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Recent developments  
of the NWP forecast system  
at DWD  
based on  
**ICON / ICON-EU**  
and  
**COSMO-DE**

16th Workshop on Meteorological Operational Systems  
ECMWF  
1-3 March 2017

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## Computing Environment

### NWP System

ICON / ICON-EU  
COSMO-DE / COSMO-DE-EPS  
“Modell-Uhr”

### NWP developments at DWD

COSMO-CD2 + EPS  
EnVar M80  
ICON-ART

### System Issues

## Computing Environment

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### System Issues

## Compute-Server Cray XC40

- Performance: upgrade by a factor of 1.59 (phase 2 of contract)  
Haswell: 415 Tera-Flop peak  
Broadwell: 660 Tera-Flop peak
- Compute nodes: mixed system – Haswell (432 cores) / Broadwell (544 cores)  
[upward binary compatible](#) → Haswell binaries
- Login nodes additional nodes for pre- and postprocessing

## Computing hall WEST


**HPC production**



<b>Megware</b> 34 node 768 cores 6656 GiB main memory	<b>Cray XC40</b> 432+544 nodes 29952 cores 122 TiB main memory	<b>Global filesystems</b> <b>Cray Sonexion/                  Panasas</b> 2.8 PiB+120 TiB
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## Computing hall EAST

**HPC research**



<b>Megware</b> 66 nodes 1528 cores 10752 GiB main memory	<b>Cray XC40</b> 432+544 nodes 29952 cores 122 TiB main memory	<b>Global filesystems</b> <b>Cray Sonexion/                  Panasas</b> 5.5 PiB+170 TiB
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### Archive system Oracle/IBM-HPSS



**Oracle STK SL8500**  
 2 tape silos  
 20000 storing positions  
 60 tape drives  
 34 PiB (March 2016)



**IBM X3650 M5**  
 9 nodes  
 184 cores  
 480 GiB main memory  
 2 PiB disk storage

### Data server production



**5 \* SUN x2-4/x2-8**  
 320 cores  
 4096 GiB main memory  
 1656 TiB SAN disk storage

### Data server research



**5 \* SUN x2-4/x2-8**  
 320 cores  
 4096 GiB main memory  
 1382 TiB SAN disk storage

10 GBit

# The **deterministic** NWP system at DWD in March 2017

## Global model **ICON**

Grid spacing: **13** km

Layers: **90**

Forecast range:

180h at 00, 12 UTC

120h at 06, 18 UTC

30h at 03, 09, 15, 21 UTC

1 grid element: 173 km<sup>2</sup>

## **ICON-EU Nest**

Grid spacing: **6.5** km

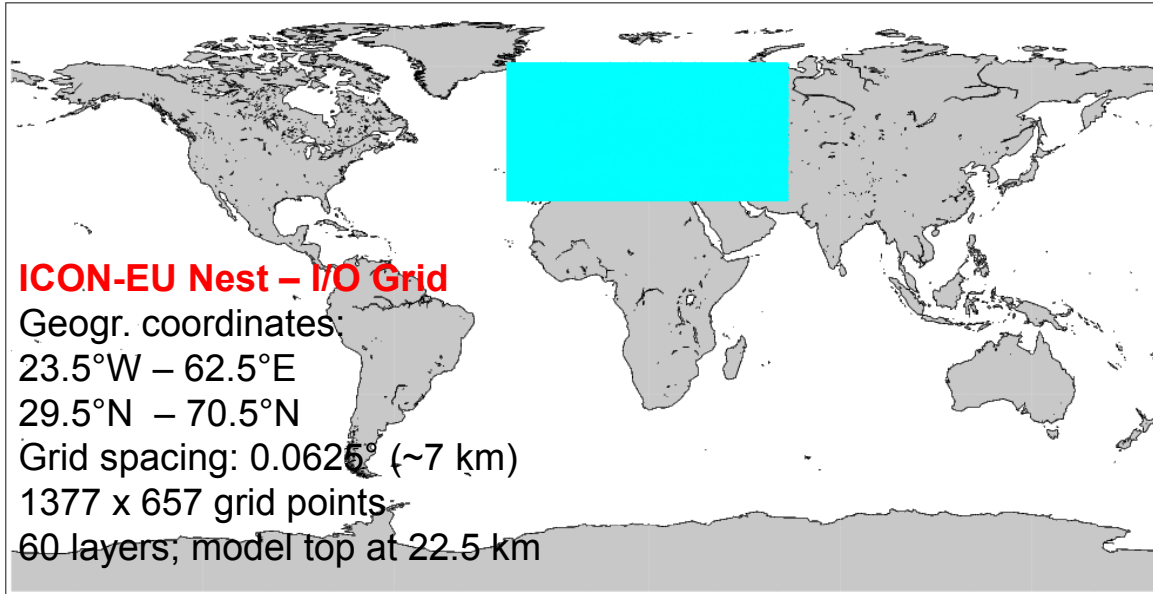
Layers: **60**

Forecast range:

120h at 00, 06, 12, 18 UTC

30h at 03, 09, 15, 21 UTC

1 grid element: 43 km<sup>2</sup>



# The **deterministic** NWP system at DWD in March 2017

## Global model **ICON**

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Forecast range:

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Forecast range:

120h at 00, 06, 12, 18 UTC

30h at 03, 09, 15, 21 UTC

1 grid element: 43 km<sup>2</sup>

## **COSMO-DE**

Grid spacing: **2.8 km**

Layers: **50**

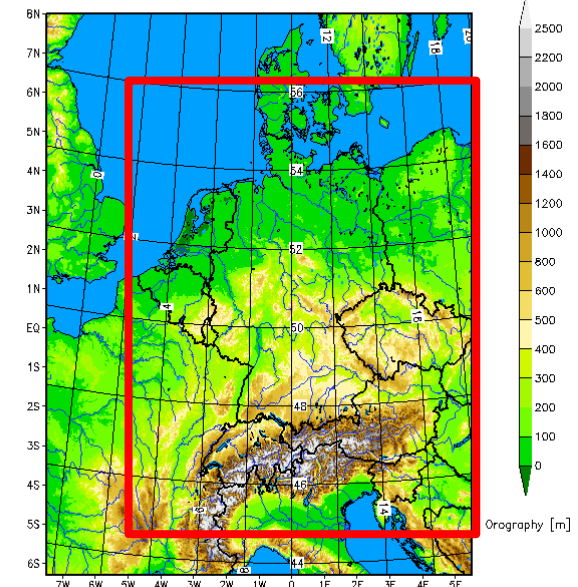
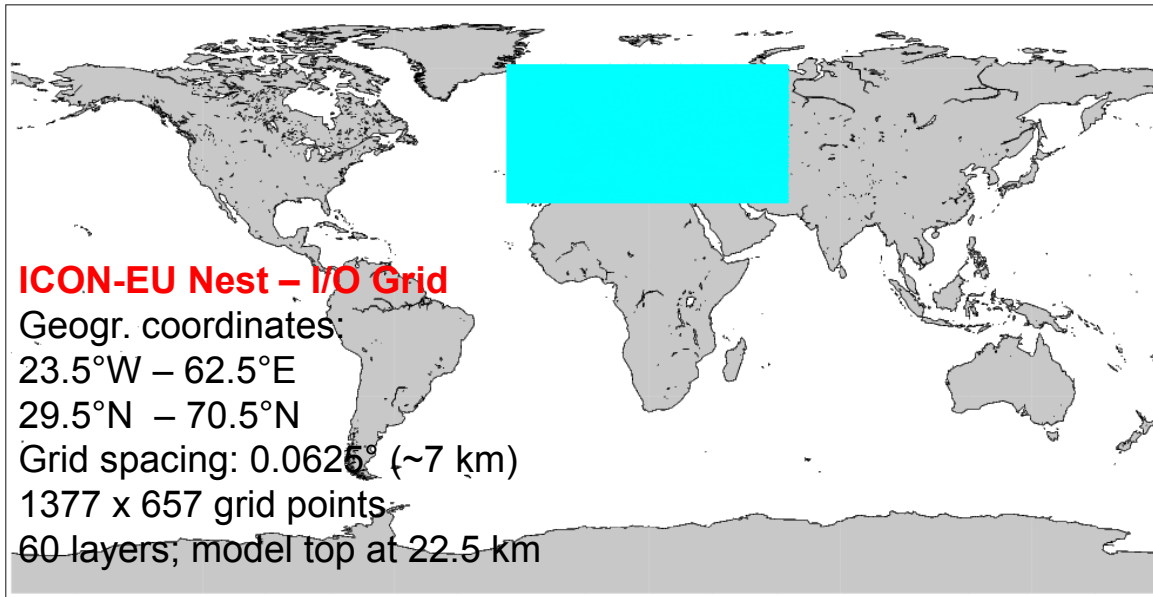
Forecast range:

27h / **45h** at 00, **03**, 06, 09,

12, 15, 18, 21 UTC

**421x461** grid points

1 grid element: 8 km<sup>2</sup>



# The **probabilistic** NWP system at DWD in March 2017

## ICON-EPS: M40

Grid spacing: 40 km

Layers: 90

Forecast range:

180h at 00, 12 UTC

120h at 06, 18 UTC

30h at 03, 09, 15, 21 UTC

1 grid element: 1638 km<sup>2</sup>

## ICON-EU-EPS Nest

Grid spacing: 20 km

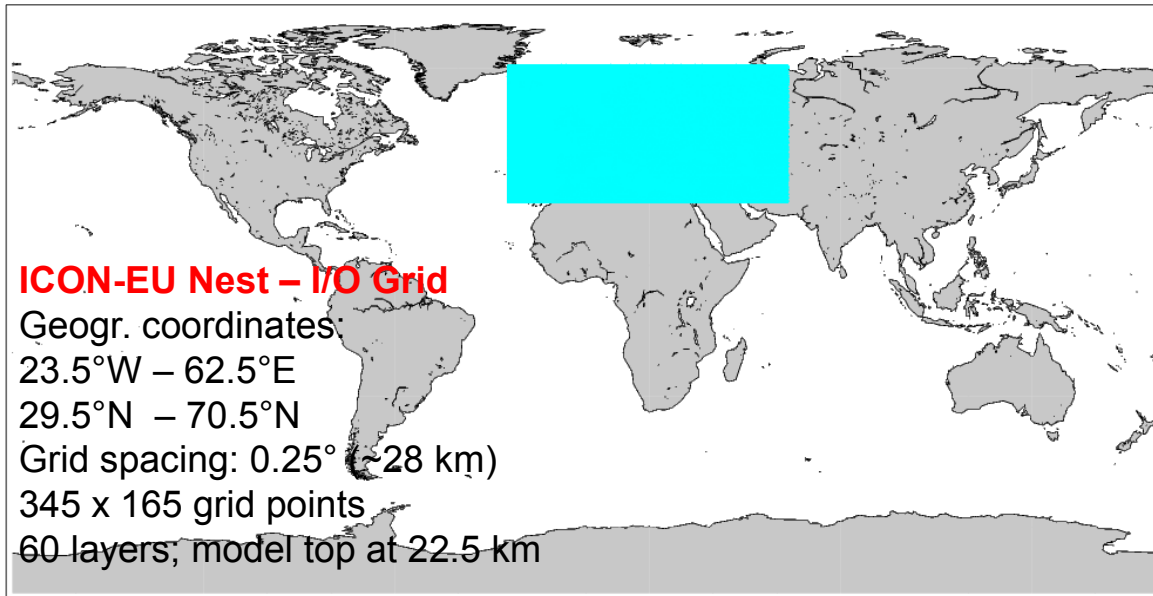
Layers: 60

Forecast range:

120h at 00, 06, 12, 18 UTC

30h at 03, 09, 15, 21 UTC

1 grid element: 407 km<sup>2</sup>



# The probabilistic NWP system at DWD in March 2017

## ICON-EPS: M40

Grid spacing: 40 km

Layers: 90

Forecast range:

180h at 00, 12 UTC

120h at 06, 18 UTC

30h at 03, 09, 15, 21 UTC

1 grid element: 1638 km<sup>2</sup>

## ICON-EU-EPS Nest

Grid spacing: 20 km

Layers: 60

Forecast range:

120h at 00, 06, 12, 18 UTC

30h at 03, 09, 15, 21 UTC

1 grid element: 407 km<sup>2</sup>

## COSMO-DE-EPS: M20

Grid spacing: 2.8 km

Layers: 50

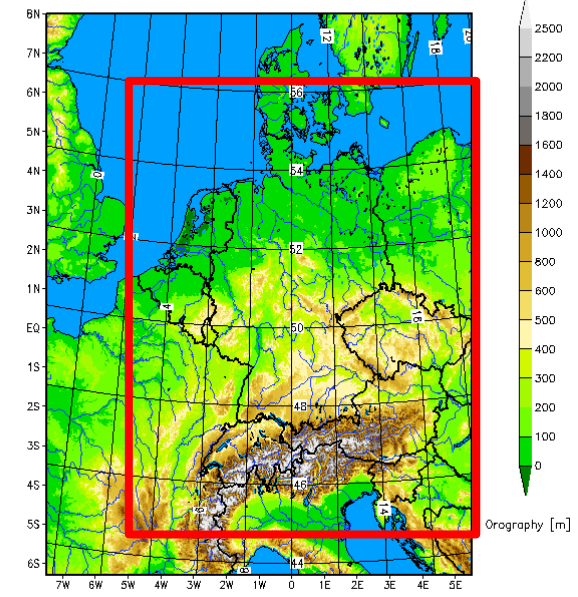
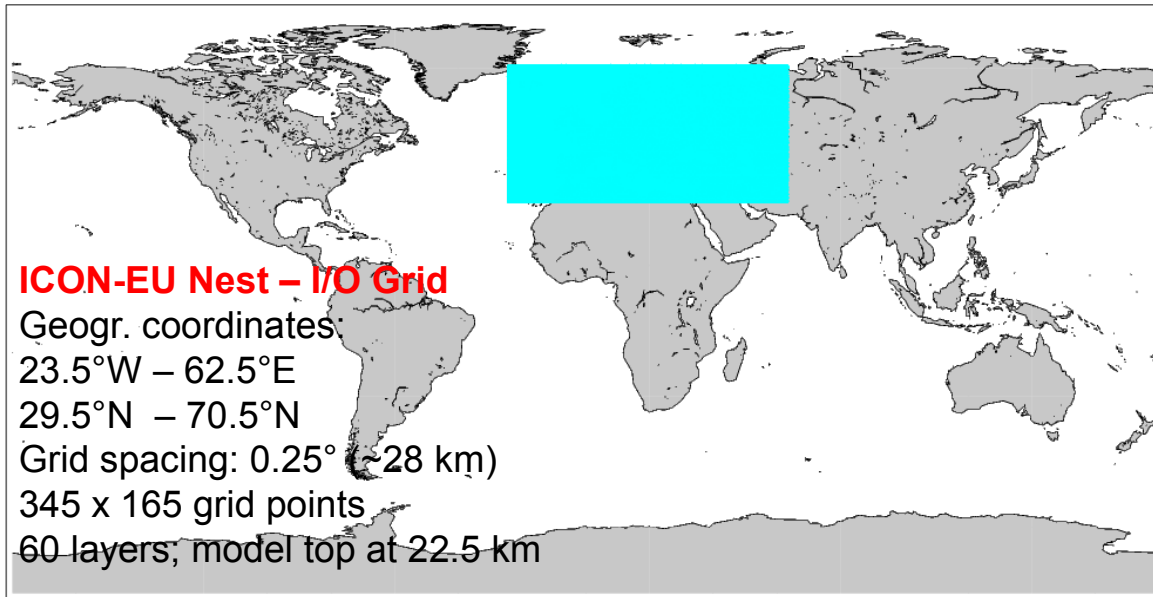
Forecast range:

27h / 45h at 00, 03, 06, 09,

12, 15, 18, 21 UTC

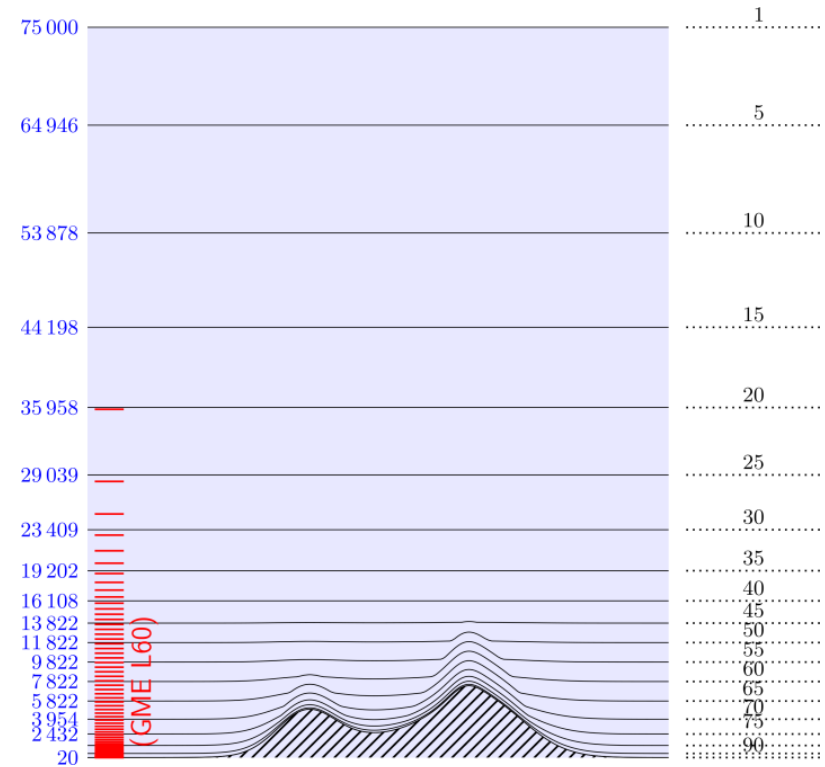
421x461 grid points

1 grid element: 8 km<sup>2</sup>





# ICON and ICON-EU Nest

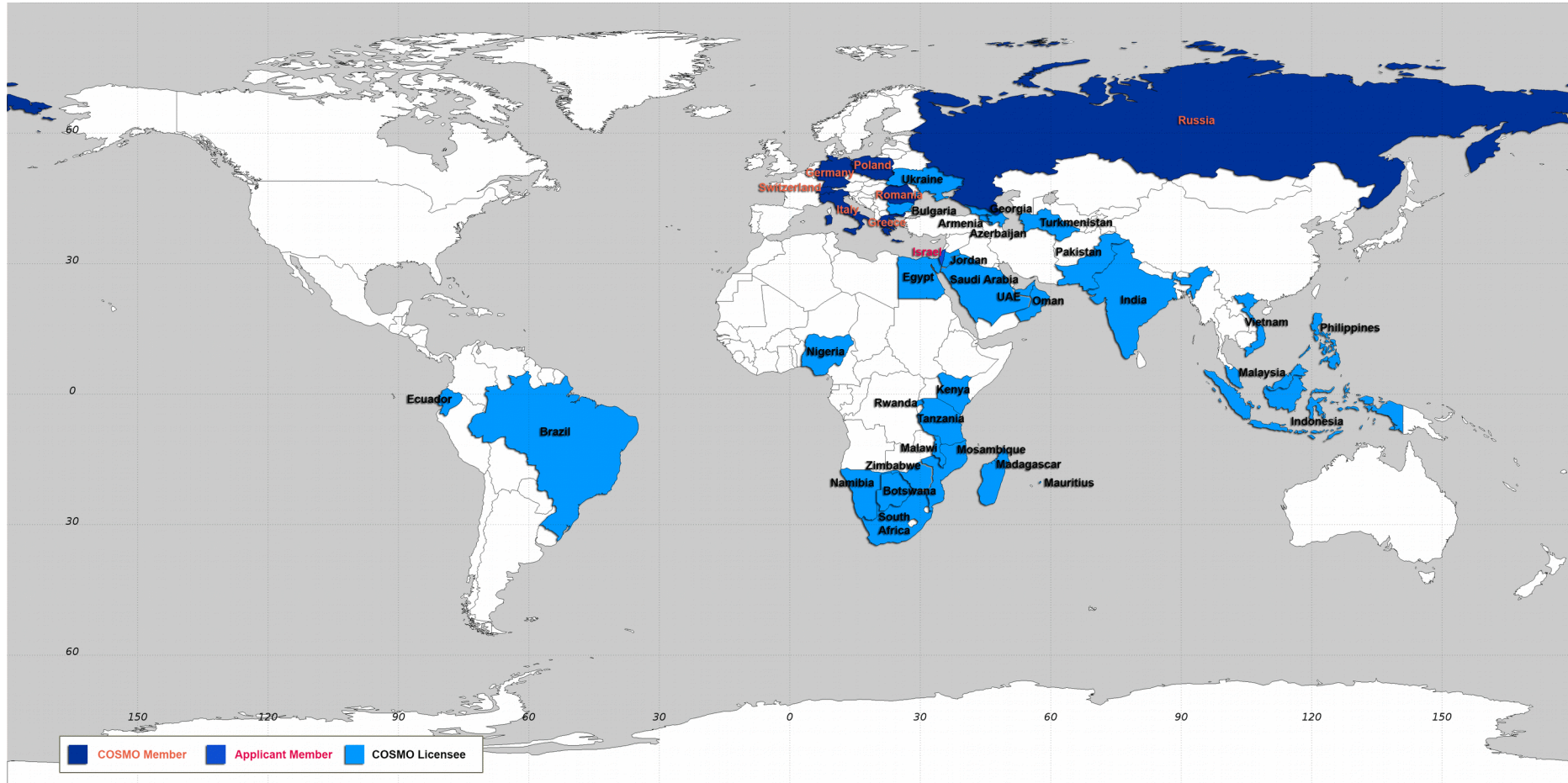


20.01.2015: ICON-global  
 21.07.2015: ICON-EU Nest

(Grid spacing 13 km, 90 layers)  
 (Grid spacing 6.5 km, 60 layers)



# COSMO consortium



- **ICON / ICON-EU**

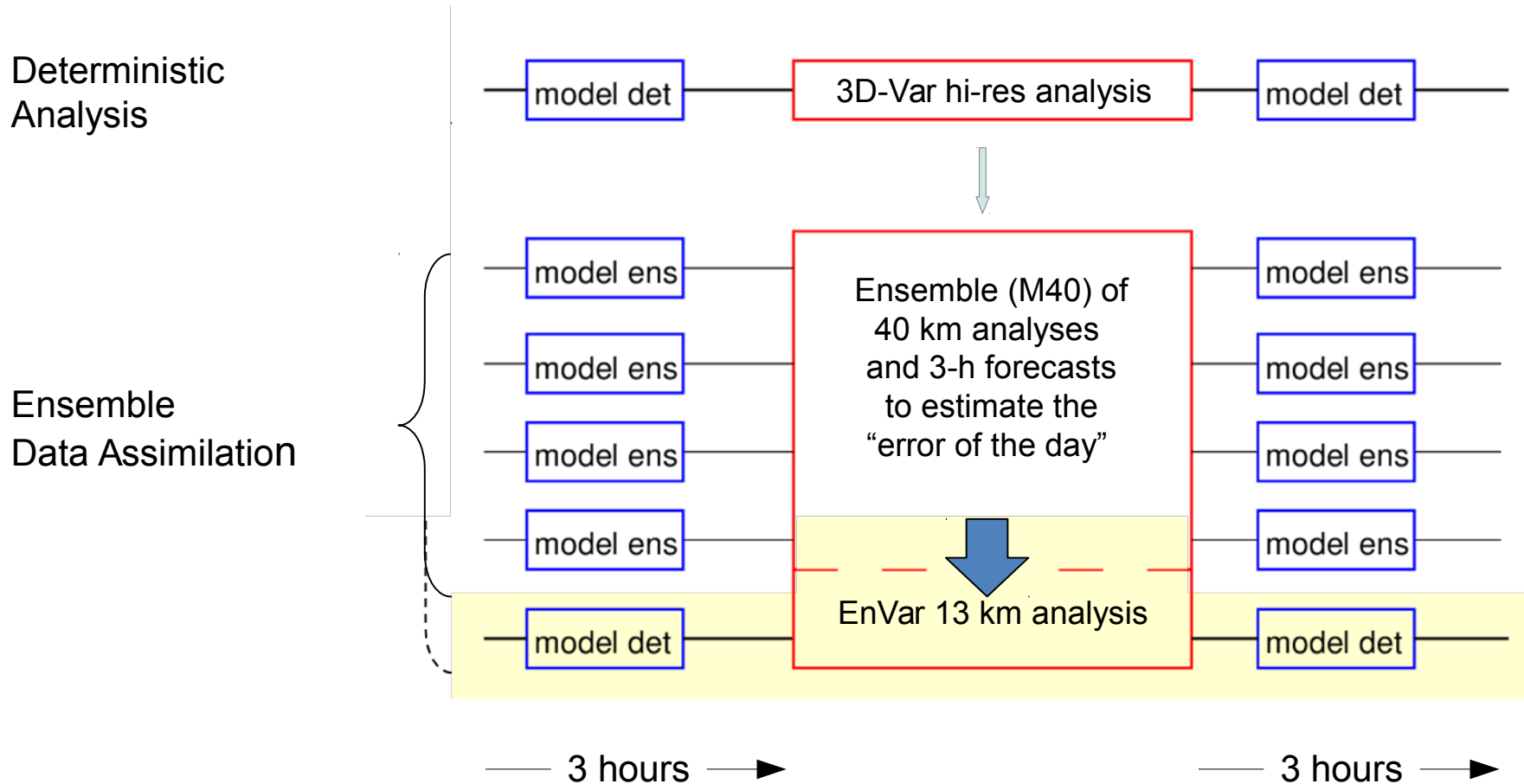
- + 01/12/2015 tile approach (soil model, lake model, sea ice)
- + 20/01/2016 **ICON EnVar operational**
- ICON-EPS pre-operational**
- + 13/04/2016 aerosol climatology

