LES

TOWARDS A SHORT TERM SOLAR IRRADIATION FORECAST USING GOES SATELLITE IMAGES AND OPTICAL FLOW TECHNIQUES

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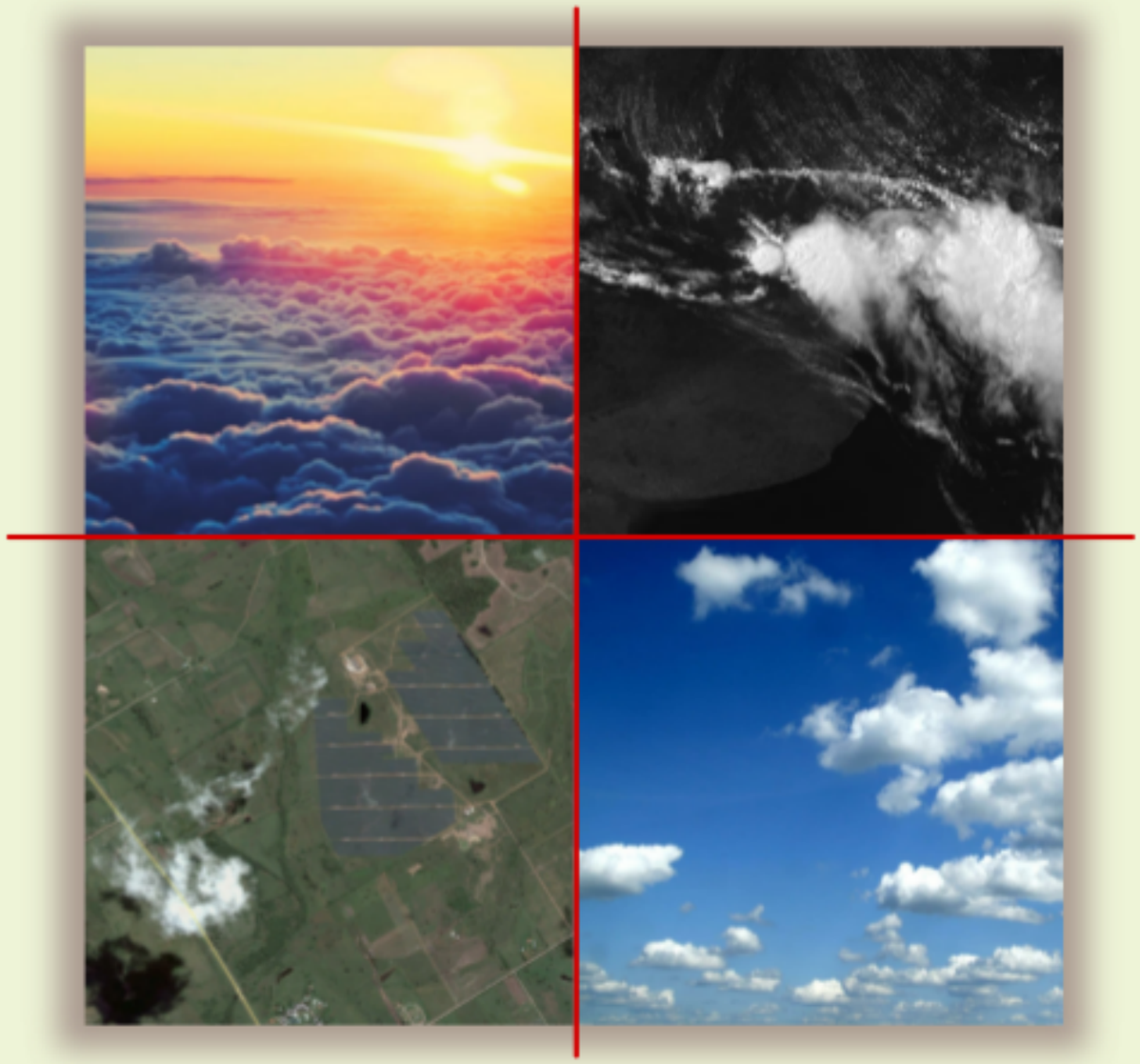
M. Roubaud, P. Musé.



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UNIVERSIDAD DE LA REPÚBLICA

ISES Solar World Congress 2017 - Abu Dhabi UAE - 30 th October 2017

AGENDA

1. INTRODUCTION + BACKGROUND

2. SATELLITE BASED FORECASTING METHOD

3. PRELIMINARY PERFORMANCE EVALUATION

4. CONCLUSIONS AND ON-GOING WORK

Uruguay's Background:

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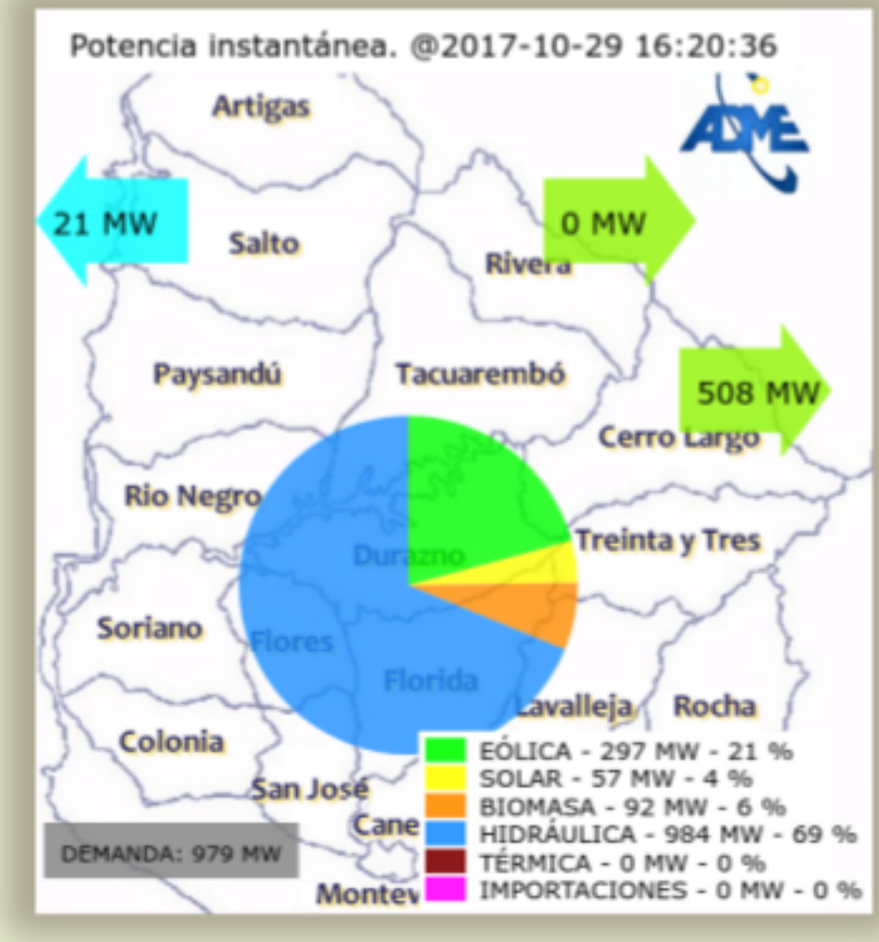
Uruguay is 100% renewable for electricity generation

(with little thermal fossil fuel backup)

This year Uruguay has turned into an energy exporting country

(to Brazil and Argentina)



Uruguay's Background:

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URUGUAY NEEDS TO FORECAST RENEWABLE'S GENERATION (WIND + SOLAR + HYDRO)

TO ANTICIPATE ENERGY PACKAGES TO SELL

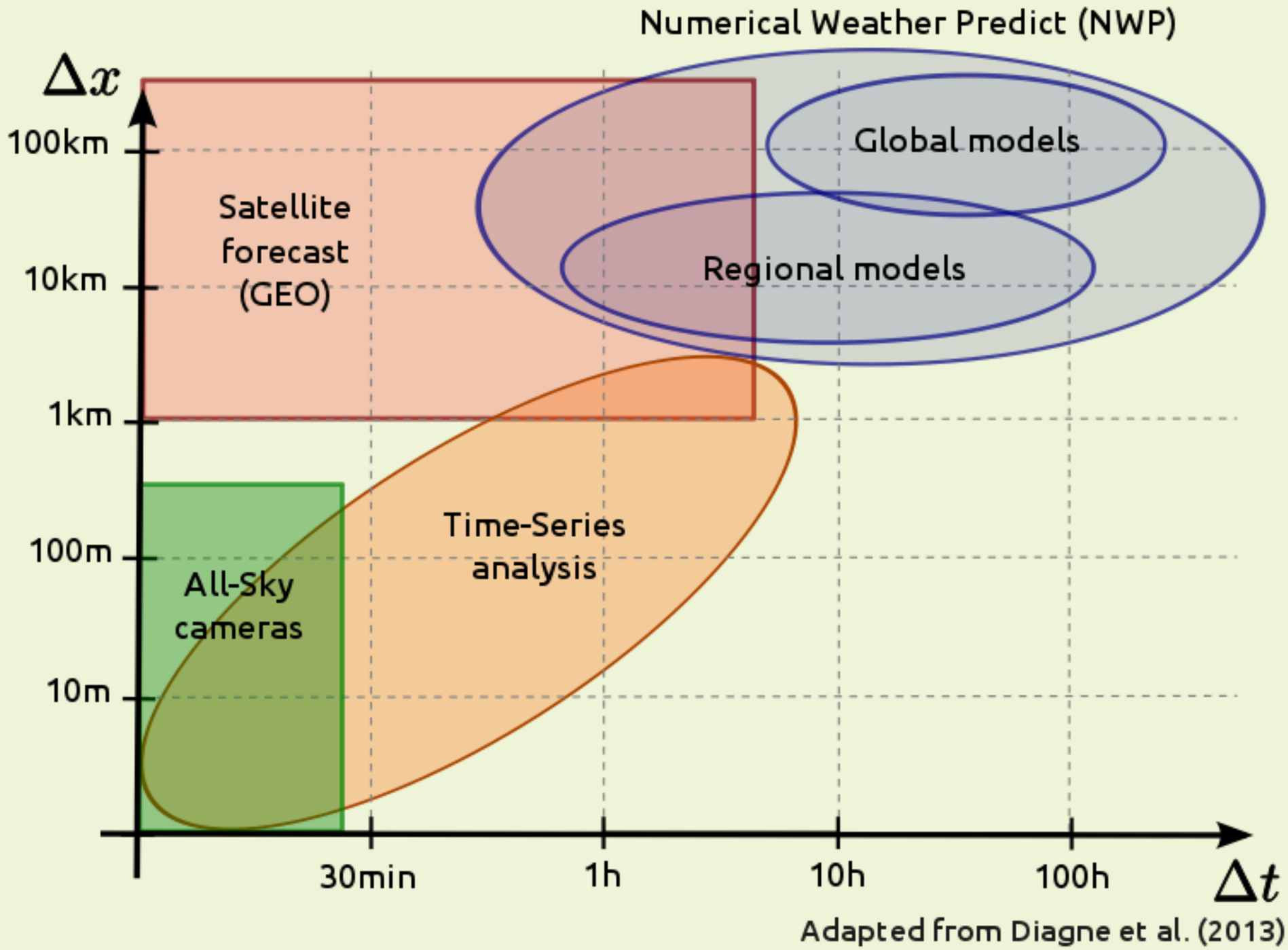
TO ESTABLISH ENERGY PRICES BASED ON AVAILABILITY

FOR EFFICIENT ENERGY DISPATCH AND TO REDUCE OPERATIONAL COST ASSOCIATED WITH THE GRID BACKUP

FORECASTING TOOLS ARE BEING DEVELOPED WITH LOCAL CAPACITIES

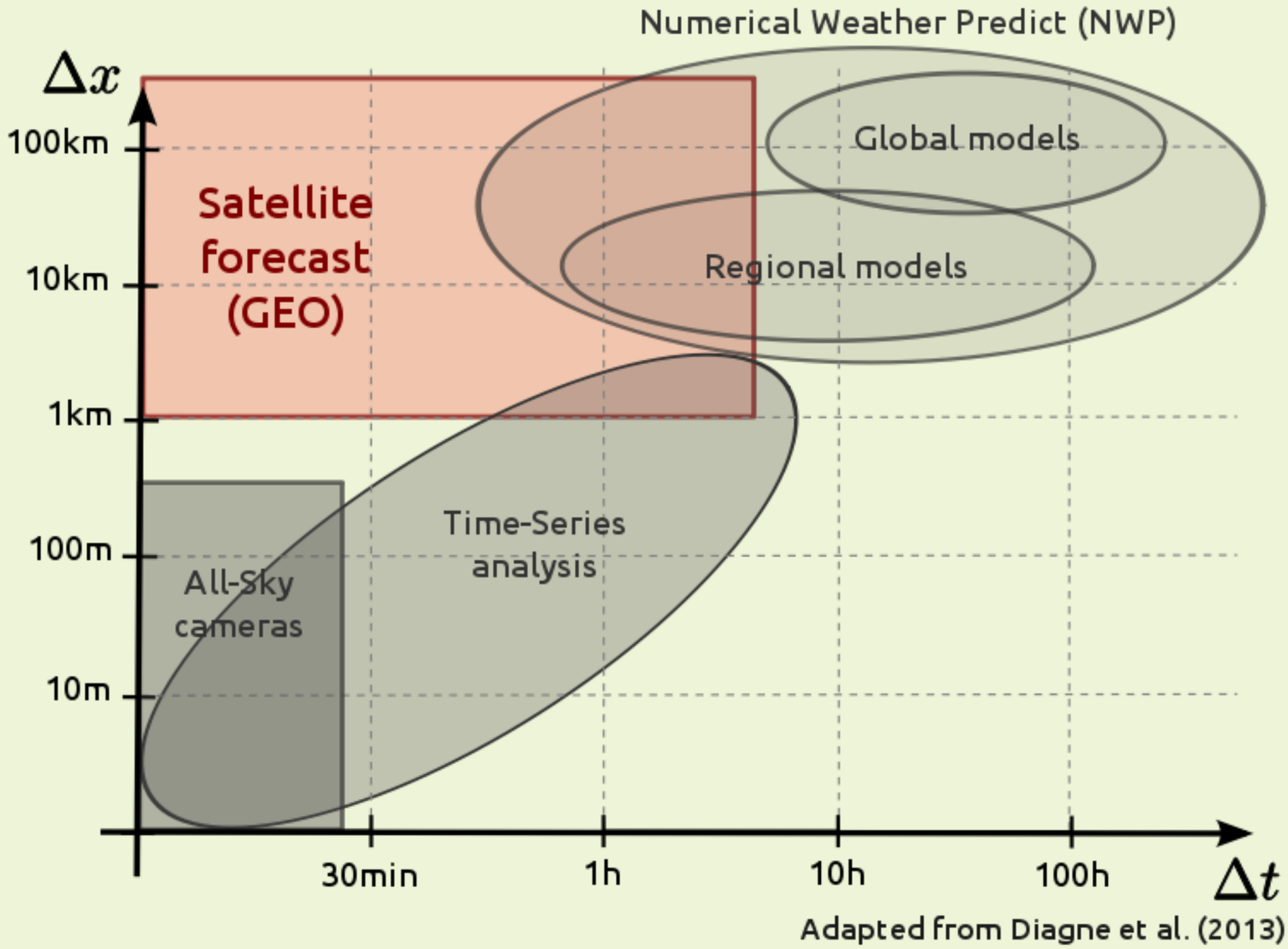
SOLAR RESOURCE FORECASTING

Solar Resource Forecasting techniques



Adapted from Diagne et al. (2013)

