Systems analysis for geophysics: Challenges of the 21st century

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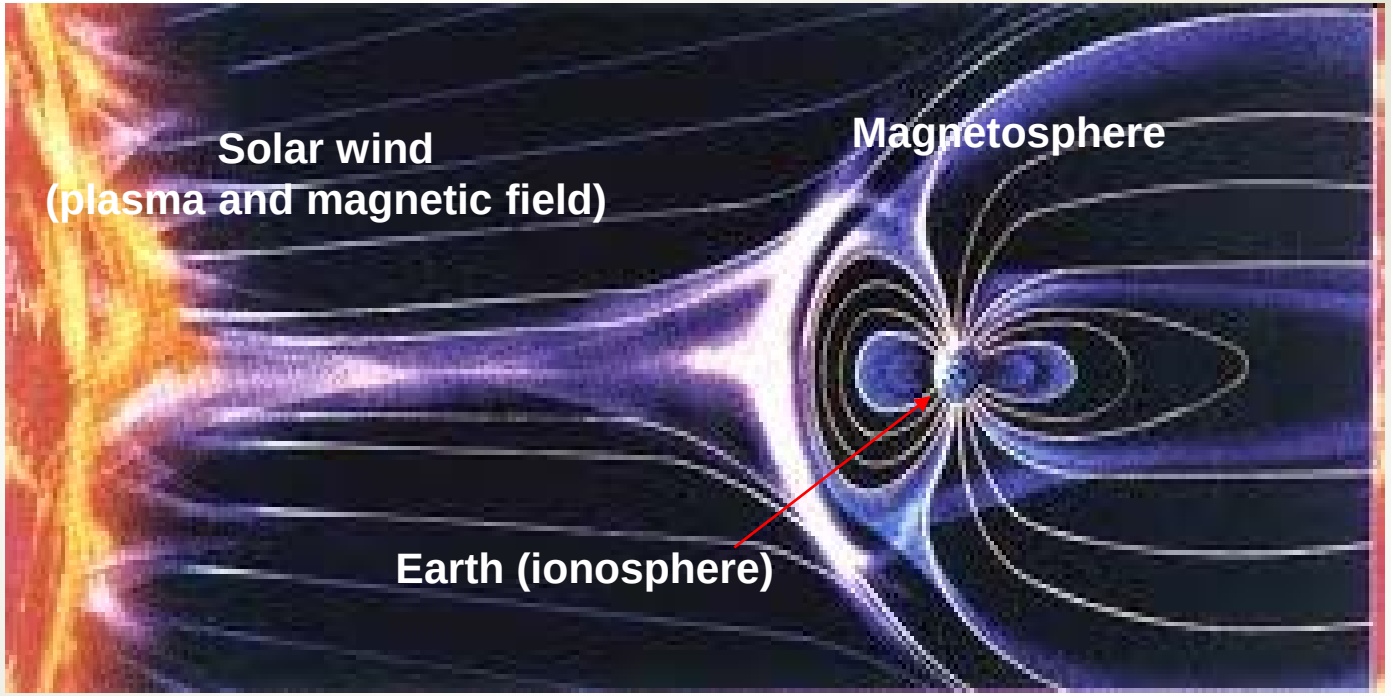
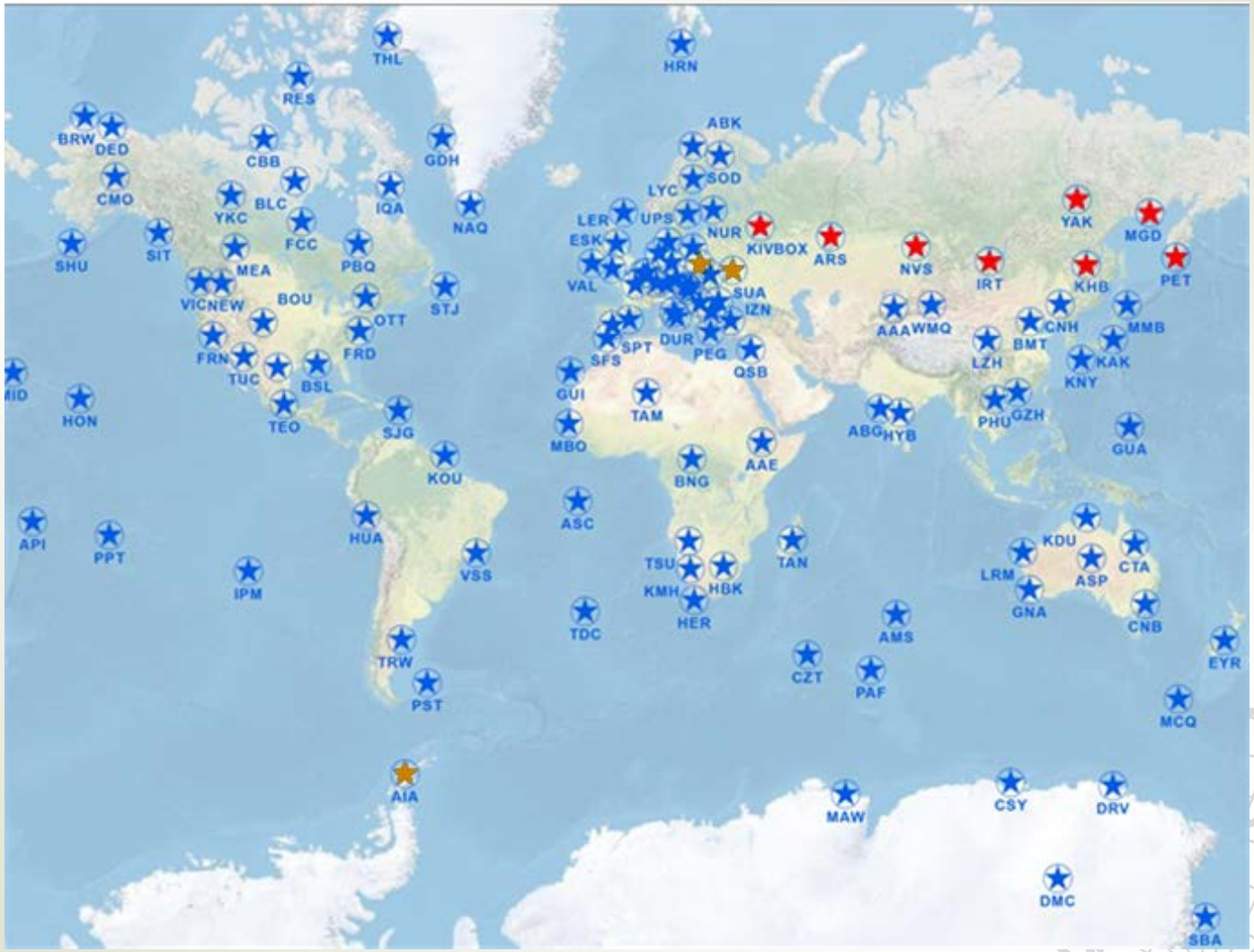
EARTH'S MAGNETOSPHERE



