

# Water Policy Interim Committee

## – The Science Behind Weather Modification

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# Overview

- Cloud Seeding – How it works
- Benefit estimates
- Common Questions
- SNOWIE Research Project



# What is cloud seeding?

- Cloud seeding of cold clouds depends upon an abundance of supercooled liquid water (SLW)
- Cloud seeding of warm clouds depends upon Collision-Coalescence
- Cloud seeding provides a mechanism to promote the growth of either a raindrop (warm cloud) or snowflake (cold cloud)
- The term cloud seeding has been used to describe:
  - Fog suppression (airports)
  - Hail suppression (reduce crop and property damage)
  - Rainfall enhancement (water supply augmentation)
  - Snowpack enhancement (snowpack augmentation)

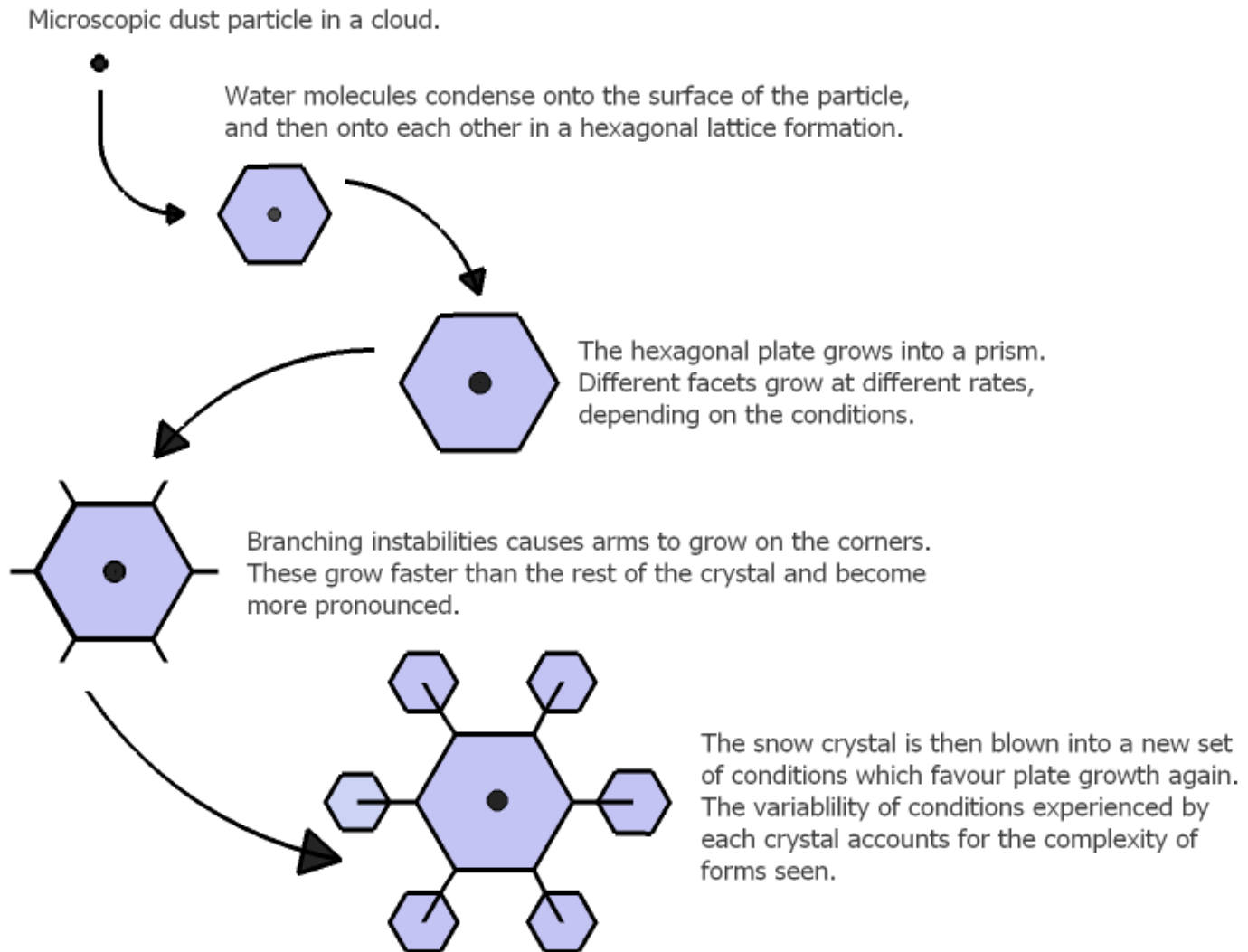
# Supercooled Liquid Water (SLW)

- Water that is cold enough to freeze, but remains in the liquid state
  - Water can freeze at 32°F
  - Water requires a nucleation process to freeze
    - Impurities in nature such as dust
  - Water in the liquid state can be present in clouds much colder than 32°F
    - Often down to 0°F or even colder





# How does a snowflake/raindrop develop? (Cold Cloud)

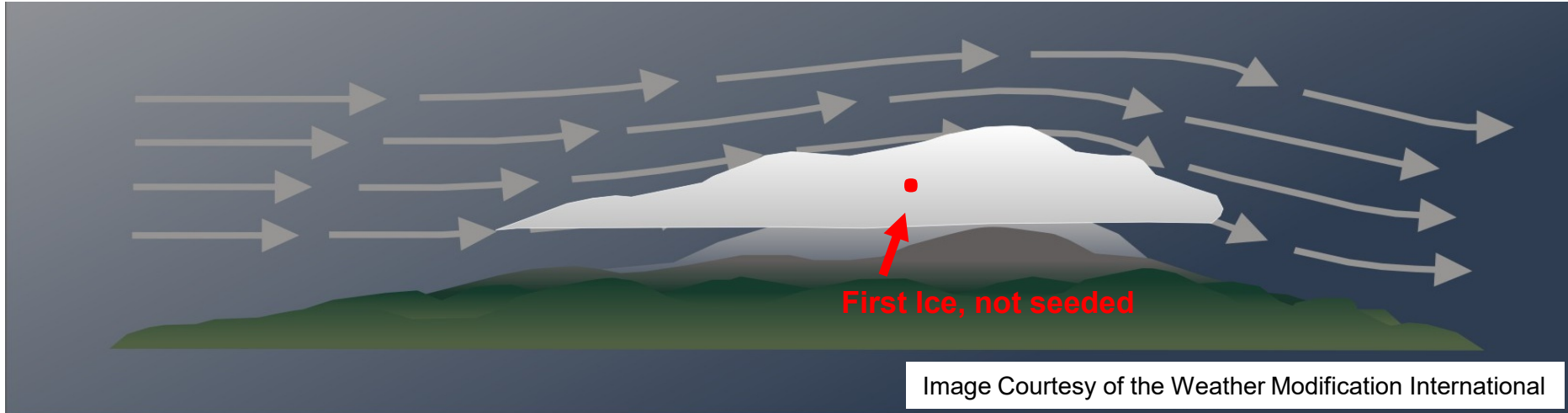


# Cold Cloud Seeding Method

- Glaciogenic Seeding
  - Conducted in clouds cold enough to promote growth of ice.
  - Seeding Agents
    - Silver Iodide
    - Dry Ice
    - Liquid Propane (expands into gas form)

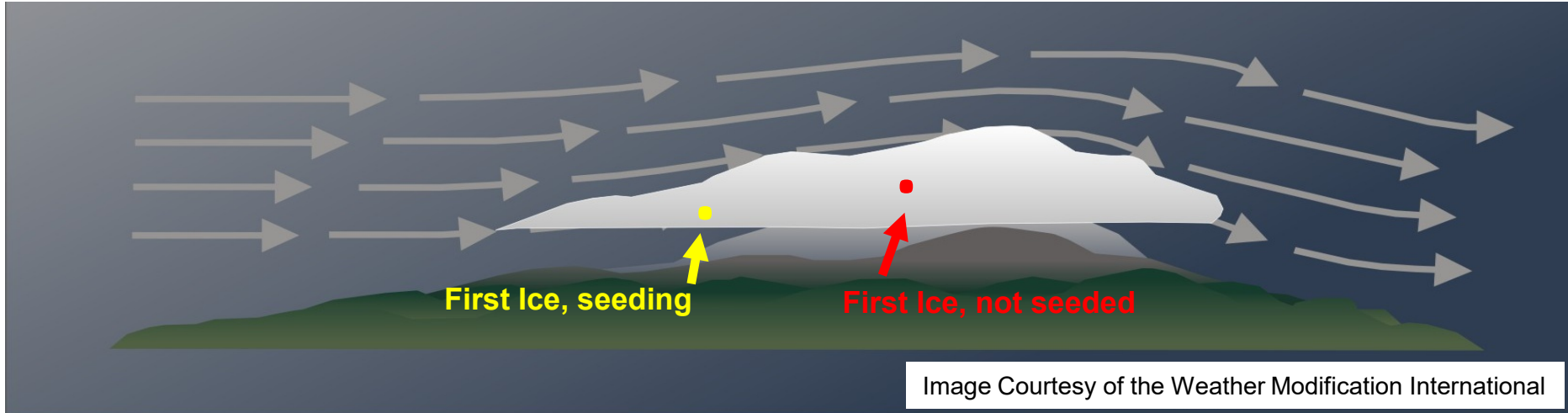
# Winter Orographic Cloud Seeding

- *Cloud seeding* provides additional efficient ice nuclei that function at warmer temperatures, allowing ice formation to begin sooner
- This occurs at temperatures as warm as 23°F, though more effectively at 17°F or colder
- Natural ice nuclei become effective below 5°F



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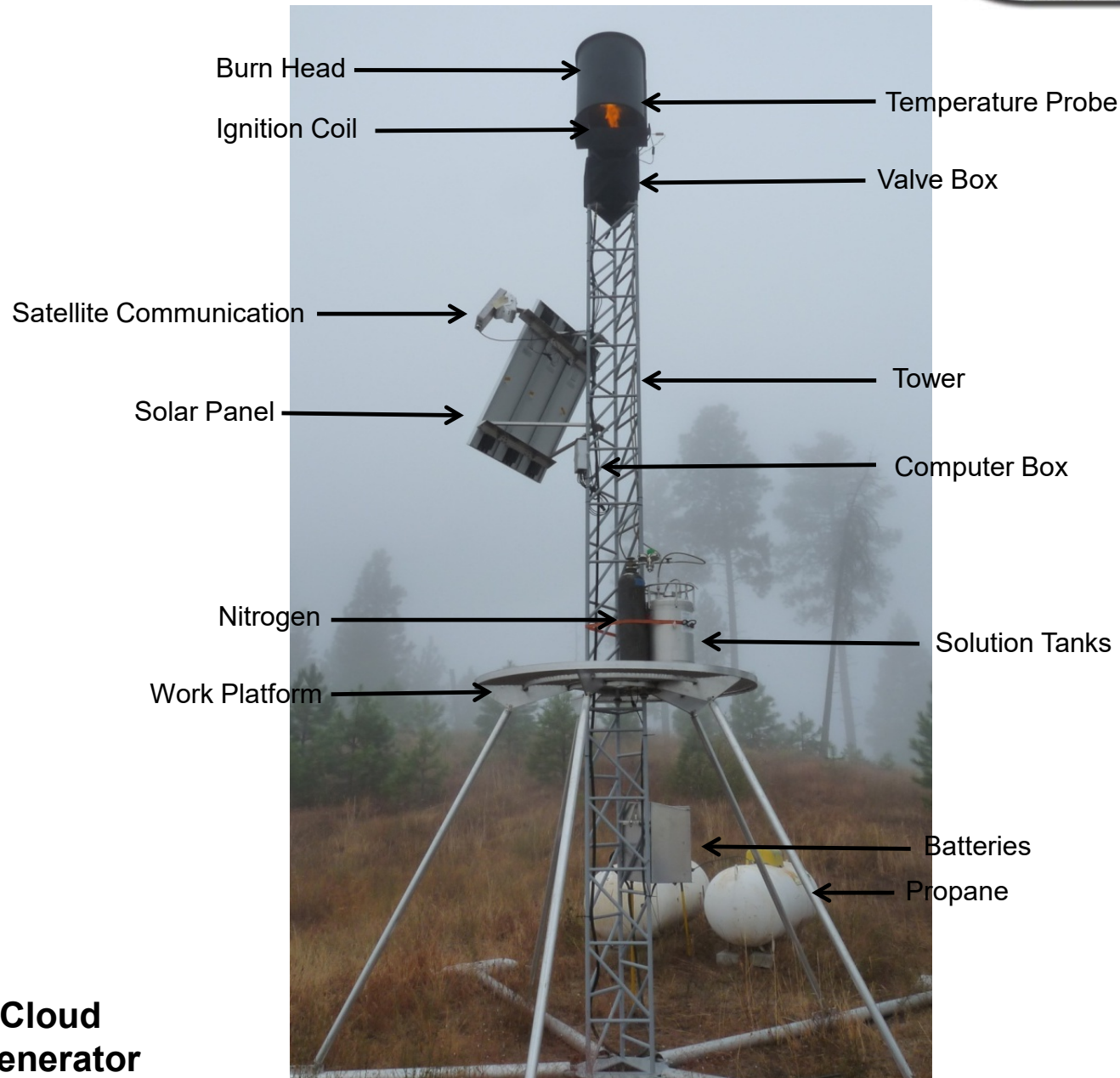


# Seeding Mechanisms



**Manual Cloud  
Seeding Generator**

# Seeding Mechanisms



**Remote Cloud  
Seeding Generator**

# Seeding Mechanisms



**Modified Aircraft**





# Cloud Seeding Programs





# Benefit Estimation

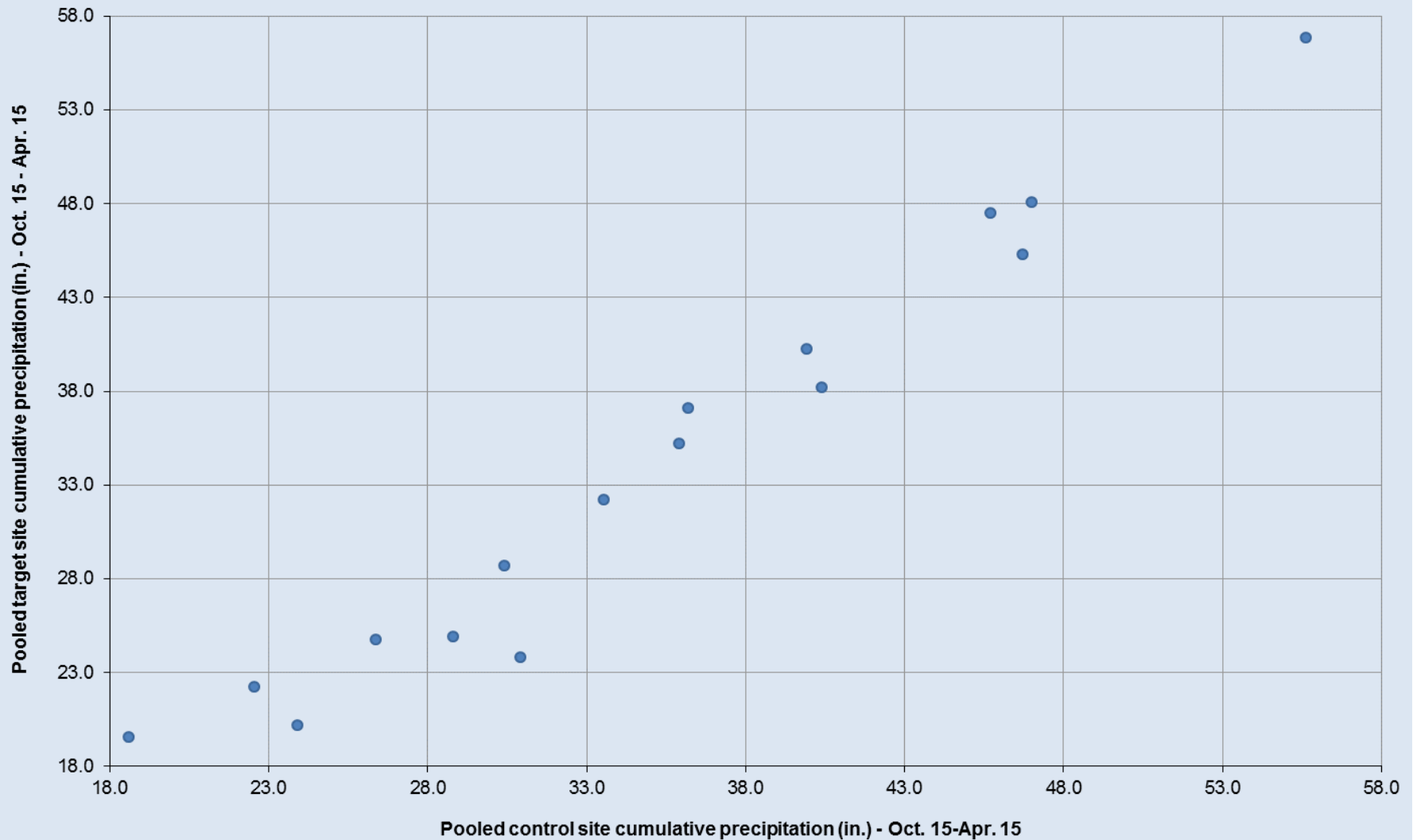


Several different approaches to assess benefits:

- 1) Target-Control Analysis
- 2) Hydrologic modeling using IPC's River Forecast System
- 3) Weather Modeling (WRF)

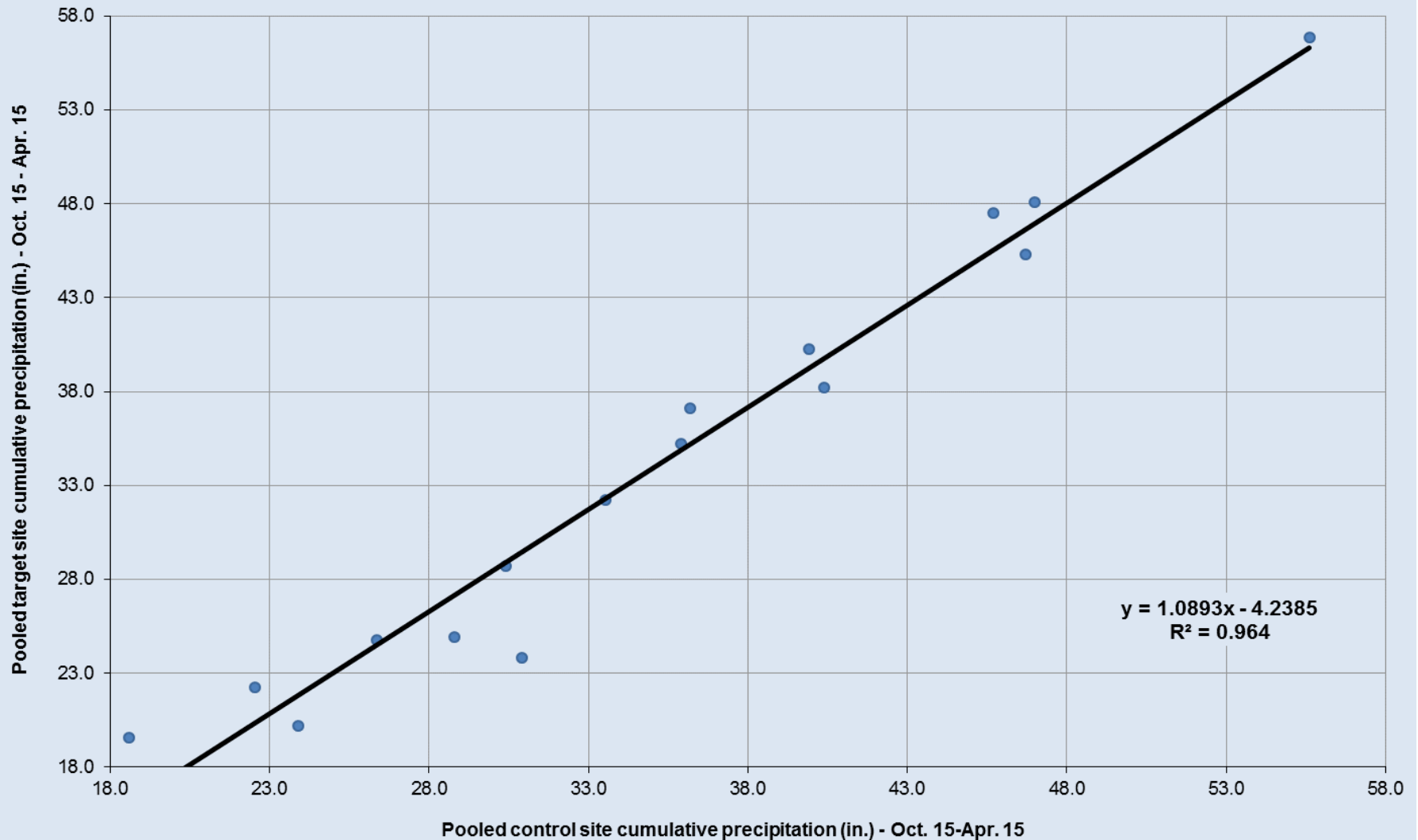
# Target/Control - Development

Target vs. Control Cumulative Precipitation  
1987-2002 Historical Relationship

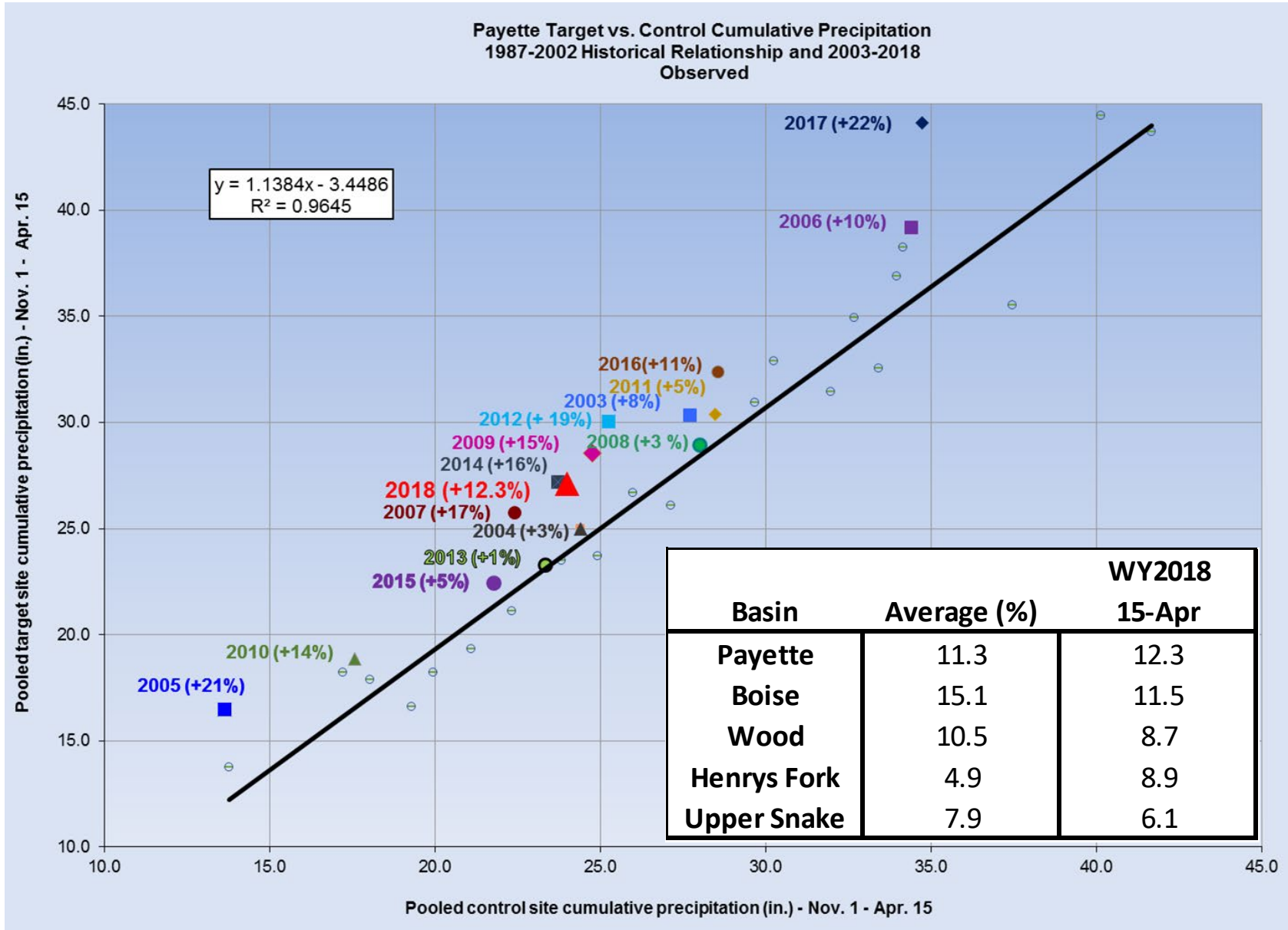


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# Benefits -Target Control





# Hydrologic Modeling

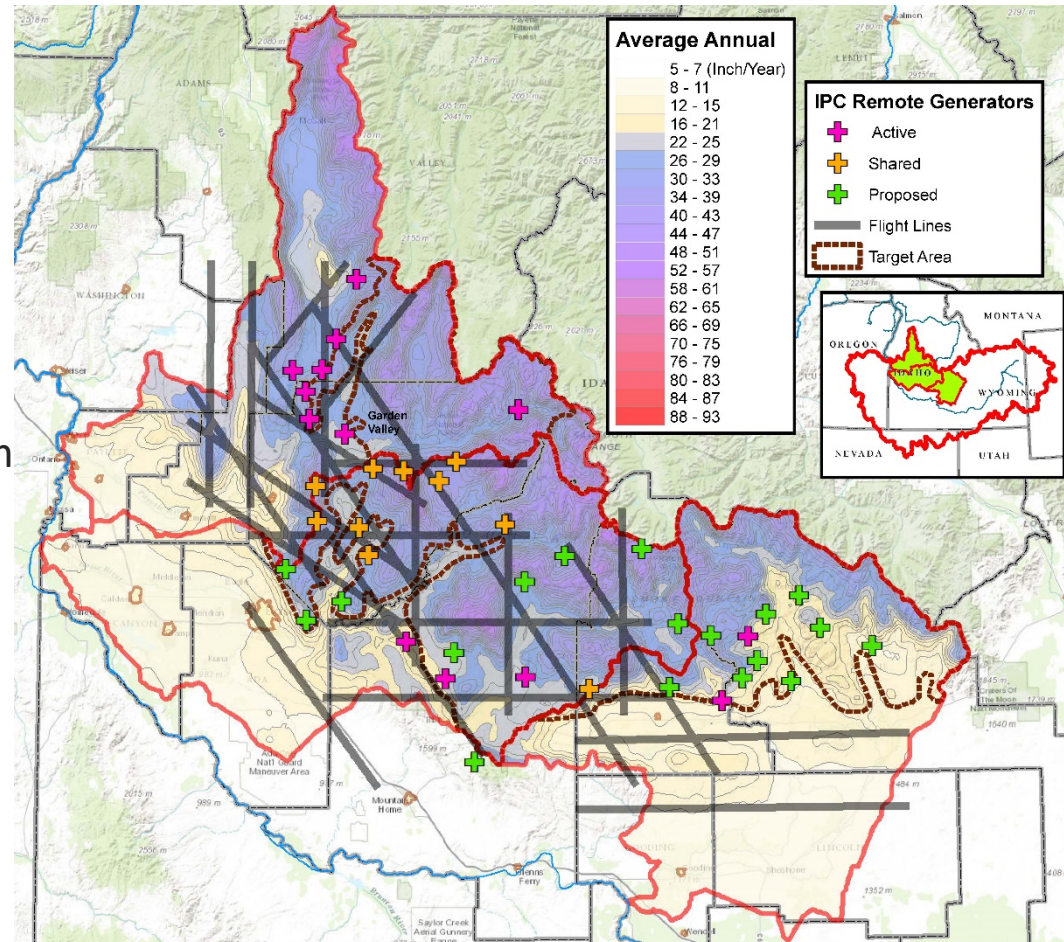
## IPC River Forecast System

### Payette Basin Benefit Estimate

- Additional runoff estimated using IPC's River Forecast System. Simulated water years 1951 – 2001.
- Two scenarios...with and without cloud seeding (adj. precipitation)
- Streamflow increase approximately **270 KAF / year** for Payette (Target – Control precipitation increase)
- Approximately half of the benefit is from remote ground generators, and half is from plane.

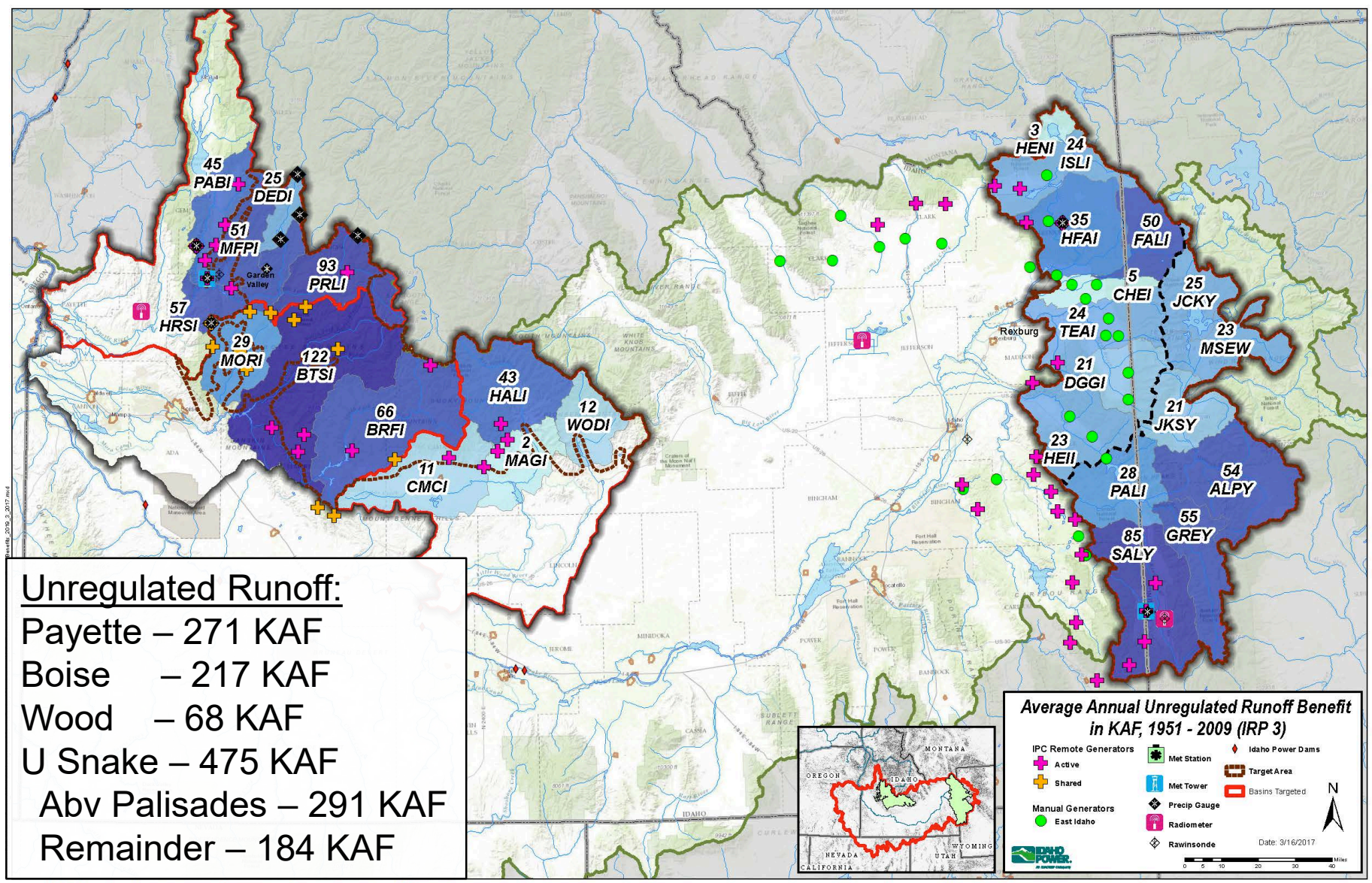
### Boise & Wood Basins (10% precip)