Today: our on-going work in hourly satellite forecast



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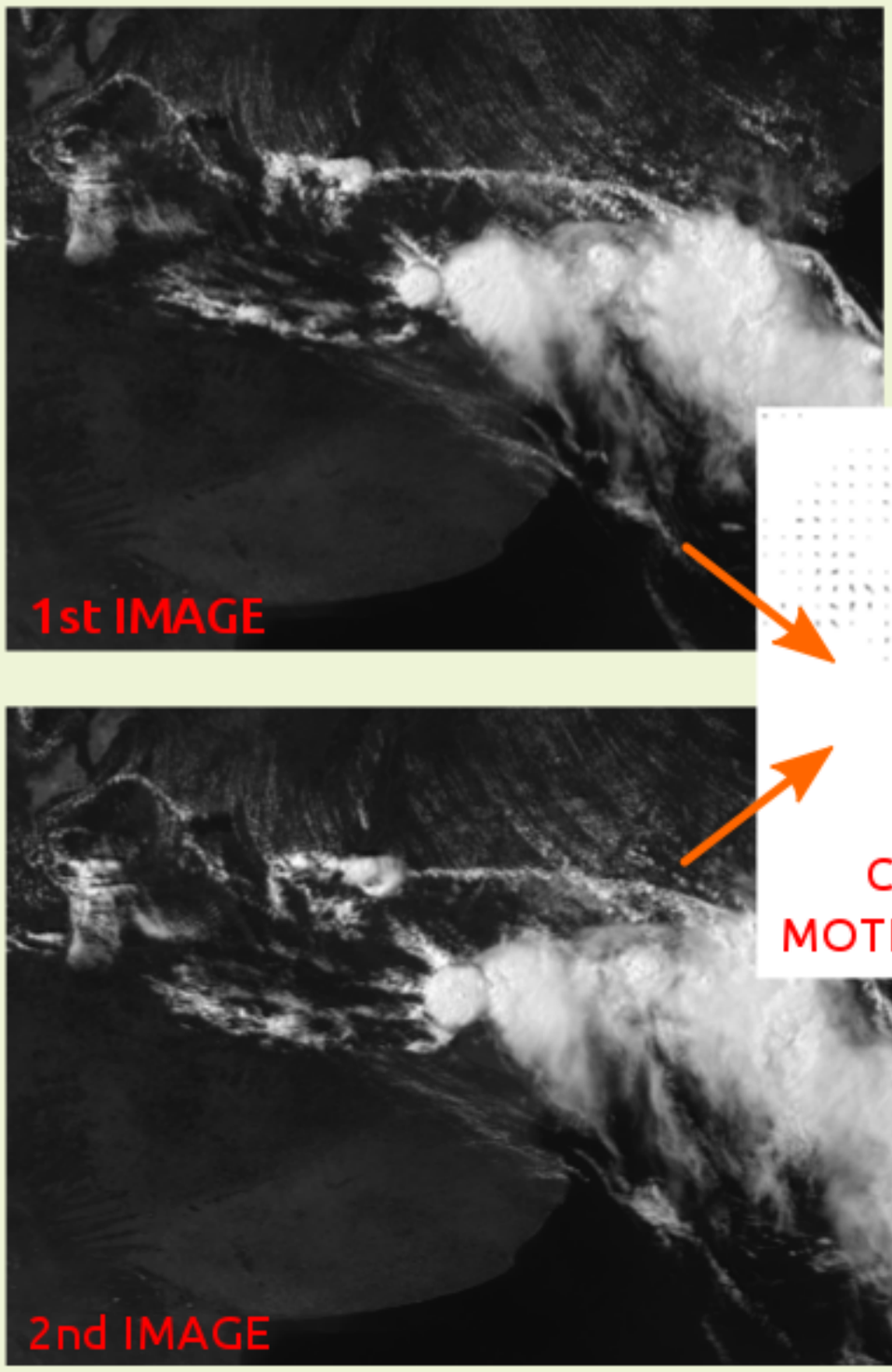
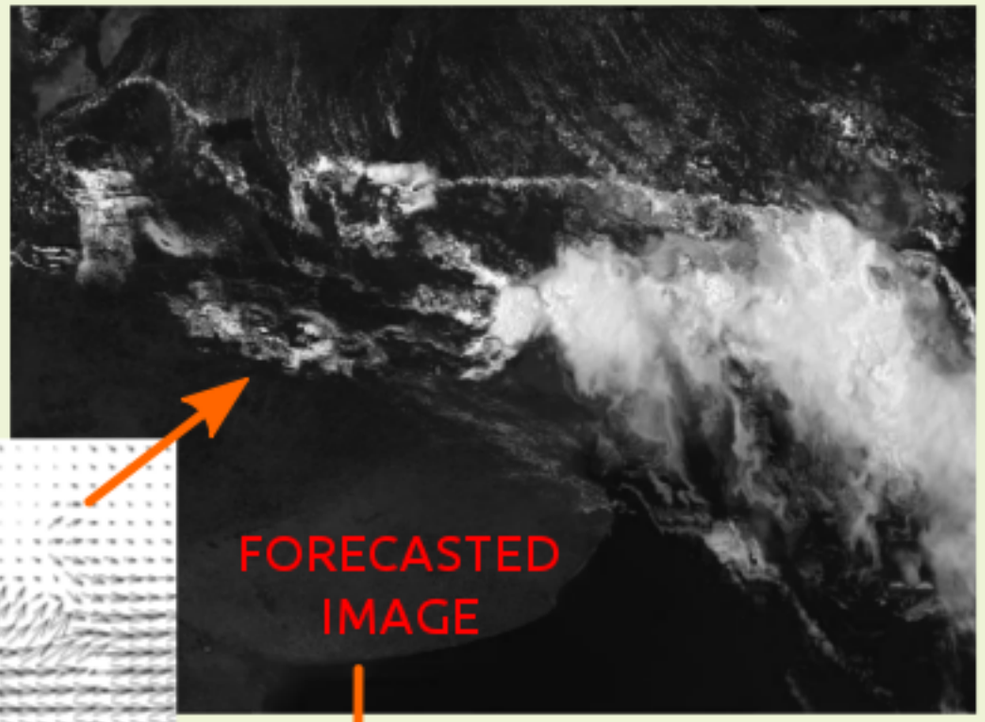
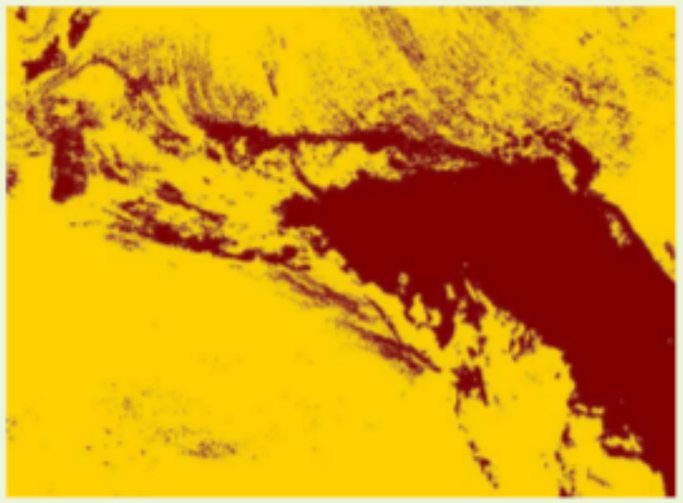
SATELLITE FORECAST





SATELLITE-BASED SOLAR
IRRADIATION MODEL



irradiation forecast

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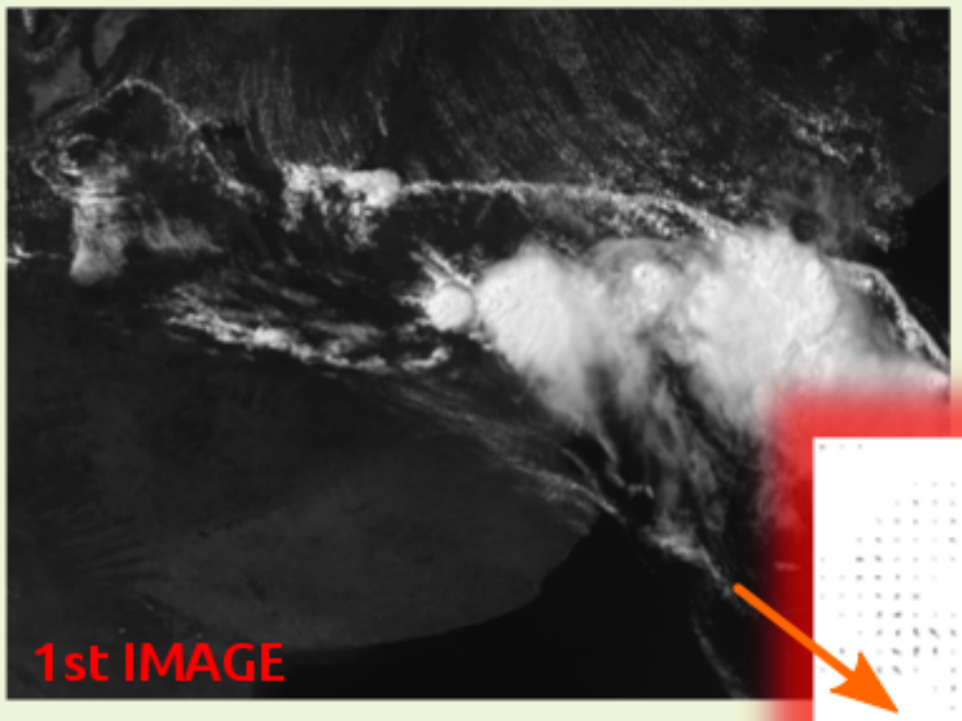
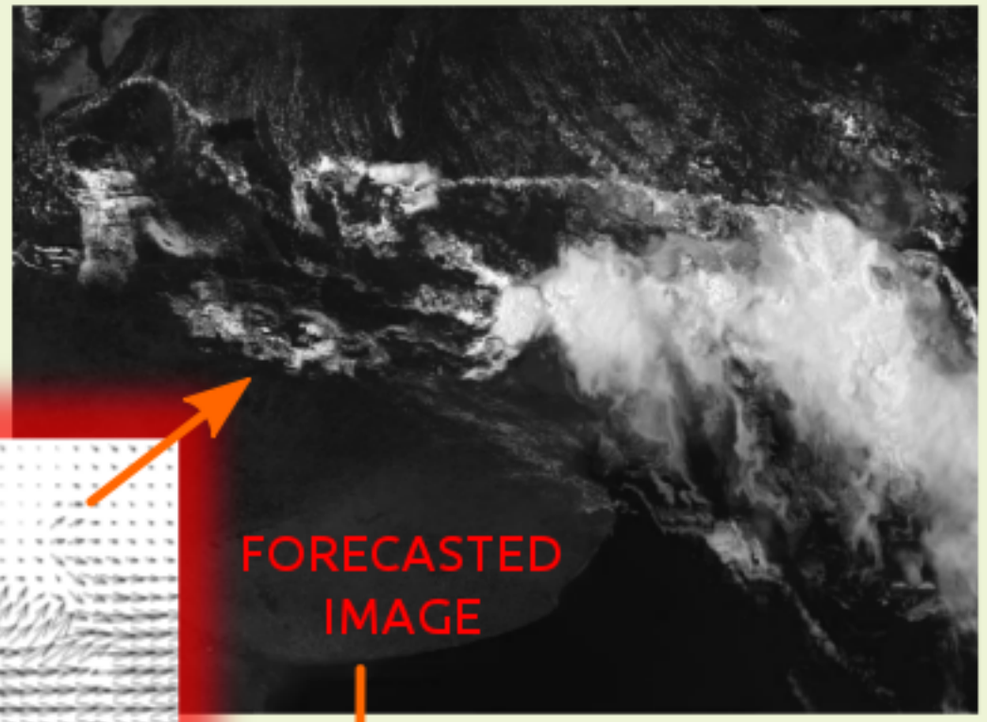
SATELLITE FORECAST



