NWS Central Region GOES-R Fog and Low Stratus – Final Evaluation

Project Title: NWS Central Region GOES-R Fog and Low Stratus Demonstration

Organization: NWS Forecast Offices: Des Moines, IA (DMX); Pleasant Hill, MO (EAX); Indianapolis, IN (IND); Jackson, KY (JKL); Louisville, KY (LMK); St. Louis, MO (LSX); Marquette, MI (MQT); and Riverton, WY (RIW)

Evaluator(s): NWS Forecasters

Duration of Evaluation: 1 August 2012 – 31 December 2012

Prepared By: Chad Gravelle (NWS OPG GOES-R Liaison)

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1. Executive Summary

The main objective of GOES-R product demonstrations is to test, evaluate, and integrate products into operations while promoting interaction between product developers and National Weather Service (NWS) forecasters. More specifically, this demonstration sought to determine the usefulness of prognostic and diagnostic GOES-R fog and low stratus (FLS) products. In early July 2012, NWS Forecast Offices throughout Central Region were invited to participate in this formal product evaluation with the GOES-R Proving Ground. Ultimately, the following eight NWS Forecast Offices in Central Region evaluated the GOES-R FLS suite of products and WRF 10.35-3.9 μm Simulated Satellite Forecasts between 1 August 2012 and 31 December 2013:

- Des Moines, IA (DMX)
- Pleasant Hill, MO (EAX)
- Indianapolis, IN (IND)
- Jackson, KY (JKL)
- Louisville, KY (LMK)
- St. Louis, MO (LSX)
- Marquette, MI (MQT)
- Riverton, WY (RIW)

A participating forecast office point of contact (POC; in most cases the Science and Operations Officer or Forecast Office Satellite Focal Point) was assigned to coordinate product ingest and display into AWIPS, participate in and organize product training participation, and solicit feedback from forecasters for the GOES-R Proving Ground and product developers.

2. Introduction

Widespread or locally dense fog or low ceilings can have a significant impact on ground and aviation transportation. For example, visibility reductions due to fog can create dangerous conditions for vehicles on roadways. From 1995 to 2005 the National Highway Traffic Safety Administration (NHTSA) determined an average of 38,700 vehicular accidents, resulting in about 16,300 injuries and 600 deaths, were directly related to fog each year in the United States. When visibility is not impaired near the ground, low ceilings can be a hazard to aviation interests. Millions of dollars are lost each year by commercial airlines from cancellations, delays, and rerouting forced by low visibilities at airports due to fog and low stratus clouds.

3. Products Evaluated

The products chosen to be demonstrated within the NWS Central Region are identified in the table below.

Demonstrated GOES-R Product	Category
WRF 10.35-3.9 µm Simulated Satellite Forecasts	Baseline
GOES-R Fog and Low Stratus	Future Capability
Category Definitions: **Baseline Products** - GOES-R products that are funded for operational implementation as part of the ground segment base contract. **Future Capability** - New capabilities made possible by ABI that are not in the baseline algorithm set.	

3.1 GOES-R Fog and Low Stratus

The GOES-R FLS products are designed to quantitatively (expressed as a probability) identify clouds that produce MVFR, IFR, and LIFR conditions. This fused product uses both satellite and NWP model (i.e., Rapid Refresh) data as predictors and ceilometer based surface observations of cloud ceiling are used to train the algorithm. During the day, the 0.65, 3.9, and 11 µm channels (in various ways) along with boundary layer relative humidity information from the NWP model are used as predictors (similar approach is utilized at night without the 0.65 µm channel). Verification studies by the product developers indicate that, when compared to surface observations, the GOES-R IFR probability product greatly outperforms the traditional 3.9 – 11 µm brightness temperature difference. In addition to the probability products, the physical thickness of water cloud layers is estimated in the Fog Depth product. The GOES-R FLS algorithm is described in detail in the product Algorithm Technical Basis Document.

FLS product training for the participating forecast offices took place on 24 July 2012 via GoToMeeting with the product developer, Mike Pavolonis (NOAA/NESDIS/STAR). Each forecast office had at least one representative on the one hour training session. The training was recorded at the NWS Training Center in Kansas City, MO and made available to each forecast office POC for distribution to forecasters that could not attend. In addition to the GoToMeeting training, the GOES-R FLS Blog was also available to forecasters during the 6-month evaluation. Available at http://fusedfog.blogspot.com/, this real-time training resource is updated biweekly with FLS product examples.

The primary method to gather feedback after forecasters utilized the GOES-R FLS products in operations was through an online survey and Area Forecast Discussions. The survey was developed by the GOES-R Liaison with input by the product developer with the main objective of capturing how well the FLS products performed when compared to legacy FLS products. Other feedback was obtained through email correspondence between the GOES-R Liaison and the forecast office POC.

3.2 WRF 10.35-3.9 µm Simulated Satellite Forecasts

The 10.35-3.9 µm simulated satellite forecasts are generated by the Cooperative Institute for Research in the Atmosphere (CIRA) after the National Severe Storms Laboratory (NSSL) runs their 0000 UTC 4-km WRF-ARW. Although the GOES-R ABI bands will have 2-km resolution, the resolution of the simulated satellite forecasts is 4-km to match the input resolution of the cloud model. The hourly 1200-1200 UTC (F012-F036) WRF forecasts are sent to the participating NWS forecast offices once a day around 0900 UTC. Since the simulated satellite imagery is displayed in AWIPS as though it is satellite imagery, it is easier for forecasters to identify features of interest than using traditional model output resources (e.g., relative humidity fields).

Product training on the WRF 10.35-3.9 µm simulated satellite forecasts for the participating forecast offices took place on 17 July 2012 via GoToMeeting with the product developers, Dan Bikos (CIRA) and Dan Lindsey (NOAA/NESDIS/STAR). Each forecast office had at least one representative on the one hour training session. The training was recorded at the NWS Training Center in Kansas City, MO and made available to each forecast office POC for distribution to forecasters that could not attend.

The primary method to gather feedback after forecasters utilized the simulated satellite forecasts in operations was through an online survey and NWS Area Forecast Discussions. The survey was developed by the GOES-R Liaison with input by the product developers with the main objective of capturing if the WRF forecasts gave additional confidence when compared to traditional model output resources. Other feedback was obtained through email correspondence between the GOES-R Liaison and the forecast office POC.

4. Results

In sections 3.1 and 3.2, feedback gathered from the surveys and Area Forecast Discussions are presented. Although the majority of the survey questions were quantitative (i.e., participants are asked questions to determine the frequency and percentage of their responses). For each question there was an opportunity for forecasters to give a qualitative response (i.e., participants are asked to respond to general questions, and their responses are explored to identify and define peoples' perceptions, opinions, and feelings) response. These qualitative responses are embedded in italics within the summary of results below. Forecaster participation in the surveys is only suggested and not required. There were 88 surveys completed during the evaluation. Forecasters, Lead Forecasters, and Science and Operations Officers completed the majority of the surveys (83%). Of all respondents, 81% had been at their respective office for 3 or more years. The complete list of questions and results are located in Appendixes A and B. Forecasters mentioned the GOES-R FLS products in eight NWS Area Forecast Discussions and the WRF 10.35-3.9 µm Simulated Satellite Forecasts nineteen times.

4.1 GOES-R Fog and Low Stratus

Survey results indicate that the GOES-R FLS products were primarily utilized for terminal aerodrome forecasts, current conditions, and short-term forecasts (87%) to diagnose widespread radiation fog and synoptic-scale low stratus (71%). One of the goals of the FLS evaluation was to encourage forecasters to use the FLS products based on MODIS imagery. Although only one or two MODIS passes over a location may be available every 12 hours, the advantage to the MODIS products is that their spatial resolution will be closer to that of GOES-R. Not only does this give the forecaster a sense of how the products will perform with GOES-R, but they also allow the detection of small-scale valley fog that may be missed by the current GOES footprint. However, only 9 percent of forecasters that completed the survey utilized the MODIS products in operations and the following feedback was received about using the MODIS products:

"I have little hope the MODIS products will ever be used much here. Something that only comes in twice a day just has very limited operational utility."

The importance of utilizing the MODIS products was shown near the end of the FLS training session. However, if using the MODIS and GOES products together is an important aspect of future FLS product evaluations then a different training approach may be needed to reverse the limited operational utility paradigm of these products and polar orbiter imagery in general.

Overall, survey results indicated that the probability products performed well when compared to surface observations and the 11.0-3.9 µm legacy channel difference product. Compared to surface observations, 69 percent felt that the products performed either well or very well.

"Lower probability IFR matched up pretty well with MVFR cigs."

"Mostly very good, although the IFR/LIFR probabilities were very low at CMX when vsbys very M1/4 before 11z."

Over one-third of forecasters utilized both the GOES-R FLS and the legacy channel difference products and of the 71 percent that did, they felt the GOES-R products performed either good or very good.

"FLS products identified the areas better than the legacy visible/fog imagery, but felt IFR/LIFR probabilities were too low considering the areal coverage and uniformity of LIFR conditions, likely due to high clouds moving across the state."

Forecaster comments like these were common and should be the focus of upcoming GOES-R FLS training sessions. It is important that forecasters understand how the GOES-R probability products are defined – this fused product allows probability information to be provided when mid to upper-level ice clouds are obstructing the satellite's view. The MVFR, IFR, and LIFR probability product quality appears to be "degraded" under these conditions because only the model information is being utilized by the algorithm to produce the products. It is essential to stress the similarities and differences when the products are derived using model/satellite and model only information in future training sessions.