- Boise Basin: **206 KAF / year**
- Wood River Basin: **80 KAF / year**





# Runoff Benefits at Build-out





# WRF Model

## Weather Research & Forecast model

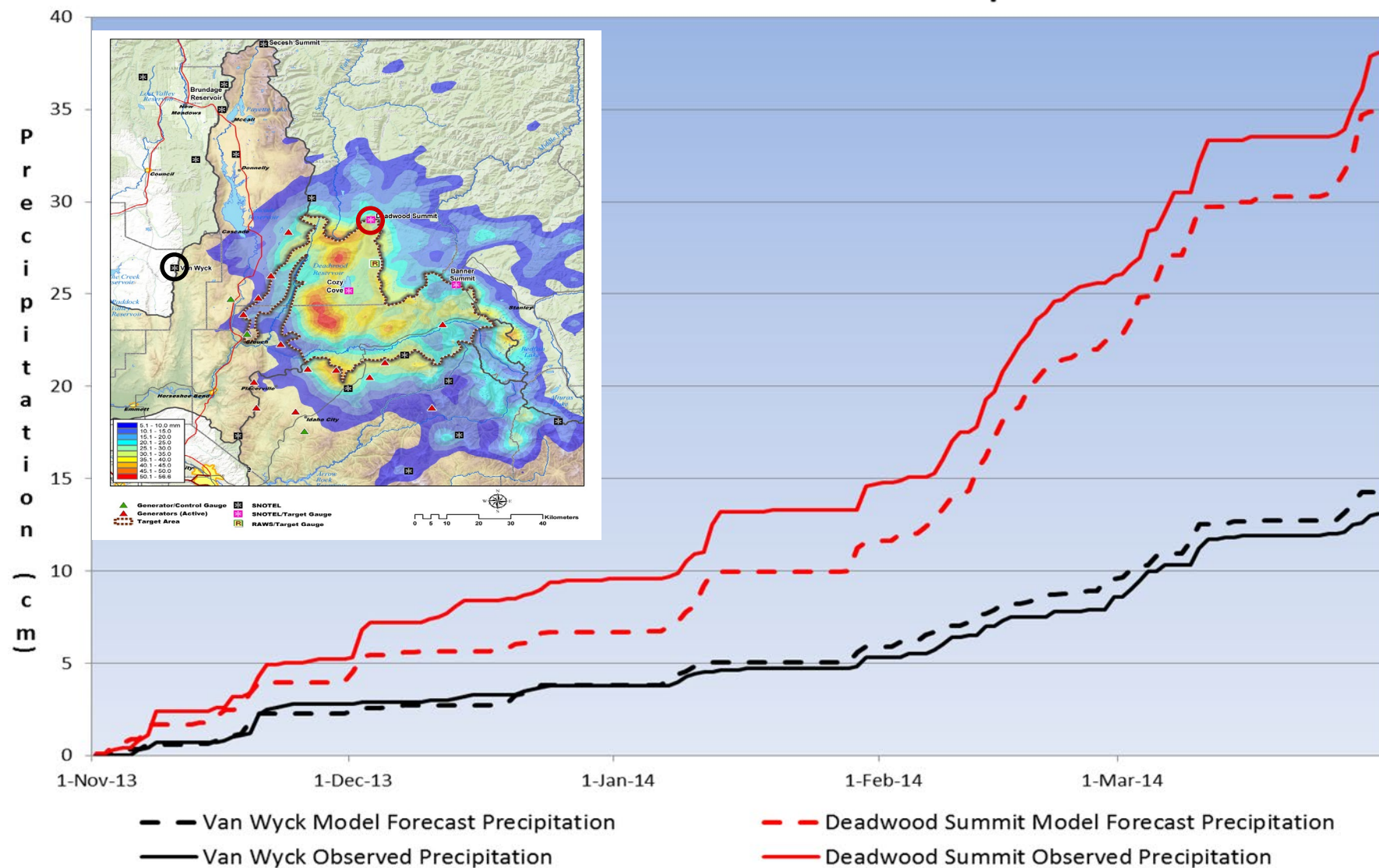
- Started working with NCAR 2011
  - High resolution model specific to our region
    - Guide CS operations
    - Planning
    - Evaluate Benefits by Season
  - Model is currently used for:
    - near term forecasting
    - ‘case calling’
    - Guiding operations
    - Planning / design
  - Model isn’t ready to evaluate benefits
    - SNOWIE project will provide data to verify model, improve model
    - NCAR, implement improvements to WRF
    - BSU, trace chemistry, WRF Hydro
  - WRF can be used to simulate SNOTEL sites (virtual SNOTEL)



# WRF CS Simulation

## Payette

### WRF Model Forecast Versus Observed Precipitation





# Extra Area Effects

- Other Names
  - Down Wind Effects
  - Down Range Effects
- One of the most commonly asked question about cloud seeding;
  - “Does increasing precipitation in a particular area decrease the amount of precipitation down range?”
    - This is the “Rob Peter to pay Paul” scenario.
- Research on the subject has shown there are neutral or positive effects (more precipitation) from a well run program

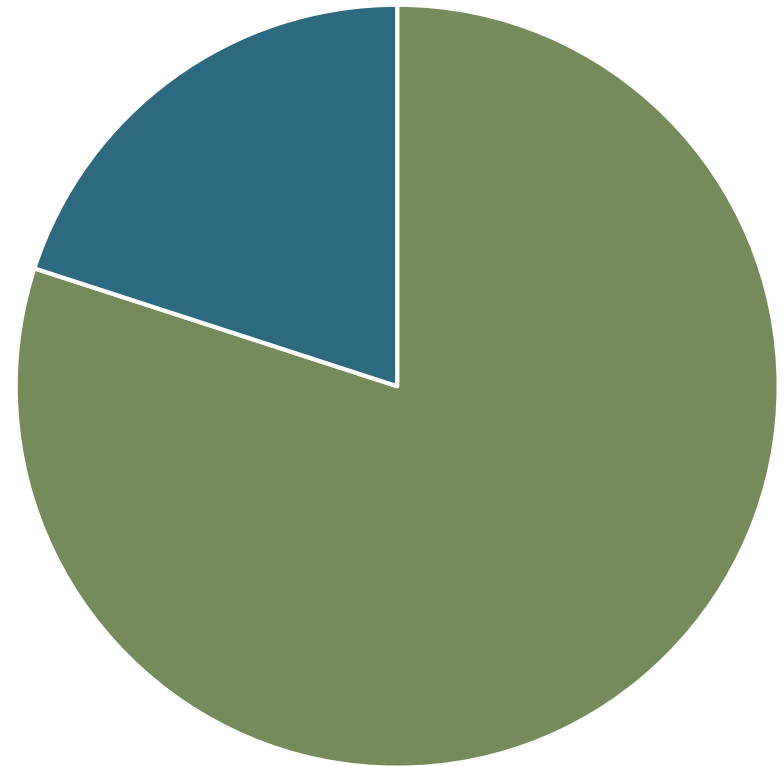
# Extra Area Effects

- Solak et al. (2003) used a target/control regression approach and concluded positive benefits up to 200 km down range of the target area in central and southern Utah. He also concluded that the apparent limit to extra area increases was about 160 – 200 km.
  - North American Weather Consultants expanded this work and concluded that there was a:
    - 14% in the target area
    - 14% increase 0-120 km east of the target area
    - 5% increase 120-240 km east of the target area

# Extra Area Effects

- To put quantities into context...
  - Nature will condense about 20% of the water vapor as moist air rises over a mountain barrier (the remaining 80% remains uncondensed).

Atmospheric Water Budget

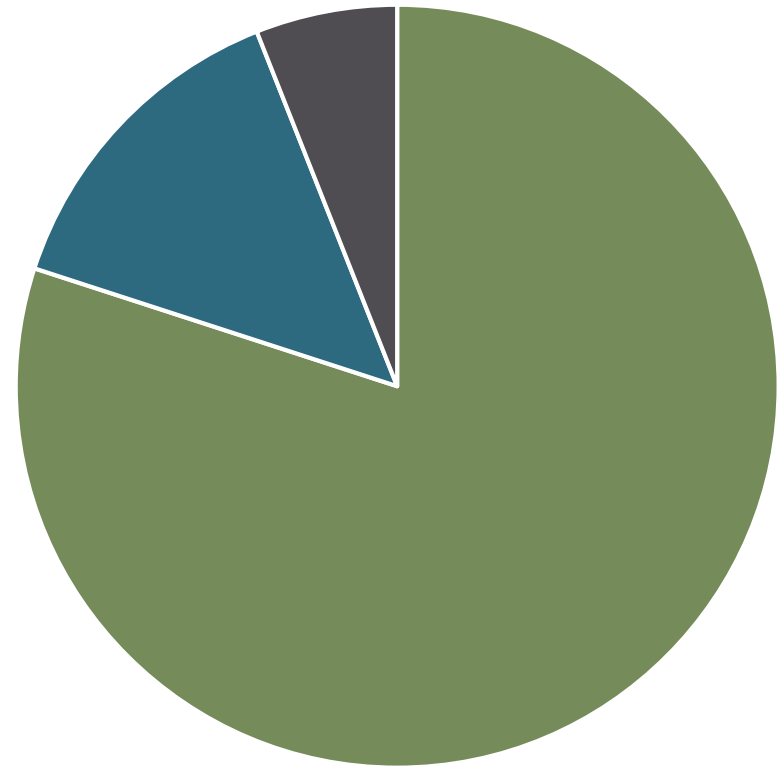


- Uncondensed Water Vapor
- Condensed into Cloud

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  - Winter storms are typically about 30% efficient, meaning 30% of the 20%, or 6% of the total, reaches the ground.

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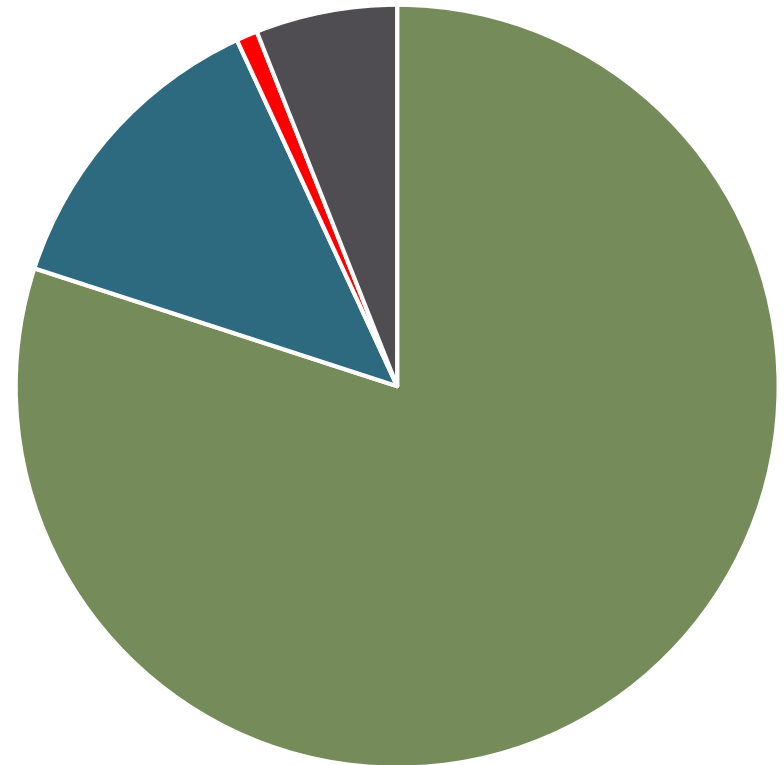


■ Uncondensed Water Vapor ■ Condensed into Cloud  
■ Precipitation

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  - Winter storms are typically about 30% efficient, meaning 30% of the 20%, or 6% of the total, reaches the ground.
  - If cloud seeding increases precipitation 15%, that amounts to 15% of the 6%, or 0.9% of the total water vapor is the additional amount cloud seeding pulls from the atmosphere.

Atmospheric Water Budget



■ Uncondensed Water Vapor ■ Condensed into Cloud  
■ Cloud Seeding ■ Precipitation



# Environmental Safety of Silver Iodide

- The WMA has issued a statement on toxicity of silver originating from cloud seeding...  
[http://www.weathermodification.org/images/AGI\\_toxicity.pdf](http://www.weathermodification.org/images/AGI_toxicity.pdf)
  - “The published scientific literature clearly shows **no environmentally harmful effects** arising from cloud seeding with silver iodide aerosols have been observed; nor would they be expected to occur. Based on this work, the WMA finds that silver iodide is environmentally safe as it is currently being dispensed during cloud seeding programs.”
- Australia’s Natural Resource Commission’s review of Snow Hydro’s analysis of their seeded watershed resulted in no evidence of adverse environmental impact.  
<http://www.nrc.nsw.gov.au/cloud-seeding>
  - “Our review of Snowy Hydro’s analysis of data from its environmental monitoring over the first phase of the trial (2004 to 2009) found that it provides **no evidence that the trial has had adverse environmental impacts** over this period. The analysis provides *no evidence of accumulation of silver iodide or indium trioxide in sampled soils, sediment, potable water or moss in the areas being tested*. It also provides no evidence of impacts on mountain riverine ecosystems or snow habitats. In addition, it detected no difference between the concentrations of ammonia and nitrogen oxides in seeded and unseeded snow.”
- Other Technical Documents:
  - <http://weathermodification.org/technicaldocs.php>



# Environmental Concerns

More than 20 comprehensive studies and data reviews of the environmental affect of the use of silver iodide for cloud seeding all concur that there is ***no evidence for adverse effects to human health or the environment*** from the use of silver iodide for cloud seeding.

- PG&E EA – 1995, 2006
- Snowy Hydro – 2004-2014, ongoing
- Williams and Denholm – 2009
- USBR Project SkyWater – 1977, 2009, 2013
- Cardno/Entrix Geochemistry and Impacts of Silver Iodide Use in Cloud Seeding (for PG&E) – 2011
- Santa Barbara County CEQA – 2013
- BSU and Heritage Environmental: Literature Review – 2015
- Sacramental Municipal Utility District – 2017
- State of Wyoming Level III Feasibility Study Laramie Range Siting and Design Final Report – 2017
- Placer County Water Agency CEQA – 2018

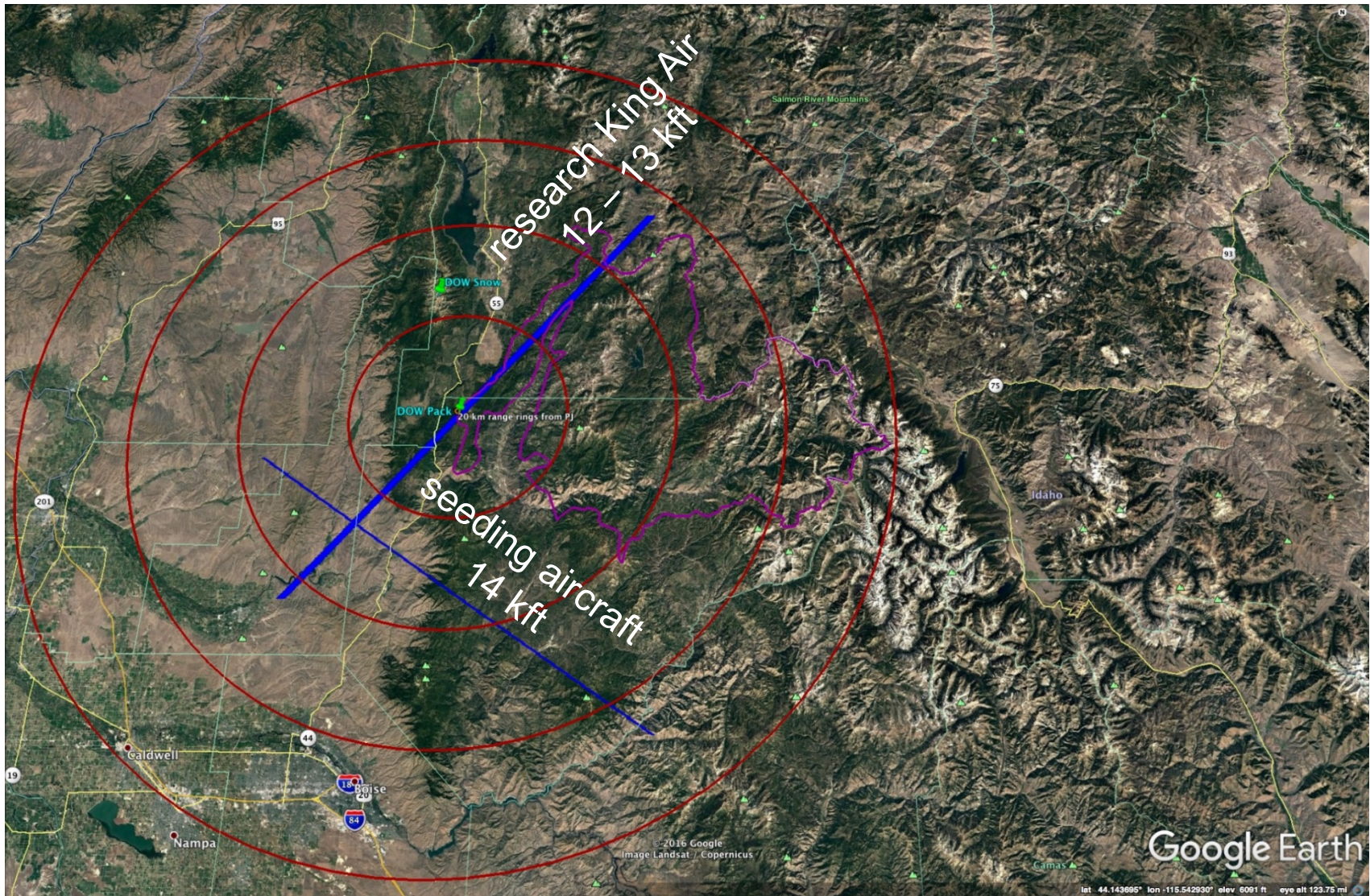
# Flooding

- Cloud seeding has raised concerns about flooding from early on
  - Rain-on-snow
  - Excessive snowpack
- Well-designed and responsibly conducted programs include suspension criteria
- Suspension criteria was part of Idaho Power's original proposal to the IPUC
- Suspension criteria are reviewed and updated. Suspension criteria for the Upper Snake was recently modified to incorporate reservoir conditions.



