The modern reality of a Hail Suppression Program's application

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Primer Workshop Regional de Modificación Artificial del Tiempo

Viernes 28 de Agosto de 2015,
Universidad Tecnológica Nacional, Facultad Regional Mendoza, Rodriguez 273,
Ciudad Mendoza

Outlines

→ **The Design of a Hail Suppression Program**
→ **A typical evaluation of a H.S. program**
→ Climate Change & Weather Modification
→ **The "Mendoza's" case**
→ **Recommendations**

DESIGN OF A HAIL SUPPRESSION PROGRAM

- **The design of a hail suppression program typically includes two fundamental stages:**
  - A program demand targeting to specific frame and scope, as established by program's sponsor potential.
  - An initial feasibility study.

FEASIBILITY STUDY

- **Establish the scientific basis for a project**
  Consider the transferability of results from research or operational programs conducted in similar geographical and climatological settings.

- **Examination of local climate conditions**
  Thunderstorm characteristics climatology
  Determine whether or not cloud seeding technology has a reasonable expectation of hail suppression.

- **Identify program objectives and resources**
  Major objective to reduce hail damage to crop and property.

FEASIBILITY STUDY cont'd

- **Cost of project**

  An estimate of the total cost of conducting the cloud seeding program than can then be compared to the estimated program benefit.

- **Effectiveness and economic benefit**

  Estimates of the hail suppression effectiveness can be derived from other similar research or operational programs through analyses of the climatology of the area of interest focusing on hail or radar data or historical economic (insurance) data of hail damage to crop.

THE DESIGN OF AN OPERATIONAL HAIL SUPPRESSION PROGRAM

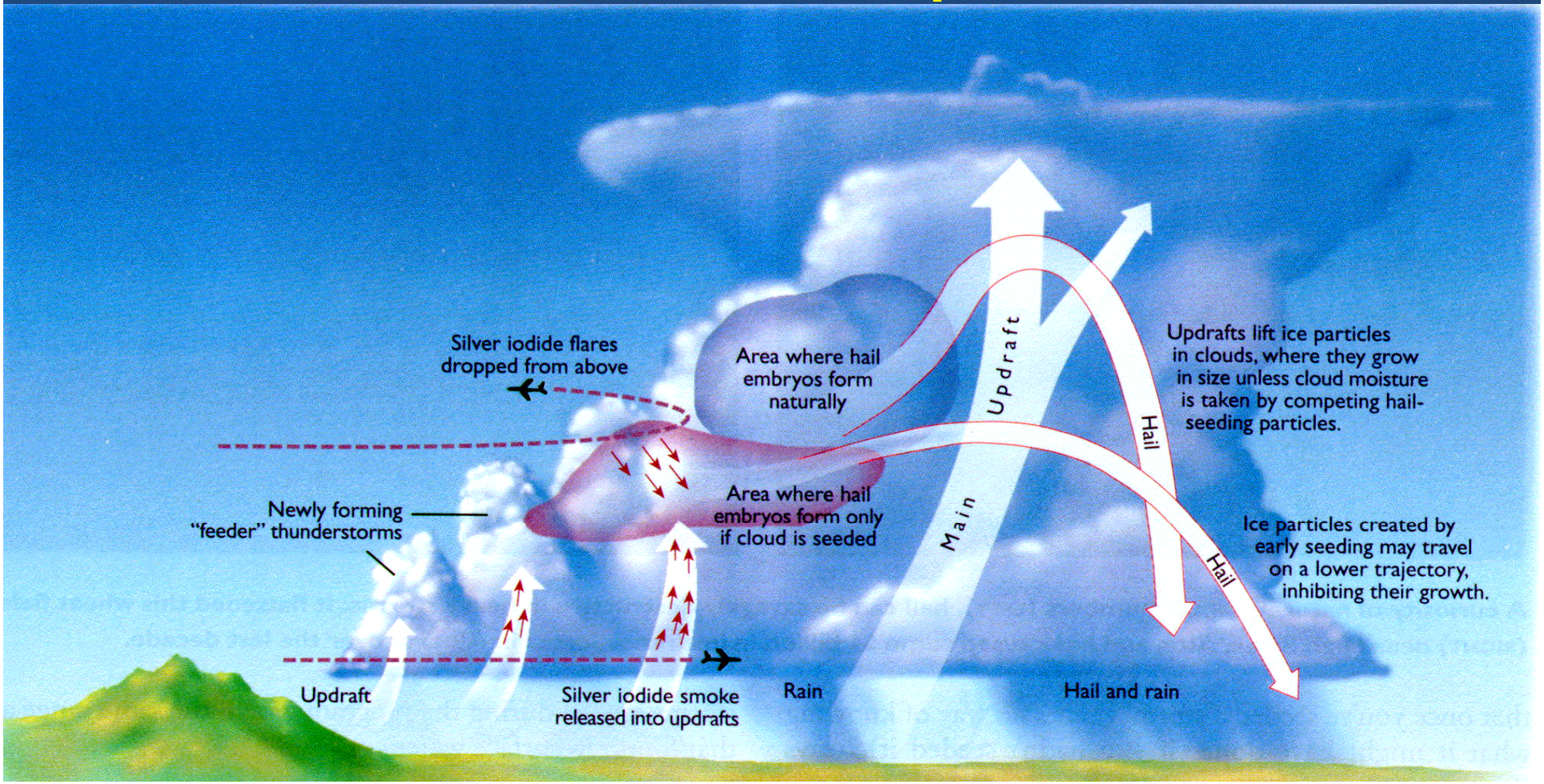
- The main components of an operational hail suppression program include:
  - Definition of program frame, scope and personnel
  - Hail suppression seeding hypotheses and criteria
  - Operational area(s), target and control
  - Climatology or project area(s)
  - Seeding agents
  - Seeding delivery methods
  - Considerations in cloud seeding
  - Cloud seeding methodologies for hail suppression
  - Meteorological data collection, instrumentation and siting
  - Evaluation of program effectiveness
  - Legal and environmental issues

DEFINITION OF PROGRAM FRAME

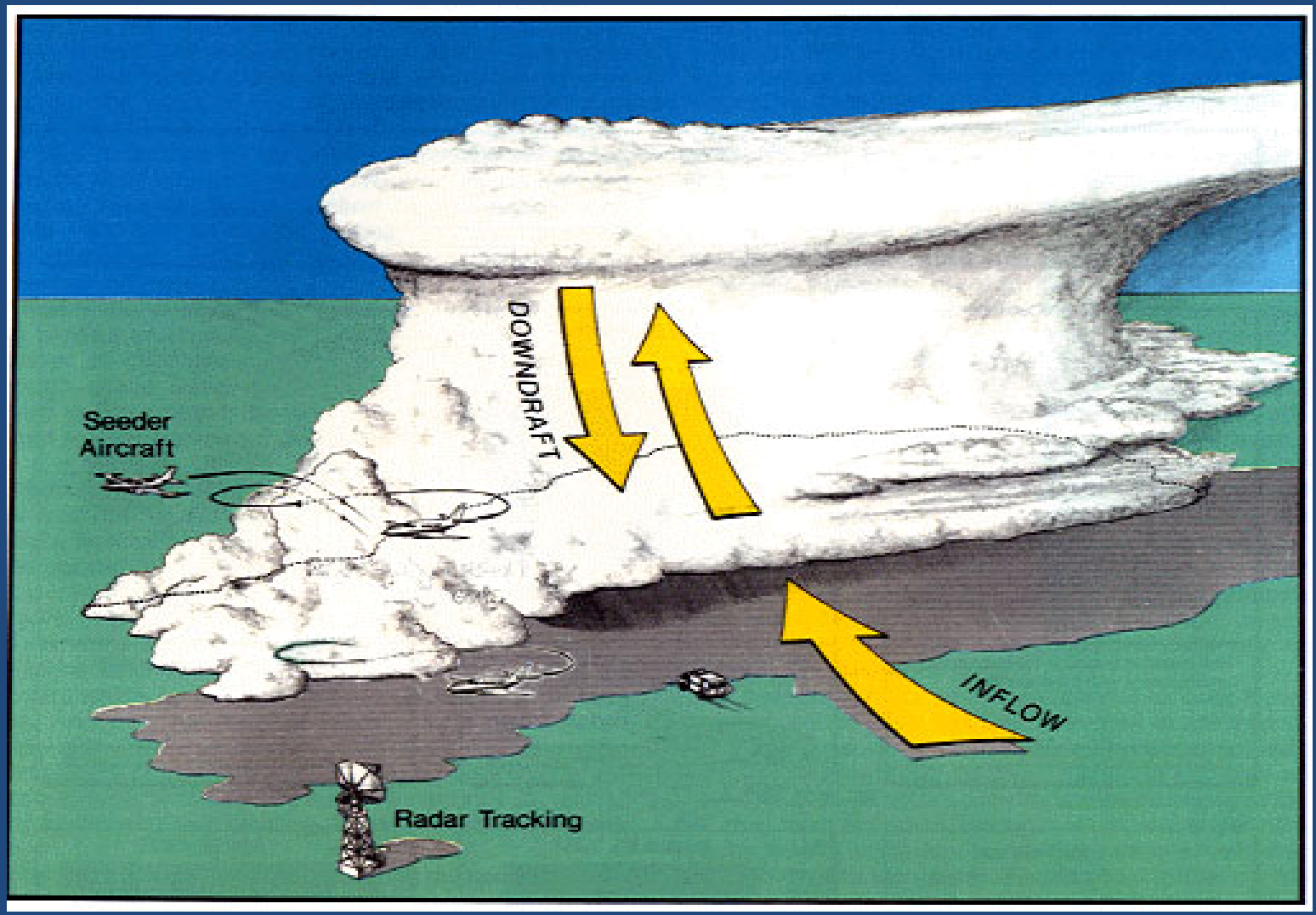
- Specify the objectives of the program as agreed by the program sponsor(s).
- Specify the operational area(s) and possible control areas.
- Specify personnel requirements and organization.
- Specify evaluation method and procedure.

