Weather Observation Improvements: Value and Challenges of Automating the Reporting of Three Precipitation Types and Intensities in ASOS

Victor Passetti
William J. Hughes Technical Center
Weather Engineering & Evaluation Branch (ANG-C63)
FAA Aviation Weather Division, NextGen Office
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Introduction

The Weather Observation Improvements (WOI) program examined whether industry has the sensor technology that can enable ASOS to discriminate and report the occurrence of ice pellets and drizzle.

- There are many aspects to this challenge. Today will focus on automated reporting of three precipitation types and intensities, and hopefully the start of a productive collaboration.

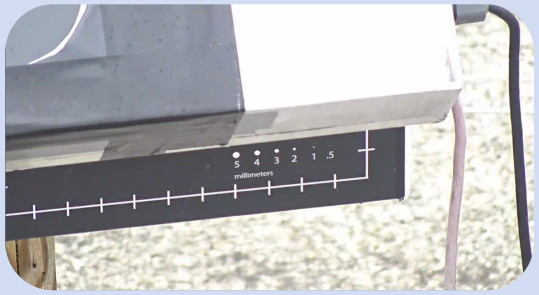
- Cost-effective, repeatable ground-truthing was our most important tool for understanding industry capabilities and putting “real weather” behind the search for optimized requirements. The approach is its own topic and we are happy to have an in-depth discussion at an appropriate time. For a self-introduction to WOI ground truth procedures see:

    - URL: https://ral.ucar.edu/solutions/products/identifying-precipitation-types-and-intensity-changes

The Automation of Weather Observing is Challenging!!!!

Sensing

Manual



Automated

Regulatory

- International Standards
- Federal Requirements
- Procurement Requirements
- System Requirements
- Data Formats

Mission Needs

It is especially challenging when multiple architectures (ASOS/AWOS) are in service!

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Motivation

WOI's recent work is based on the documented needs of the aircraft deicing and anti-icing programs.

Challenge:

WOI found many requirement traceability discontinuities exist between:

- Sensor performance requirements for use in procurement testing of a sensor, and
- The resultant operational capability of the AWOS/ASOS, whose requirements are represented in the FMH-1 and FAA Order 7900, and should trace to ICAO either directly or via exception.

User needs are fulfilled from system requirements, not individual sensor requirements.

- In the future, flexible architectures may allow users sensor-level access.

Sample Sensor Requirement Challenges

Question	Considerations
Precipitation Type	
What is the format of the sensor message?	• Does the format allow for specificity of detection and intensity. • Can the format support legacy operations?

How long of a retrospective window is used for determining the content of the sensor message?	• Tradeoff:
	  ○ Stable output
	  ○ Latency in reporting changing precipitation type

Does the sensor report based on priority or dominance?	
Precipitation Intensity	
How is the precipitation intensity determined for each type of precipitation (e.g., by visibility, rate-of-fall, PWS-measurement)?	• Visibility is also reduced by obscurations • Inability to discern fall rate by precipitation type during mixed conditions • PWS-measured intensities not validated • Pass/fail for intensity at sensor level?
Are separate intensities determined for each type, or just the intensity for the most dominant?	• Technical limitation at sensor level restricted to fall rate
What time window should be used for determining intensity(ies)?	• Arbitration of rapidly varying intensity in changing precipitation • Latency in reporting changing intensity
How should sparse (i.e., very light) intensity be reported? What thresholds should delineate sparse precipitation?	• Operational impact of sparse precipitation vs sensor performance value

Sample ASOS (System) Design Challenges

Question	Considerations
Precipitation Type	
What is the optimal way to use sub-minute samples from the PWS to assess a one-minute seed value of the observed precipitation type(s)?	• Intermittent reporting of a precipitation due to the finite sensing volume • Precipitation variability

How long of a retrospective sliding window should be used for determining the one-minute observation of the precipitation type(s)?	• Tradeoff:
	  ○ Stable output
	  ○ Latency in reporting changing precipitation type

How many one-minute seed values of an individual type are sufficient for that type to be included in the one-minute observation over a sliding window?	
Precipitation Intensity	
How is the precipitation intensity determined for each type of precipitation (e.g., by visibility, rate-of-fall, PWS-measurement)?	• Visibility is also reduced by obscurations • Inability to discern rate-of-fall by precipitation type during mixed conditions • PWS-measured intensities not validated
Are separate intensities determined for each type, or just the intensity for the most dominant?	• Technical limitation, overlaps
What time window should be used for determining intensity(ies)?	• Arbitration of rapidly varying intensity in convective precipitation • Latency in reporting changing intensity
How should sparse (i.e., very light) intensity be reported? What thresholds should delineate sparse precipitation?	• Operational impact of sparse precipitation
Present Weather Reporting	
What, if any, restructuring of the METAR will be required?	• Operational needs • Constraints of the message type
What other (non-METAR) products will be necessary for decision making?	• Operational needs