Forecasters were also asked if they noticed increases or decreases (e.g., an area when the IFR probability increases from 40 to 70% over 60-90 minutes) in the GOES-R FLS probability products. About two-thirds of forecasters did notice trends in probabilities and of those, it gave confidence to more than half for the presence or absence of FLS.

> *"The amount of fog/status changed in both magnitude and areal coverage through the entire shift. The GOES-R products helped place the location/severity of the fog, but confidence was lower because it was constantly changing."*

> *"On this morning, the GOES-R datasets gave increased confidence that fog/low clouds were developing near KSAW, despite having high clouds initially over the site."*

During the GOES-R FLS training sessions, forecasters were trained to use the FLS cloud thickness product as a prognostic tool to determine how long radiation fog will take to dissipate after sunrise. The majority of forecasters that utilized the cloud thickness product for fog dissipation (~ 65%) felt the product was either somewhat useful (46%) or very useful (36%). One of the forecasters that found the cloud thickness product to be "very useful" commented that there could be regional and local terrain differences with how quickly fog dissipates.

> *"We're currently trying to use the data to create our own scatter chart. We've noticed significant differences on timing of (fog) dissipation based on the orientation of the valleys."*

Other forecasters found that the time of year (i.e., sun angle) also contributes to the amount of time needed for radiation fog to dissipate. The following excerpt was from an Area Forecast Discussion on 21 November 2012:

> *"GOES-E CLOUD THICKNESSES OF 1000-1200 FEET SUGGEST THE RADIATION FOG TO LAST 4-5 HOURS AFTER SUNRISE OR 11 AM TO NOON. HOWEVER...GIVEN WEAK SUN ANGLE/TIME OF YEAR AND LITTLE MIXING ESPECIALLY OVER THE EASTERN CWA...LIKE YESTERDAY BELIEVE THIS IF ANYTHING MAY BE UNDERESTIMATED."*

Used as a prognostic tool, the cloud thickness product appears to have utility based on the survey results. However, more robust research on a regional scale would give forecasters more confidence in utilizing the product to assist in short-term forecasts.

Finally, forecasters were asked how useful they found the GOES-R FLS products and how likely they would be to utilize the products again. Overwhelmingly (three-fourths of survey participants), forecasters felt the suite of FLS products was extremely useful, very useful, or somewhat useful and a similar number would use the products again when diagnosing FLS.

> *"A good additional tool. I'm sure our interpretive skill will improve as we use it more."*

> *"We are becoming increasingly confident of using this information for TAFs, etc. and it gives us confirmation of what we normally think should be going on."*

Although in the minority, those forecasters that did not feel the products were useful felt that they did not provide additional information that could not be found elsewhere.

"Didn't tell me anything I didn't already know."

"Didn't reveal anything that I couldn't get elsewhere (from surface observations or the band difference product) with higher confidence and less mental effort. I would only use the products again because our office is participating in this test."

Overall, forecasters felt the GOES-R FLS products were successful at providing probabilistic guidance of exceeding flight-rule thresholds. They felt that the products performed well when compared to observations and the legacy channel difference product. In addition, the probabilistic products provided confidence to the majority of users that FLS was present during an unobstructed view to the liquid water clouds as well as when high clouds were present. During a post-evaluation discussion, the participating NWS Forecast Office point of contacts felt that the products are best used in combination with more traditional FLS detection tools forecaster are familiar with. It was also stated that forecasters would question why the probabilities were not higher (i.e., 100%) when the flight-rule threshold was exceeded in METAR observations. Questions similar to these suggest a lack of understanding of the products or probabilistic guidance in general. However, that being stated, all the point-of-contacts felt that the product training was more than adequate for the evaluation.

4.2 WRF 10.35-3.9 µm Simulated Satellite Forecasts

Survey results indicate that the WRF 10.35-3.9 µm Simulated Satellite Forecasts (hereafter FLS WRF Forecasts) were primarily utilized to diagnose widespread radiation fog and synoptic-scale low stratus (66%) in the upcoming forecast. In addition to the FLS WRF Forecasts, participating NWS Forecast Offices also received the 10.35 µm simulated satellite forecasts which survey results indicated they were utilized for forecasts of convective development, convective cloud debris, and mid-upper level cirrus development. Although the FLS WRF Forecast algorithm discriminates low-level clouds from upper-level clouds well, when upper-level clouds are present the low-level clouds are obscured. However, only 10 percent of forecasters mentioned the forecasts could not be used to detect FLS because of intervening high clouds.

The most noticeable limitation with the FLS WRF Forecasts is that they are only as accurate as the cloud model forecast; if the model does not forecast FLS, then FLS will be absent from the synthetic imagery. This was clear in the feedback gathered from forecasters as only about half felt the model performed either well or very well when compared to observations at the observed analysis time.

"Good in some areas, but fog in a lot of areas where model didn't predict it."

"Western extent of the clouds did not form as expected, but timing was pretty good for the central and eastern CWA."

When the forecasters were asked if the FLS WRF Forecasts gave additional confidence when compared to traditional model output resources used for forecasting FLS, the results were mixed again. The forecasts gave 46 percent very high or high confidence, 26 percent average confidence, and 28 percent low or very low confidence.

"Although confidence was very high, there were other factors pointing in same direction. In practical terms, the FLC boosted confidence from 'high' to 'very high'."

"I used this product in conjunction with soundings/RH plots. When used together, this does give me high confidence in fog/stratus potential."

The majority of forecasters (67%) that completed the FLS WRF Forecast survey did not use the products specifically for an aviation forecast or terminal aerodrome forecast. However, the forecasts were included in 19 Area Forecast Discussions, more than twice as many as the GOES-R FLS products. It is possible that simulated satellite imagery fills a void between traditional model output fields that are used for FLS detection and remotely sensed data. Finally, forecasters were asked how useful they found the FLS WRF Forecasts and how likely they would be to utilize the forecasts again. Almost half of forecasters felt the forecasts were extremely or very useful and 86 percent were either extremely or very likely to use the products again. Overall, this suggests that the WRF FLS forecasts are generally useful despite the normal inconsistencies with model output.

5. Participating NWS Forecast Office Recommendations

5.1 GOES-R Fog and Low Stratus

• It is recommended that future GOES-R Fog and Low Stratus training sessions provide a more detailed explanation of how to interpret the GOES-R probabilities. For example, what information is a 70% probability of exceeding IFR conditions at a pixel giving the user?

5.2 WRF 10.35-3.9 μm Simulated Satellite Forecasts

• No recommendations for improvements.

6. Summary

6.1 GOES-R Fog and Low Stratus

• The majority of forecasters thought the GOES-R FLS products were successful at providing probabilistic guidance of exceeding flight-rule thresholds and would use the products again in operations.

• The majority of forecasters thought that the GOES-R FLS products performed well when compared to surface observations (69%) and the legacy channel difference product (71%).

• The probabilistic products provided confidence to the majority of users that FLS was present during an unobstructed view to the liquid water clouds as well as when high clouds were present.

• Forecasters suggested, at least currently, that the GOES-R FLS products are best used in combination with more traditional FLS detection tools forecaster are familiar with.

• The WFO POCs suggested that additional research should be completed on how the Fog Depth product can be used to diagnose the dissipation time for the liquid cloud layer.

• The Forecast Office Point-of-Contacts thought the product training was more than adequate for the evaluation, but thought some forecasters did not understand the basics of probabilistic guidance.

6.2 WRF 10.35-3.9 µm Simulated Satellite Forecasts

• The majority of forecasters (67%) used the Simulated Satellite Forecasts to update their short-term forecasts.

• The Simulated Satellite Forecasts were included in 19 NWS Area Forecast Discussions.

• Almost half of forecasters thought the Simulated Satellite Forecasts were extremely or very useful and 86 percent were either extremely or very likely to use the products again.

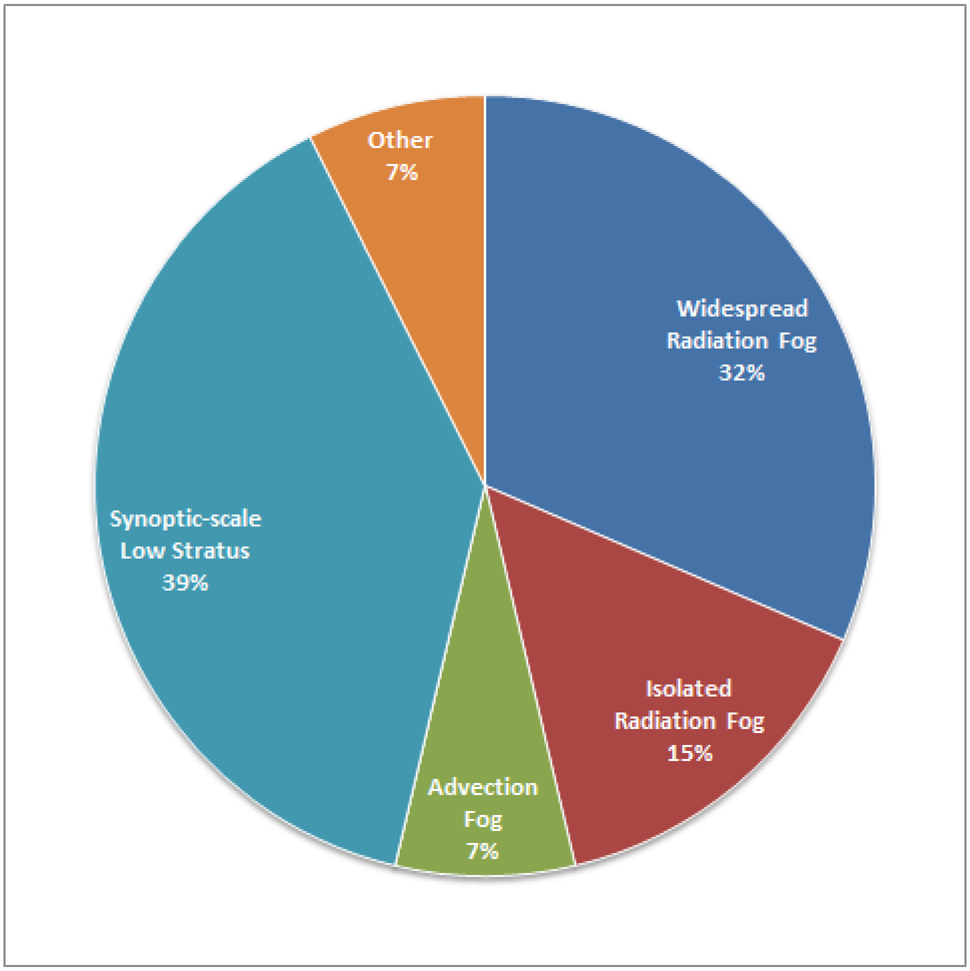
• Despite model limitations and errors in the forecasts, results from the Simulated Satellite Forecast evaluation show there is a need for this type of information when producing short-term forecasts.