HAIL SUPPRESSION HYPOTHESES

The most popular hail suppression hypotheses used in many programs around the world, is the well known cloud microphysical conceptual model of **“Beneficial Competition”.**



Hailstorm

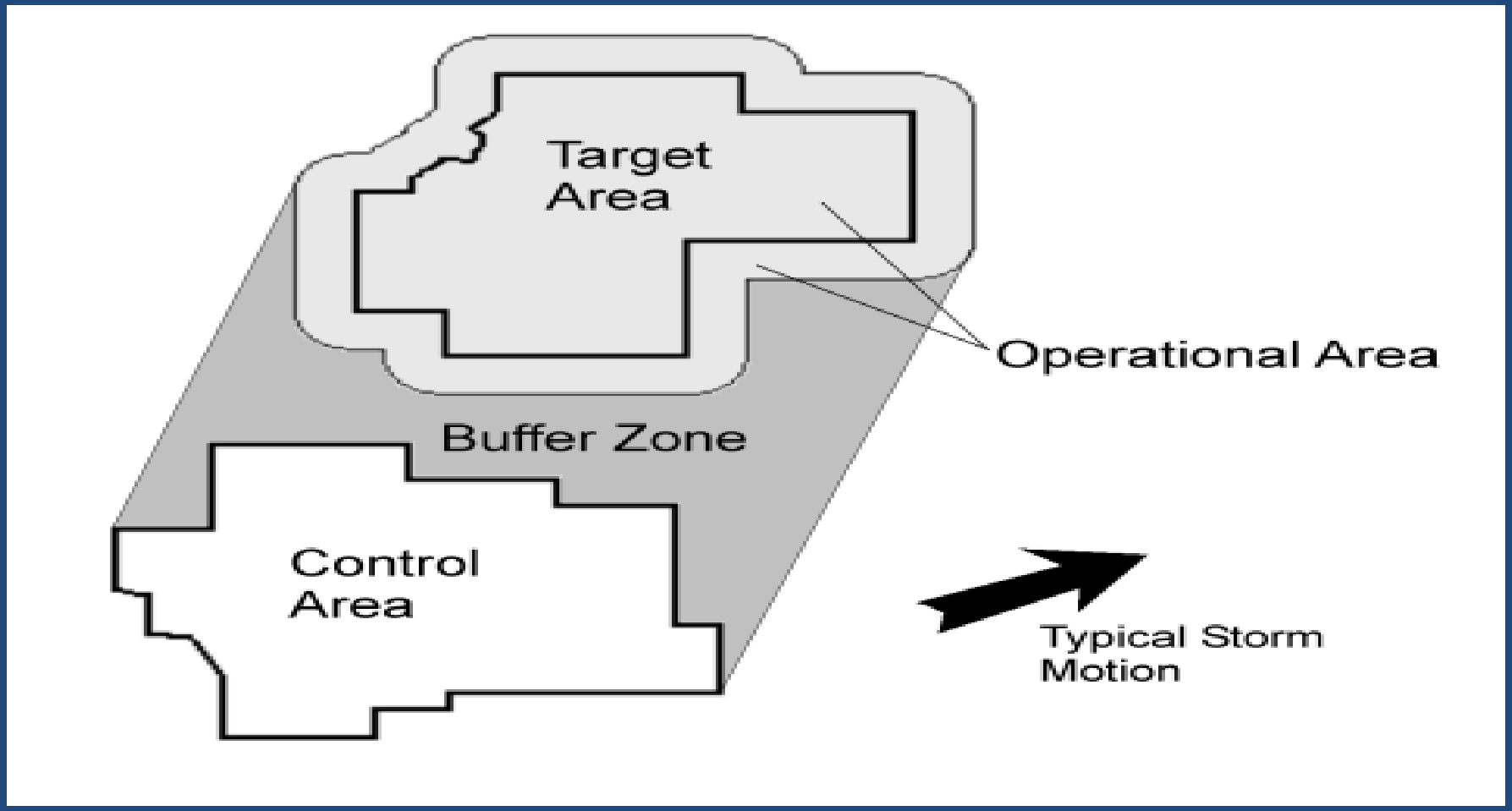


The real… Hailstorm

CLOUD SEEDING CRITERIA

- Specify the hail suppression seeding criteria as considered to:
  - The treatment of any cloud which possesses radar reflectivity signatures over a threshold measured above specified heights.
  - Clouds which without treatment believed to be capable of hail occurrence on the ground.

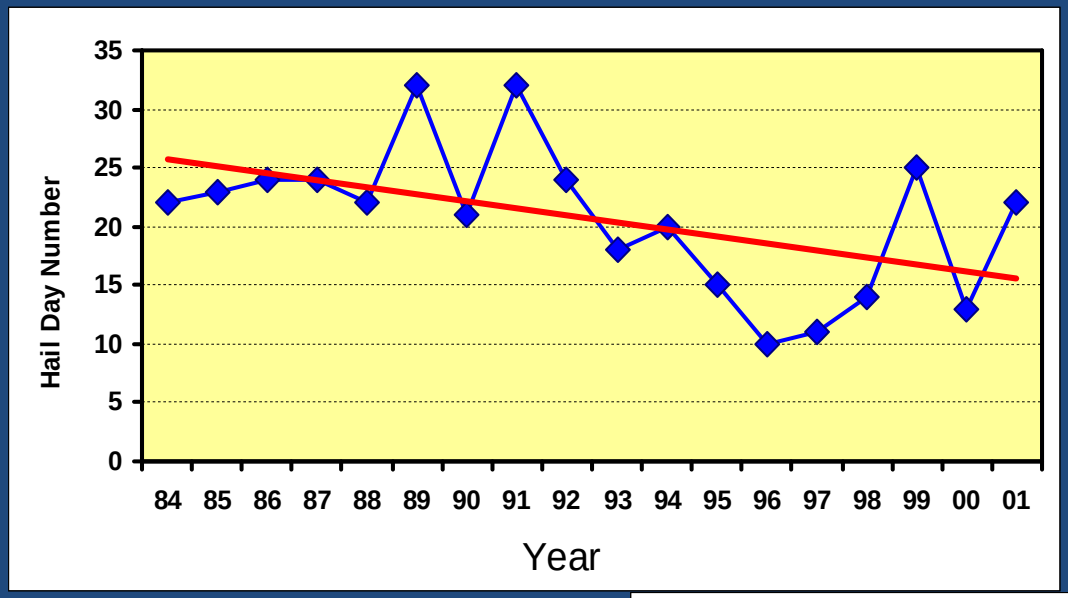
OPERATIONAL AREA(S)

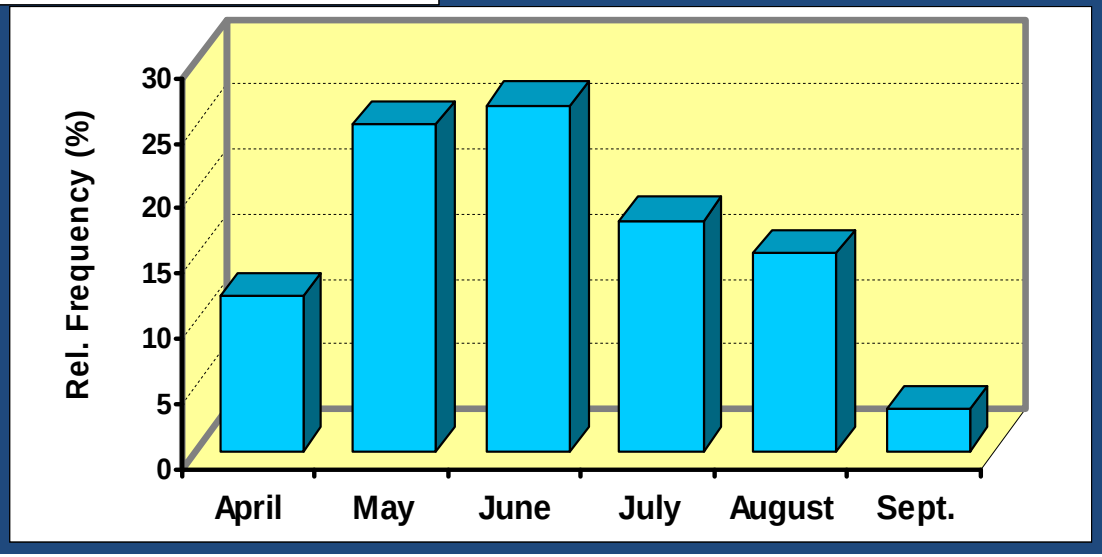


CLIMATOLOGY OF PROGRAM AREA

- A climatology of the proposed project area needs to be developed that will include:
  - Thunderstorm characteristics, including among others, severity and types of thunderstorms
    - Single-cell, Multi-cell, Supercell
    - Isolated or Embedded
    - Line thunderstorms and Squall line
  - Temporal and spatial distribution of thunderstorm frequency, start, end, duration of thunderstorm activity.
  - Temporal and spatial distribution of hail occurrences.
  - Wind field directions, speed and airflow interactions with the terrain.
  - Relationships between radar-echo characteristics and hail on the ground.

EXAMPLE: HAILFALL OCCURRENCE IN CENTRAL MACEDONIA, GREECE





SEEDING AGENTS

There are two major classes of seeding agents:

- Glaciogenic nucleants (form ice)
  - Pyrotechnic flares
  - Ejectable flares, from belly racks, usually in form of 20 gr
  - End Burned flares, wing mounted, usally in form of 150 gr
  - Solutions of silver-iodide, salts, and oxidizers, mixed in acetone.
  - Bacteria (e.g. pseudomonas syringae)
  - Dry ice
  - Liquid propane
- Hygroscopic nucleants (form larger cloud droplets)
  - Pyrotechnics
  - Dry Salts
  - Saline solutions

Since the discovery of glaciogenic materials more than 50 years ago, silver iodide has been the most widely used cloud seeding material .
Silver iodide enhances the ice crystal concentration in clouds by either nucleating new crystals or freezing cloud droplets.

