



Assimilation cycle in observation-sparse regions

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Israel Meteorological Service

This winter upgrade

**IMS to Pavel:
100 cm
official ruler
for snow**

Last winter

**30 cm
ruler**



Last winter

**25 cm
snow depth
measured in
Jerusalem !**



This winter

0 !



1. COSMO model at Israel Meteorological Service

- a. Overview
- b. Main problem – loss of humidity
- c. Consequence – in assimilation cycle the model dries up if not enough in observations assimilated

2. Technical solution for observation sparse regions:

Each run CHOOSE cold start/warm start depending on fast verification

- a. Example
- b. Method
- c. Results

3. Conclusions

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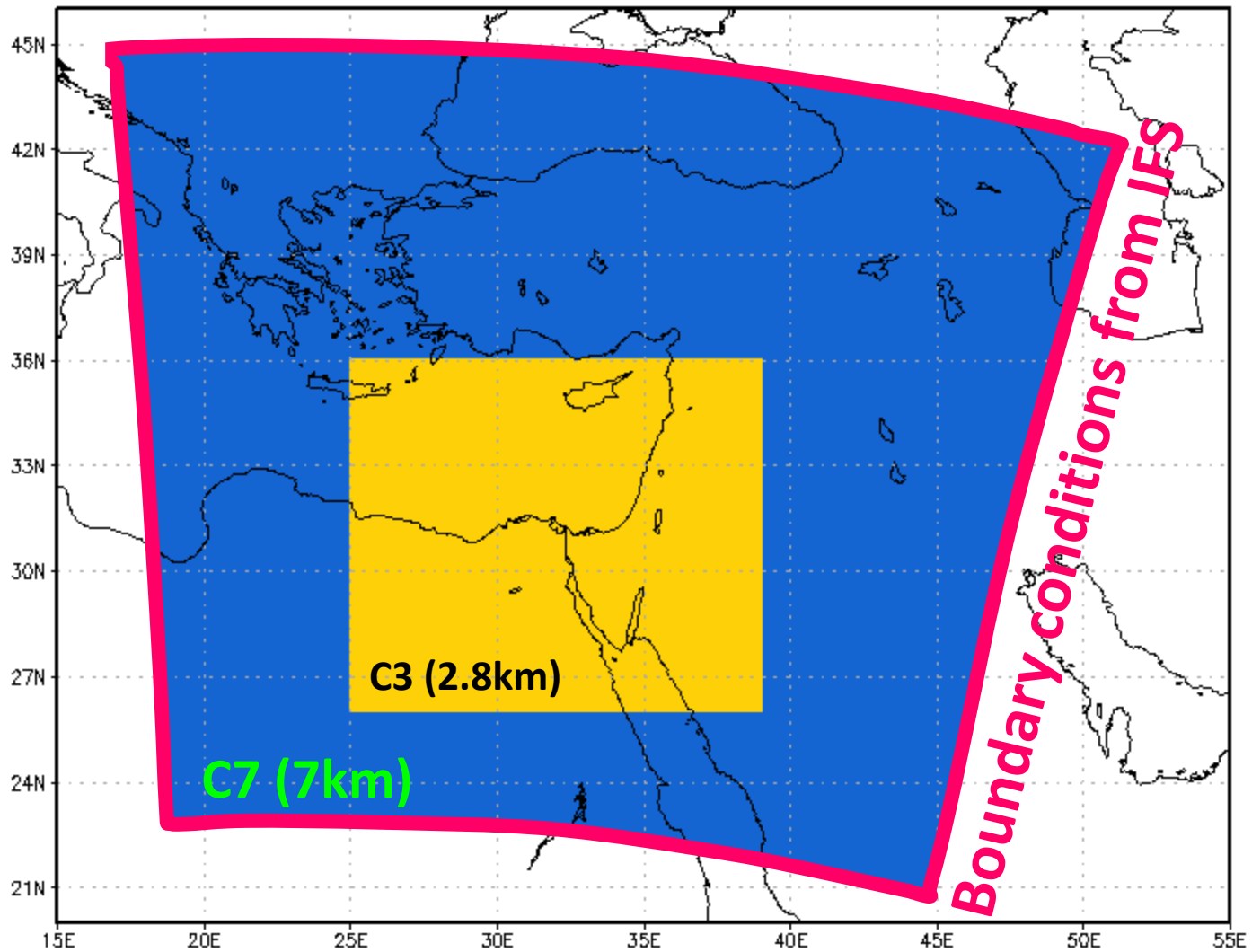
- a. Example
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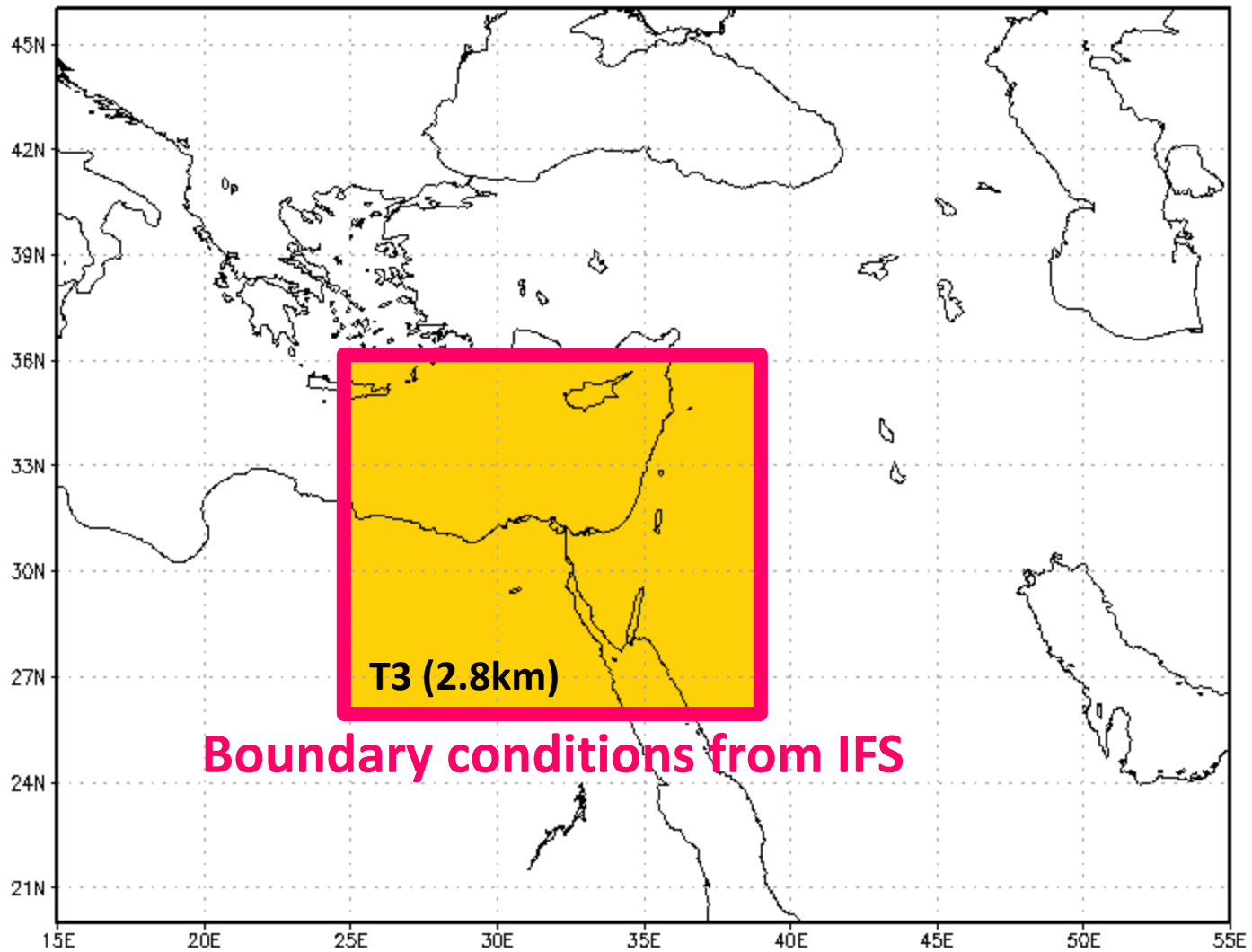
A satellite image of Earth showing a large, well-defined cyclone or storm system over the ocean. The storm has a distinct eye and is surrounded by dense, swirling cloud bands. The surrounding ocean surface shows some wave patterns. The word "DOMAINS" is overlaid in the center of the image.

DOMAINS

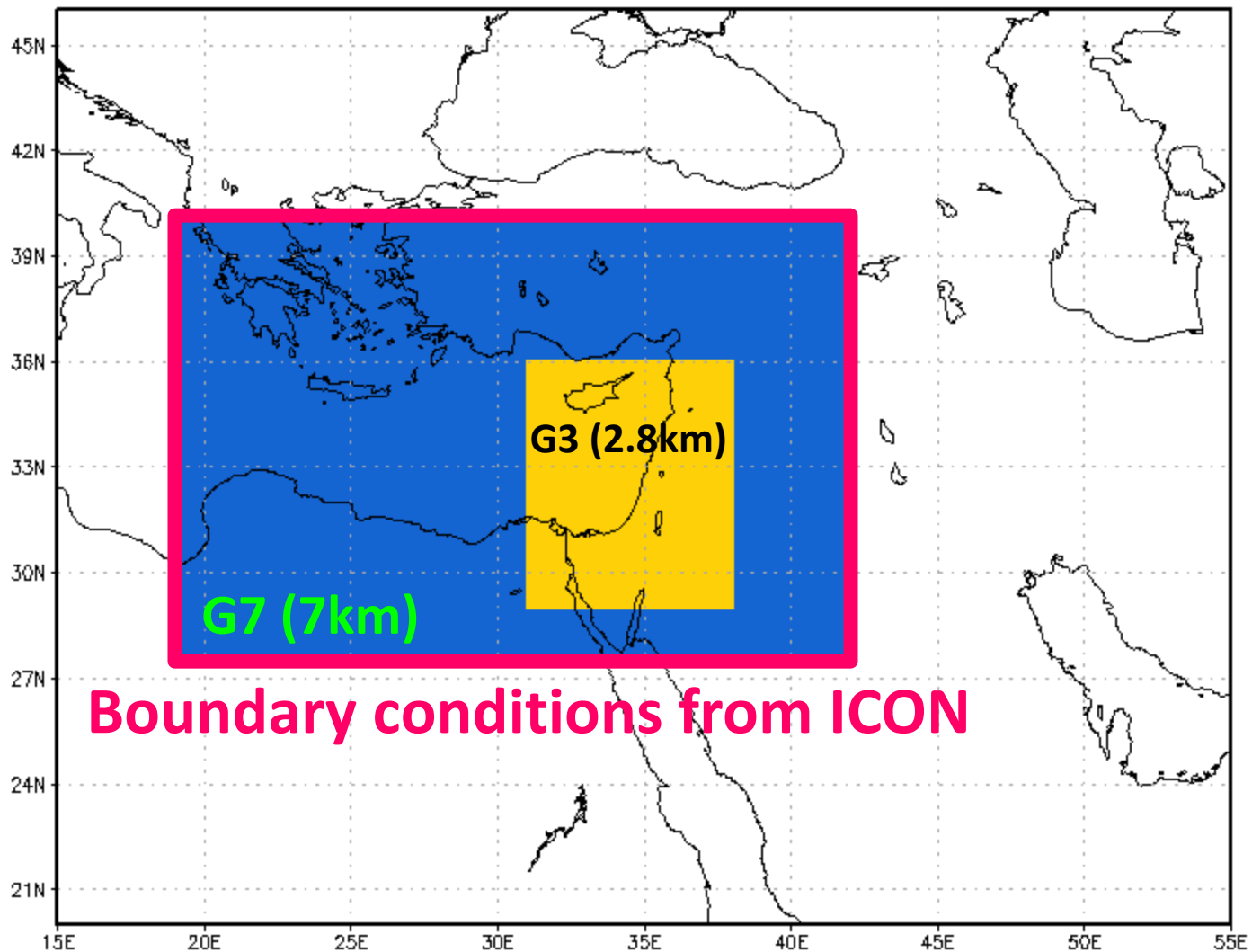
Operational version (IFS driven)



Test version (IFS driven)



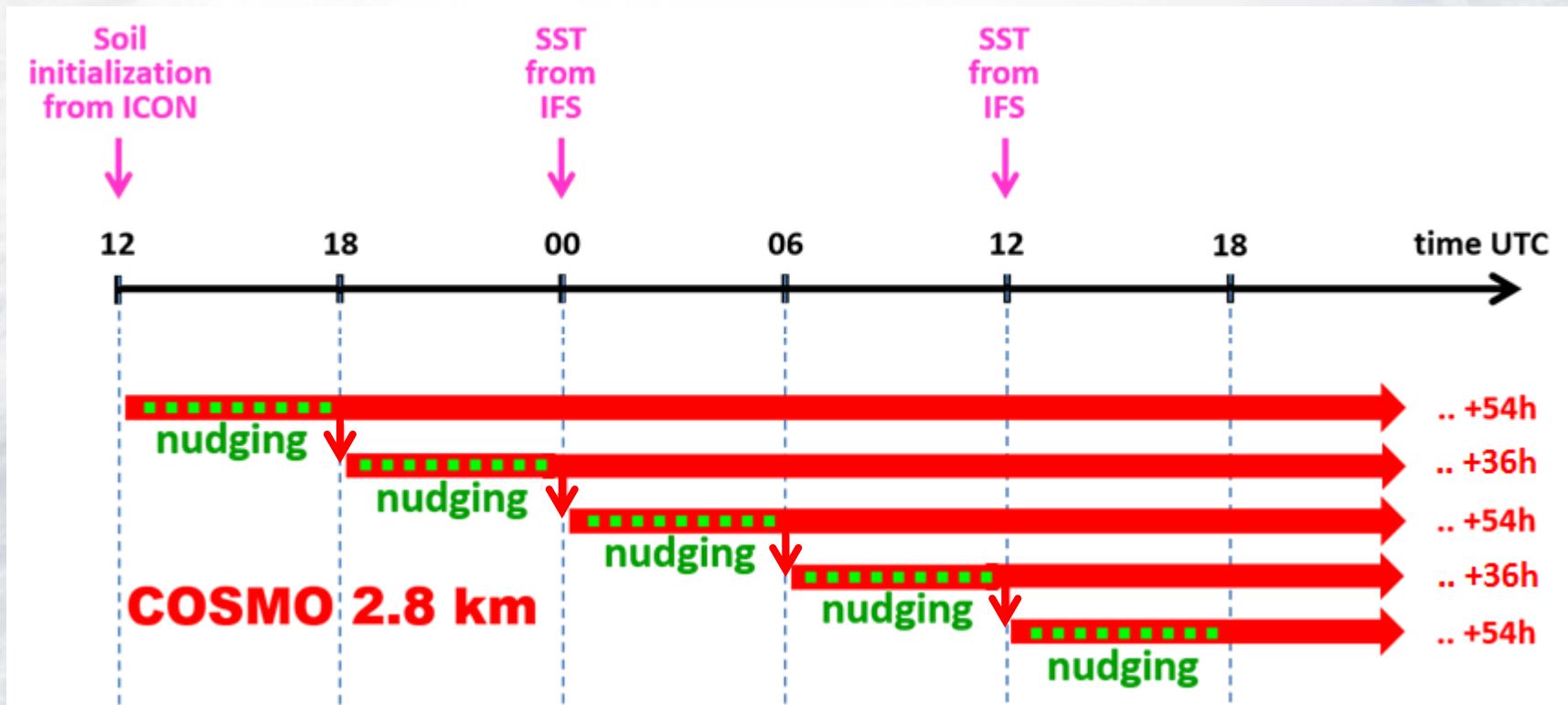
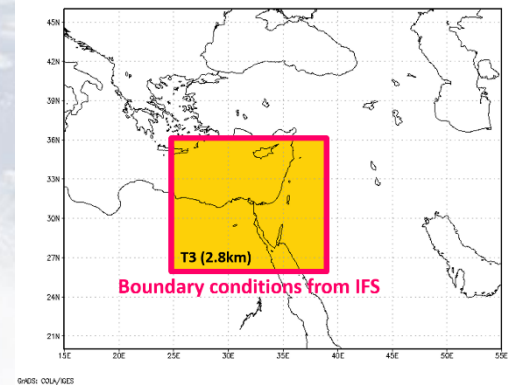
Test version (ICON driven)



4 times a day assimilation cycle

Overview

Test version (IFS driven) :



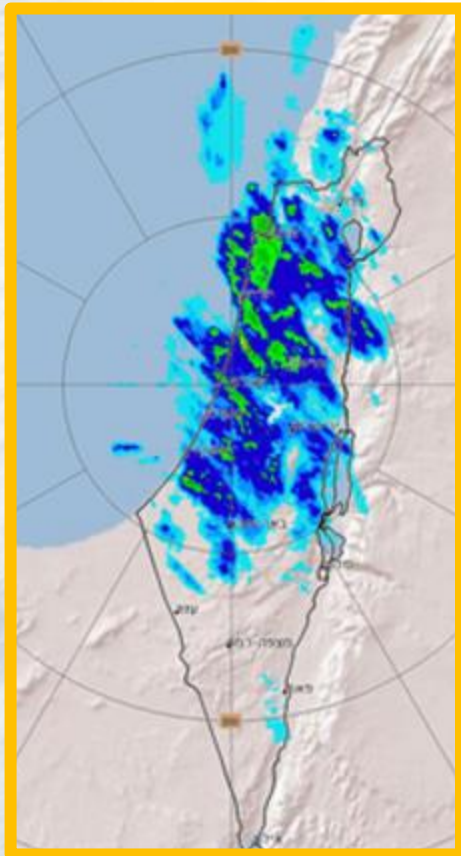
Latent Heat Nudging

A satellite image of Earth's atmosphere, showing a large-scale weather system with a prominent central vortex and surrounding cloud bands. The image is used as a background for the title slide.

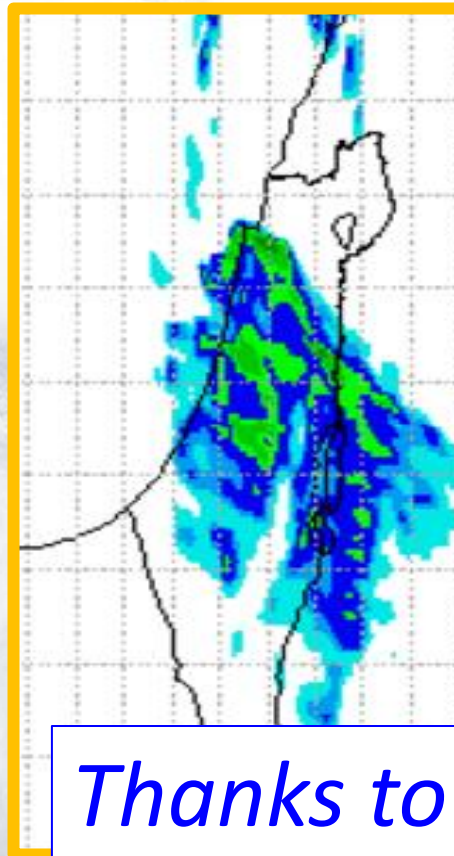
Example:

COSMO forecast from 23/2/2016 00 UTC +6h till +12h

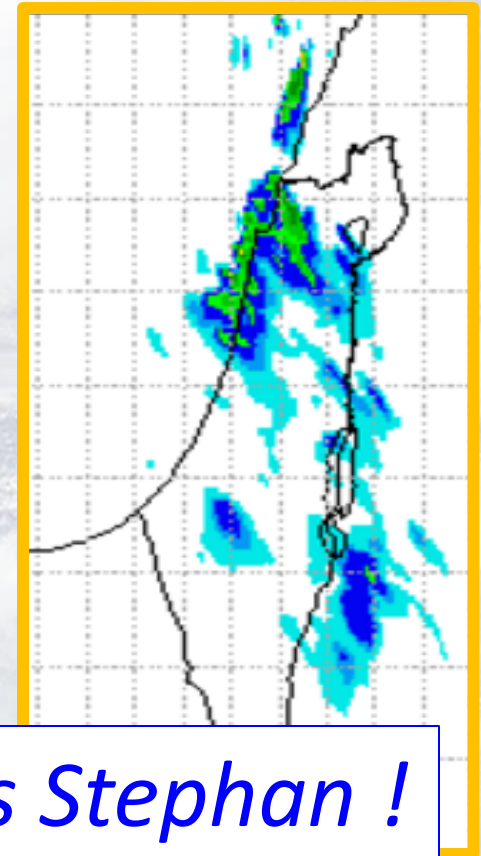
RADAR



COSMO 2.8km
with LHN



COSMO 2.8km
without LHN



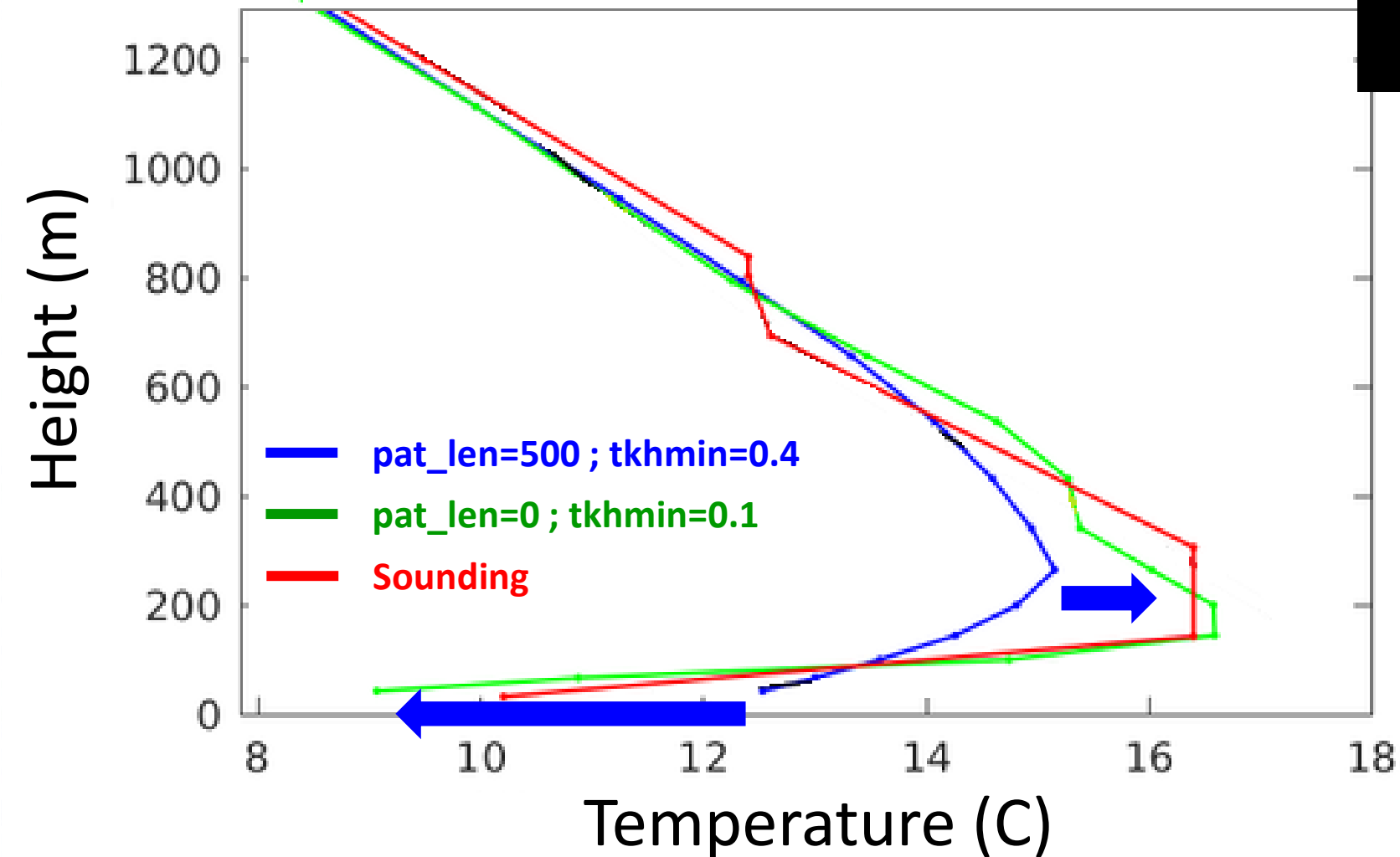
Thanks to Klaus Stephan !

Achievements



Achievement 1: better night time temperature profile

Example: COSMO 2.8km forecast from 4/3/2016 00 UTC +24h



Thanks to Ines Cerenzia, Uli Blahak, Matthias Raschendorfer!

A satellite image of a cyclone, showing a central eye surrounded by dense, swirling cloud bands. The image is in grayscale, highlighting the intricate patterns of the storm's structure.

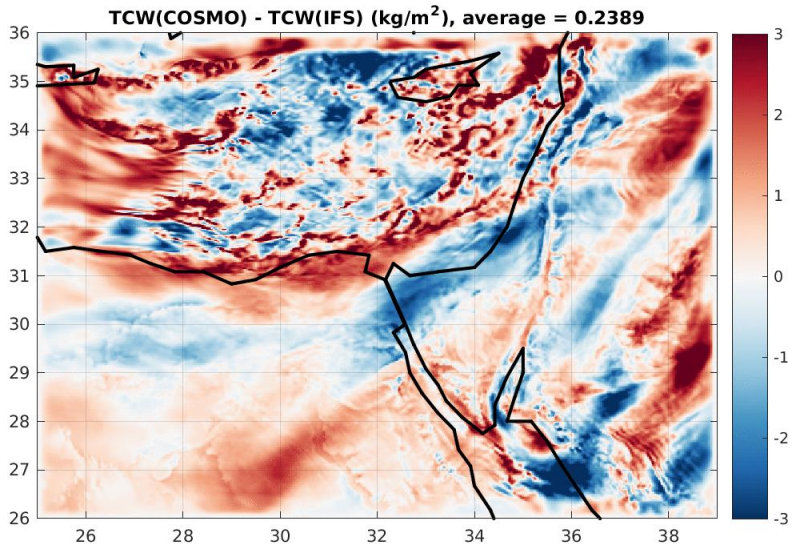
Main problem of IMS COSMO:

**loss of humidity (→ less rain) during forecast,
especially at the decay stage of a cyclone**

A satellite view of Earth's atmosphere, showing a large, bright, circular cloud cluster in the center, surrounded by a vast expanse of white clouds. The background is a deep blue, representing the Earth's surface. The text is overlaid in the center of the image.

**Increased evaporation from sea and land
by reducing r_{lam_heat} from 1 to 0.75 ...**

Reference (rlam_heat=1)



EXAMPLE:

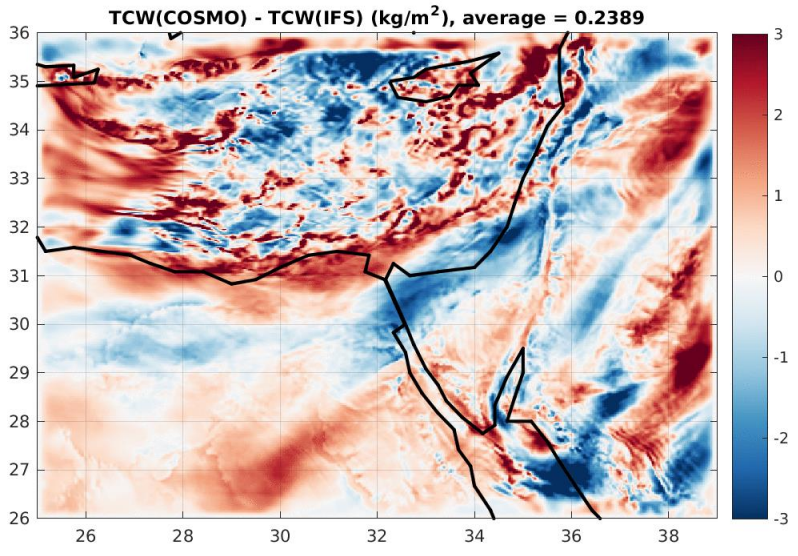
COSMO forecast from 18/1/2016 18 UTC +...