1st IMAGE

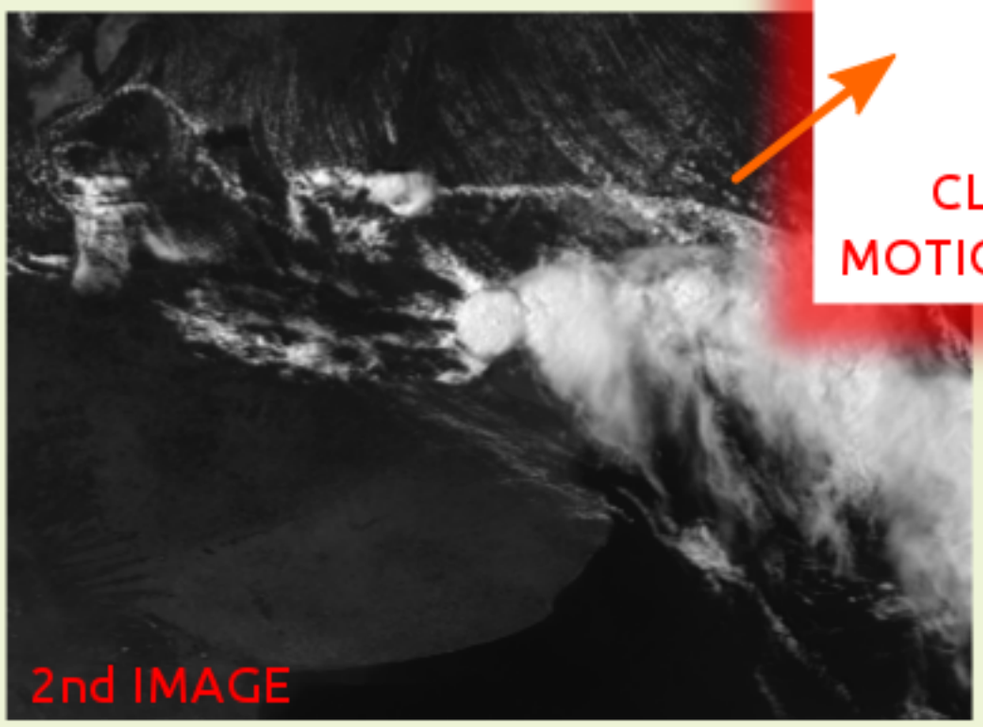
KEY STEP

CLOUD MOTION FIELD

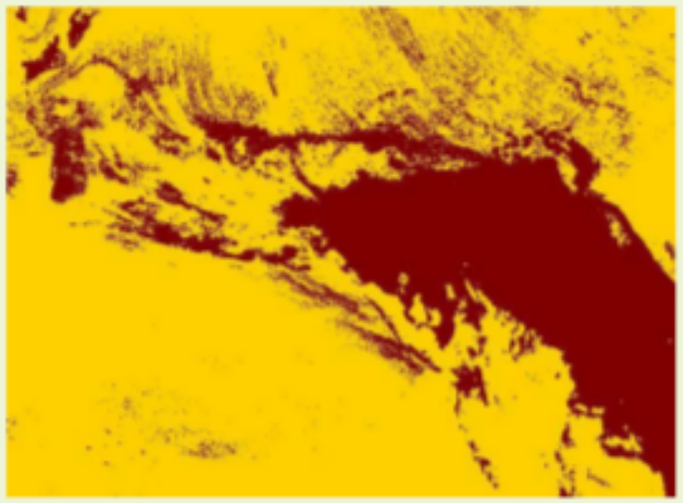


FORECASTED IMAGE

SATELLITE-BASED SOLAR IRRADIATION MODEL

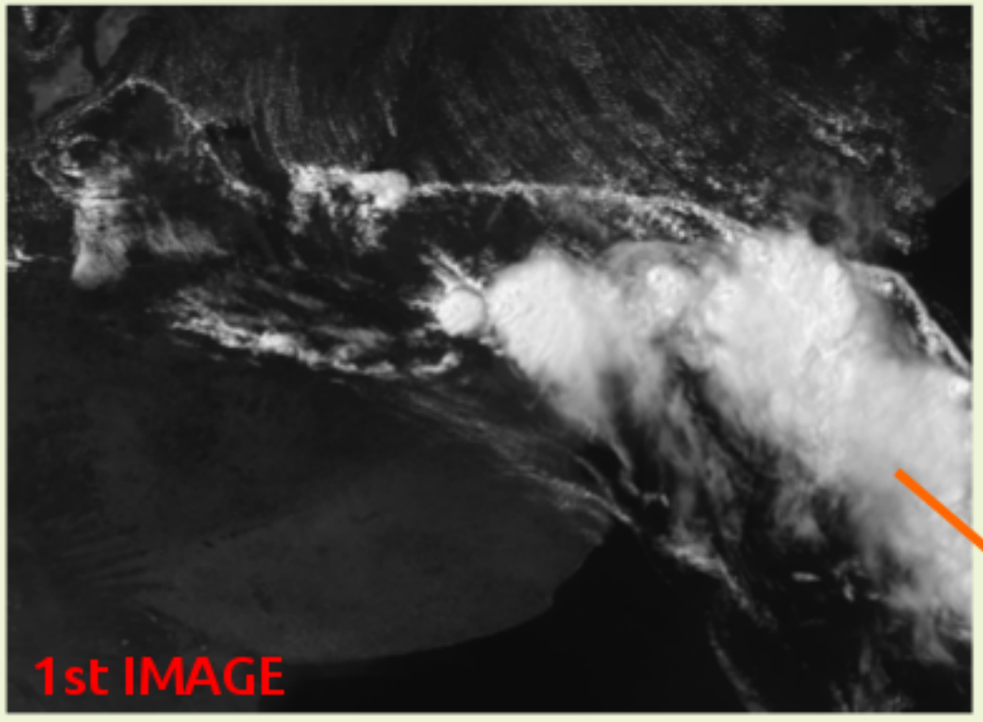


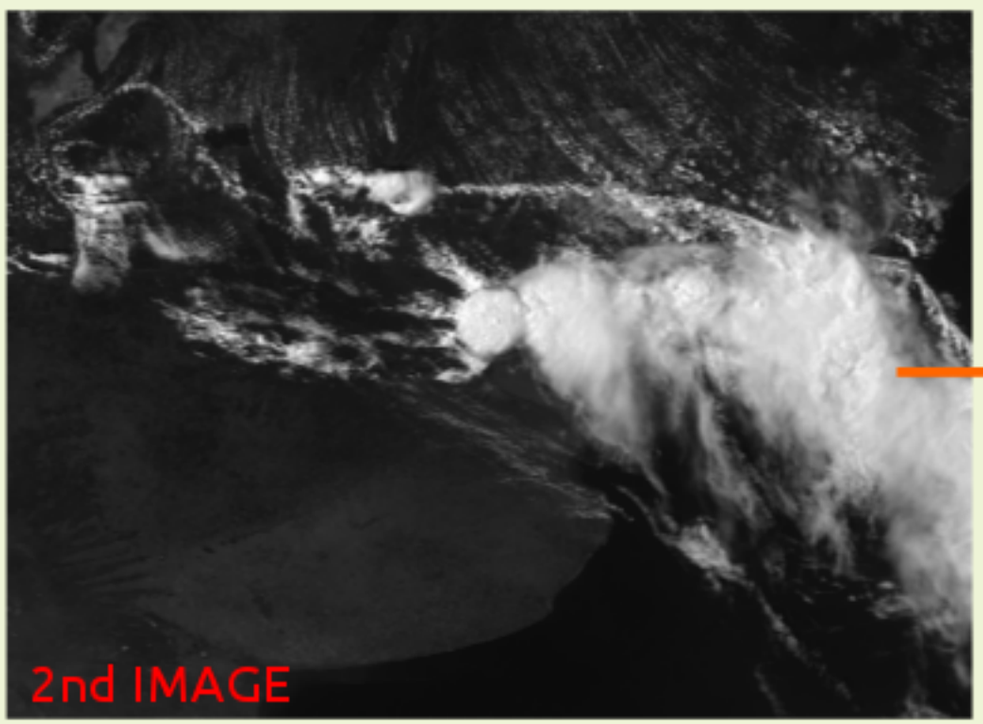
2nd IMAGE



irradiation forecast

TWO CONSECUTIVES IMAGES



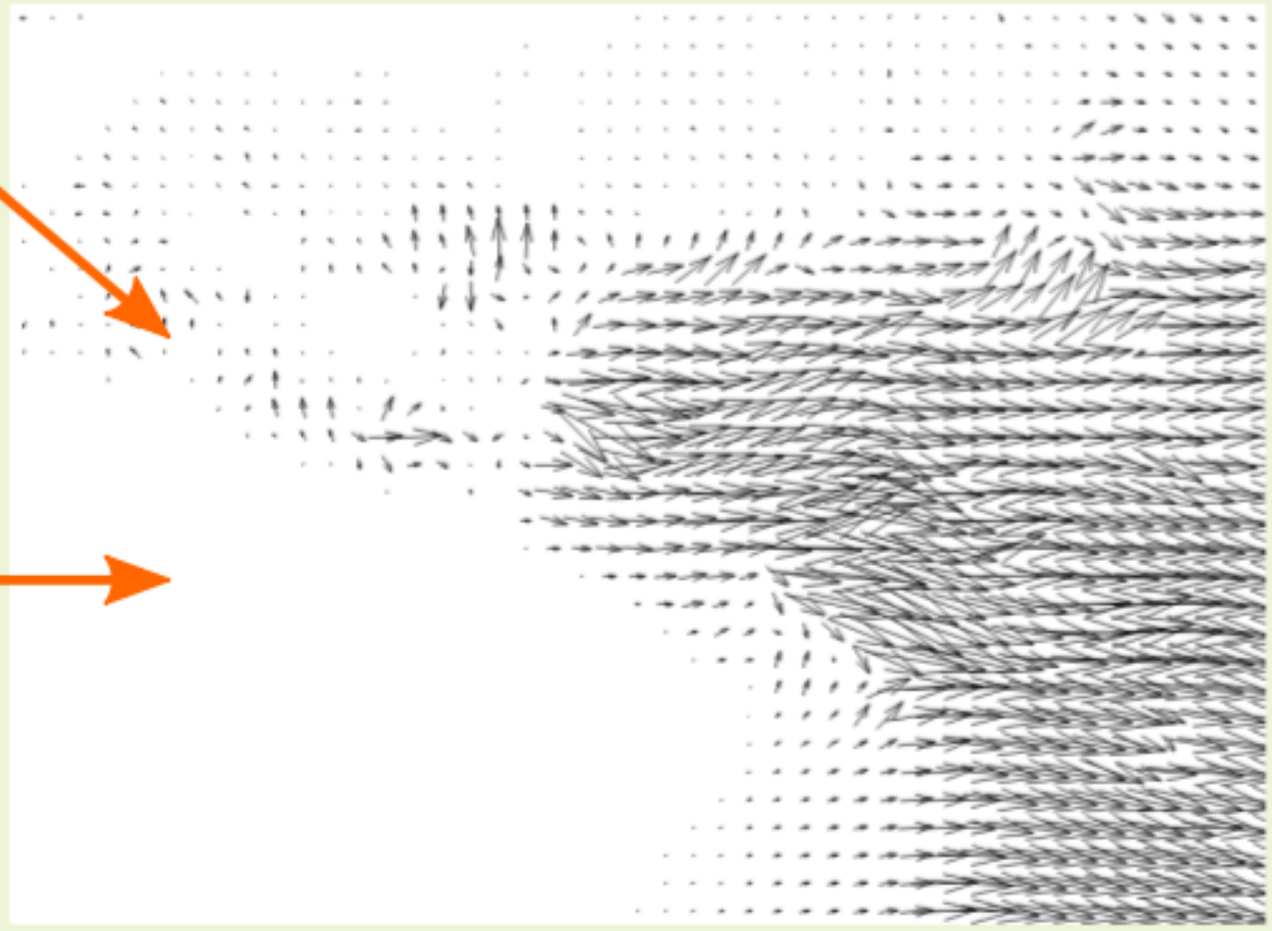


Key step: from the last consecutive images a cloud motion field is estimated

Elke Lorenz's method is a well-known correlation technique for this purpose

We are working on an optical flow technique to estimate cloud motion fields from the images

VELOCITY FIELD (CLOUD MOTION FIELD)



OPTICAL FLOW:

PIXEL IN THE IMAGE: (x, y)

IMAGE SEQUENCE: $I(x, y, t)$

VELOCITY FIELD: (u, v)

BASIC ASSUMPTION: Gray value stays approx. constant

$$I(x, y, t) \approx I(x + u, y + v, t + 1)$$

THIS LEADS TO THE OPTICAL FLOW CONSTRAIN

$$\mathrm{OFC}(u, v) = I_t + I_x u + I_y v \approx 0$$

CMF ESTIMATION: A VARIATIONAL METHOD (Zach et al, 2007)

$$\mathrm{Argmin}_{u,v} \left\{ \int_\Omega \left(|\nabla u| + |\nabla v| + \lambda |I_t + I_x u + I_y v| \right) \mathrm{d}\Omega \right\}$$

RESULTING CMF (u,v) IS THE FIELD WHICH MINIMIZES THIS COST FUNCTION

Dense estimation: the motion field is calculated in each pixel

OPTICAL FLOW:

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CMF ESTIMATION: A VARIATIONAL METHOD (Zach et al, 2007)

Tradeoff parameter

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RESULTING CMF (u,v) IS THE FIELD WHICH MINIMIZES THIS COST FUNCTION

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REGULARIZATION CONSTRAINS

Favours small gradients

Allows discontinuities in the motion field

OPTICAL FLOW CONSTRAIN

Data fit term robust against outliers (noise)