Solar activity determines the state of the magnetospheric plasma condition and ionospheric conductivity.

M and I are electromagnetically coupled.

INTERMAGNET OBSERVATORIES



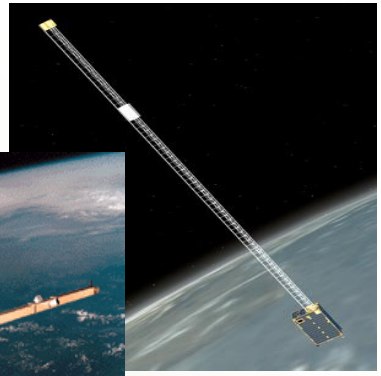
MAGNETIC MEASUREMENTS IN THE IONOSPHERE

Low polar orbiting satellites carry high-precision vector and scalar magnetometers

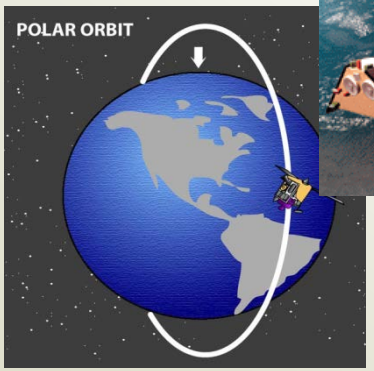
***SWARM* 2013 -**
(European Space Agency)

Oersted* 1999–2010 *(Denmark)