Appendix A: NWS Area Forecast Discussion References

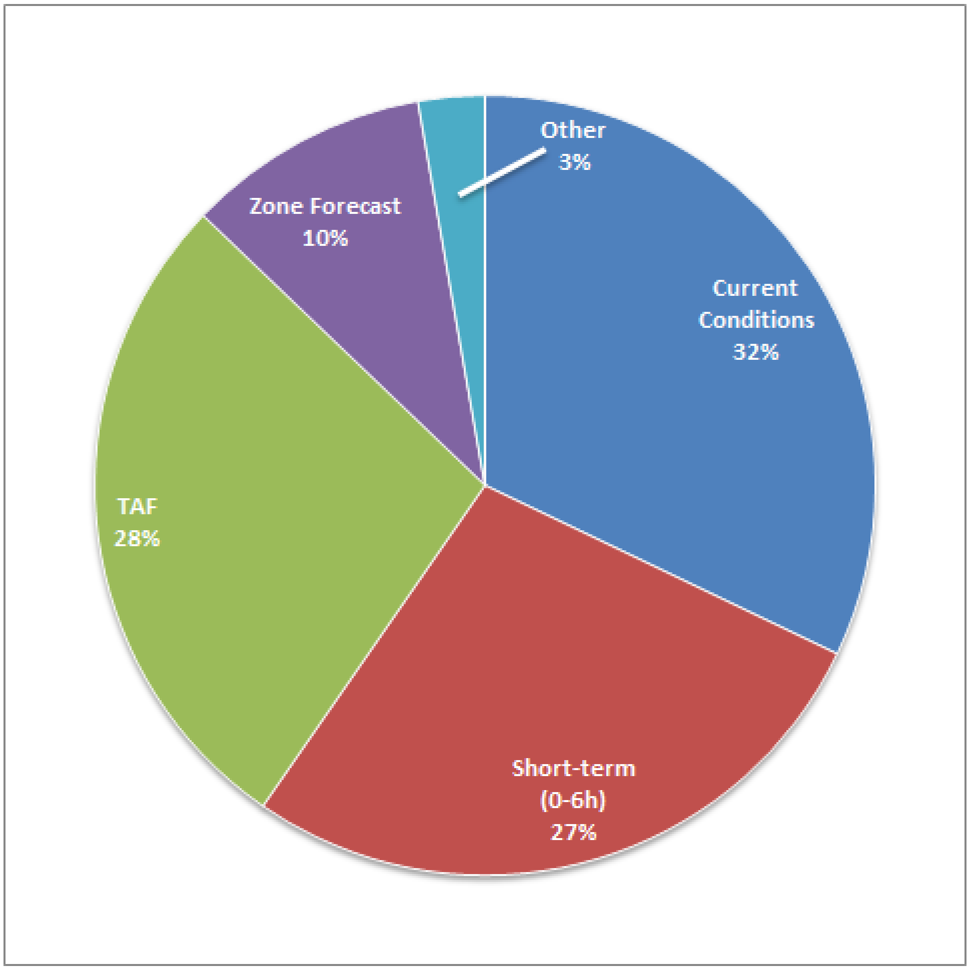
10 August 2012: DMX – WRF Forecasts
10 August 2012: LSX – FLS Probabilities
15 August 2012: JKL - WRF Forecasts
2 September 2012: EAX - WRF Forecasts
5 September 2012: JKL - WRF Forecasts
24 September 2012: DMX - WRF Forecasts
11 October 2012: DMX - WRF Forecasts
15 October 2012: LMK - WRF Forecasts
20 October 2012: DMX - WRF Forecasts
24 October 2012: MQT - FLS Probabilities
8 November 2012: LMK - WRF Forecasts
14 November 2012: LMK - WRF Forecasts
17 November 2012: MQT - FLS Probabilities
20 November 2012: DMX - WRF Forecasts
20 November 2012: LMK - WRF Forecasts
20 November 2012: DMX - WRF Forecasts
21 November 2012: LSX - FLS Cloud Thickness
23 November 2012: EAX - WRF Forecasts
1 December 2012: DMX - WRF Forecasts
2 December 2012: DMX - WRF Forecasts
2 December 2012: MQT - FLS Probabilities
5 December 2012: LMK - WRF Forecasts
6 December 2012: DMX - WRF Forecasts
7 December 2012: LSX - FLS Probabilities
14 December 2012: MQT - FLS Cloud Thickness
14 December 2012: EAX - WRF Forecasts
24 December 2012: LSX - FLS Cloud Thickness

Appendix B: GOES-R Fog and Low Stratus Survey Results (n=45)

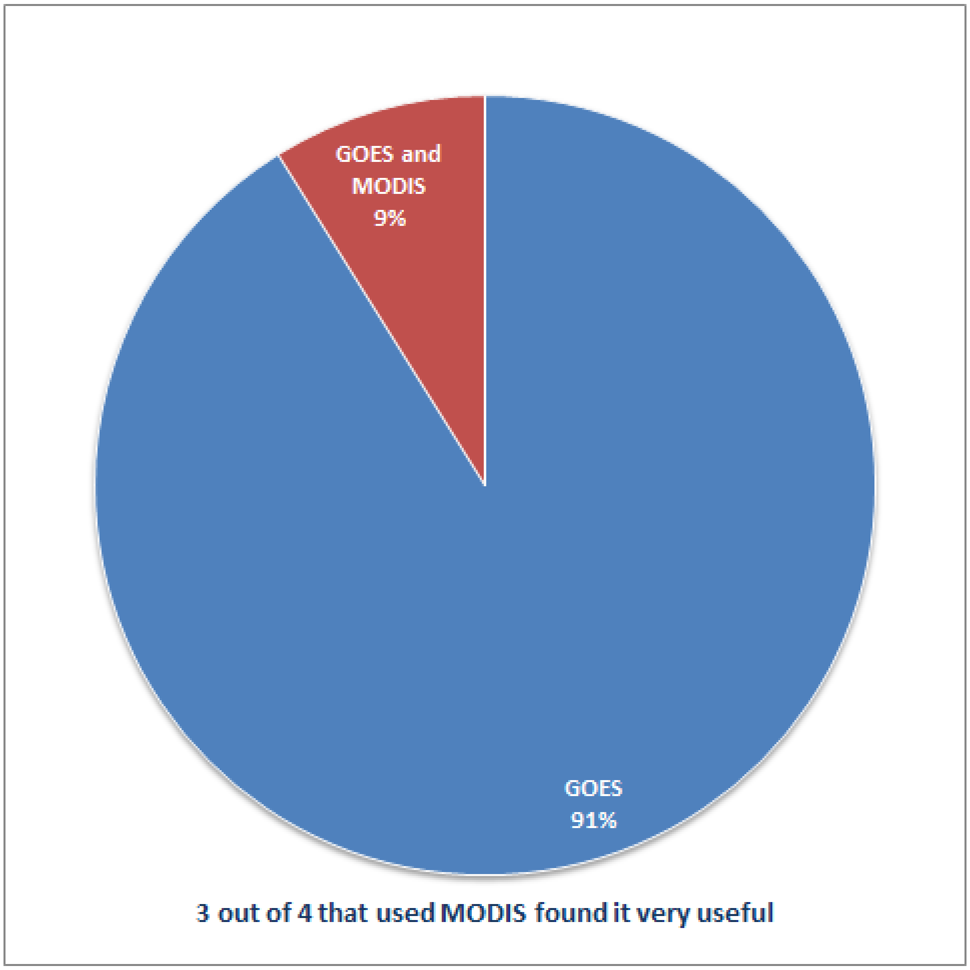
1. What was the FLS problem of the day? Choose all that apply.



