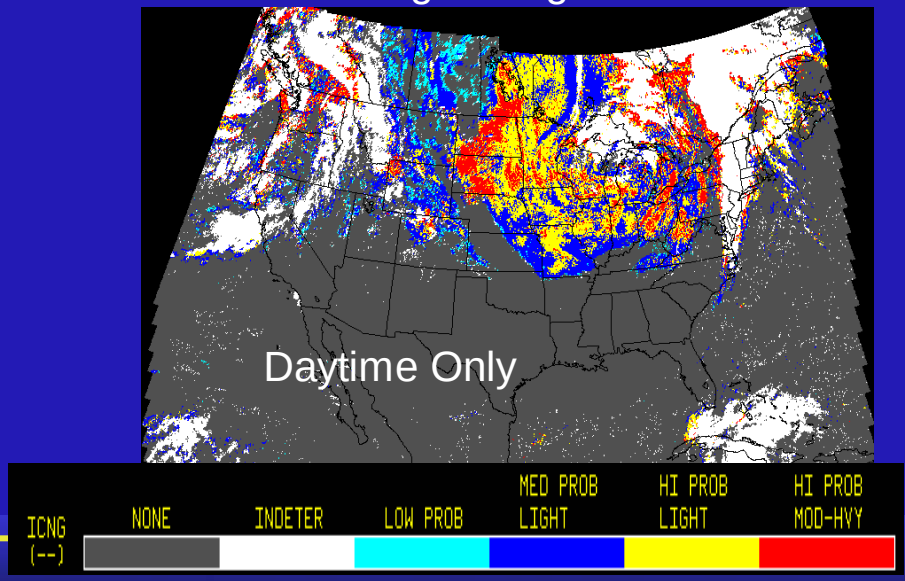


Validating with PIREPS, Winter 2006/07, 2007/08

- Excellent detection of icing conditions
- False reports common, but small % of total
  - 'No Icing' not reported often
  - Icing depends on A/C

Probability of Detecting Icing

		PIREPS Y	PIREPS N
Satellite	Y	3703	328
	N	273	151

PODy = 93% PODn = 32% Skill = 87%

- Classification of severity has skill but not as much as IP
- Icing severity often subjective & depends on A/C

Probability of Detecting Light/Moderate Icing

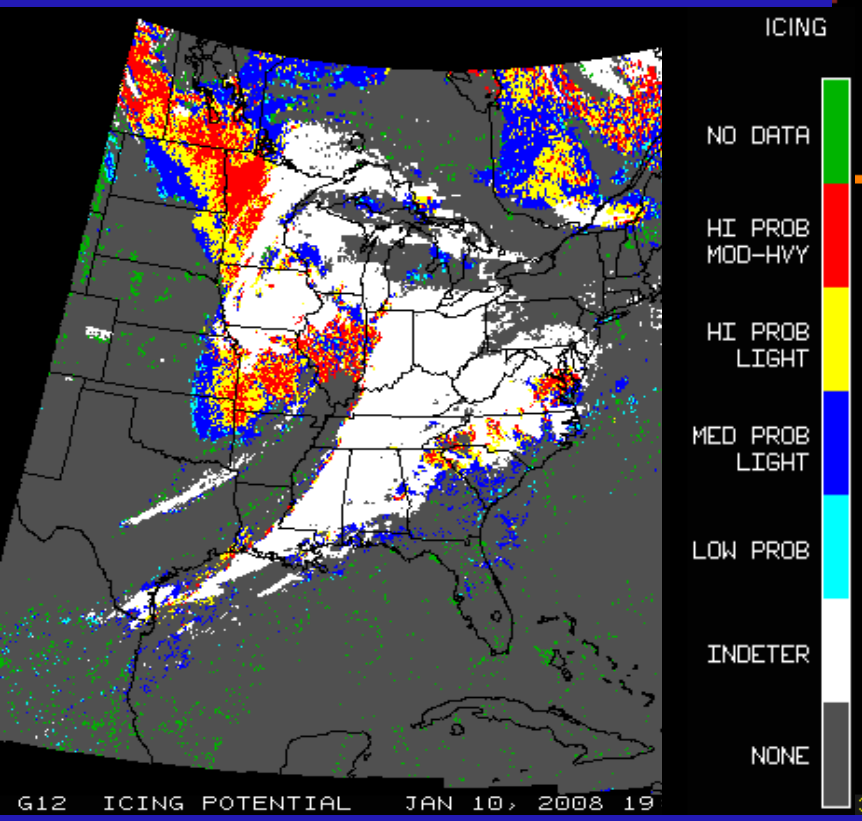
		PIREPS L	PIREPS M
Satellite	L	1279	487
	M	1157	780