- **COSMO-DE (-EPS)**

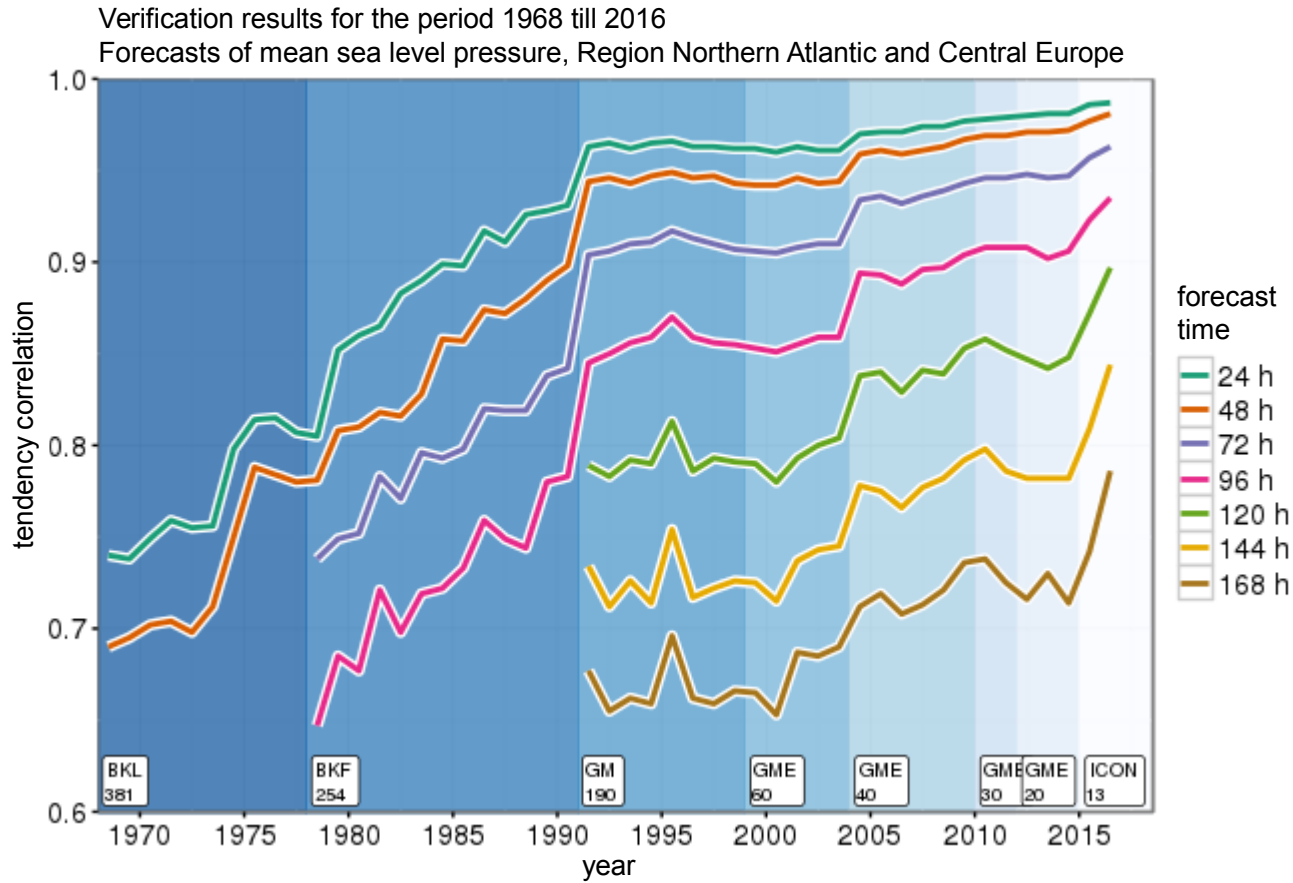
- + 09/05/2016 **KENDA and new COSMO-DE-EPS pre-operational**
- + 13/07/2016 boundary model: COSMO-EU → ICON-EU
- + 02/11/2016 random perturbations of physics (EPS)
- + 08/11/2016 T\_SO: grib store with 24bit
- + 21/03/2017 **KENDA and new COSMO-DE-EPS operational**

# Global Ensemble Data Assimilation (ICON-EDA)

**EnVar:** Deterministic analysis of high-resolution ICON based on hybrid 3DVar – EnKF System; weighting 70% - 30%



# Verification 1968–2016

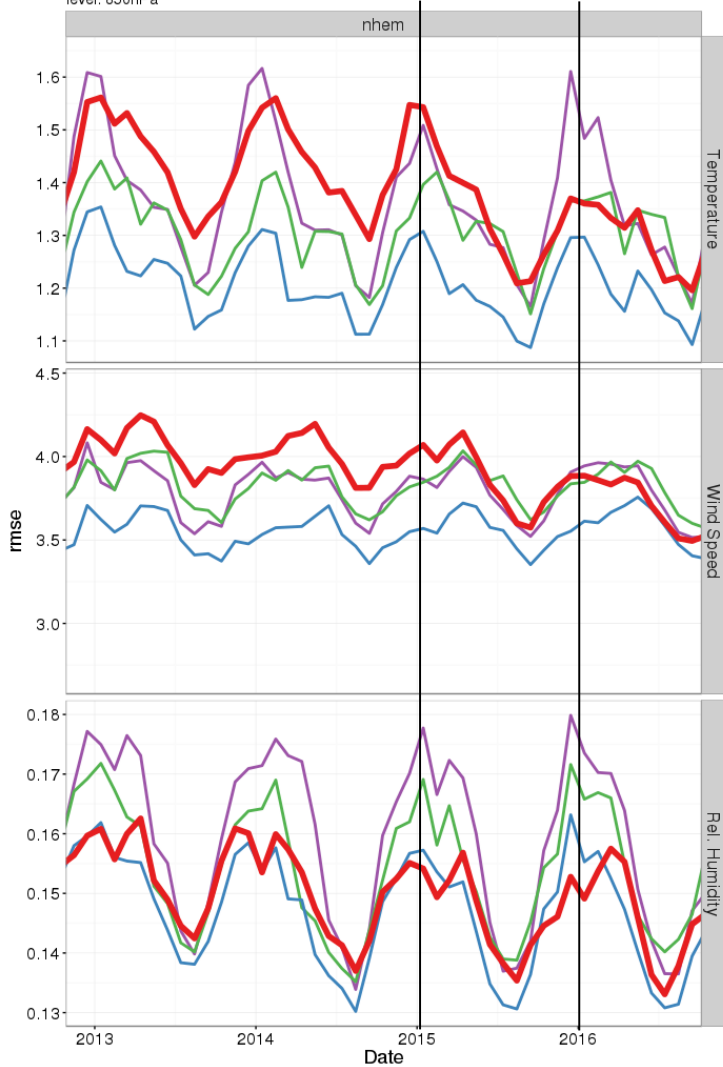


# WMO TEMP-Verification Europe, +24h and +72h

WMO verification against observations  
 lead-time: 24h  
 valid-time: 12UTC  
 level: 850hPa