# SNOWIE IOP

Seeded and Natural Orographic Wintertime clouds - the Idaho Experiment  
Intensive Observation Period

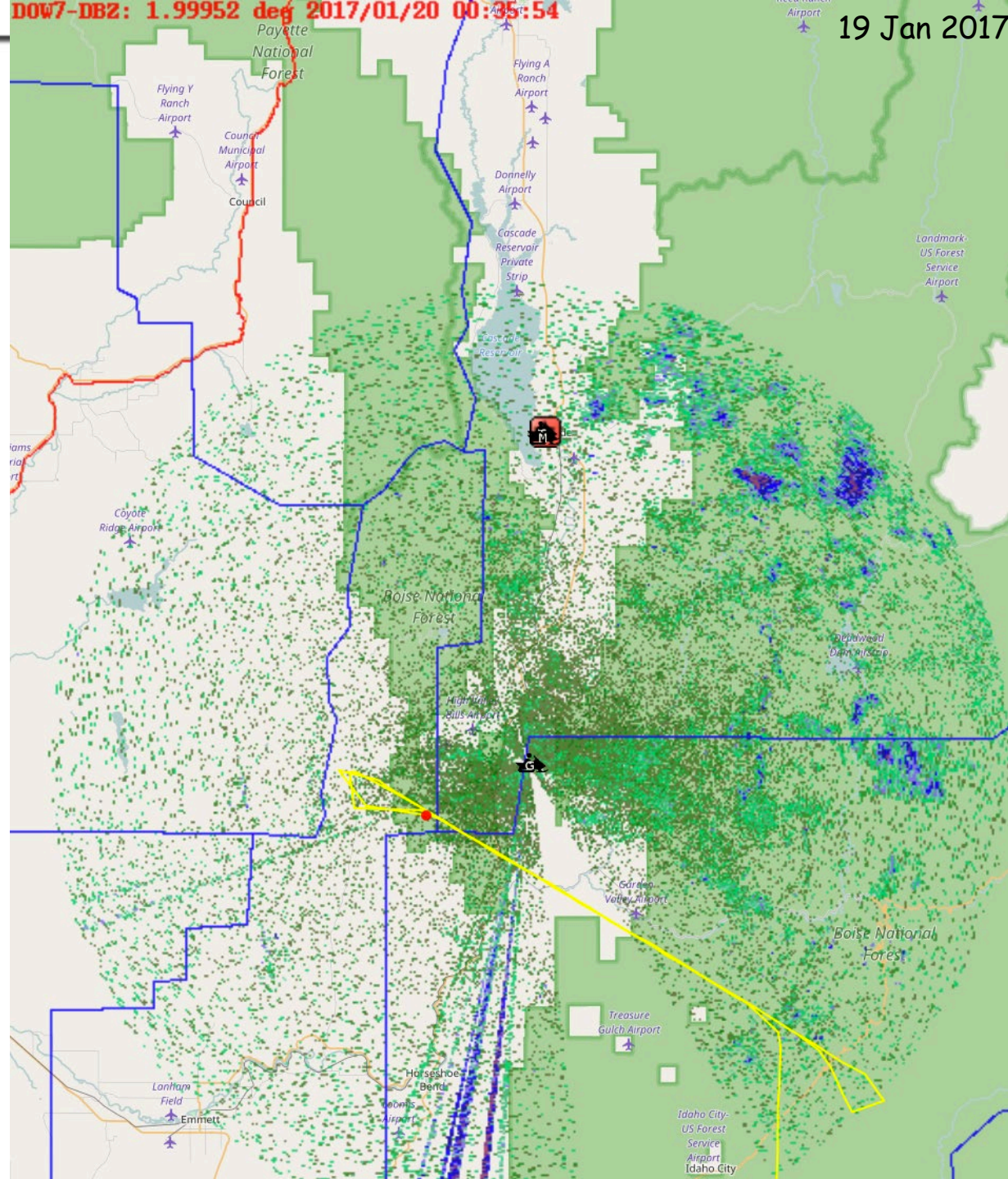




19 Jan 2017

A map of the Boise National Forest area. The map shows various airports, including Council, Donnelly Airport, Cascade Reservoir Private Strip, Boise, Garden Valley Airport, Treasure Gulch Airport, Idaho City-US Forest Service Airport, Emmett, and Horseshoe Bend. It also shows landmarks like US Forest Service Airports and the Boise National Forest. A yellow line labeled 'track 2B' is drawn across the map, starting from the bottom left and extending towards the top right. A red dot is located on this line near the bottom right. The map is overlaid with a grid of green and blue dots, and a blue line representing a boundary or road.

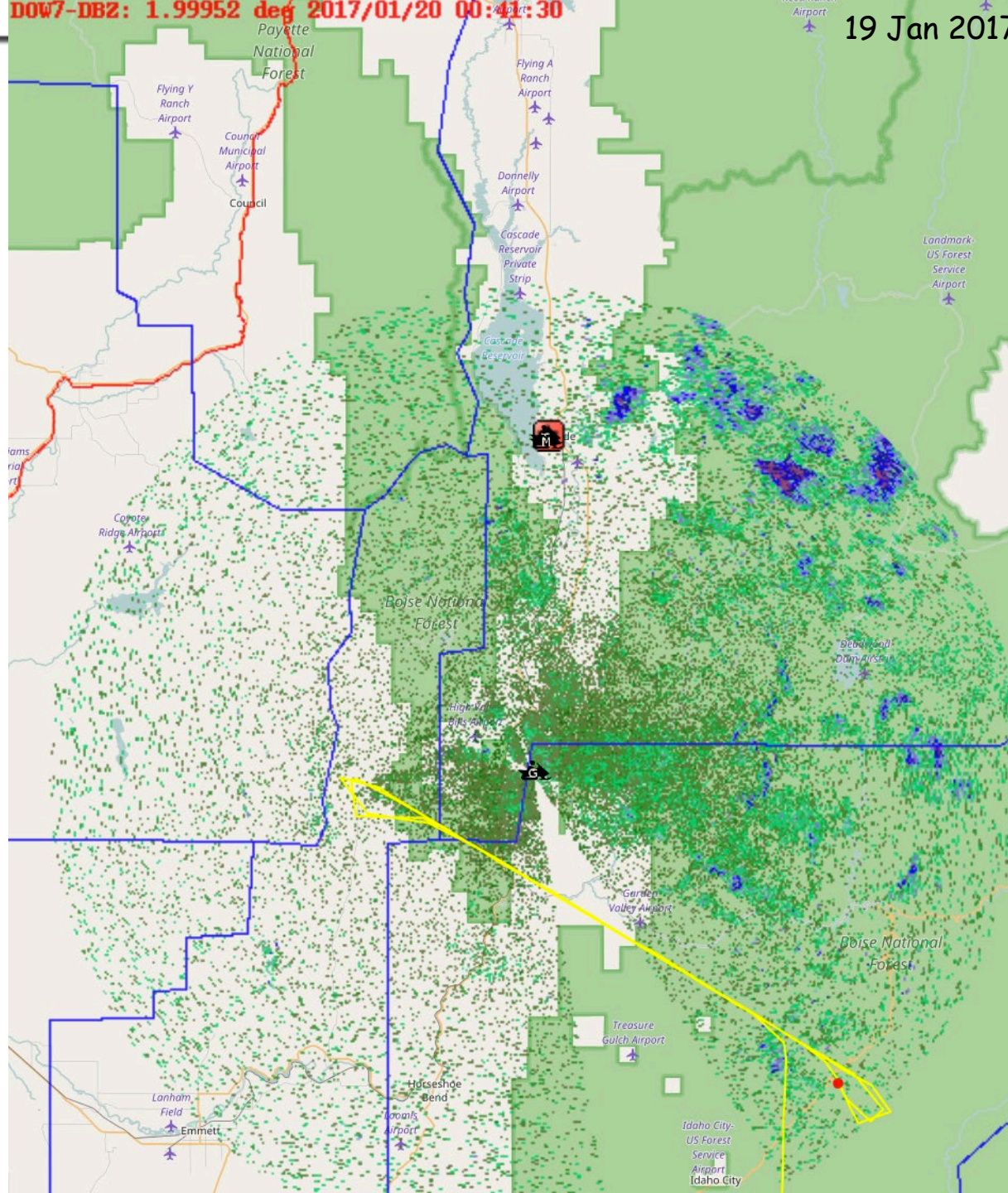




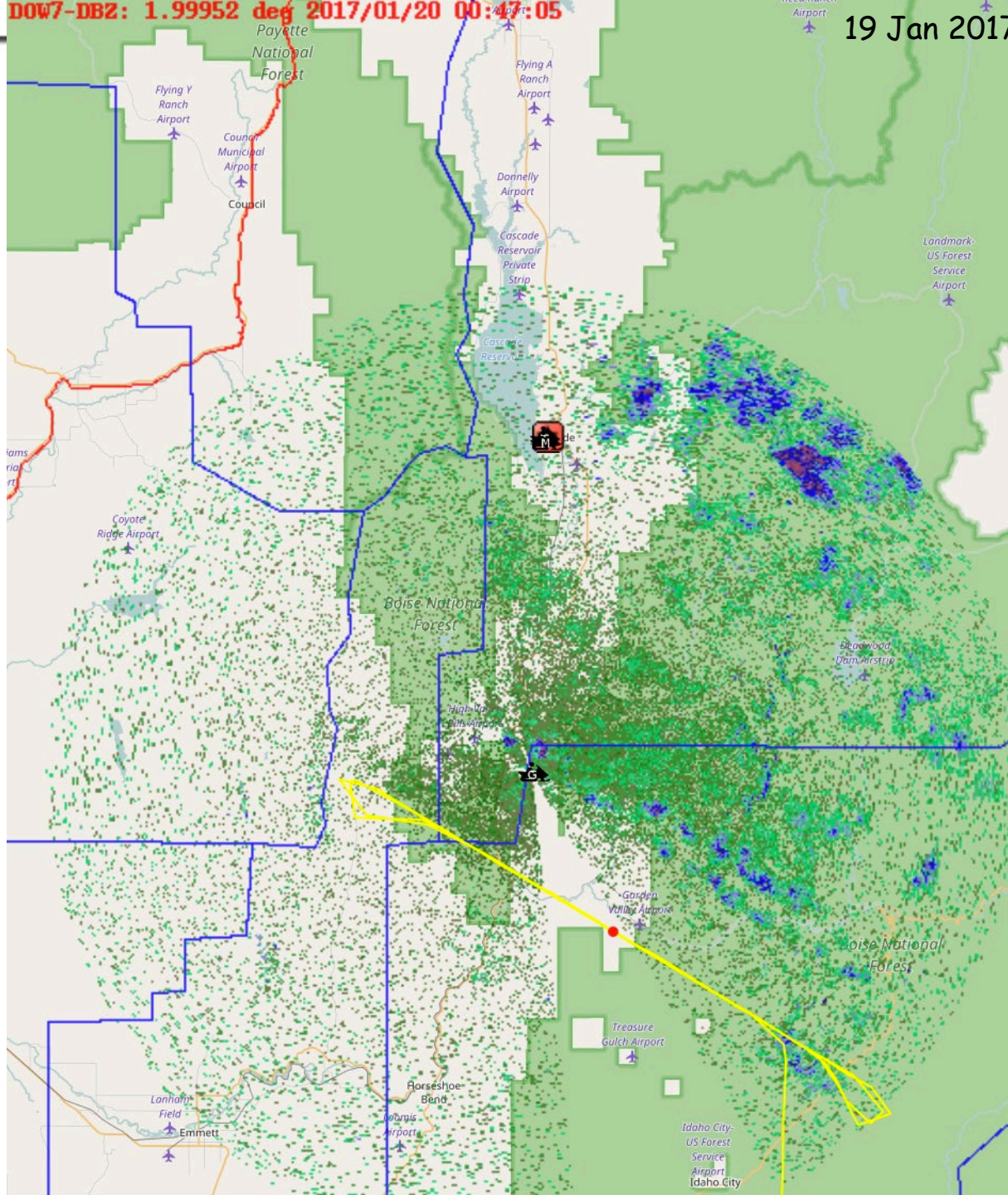


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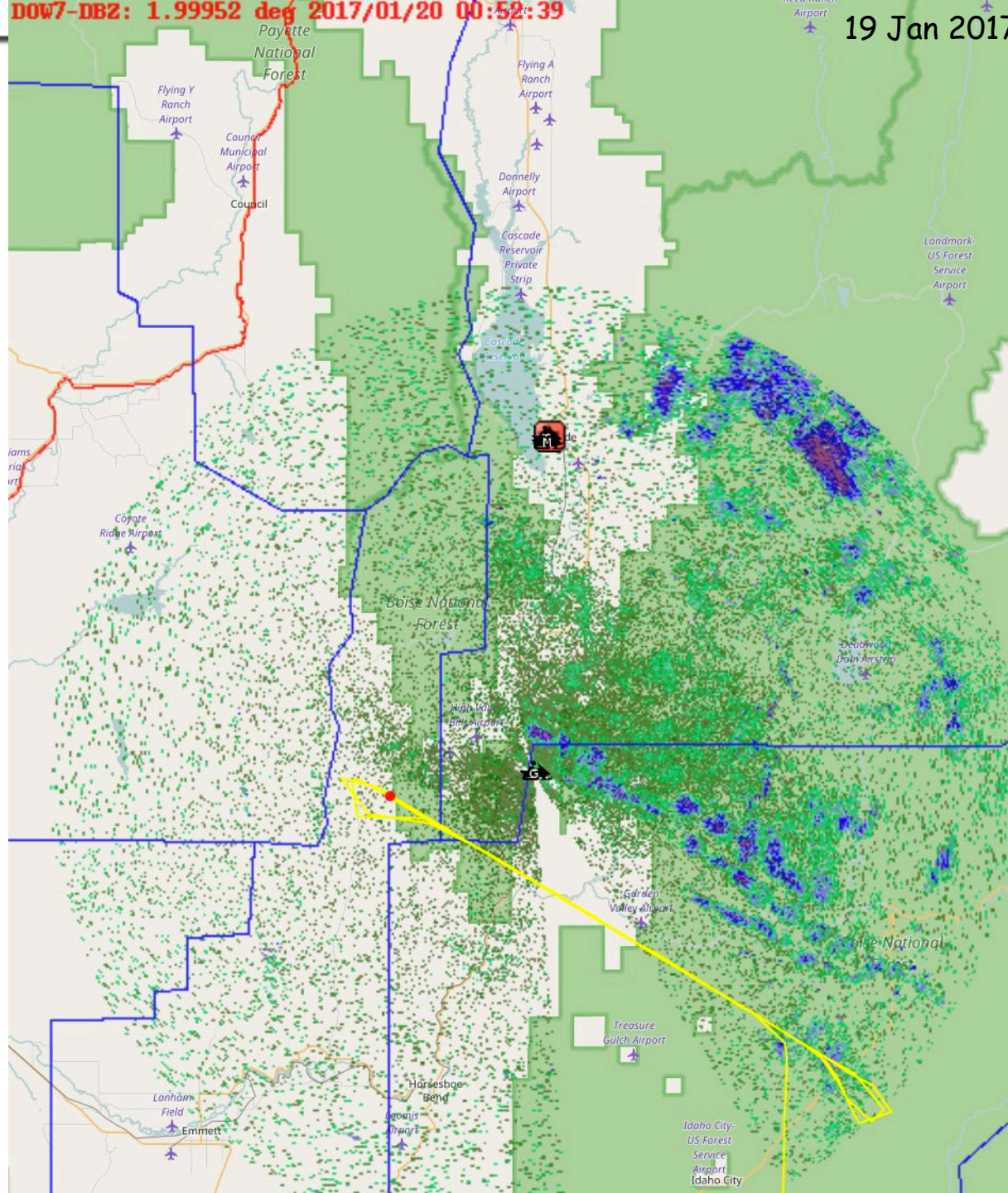
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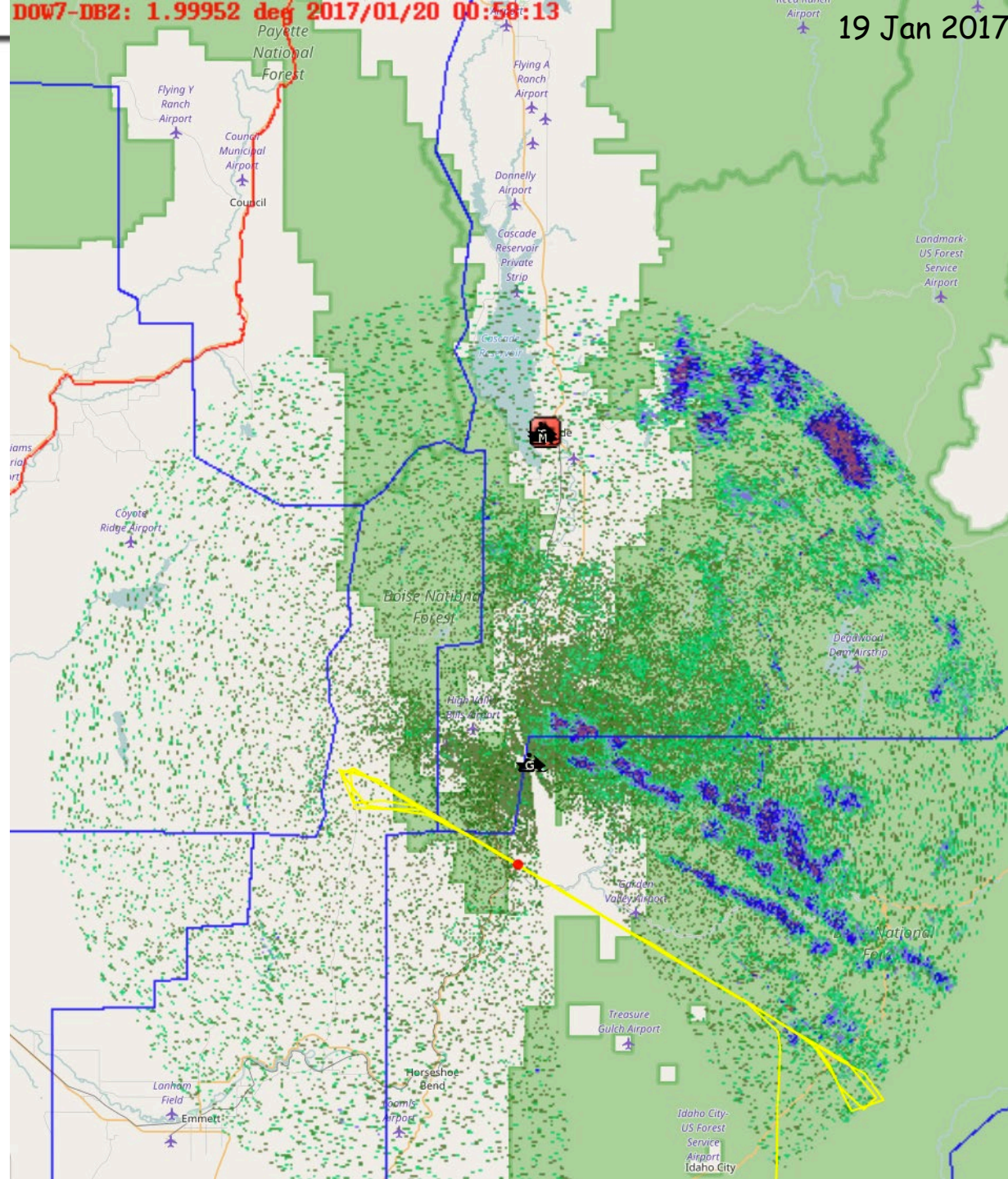