Total column water (COSMO)

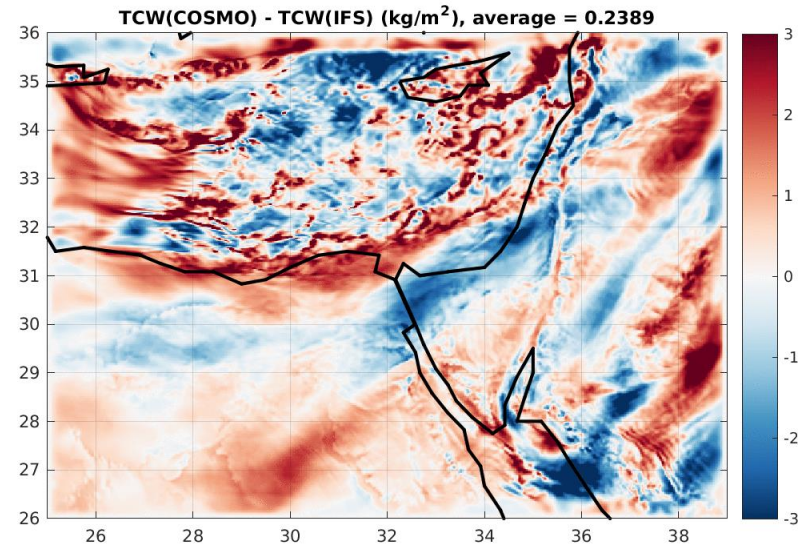
—

Total column water (IFS)

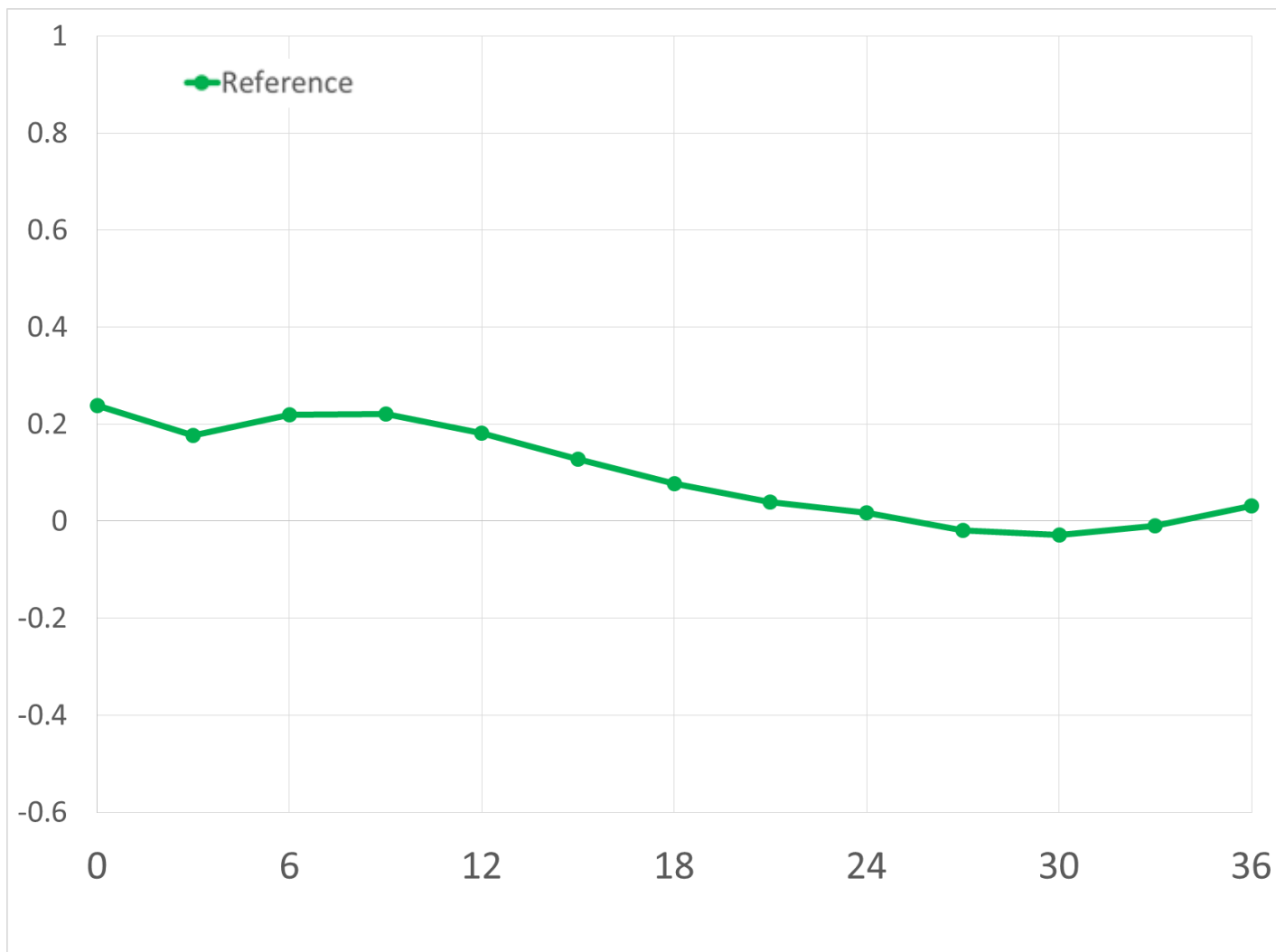
High evaporation from sea (rlam_heat=0.1)



Slightly more evaporation from sea (rlam_heat=0.1)

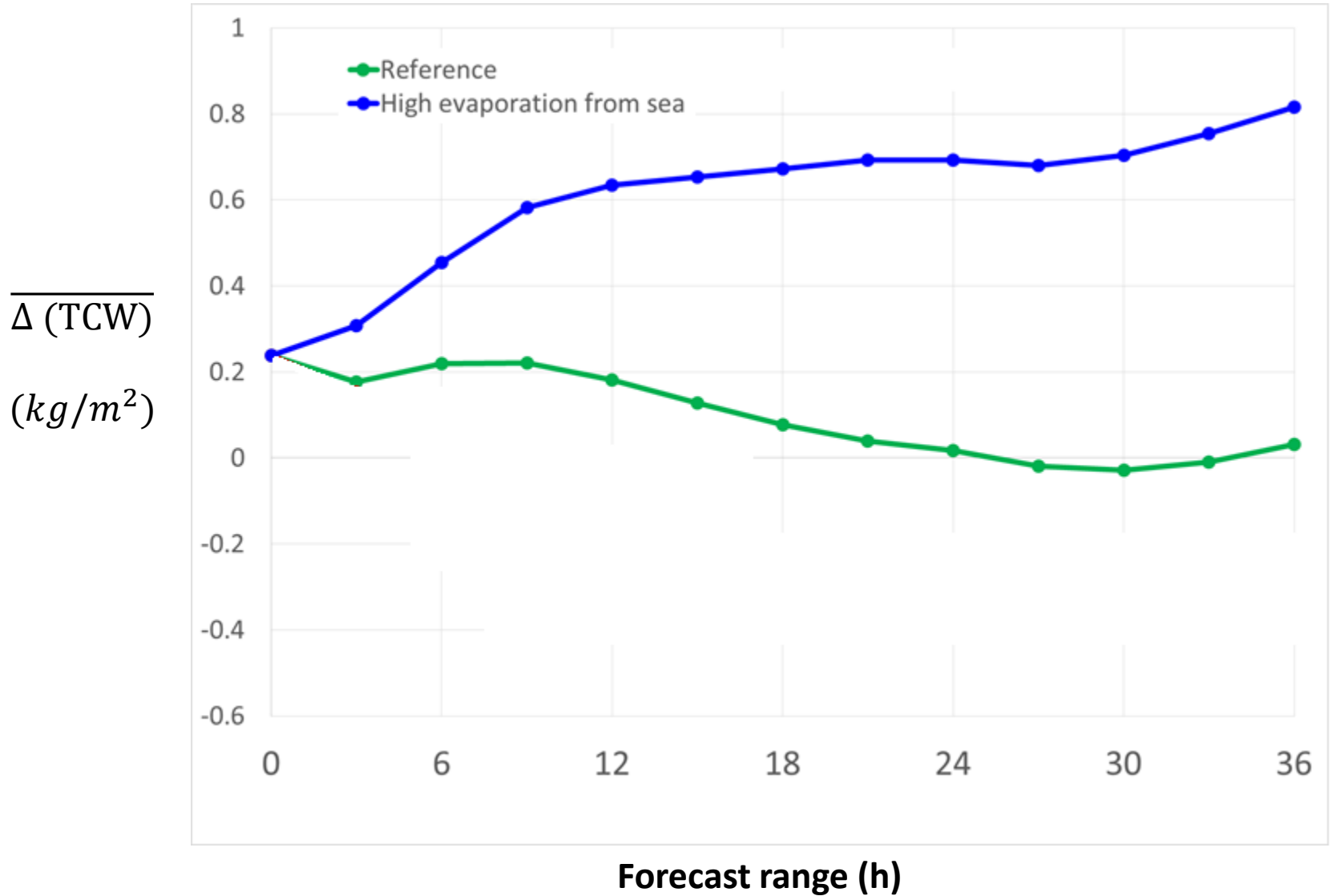


Domain averaged TCW(COSMO) – TCW(IFS)

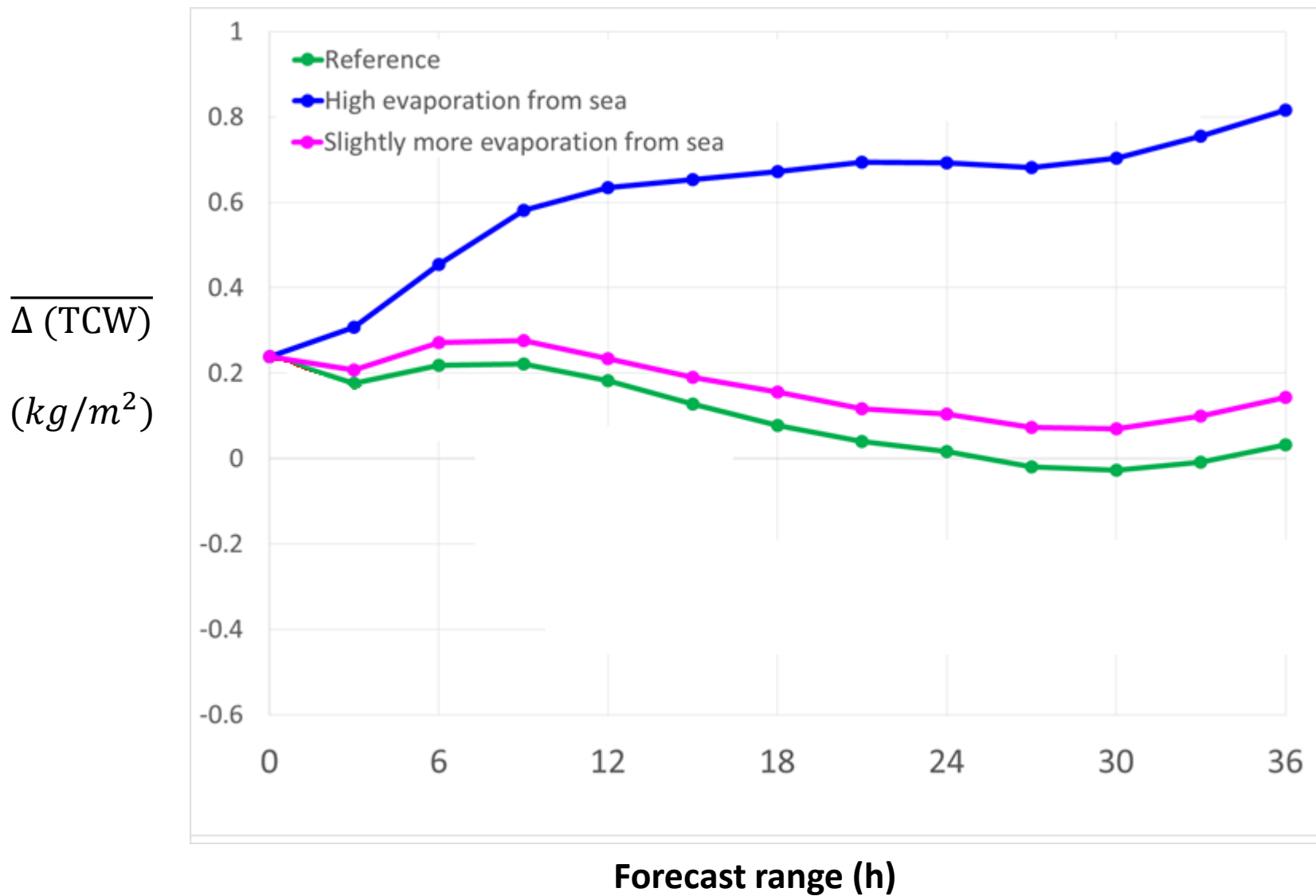


Forecast range (h)

Domain averaged TCW(COSMO) – TCW(IFS)



Domain averaged TCW(COSMO) – TCW(IFS)



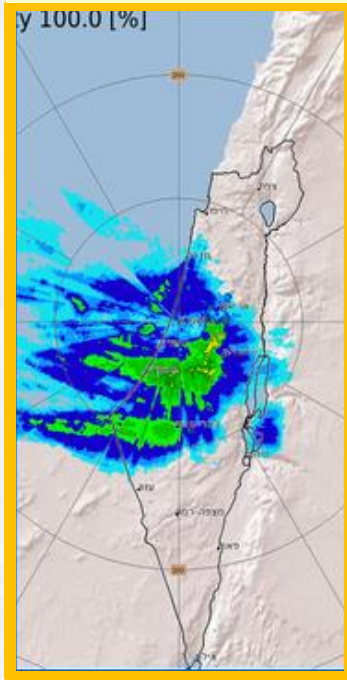
A satellite image of a tropical cyclone, showing a well-defined eye and a dense, swirling cloud structure. The eye is a small, dark, circular area in the center of the storm, surrounded by a thick, white ring of clouds. The outer rings of the storm are composed of numerous smaller, white clouds that spiral inward. The background is a light blue, hazy atmosphere.

**Consequence:
Better precipitation forecast**

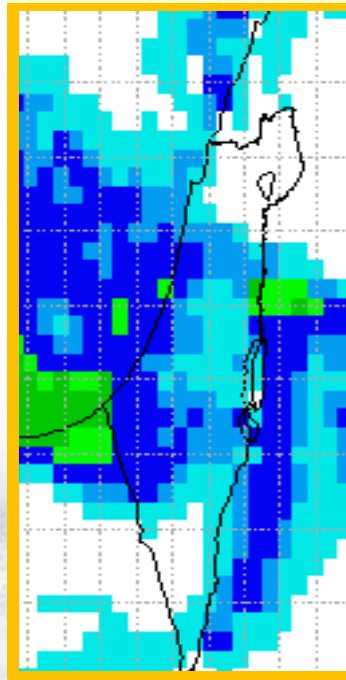
Achievement 2: better precipitation forecast

Example: COSMO forecast from 25/1/2016 12Z+...

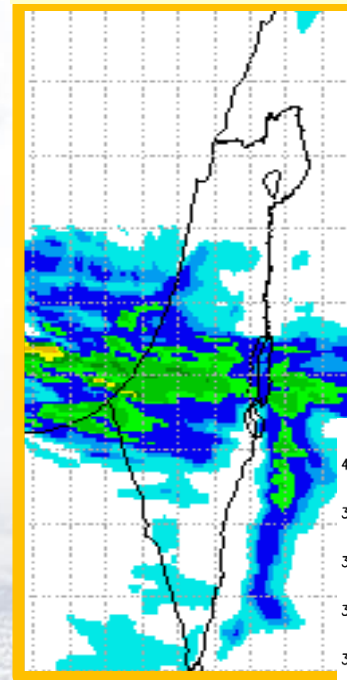
RADAR



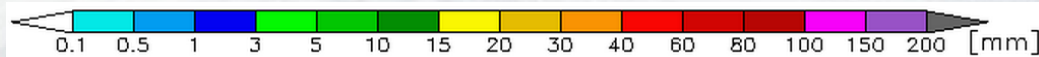
IFS



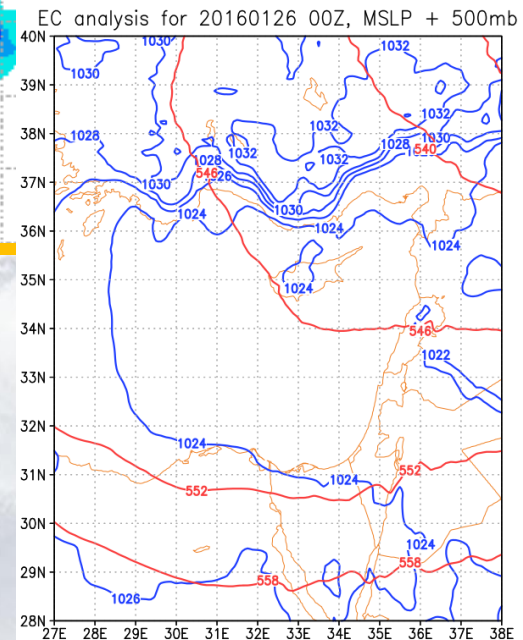
COSMO



EC analysis
26/1/2016 00Z



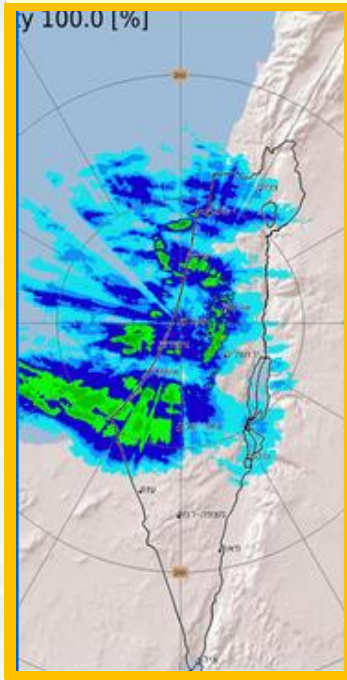
25/01/2016 12Z+12h



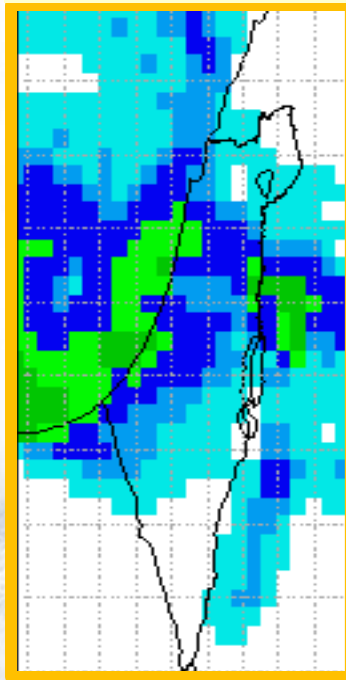
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Example: COSMO forecast from 25/1/2016 12Z+...

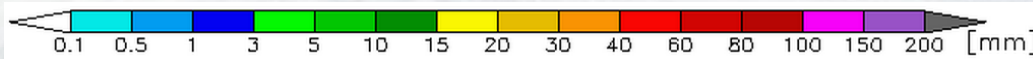
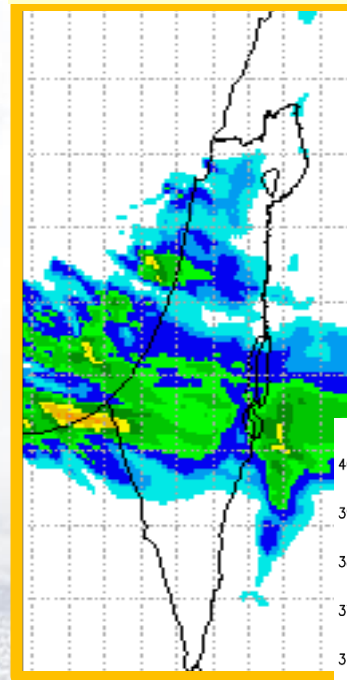
RADAR



IFS

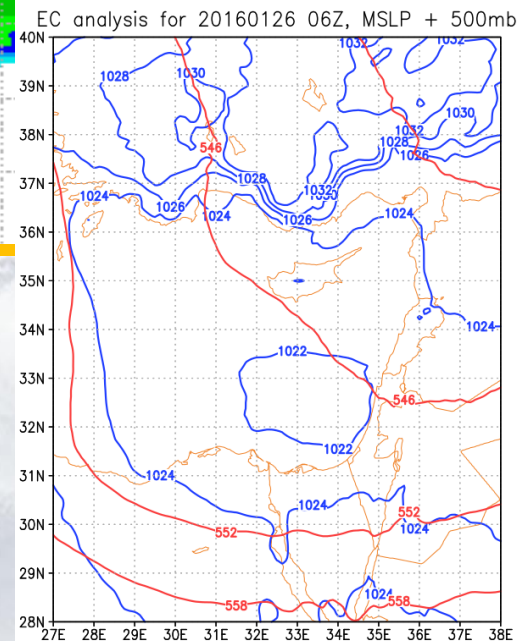


COSMO



25/01/2016 12Z+18h

EC analysis
26/1/2016 06Z

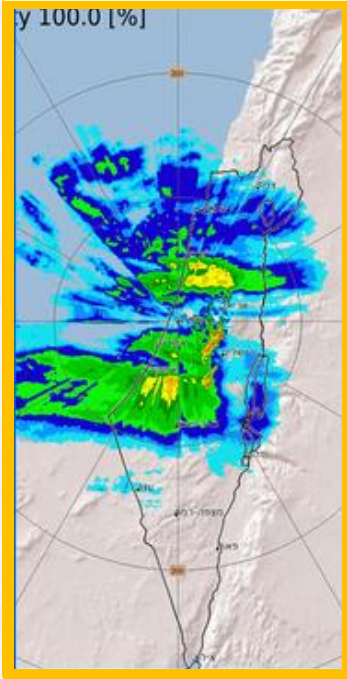


26/1/2016
00-06Z

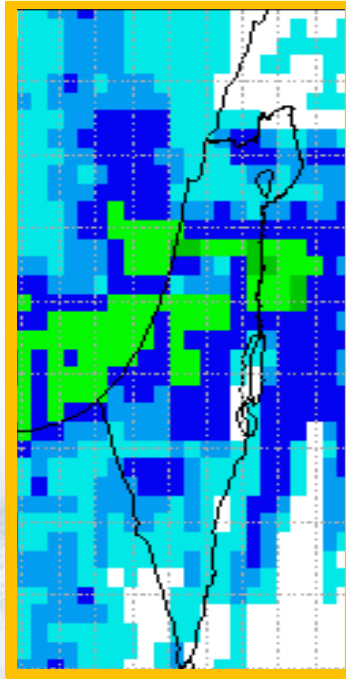
Achievement 2: better precipitation forecast

Example: COSMO forecast from 25/1/2016 12Z+...

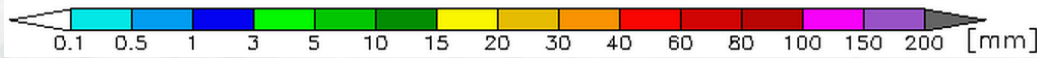
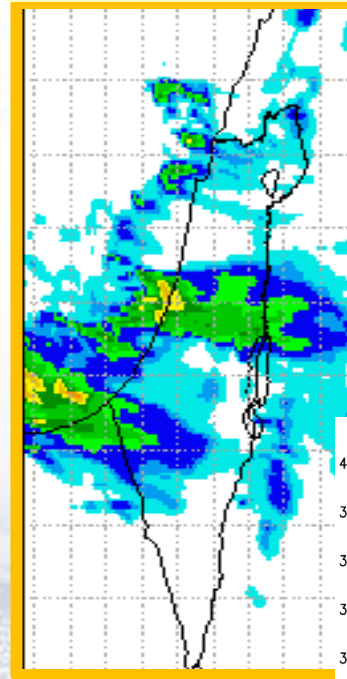
RADAR



IFS

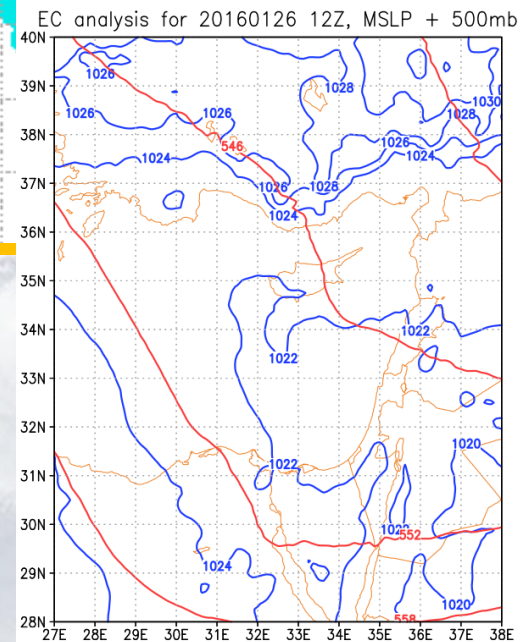


COSMO



25/01/2016 12Z+24h

EC analysis
26/1/2016 12Z



26/1/2016
06-12Z

Which precipitation species did we have ?