SATELLITE FORECAST EXAMPLE

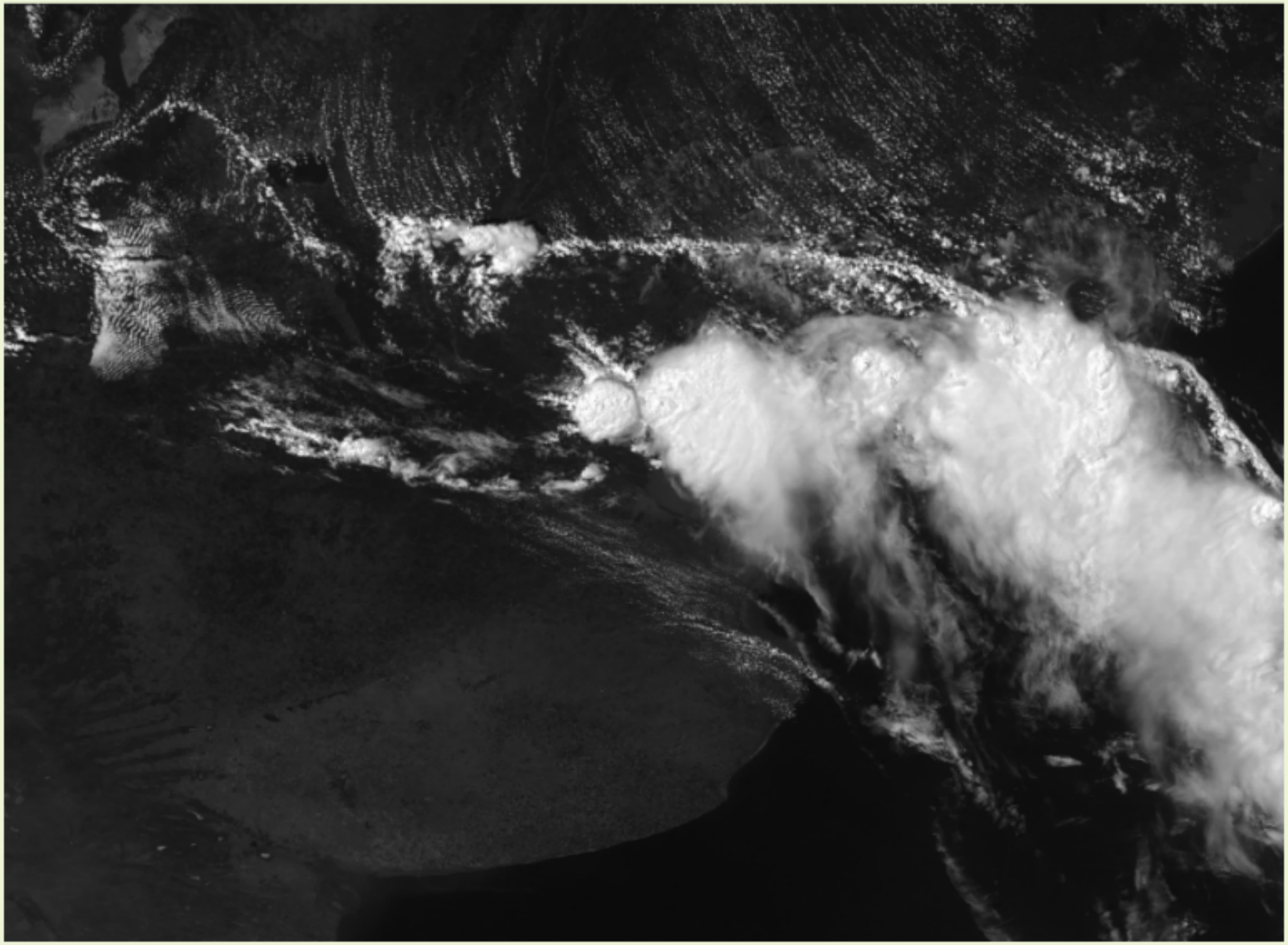


IMAGE 1

SATELLITE FORECAST EXAMPLE

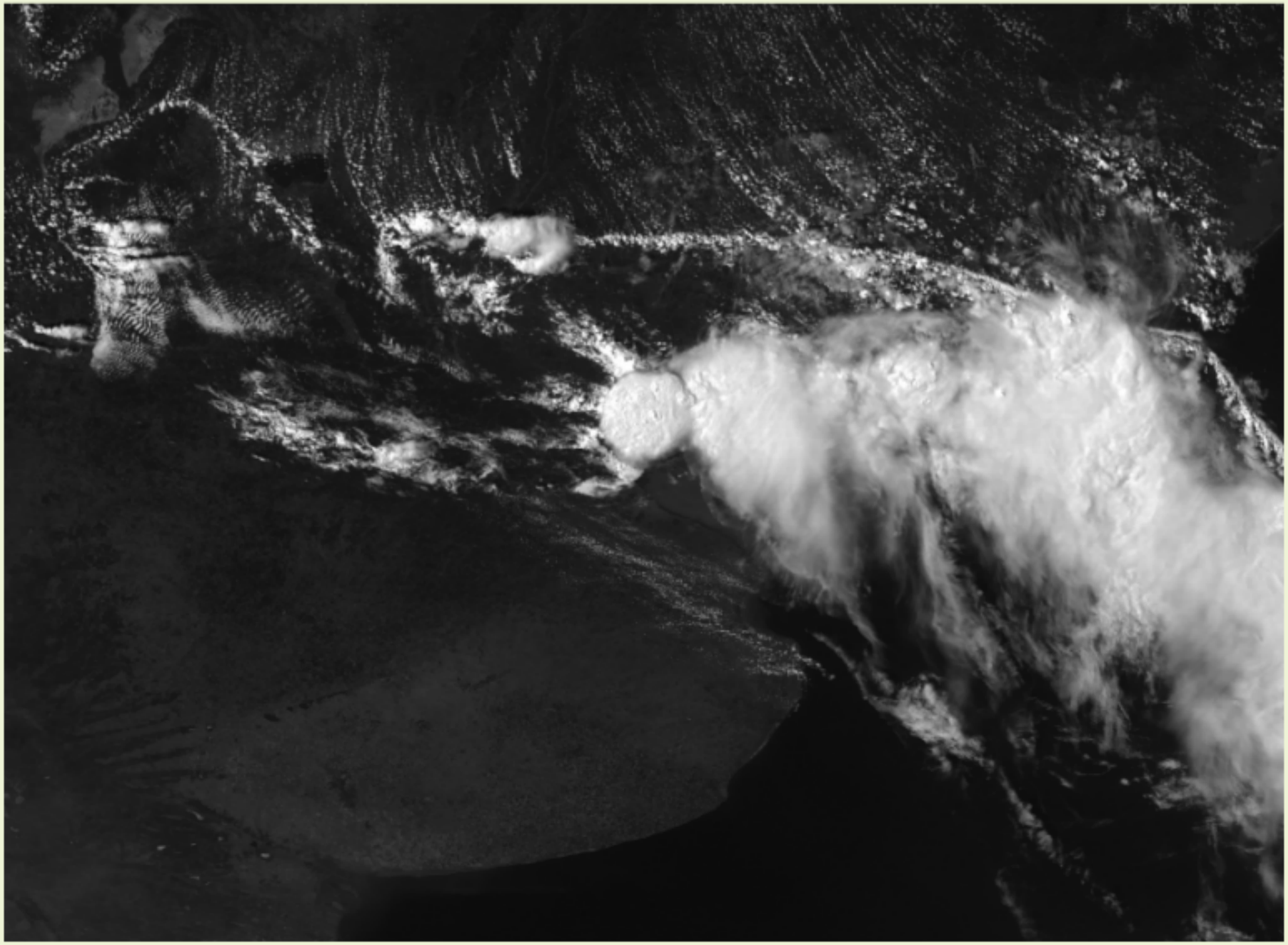
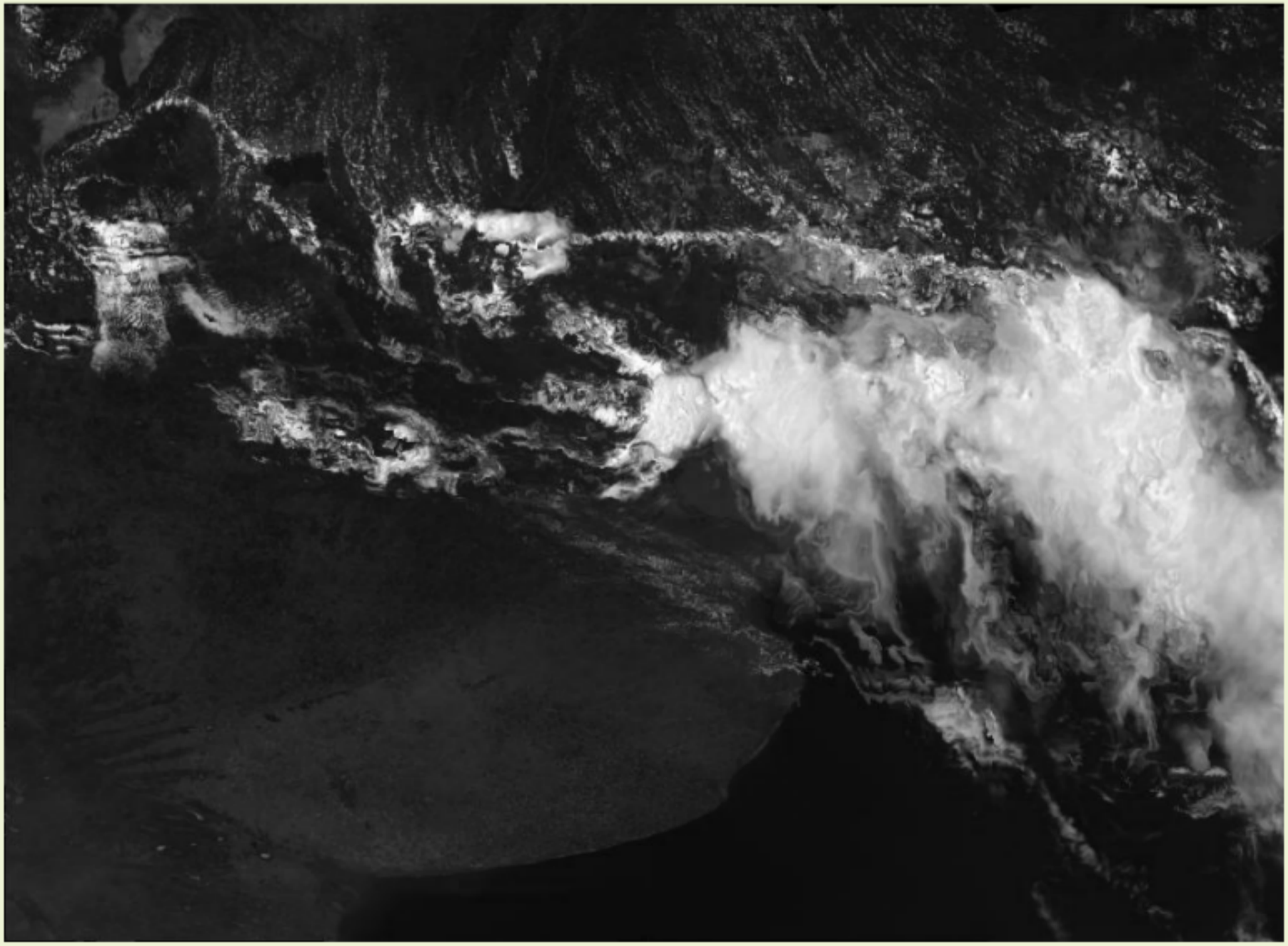