ICON

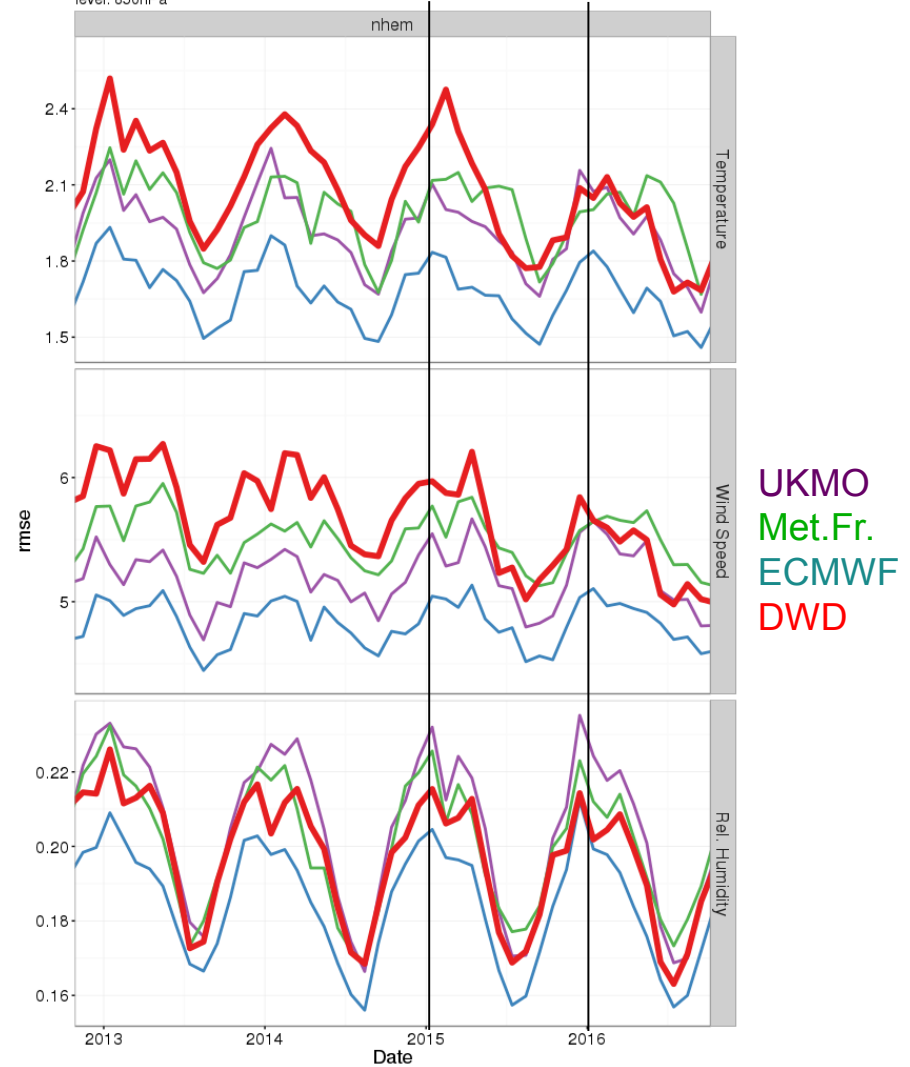
EnVar



WMO verification against observations  
 lead-time: 72h  
 valid-time: 12UTC  
 level: 850hPa

ICON

EnVar



# Main changes of the NWP Model-Suite



- **ICON / ICON-EU**

- + 01/12/2015 tile approach (soil model, lake model, sea ice)
- + 20/01/2016 **ICON EnVar operational**
- ICON-EPS pre-operational**
- + 13/04/2016 aerosol climatology

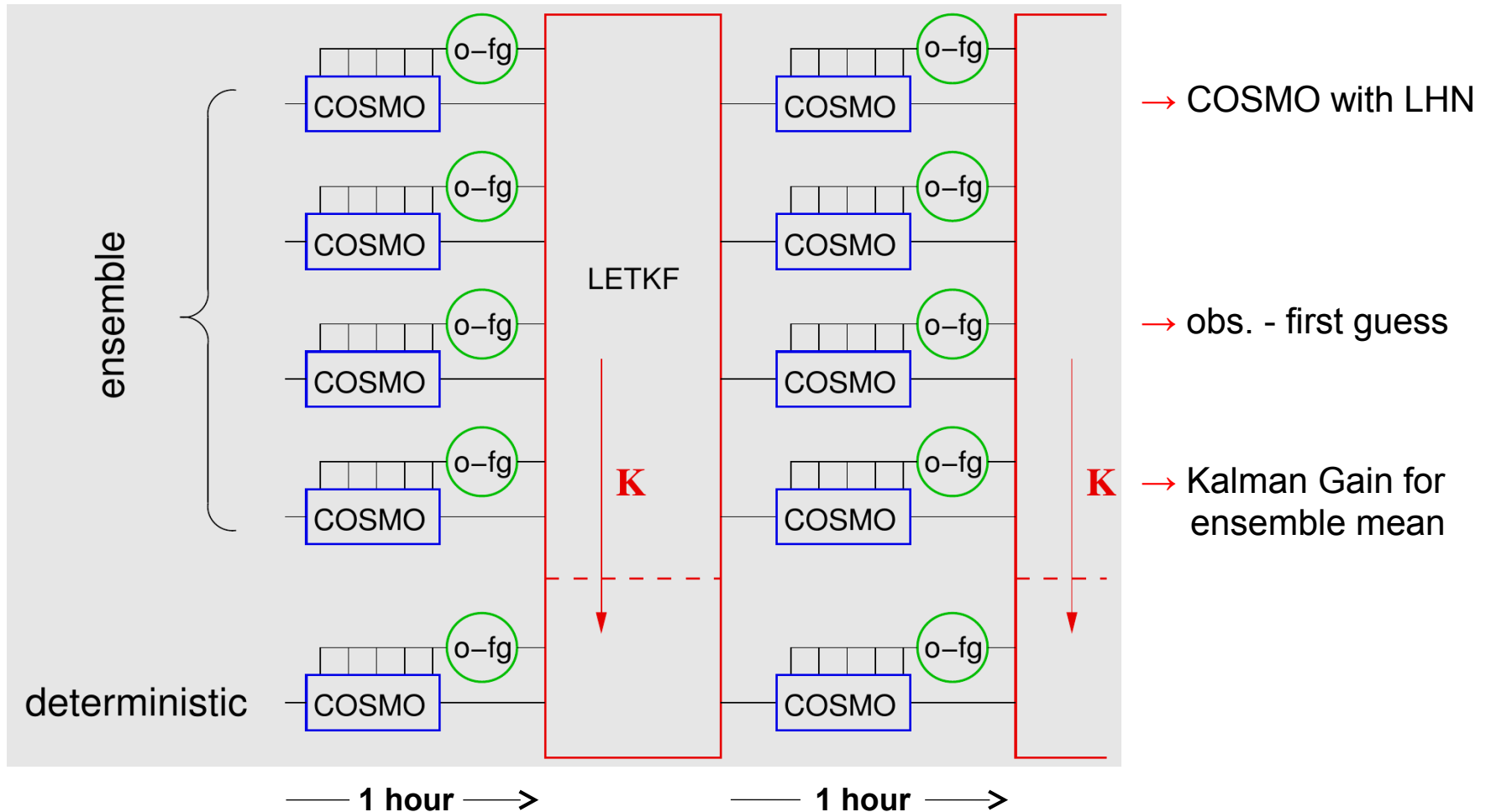
- **COSMO-DE (-EPS)**

- + 09/05/2016 **KENDA and new COSMO-DE-EPS pre-operational**
- + 13/07/2016 C-DE boundary model: COSMO-EU → ICON-EU
- + 02/11/2016 random perturbations of physics (EPS)
- + 08/11/2016 T\_SO: grib store with 24bit
- + 21/03/2017 **KENDA and new COSMO-DE-EPS operational**



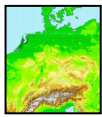
# KENDA

KENDA = Km-scale ENsemble Data Assimilation (Local Ensemble Transform Kalman Filter)