Industry Capability

Industry has the technology to enable ASOS to effectively discriminate rain, snow, drizzle and ice pellets (and mixtures). To best utilize the technology, ASOS must evolve:

- To report ice pellets and drizzle, the ASOS present weather identification algorithms must automatically report up to three precipitation types (mixed precipitation).
  - Managing the format and nomenclature of messages received from the present weather sensor is crucial for baselining ASOS reporting capabilities.
  - Requirements for assigning precipitation intensity need to evolve. There are overlaps and user preferences will likely be divided.
  - Sensor- and system-level automated dominance vs priority reporting techniques do not trace to requirements.

Current ASOS/AWOS Algorithm

- Not designed to AUTOMATICALLY report more than one precipitation type at a time (mixed precipitation) in the present weather field.
- Populates the present weather field based on output derived from a 10 minute window to capture airfield-wide conditions.
- Corresponding start/end times are reported in the remarks field via a separate algorithm.
- The 10 minute window in the PW algorithm is based on precedence assignments.
- Does not account for intensity!

	Priority - Current	
Frozen	1	Snow
	2	Ice Pellets
	3	Hail
Freezing	4	Small Hail/ Snow Pellets
	5	Freezing Rain
Liquid	6	Freezing Drizzle
	7	Rain
	8	Drizzle
	9	Unknown

Alternate Table	
1	Ice Pellets
2	Snow
3	
4	
5	
6	
7	
8	
9	

Frozen vs. Frozen?

WOI examined algorithm output using multiple precedence values. However, we recommend development of an algorithm that can yield multiple precipitation types.

Challenge: Evolving the Sensor Message Type

The WOI team and industry have demonstrated a new message type (message x) which allows the sensor to output up to three precipitation types and intensities per message, and is intended be used as input to the next generation AWOS/ASOS automated present weather algorithm.

Example of current constraints

Type of Precipitation	Internal	NWS Code	SYNOP ww Tab.4677	METAR/SPECI w'w' Tab.4678	SYNOP $w_a w_a$ Tab.4680
Sensor error	0		-1 *	????? **	-1 *
No precipitation	1	C	00	NP	00
Precipitation (not identified ****)	2	P-,P,P+	-2,-3,-4 *	-UP,UP,+UP	41,41,42
Drizzle (also freezing ***)	3	L-,L,L+	51,53,55	-DZ,DZ,+DZ	51,52,53
Freezing drizzle (see drizzle ***)	3	[ZL] L-,L,L+	[56,57,57] 51,53,55	[FZDZ] -DZ,DZ,+DZ	[54,55,56] 51,52,53
Drizzle with rain (also freezing ***)	4	RL-,RL,RL+	58,59,59	-RADZ, RADZ,+RADZ	57,58,58
Rain (also freezing ***)	5	R-,R,R+	61,63,65	-RA,RA,+RA	61,62,63
Freezing rain (see rain ***)	5	[ZR] R-,R,R+	[66,67,67] 61,63,65	[FZRA] -RA,RA,+RA	[64,65,66] 61,62,63
Rain and/or drizzle with snow	6	RLS-,RLS, RLS+	68,69,69	-RASN, RASN,+RASN	67,68,68
Snow	7	S-,S,S+	71,73,75	-SN,SN,+SN	71,72,73
Ice pellets (see soft hail ***)	9	[IP] SP	[79] 87,88,88	[PE/PL] GS	74,75,76
Snow grains (also ice prisms ***)	8	SG	77	-SG,SG,+SG	77
Ice crystals /-needles (see snow grains ***)	8	[IC] SG	[76] 77	[IC] SG	[78] 77
Soft hail (also ice pellets ***)	9	SP	87,88,88	-GS,GS,+GS	74,75,76
Hail	10	A	89,90,90	GR	89

Table 6: Code table SYNOP / METAR

* Code comply not with table 4677 / 4680

** Code comply not with table 4678

*** Definitions of table 4677/4678/4680 were not meet by liquid precipitation (determination freezing / not freezing), determination soft hail / ice pellets and snow grains / ice prism.