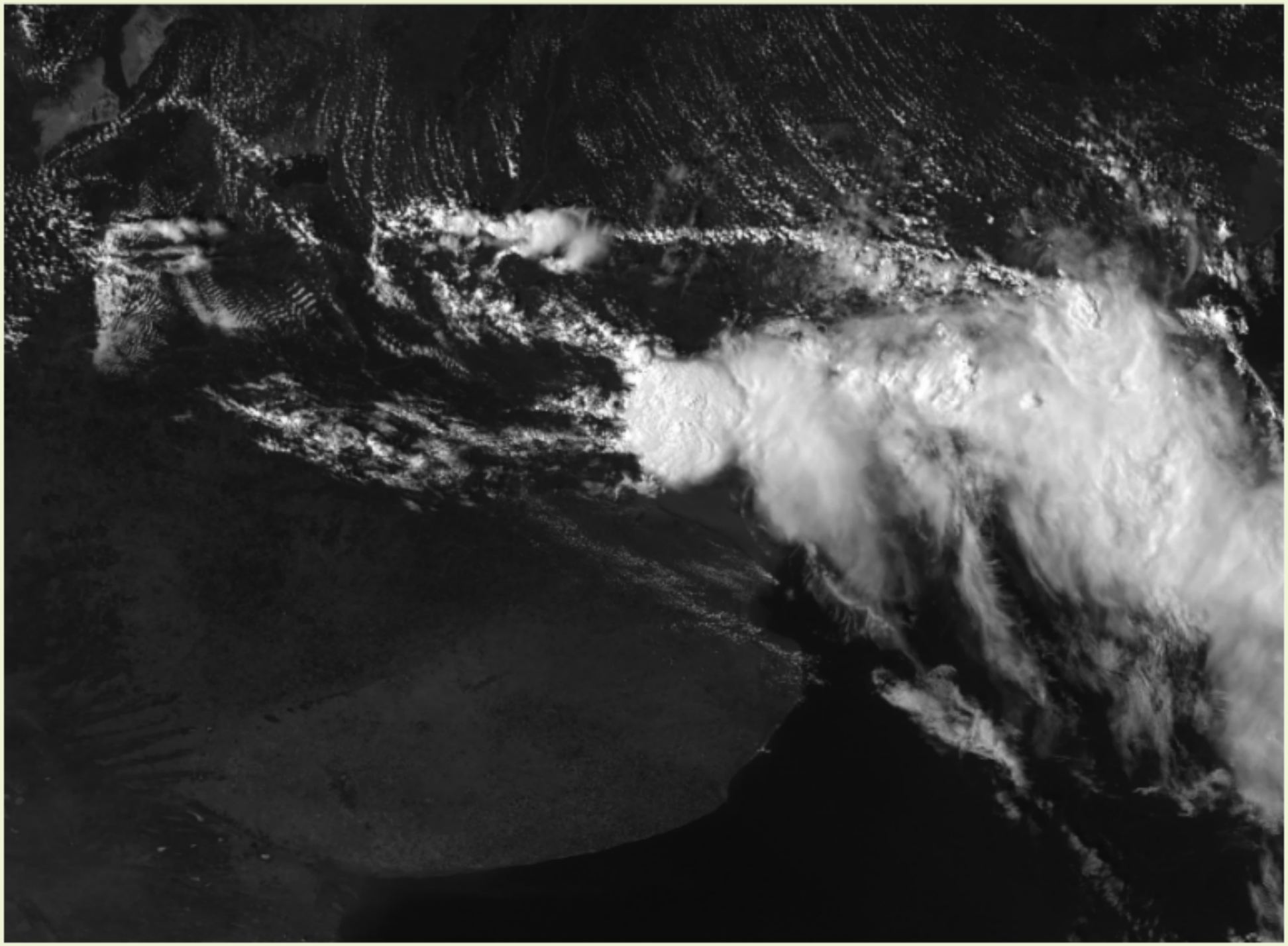
IMAGE 2

SATELLITE FORECAST EXAMPLE



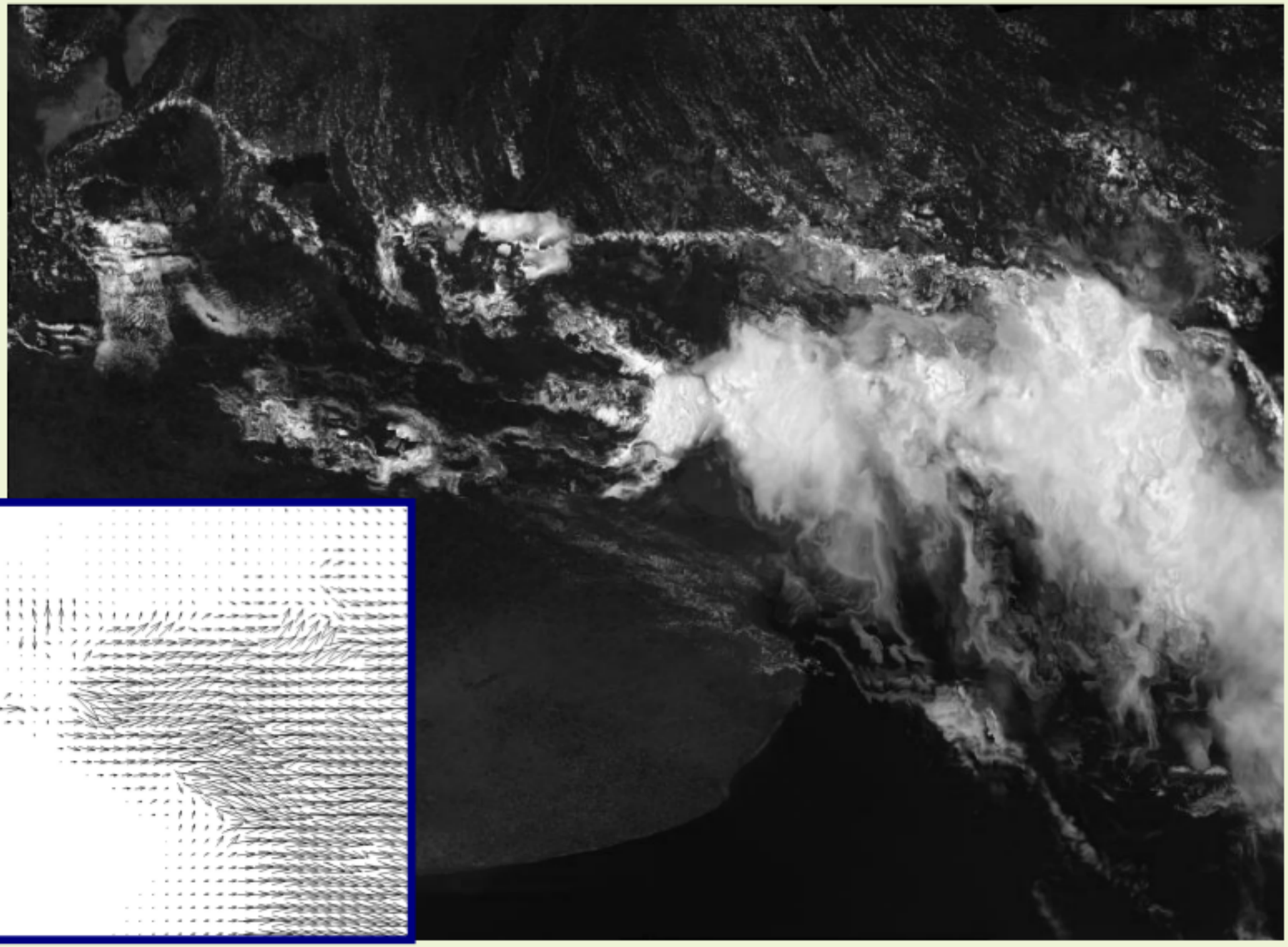
PREDICT. IMAGE

SATELLITE FORECAST EXAMPLE



REAL IMAGE

SATELLITE FORECAST EXAMPLE



PREDICT. IMAGE

ANOTHER EXAMPLE

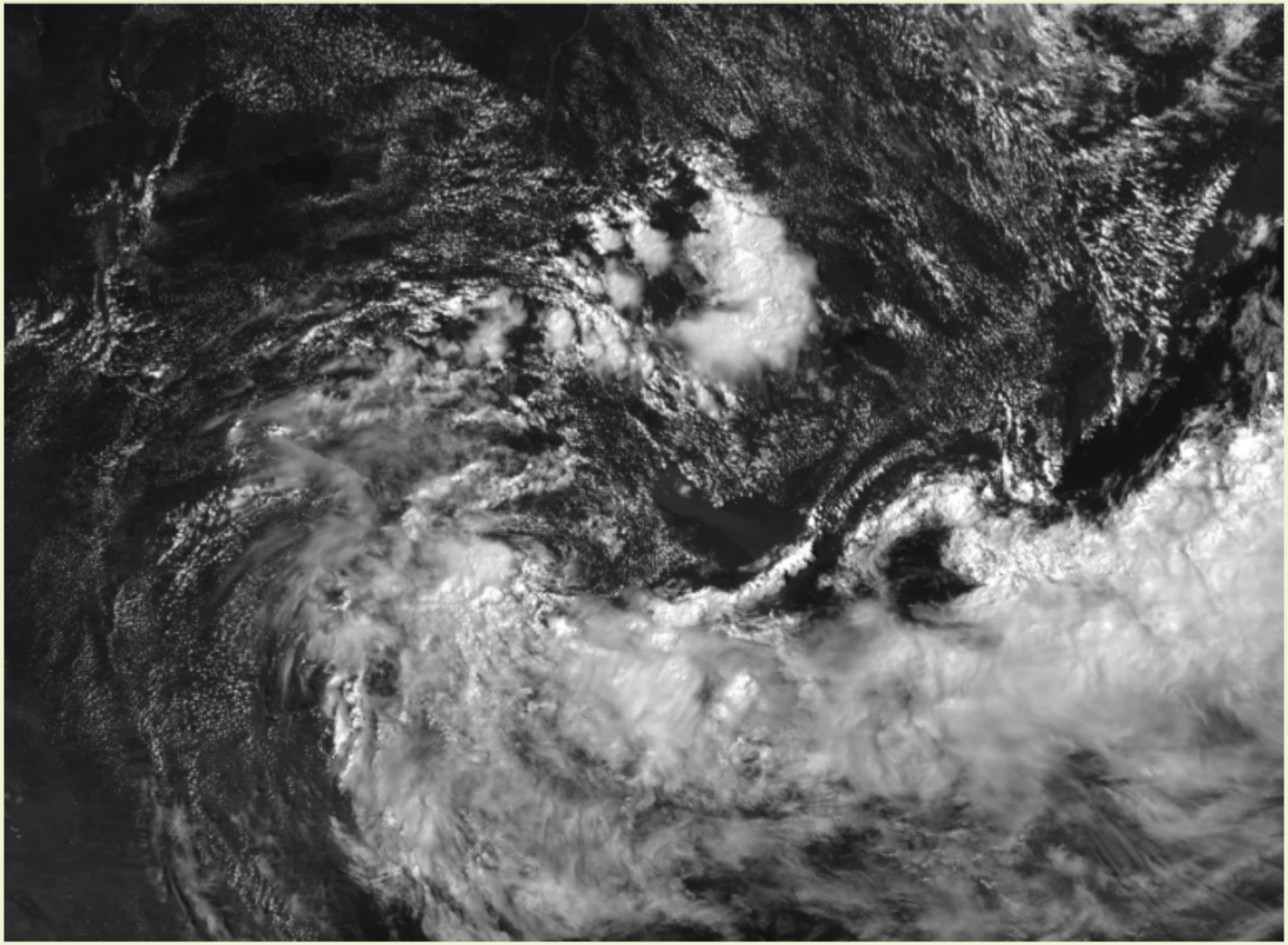


IMAGE 1

ANOTHER EXAMPLE

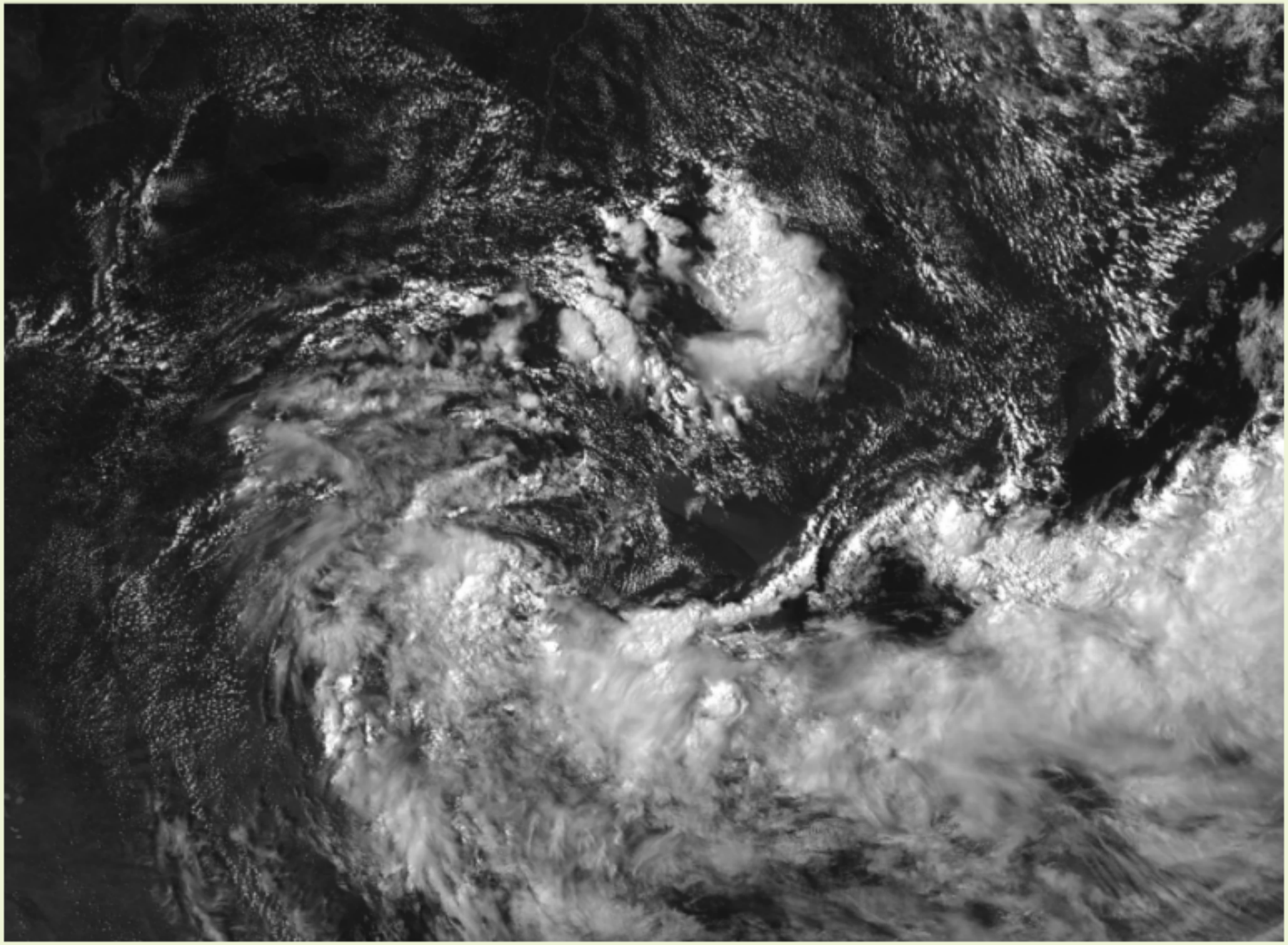
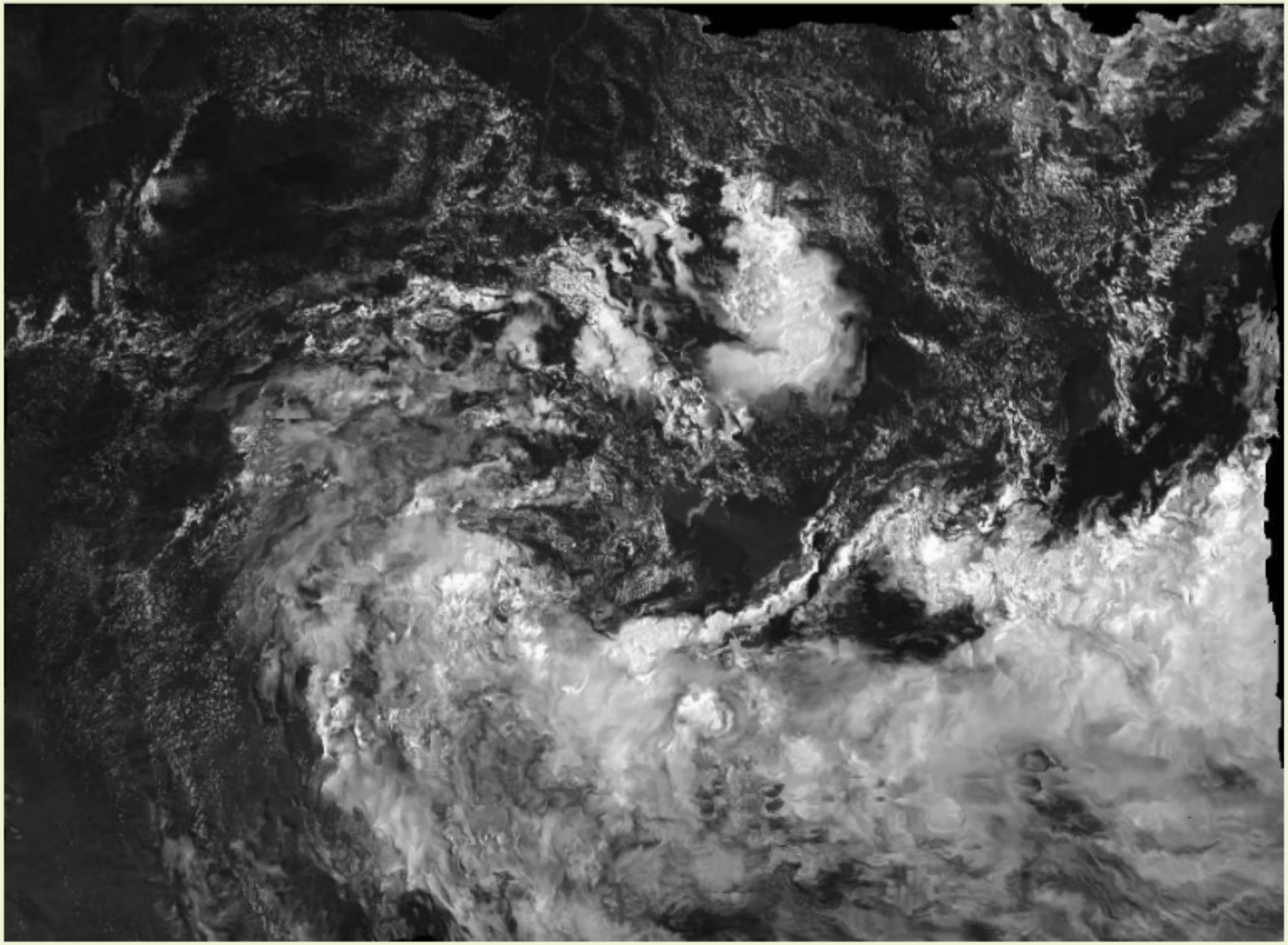