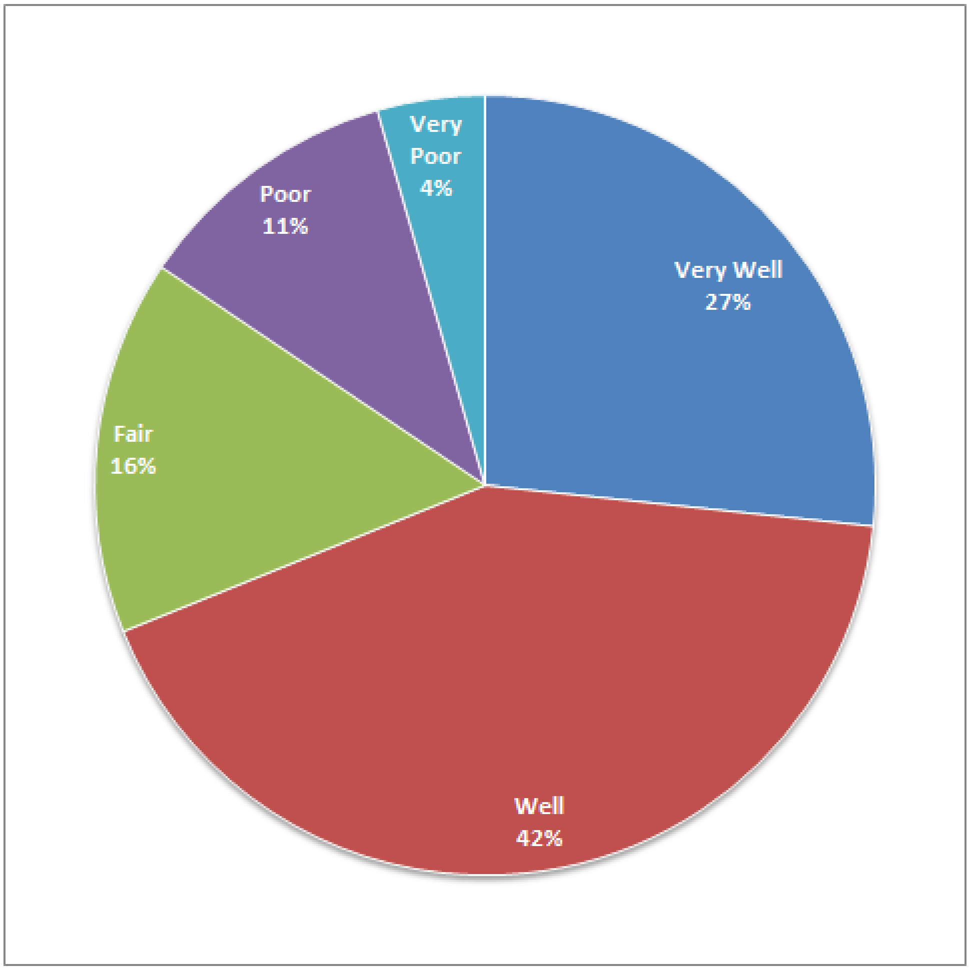
2. How were the GOES-R FLS products utilized? Choose all that apply.



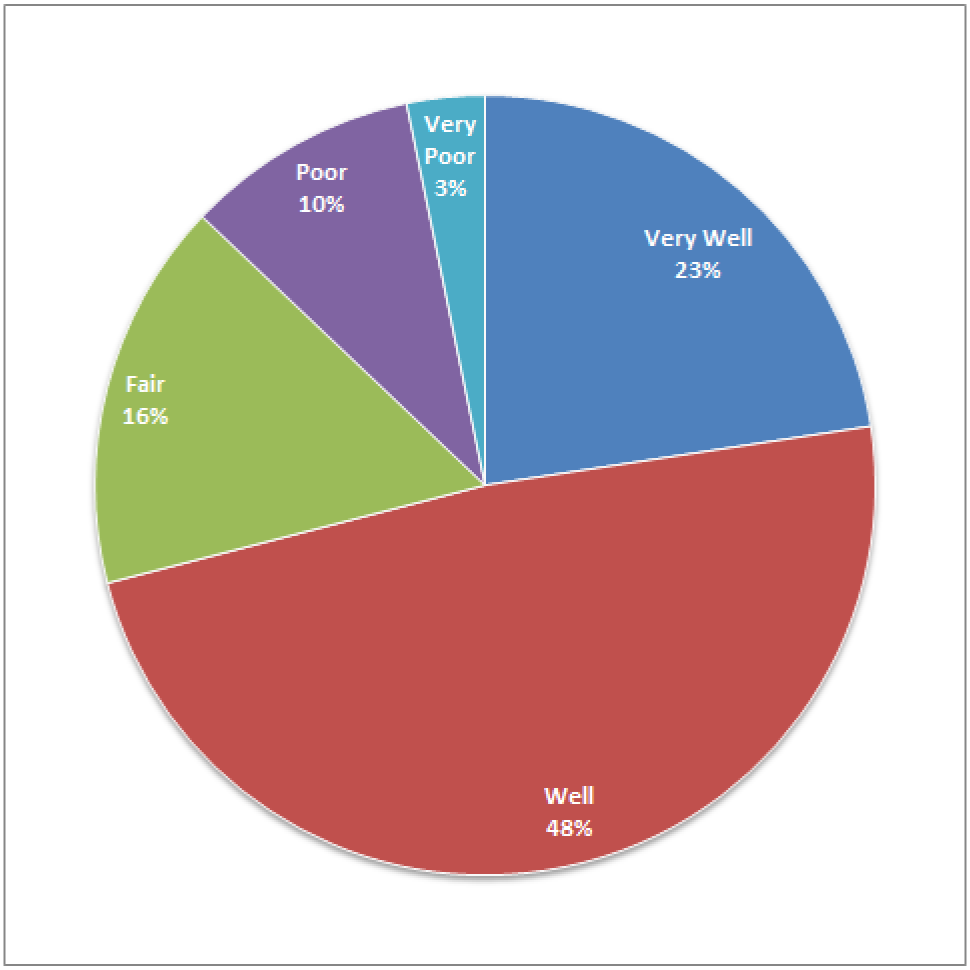
3. What satellite imagery did you use to analyze the GOES-R FLS products?



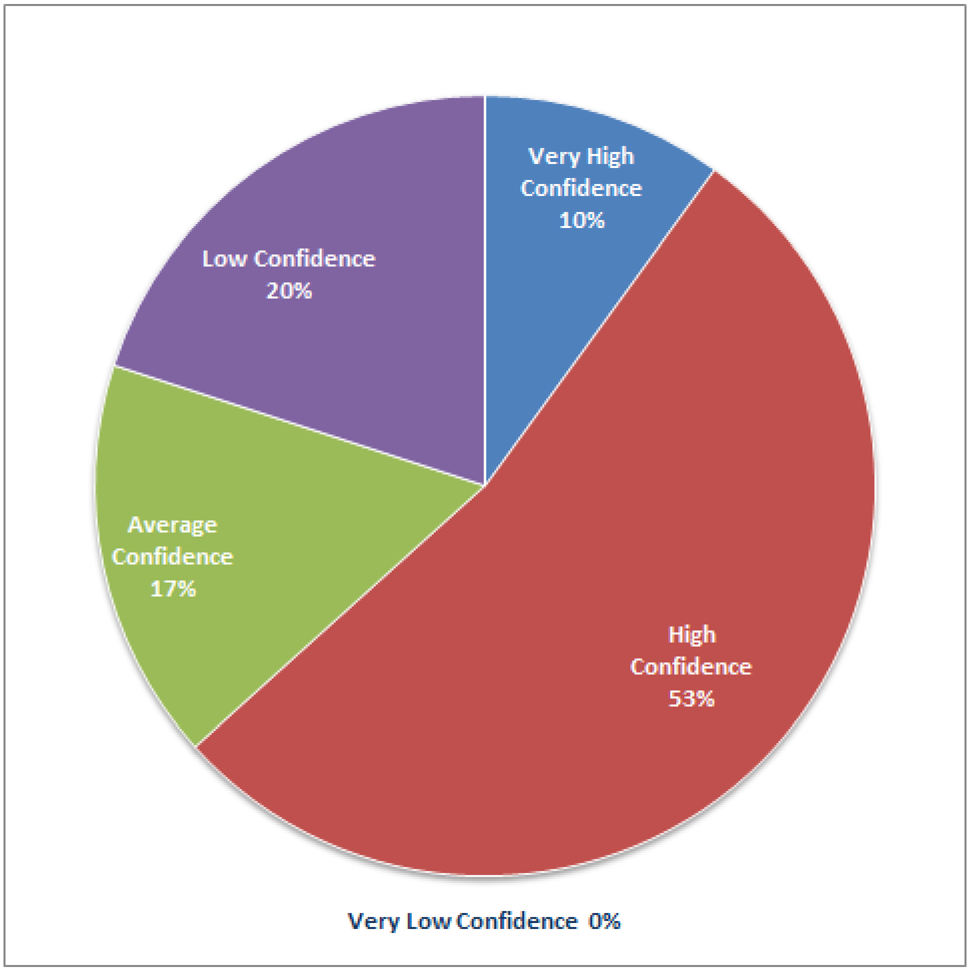
4. How did the GOES-R FLS products perform when compared to surface observations?