**** If this precipitation type is often detected, the sensor should be cleaned. Normally natural reasons (e.g. spider web) are responsible for this behaviour. This report should be managed as a error, therefore we recommend to not use this precipitation type and the intensity. In the same way the precipitation types drizzle and snow grains should not observed until the disturbance is eliminated, because they could be erroneous.

[...] Not identifiable / reference value i.e. code in brackets will be not transmitted.

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Sensor Message Type

Current Industry Nomenclature

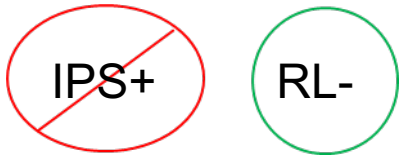
Precipitation	NWS Code
Clear	C
Precipitation	P
Precipitation, slight or moderate	P-
Precipitation, heavy	P+
DRIZZLE	L
Drizzle, not freezing slight	L-
Drizzle, not freezing moderate	L
Drizzle, not freezing heavy	L+
Drizzle, freezing slight	ZL-
Drizzle, freezing moderate	ZL
Drizzle, freezing heavy	ZL+
Drizzle and rain, slight	RL-
Drizzle and rain, moderate	RL
Drizzle and rain, heavy	RL+

Precipitation	NWS Code
ICE PELLETS	IP
Ice Pellets, slight	IP-
Ice Pellets, moderate	IP
Ice Pellets, heavy	IP+
SNOW GRAINS	SG
Snow Grains, slight	SG-
Snow Grains, moderate	SG
Snow Grains, heavy	SG+
ICE CRYSTALS	IC
Ice Crystals slight	IC-
Ice Crystals moderate	IC
Ice Crystals heavy	IC+
SNOW pellets	SP
Hail	A

Precipitation	NWS Code
RAIN	R
Rain, slight	R-
Rain, moderate	R
Rain, heavy	R+
Rain, freezing, slight	ZR-
Rain, freezing, moderate	ZR
Rain, freezing, heavy	ZR+
Rain (or drizzle) and snow, slight	RS-
Rain (or drizzle) and snow, moderate	RS
Rain (or drizzle) and snow heavy	RS+
SNOW	S
Snow Slight	S-
Snow, moderate	S
Snow, heavy	S+

Industry Readiness Finding:

- Limited ability to identify concurrent precipitation types due to ASOS three character limit.
- Specification must standardize coding.



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Demonstrated Message Type & Codes

- **2021-04-19T12:37:00Z 00 15256 10394 IP6 ZR2 A0 67**

Precipitation	NWS Code
Clear	C
Precipitation	P
Precipitation, slight or moderate	P-
Precipitation, heavy	P+
DRIZZLE	L
Drizzle, not freezing slight	L-
Drizzle, not freezing moderate	L
Drizzle, not freezing heavy	L+
Drizzle, freezing slight	ZL-
Drizzle, freezing moderate	ZL
Drizzle, freezing heavy	ZL+
Drizzle and rain, slight	RL-
Drizzle and rain, moderate	RL
Drizzle and rain, heavy	RL+

Precipitation	NWS Code
ICE PELLETS	IP
Ice Pellets, slight	IP-
Ice Pellets, moderate	IP
Ice Pellets, heavy	IP+
SNOW GRAINS	SG
Snow Grains, slight	SG-
Snow Grains, moderate	SG
Snow Grains, heavy	SG+
ICE CRYSTALS	IC
Ice Crystals slight	IC-
Ice Crystals moderate	IC
Ice Crystals heavy	IC+
SNOW pellets	SP
Hail	A

Precipitation	NWS Code
RAIN	R
Rain, slight	R-
Rain, moderate	R
Rain, heavy	R+
Rain, freezing, slight	ZR-
Rain, freezing, moderate	ZR
Rain, freezing, heavy	ZR+
Rain (or drizzle) and snow, slight	RS-
Rain (or drizzle) and snow, moderate	RS
Rain (or drizzle) and snow heavy	RS+
SNOW	S
Snow Slight	S-
Snow, moderate	S
Snow, heavy	S+

Removes combinations, three individual types with individual intensity assigned (0-9)