IMAGE 2

ANOTHER EXAMPLE



PREDICT. IMAGE

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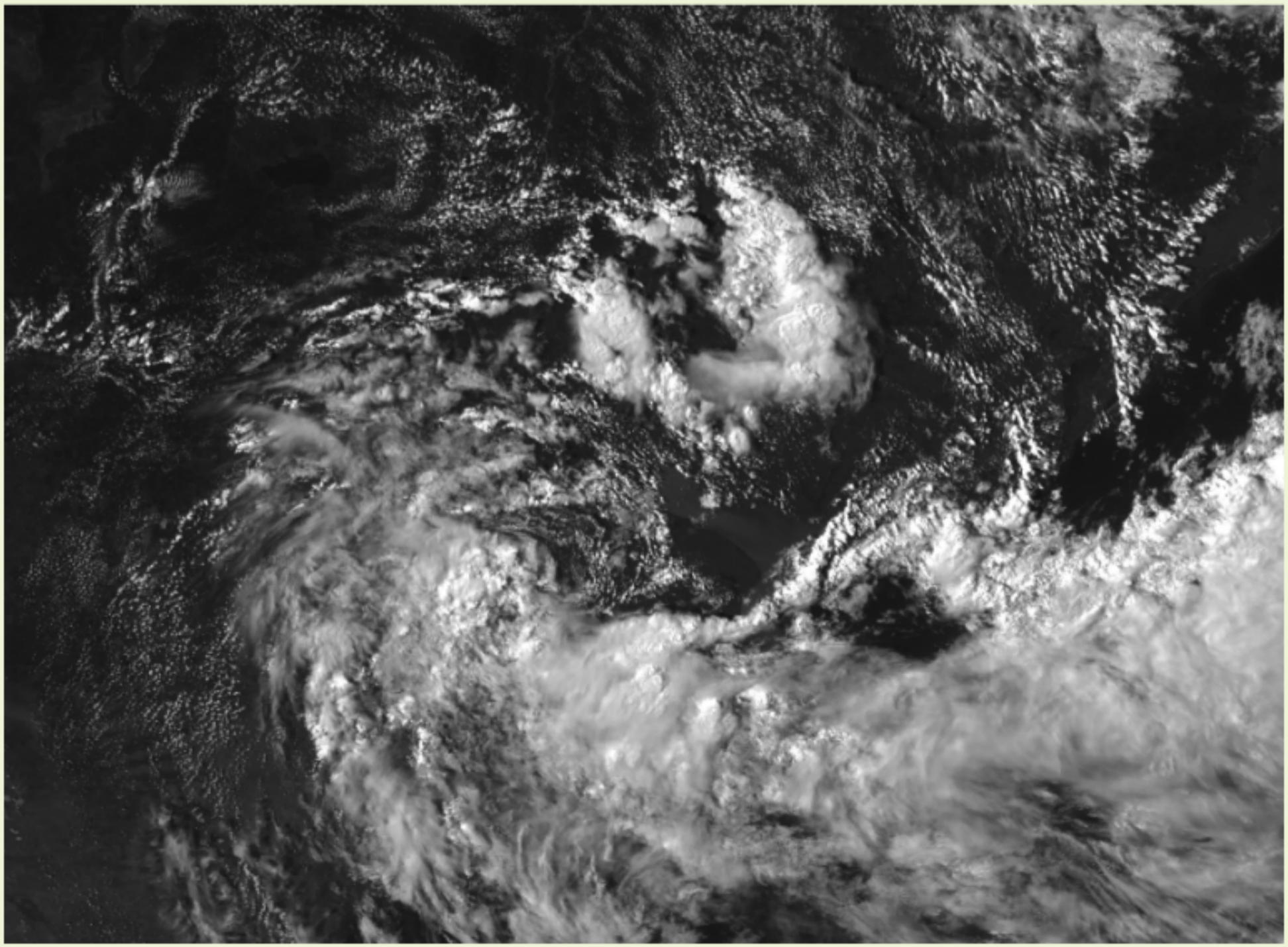

REAL IMAGE

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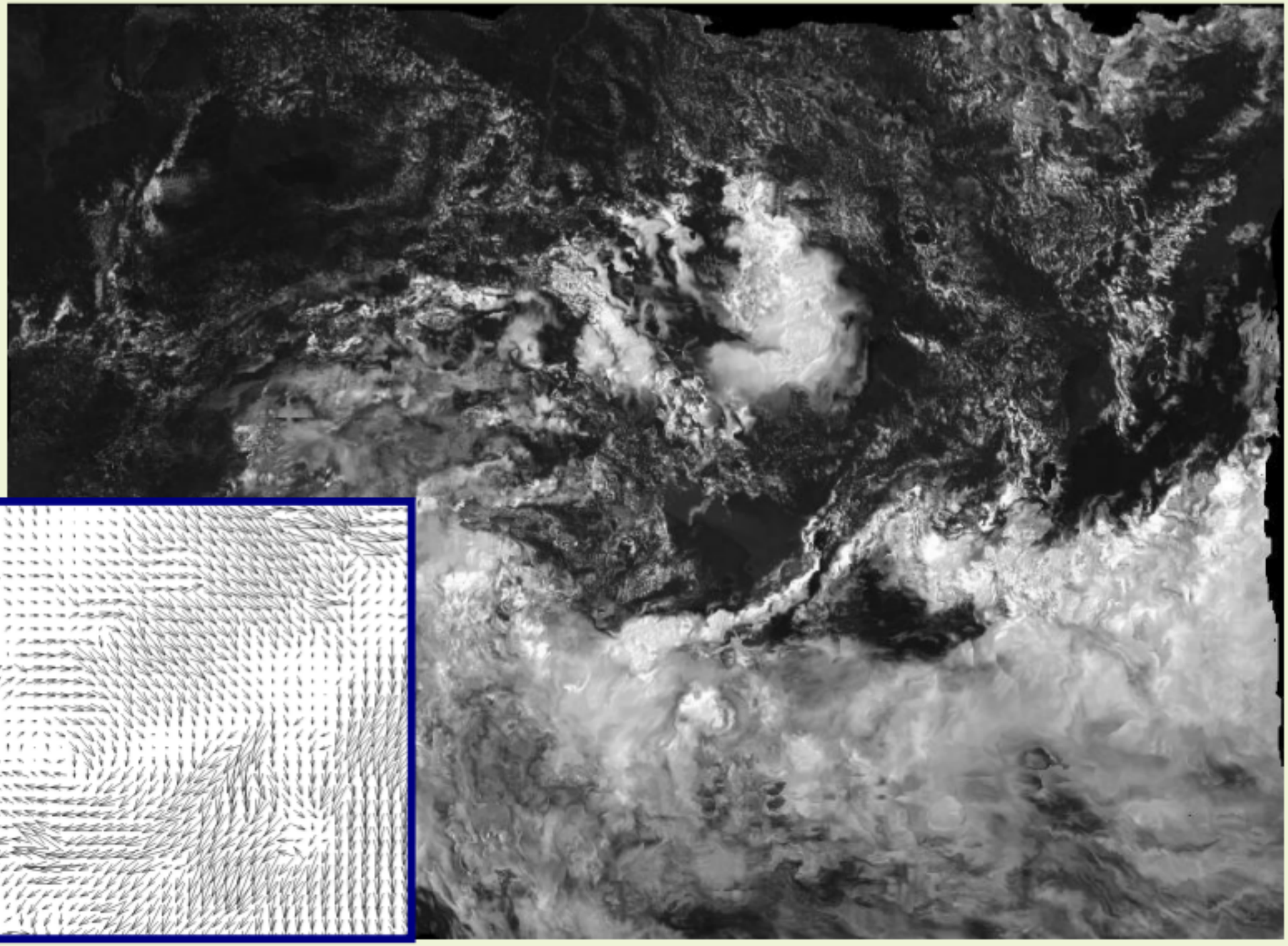


PREDICT. IMAGE

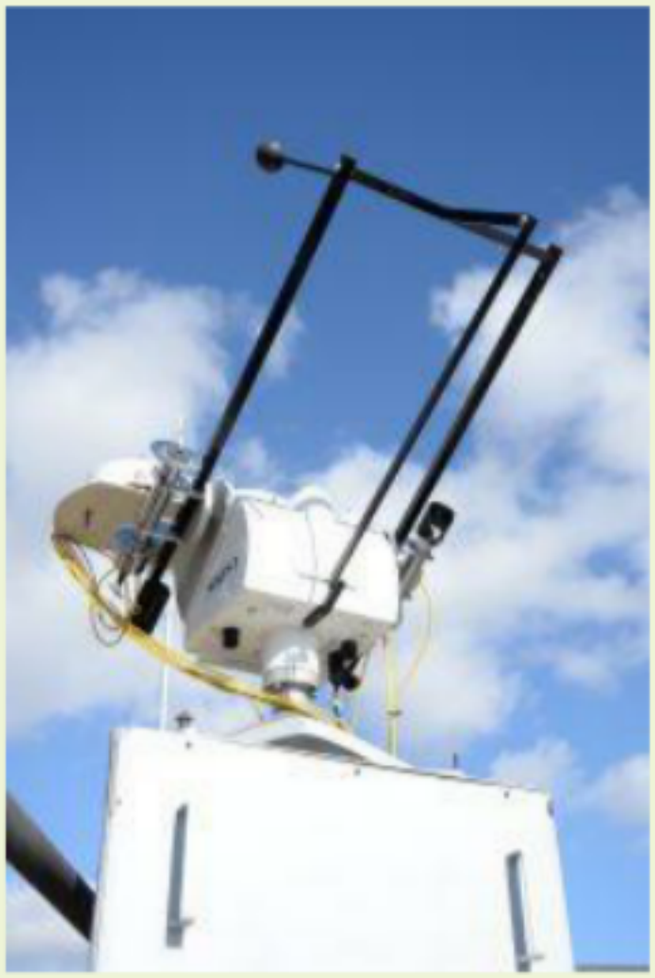
SINGLE-SITE PERFORMANCE EVALUATION

SITE: Solar Energy Laboratory (LES/UdelaR)

EQUIPMENT: SOLYS2 ground station (CMP11)

PERIOD OF TIME: complete year 2016

Higher quality measurements available in Uruguay



LES SOLYS2 GROUND STATION

1h-ahead forecast evaluation

Hourly irradiation in the next hour from 2nd image

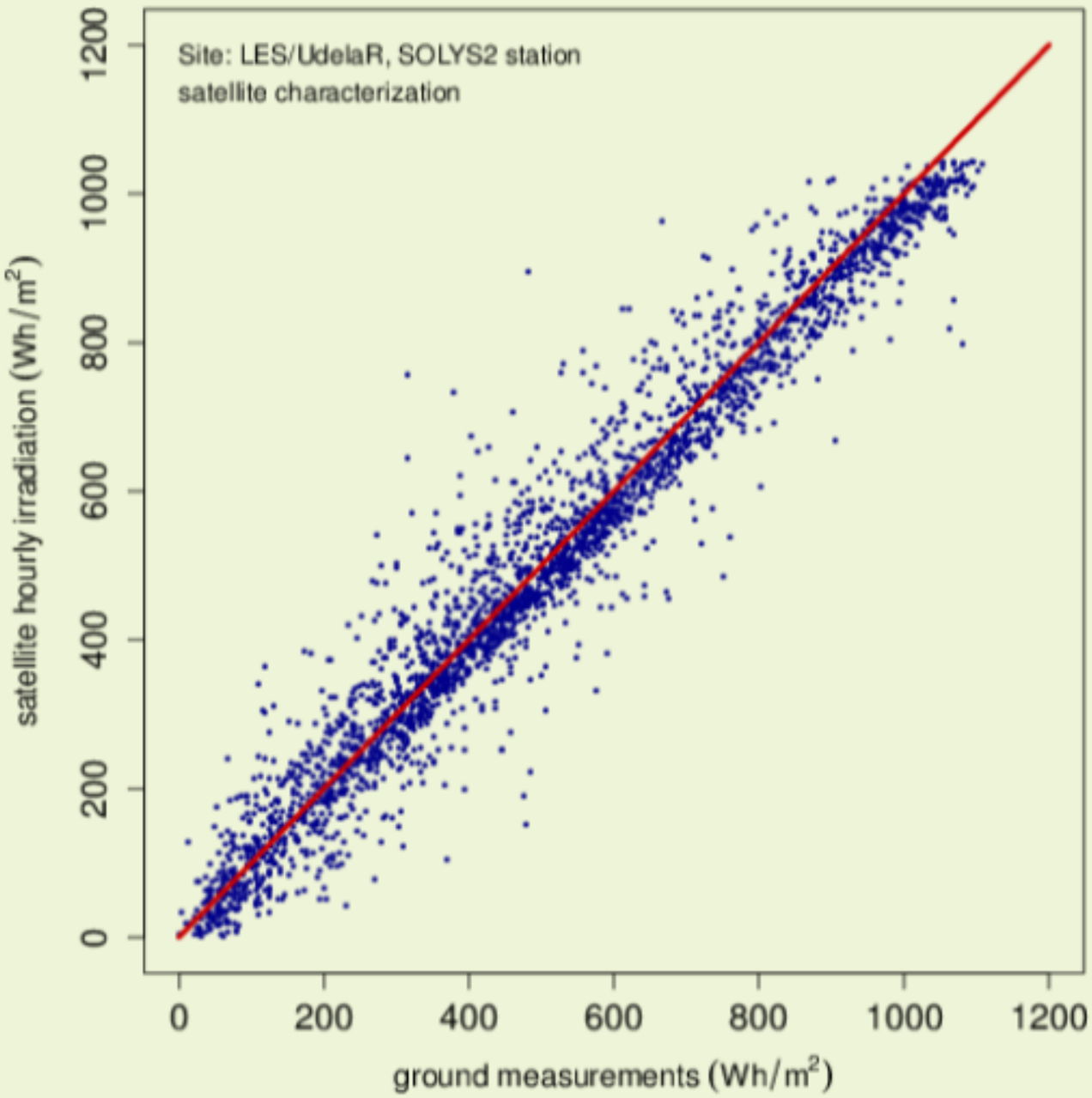
Irregular satellite availability: only images with half an hour time diference were used