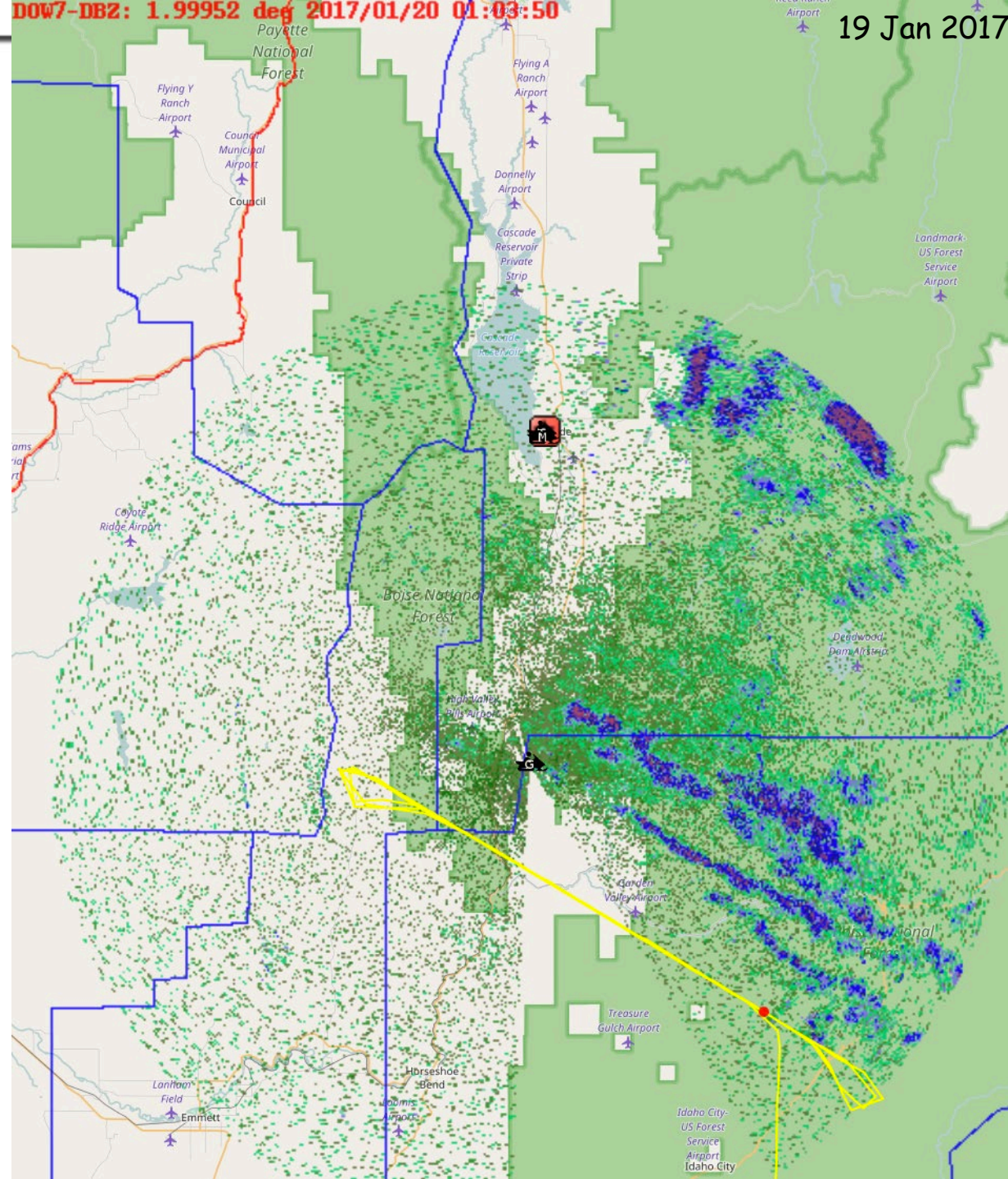




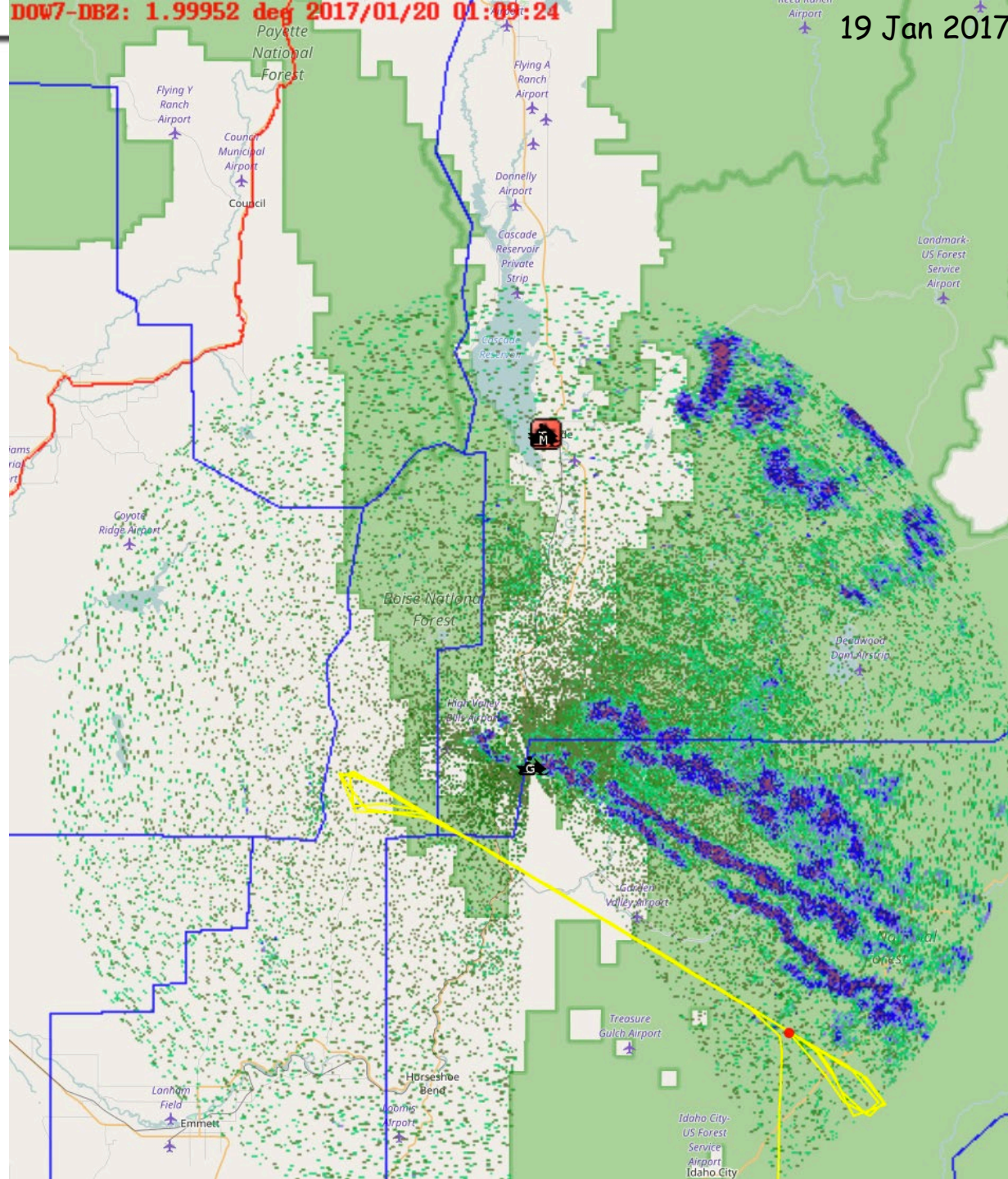


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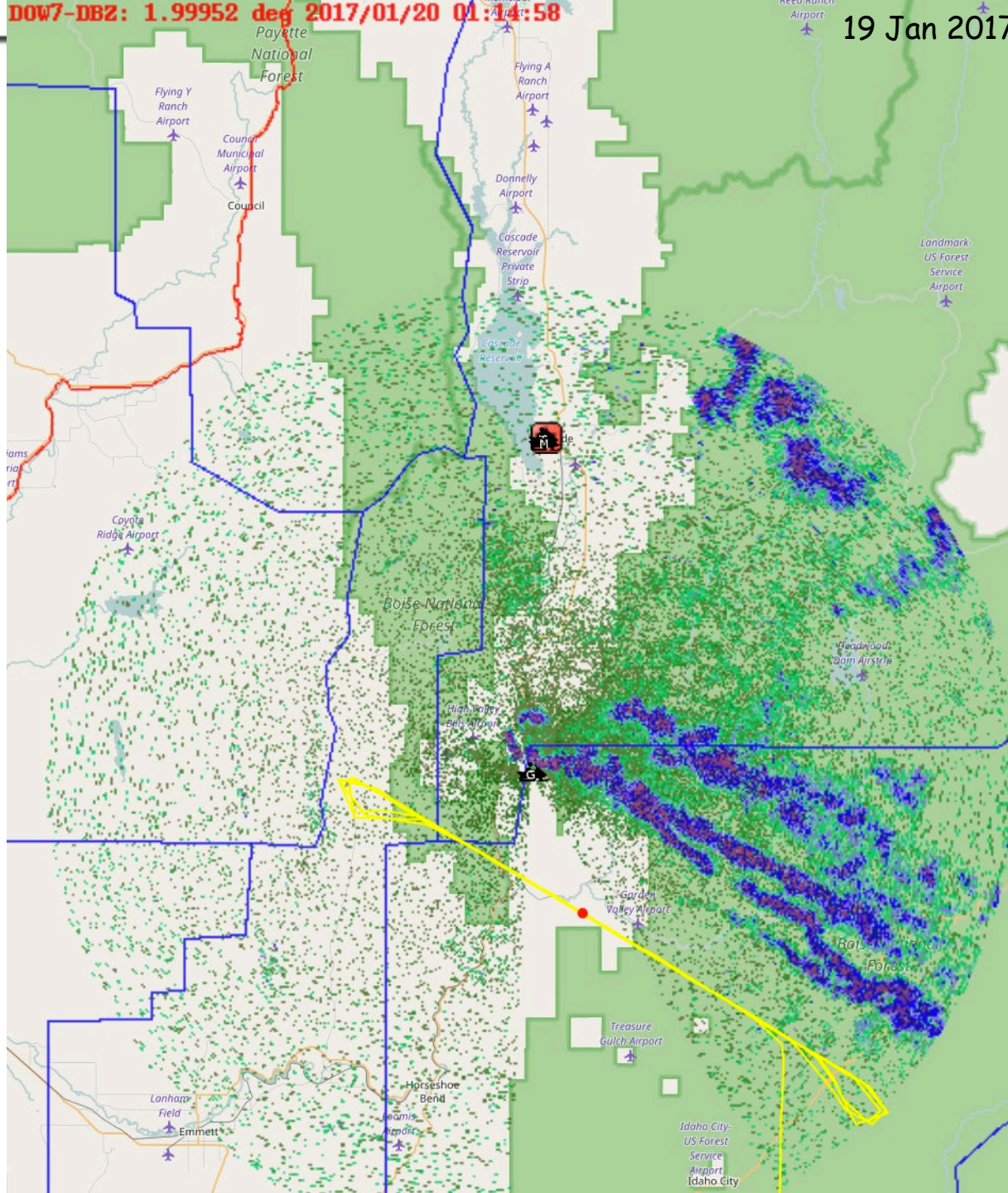






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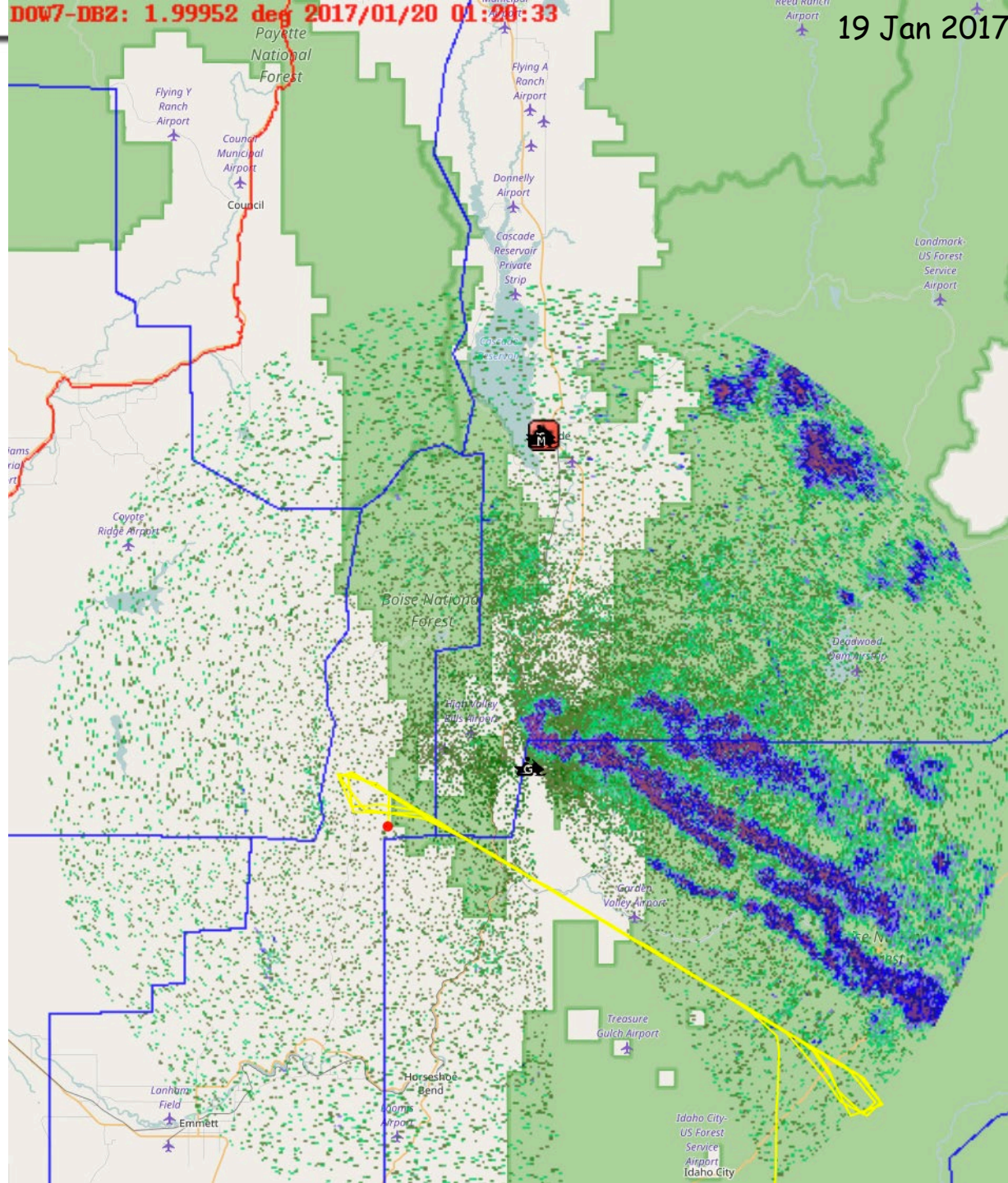
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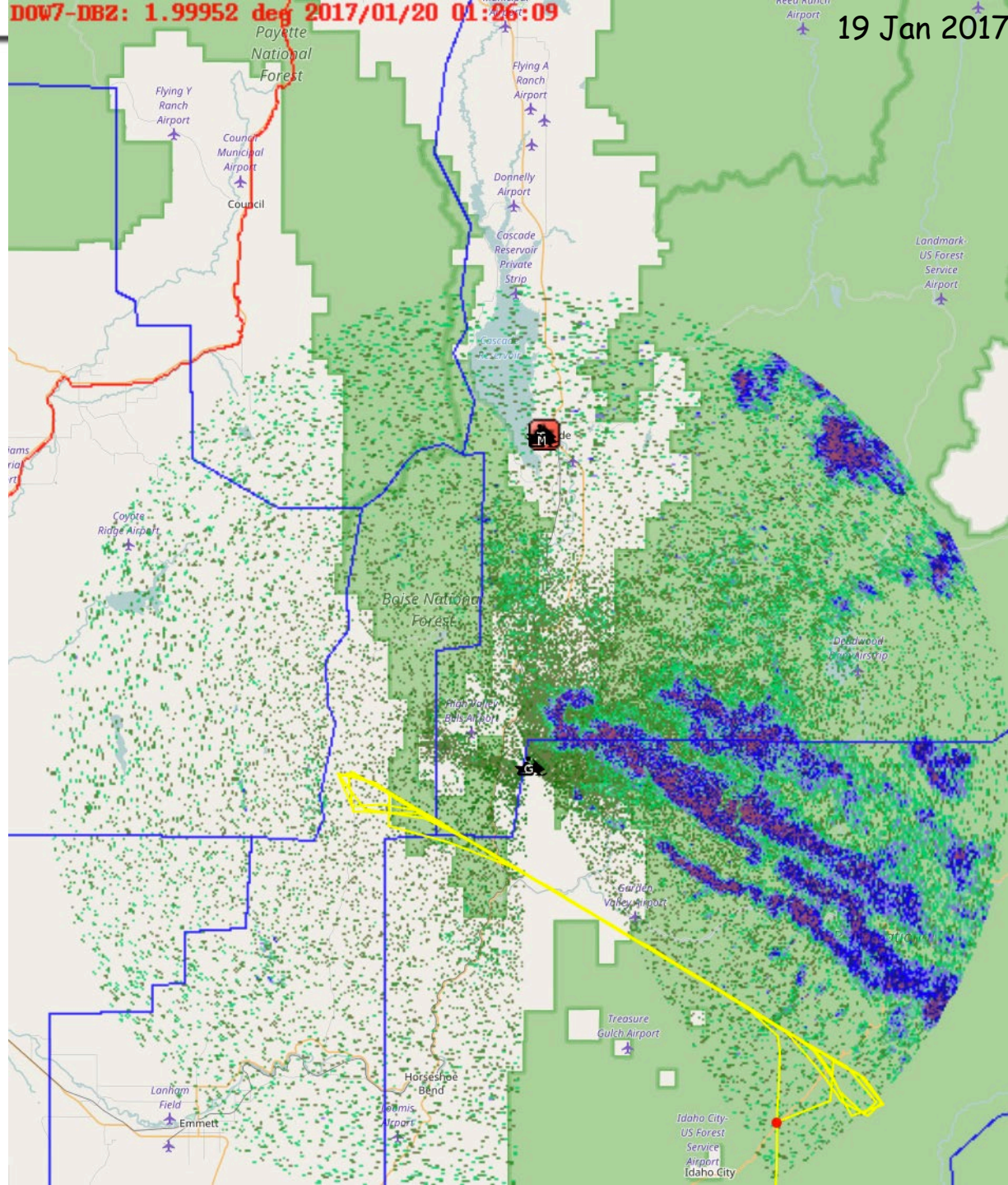