***CHAMP* 2000–2012**
(Germany)



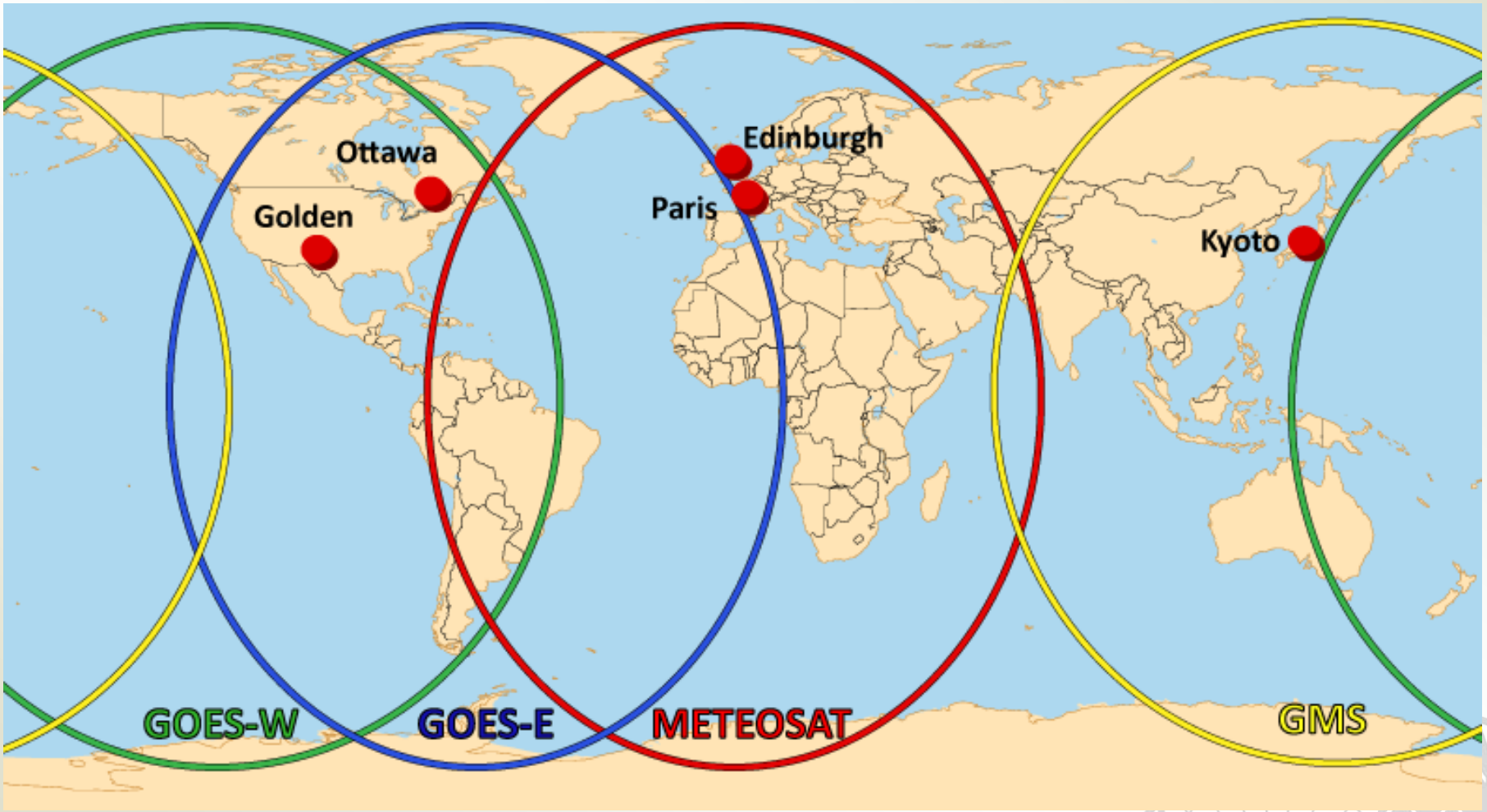
***Magsat* 1979–1980**
(NASA)



Multi-satellite. Simultaneous measurement at different geographical points. Separation of spatial and temporal variations