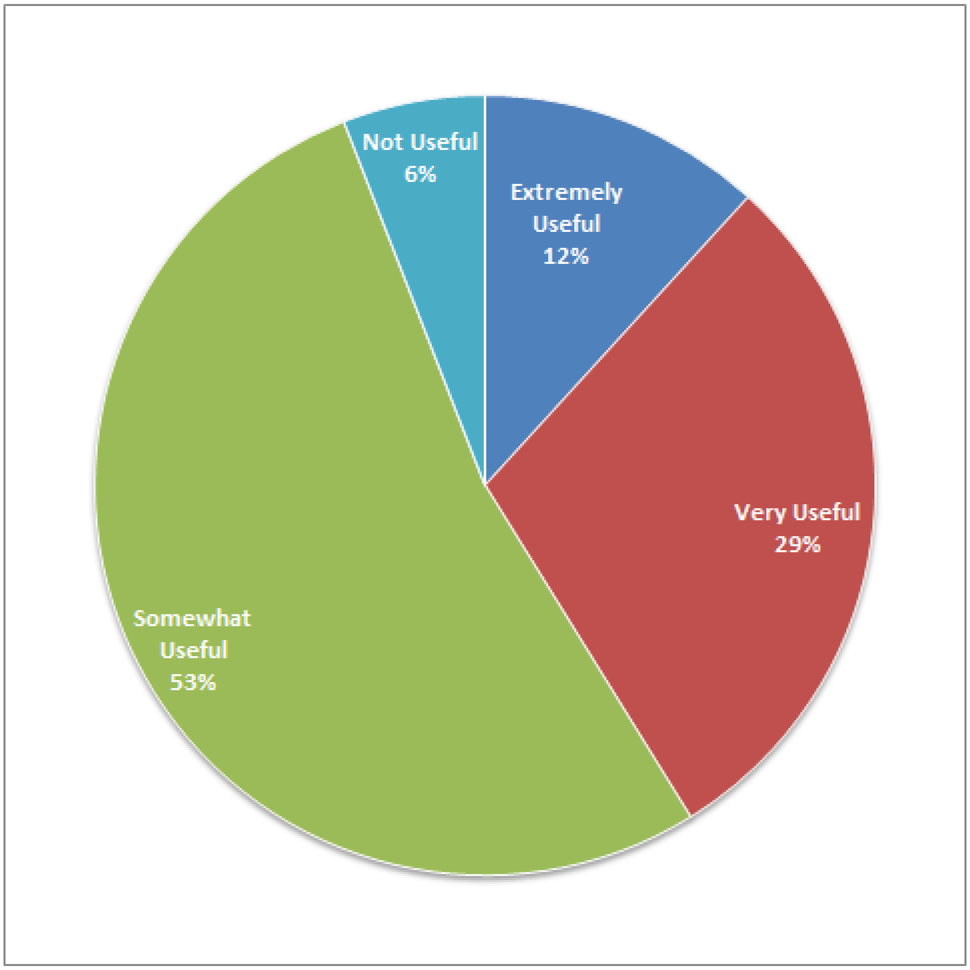
5. How did the GOES-R FLS products perform when compared to legacy fog products?



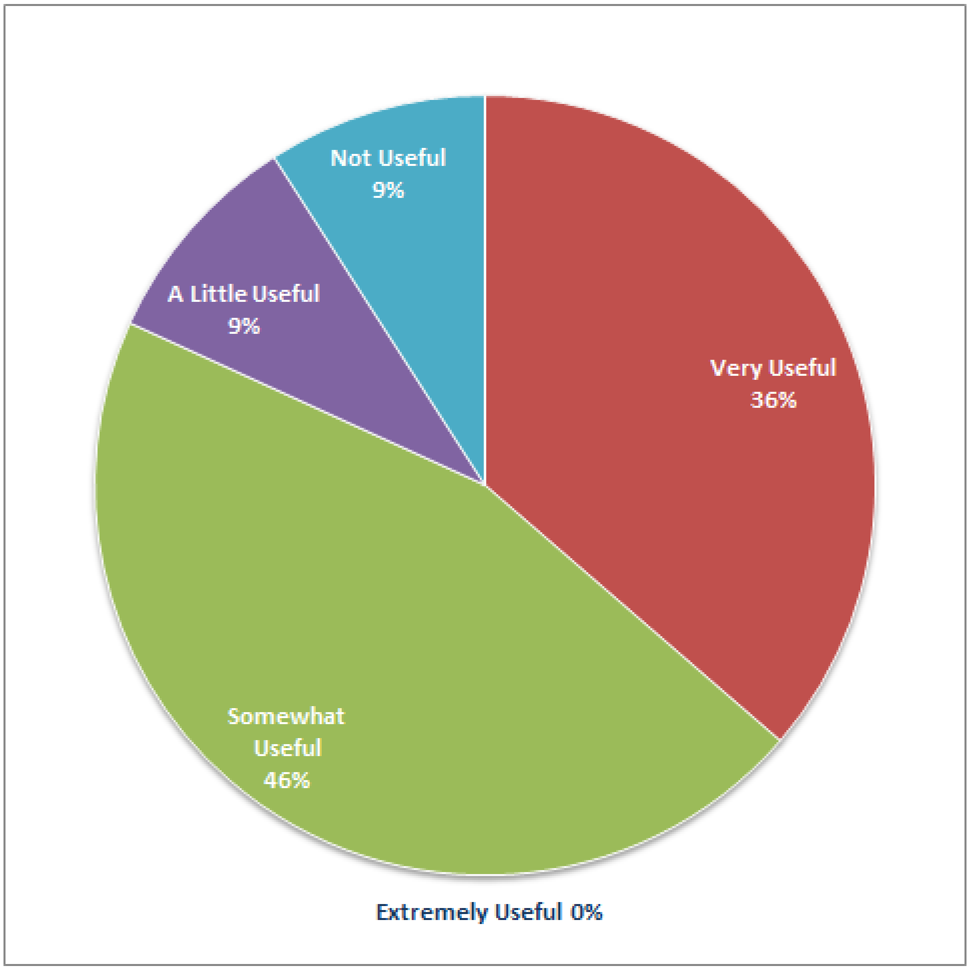
6. If you notice an increase in the GOES-R FLS probabilities, did these probability trends give confidence for the formation or dissipation of FLS?



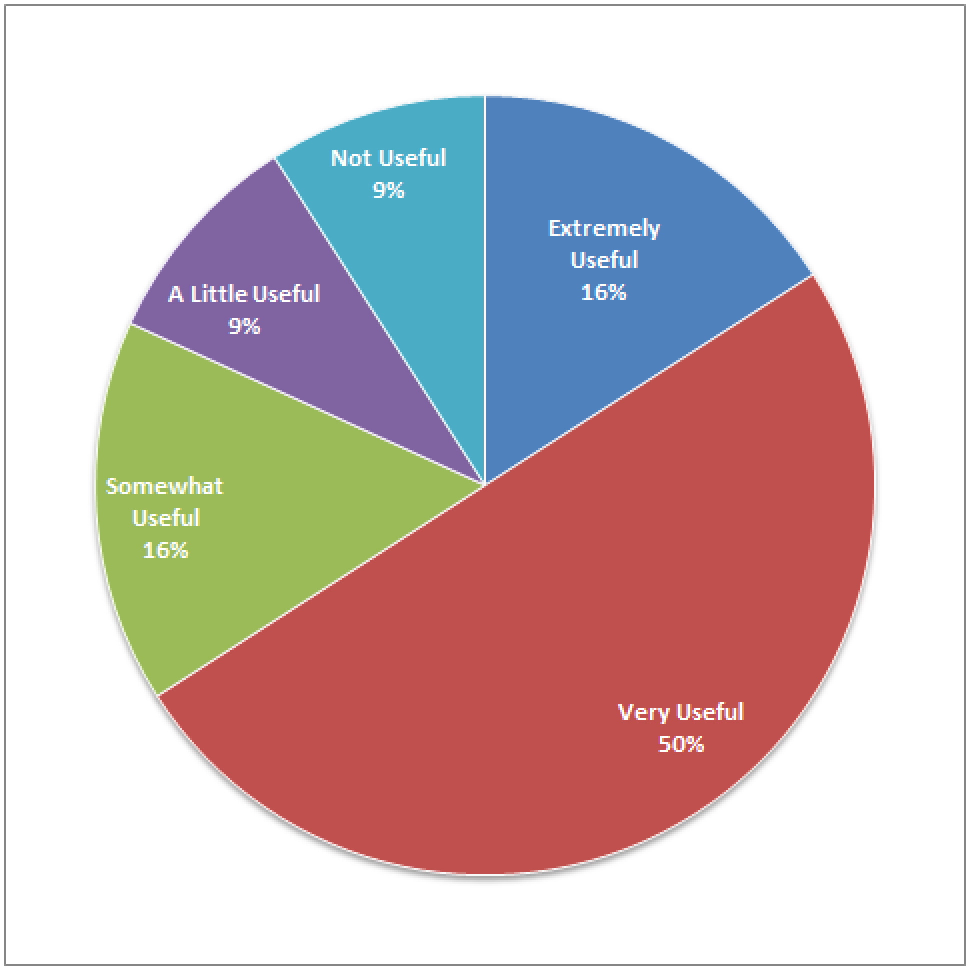
7. How useful was the GOES-R cloud thickness product?