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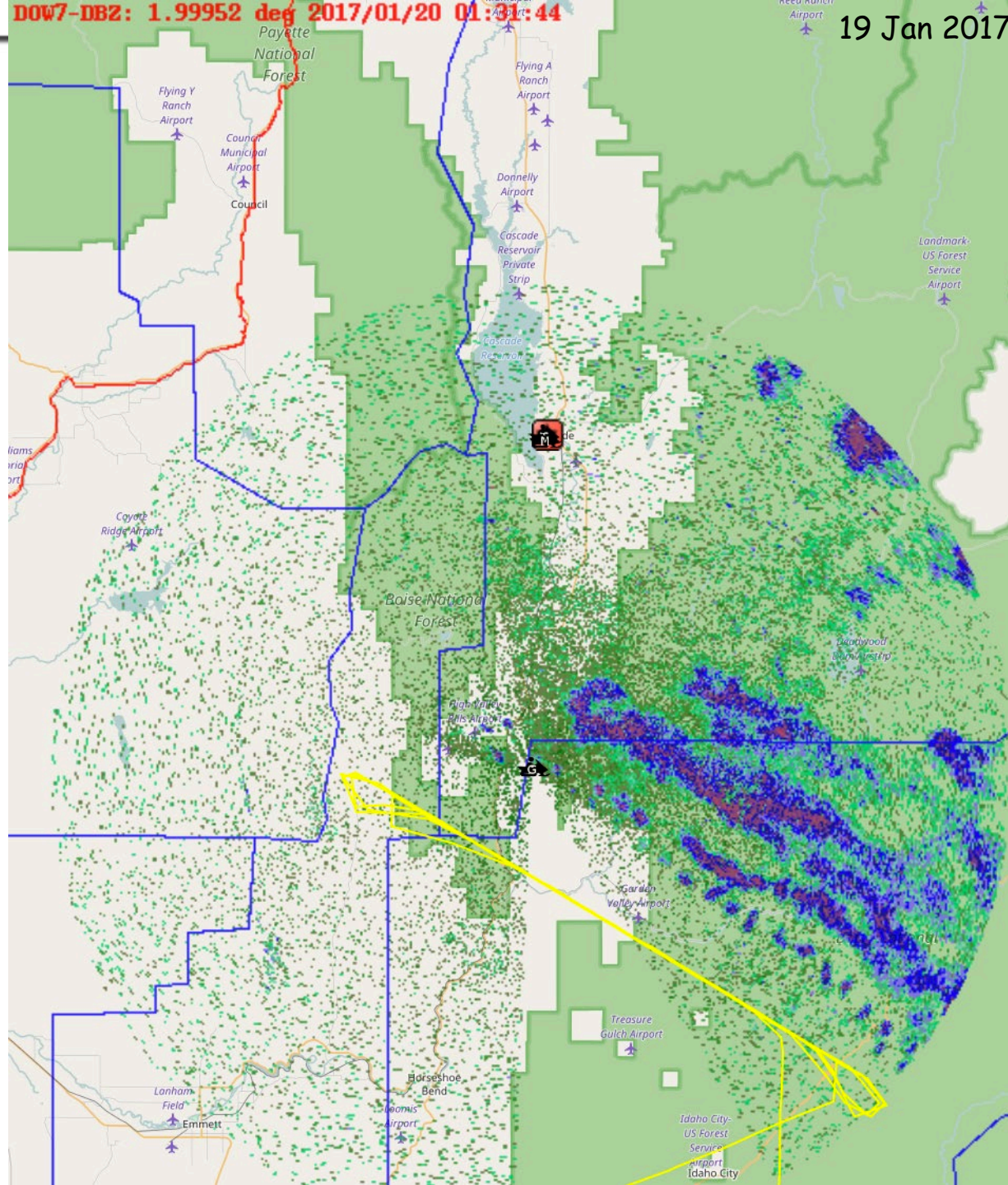






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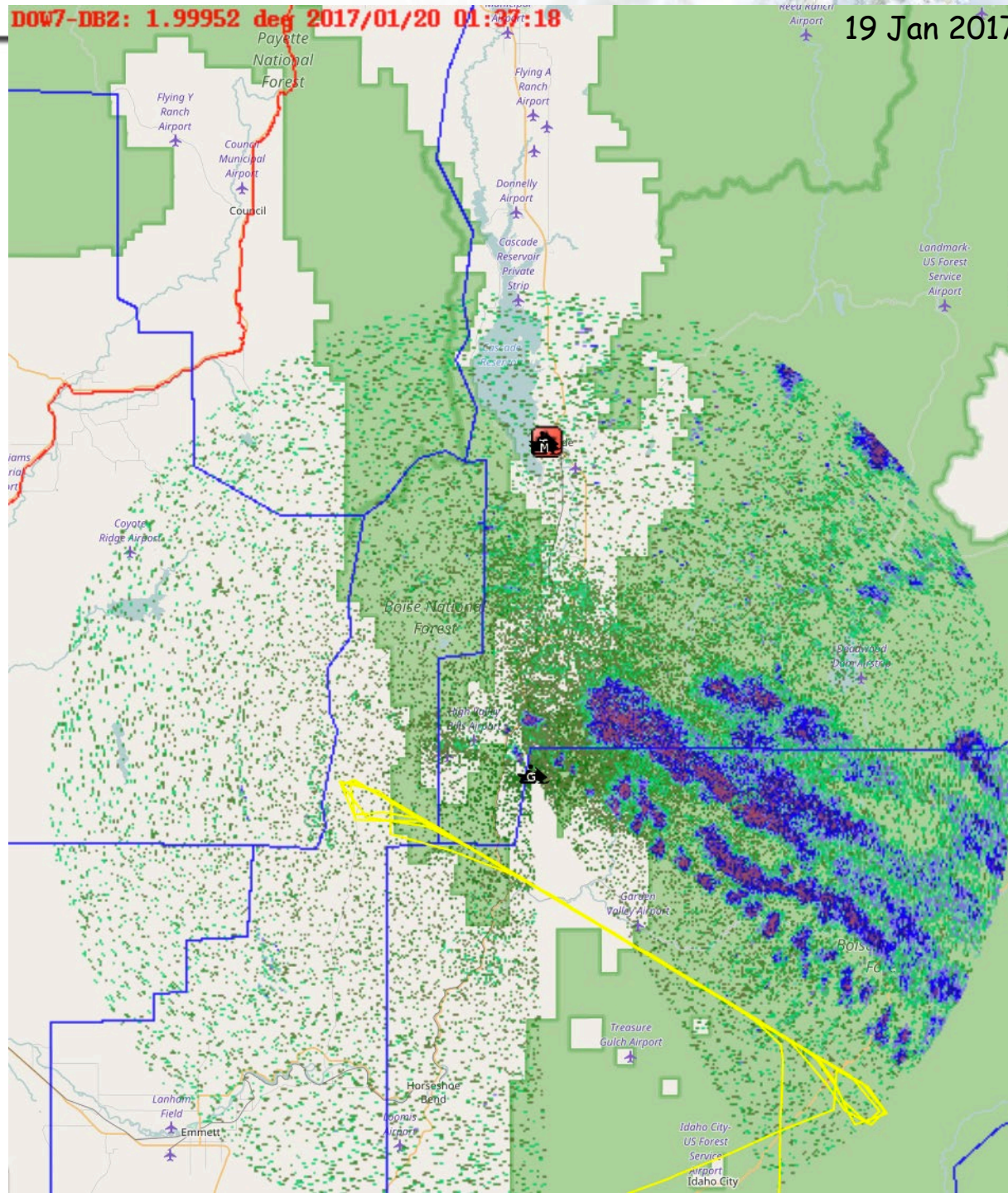
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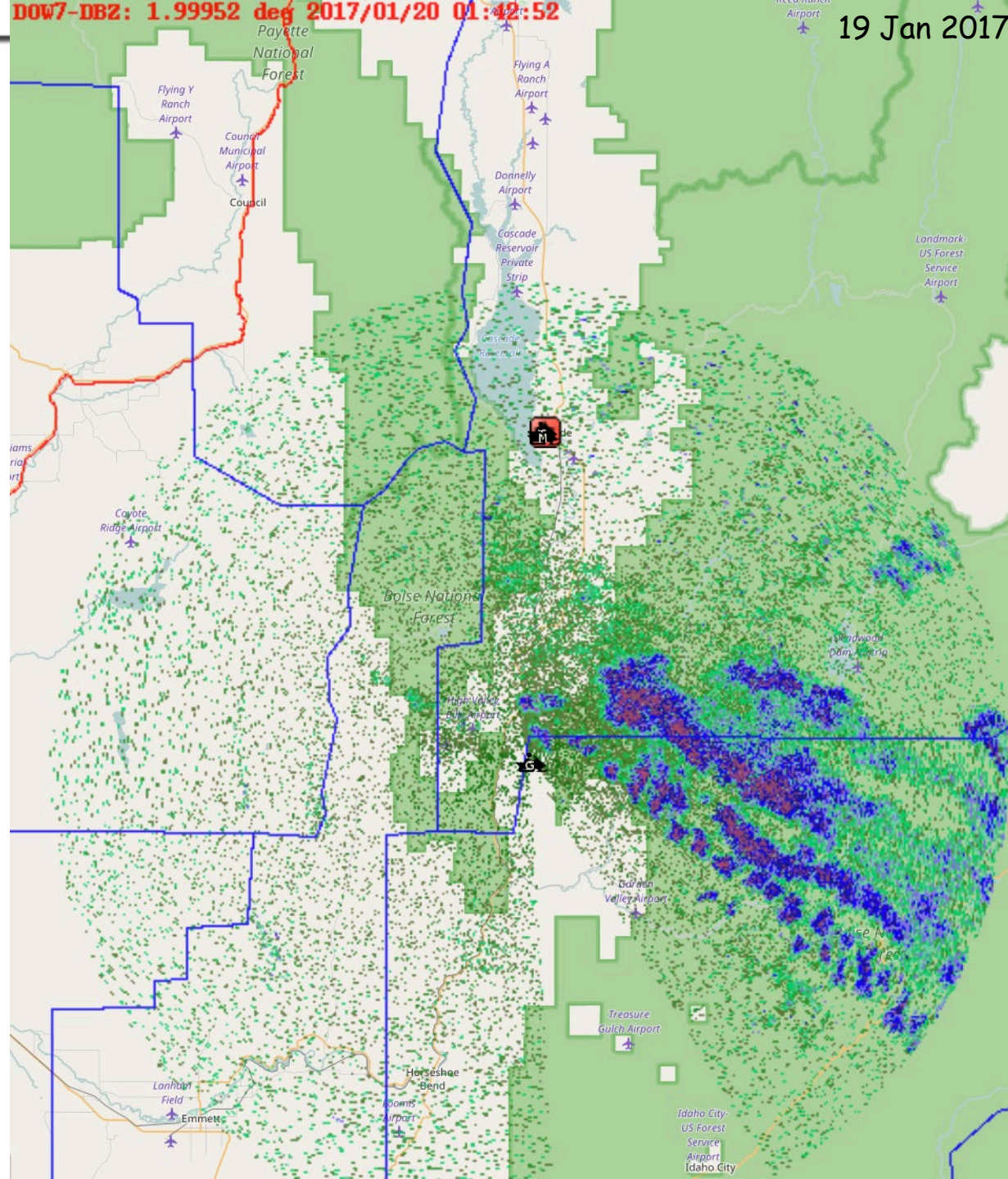


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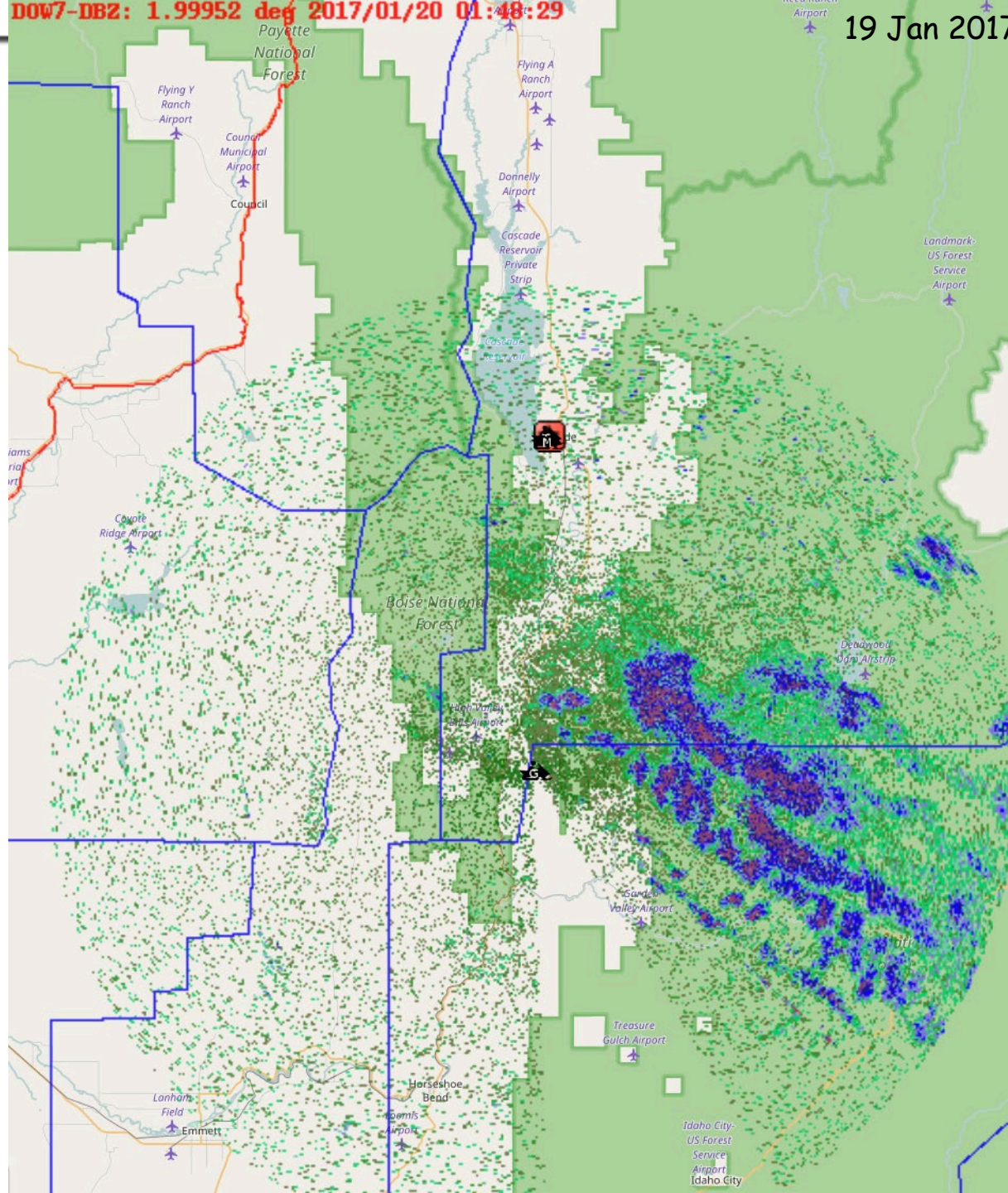