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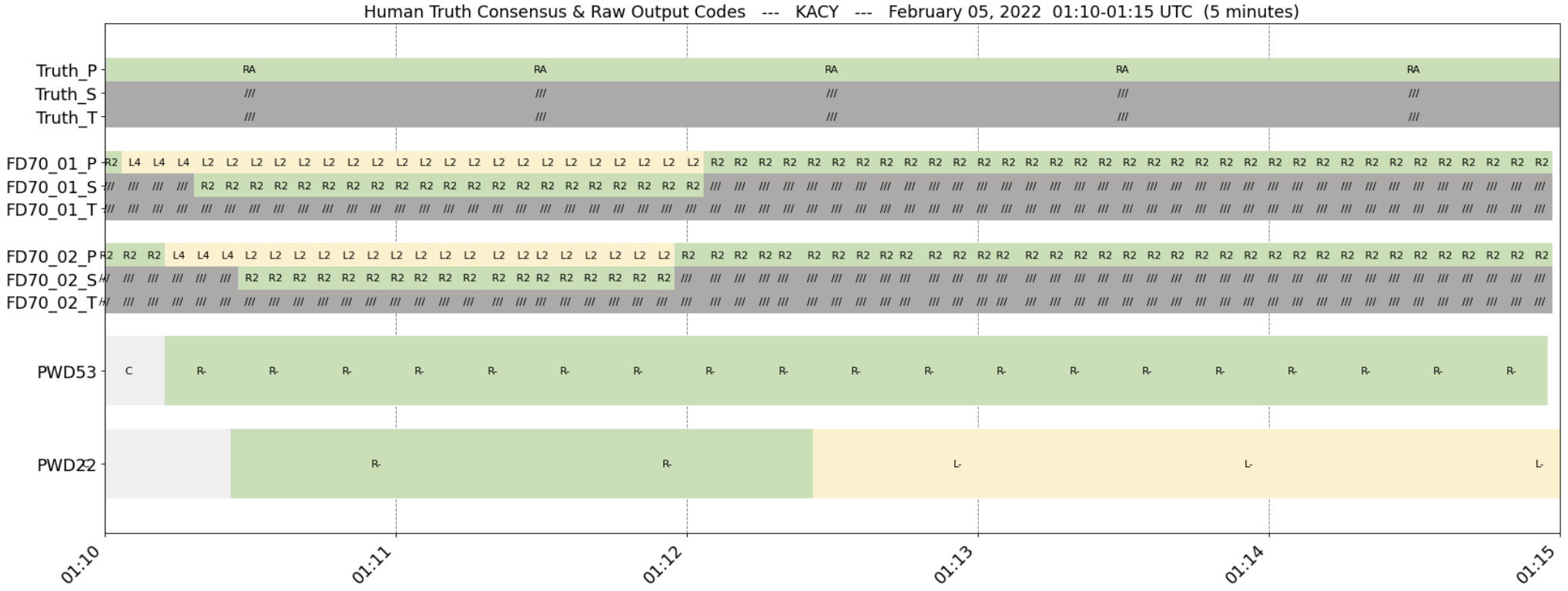
Benefit of New Message Type

Much Higher Resolution!



Value: Technology exists to manage precipitation type reporting at resolutions offering multiple operational translations