One-satellite mission

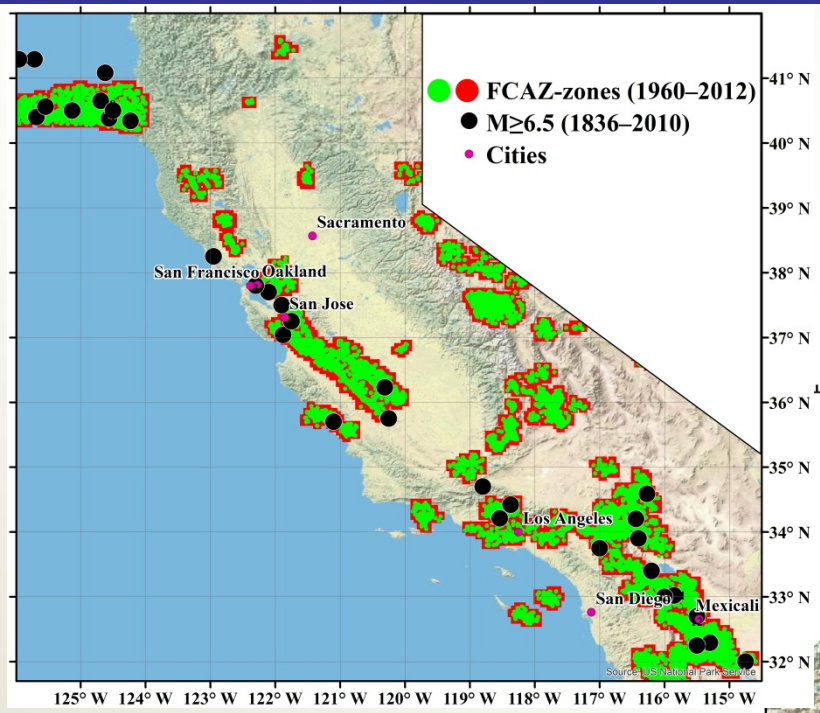
GEOMAGNETIC INFORMATION NODES



SYSTEM ANALYSIS IN INTERMAGNET CENTERS

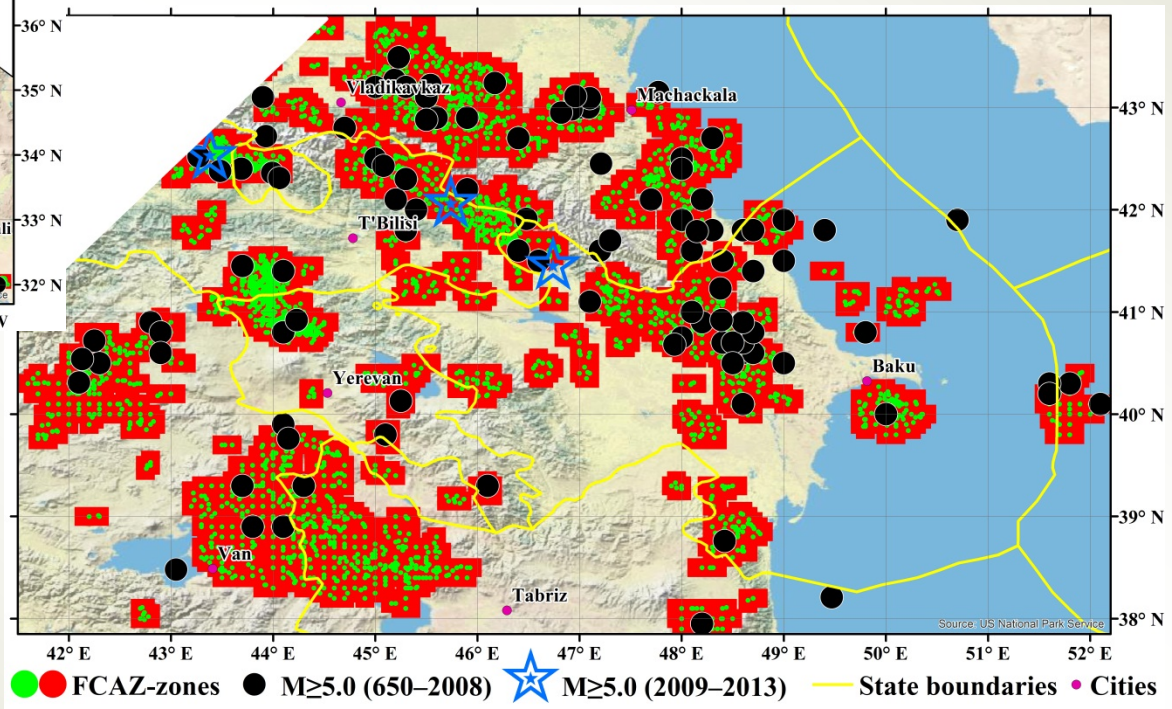
Data
- -acquisition of observatories
- -transmition
- -storage
- -data base management
- -correlation to definitive magnetgrams
- -retrieval
- -integration of with satellite and sun data
- -data mining
- -pattern recognition
- -knowledge base
- -interaction with other centers