POD(light) = 53% POD(mdt) = 62%

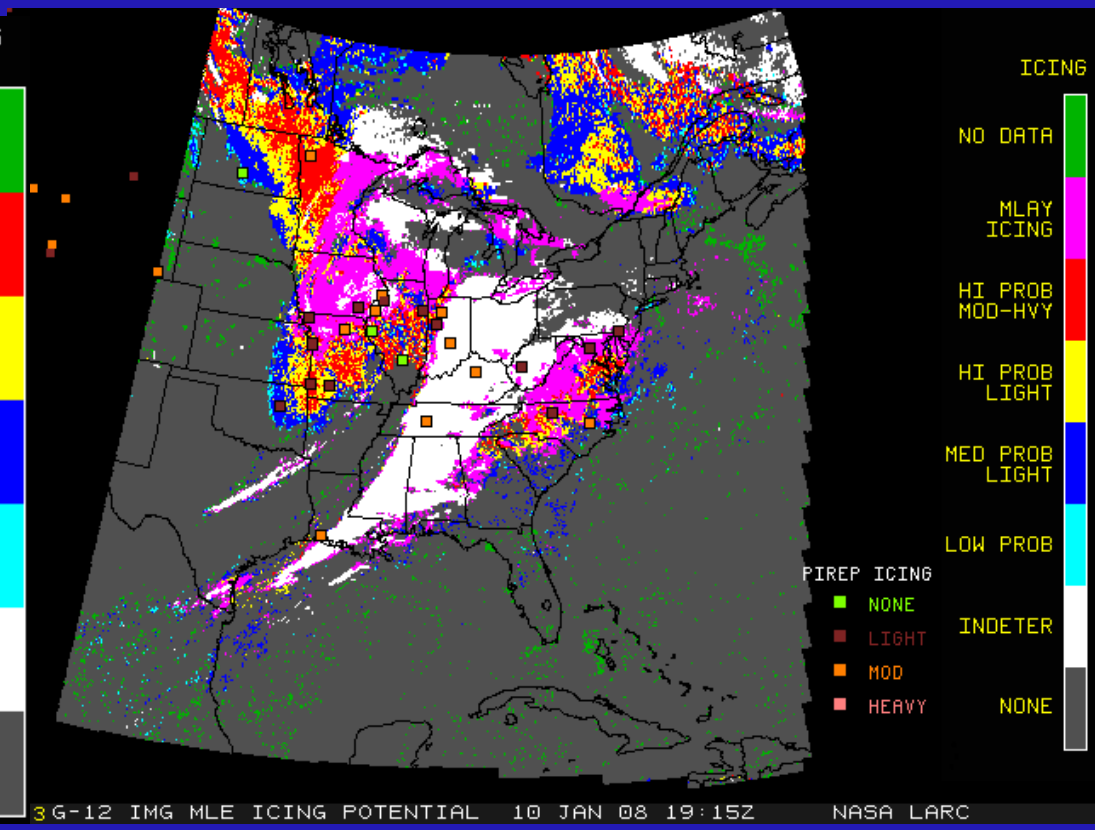
Reducing Indeterminate Cases with Multilayer Algorithm