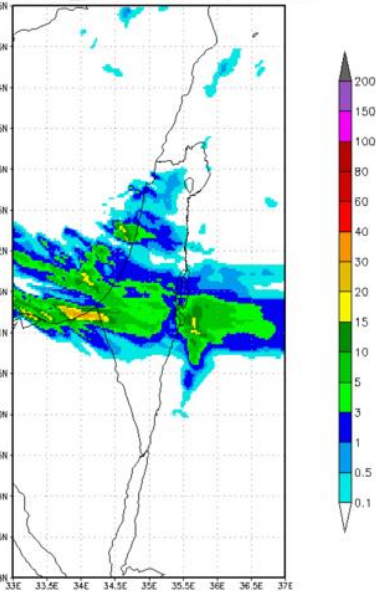
**Total
precipitation**

Rain

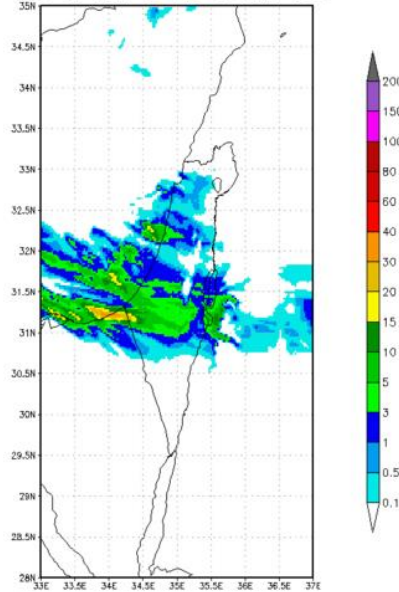
Graupel

Snow

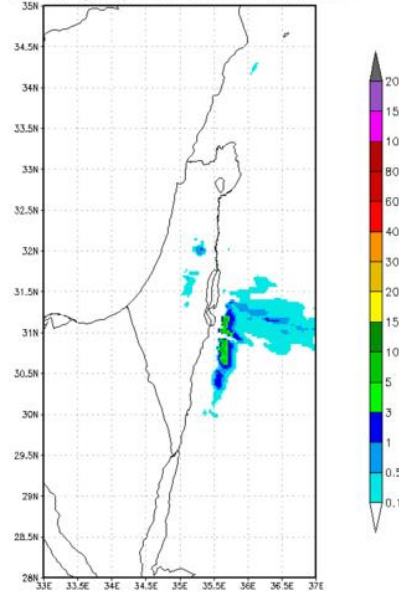
A3 6h tot_prec to Tue 26 JAN 06Z



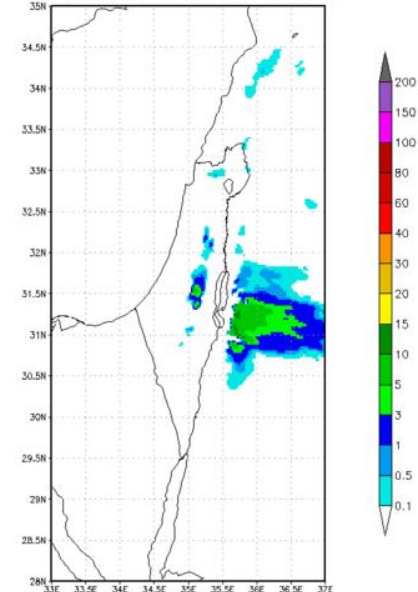
A3 6h rain to Tue 26 JAN 06Z



A3 6h graupel to Tue 26 JAN 06Z



A3 6h snow to Tue 26 JAN 06Z



Hole in rain
forecast in
mountains

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a. Example

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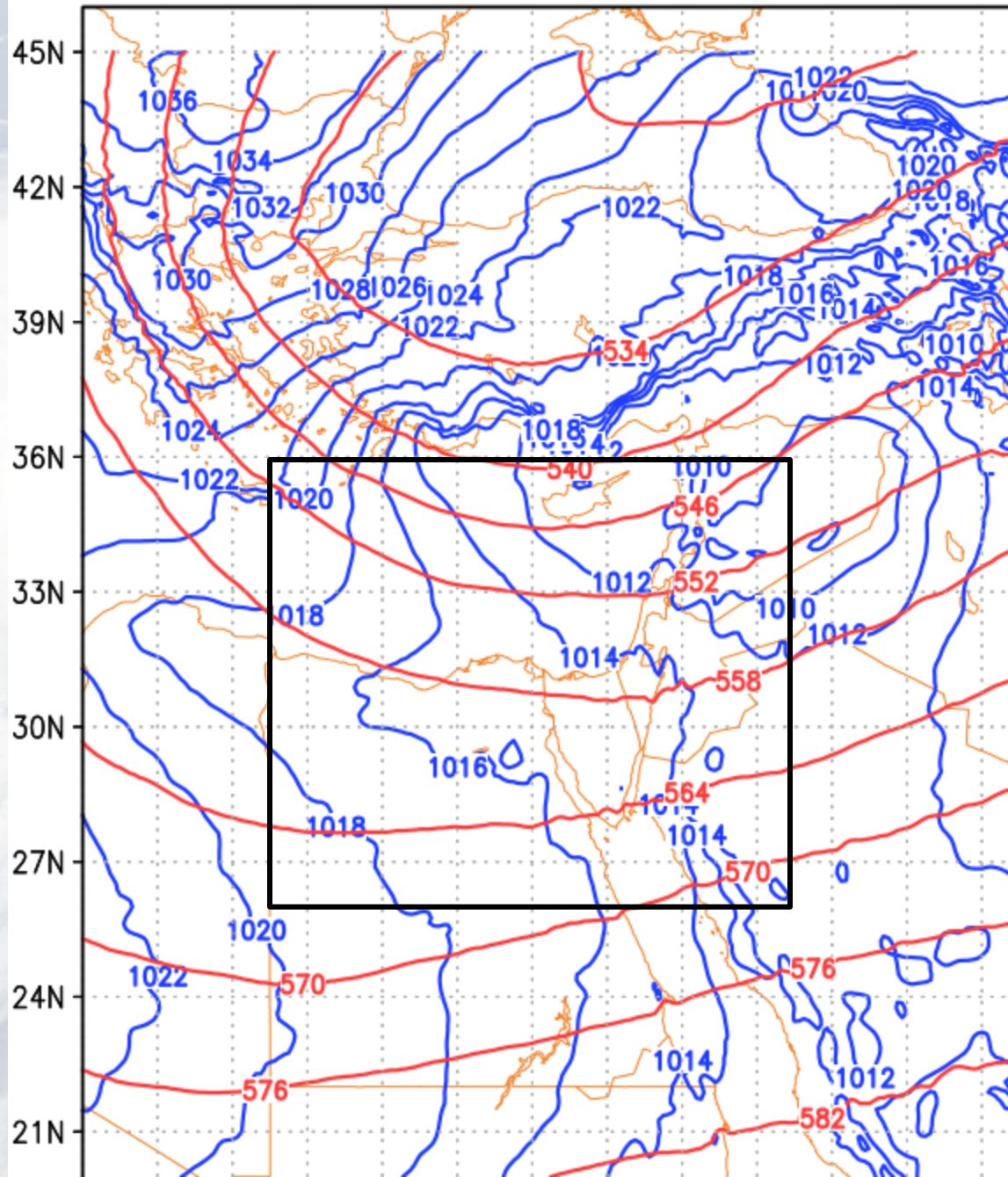
HOWEVER

1. Does $rlam_heat=0.75$ give the correct evaporation ?
(We plan to compare COSMO evaporation rates with IFS/ICON)
2. Slight evaporation increase does not always yield enough water vapor in region of interest

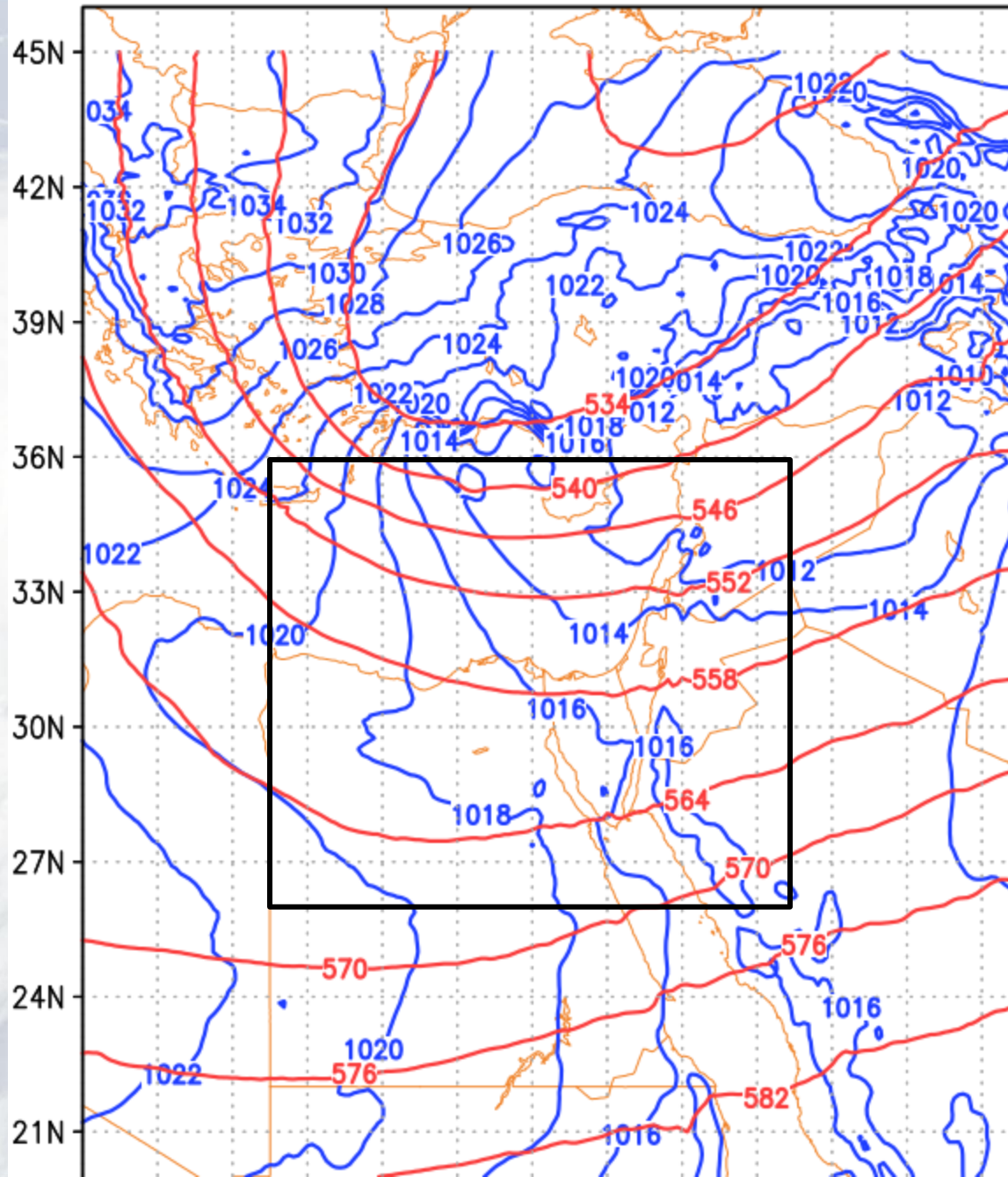
Example:
31/12/2015 12UTC +...



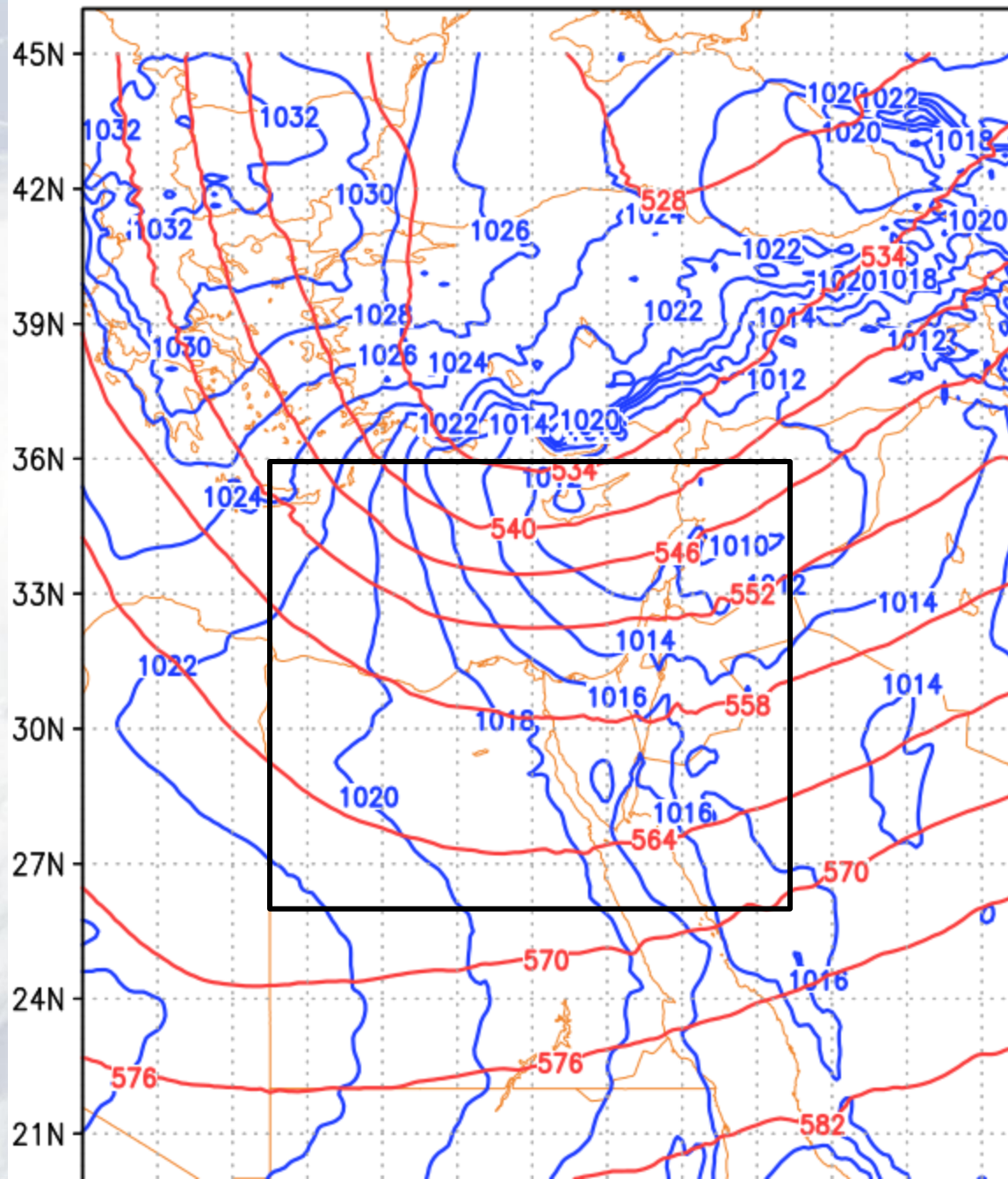
EC analysis for 20151231 12Z, MSLP + 500mb



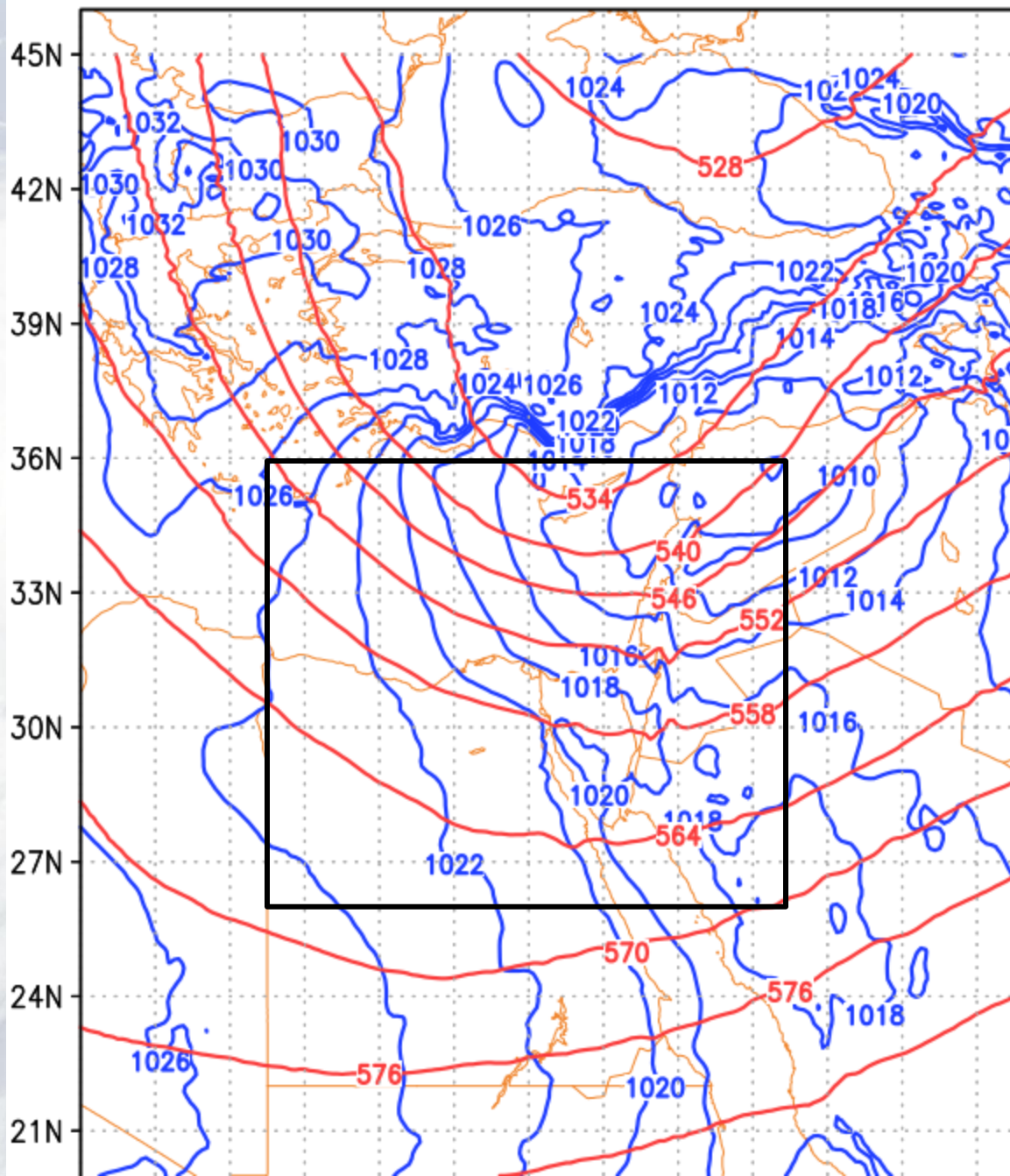
EC analysis for 20151231 18Z, MSLP + 500mb



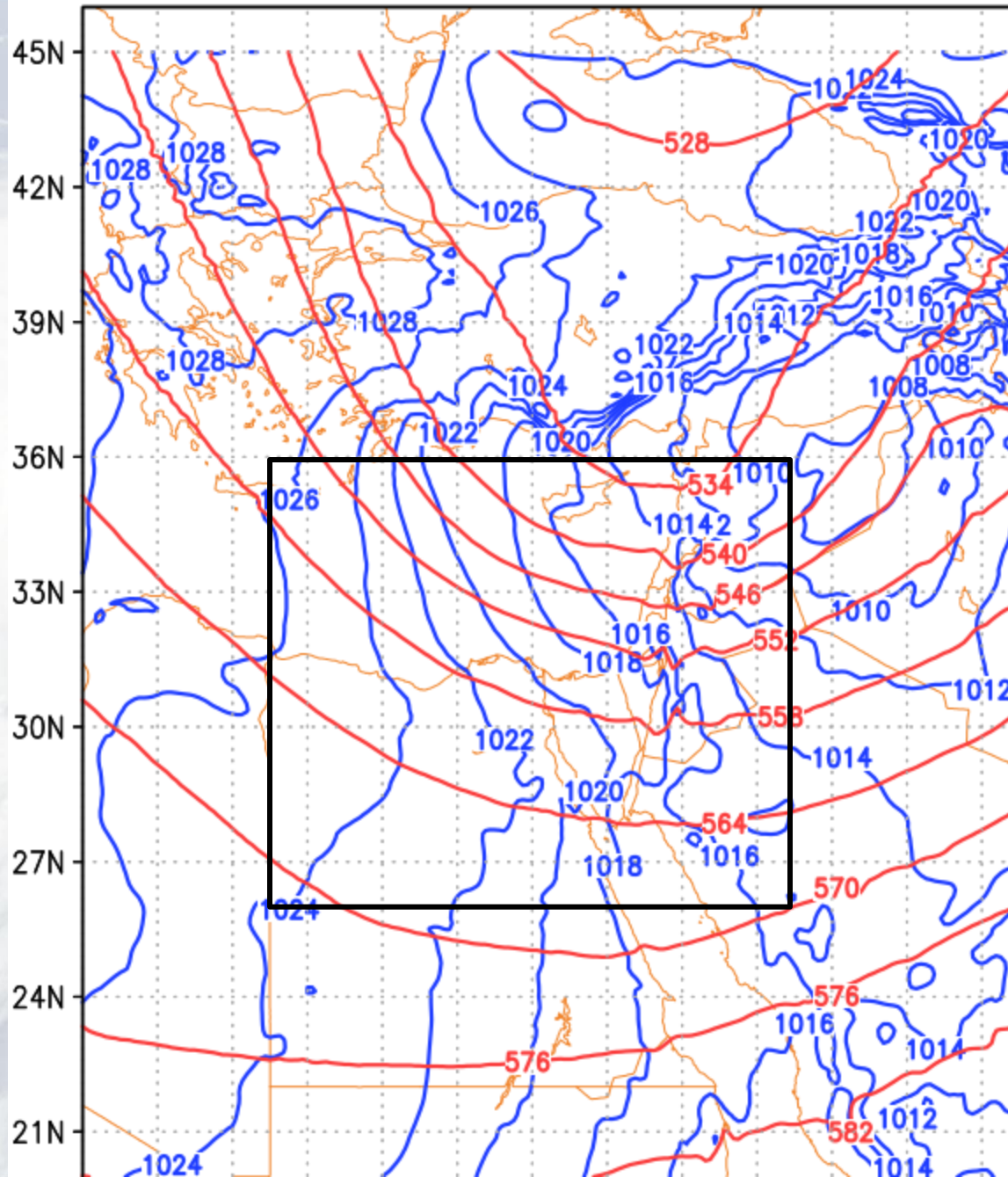
EC analysis for 20160101 00Z, MSLP + 500mb



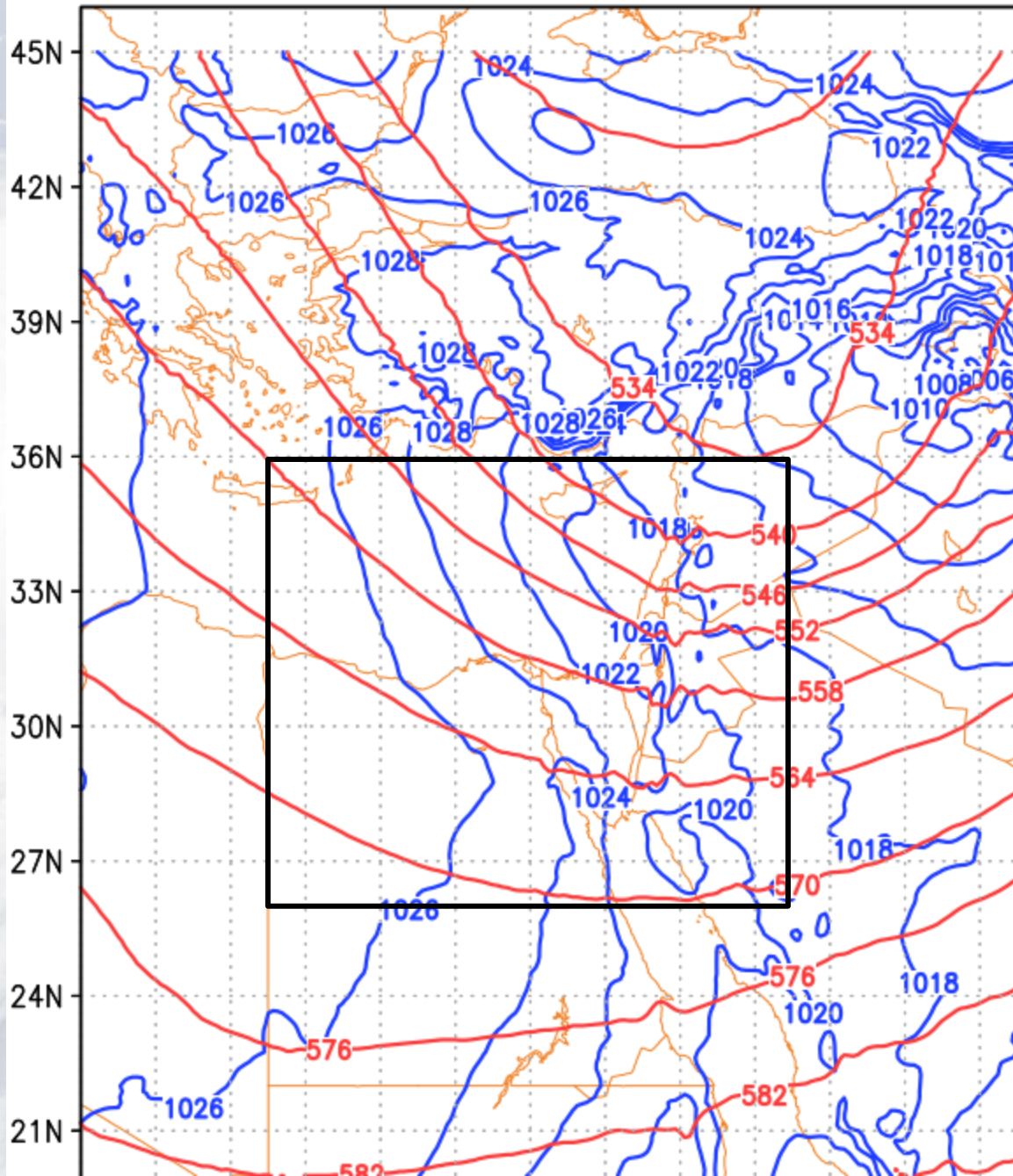
EC analysis for 20160101 06Z, MSLP + 500mb



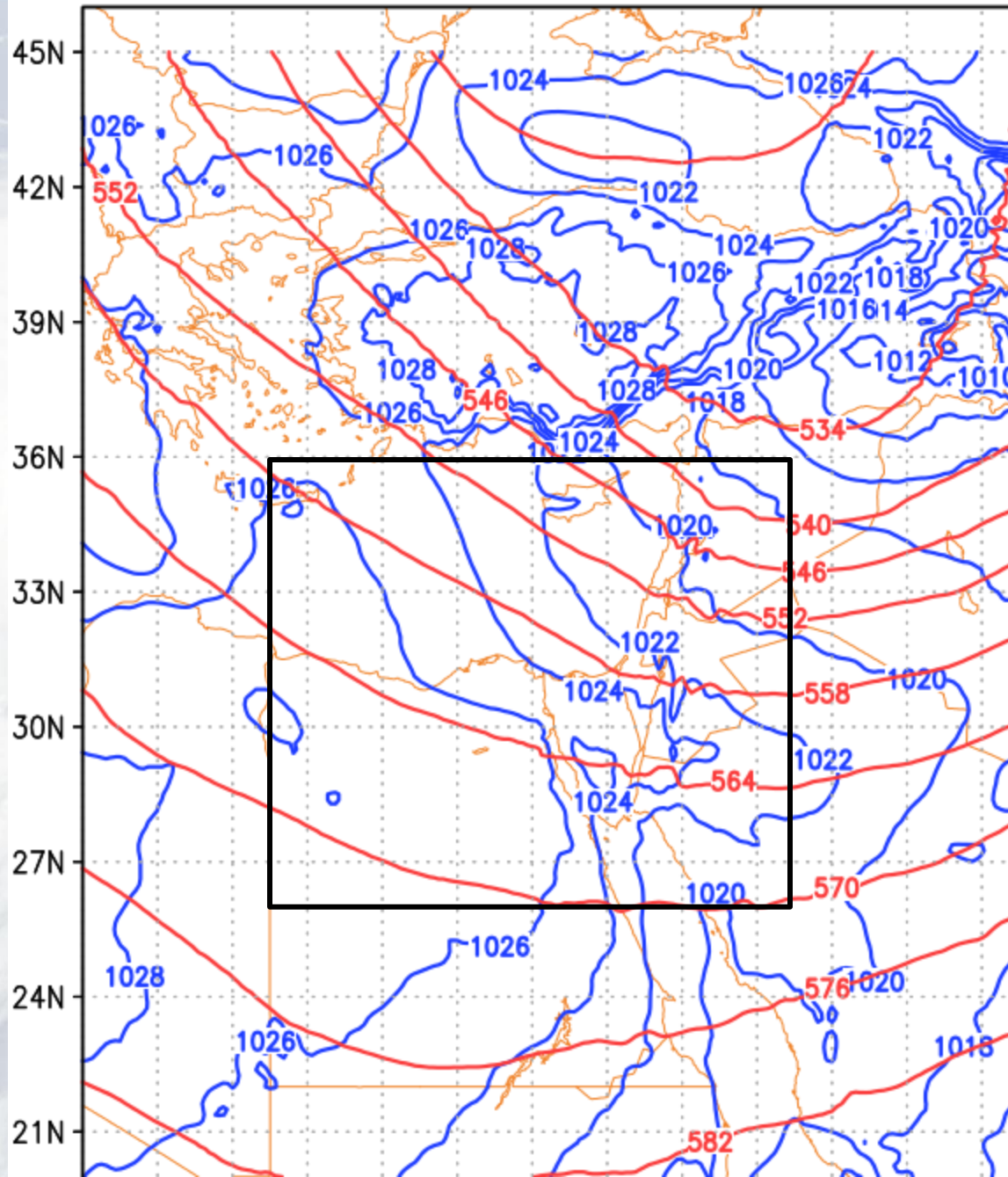
EC analysis for 20160101 12Z, MSLP + 500mb