RECOGNITION OF CRUSTAL EARTHQUAKE-PRONE AREAS FOR MODERATE (5.0) AND STRONG (6.5) EARTHQUAKES

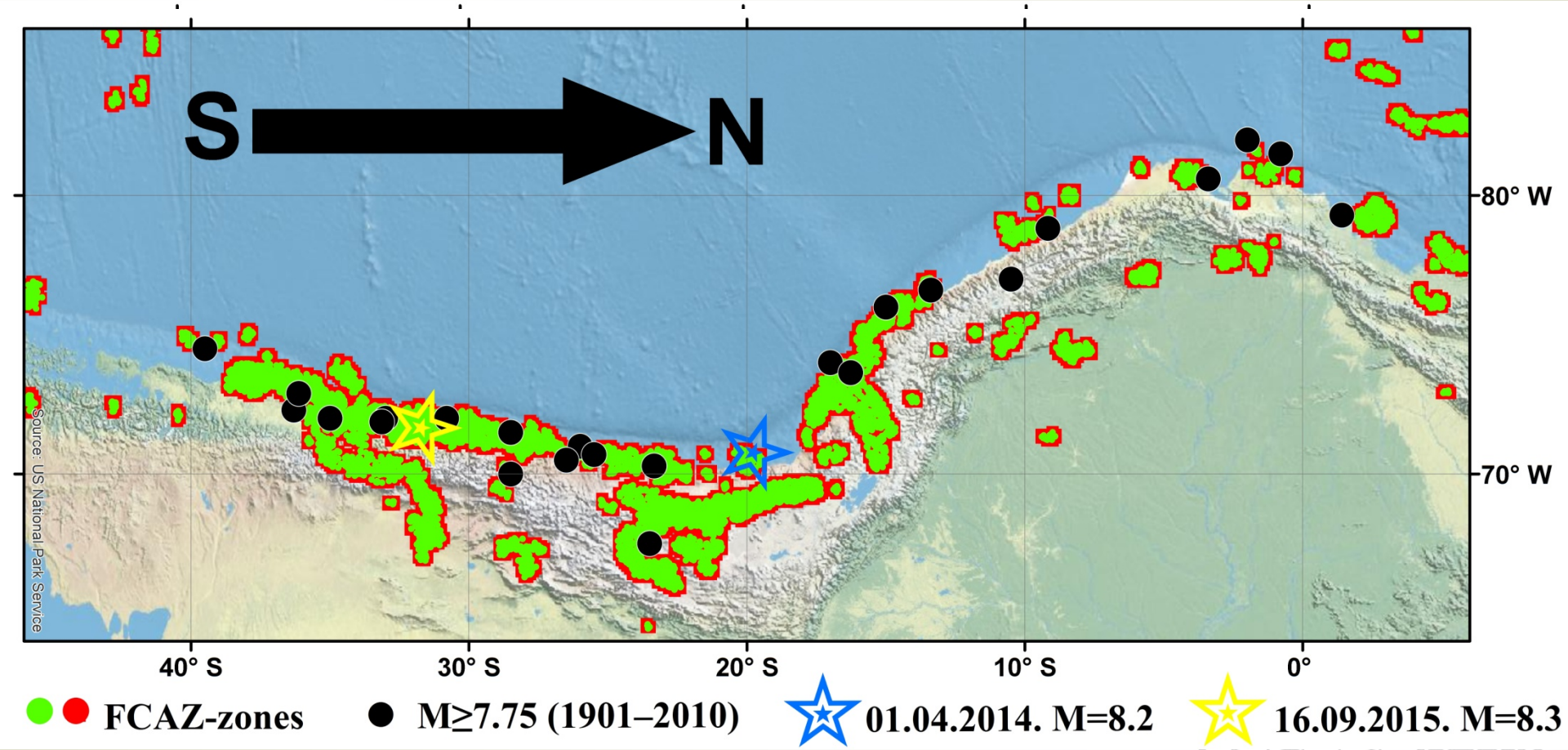


California, strong events M≥6,5

The Caucasus, moderate events M≥5,0