1915 UTC 10 Jan 2008

Standard SL Results



With ML Results



Multilayer retrievals pick up additional areas with icing that were formerly indeterminate … some areas remain undetected

Summary of PIREPS Comparisons

GOES-12, Oct 20 - Nov 11, 2008, hourly images from 15-19 UTC

ICING-Non ML ICING-ML enhanced PIREP PIREP

S	YES	NO	S	YES	NO
A YES	738	34	A YES	817	41
T NO	96	12	T NO	100	11

pody=yy/(yy+ny)=PODy=**88.5%** PODy = **89.1%**

podn=nn/(yn+nn)=PODn=**26.1%** PODn = **21.1%**

Ntot=969 Ntot=880

Indeterminate GOES icing excluded

- Identifies icing ~ 90% of the time
- Multilayer method as accurate as single-layer technique

Current Flight Icing Threat Algorithm (Satellite)

- **Features**
  - » Algorithm utilizes satellite-derived cloud macro-physical parameters
  - » FIT derived at full spatial and temporal resolution of the satellite

- **Advantages**
  - » Efficient
  - » Partially based on Icing PIREPS (Large database over CONUS)
  - » Top and Base altitude of the icing layer is determined (RMS < 1 km for low clouds)
  - » Provides information on icing intensity
  - » Improvement potential

- **Disadvantages**
  - » Partially based on Icing PIREPS (reporting errors, inherently biased, subjective)
  - » Difficult to calibrate (FIT depends on airframe/flight characteristics)
  - » Lack of vertical resolution
  - » Indeterminate when high thick clouds obscure view
  - » No temperature dependence
  - » based on total LWP not SLWP
  - » No info on mixed phase (ice crystals below SLW tops)

NASA Icing Remote Sensing System (NIRSS)

(Reehorst et al. 2009)

LWP and Cloud Boundaries

Ground-based Sensors at NASA GRC

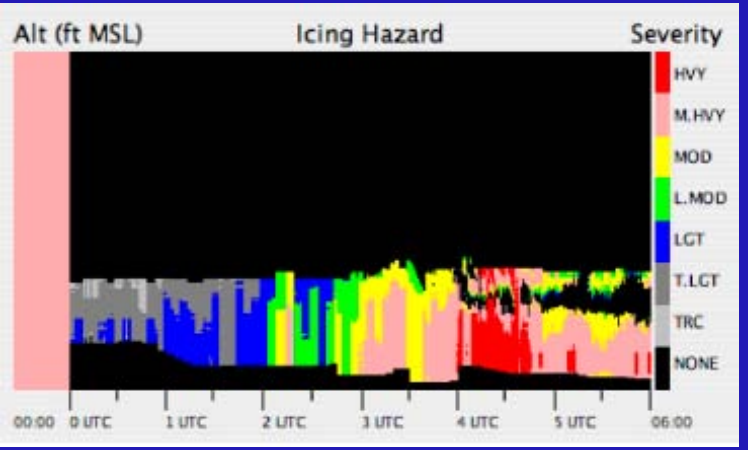
Assumed LWC Profiles to distribute LWP

Typical Profile	Liquid Cld	Mixed Cld
Uniform	0.1	0.15
Wedge	0.3	0.25
Temp	0.1	0.5
REFL	0.5	0.1

Convert LWC to Intensity

LWC (gm^{-3})	Icing severity
<0.01	No icing
0.01 to 0.017	Trace
0.017 to 0.03	Trace-light
0.031 to 0.066	Light
0.067 to 0.012	Light-moderate
0.02 to 0.2	Moderate
0.20 to 0.37	Moderate-heavy
>0.37	Heavy