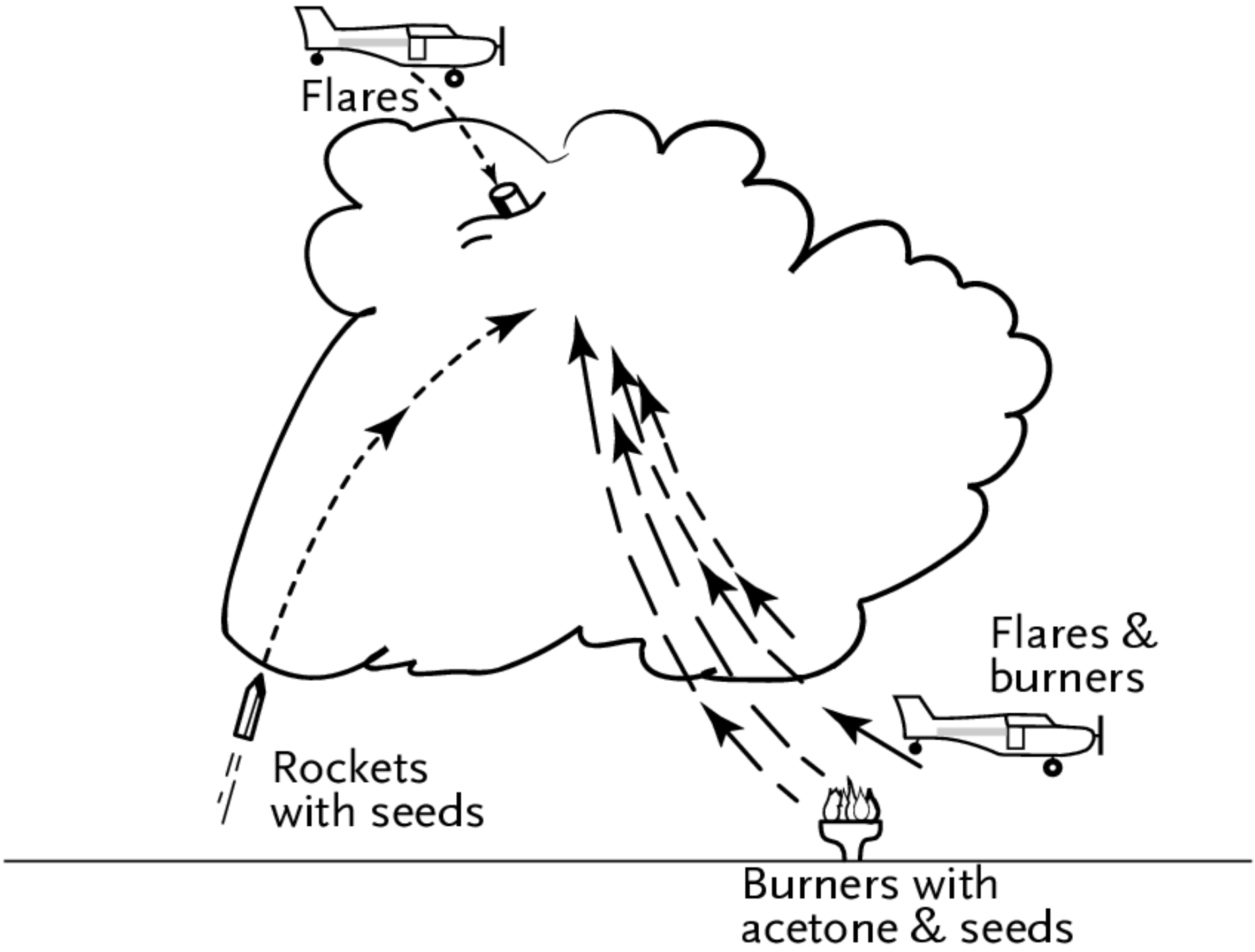
SEEDING DELIVERY METHODS

Two major methods of cloud seeding for hail suppression:

- Airborne

SEEDING DELIVERY METHODS cont'd

- Ground-based
  - Generators
  - Rockets
  - Pyrotechnic flares
  - Remote firing
  - Hail cannons
  - Artillery seeding


Flares
Flares &
burners
Rockets
with seeds
Burners with
acetone & seeds

CONSIDERATIONS IN CLOUD SEEDING TARGETING FOR HAIL SUPPRESSION

- Favorable seeding targets are the location of updrafts and supercooled liquid water.
- Effectiveness of seeding agent (threshold temperature, nuclei number production, rate of production, persistence of effects).
- Seeding delivery mean (aircraft, ground, flares, solution, mechanism).
- There is no one best seeding agent or delivery mean. **Agent and method must be adjusted for the area of interest.**

CLOUD SEEDING METHODOLOGIES FOR HAIL SUPPRESSION

Several airborne cloud seeding methodologies may be used, depending on factors including storm type, visibility, terrain proximity and time of day. Seeding material is released in one of the following locations:

- Growing cloud towers (feeder cells) on the upshear flanks of multi-cell storms.
- Regions of identifiable liquid water and/or updraft in single convective cells.
- Weak updraft regions below the base of feeder cells.
- The main updraft region below the base of single convective cells.
- Regions of expected storm inflow based on ground-radar information in the absence of good visibility.

SEEDING SUSPENSION CRITERIA

Each program design needs to include specific seeding suspension criteria:

- Cloud seeding operations for hail suppression should be suspended in cases of severe weather warnings (i.e severe squall line affecting the operational area).

METEOROLOGICAL DATA, INSTRUMENTATION AND SITING

There are two basic requirements for data:

- Real time weather data needed to support decision making and monitoring operations.
- Program specific measurements needed to perform evaluations of seeding effectiveness.

Siting of equipment

- Hailpad and rain gauge network installation
- Radar siting (Ground clutter, range, etc.)
- Aircraft considerations (operational performance)
- Installation of ground generators (operators, access etc.)
- Installation of rocket launchers or artillery (operators, access).

REAL TIME WEATHER DATA

- Program specific data
  - Weather Radar
  - Computer radar display (TITAN)
  - Airlink patrol and seeding flight route data display
  - Flares burned information display
  - Sounding data
  - Computer simulations
  - Liquid water measurements
  - Aerial cloud physics observations

DATA FOR HAIL SUPPRESSION PROGRAM ASSESSMENTS

- Hailpad and rain gauge network data
- Radar data
- Hail crop damage and insurance data
- Cloud physics data
- Numerical modeling

The Greek
National
Hail Suppression
Program

HAIL Protection with airborne seeding

- 3 Piper Cheyenne II (3D s.a.)
- 2 full upgraded Weather Radars (3D s.a.)
- Seeding agent :AgI Flares 20gr and 75gr (ICE CRYSTAL)
- Total Protected Area :5000 km²
- Cultivation : Crops

The modified aircrafts

Flare racks for cloud top and cloud base seeding

- Seeding Equipment
  - Ejectable Flares Seeding Racks (Belly Type): 3 racks with totally 306 ejectable Silver Iodide (AgI) 20 gr flares
  - Burn in Place Seeding Racks (Wing Mounted): 2 racks of 24 end-burner Silver Iodide (AgI) 75 gr flares

Probes used in the Greek Hail Suppression project

Liquid Water Content

Dew Point sensor

TAS

Weather Radars

Weather radar is also essential for cloud seeding operations and research.

3D offers 2 fully-equipped ready-to-run radars, complete with TITAN data acquisition and processing software and aircraft tracking.

Aircraft positions can be down-linked to the radar and superimposed on real-time radar displays, facilitating mission coordination and increasing operational safety.

Seeding data are also displayed in real-time.

3D‘s Weather Radars

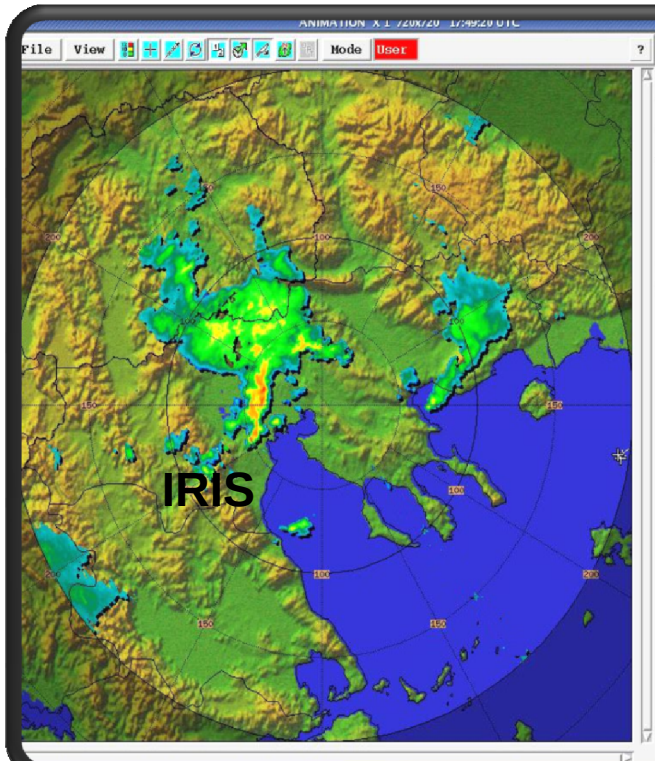
Latest Upgraded

- WR-100 Enterprise Electronics Corporation (EEC)

  - 1st Upgrade
    (Existing Transceiver, Antenna System & Servo Amplifier)
    → Sigmet RVP8+RCP8+IRIS software