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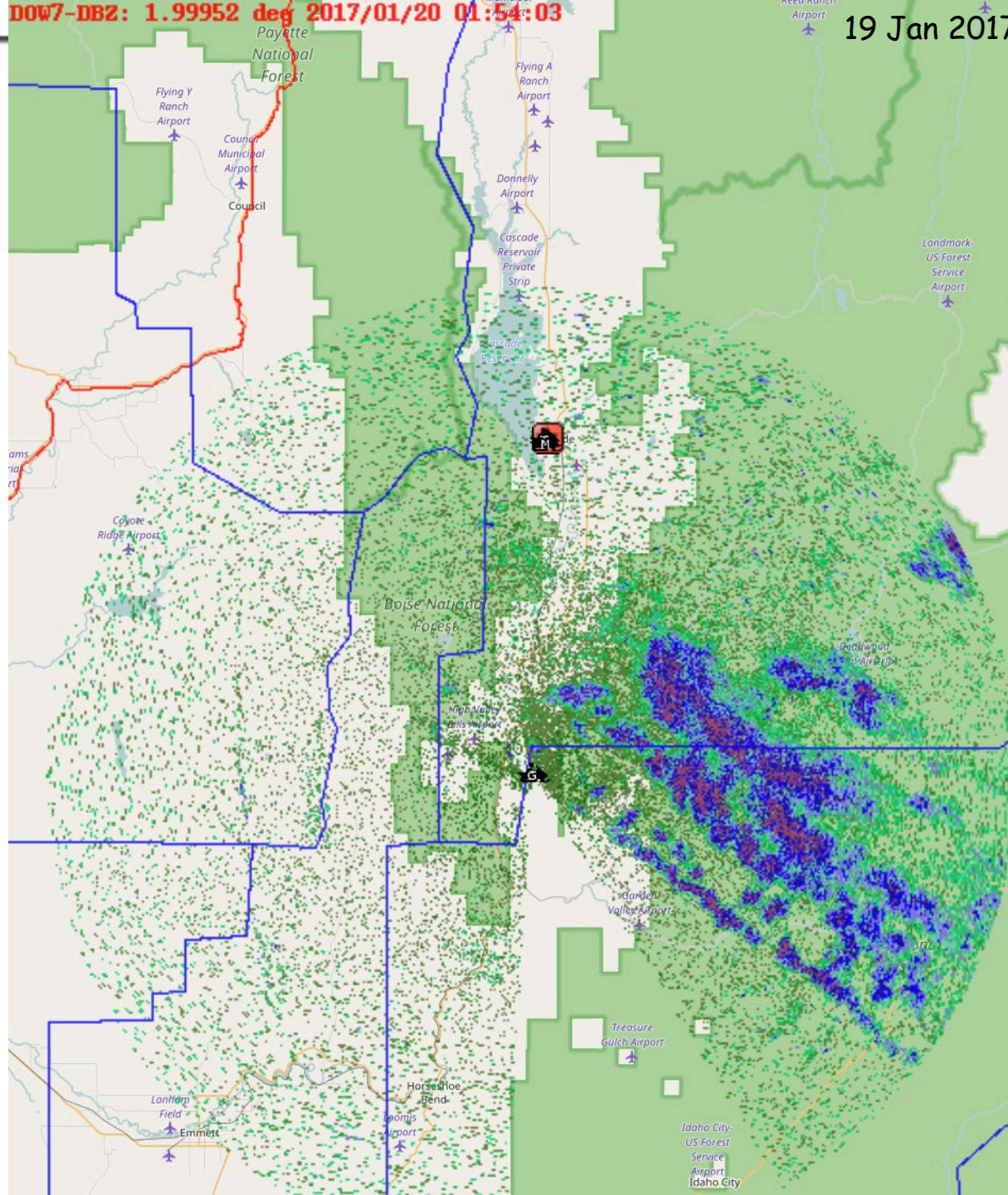
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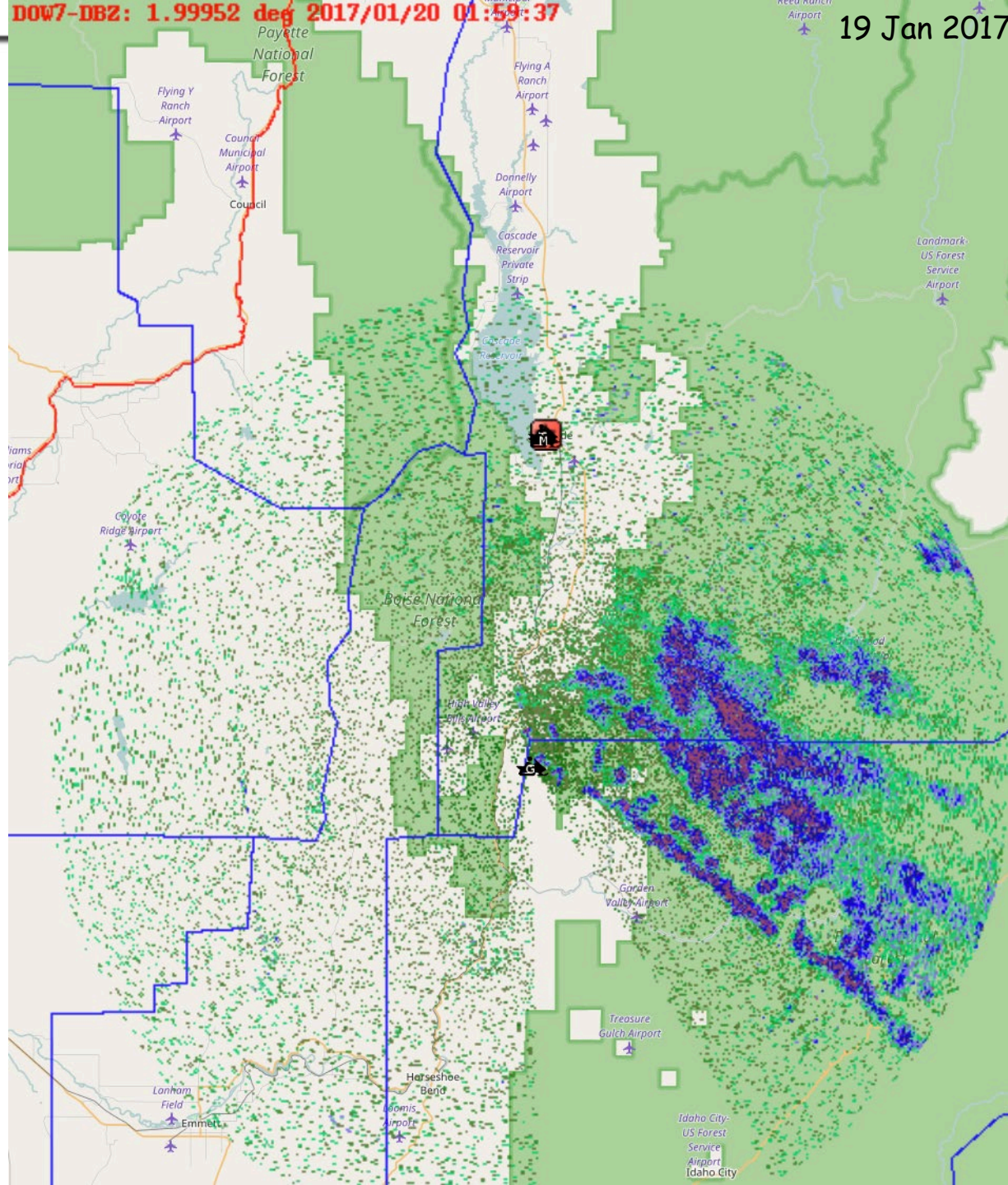
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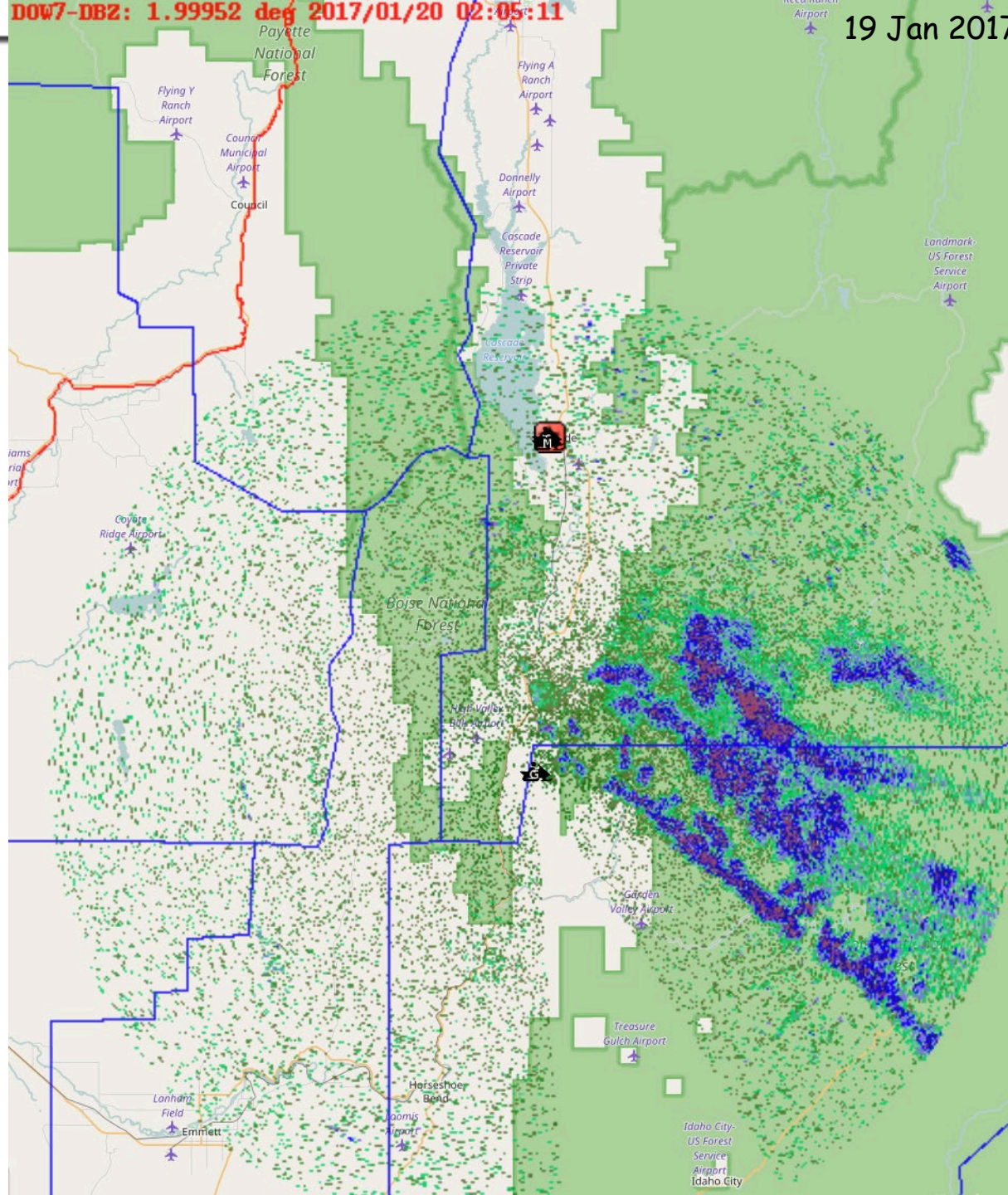
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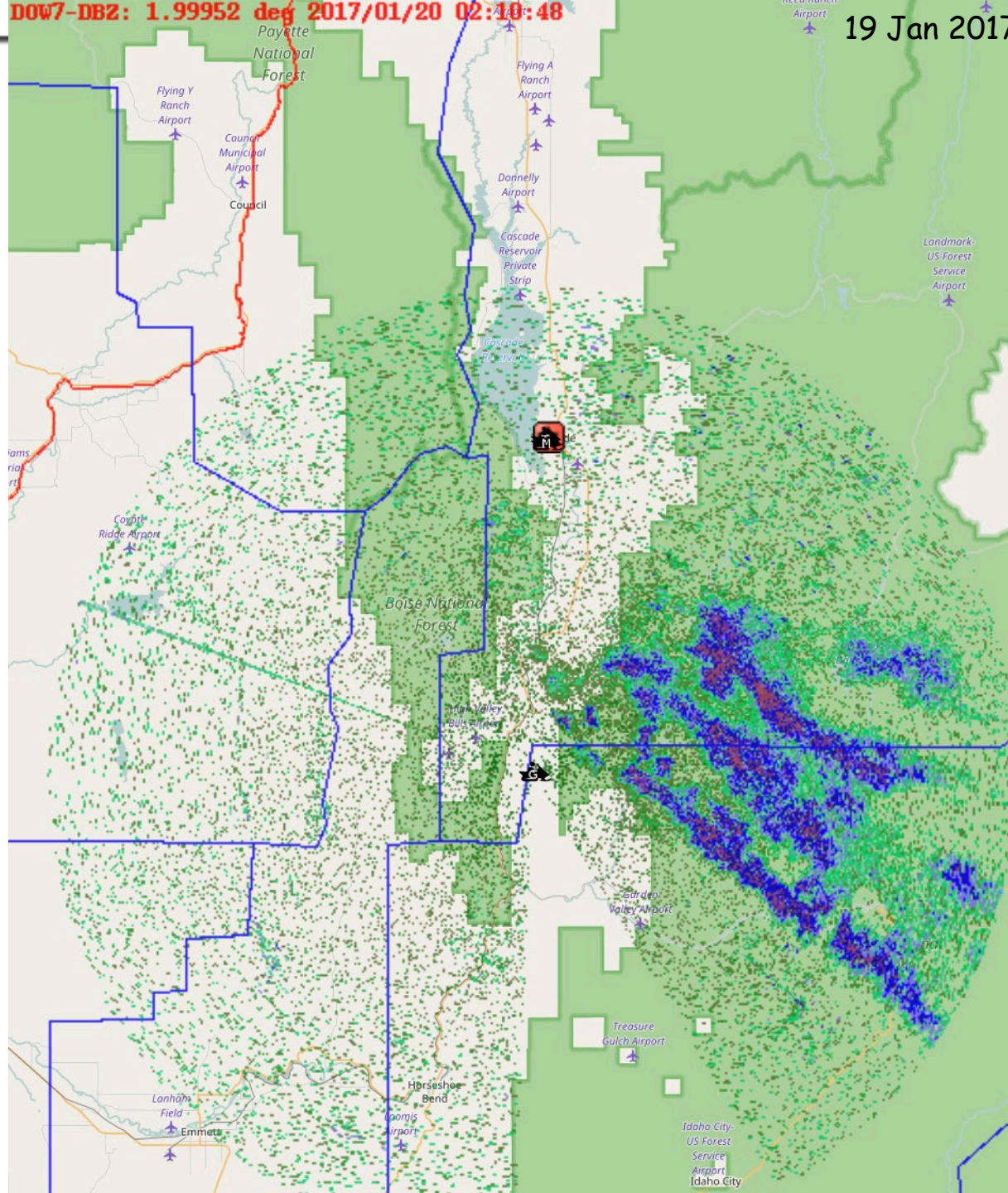
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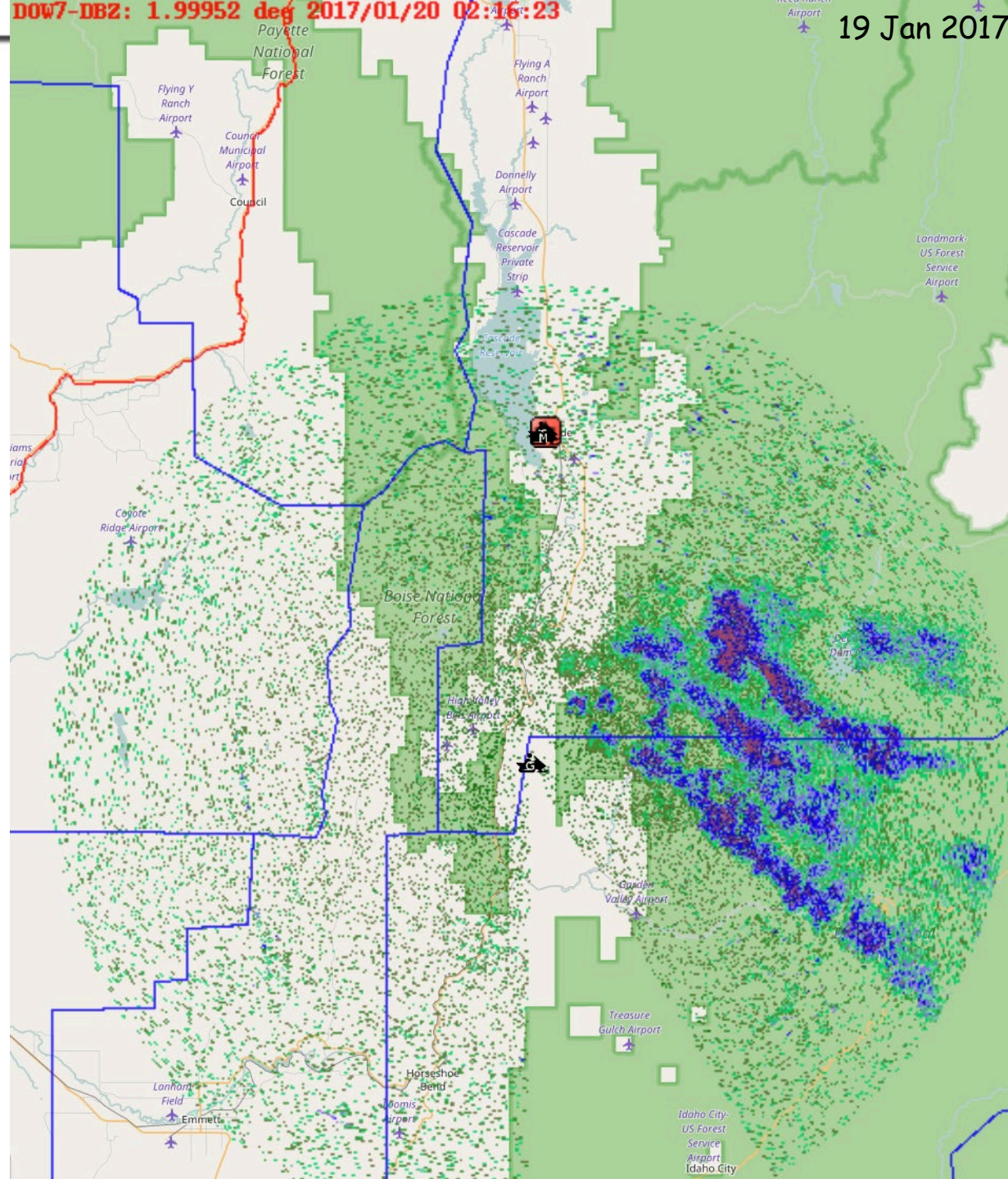