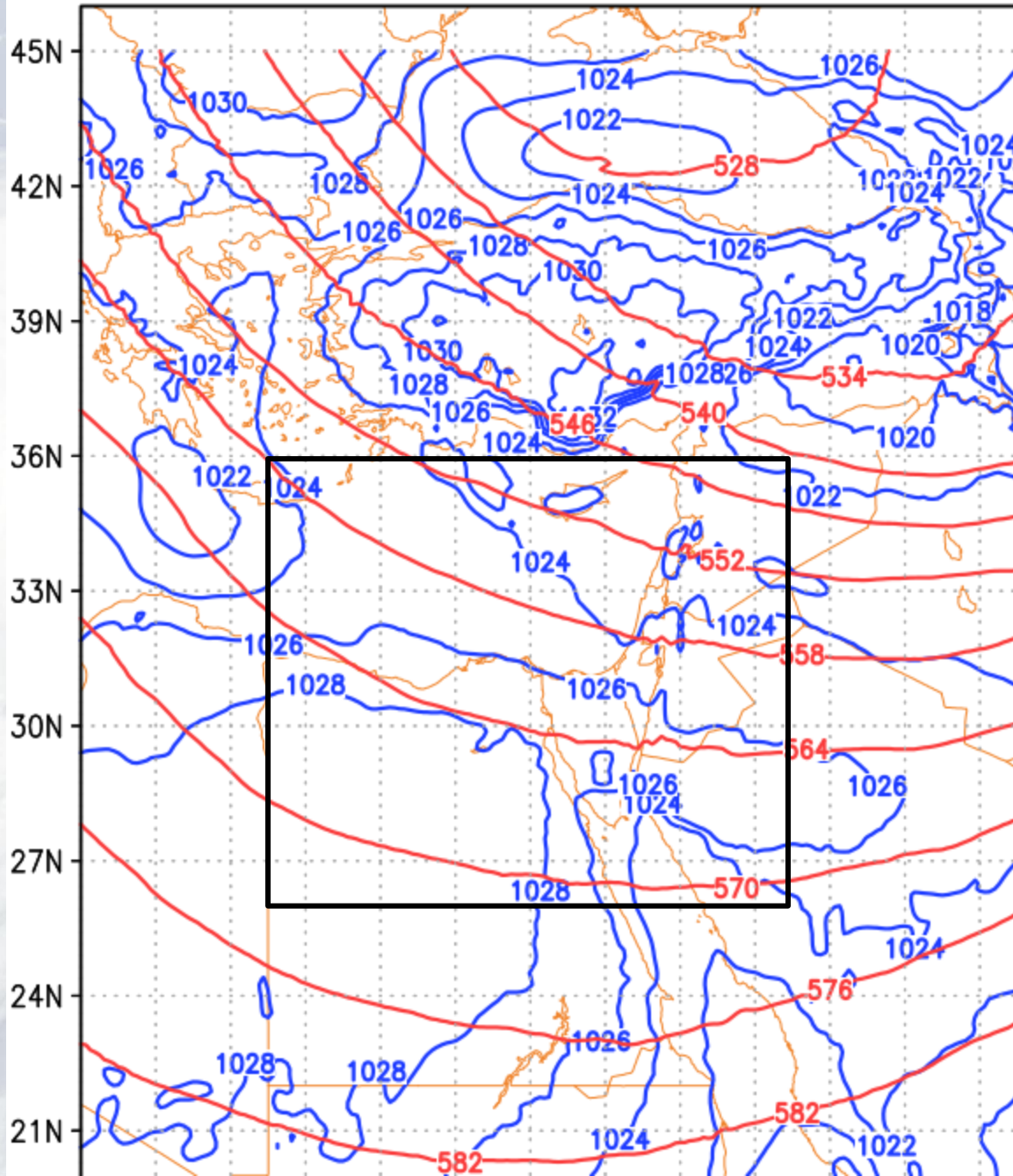
EC analysis for 20160101 18Z, MSLP + 500mb



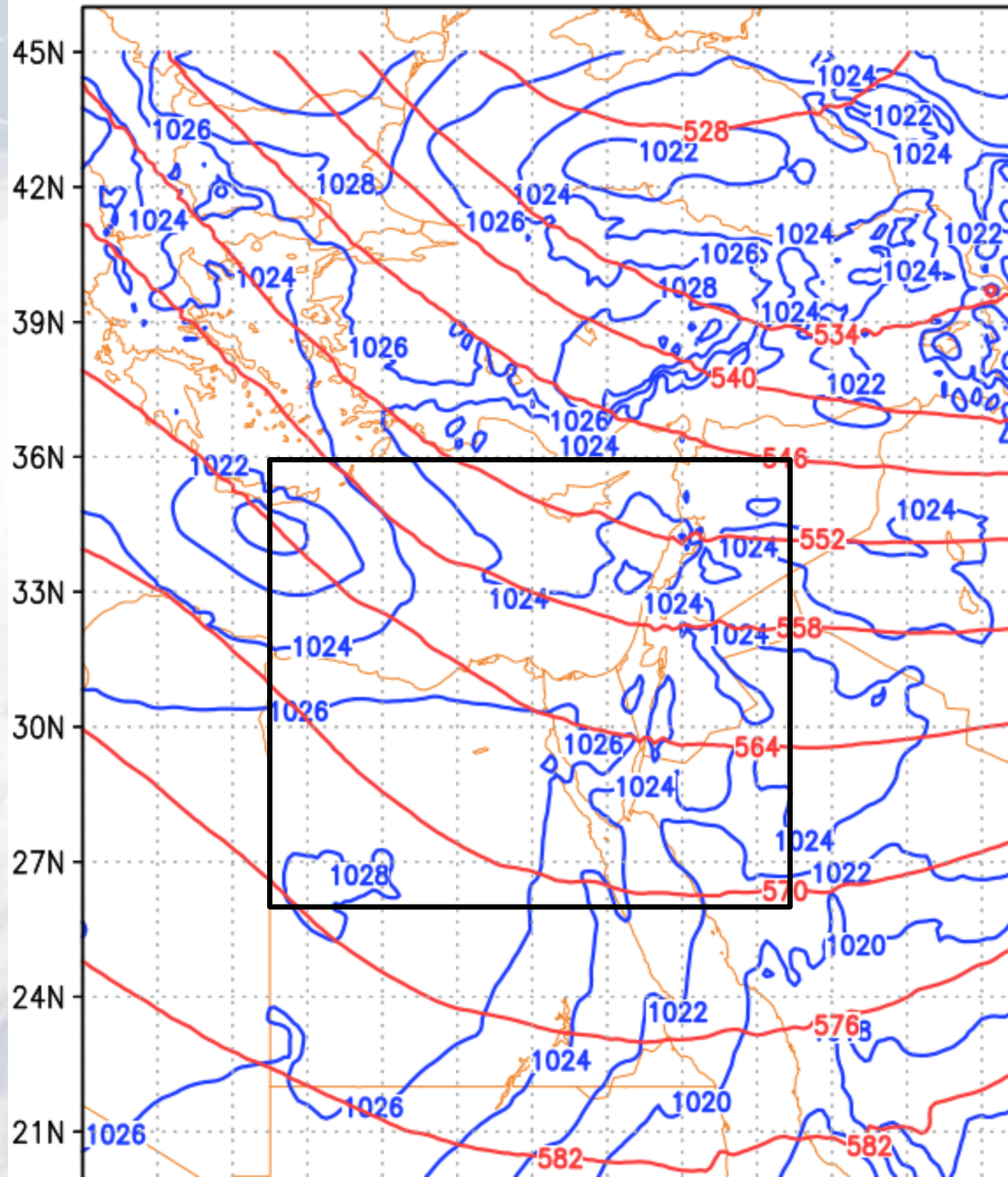
EC analysis for 20160102 00Z, MSLP + 500mb



EC analysis for 20160102 06Z, MSLP + 500mb

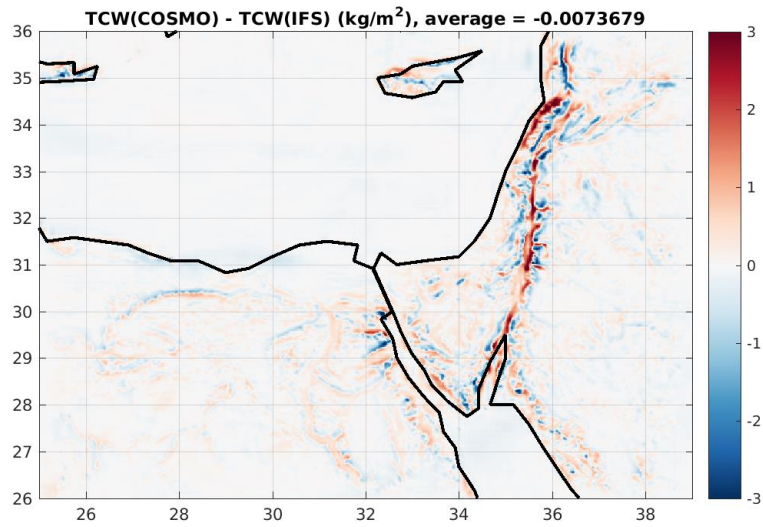


EC analysis for 20160102 12Z, MSLP + 500mb



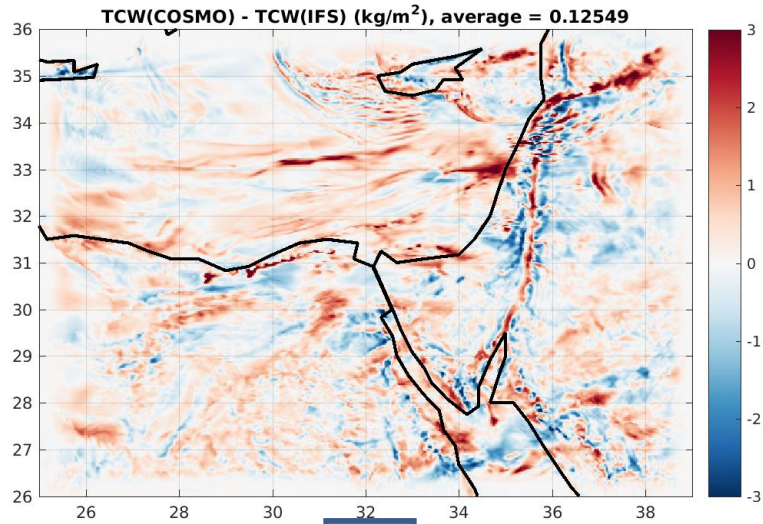
Total column water (COSMO – IFS)

2015/12/31 12UTC + 00h

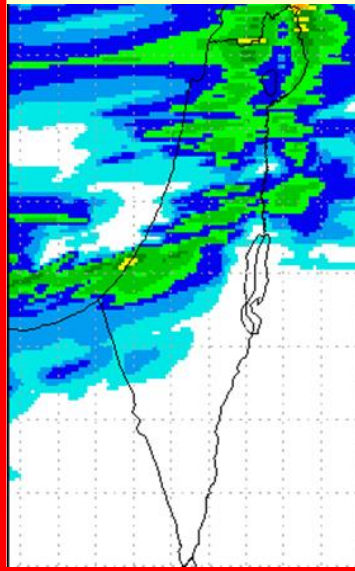


Total column water (COSMO – IFS)

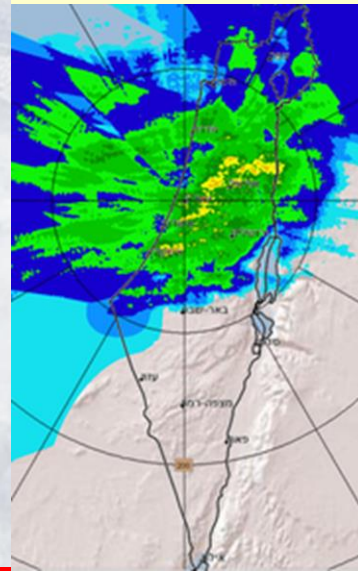
2015/12/31 12UTC + 03h



COSMO



RADAR



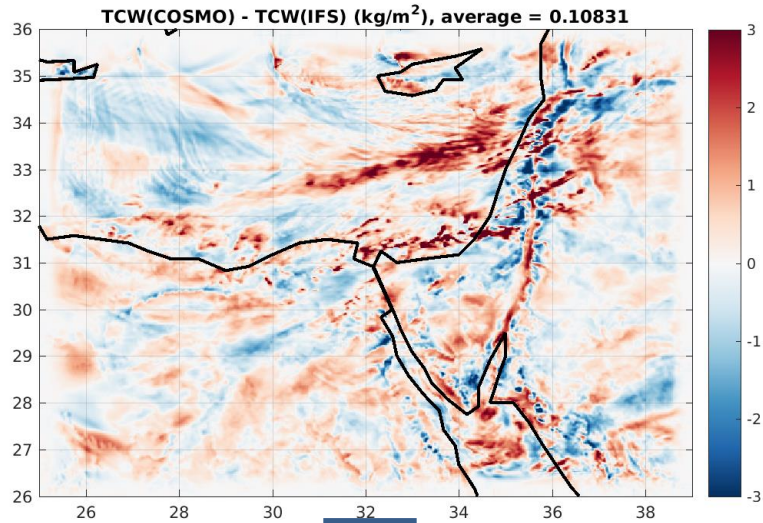
mm/6h



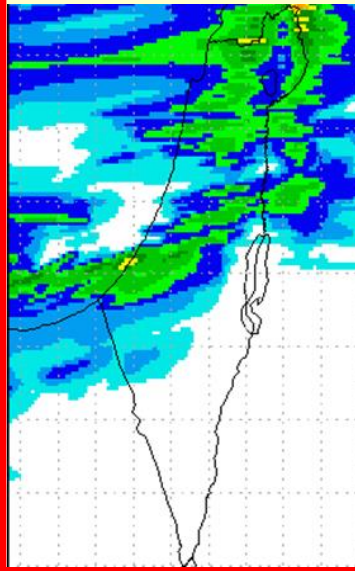
2015/12/31
12-18UTC
accum.
precip.

Total column water (COSMO – IFS)

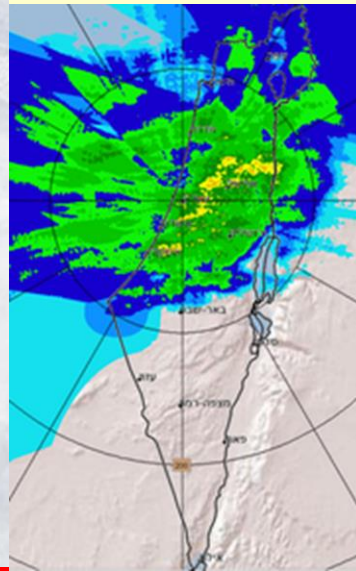
2015/12/31 12UTC + 06h



COSMO



RADAR



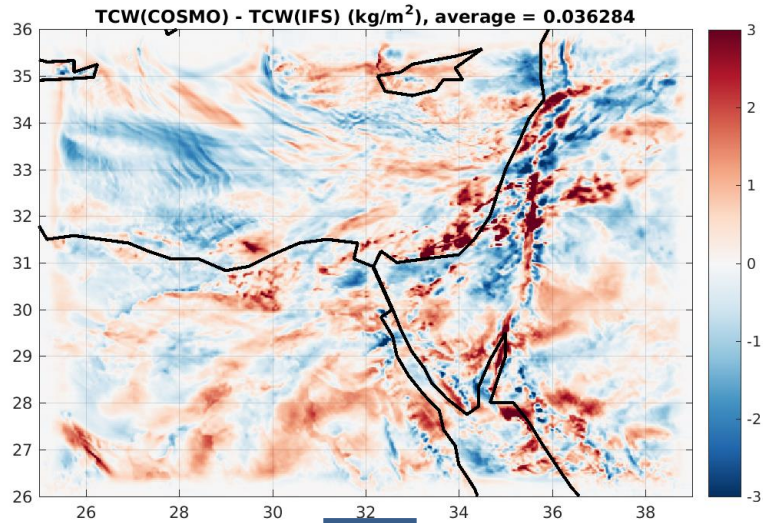
mm/6h



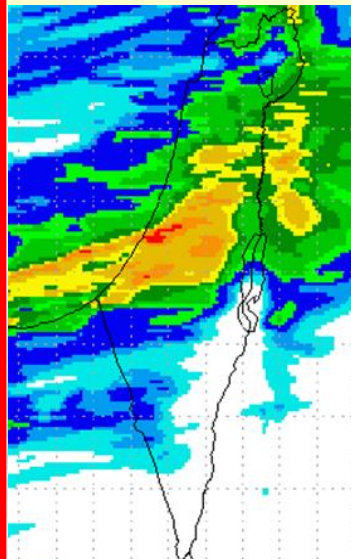
2015/12/31
12-18UTC
accum.
precip.

Total column water (COSMO – IFS)

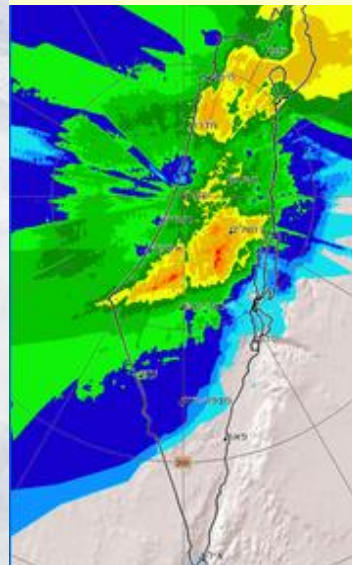
2015/12/31 12UTC + 09h



COSMO



RADAR



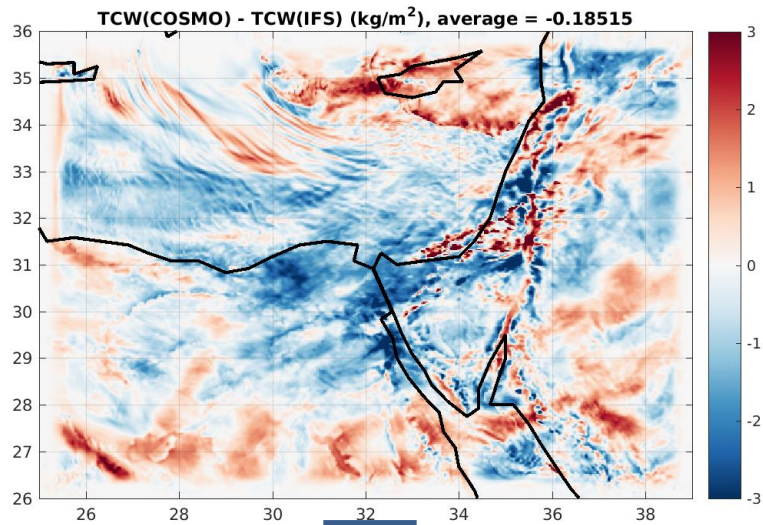
mm/6h



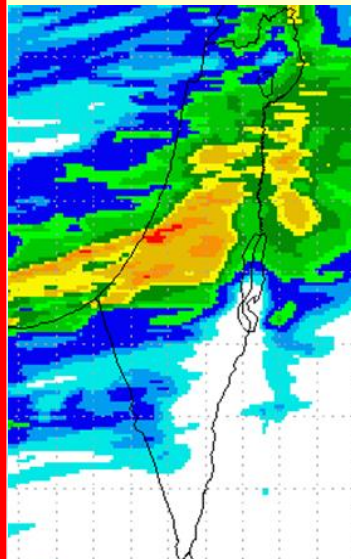
2015/12/31
18-24UTC
accum.
precip.

Total column water (COSMO – IFS)

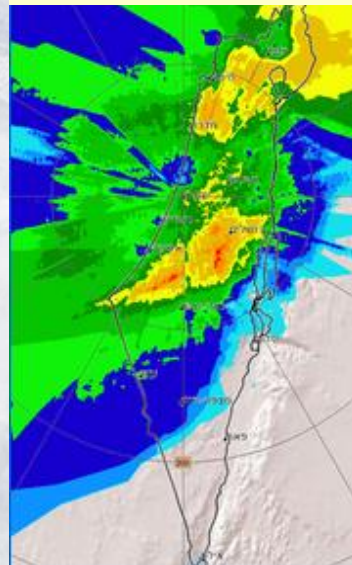
2015/12/31 12UTC + 12h



COSMO



RADAR



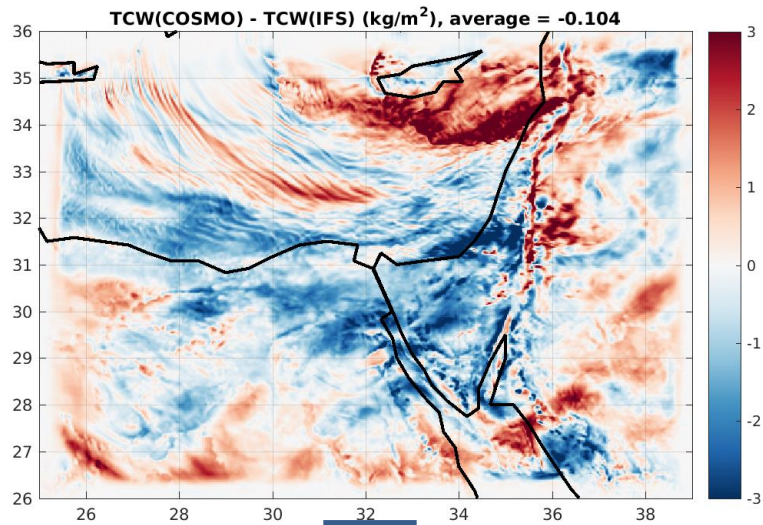
mm/6h



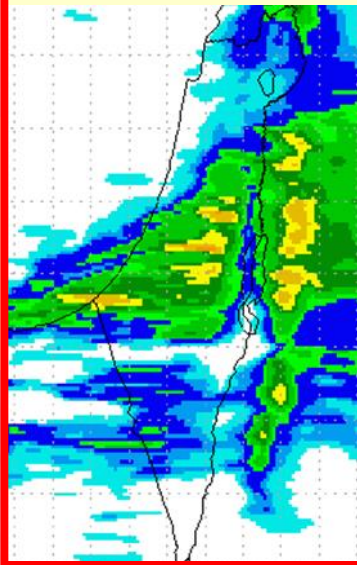
2015/12/31
18-24UTC
accum.
precip.

Total column water (COSMO – IFS)

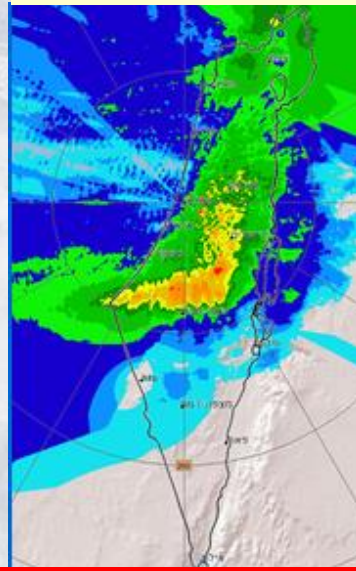
2015/12/31 12UTC + 15h



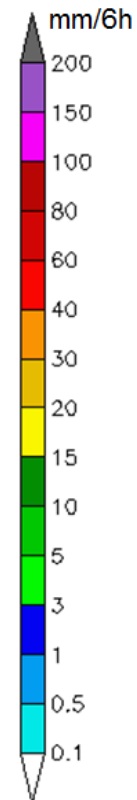
COSMO



RADAR

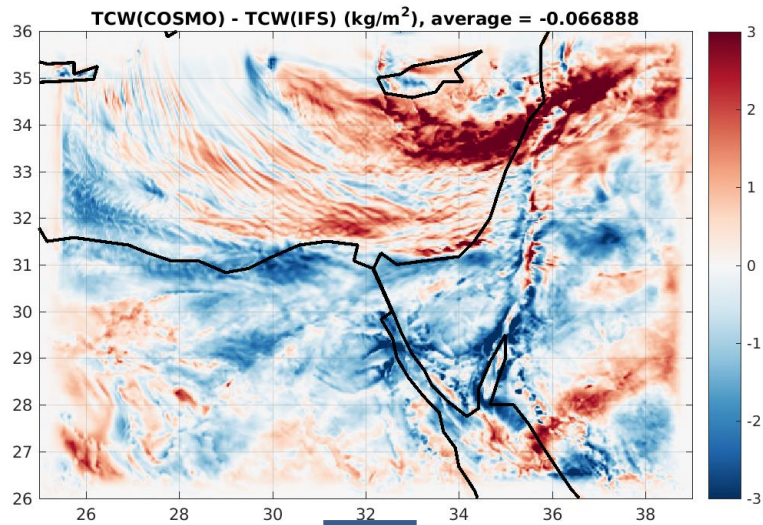


2016/1/1
00-06UTC
accum.
precip.

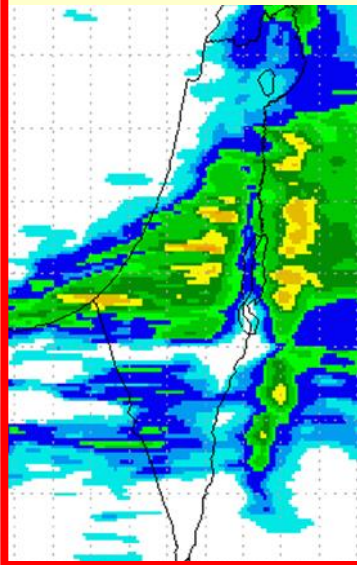


Total column water (COSMO – IFS)

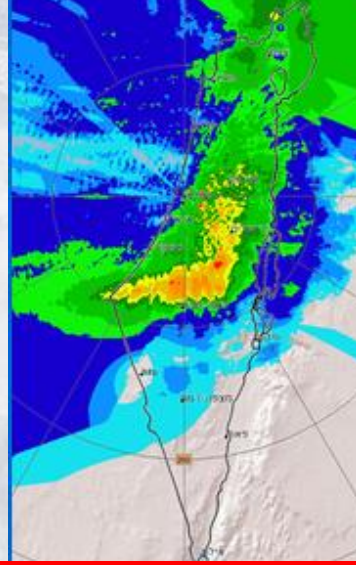
2015/12/31 12UTC + 18h



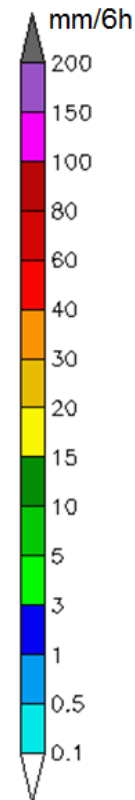
COSMO



RADAR

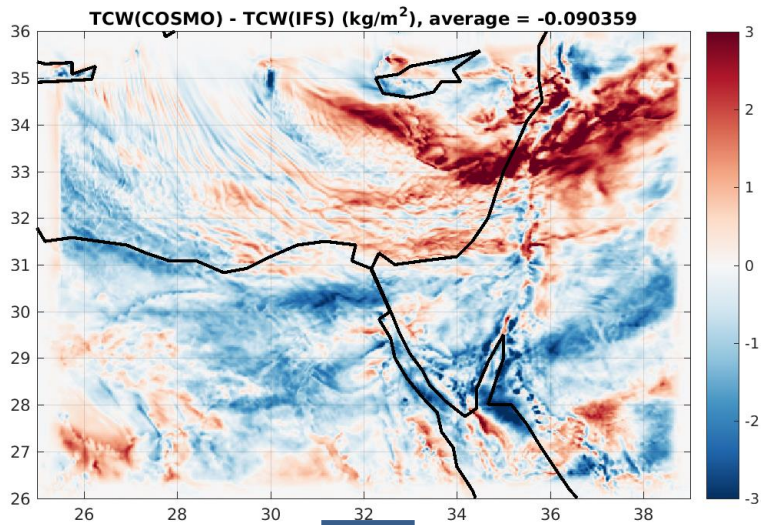


2016/1/1
00-06UTC
accum.
precip.