  - 2nd Upgrade
    → Pulse Systems Transceiver Inc, TR-1001A 350KW C-Band

Radar Software



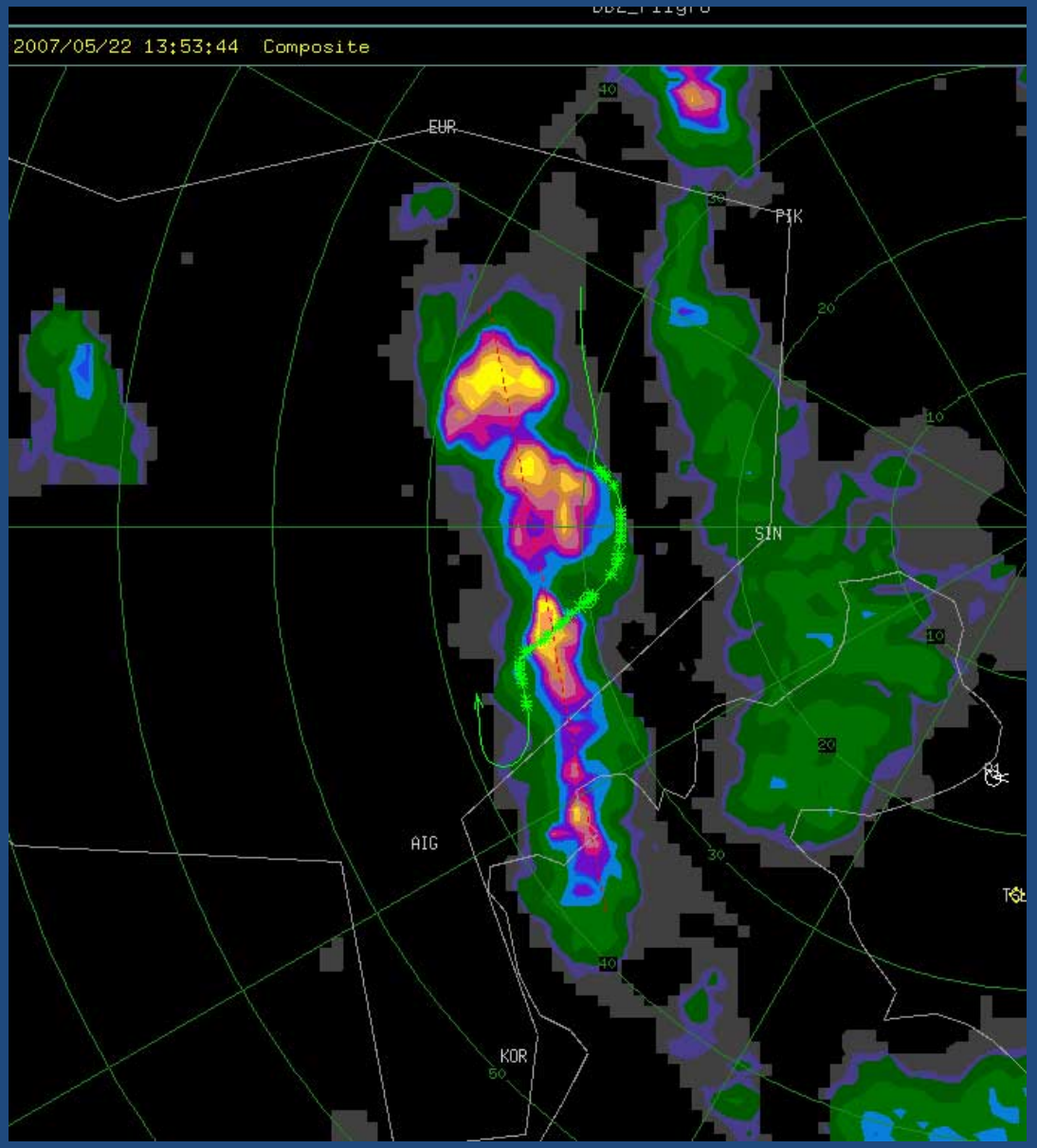
IRIS

TITAN

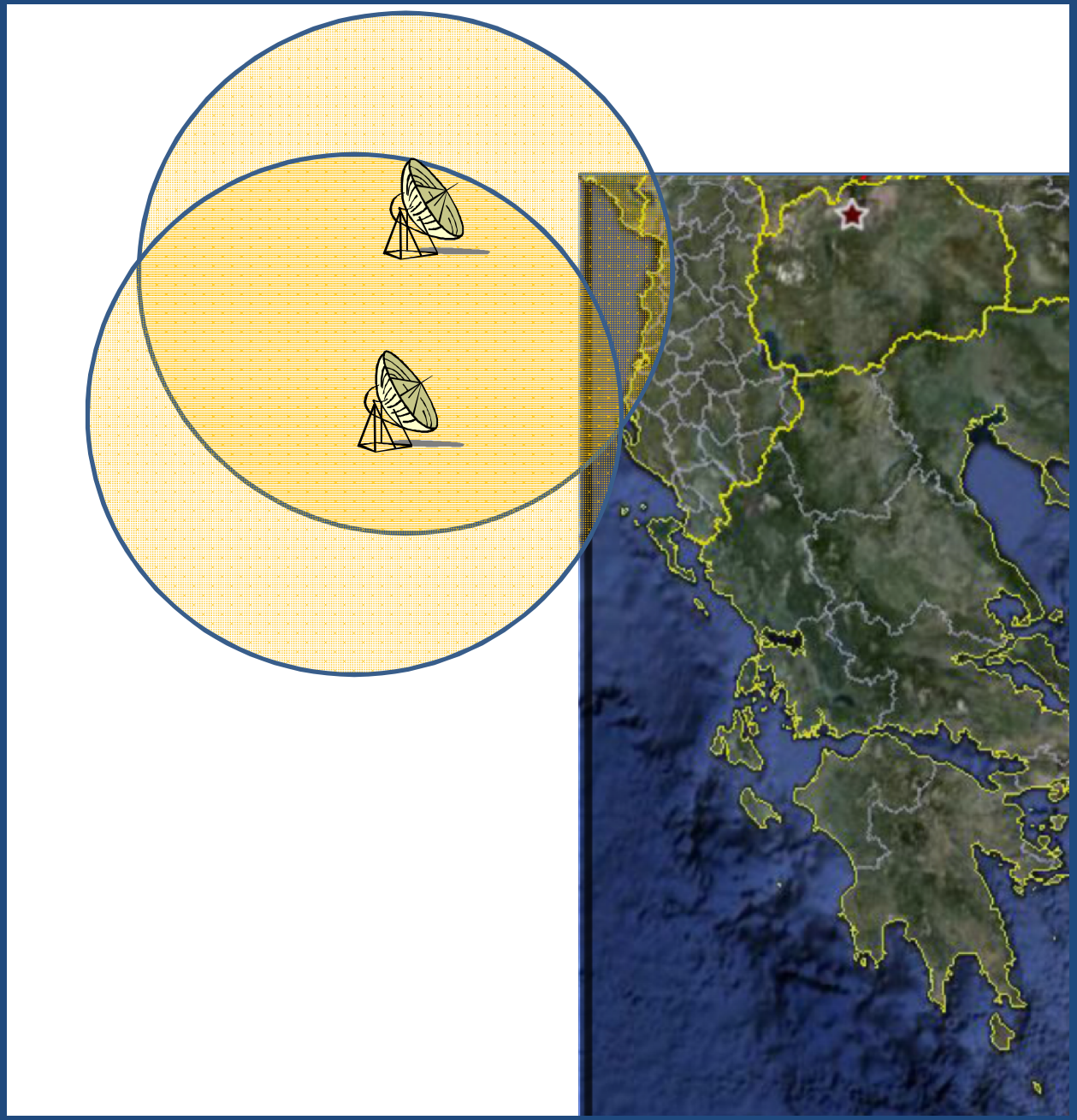
Telemetry system displaying:

- GPS position of the seeding aircraft
- Flare firing position on the radar data recording system
- Ground speed
- Outside temperature
- Liquid water content
- and dew point rates

  are also displayed in **real time** at the control station.



3D S.A.
Radar Coverage




RADAR AT THE AREA OF Filyro – PREFECTURE OF Thessaloniki
2 9 2011


SIGMET
RVP8
SIGMET
RF Receiver
AZIMUTH AND ELEVATION
SERVO AMPLIFIER
2 9 2011


2 9 2011


WARNING
ALARM
POWER
P 382
DISPLAY
PARAMETER SELECT
FAULT CODE SELECT
ADH-2A COM DEHYDRATOR
ENVIRONMENTAL TECHNOLOGY, INC
SOUTH BEND, INDIANA U.S.A.
Tektronix
RM2000B
Rack Mount
Tektronix TDS 2022B
2 9 2011


2 9 2011

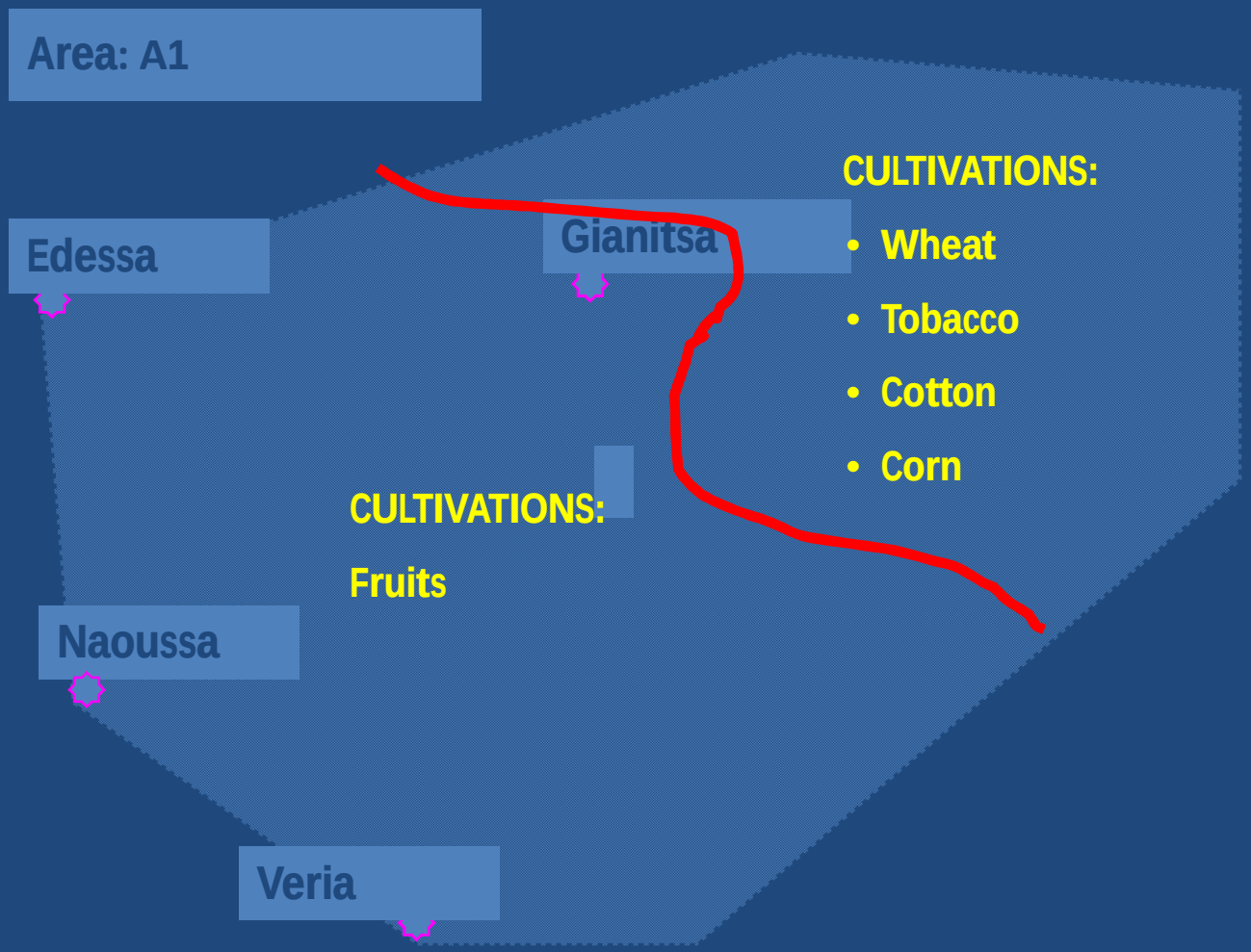
The 3D's Radars are leased to the Greek National Hail Suppression Project