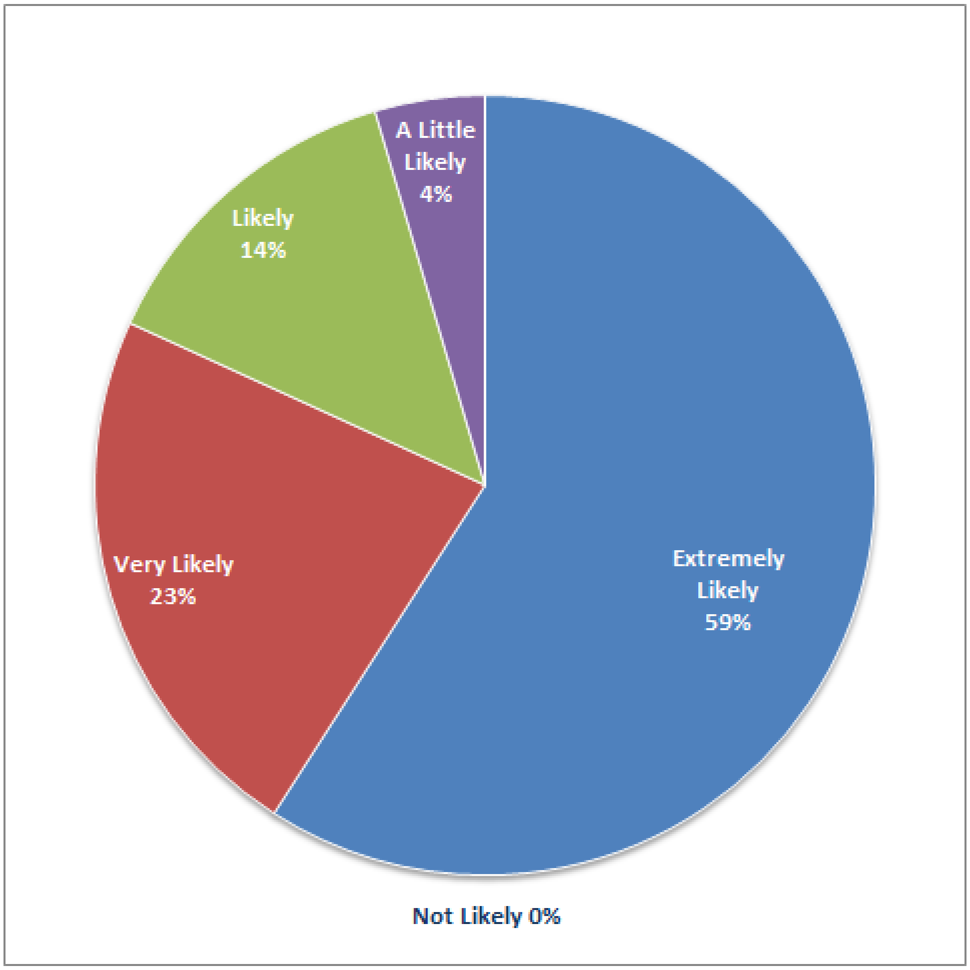
8. How useful was the cloud thickness product to assist with estimating fog dissipation?



9. Overall, how useful did you find the GOES-R FLS Products?

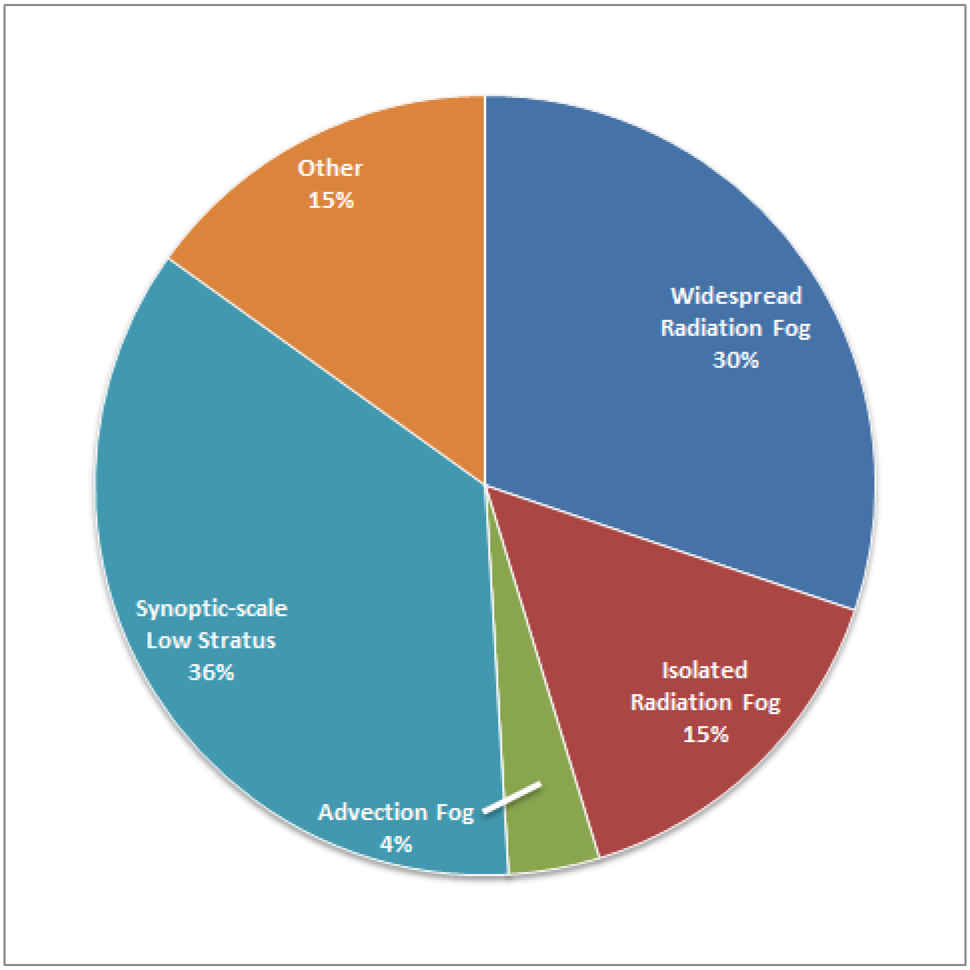


10. How likely are you to use the GOES-R FLS products again when diagnosing FLS?

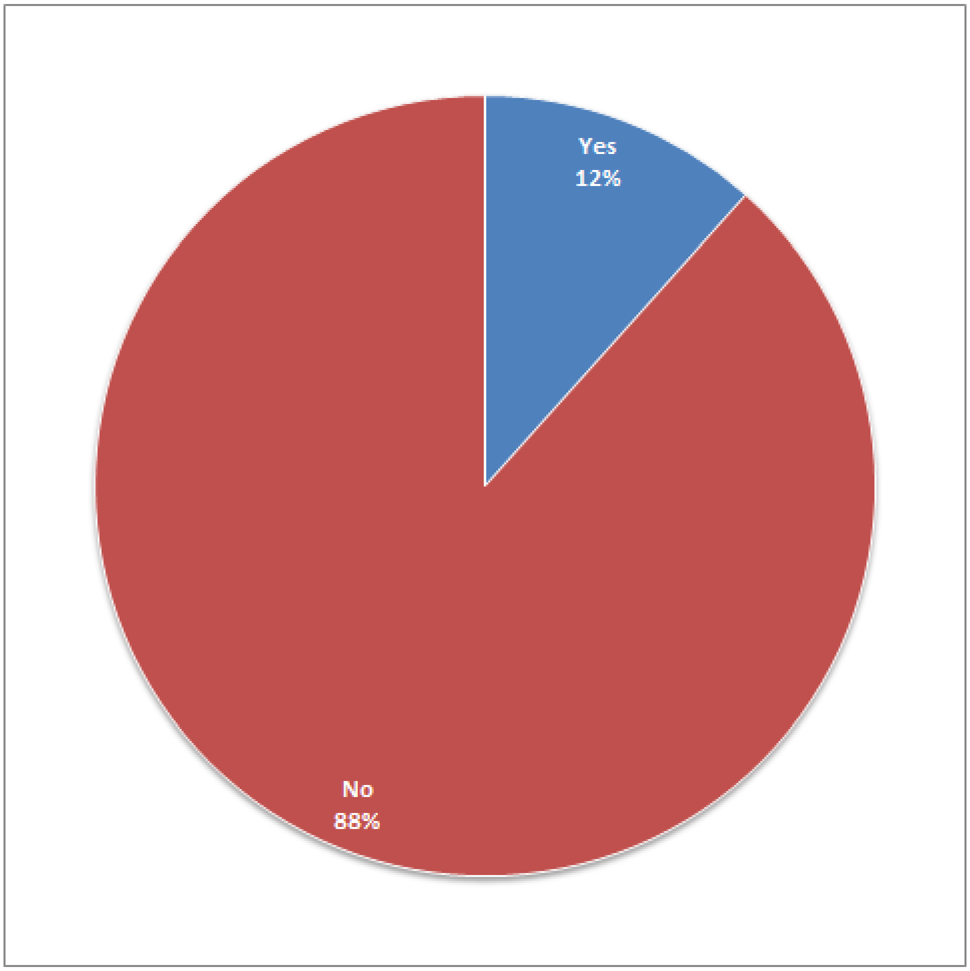


Appendix C: WRF 10.35-3.9 µm Simulated Satellite Forecasts Survey Results (n=42)