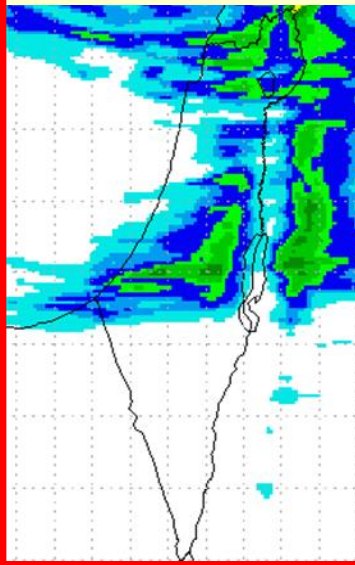


Total column water (COSMO – IFS)

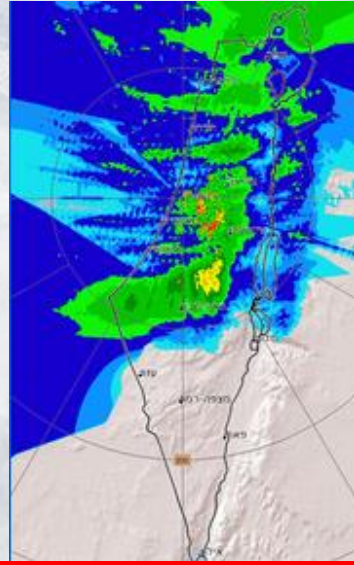
2015/12/31 12UTC + 21h



COSMO



RADAR



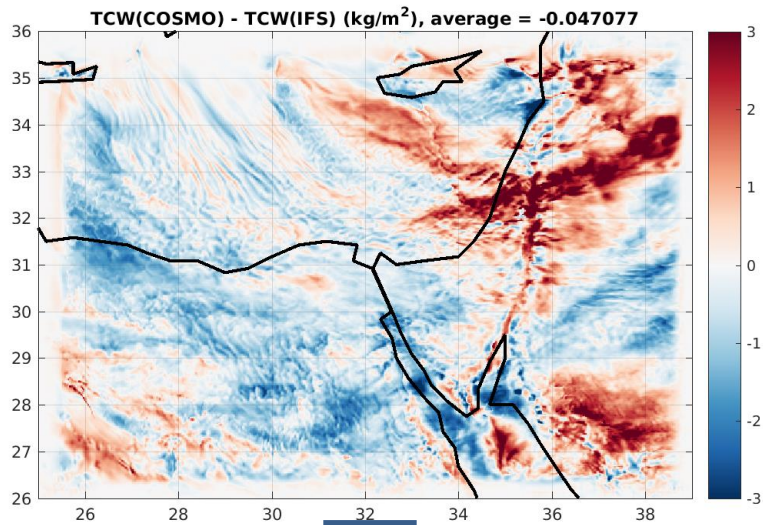
mm/6h



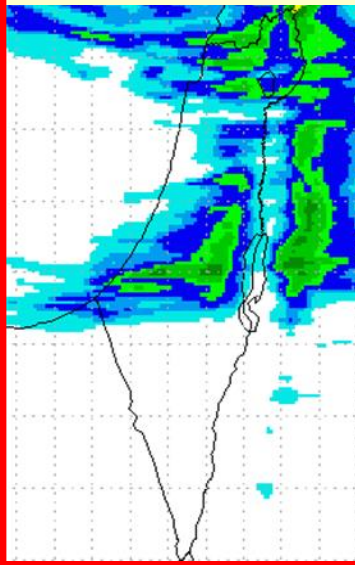
2016/1/1
06-12UTC
accum.
precip.

Total column water (COSMO – IFS)

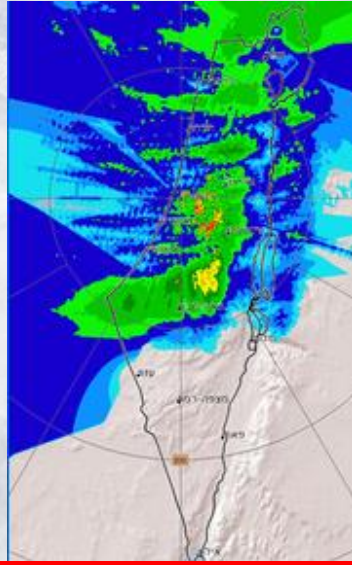
2015/12/31 12UTC + 24h



COSMO



RADAR



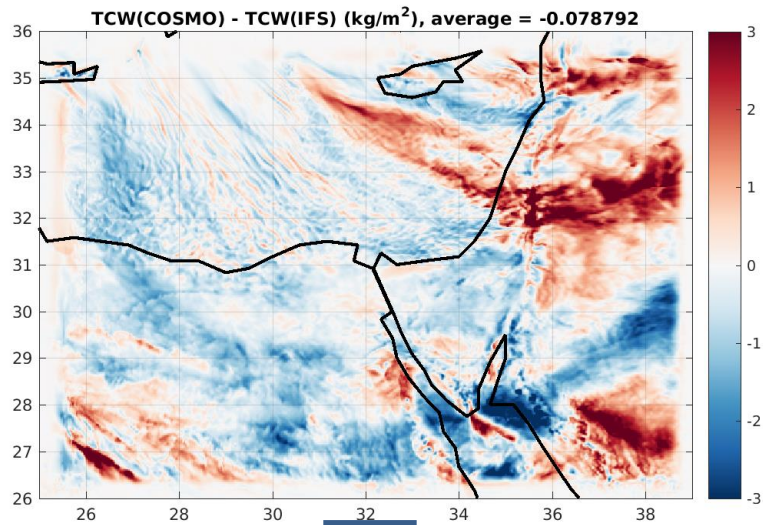
mm/6h



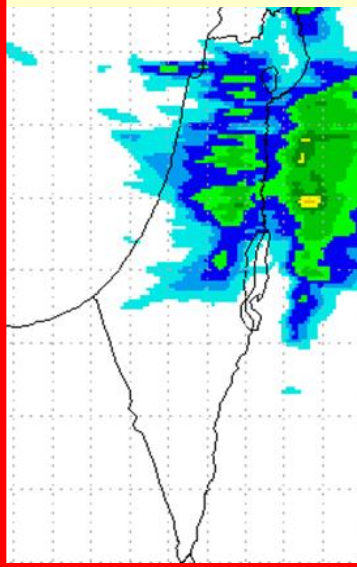
2016/1/1
06-12UTC
accum.
precip.

Total column water (COSMO – IFS)

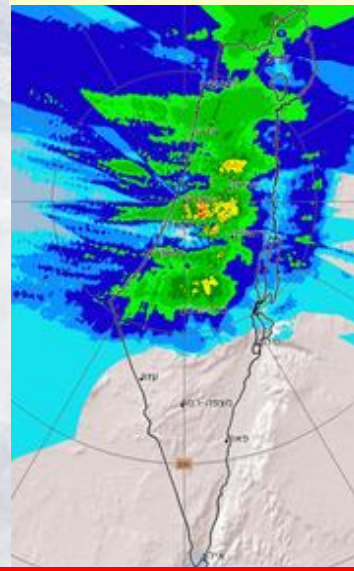
2015/12/31 12UTC + 27h



COSMO

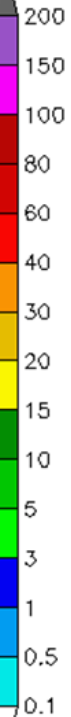


RADAR



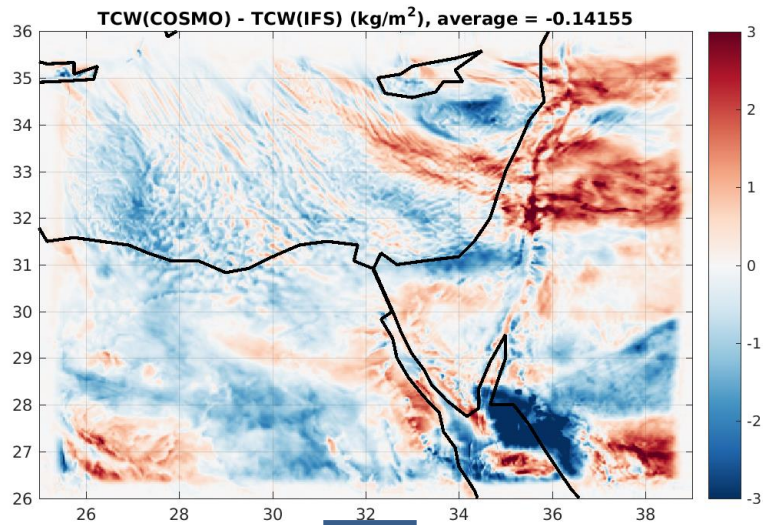
2016/1/1
12-18UTC
accum.
precip.

mm/6h

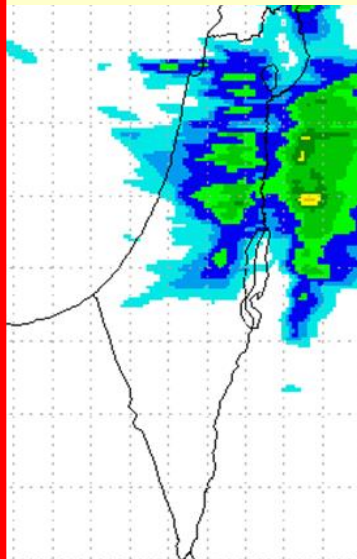


Total column water (COSMO – IFS)

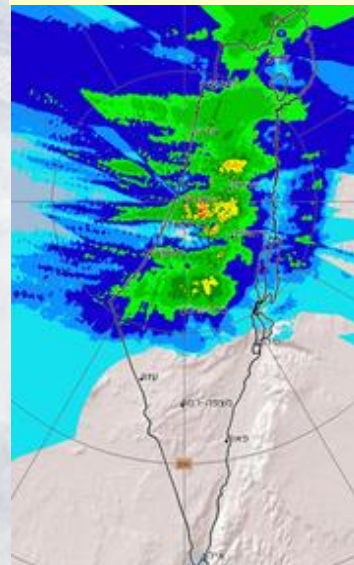
2015/12/31 12UTC + 30h



COSMO



RADAR



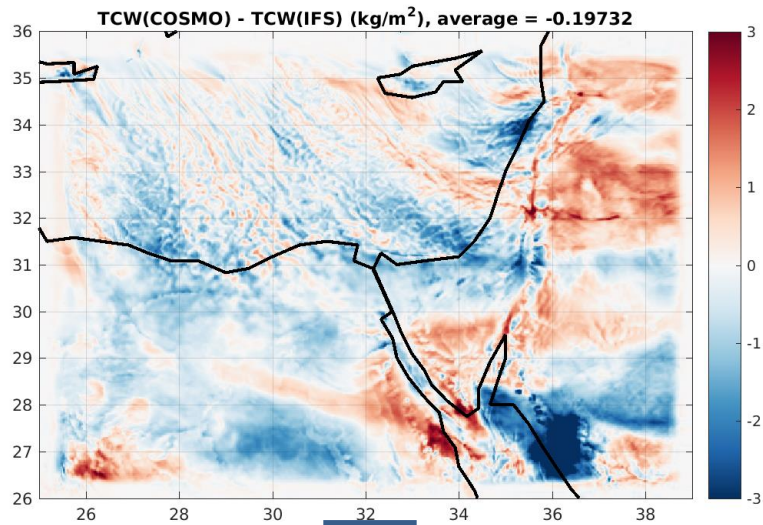
mm/6h



2016/1/1
12-18UTC
accum.
precip.

Total column water (COSMO – IFS)

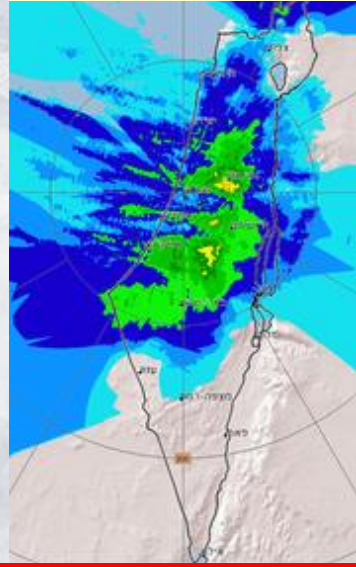
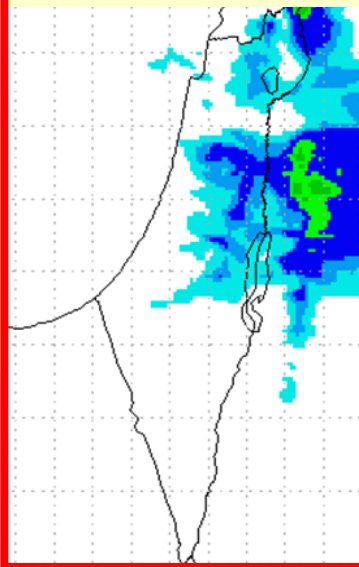
2015/12/31 12UTC + 33h



COSMO

RADAR

2016/1/1
18-24UTC
accum.
precip.

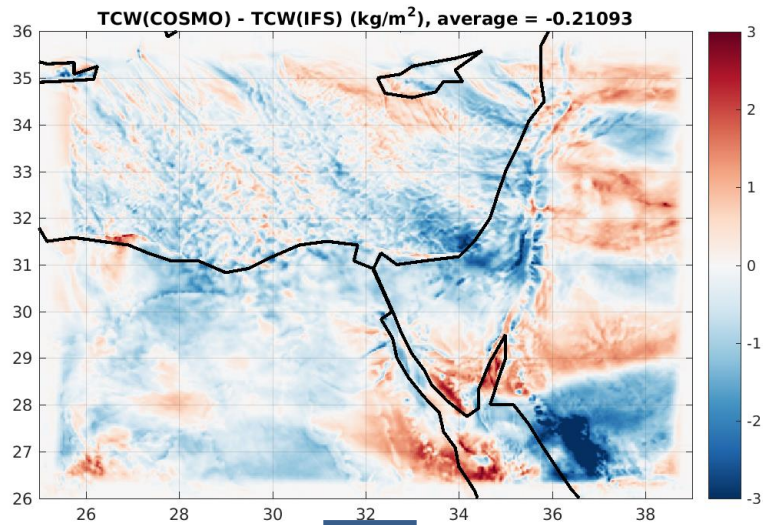


mm/6h



Total column water (COSMO – IFS)

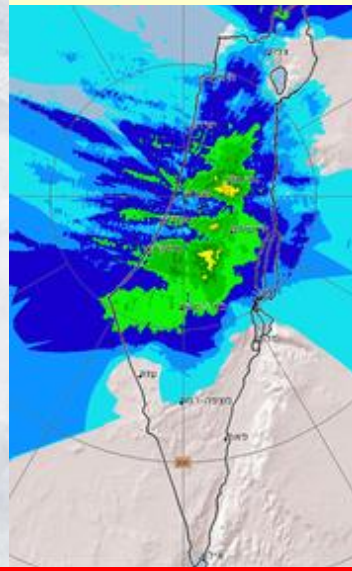
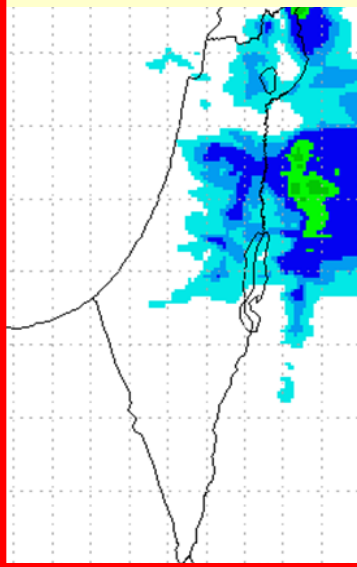
2015/12/31 12UTC + 36h



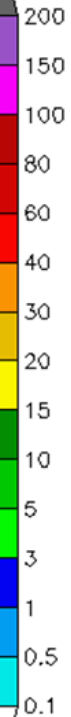
COSMO

RADAR

2016/1/1
18-24UTC
accum.
precip.



mm/6h



1. COSMO model at IMS

a. Overview

b. Main problem – loss of humidity

c. Consequence – in assimilation cycle the model dries up if not enough in observations assimilated

2. Technical solution for observation sparse regions:

Each run CHOOSE cold start/warm start depending on fast verification

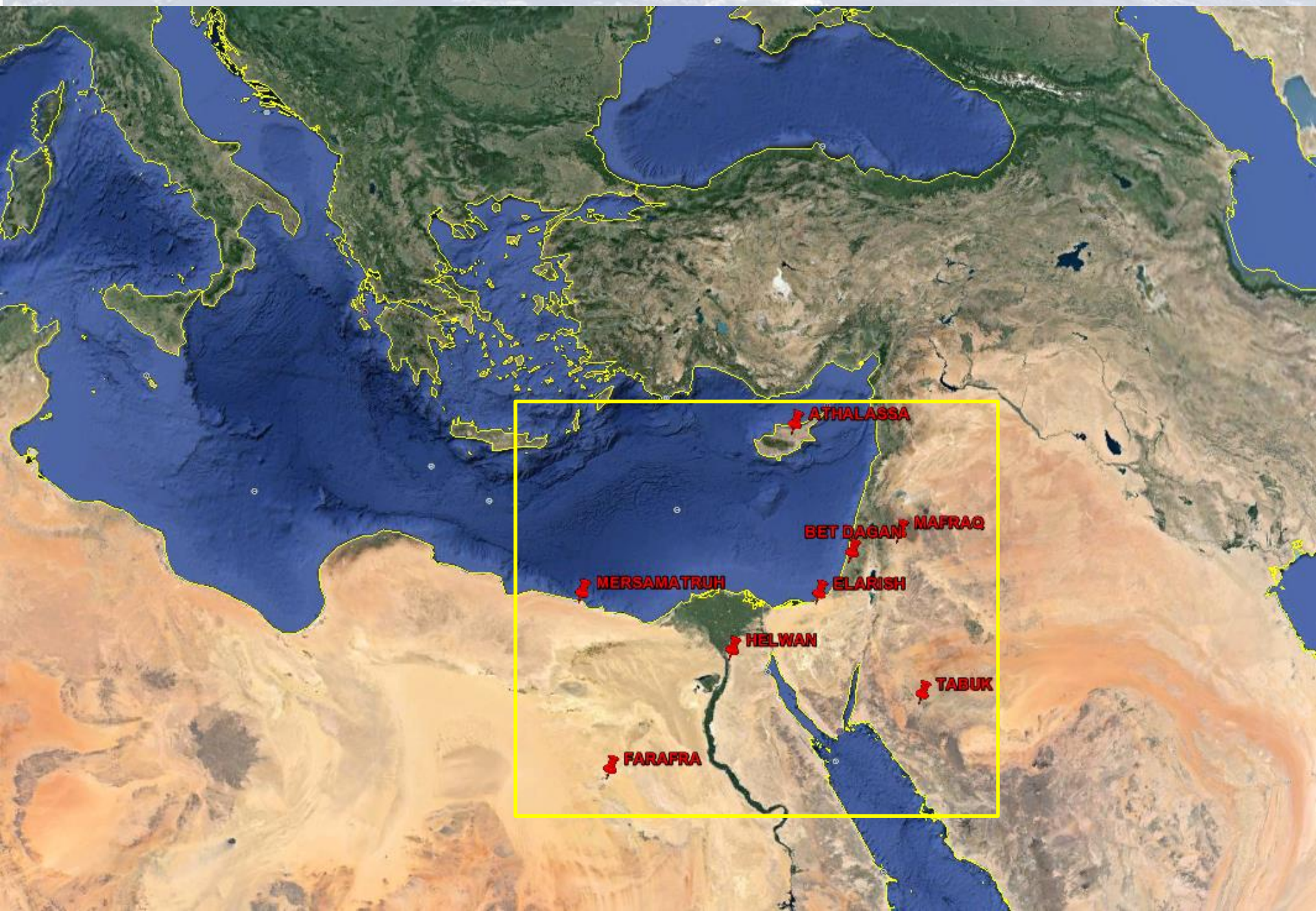
a. Example

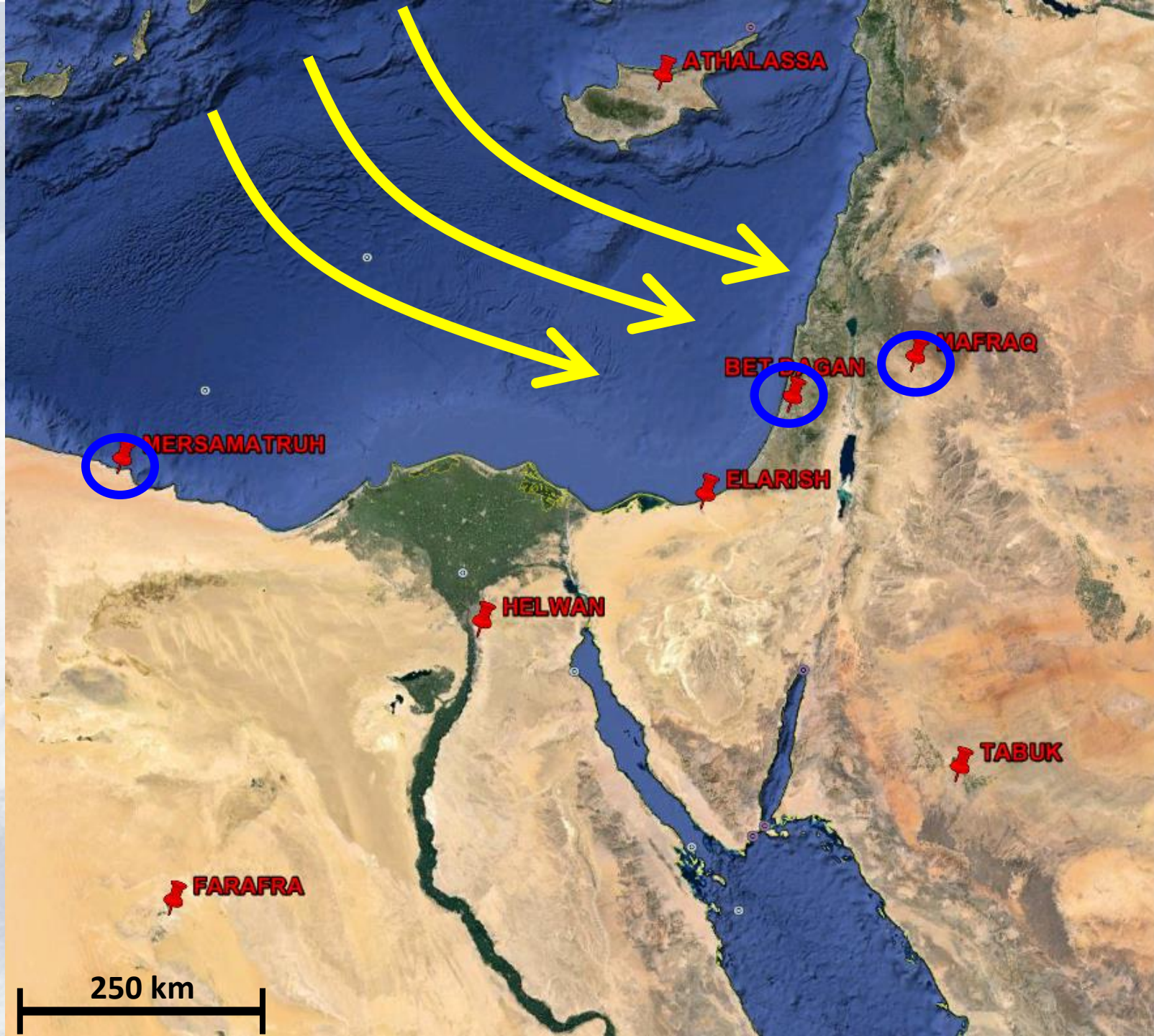
b. Method

c. Results

3. Conclusions

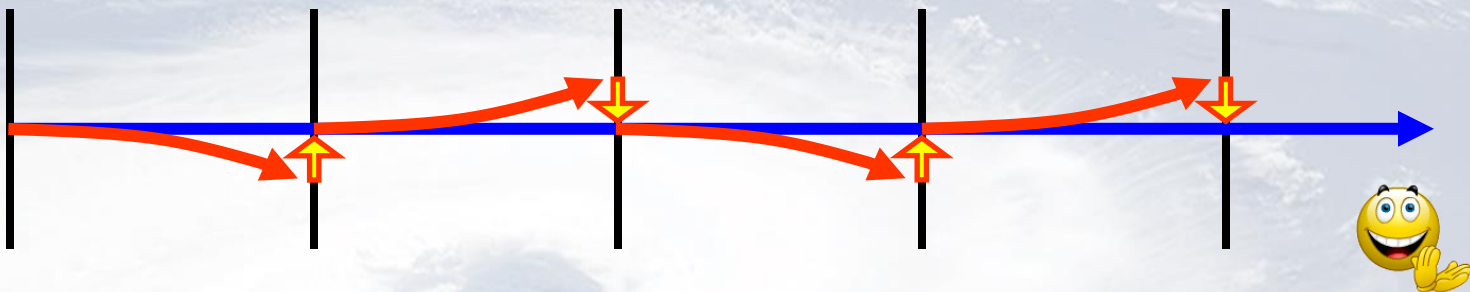
Soundings in COSMO-IL domain



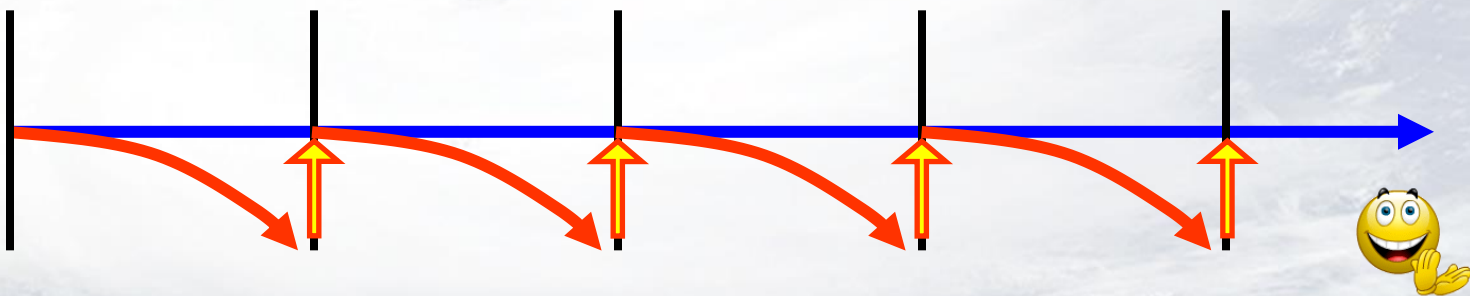


If not enough observations, not tuned model diverges...