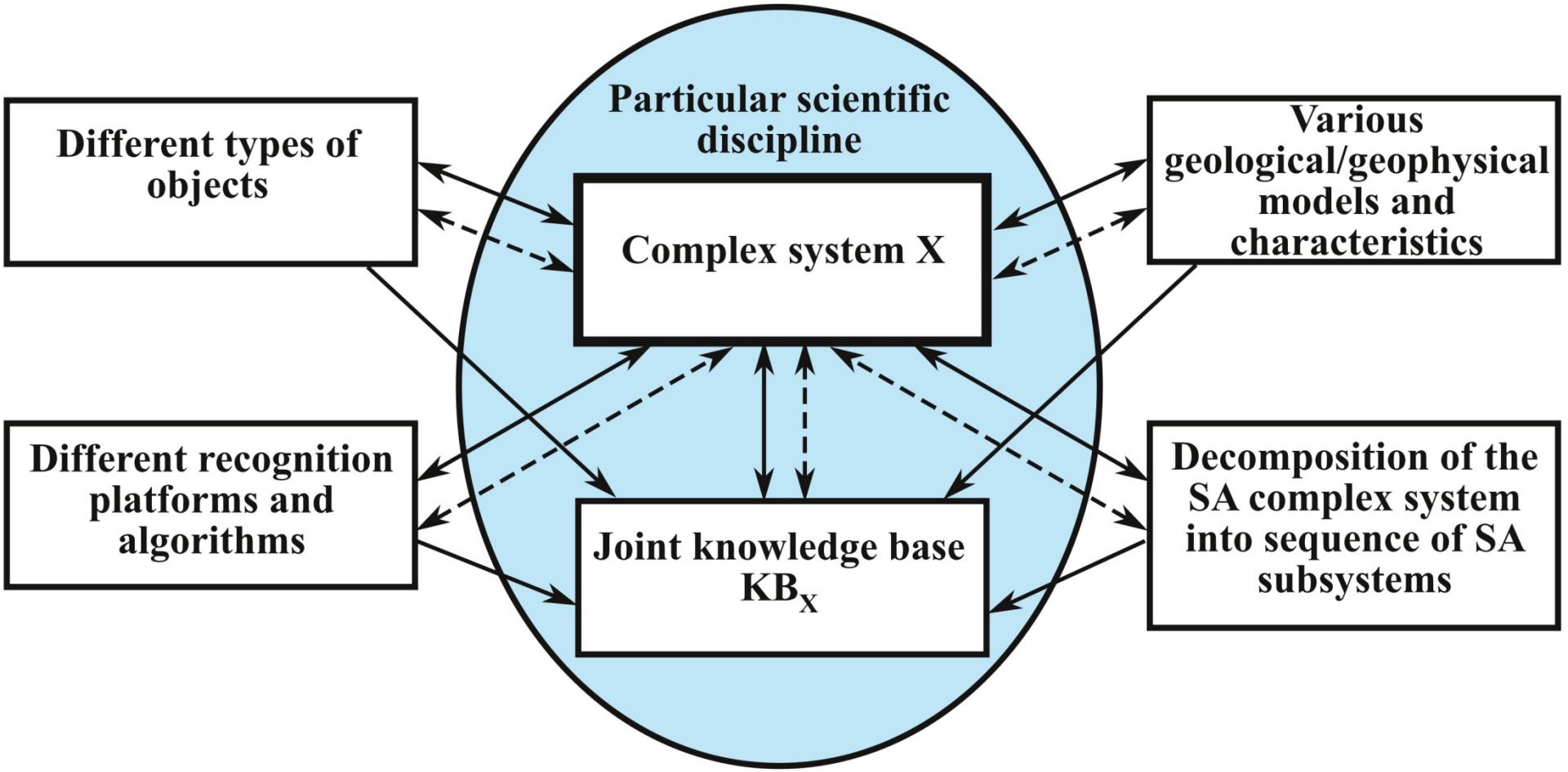


FCAZ RECOGNITION OF M≥7.75 CRUSTAL EARTHQUAKE-PRONE AREAS IN THE ANDES



$$\mathrm{FCAZ}(q,\beta,w,v) = \mathrm{E}^2\mathrm{XT}(w,v) \circ \mathrm{DPS}(q,\beta)$$