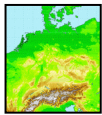


# COSMO-DE-EPS


## 20 EPS members – old setup till 21/03/2017



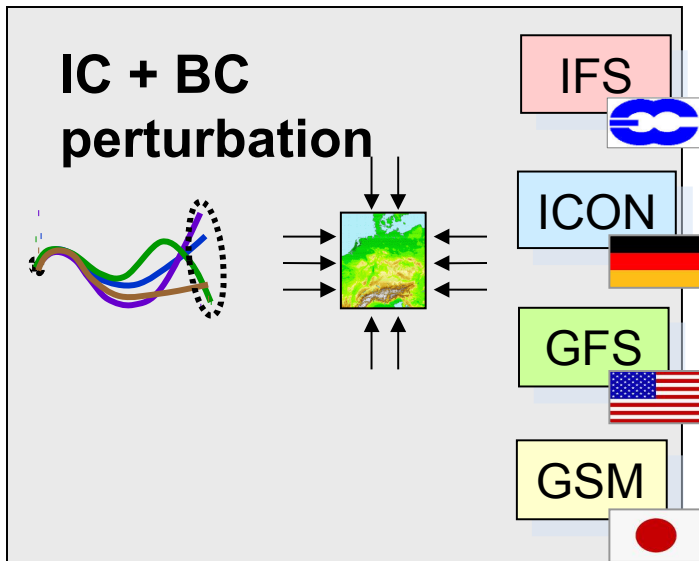
„+“ soil moisture anomaly



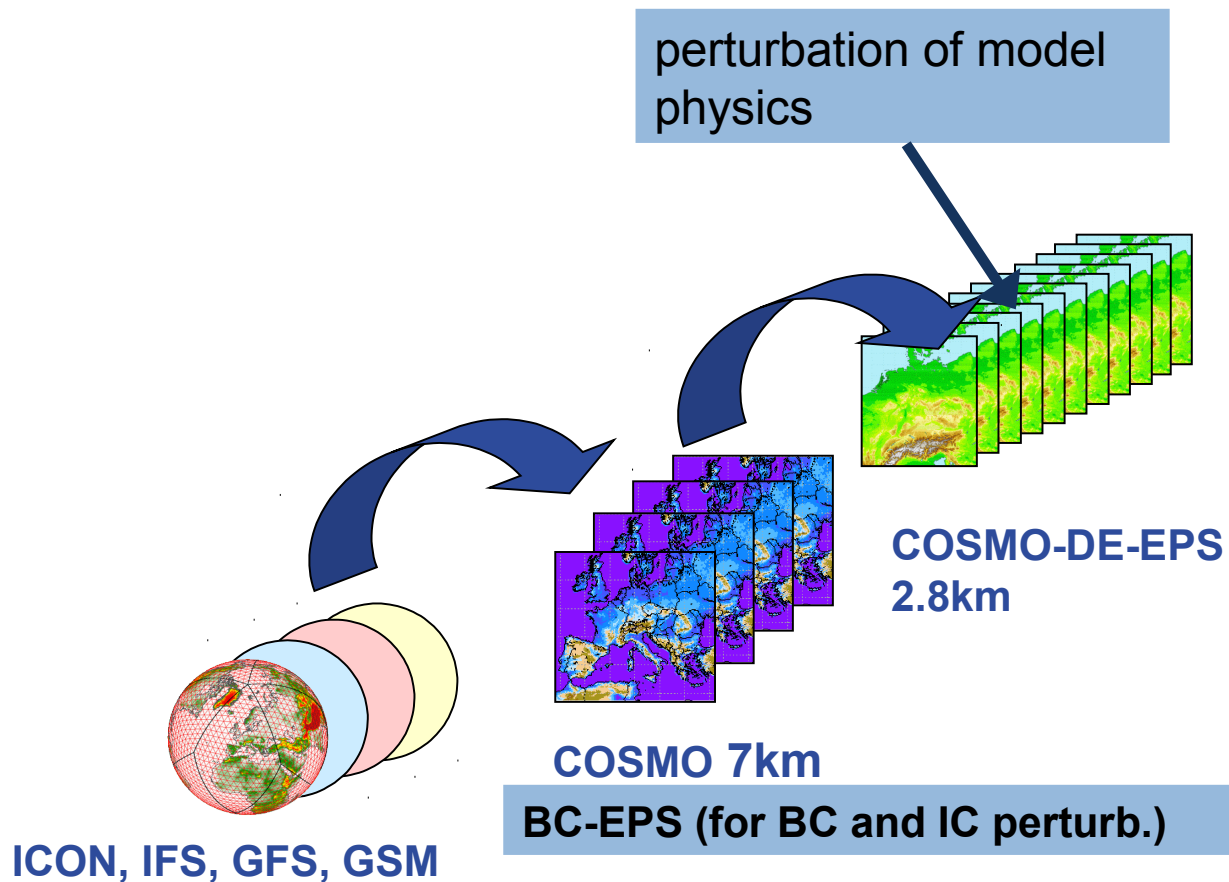
„-“ soil moisture anomaly

**physics param. Perturbation**  12 param.

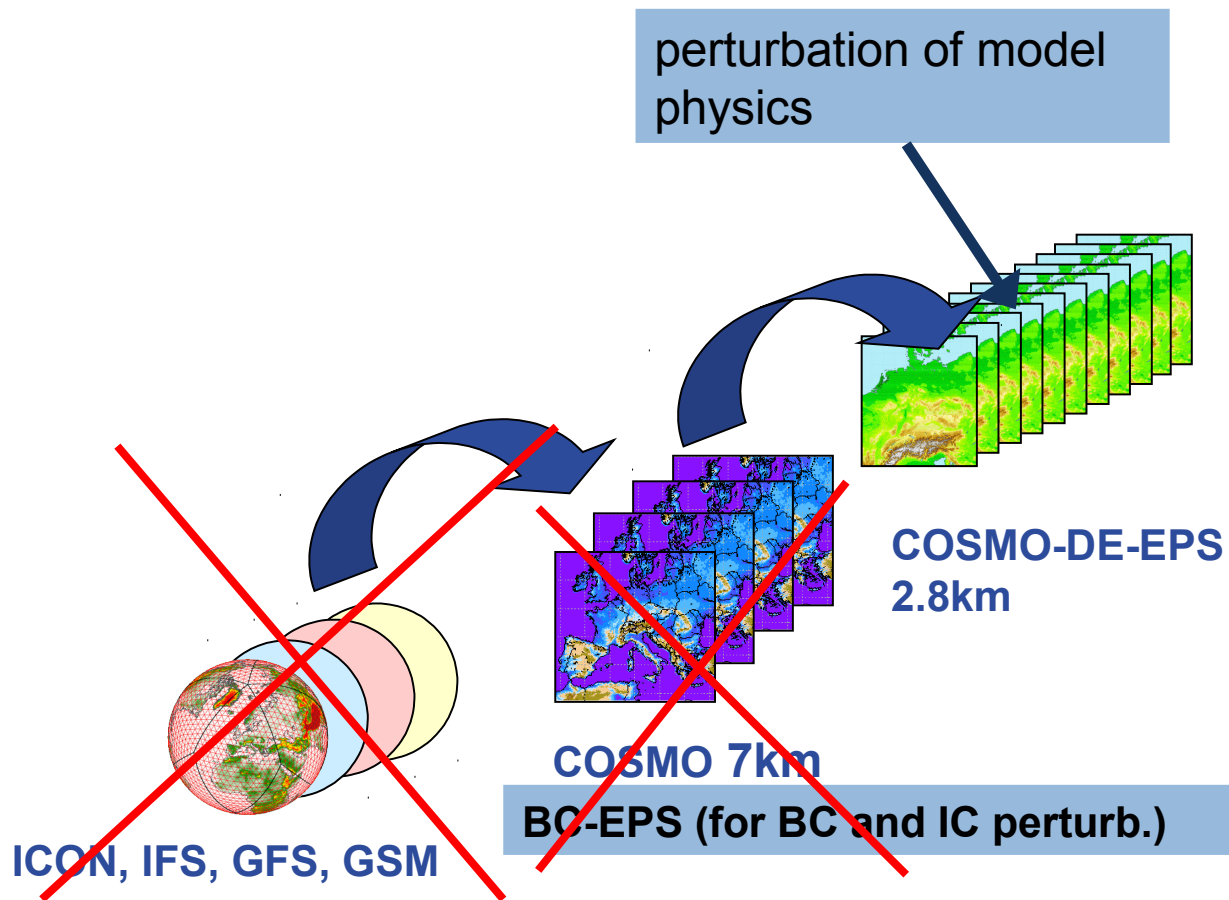
randomly assigned to each member  
constant during forecast