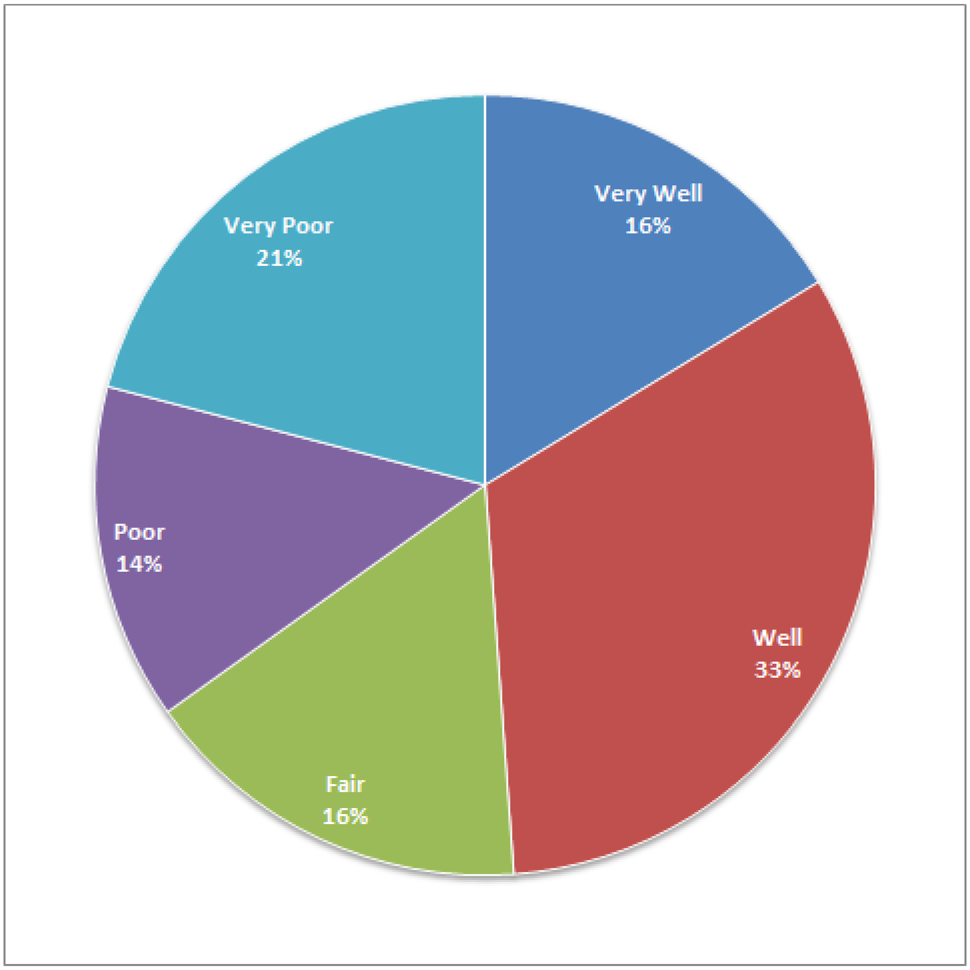
1. What was the FLS problem of the day? Choose all that apply.



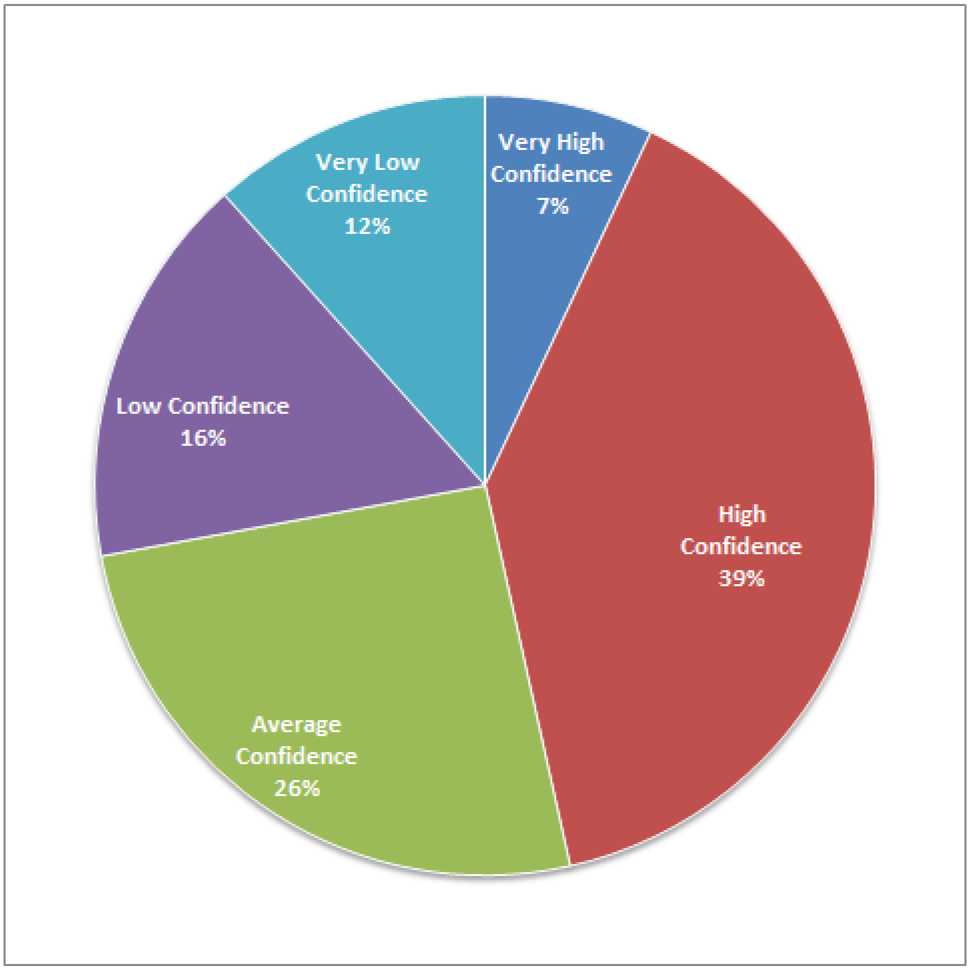
2. Did intervening forecast high clouds (in black and gray) prevent you from diagnosing whether or not the model had liquid water clouds (in blue) in the region of interest?



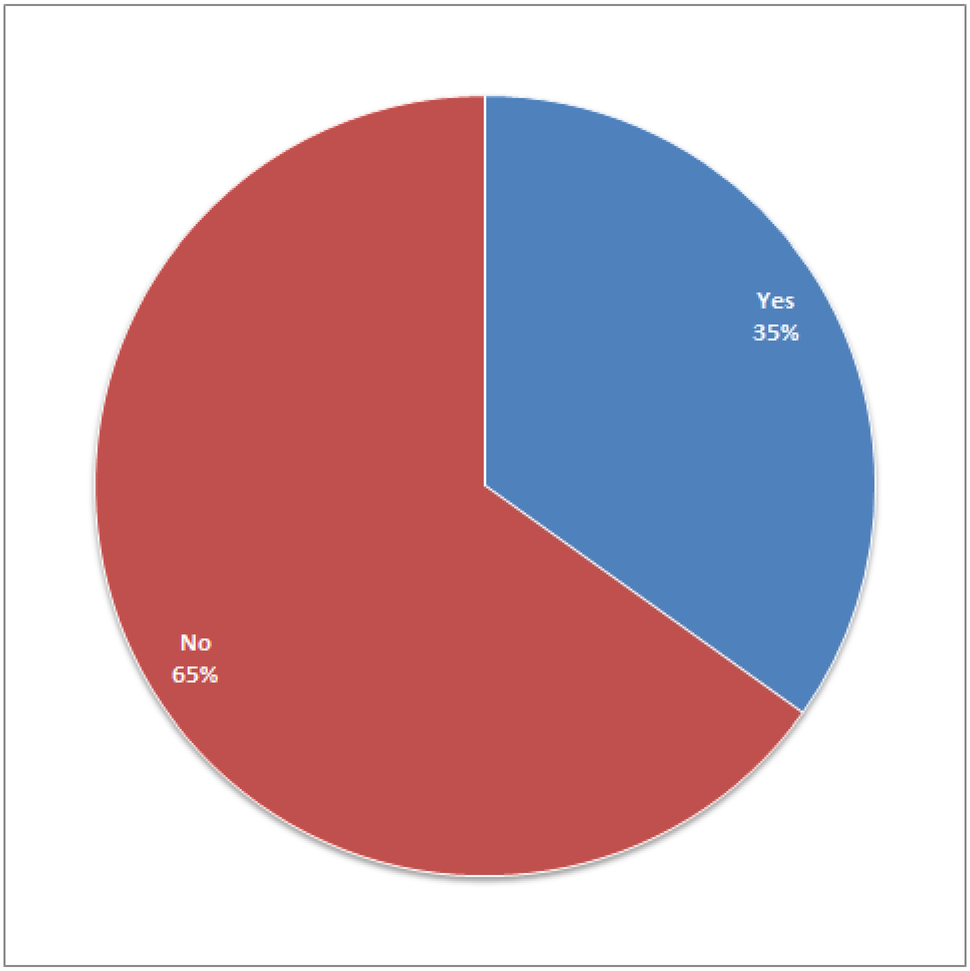
3. How well did the model-forecast liquid water clouds (forecast low clouds in blue) match with observed liquid water clouds (observations) at the observed analysis time? For example...if the simulated 10.35-3.9um forecasts are being used at 7Z, how well did the simulated forecasts valid at 7Z match the observations at 7Z?