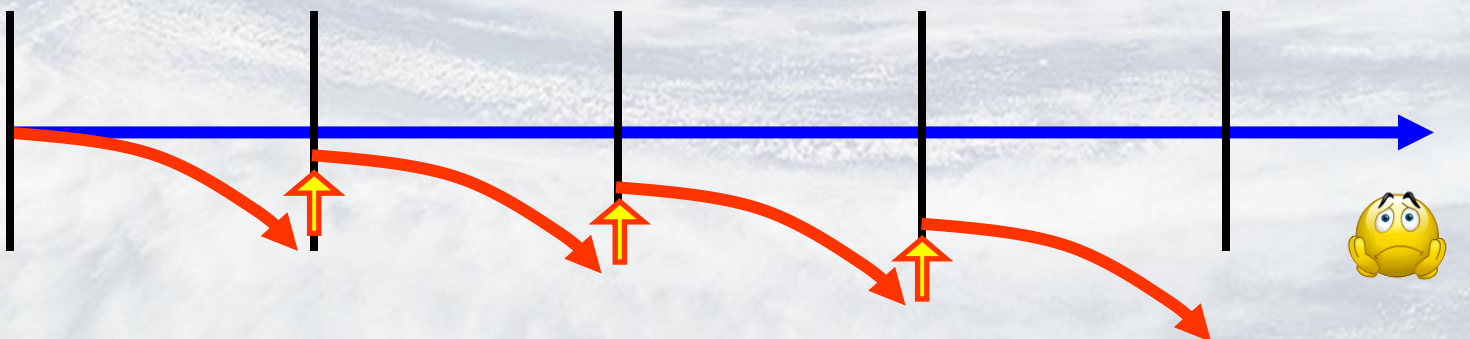
Tuned model,
Many observations



Not tuned model,
Many observations



Not tuned model,
Few observations



1. COSMO model at IMS

- a. Overview
- b. Main problem – loss of humidity
- c. Consequence – in assimilation cycle the model dries up if not enough in observations assimilated

2. Technical solution for observation sparse regions:

Each run CHOOSE cold start/warm start depending on fast verification

- a. Example
- b. Method
- c. Results

3. Conclusions

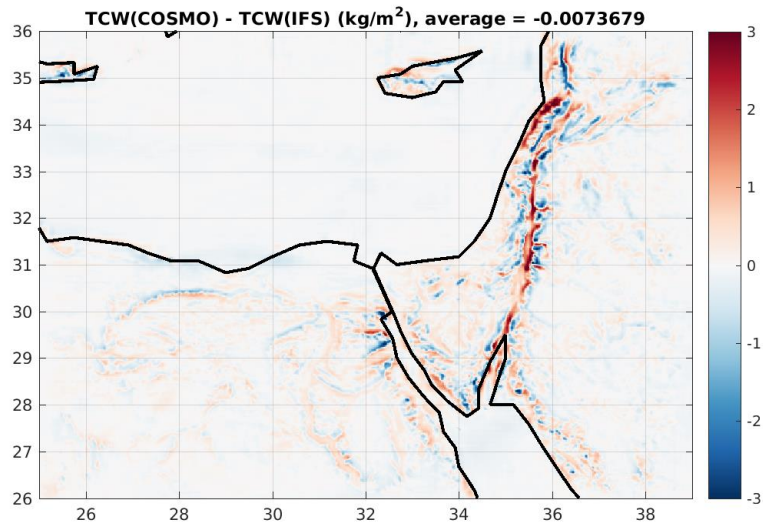
COLD START MAY HELP

**The same example (again):
31/12/2015 12UTC +...**



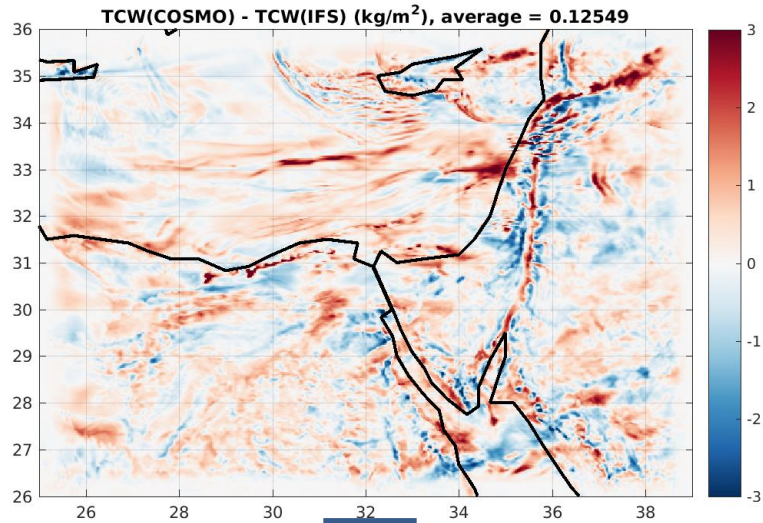
Total column water (COSMO – IFS)

2015/12/31 12UTC + 00h

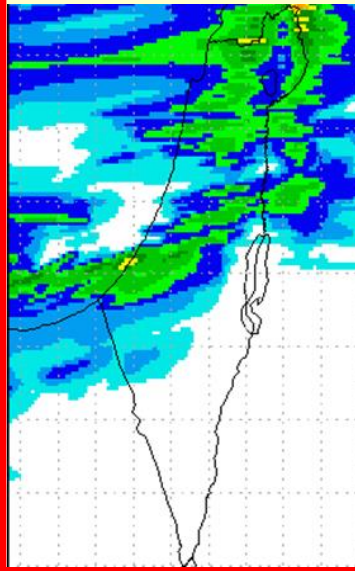


Total column water (COSMO – IFS)

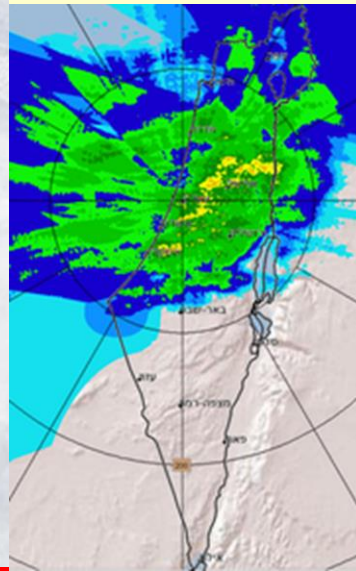
2015/12/31 12UTC + 03h (with nudging)



COSMO



RADAR



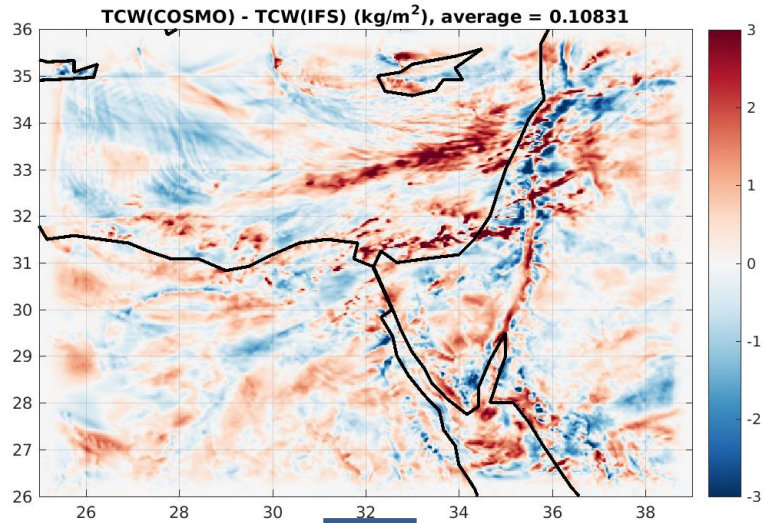
mm/6h



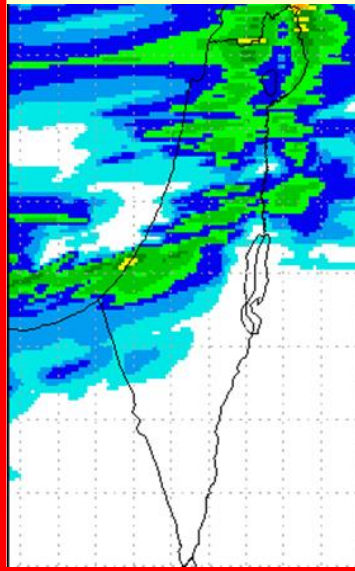
2015/12/31
12-18UTC
accum.
precip.

Total column water (COSMO – IFS)

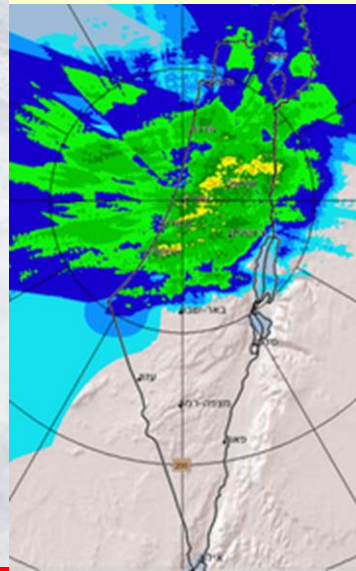
2015/12/31 12UTC + 06h (with nudging)



COSMO



RADAR



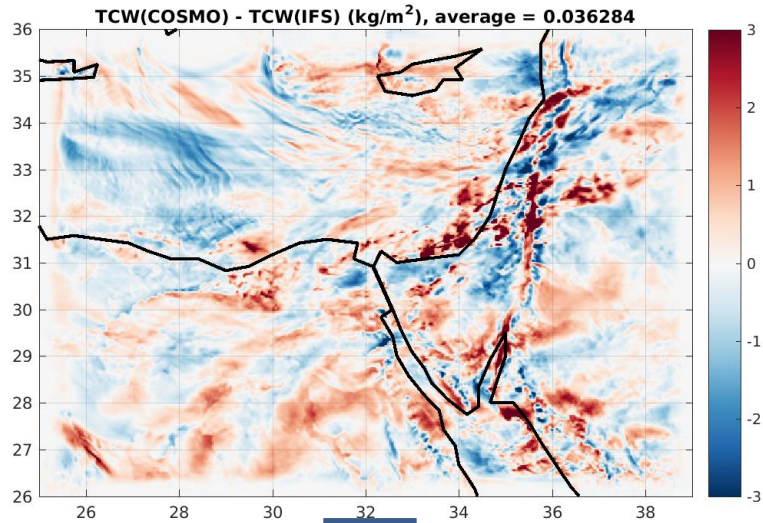
mm/6h



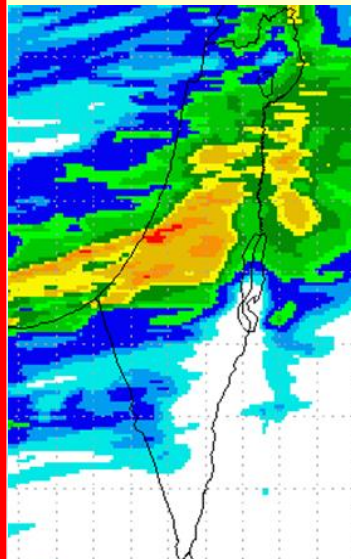
2015/12/31
12-18UTC
accum.
precip.

Total column water (COSMO – IFS)

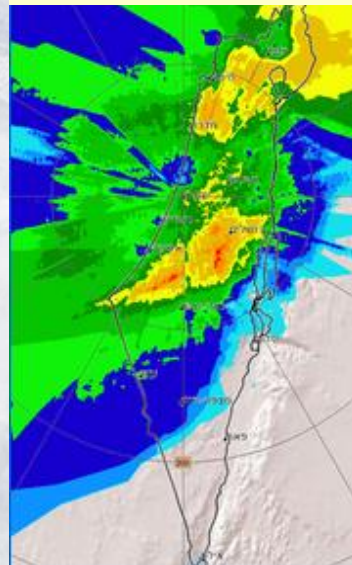
2015/12/31 12UTC + 09h (with nudging)



COSMO



RADAR



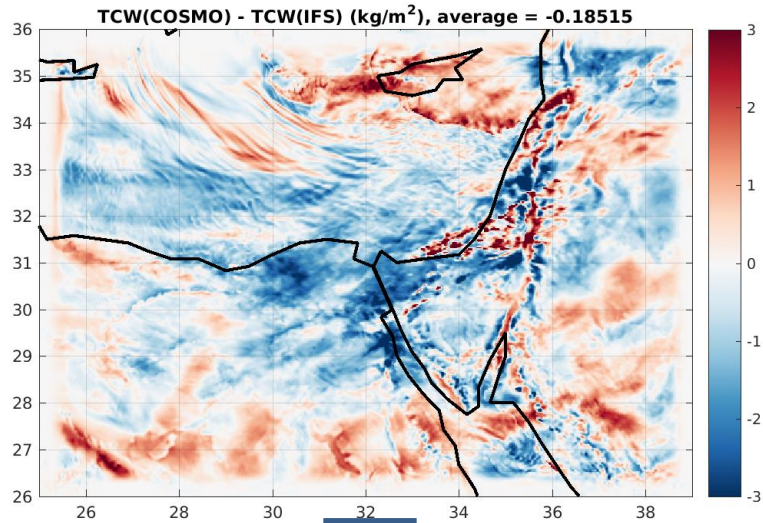
mm/6h



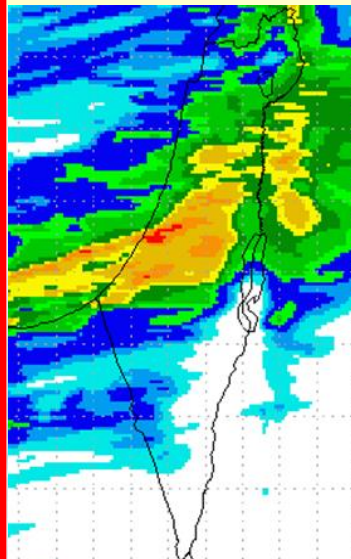
2015/12/31
18-24UTC
accum.
precip.

Total column water (COSMO – IFS)

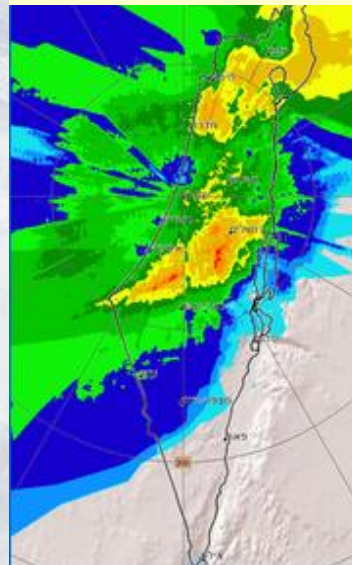
2015/12/31 12UTC + 12h (with nudging)



COSMO



RADAR



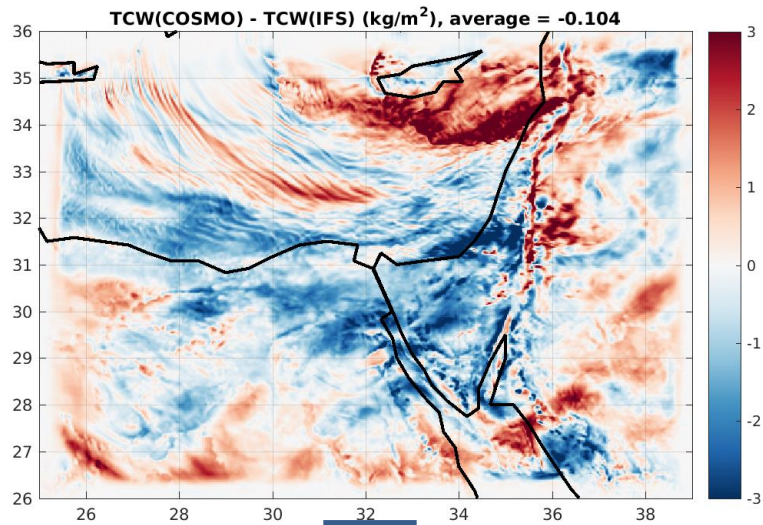
mm/6h



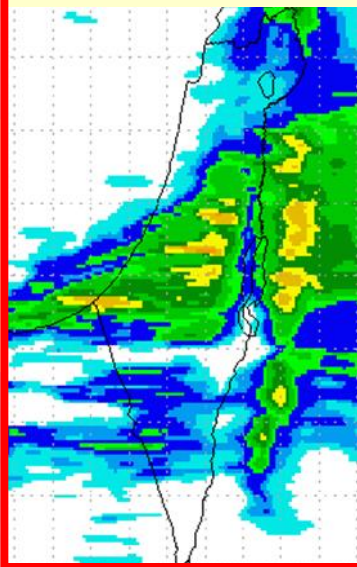
2015/12/31
18-24UTC
accum.
precip.

Total column water (COSMO – IFS)

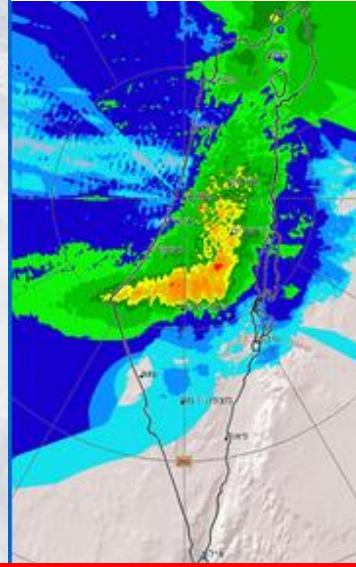
2015/12/31 12UTC + 15h (with nudging)



COSMO

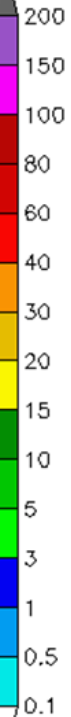


RADAR



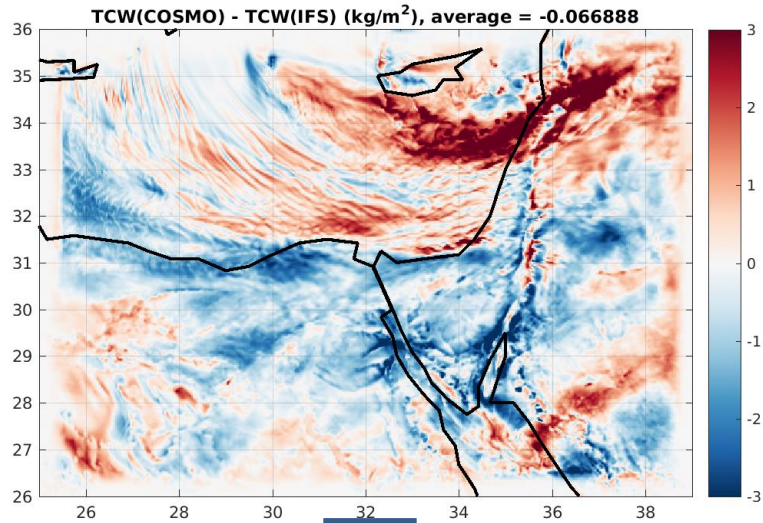
2016/1/1
00-06UTC
accum.
precip.

mm/6h

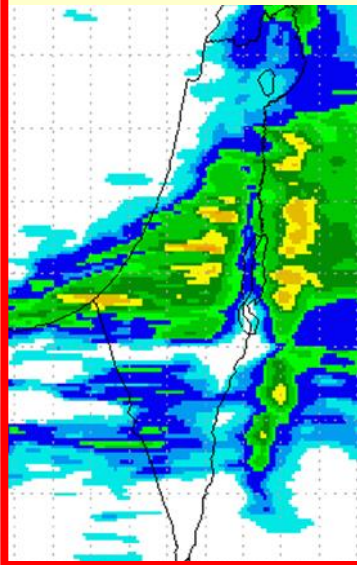


Total column water (COSMO – IFS)

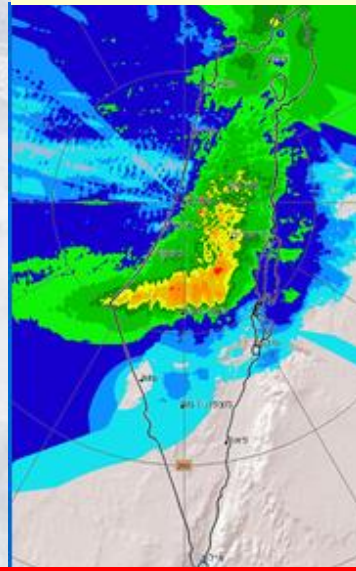
2015/12/31 12UTC + 18h (with nudging)



COSMO



RADAR



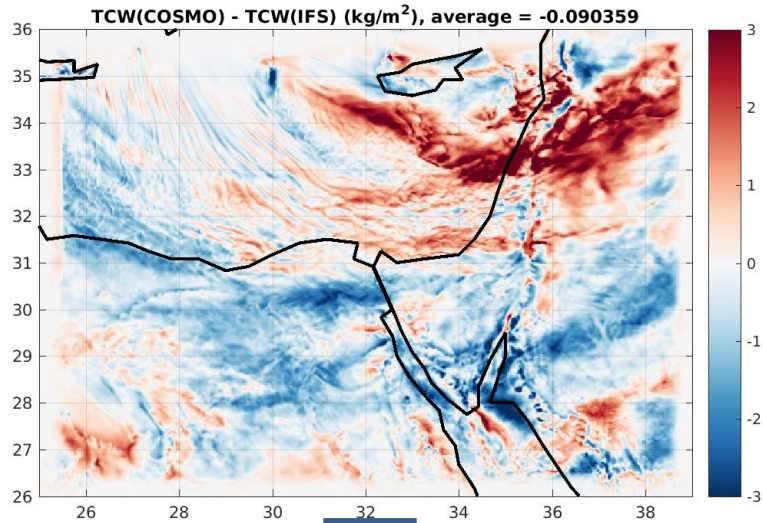
mm/6h



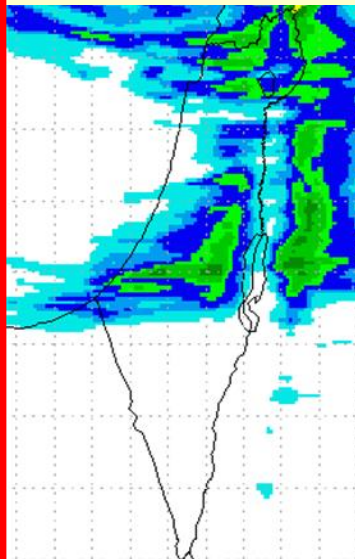
2016/1/1
00-06UTC
accum.
precip.

Total column water (COSMO – IFS)

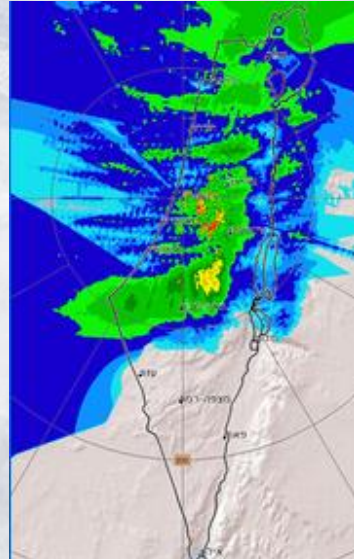
2015/12/31 12UTC + 21h (with nudging)



COSMO



RADAR



mm/6h

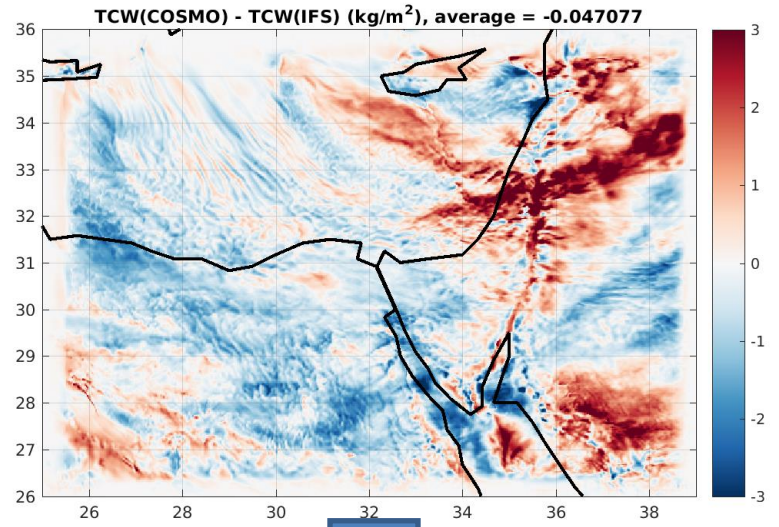


2016/1/1
06-12UTC
accum.
precip.

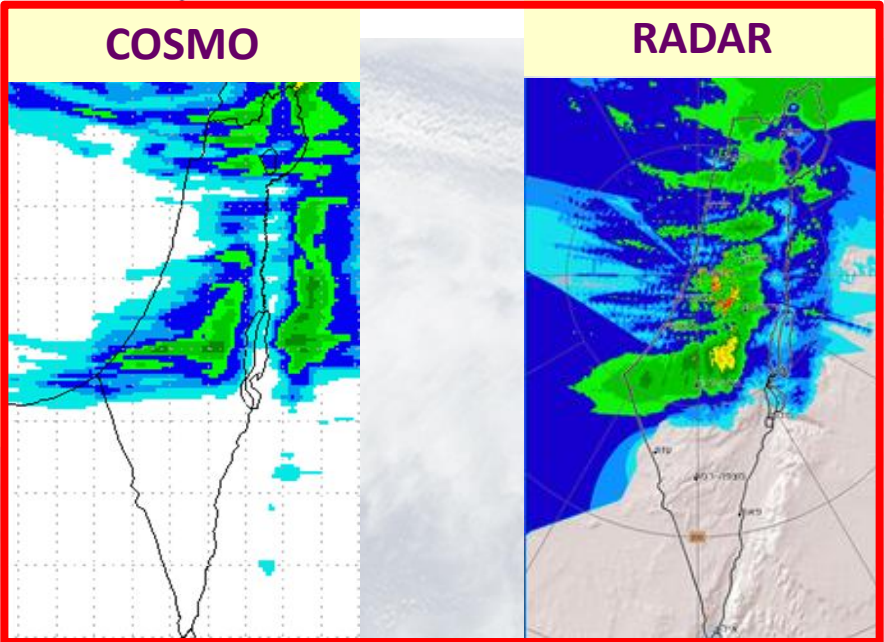
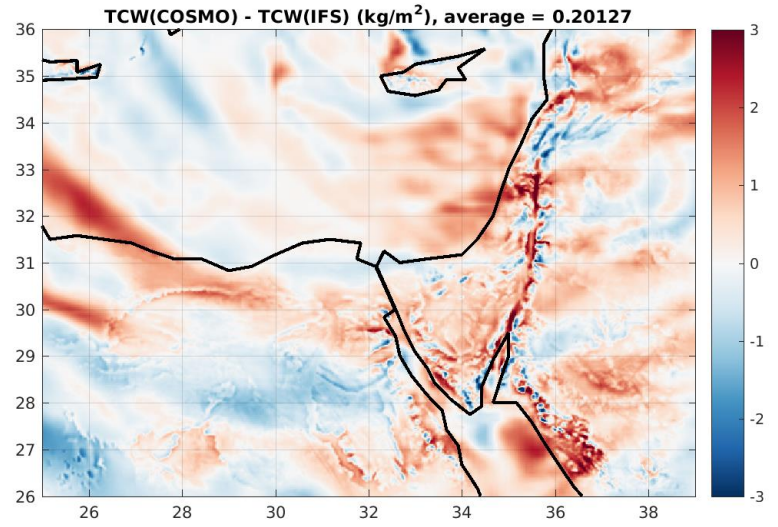
COLD START



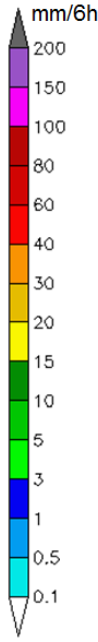
2015/12/31 12UTC + 24h (with nudging)



2016/1/1 12UTC + 00h



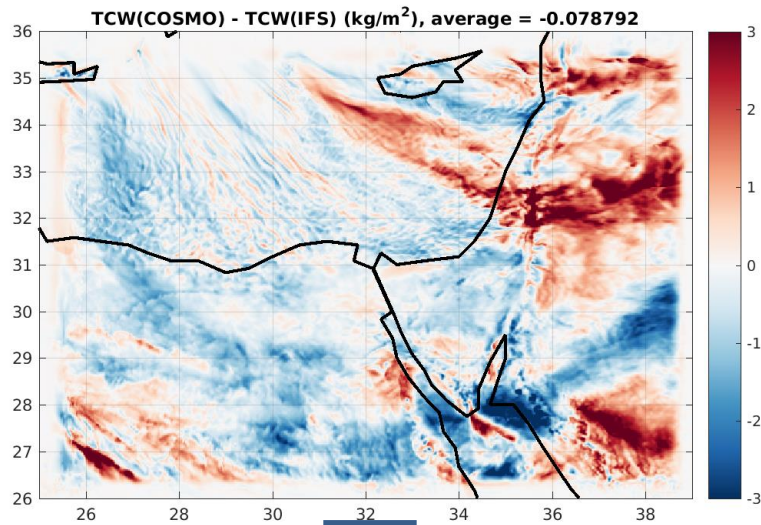
2016/1/1
06-12UTC
accum.
precip.