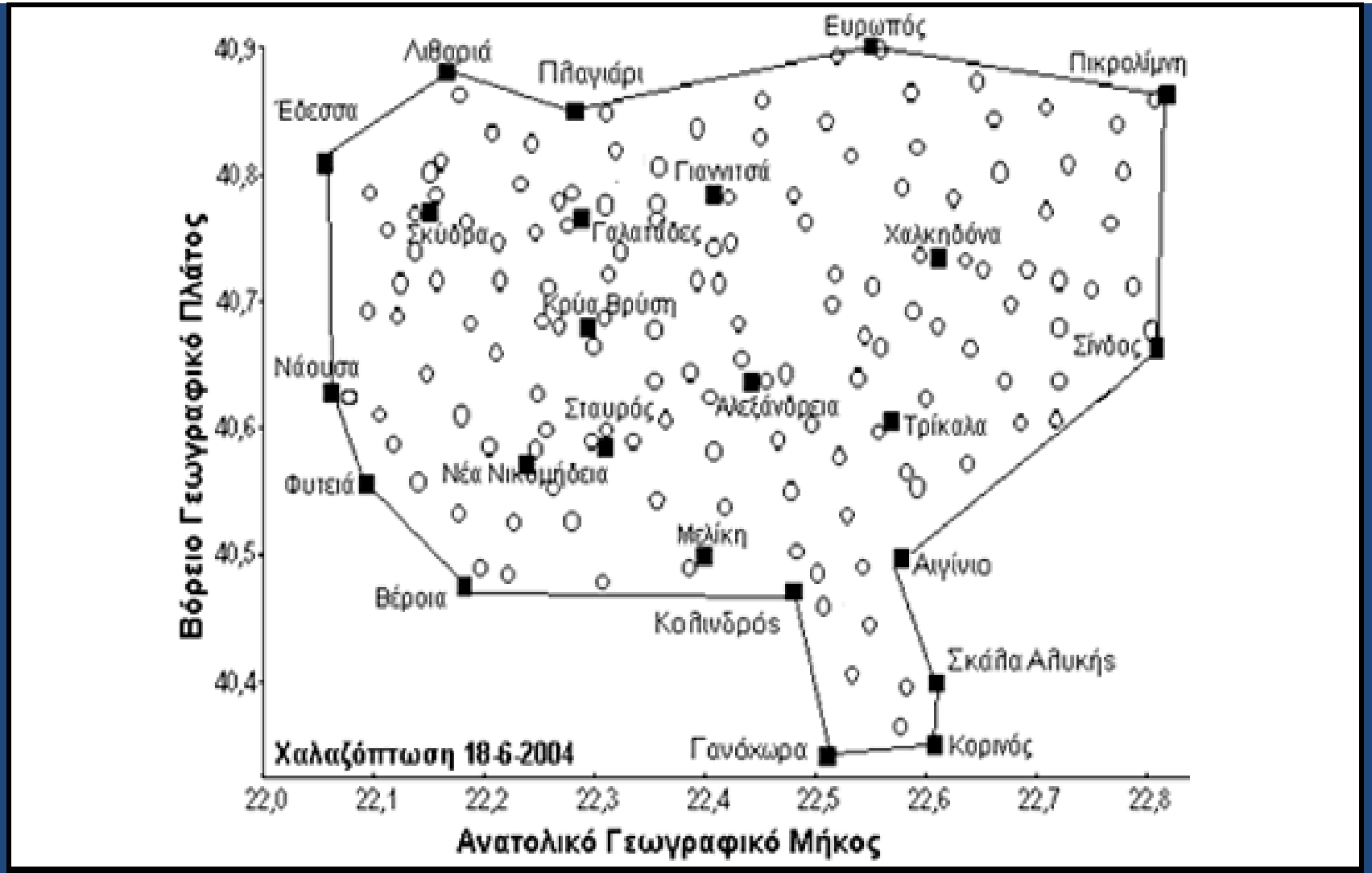
Why?

- 3D lease to ELGA 2 Radars since 2006
- In the past ELGA used the two S-Band Radars which were operating in common use status with HNMS .
- Up to 2005 the radar availability provided by HNMS were less than 70%
- 3D guaranteed to ELGA Radar availability more than **97%**
- The contract that 3D has signed with ELGA (Hail Suppression system + Radar lease + seeding agent) is the hardest in all over the world because of the highest requested readiness

OPERATIONAL AREAS

HAIL control (Thessaloniki airport)

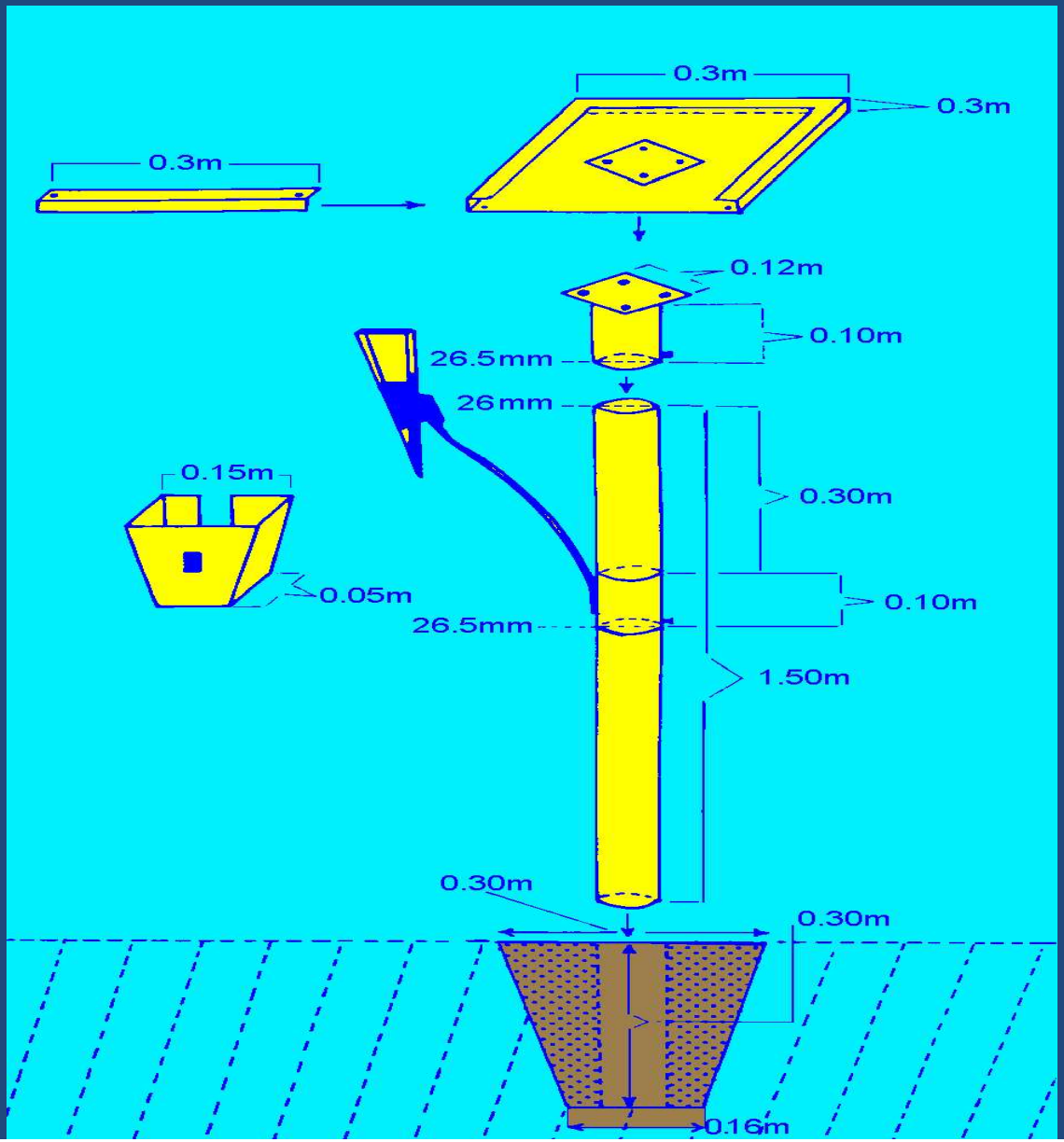

Area: A1
Edessa
Gianitsa
CULTIVATIONS:
• Wheat
• Tobacco
• Cotton
• Corn
CULTIVATIONS:
Fruits
Naoussa
Veria



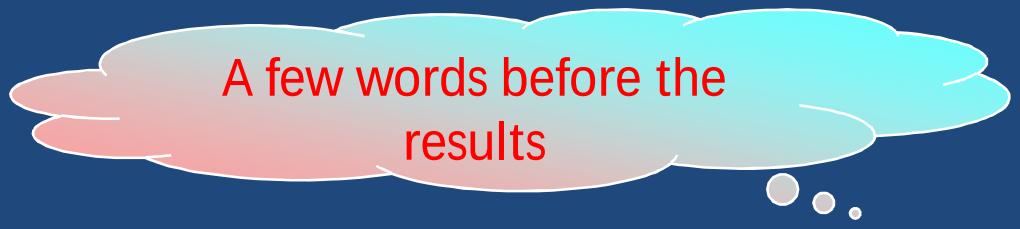
142 Hailpads 64 Rain gauges

Hailpad Network

Typical Hailpad



Evaluation of the Greek Hail Suppression Program



It’s reasonable to Evaluate an Operational Cloud Seeding Program?

TRESSA FOWLER

- No conclusions can be drawn from statistical evaluations of operational programs.
- No exceptions.