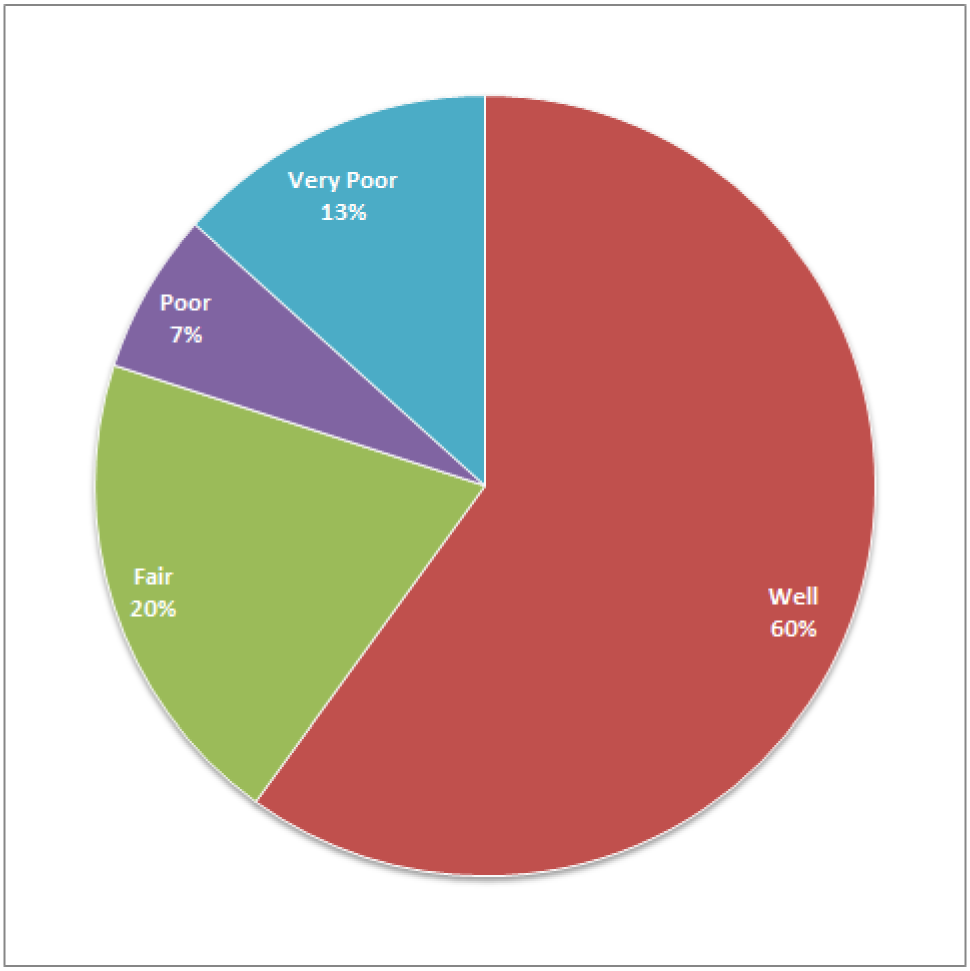
4. Based on a comparison between traditional model output resources used for forecasting FLS (e.g., point soundings and relative humidity fields) and the WRF FLS simulated imagery, how did much confidence did the WRF FLS forecasts give you?



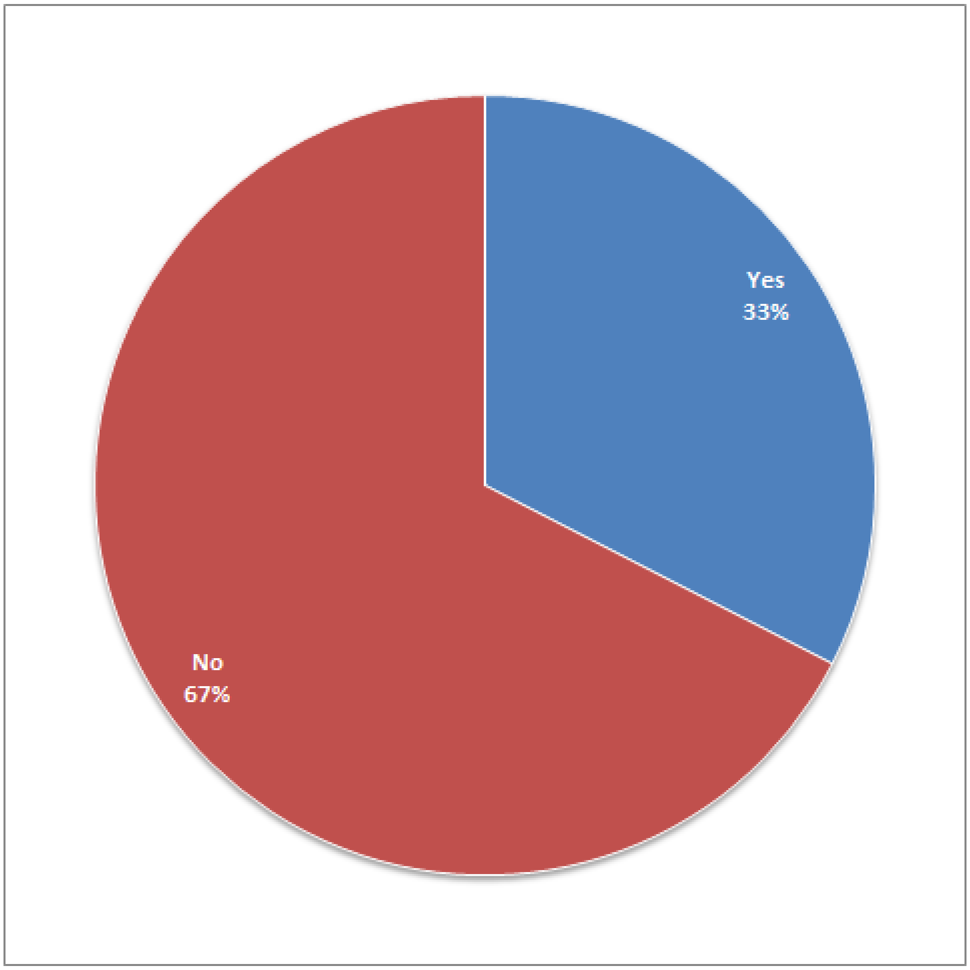
5. Did you analyze the simulated 10.35 µm band in addition to the simulated 10.35-3.9 µm fog product?



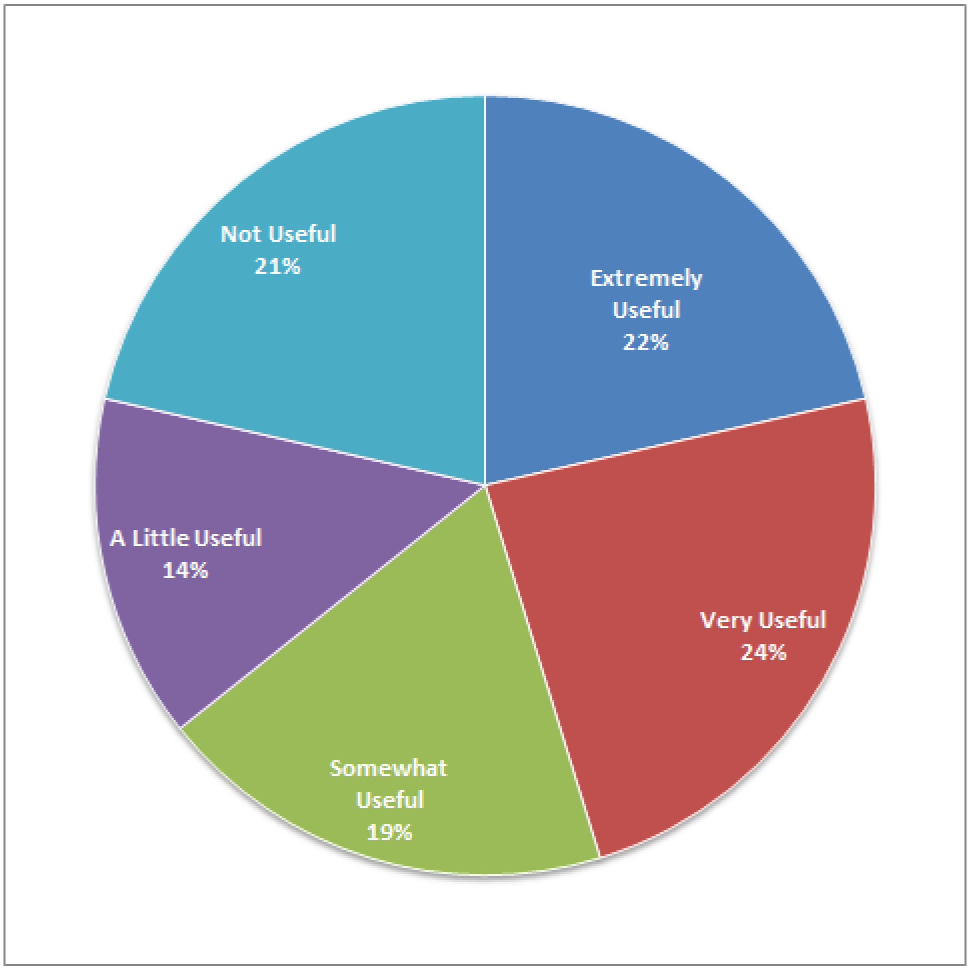
6. How well did the simulated fog product do at differentiating the liquid water clouds from the ground and the ice clouds (from the 10.35 µm band)?



7. Did the WRF FLS forecasts directly assist with an aviation forecast or TAF?



8. Overall, how useful did you find the CIRA NSSL WRF FLS Forecasts?



9. Overall, how likely are you to use the CIRA NSSL WRF FLS Forecasts again when forecasting FLS?