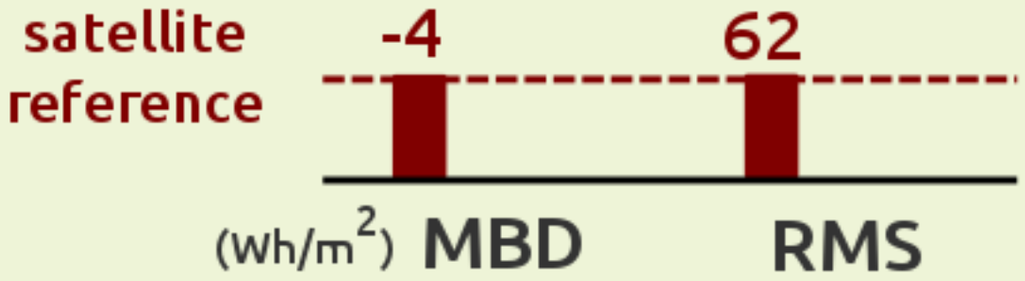
Solar altitude greater than 10º

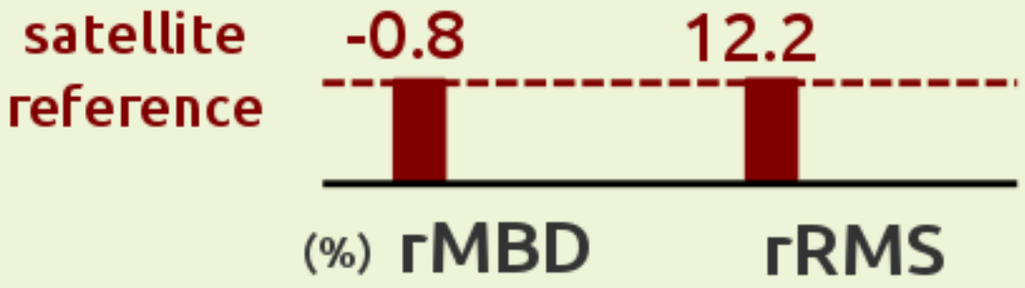
Not using the first two images in the morning (low brightness)

Comparison against persistence and satellite characterization reference

SINGLE-SITE PERFORMANCE EVALUATION







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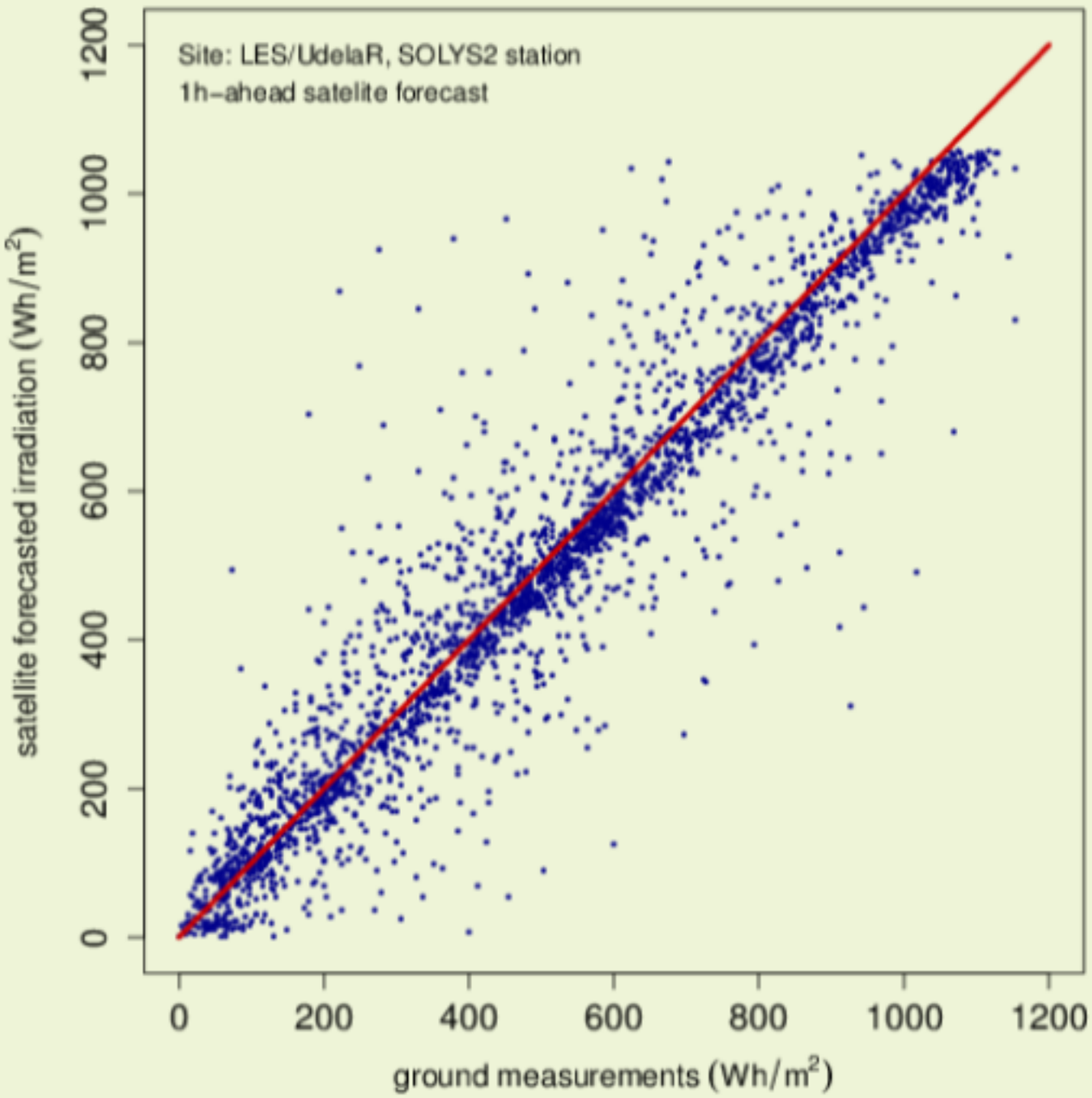

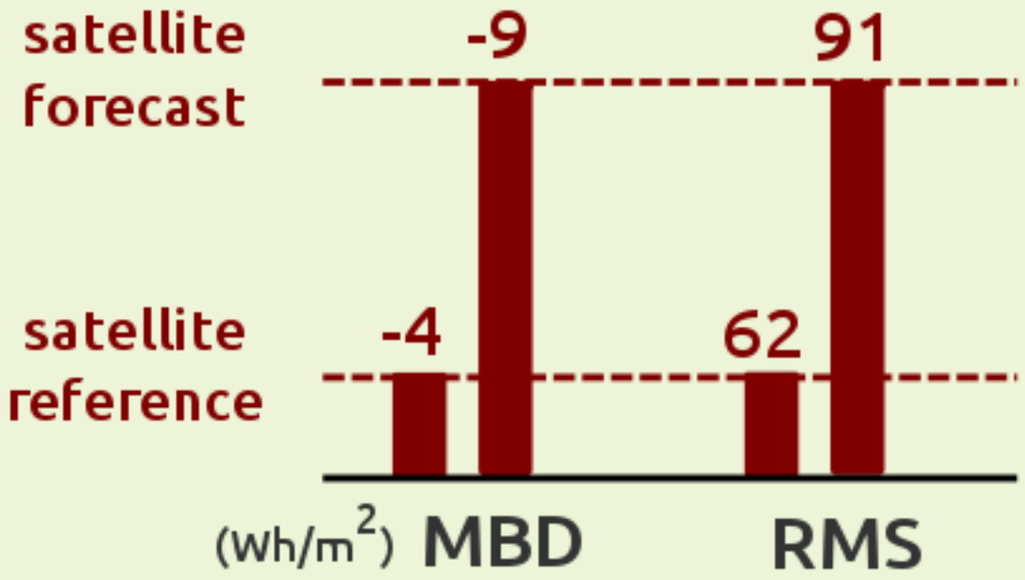

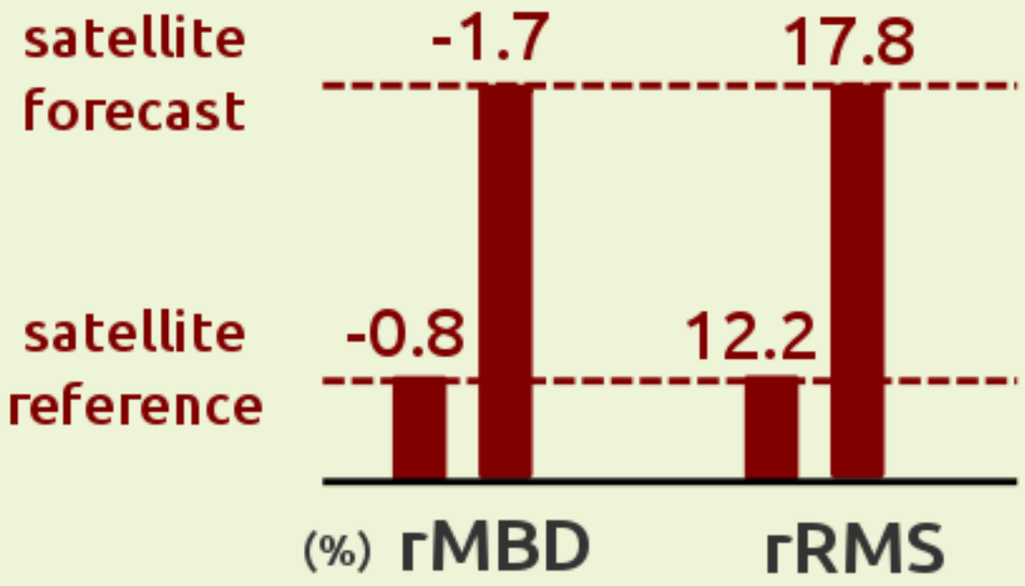

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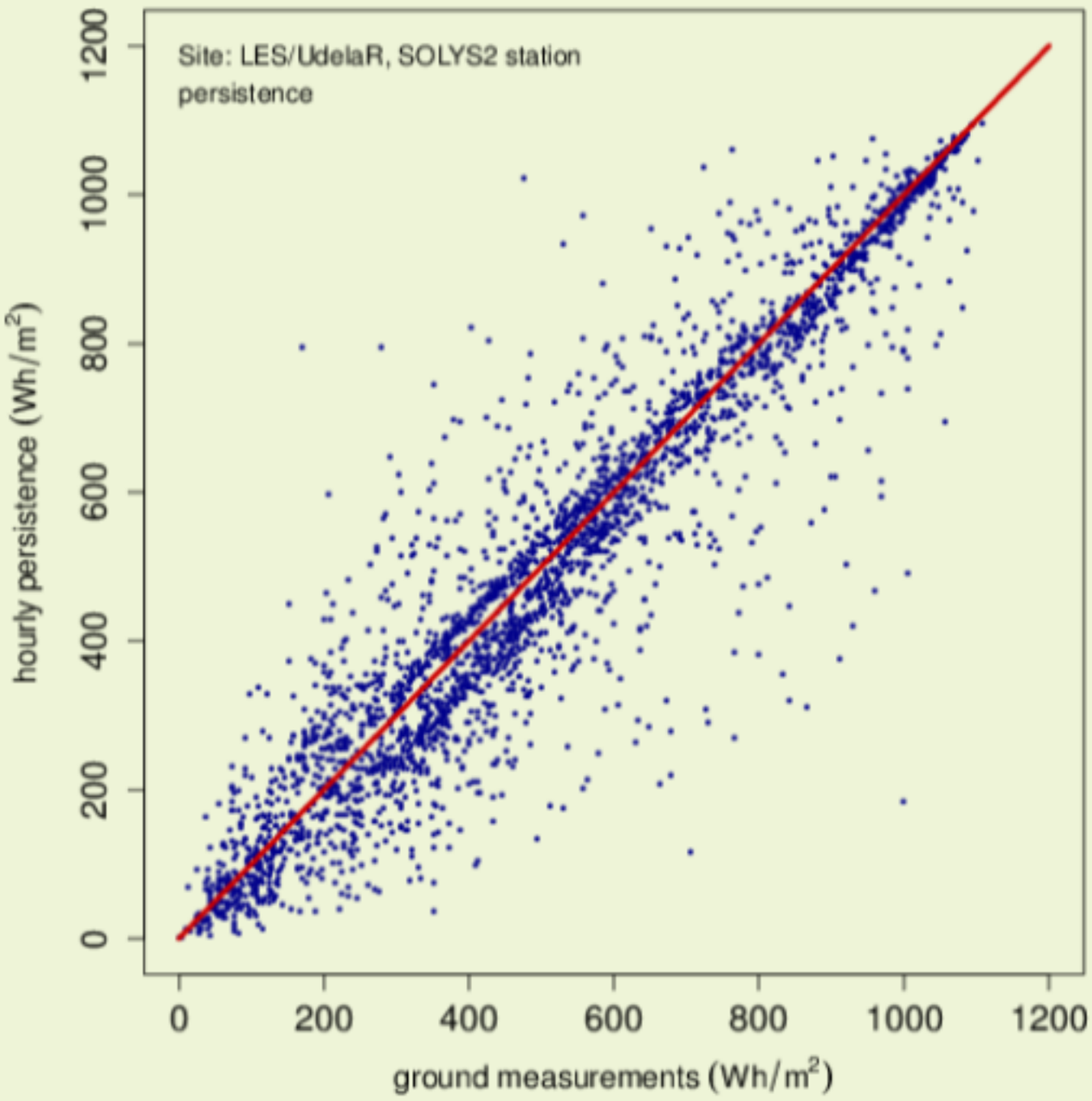