TO TEST
THE PHYSICAL HYPOTHESES
OF HOW SEEDING
IS SUPPOSED TO WORK,
RANDOMIZED EXPERIMENTS
ARE NEEDED

DIFFICULTIES ON STATISTICAL EVALUATION

NEED TO CONVIENCE

SCIENTISTS

Theoretician

- Conceptual model
- Physical hypothesis

Operational

- Procedures
- Equipment

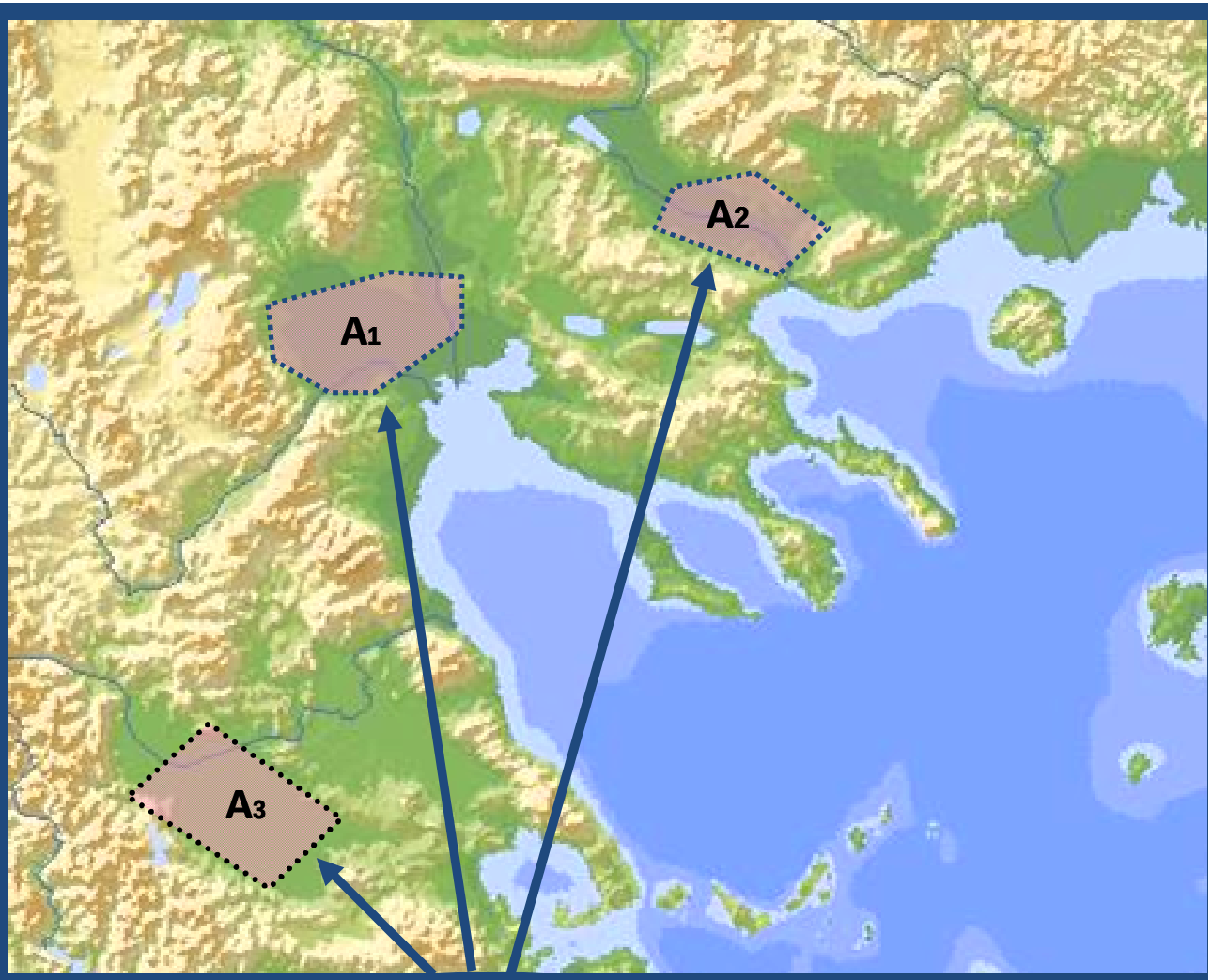
FINANCIER

They do not care about evaluation, but just for the (economic) results.

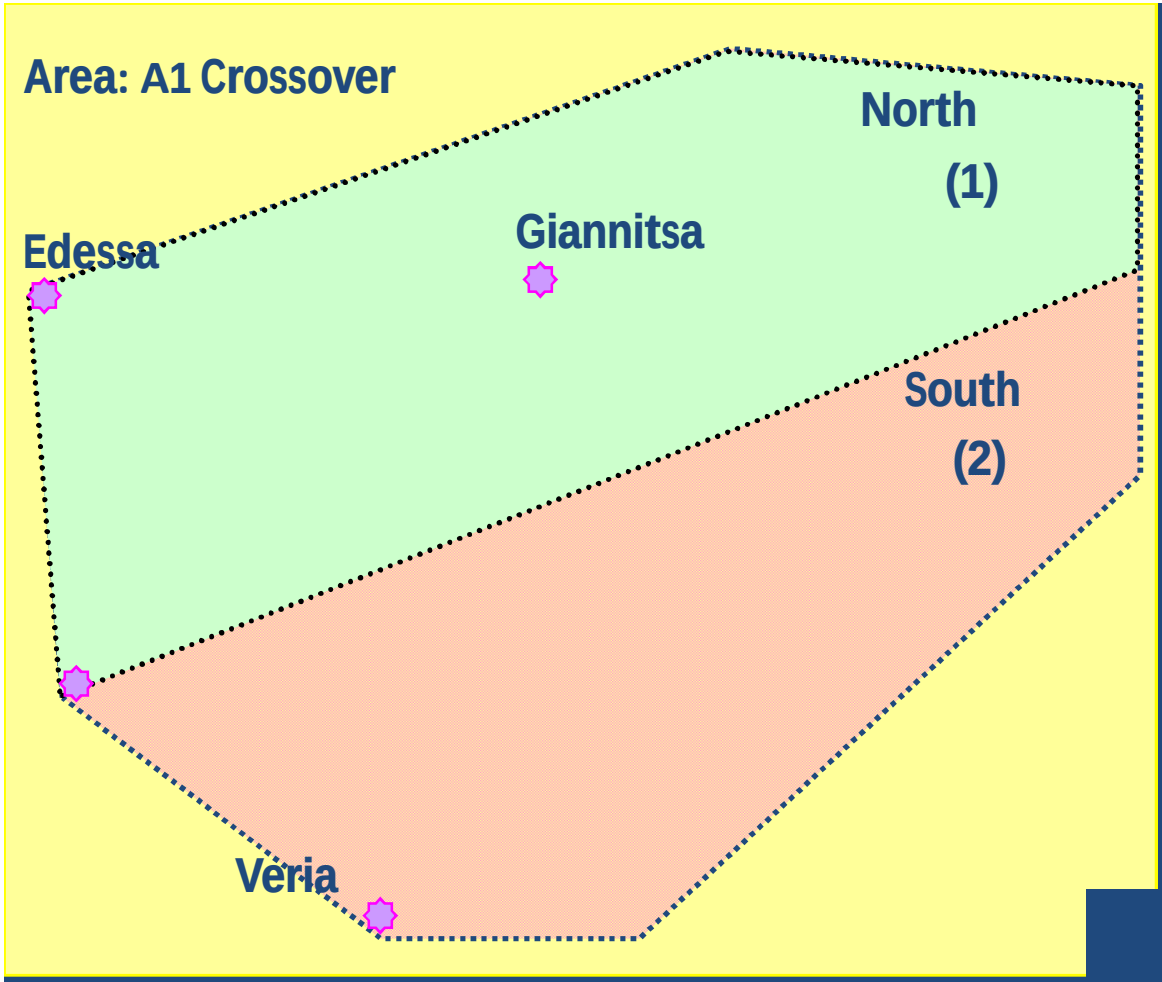
PEOPLE

They care about rain enhancement or hail suppression.

THE GREEK NATIONAL HAIL SUPPRESSION PROJECT



- OPERATION. AREAS: A1, A2 A3 (4000 Km²)
- TIME PERIOD :1984-88: 15-Apr. - 30 Sep.
- KIND OF OPERAT.: A1 Research & Ops

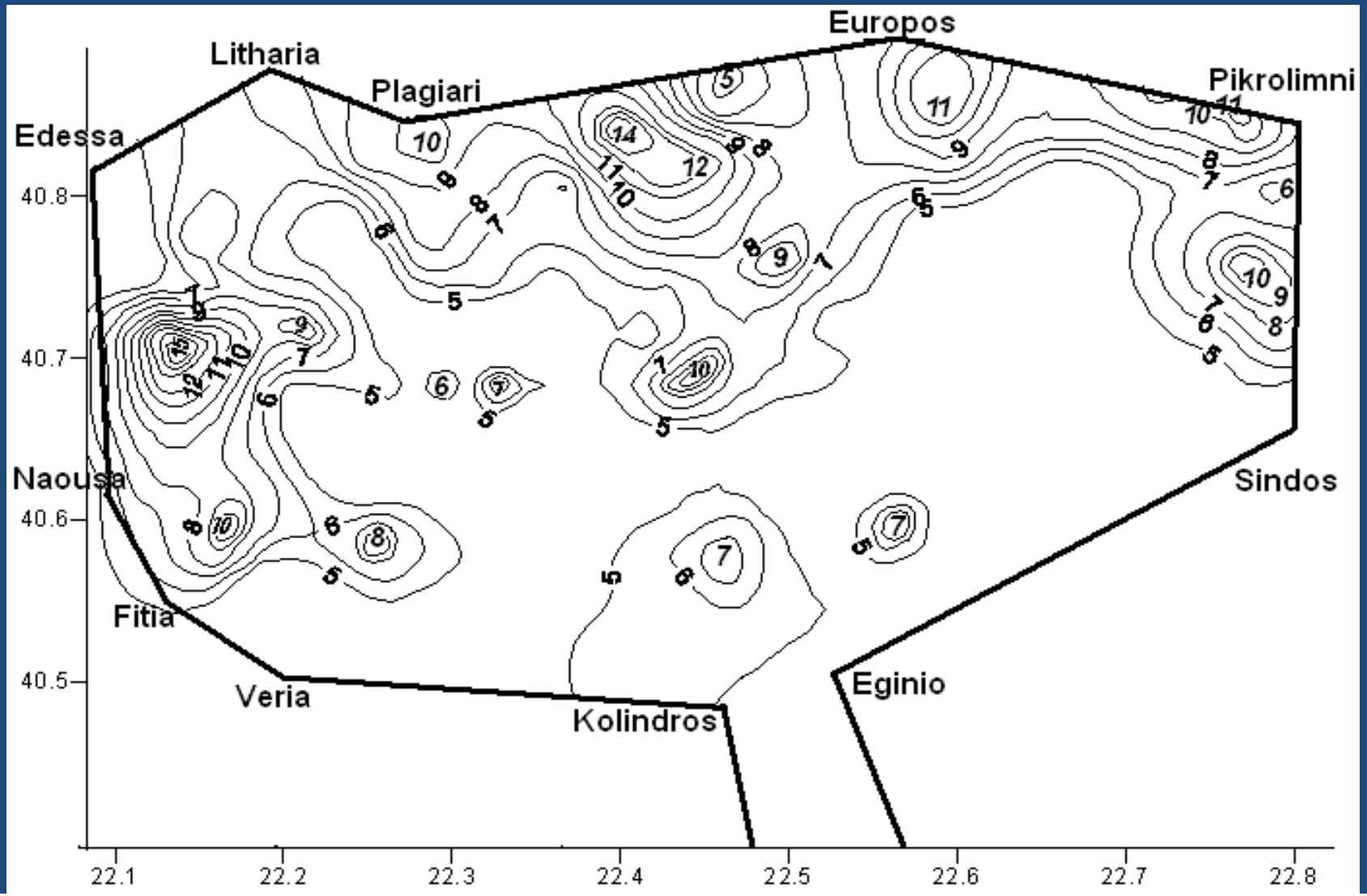


"CROSSOVER DESIGN"

Randomize the two areas (North and South) for each experimental unit.

End of experimental unit, 7 daylight hours after last operation.