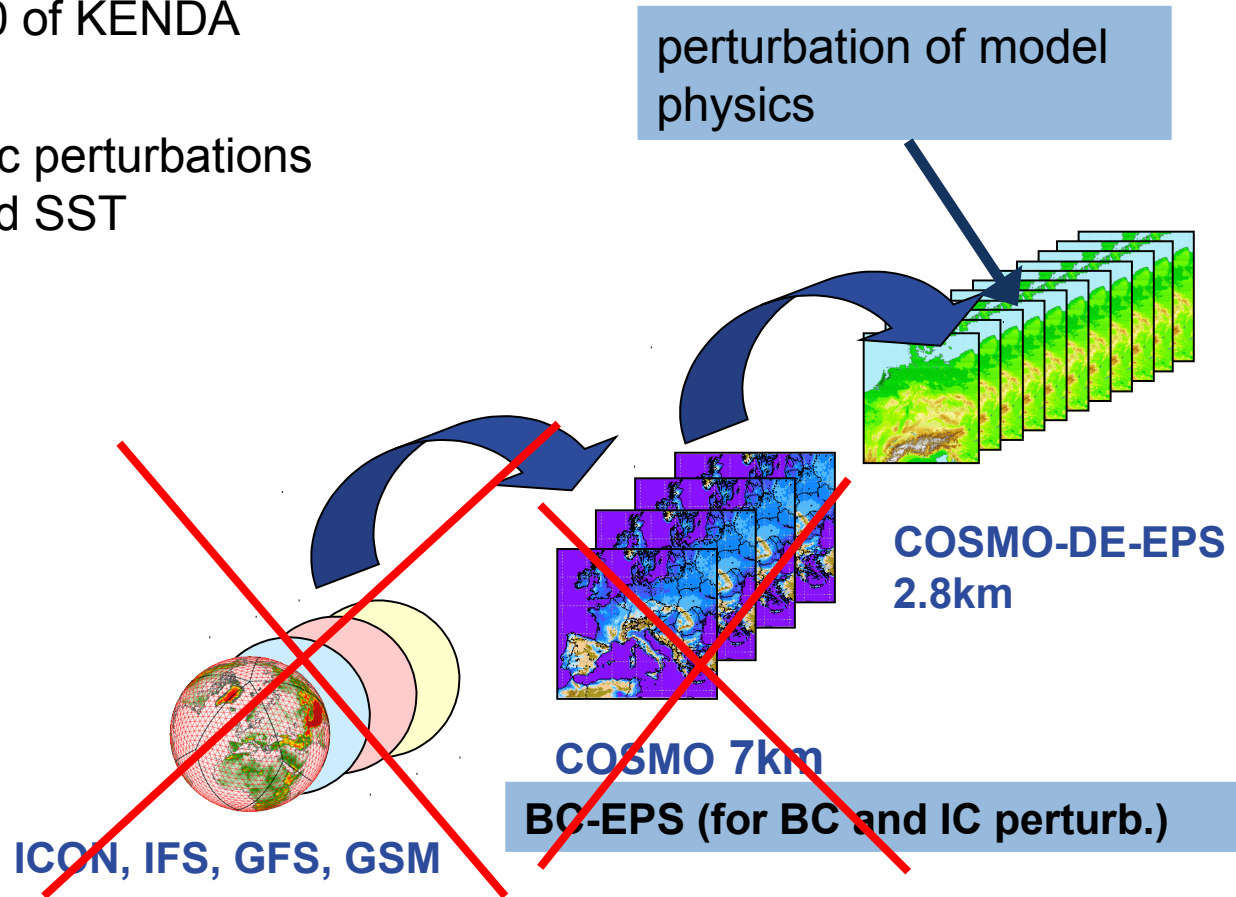


## 20 EPS members – new setup from 21/03/2017



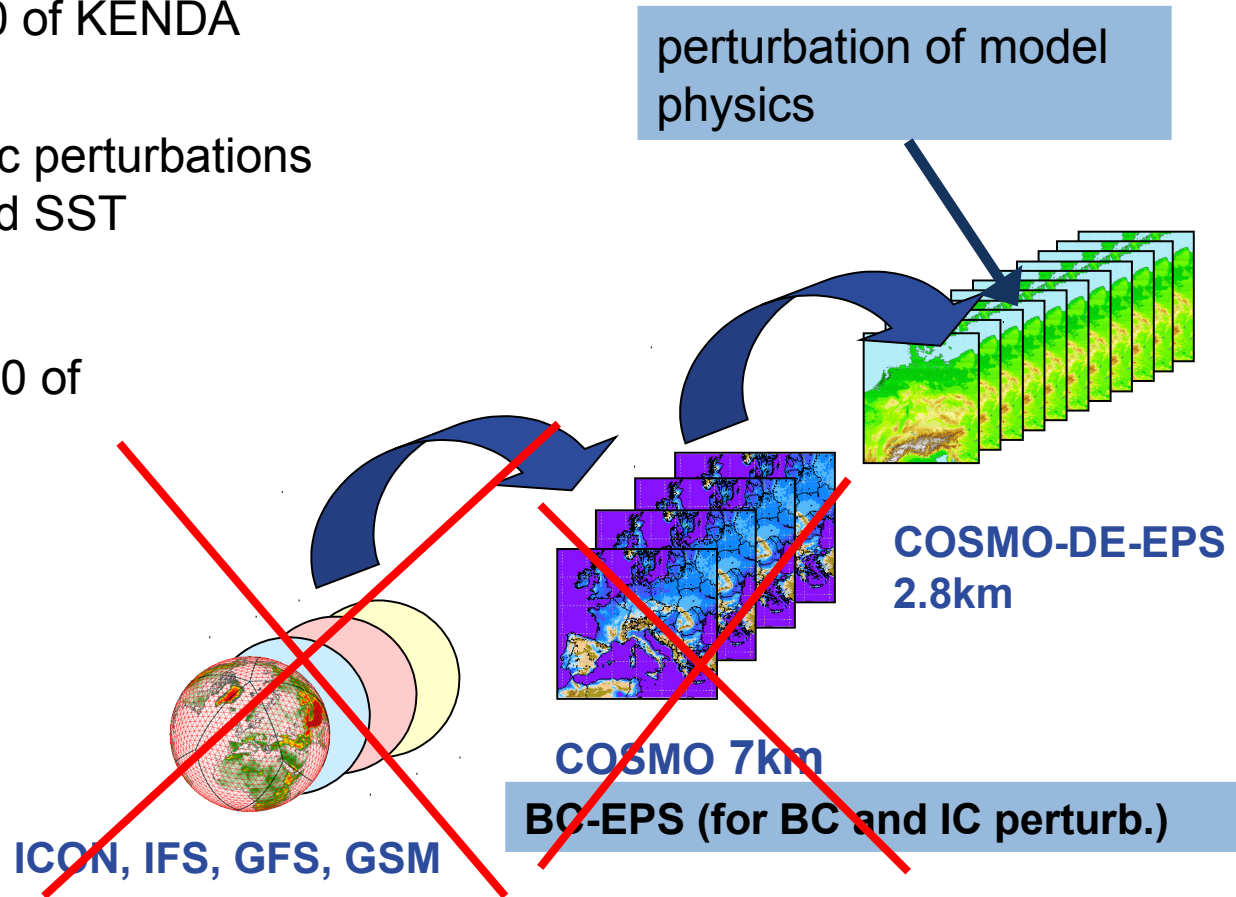
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- IC: uses members 1-20 of KENDA assimilation
  - including stochastic perturbations of soil moisture and SST



## 20 EPS members – new setup from 21/03/2017

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  - including stochastic perturbations of soil moisture and SST
- BC: uses members 1-20 of ICON-EPS (res 20km)

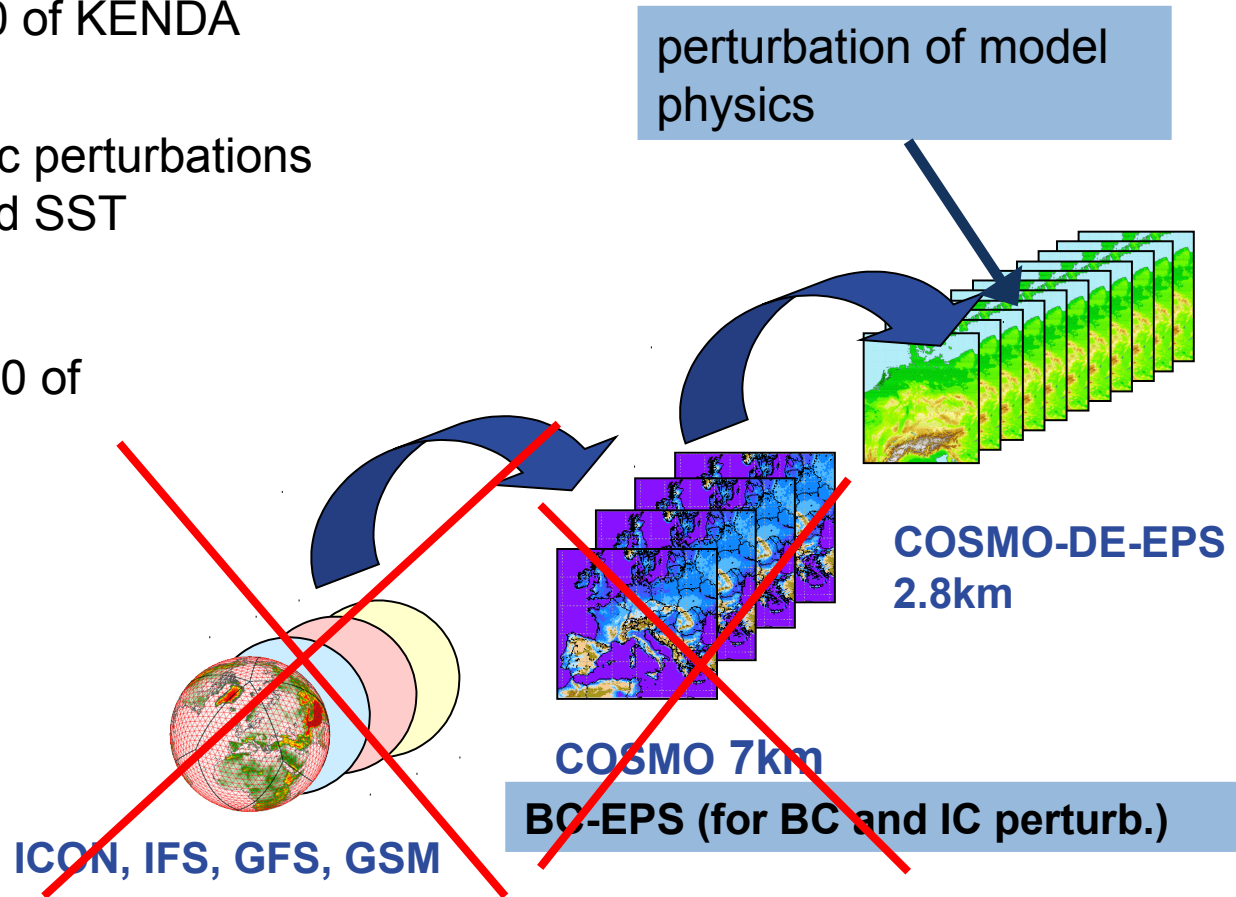


## 20 EPS members – new setup from 21/03/2017

- IC: uses members 1-20 of KENDA assimilation
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- BC: uses members 1-20 of ICON-EPS (res 20km)