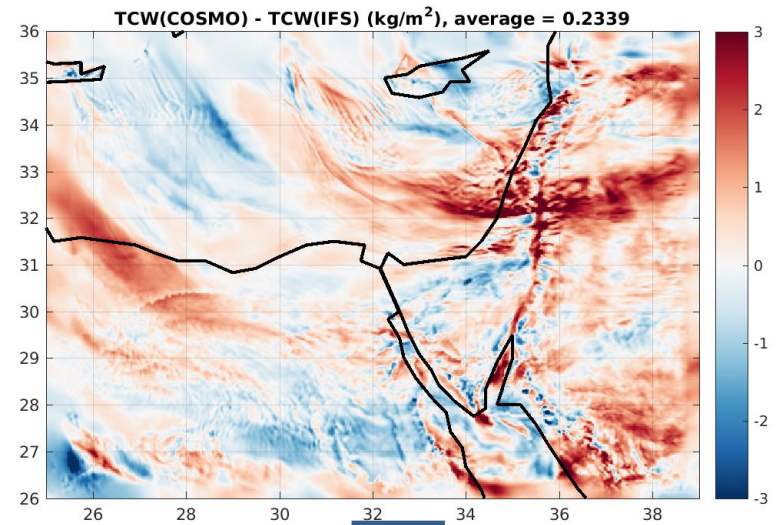
after COLD START



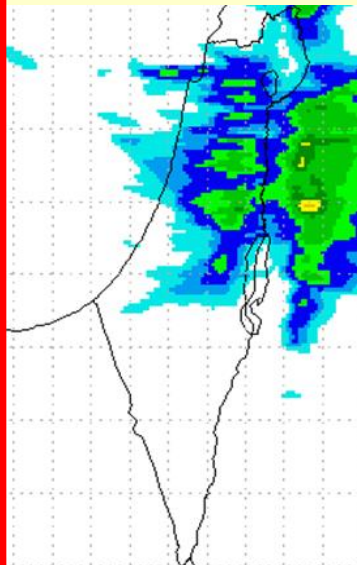
2015/12/31 12UTC + 27h (with nudging)



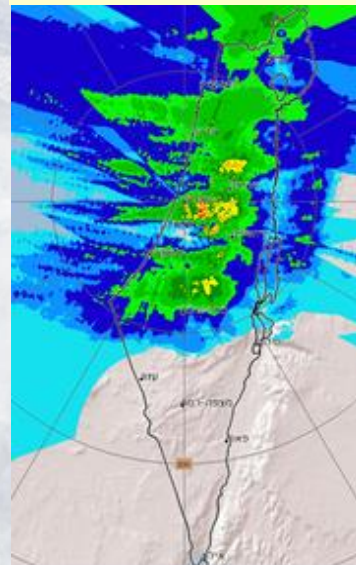
2016/1/1 12UTC + 03h (with nudging)



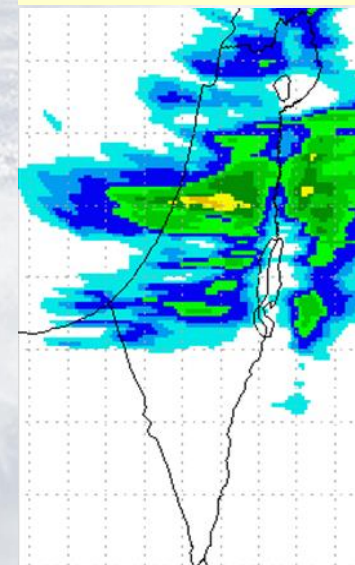
COSMO after WS



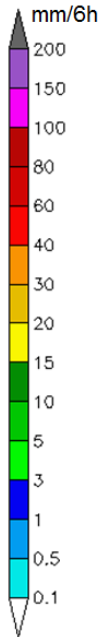
RADAR



COSMO after CS



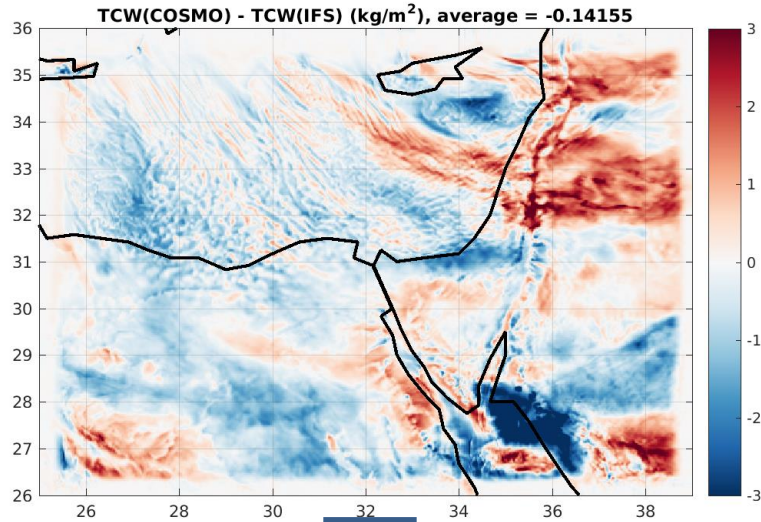
2016/1/1
12-18UTC
accum.
precip.



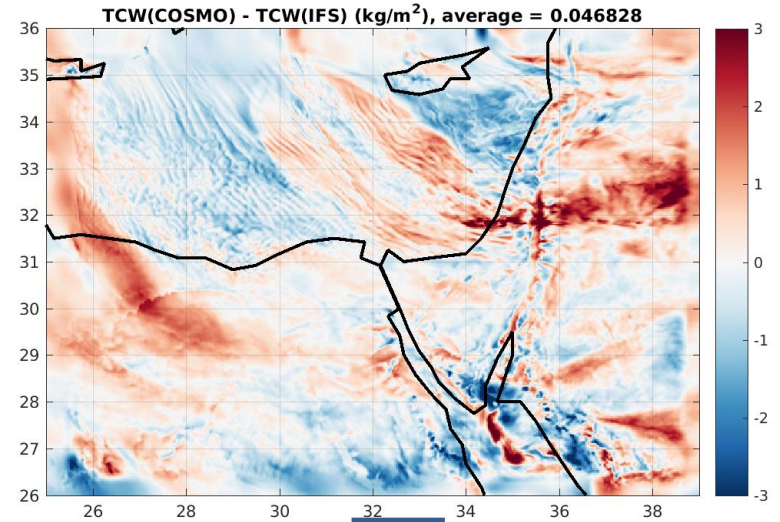
after COLD START



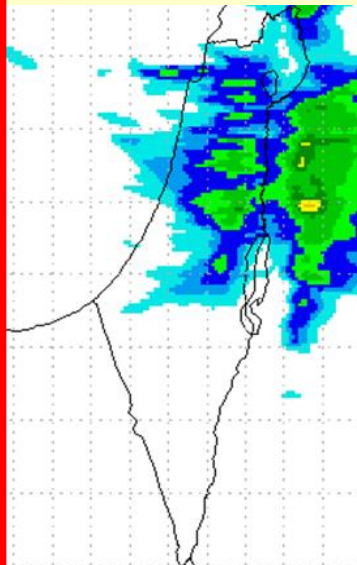
2015/12/31 12UTC + 30h (with nudging)



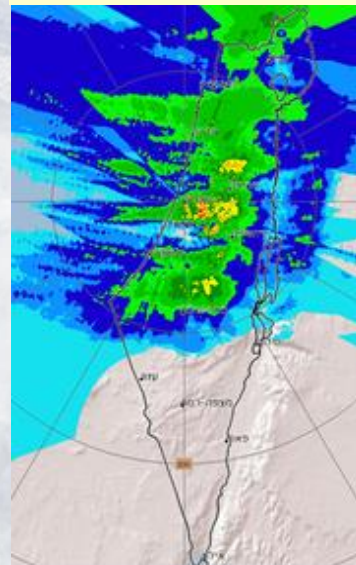
2016/1/1 12UTC + 06h (with nudging)



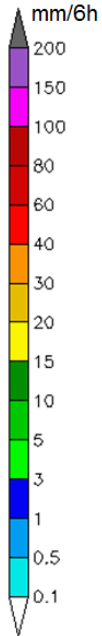
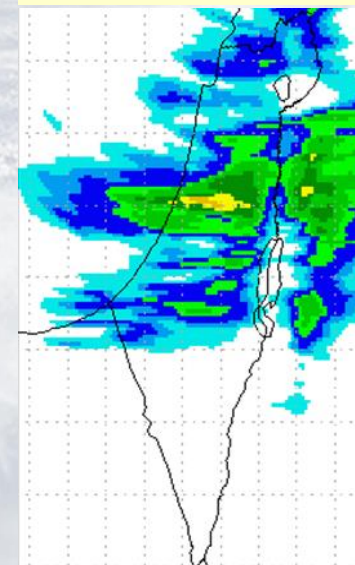
COSMO after WS



RADAR



COSMO after CS

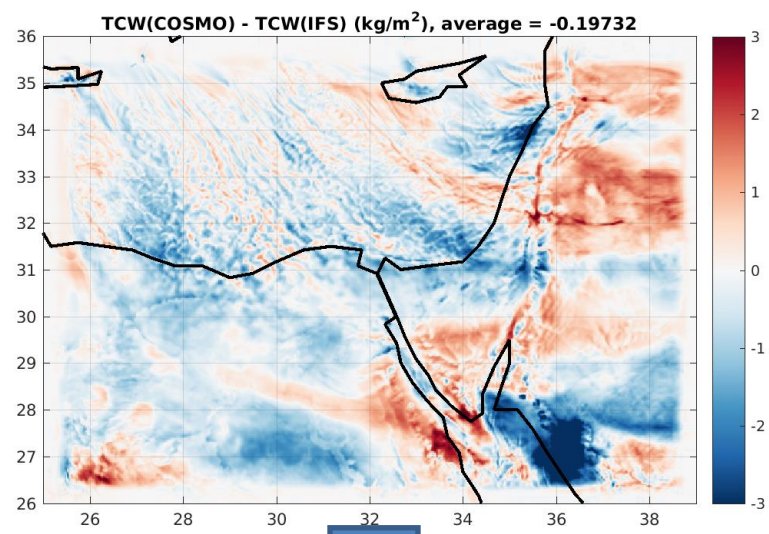


2016/1/1
12-18UTC
accum.
precip.

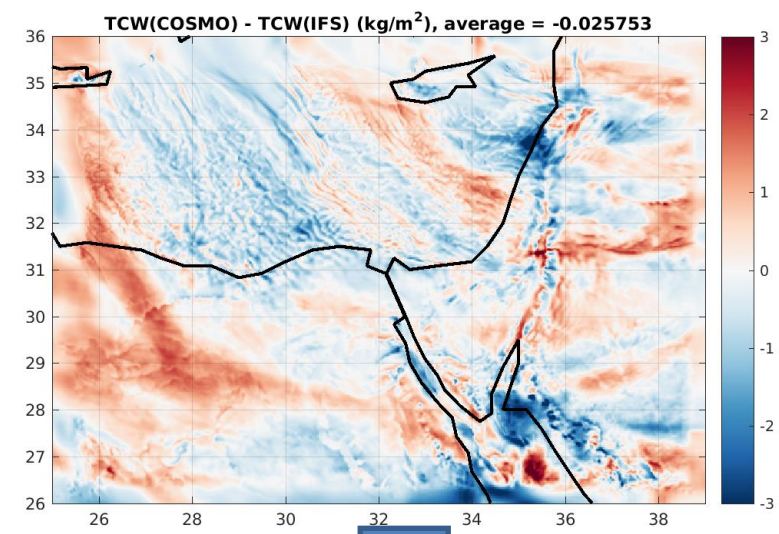
after COLD START



2015/12/31 12UTC + 33h



2016/1/1 12UTC + 09h

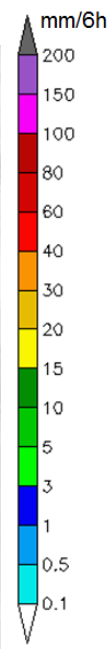
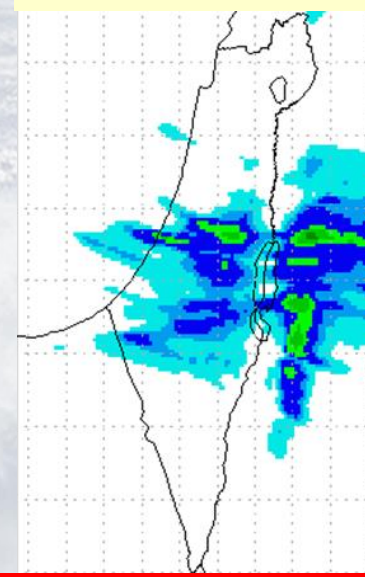
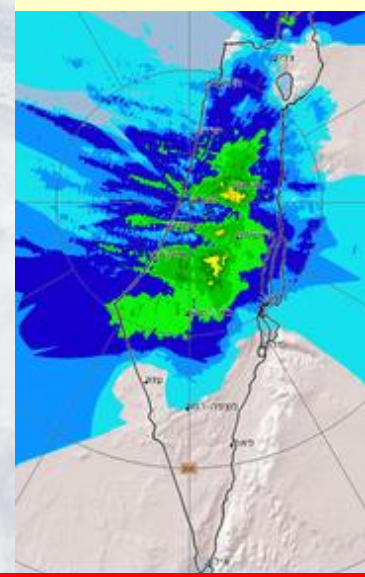
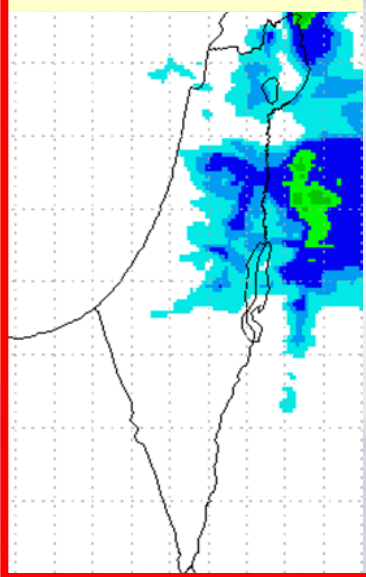


COSMO after WS

RADAR

COSMO after CS

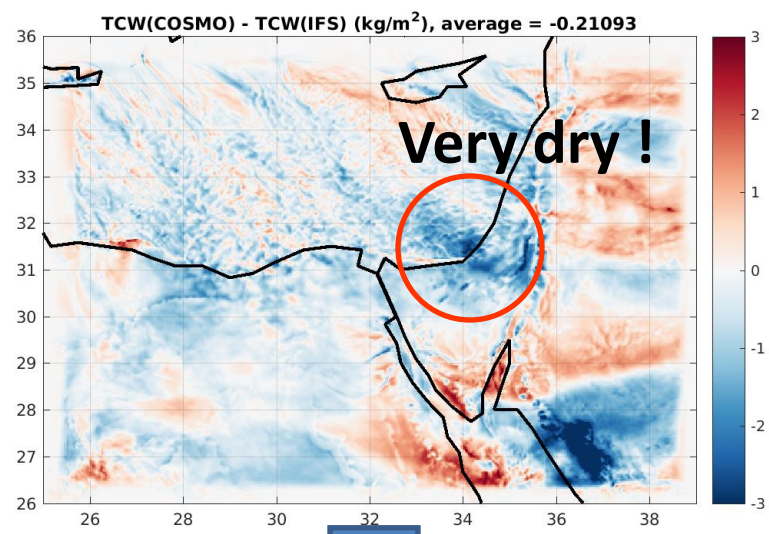
2016/1/1
18-24UTC
accum.
precip.



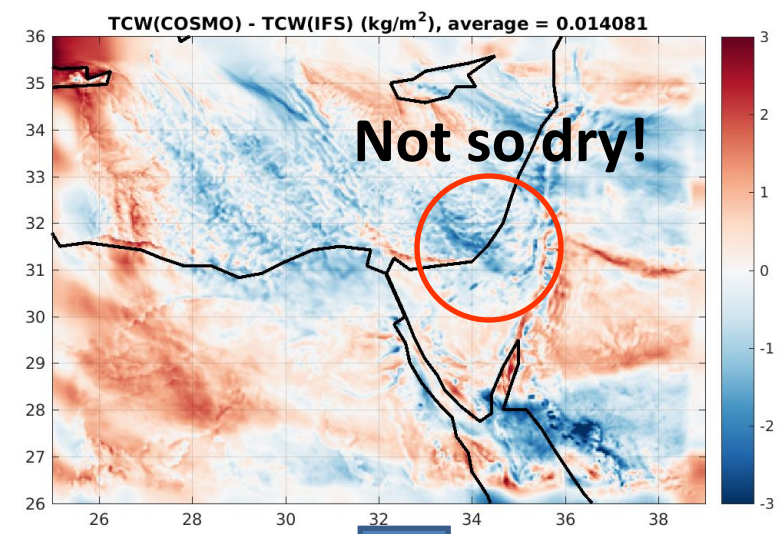
after COLD START



2015/12/31 12UTC + 36h



2016/1/1 12UTC + 12h

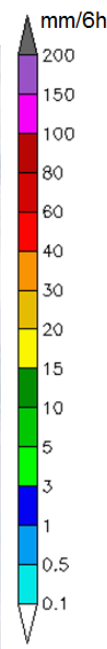
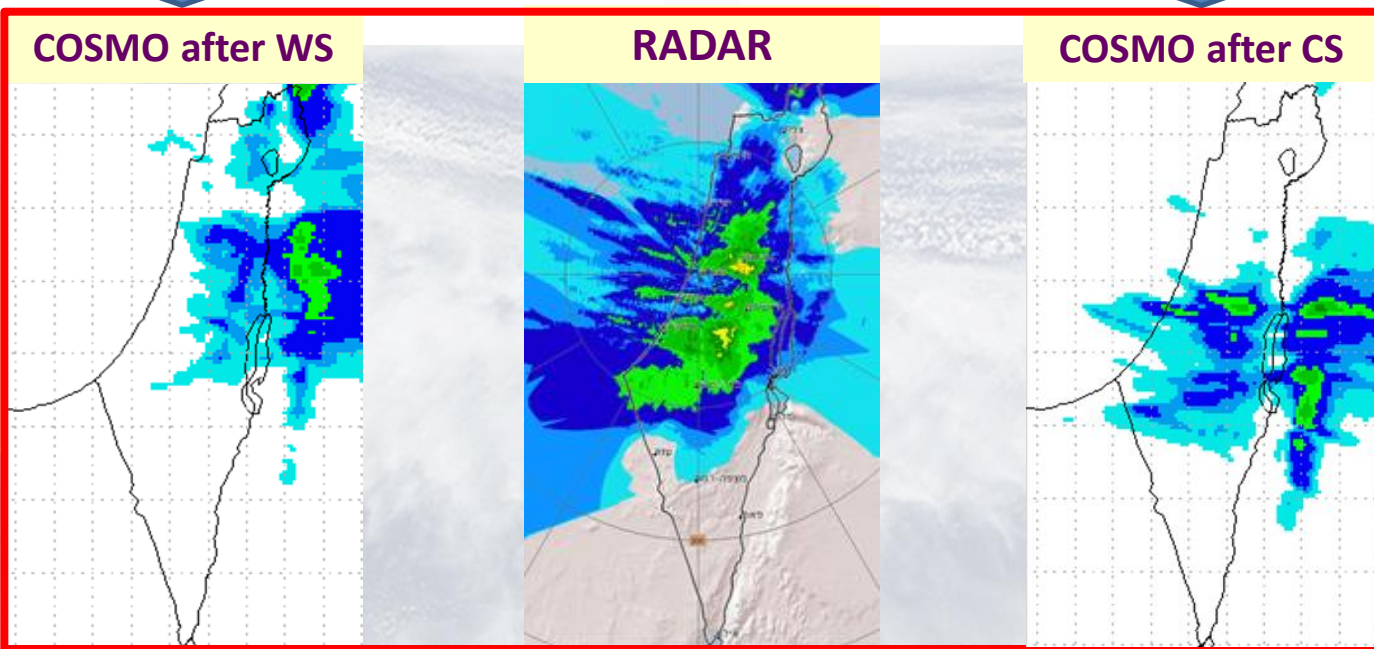


COSMO after WS

RADAR

COSMO after CS

2016/1/1 18-24UTC accum. precip.



1. COSMO model at IMS

- a. Overview
- b. Main problem – loss of humidity, example, possible solutions
- c. Consequence – in assimilation cycle the model dries up if not enough in observations assimilated

2. Technical solution for observation sparse regions:

Each run CHOOSE cold start/warm start depending on fast verification

- a. Example
- b. Method
- c. Results

3. Conclusions

Technical solution for observation-sparse regions

(thanks to Harel Muskatel)

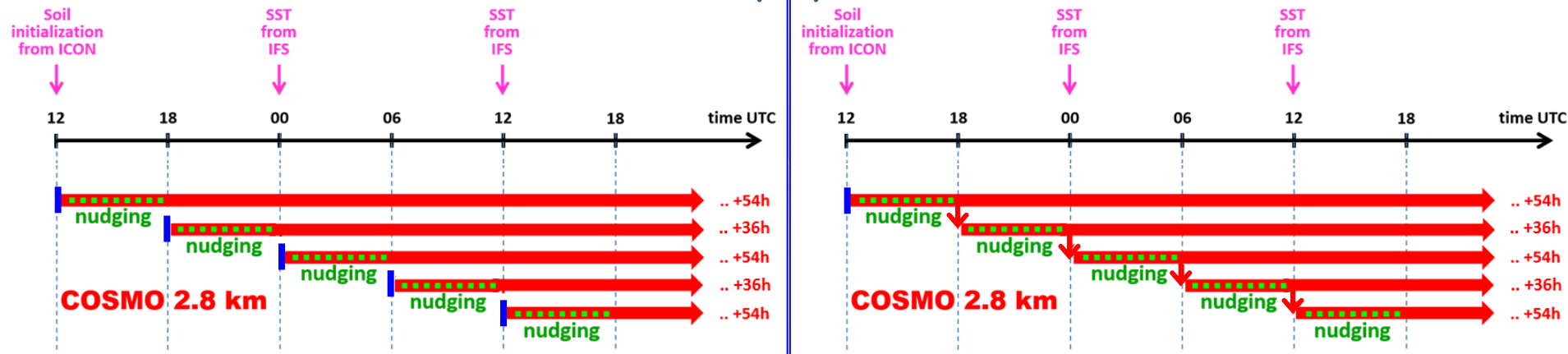
Automatic choice between Warm Start and Cold Start using “analysis score” comparing to observations (sounding profiles)

If the previous forecast was bad, it will be revealed and COSMO will perform Cold Start

“Cold-starts”



“Warm-starts” (ass. cycle)



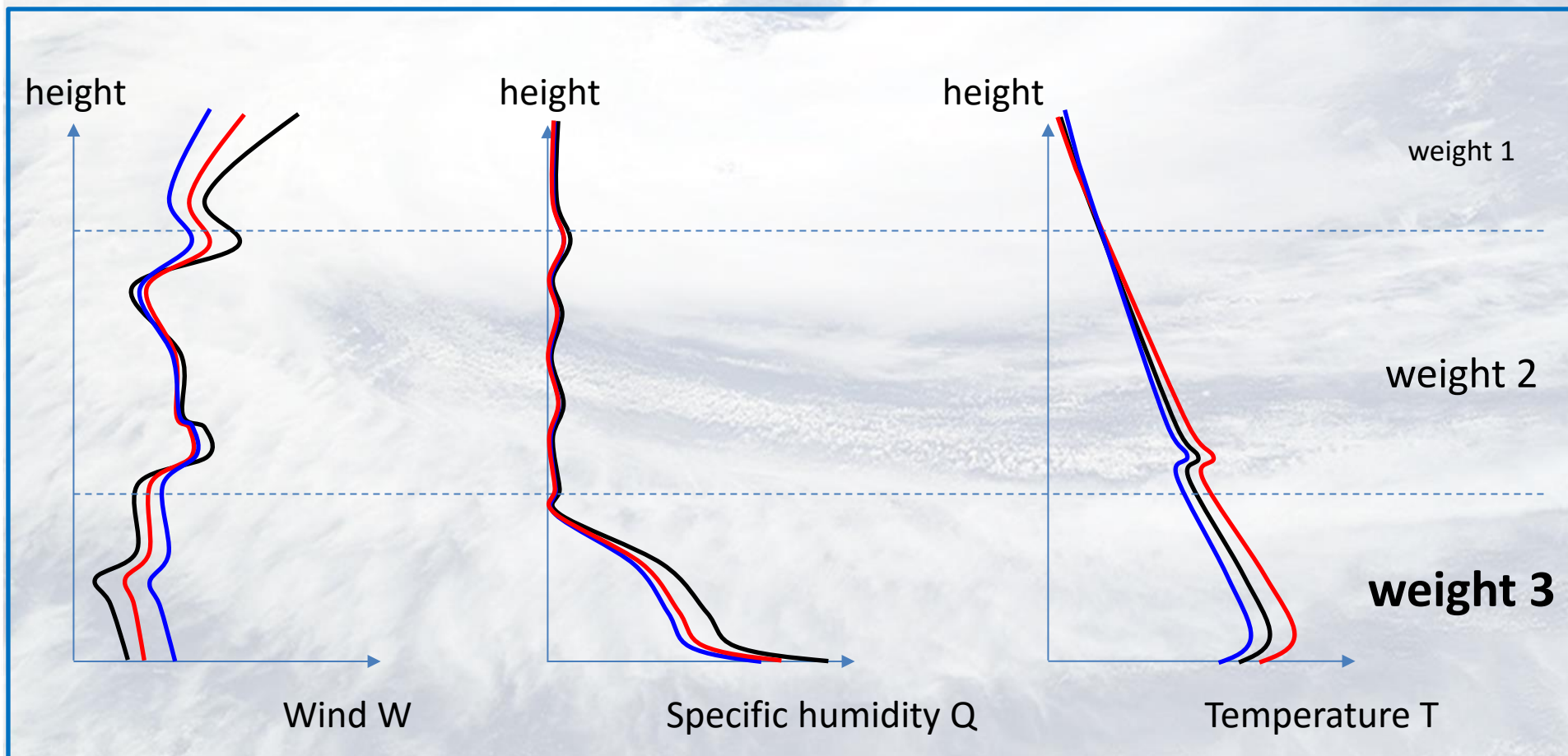
Available soundings



“Fast verification” of **cold start** / **warm start** analysis against available soundings

How it looks like ?