TOTAL HAILFALL OCCURRENCES AT EACH HAILPAD SITE
IN CENTRAL MACEDONIA, GREECE



RATIO STATISTICS

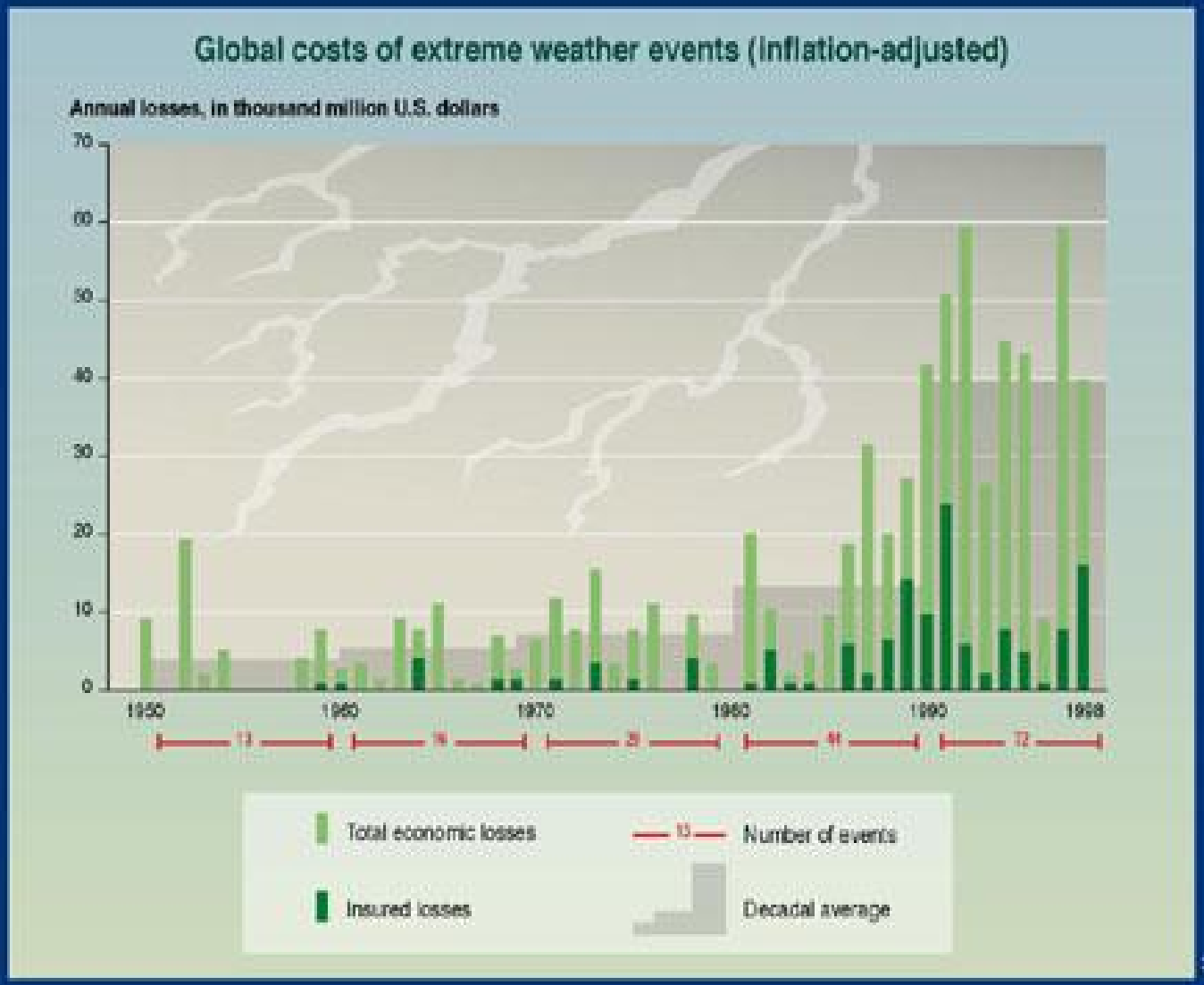
1. *The results are positive.*
2. *18 (out of 21) parameters are statistically accepted at the 5% level of significance.*
3. *Their effect is between 35% and 72%.*
4. *Only 3 (out of 21) parameters are not statistically accepted at α=0.05. In spite of that, they show positive results.*

***Single Ratio**: seeding at the **south part** of area A, was more successful of that at the **north part**.*

*The **Stone Kinetic Energy (T)** parameter was considered as the tentative candidate for the "primary evaluation parameter". Hence, the established 70% effect, would be more valuable and trustworthy, if it would be calculated on time.*

ELGA (Greece) is running the new period 2014-2019

Climate Change
&
Weather Modification

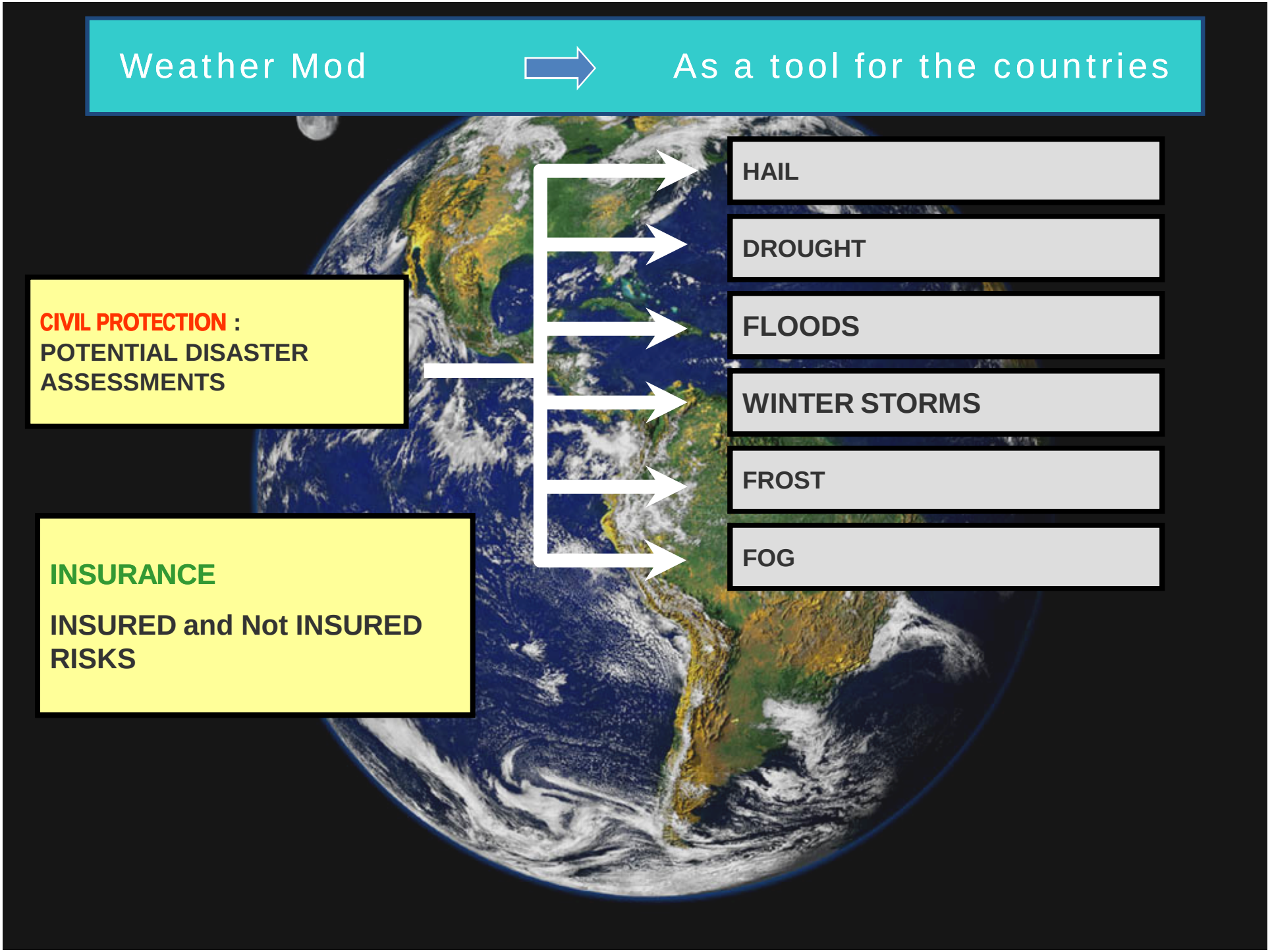


SYR - FIGURE 2-7

It’s well known..

- Climate Change is a global phenomena
- The insurance industry is inter-connected globally via reinsurance
- The price of insurance is in part determined by global dynamics
- Major weather events will impact on the affordability of insurance of many nations or countries .
- **The economic impacts of Climate Change do not stop at national borders**