COMMON FEATURES OF SA IN THE ABOVE SEISMOLOGICAL AND MAGNETIC STUDIES



Multivaluedness

$$A_{SA} = \{A_1, A_2, \dots, A_n\}$$
$$A_i : X \to KB_X^i, \qquad i = 1, \dots, n$$

Decomposability and compondness

$$A_{SA} = B_1 \oplus B_2 \oplus \cdots \oplus B_n$$

where B_i are non-linear SA operators to study subsystem X_i

Integrability of the knowledge bases

$$KB_X = \int_i KB_X^i di$$

Reproducibility

Once free parameters are fixed, KB_X remains stable in every later realization of $A: X \rightarrow KB_X$

WHAT IS SYSTEMS ANALYSIS AND WHAT IS NOT

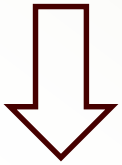
Yes, it is SA

- An applied problem (complex system X) is studied by several SA methods born outside a particular discipline and their results are integrated into joint SA knowledge base KB_X.
- **Significant added value** can be provided to a particular scientific discipline through KB_X.

WHAT IS SYSTEMS ANALYSIS AND WHAT IS NOT

No, it is not SA

- The problem (complex system X) is studied by just one method born inside a particular discipline and the knowledge base is fully constructed by the results of this unique approach.



- **Small or no added value** is provided since the level of knowledge inside the particular discipline is, apriori, higher than the one brought by SA from outside.

MATHEMATICAL FORMALIZATION

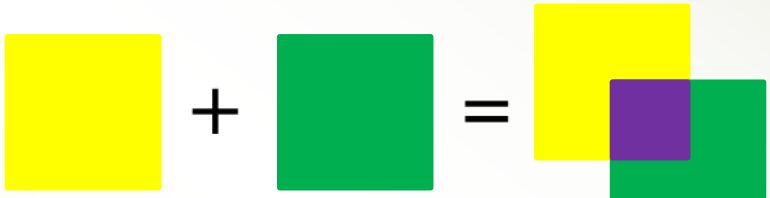
- Mathematical constructions such as fields, rings, groups, semi-groups, linear spaces, Boulean algebra etc. have it's own strict and unique axiomatics.

- As SA, those formal mathematical constructions model real objects and processes.

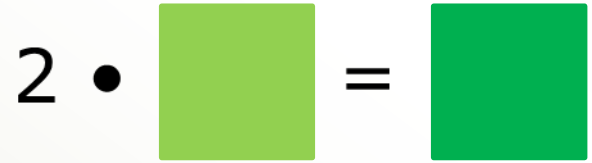
APPLIED PROBLEMS OF MATH LINEAR SPACES THEORY

- The linear space of colours

$\vec{x} + \vec{y} = \vec{z}$



$\lambda\vec{x} = \vec{y}$



$$\lambda(\overrightarrow{x_1} + \overrightarrow{x_2}) = \lambda\overrightarrow{x_1} + \lambda\overrightarrow{x_2}$$

and

$$\exists\, 0\colon \forall\, \vec{x} \quad \vec{x} + 0 = 0 + \vec{x} = \vec{x}$$

- 1D, 2D, 3D Euclidean vector spaces

Conclusions

At the present stage of impetuous development of SA, methodological efforts towards strict SA mathematical axiomatics are highly desirable.

What can we do to achieve it ? :

Pure mathematicians are needed in SA research teams.

Classes of applied problems, to which SA is applicable, should be selected and described.

#Characteristic features of these problems should be extracted and defined as formally as possible.

 # Strict axiomatics of SA is created on the basis of the previous steps.

• New stage of ASA development on the basis of SA as a mathematical discipline.