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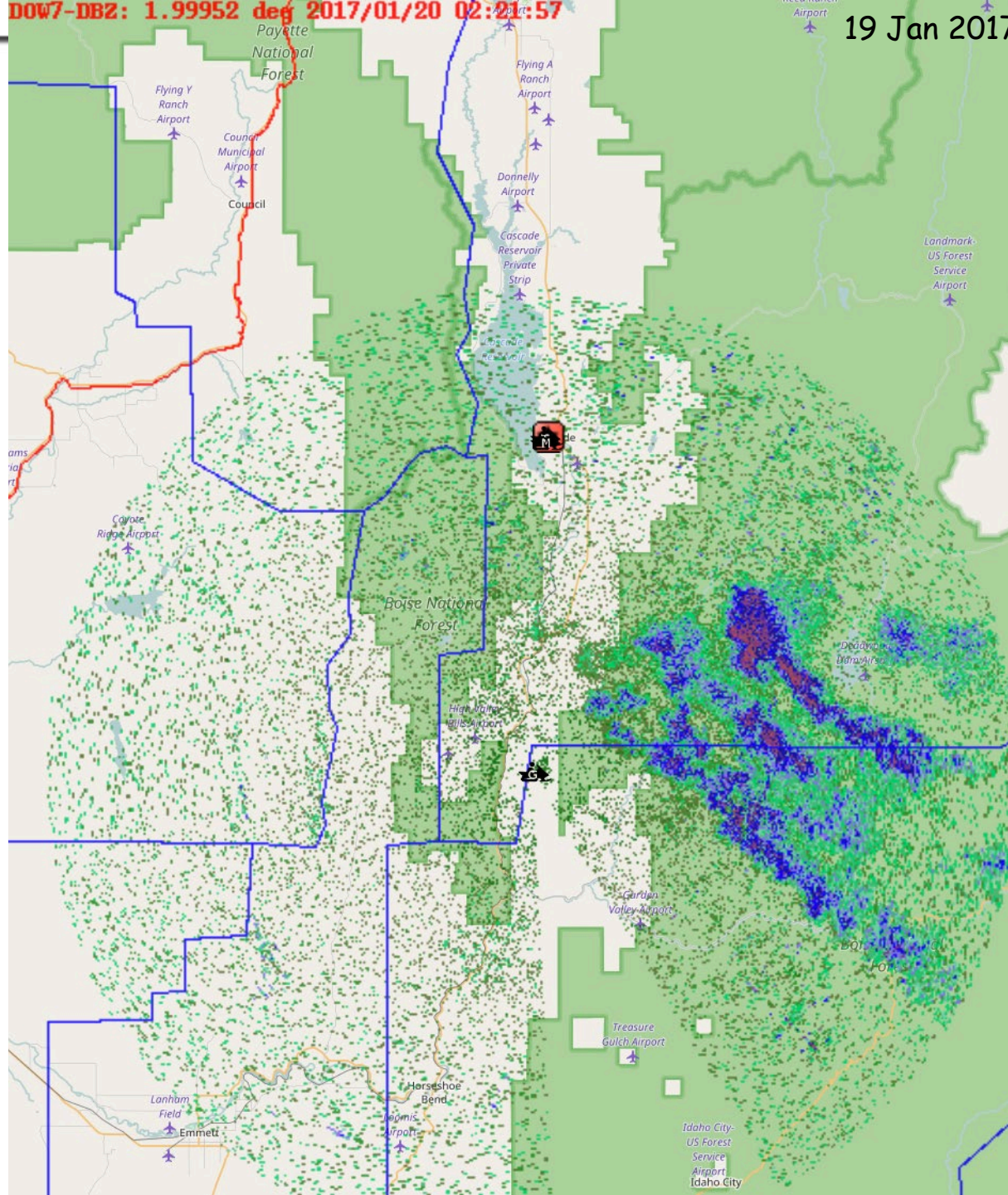






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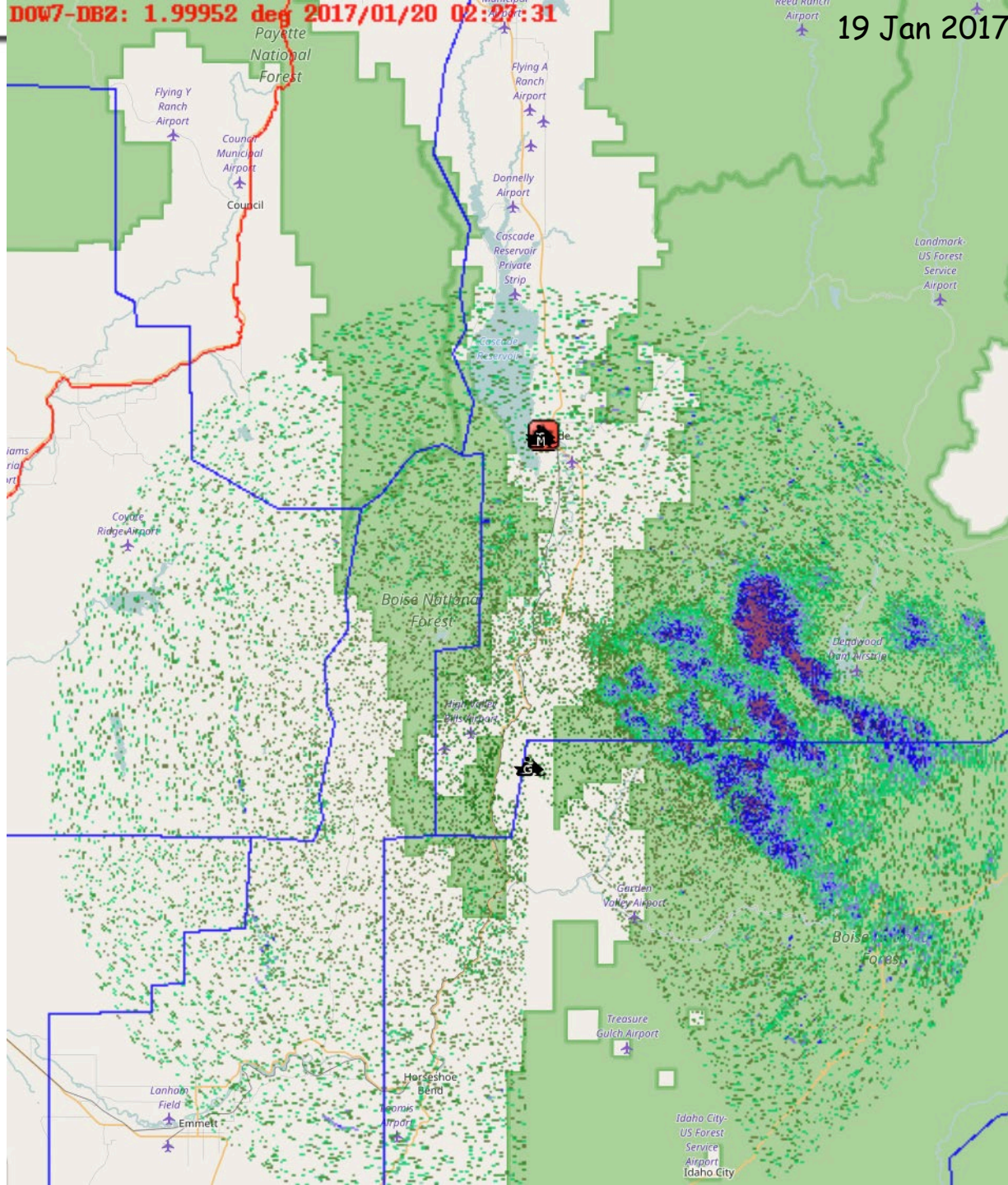
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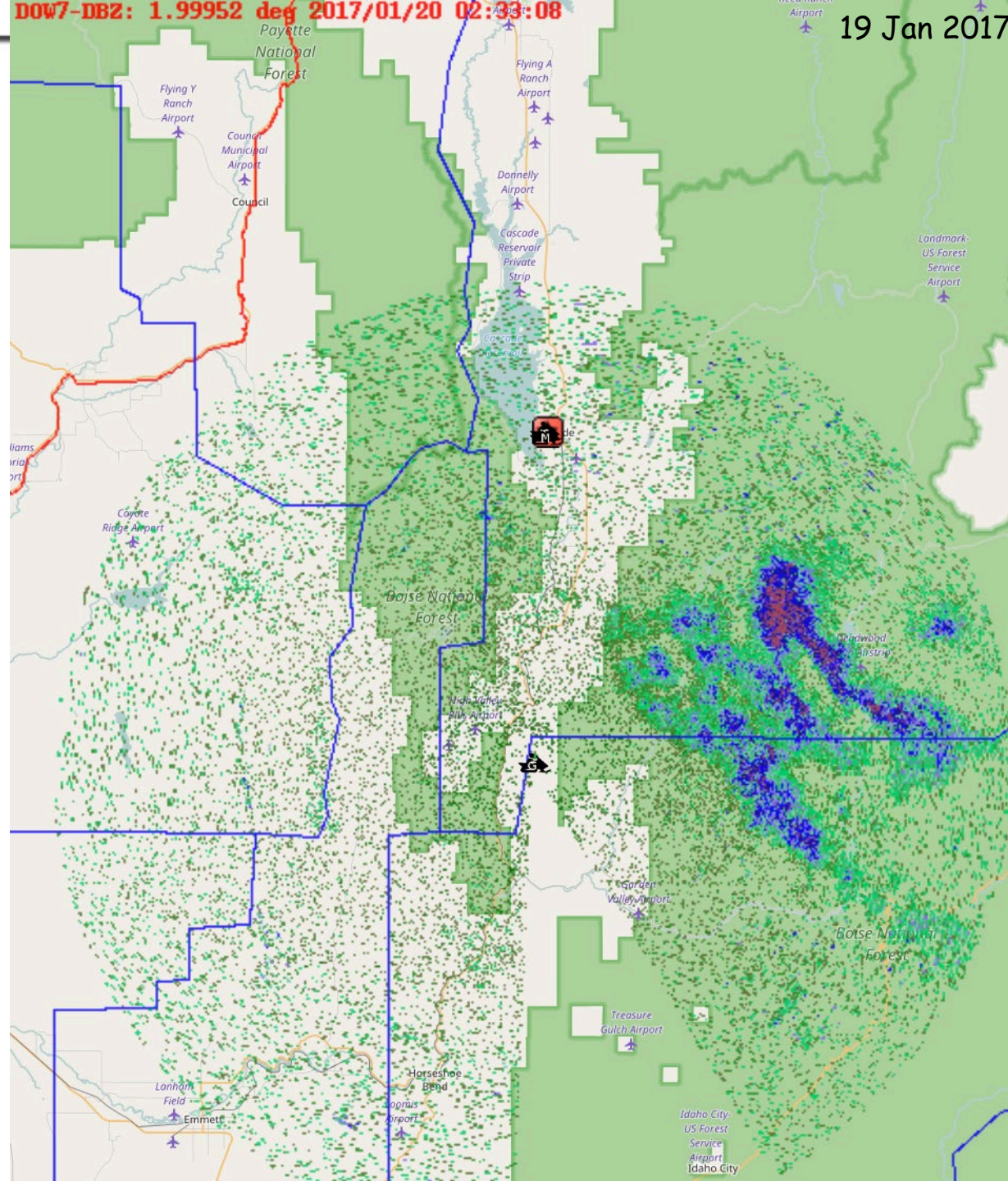


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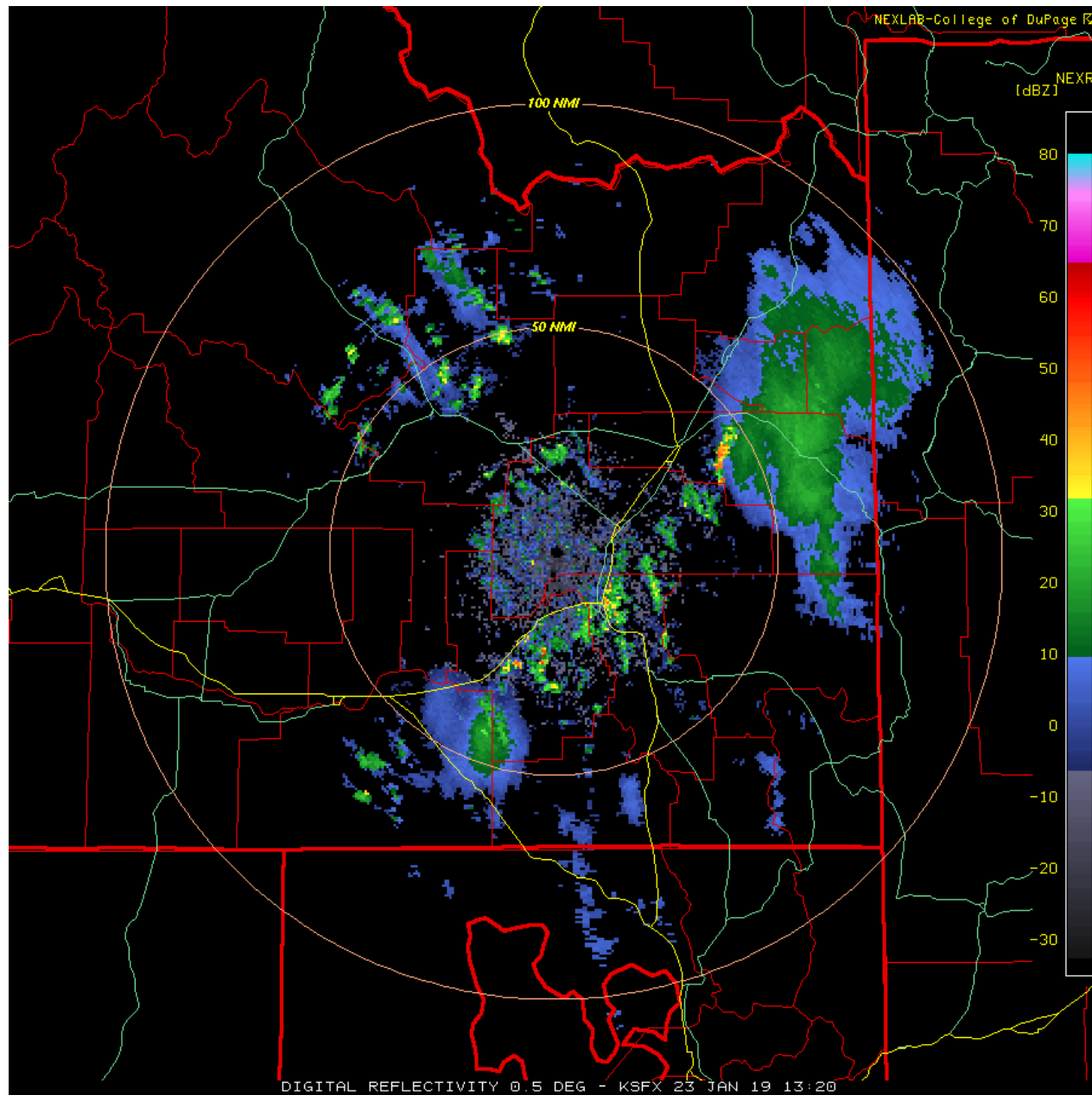


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# Pocatello NWS Radar



# Questions?