Weather Mod → As a tool for the countries



CIVIL PROTECTION :
POTENTIAL DISASTER ASSESSMENTS

INSURANCE

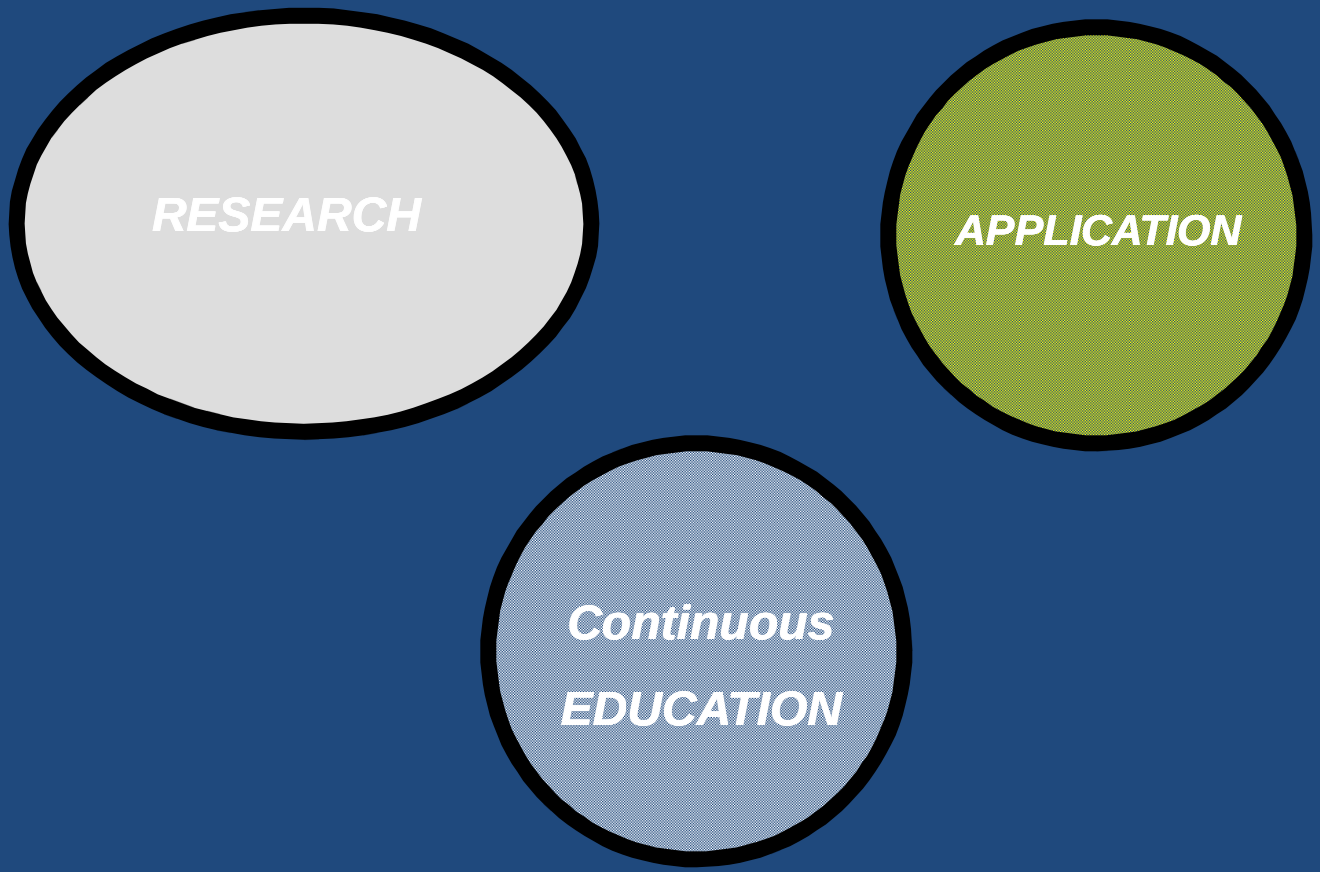
INSURED and Not INSURED RISKS

- HAIL
- DROUGHT
- FLOODS
- WINTER STORMS
- FROST
- FOG

REPORTED WEATHER MODIFICATION PROJECTS

C O U N T R Y	No of Projects	Purpose	Covered Area (km^2)	type of Seeding
AUSTRALIA	1	R A I N	2000	Airborne ✈
AUSTRIA	2	H A I L	2300	Airborne ✈
ARGENTINA	1	H A I L	20.000	Airborne ✈
BULGARIA	1	H A I L	15.000	Rockets
CANADA	1	H A I L	26.400	Airborne ✈
CHILE	1	R A I N	150	Ground Based Generators
CHINA CHINA	8	H A I L + R A I N	480.960	Airborne✈ / Gr.Bas.Gen / Rockets
CROATIA	1	H A I L	24.000	Gr. Based Gener. / Rockets
FRANCE	2	H A I L	60.400	Gr. Based Gener. / Airborne✈
GERMANY	1	H A I L	4400	Airborne ✈
GREECE	1	H A I L	5000	Airborne ✈
ISRAEL	1	R A I N	6500	Gr. Based Gener. / Airborne✈
LIBYAN	1	R A I N	69.000	Airborne ✈
MALAYSIA	1	R A I N	All the Country	Airborne ✈
MOLDOVA	1	H A I L	21.250	Rockets
RUSSIA RUSSIA	2	H A I L+R A I N redist.	80.000	Rockets
SERBIA	1	H A I L	50.000	Rockets
SOUTH AFRICA	1	R A I N	10.000	Airborne ✈
SPAIN	3	H A I L	15.300	Ground Based Generators
SYRIA	1	R A I N	150.000	Airborne ✈
TAJIKISTAN	1	H A I L	1800	Rockets
USA USA USA	40	HAIL +RAIN+SNOW	951.711	Gr. Based Gener / Airborne ✈
UKRAINE	1	H A I L	2400	Rockets
UZBEKISTAN	1	H A I L	7380	Rockets
ZIMBABWE	1	R A I N	All the Country	Airborne ✈
TOTAL COUNTRIES = 25	76		2.000.000	

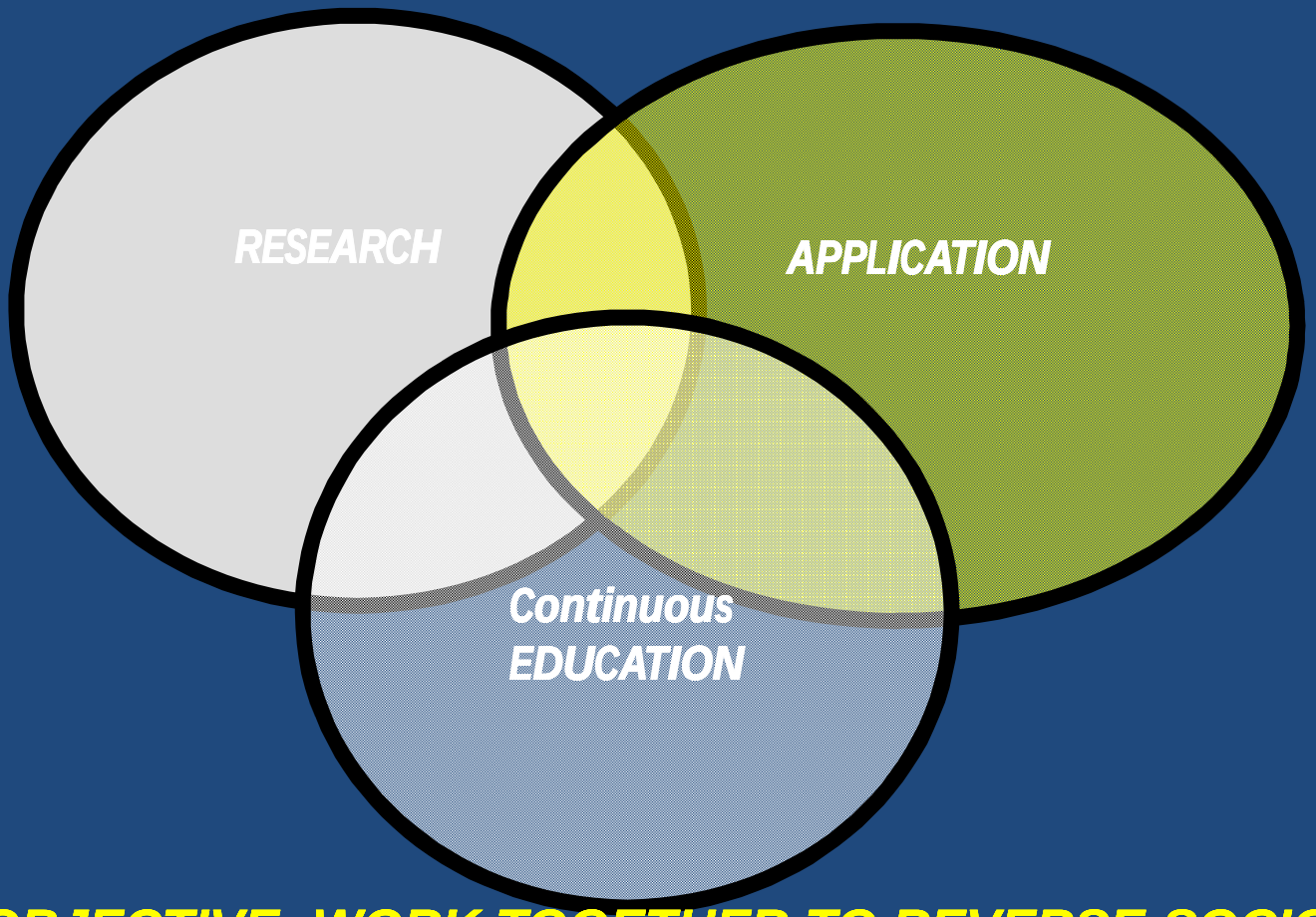
HOW WE CAN FAIL …TRYING TO ORGANIZE A WEATHER MOD. PROGRAM



ERROR: WORKING ALONE. FACT: NO ORGANIZATION CAN SOLVE THE PROBLEM BY WORKING ALONE.

HOW WE CAN SUCCEED IN REDUCING OUR VULNERABILITIES

STRATEGIC GOALS: WORKING TOGETHER TO INCREASE CAPACITY ON LOCAL, NATIONAL, AND REGIONAL SCALES



OBJECTIVE: WORK TOGETHER TO REVERSE SOCIO-ECONOMIC IMPACTS IN EVERY COUNTRY

RECOMMENDATIONS FOR THE HAIL SUPPRESSION PROGRAM IN MENDOZA

The case of the Hail Suppression Program in Mendoza

1. The existence of Hail in Mendoza is given since many years ago
2. The severity of the Hailstorms is Mendoza is UNIQUE
3. The Airborne cloud seeding is implemented in Mendoza for more than 15 years
4. The Mendoza's Hail Suppression Program needs to be upgraded ?

The answer is **YES**

Mendoza's case / Recommendations

Initial recommendations

1. Primary Mendoza hast to **CONTINUE** and to **UPGRADE** the Hail Suppression project.

Mendoza's case/ Recommendations cont.

Initial recommendations

2.

The upgrade has to include the **RECONSIDERATION** of the following .....

Mendoza's case / Recommendations cont.

Initial recommendations

3.

Scientific Supervision: You have a charismatic Scientist who scientifically supervises the Project .

Project Design: A special working team supervised by the Scientific Supervisor has to be established in order in 2 months to submit the new Project Design which will be also related with the Economical Evaluation of the Project.

Argentina's case/ Recommendations cont.

Initial recommendations

3.

Human Resources: -You have very experienced Personnel
-Continuous Training

Aircrafts: The missing piece is related with the maintenance

Radars: To be upgraded and to operate as network

Seeding Material: Quality control and references from other users for the efficiency

Mendoza's case / Recommendations cont.

The redesign's benefits

- Sufficient better result for the farmers (after evaluation)
- Mendoza could be "the leader" in the Latin America on weather mod activity
- Mendoza could export in a few years the weather mod's know-how in other countries
- Parallel economical benefits from the Hail Suppression activity .

Mendoza's case/ Recommendations cont.

Indicative parameters concerning the reorganization and the upgrade of the project

1. Reconsideration of the project purpose (it is proposed to include the protection of the Urban Areas .
2. Total upgrade of the weather radars aiming to operate as a radar network.
3. Creation of a modern operational center which will be activated on the prevention (passive- active) of natural disasters .

What are the **advantages** and the additional **benefits** of the proposal

1. The existence of Hail in Mendoza
2. The scientific experience in the weather modification sector
3. The immediate availability of the infrastructure
4. The research & operational component of the project
5. **The exploitation of the used infrastructure for other uses (pollution measurements , ambulance , fire detection , water resources , agricultural trading competition etc.)**
6. **The evaluation of the project in short period because the frequency of Hail in Mendoza is given.**

Why Not ?

A modern full upgraded airborne cloud seeding project
In Mendoza ?

a research Weather Modification center
In Mendoza ?

Never .....forget

One typical Hail fall could cost million of pesos in Argentina

The cost of a Hail Suppression Program is ≈ the 5% of a typical Hail Day

ACKNOWLDMENTS AND IMAGE GREDITS

- Don Griffith for structural material suggested.
- WMA workshops materials (J. Renick) and other sources including ASCE #39-03, “Standard Practice for the Design and operation of hail suppression projects”.
- 3D s.a.
- WMI Inc.
- ICE CRYSTALS ENGINEERING

- Image Gredits
  - 3D sa
  - Ted Karakostas
  - T. Krauss
  - J. Dessens
  - ASCE and Antigrade HS Res Center
  - N. Am. Wx Conslts
  - J. Renick