- Cold start analysis profile
- Warm start analysis profile
- Sounding



Cold Start / warm start analysis score

$$\text{Score} = \frac{1}{N} \sum_{1 \dots N} \left\{ \underbrace{1 - \frac{RMSE_T(WS)}{RMSE_T(CS)}}_{>0} + \underbrace{1 - \frac{RMSE_Q(WS)}{RMSE_Q(CS)}}_{>0} + \underbrace{1 - \frac{RMSVE_W(WS)}{RMSVE_W(CS)}}_{>0} \right\}$$

Number of available soundings

if WS is better in T
"Score_T"

if WS is better in Q
"Score_Q"

if WS is better in \vec{W}
"Score_W"

$RMSE_T$ - (Weighted) root mean square error of the model T profile against the sounding

$Score > 0$ \Rightarrow Warm start is chosen
 $Score < 0$ \Rightarrow Cold start is chosen

1. COSMO model at IMS

- a. Overview
- b. Main problem – loss of humidity, example, possible solutions
- c. Consequence – in assimilation cycle the model dries up if not enough in observations assimilated

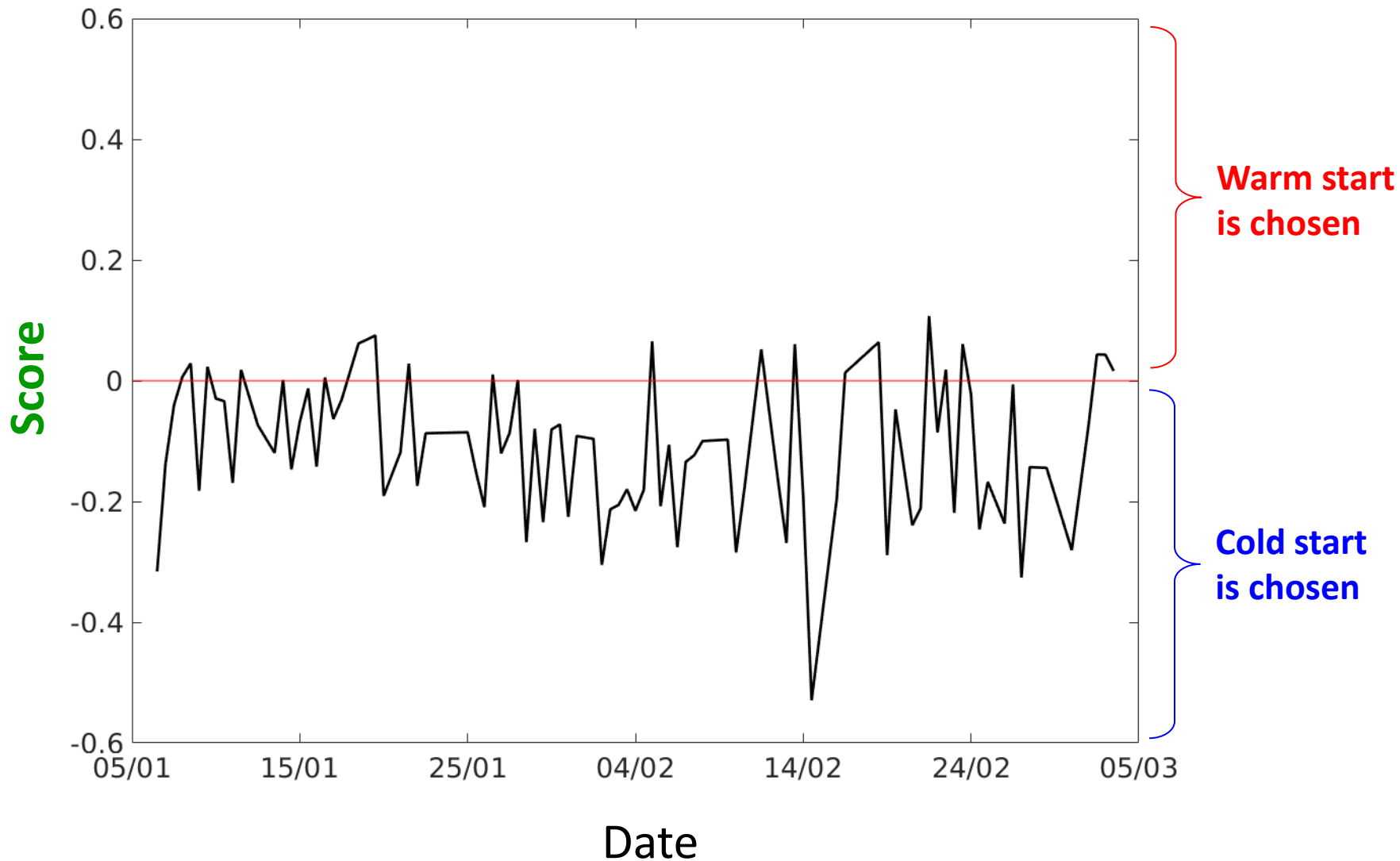
2. Technical solution for observation sparse regions:

Each run CHOOSE cold start/warm start depending on fast verification

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Warm start / Cold start score for COSMO-IL (1/2016-3/2016)



Warm start / Cold start **score** for COSMO-IL (1/2016-3/2016)

Percent of **warm starts**

	Score	Score_T	Score_Q	Score_W
Total	24%	23%	39%	12%
Night	12%	12%	22%	2%
Day	35%	33%	53%	20%

The best: Specific humidity at days 

The worst: Wind and nights 

1. COSMO model at IMS

- a. Overview
- b. Main problem – loss of humidity, example, possible solutions
- c. Consequence – in assimilation cycle the model dries up if not enough in observations assimilated

2. Technical solution for observation sparse regions:

Each run CHOOSE cold start/warm start depending on fast verification

- a. Example
- b. Method
- c. Results

3. Conclusions

Conclusions

1. COSMO model at IMS

- 4 times a day assimilation cycle + latent heat nudging
- Main problem – loss of humidity, especially at the decay stage of a cyclone
- Consequence – in assimilation cycle the model dries up if not enough in observations assimilated

2. Technical solution for observation sparse regions:

Each run CHOOSE cold start / warm start depending on fast verification

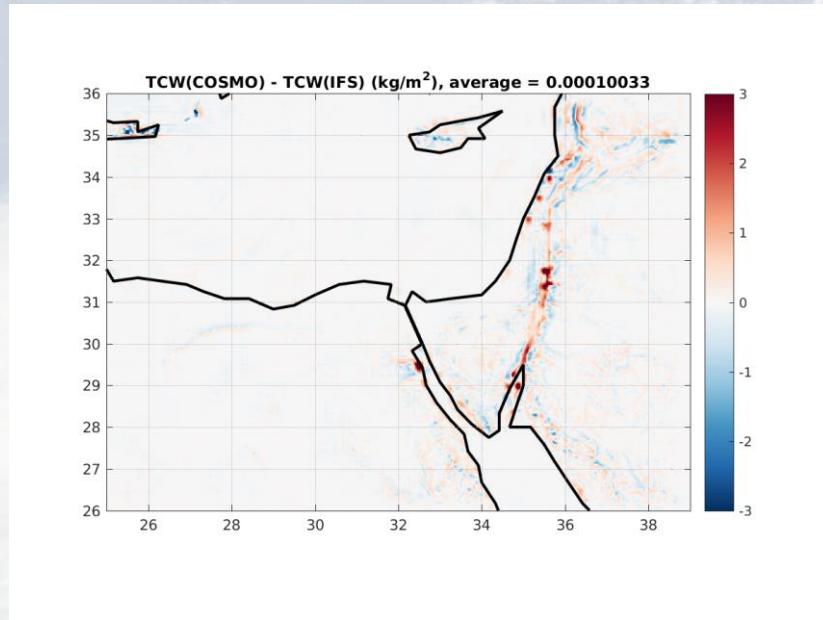


Thank you !

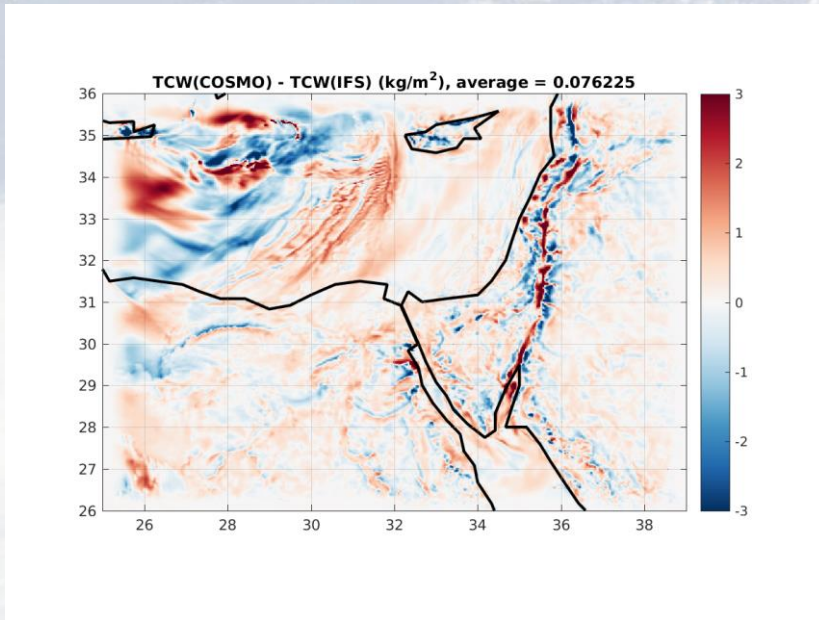
Additional slides...

Example for 21/2/2016 00UTC+...
where warm start is better

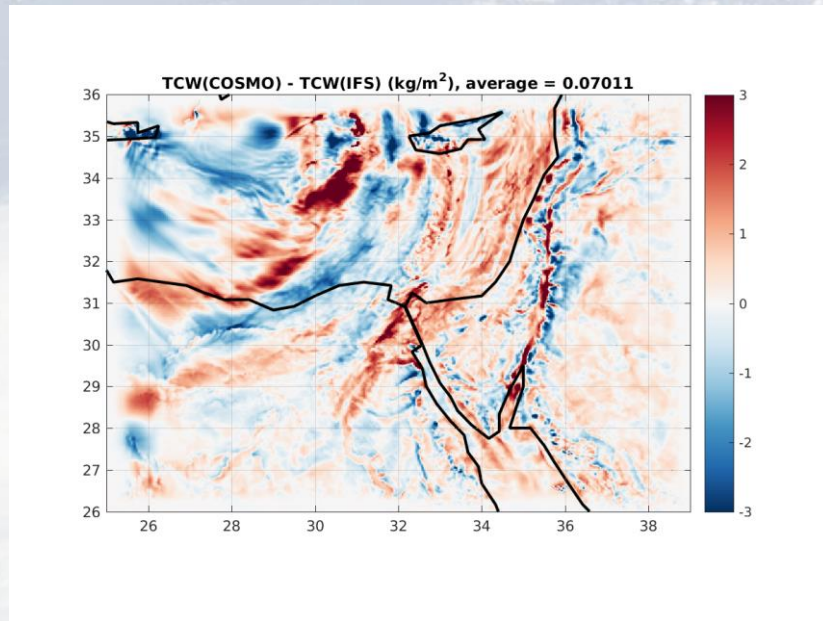
+0h



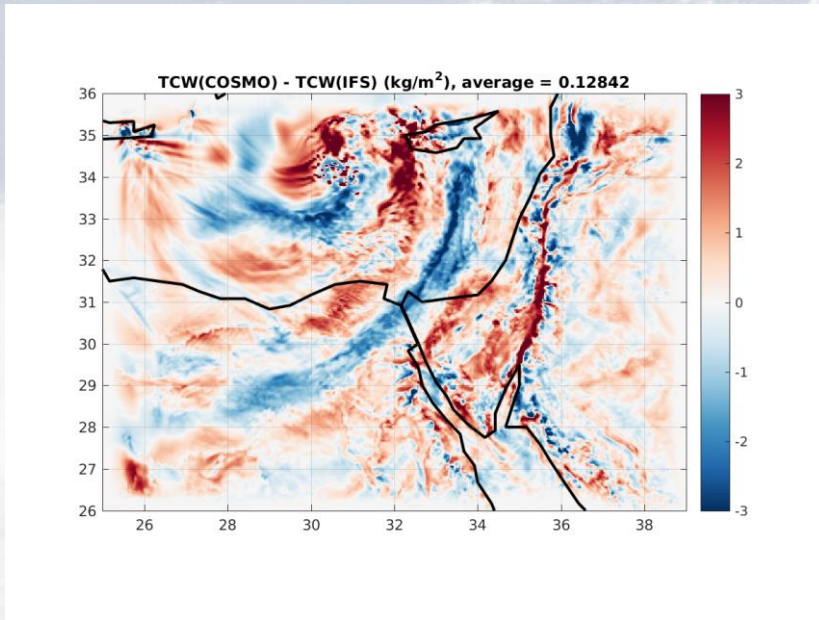
+3h



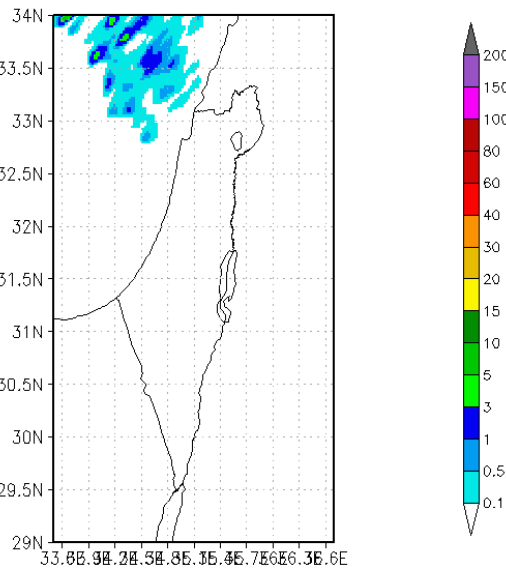
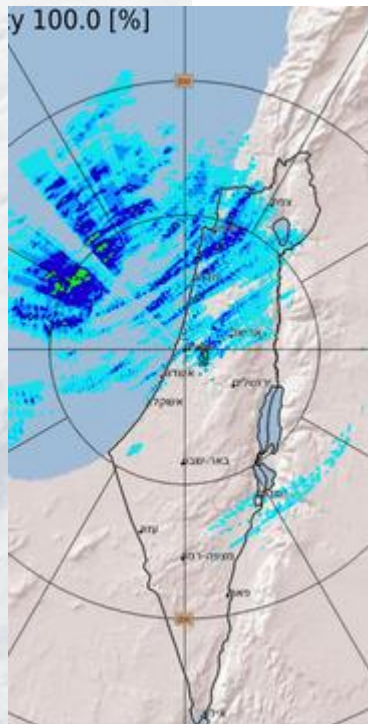
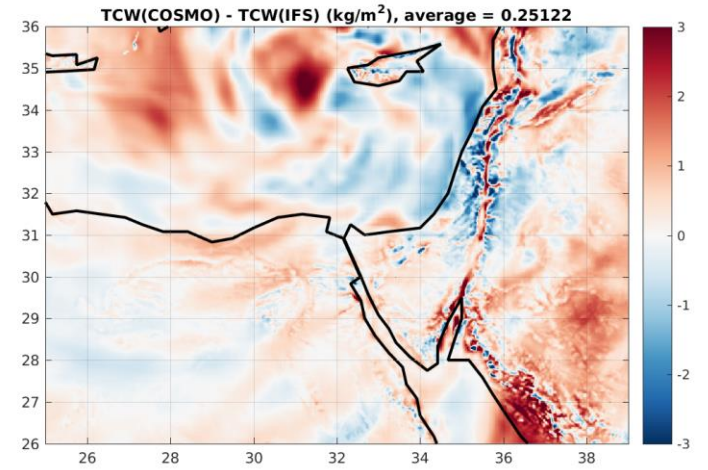
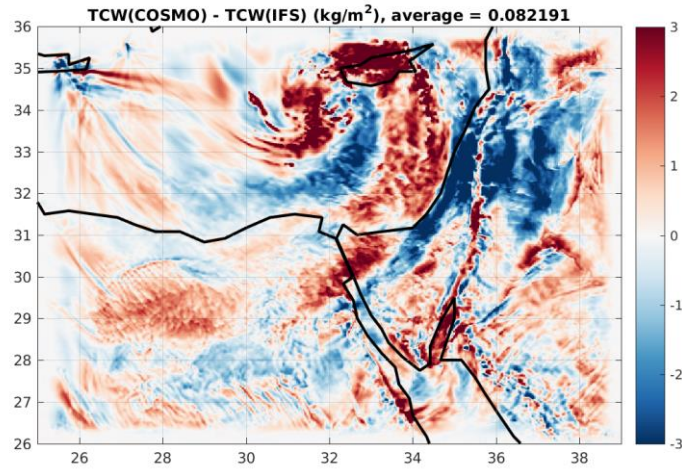
+6h



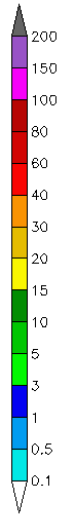
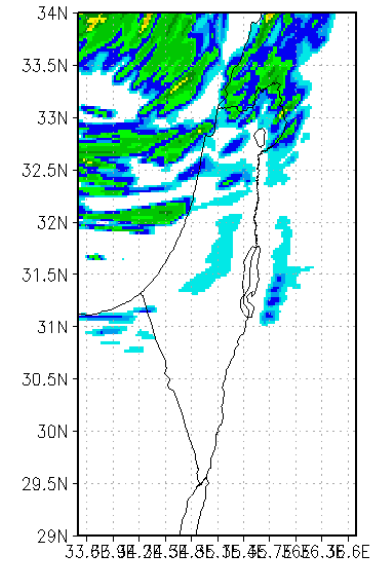
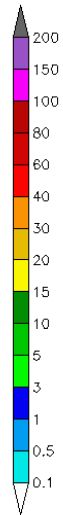
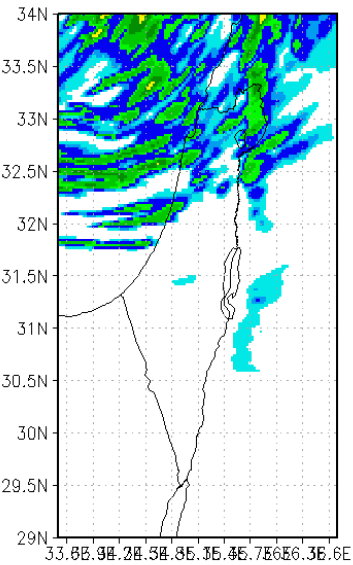
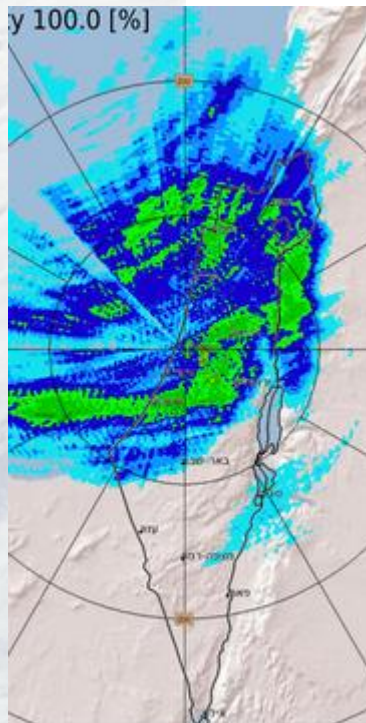
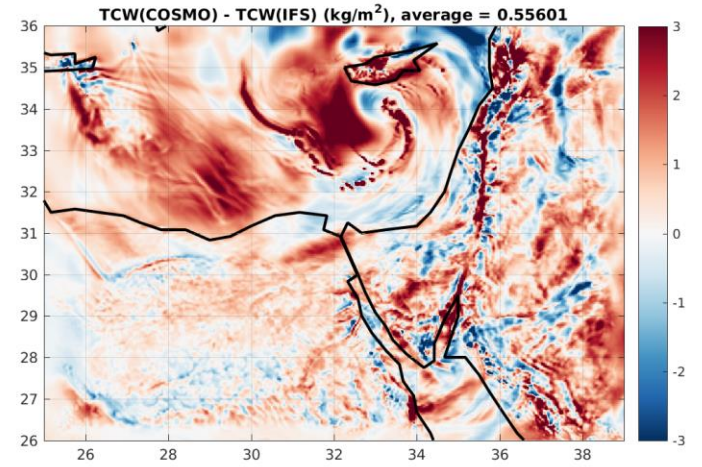
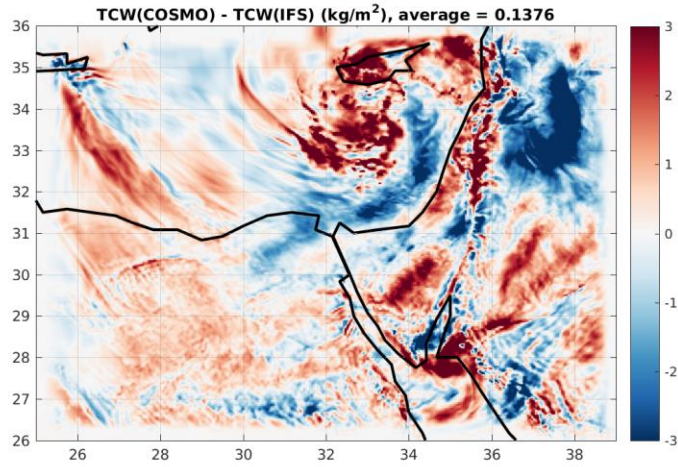
+9h



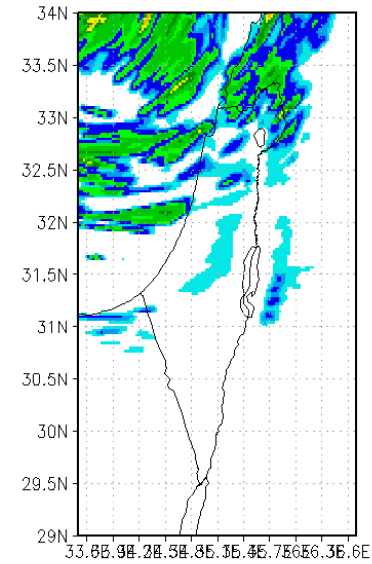
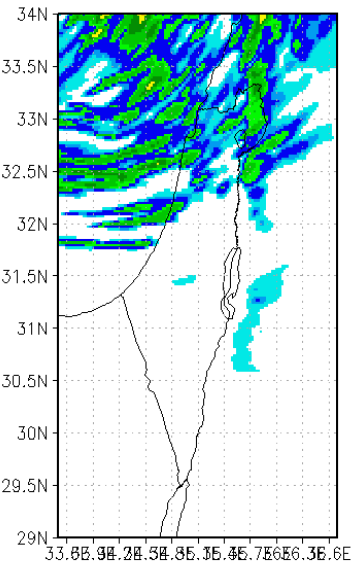
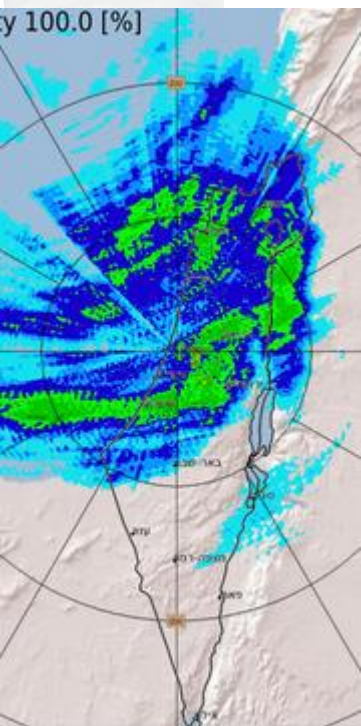
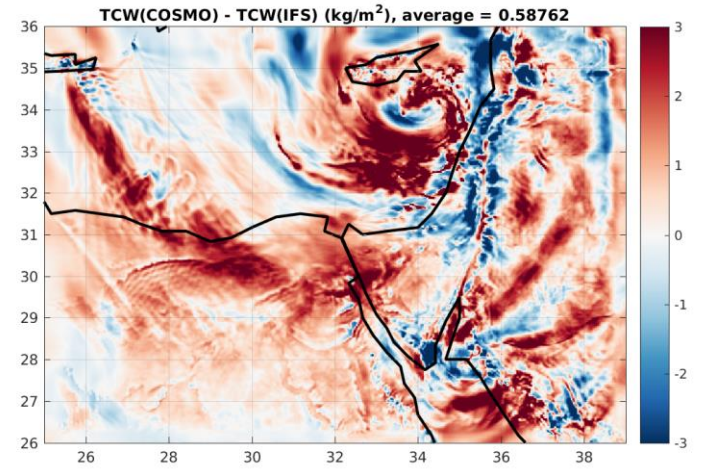
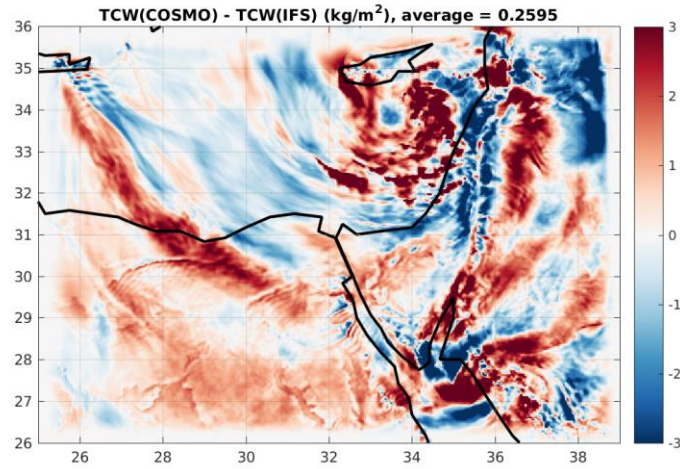
+12h



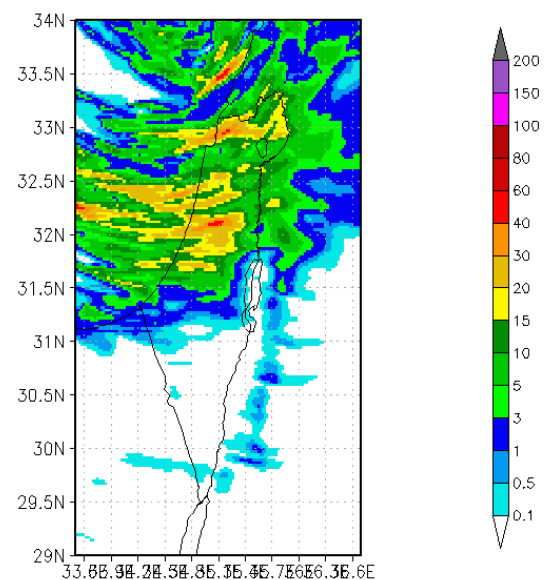
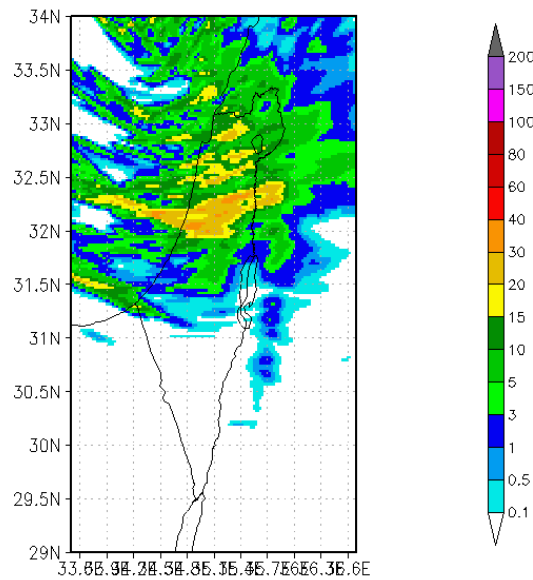
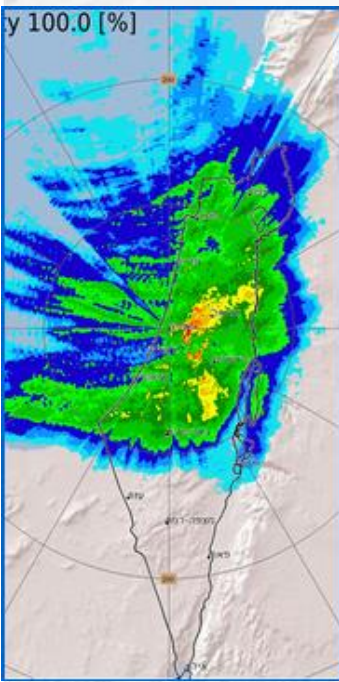
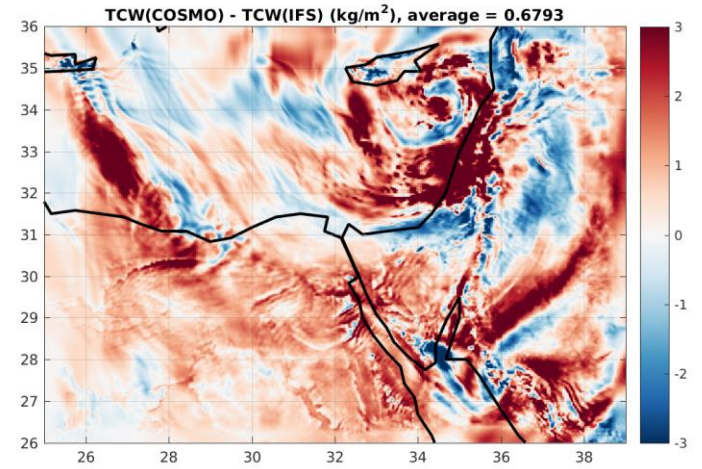
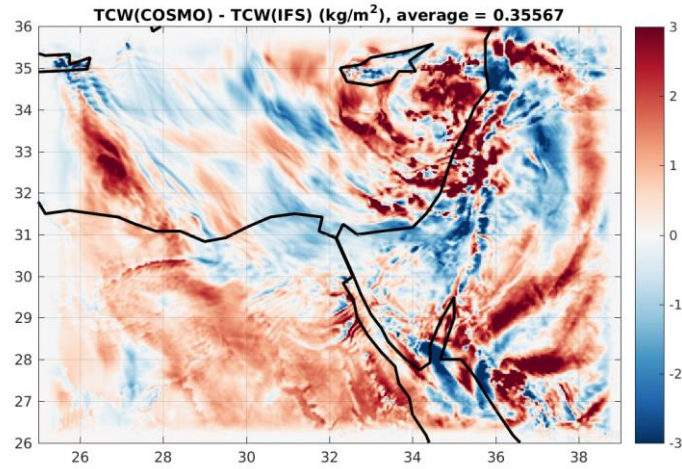
+15h



+18h



+21h



+24h