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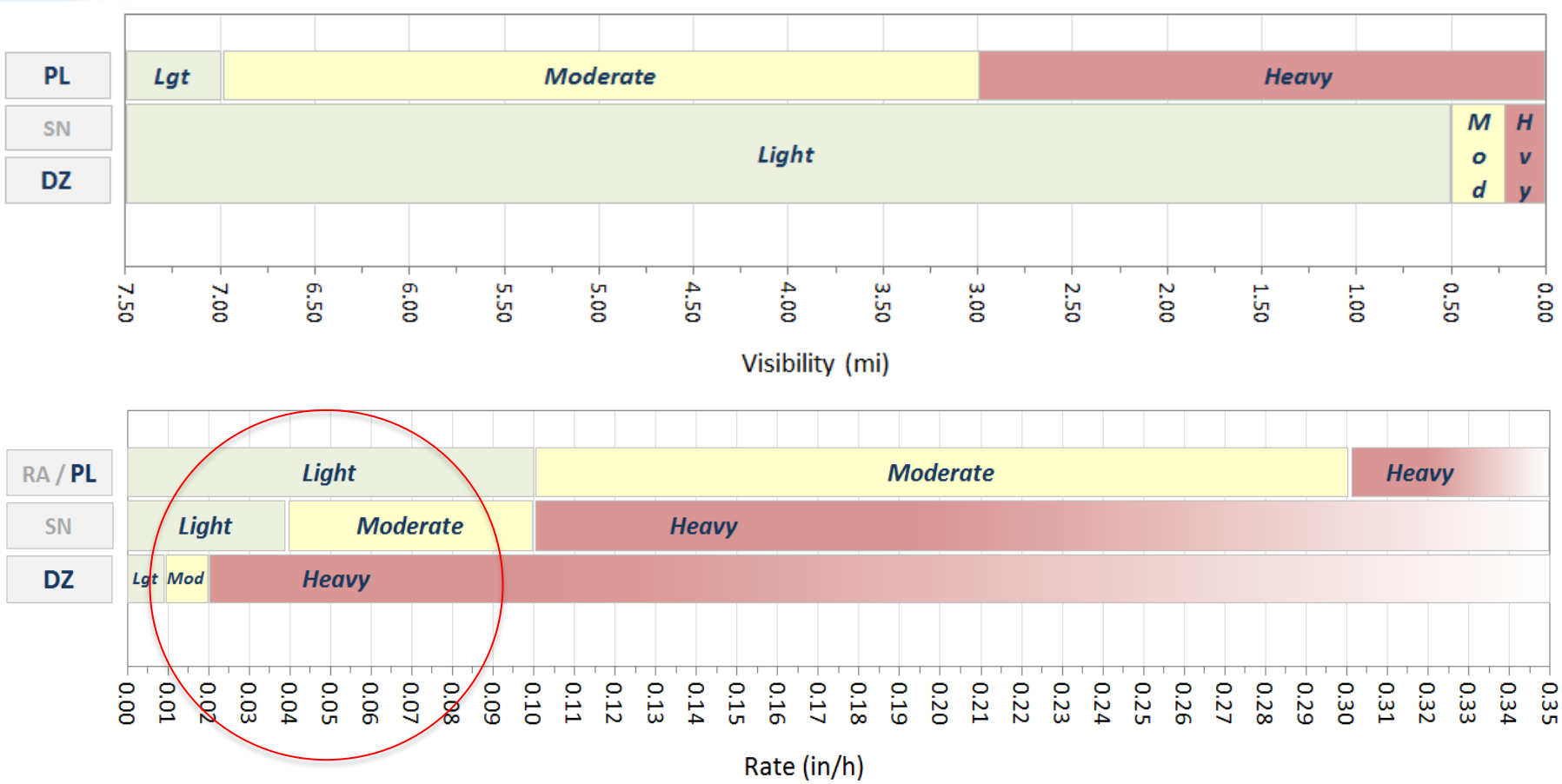
Challenge: Intensity Overlaps



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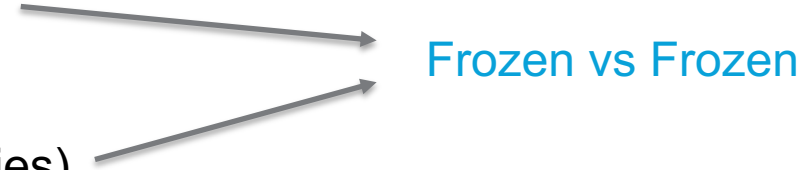
Transitioning to Improved Intensity Reporting

Priority	Precipitation Type/Intensity
1	Heavy Snow
2	Moderate Snow
3	Light Snow
4	Ice Pellets (all intensities)
5	Heavy Rain
6	Moderate Rain
7	Light Rain
8	Drizzle (all intensities)
9	Unknown
10	No Precipitation



Challenges:

- Government needs to clarify priority order for single-type reporting (Legacy Mode).
- Government needs to prioritize detection over intensity at the sensor level.
- Government needs R&D answer for best intensity formulations.

Challenge: Assigning Intensity

Precipitation Type	Intensity assigned via	Prioritization
Snow	System Vis/LWE?	HVY Snow MOD Snow LGT Snow
Ice Pellets (all intensities)		
Rain	Sensor?	LGT Rain MOD Rain HVY Rain
Drizzle	System Vis/LWE?	LGT Drizzle MOD Drizzle HVY Drizzle
Freezing Drizzle	Sensor and System ZR sensor	LGT Freezing Drizzle MOD Freezing Drizzle HVY Freezing Drizzle
Freezing Rain		LGT Freezing Rain MOD Freezing Rain HVY Freezing Rain

Assigning a single intensity to multiple types is very challenging, and will not meet new user requirements

Assigning intensity is a system requirement, not for sensor spec (rain)

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Challenges Ahead

- Socialize new sensor message type with industry*
  - Assist industry via feedback as proprietary algorithms (COTS) are tuned to support new message format
- Socialize ground truth techniques with industry
  - Establish success criteria for Sensor (not system) performance
- Clarify sensor specification for detection and intensity
- Develop strategy to incorporate LWE into METAR (via intensity or other means)*
- Develop strategy for introducing individual precipitation intensities into METAR*
- Many more…obstructions, frost, etc.

***ICAO action needed?**