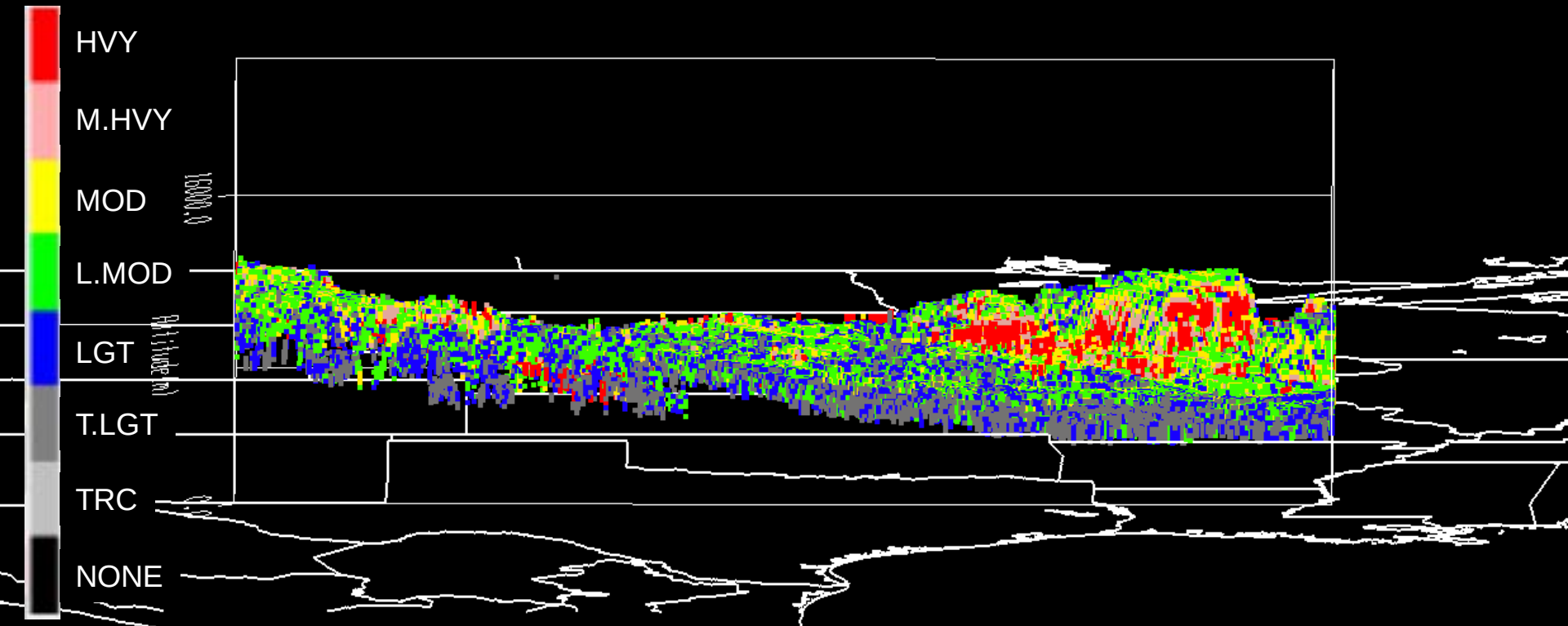
Icing intensity profiles



NIRSS should be valuable for improving the satellite technique

Similar approach can be taken for Satellite LWP, T_{cld}, Z_{top}, Z_{base} using NIRSS, DOE ARM, CloudSat LWC(Z) shapes

Preliminary 4-D Icing Intensity from GOES-12
Jan. 8, 2008 (15 – 20 UTC)



Uses CloudSat LWC(Z) Climo for SLW clouds

Summary and Conclusions

- Satellite data are valuable on their own for Icing diagnoses
  - can detect icing conditions ~90% of the time during the day
  - icing cloud boundaries to within ± 1 km
  - method is the prototype algorithm for GOES-R
  - new approach being developed using data from ARM, NIRSS, and CloudSat

- Can be used/assimilated into other nowcasting/forecasting systems
  - NCAR CIP/FIP
  - NOAA GSD Assimilation and Modeling System