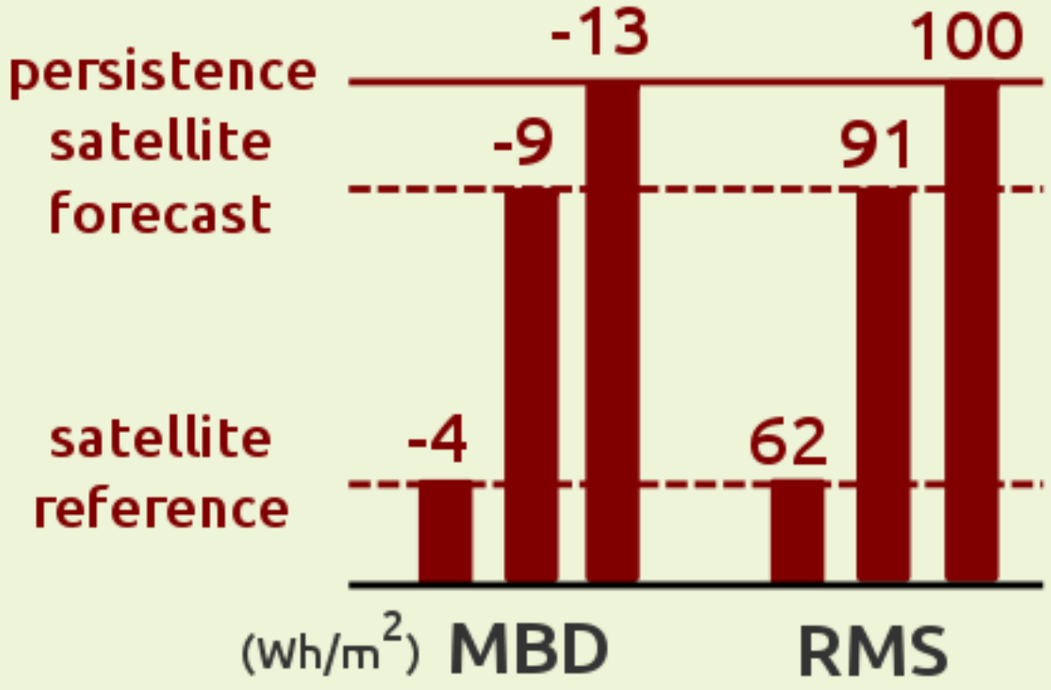

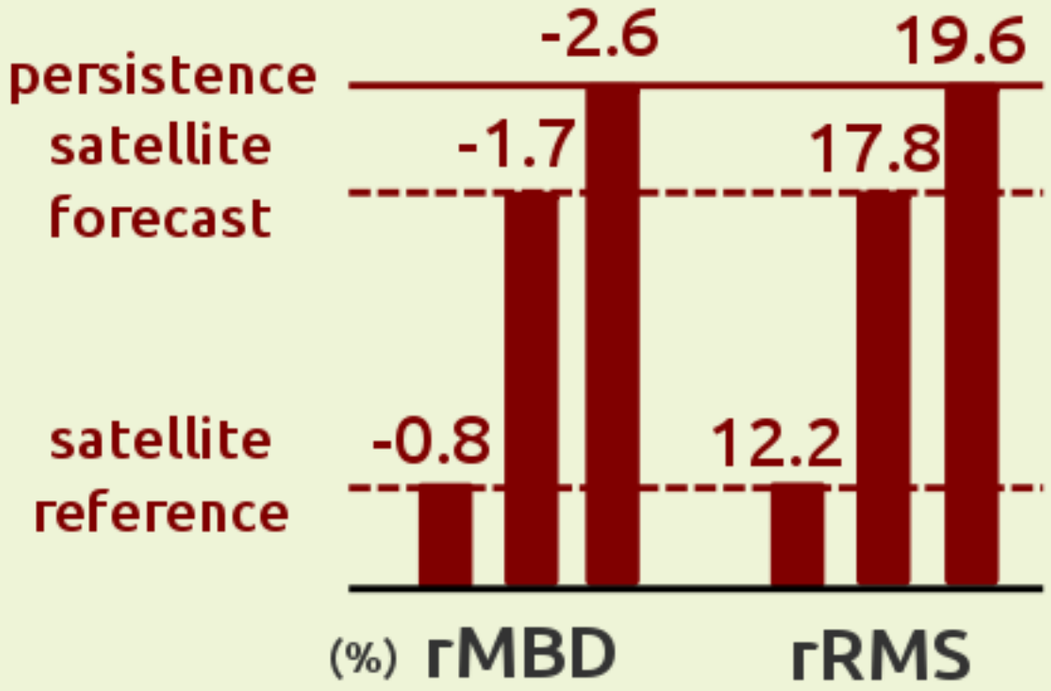

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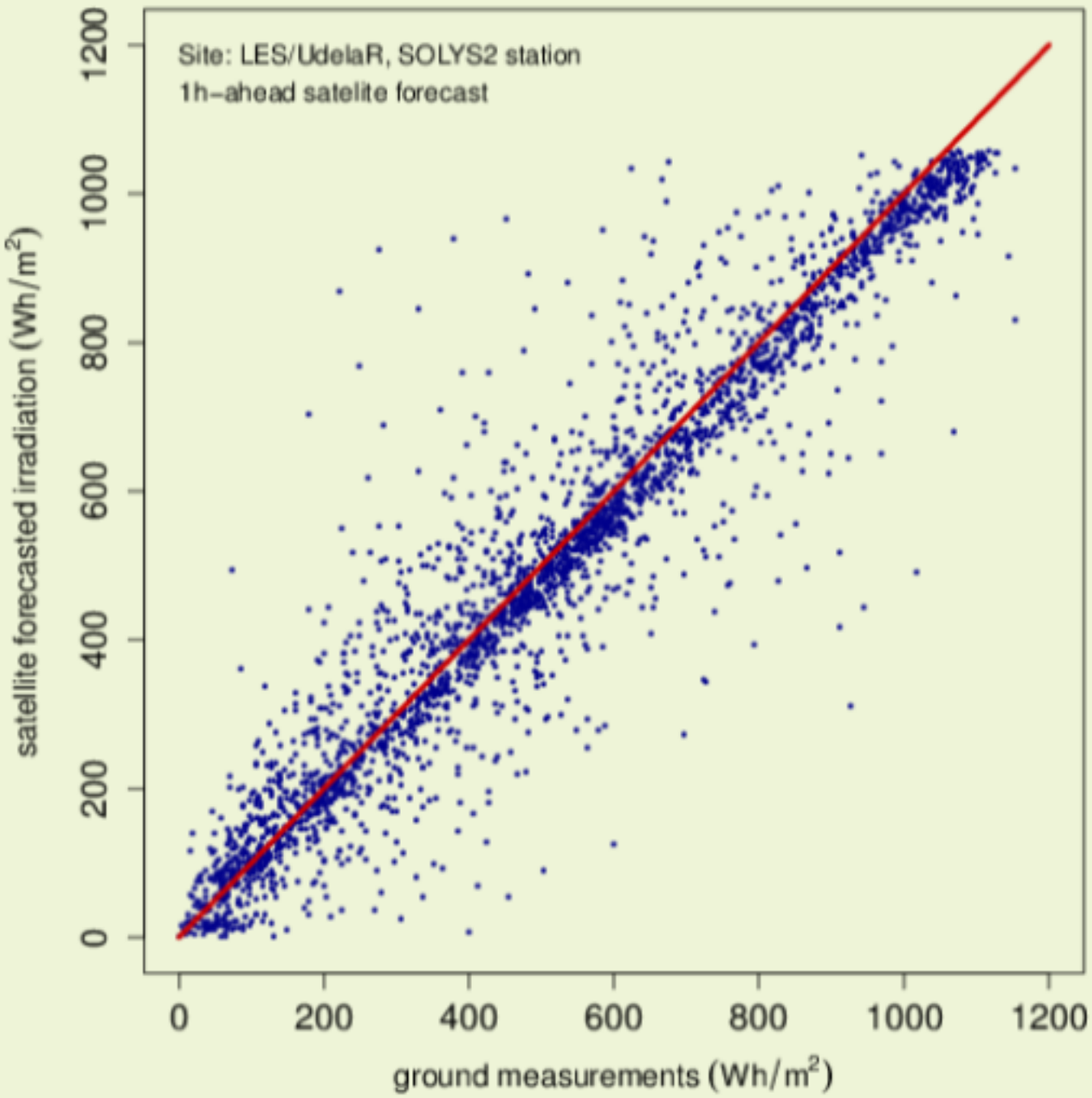

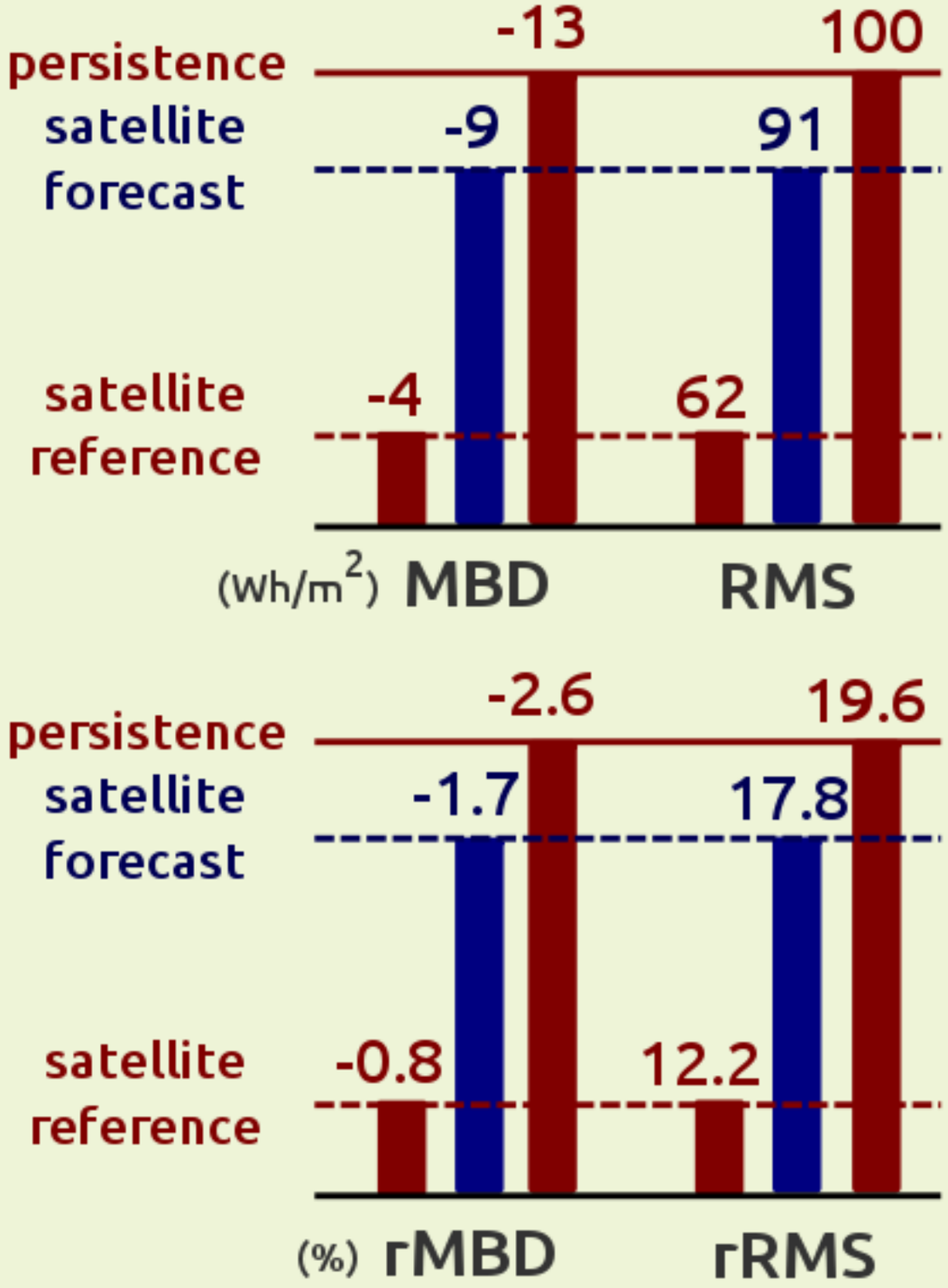

CONCLUSIONS

A NOVEL TECHNIQUE IN THE CONTEXT OF SATELLITE CLOUD MOTION FIELD ESTIMATION IS PROPOSED TO ASSESS HOURLY SOLAR IRRADIATION FORECAST.

IT FOLLOWS VERY RECENT SIGNAL PROCESSING ADVANCES, THAT ALLOW TO SOLVE THIS COMPLEX PROBLEM AND IN REAL TIME.

RESULTS FOR 1 HOUR AHEAD FORECAST SHOWS THAT THE METHOD IS A PROMISING APPROACH FOR SOLAR SATELLITE-BASED FORECASTING

FUTURE AND CURRENT WORK

EVALUATE HOURLY FORECAST FROM 2 TO 6 HOURS AHEAD.

EVALUATE REGIONAL FORECAST: GROUND NETWORK + PV PLANT'S SITES

EVALUATE THE PERFORMANCE FOR PV GENERATION FORECAST (including an evaluation of the uncertainty added in each step)

COMPARE ITS PERFORMANCE WITH LORENZ`S METHODOLOGY

Thank you very much for your attention!

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