- perturbations of model physics

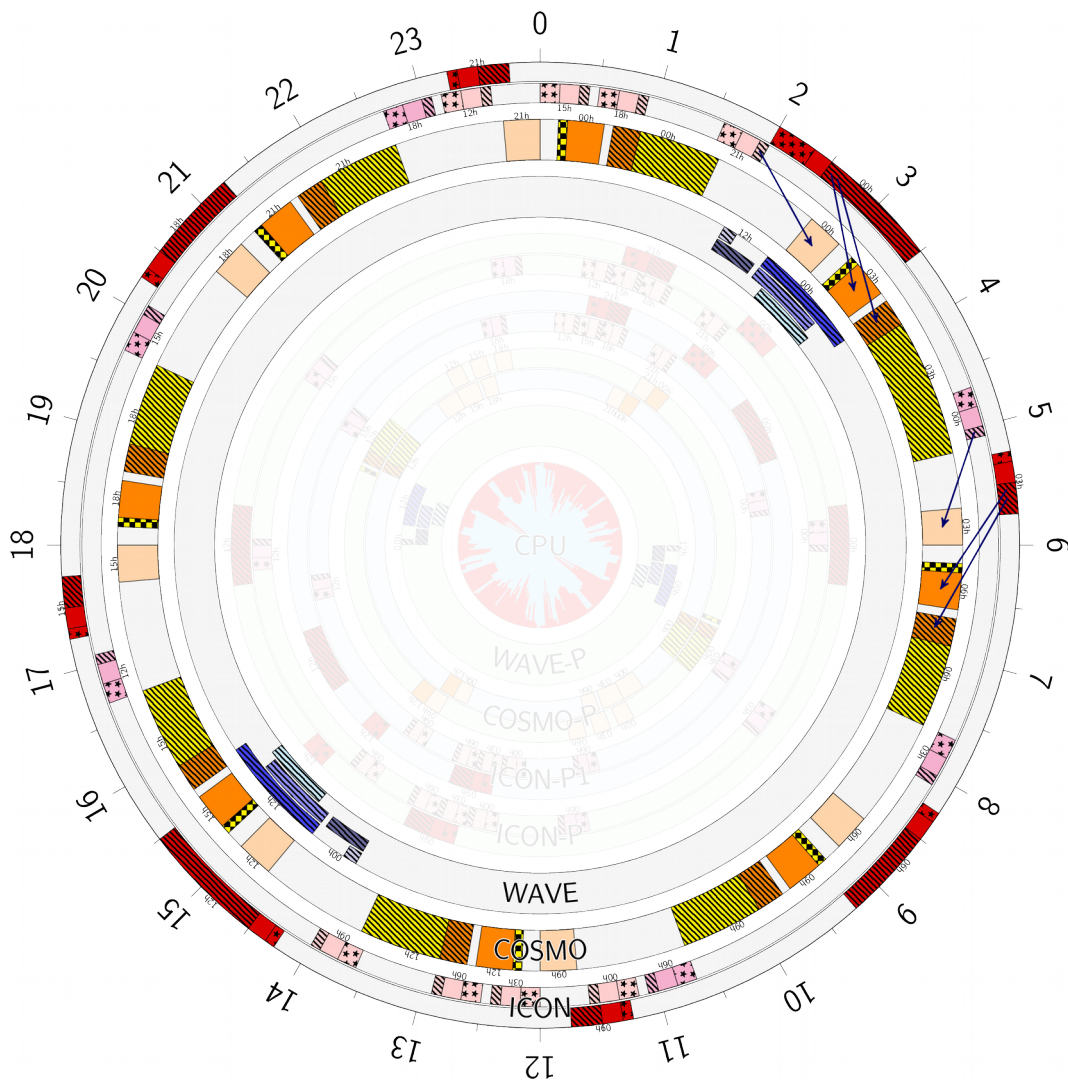










# „Modell-Uhr“

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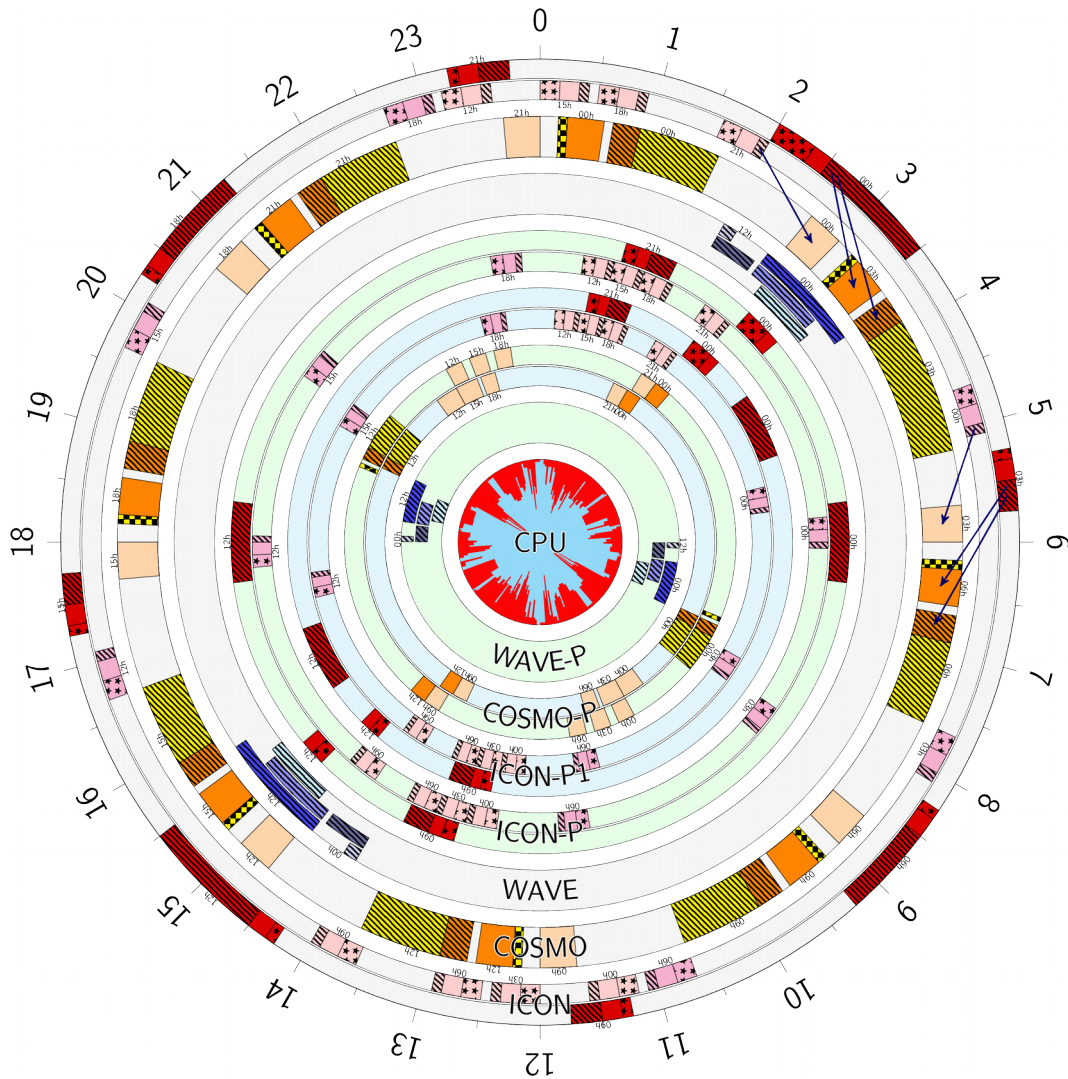


## Operational timetable of the DWD model suite











-  ICON, COSMO: analysis
-  ICON: analysis - serial part
-  ICON, COSMO: forecast
-  COSMO-DE-EPS: interpolation
-  WAVE (GWAM, EWAM, CWAM)
-  main run
-  pre-assimilation
-  assimilation
- 00..23 real time [UTC]
- 00h, 03h, .. model time [UTC]
- P, P1 parallel suite



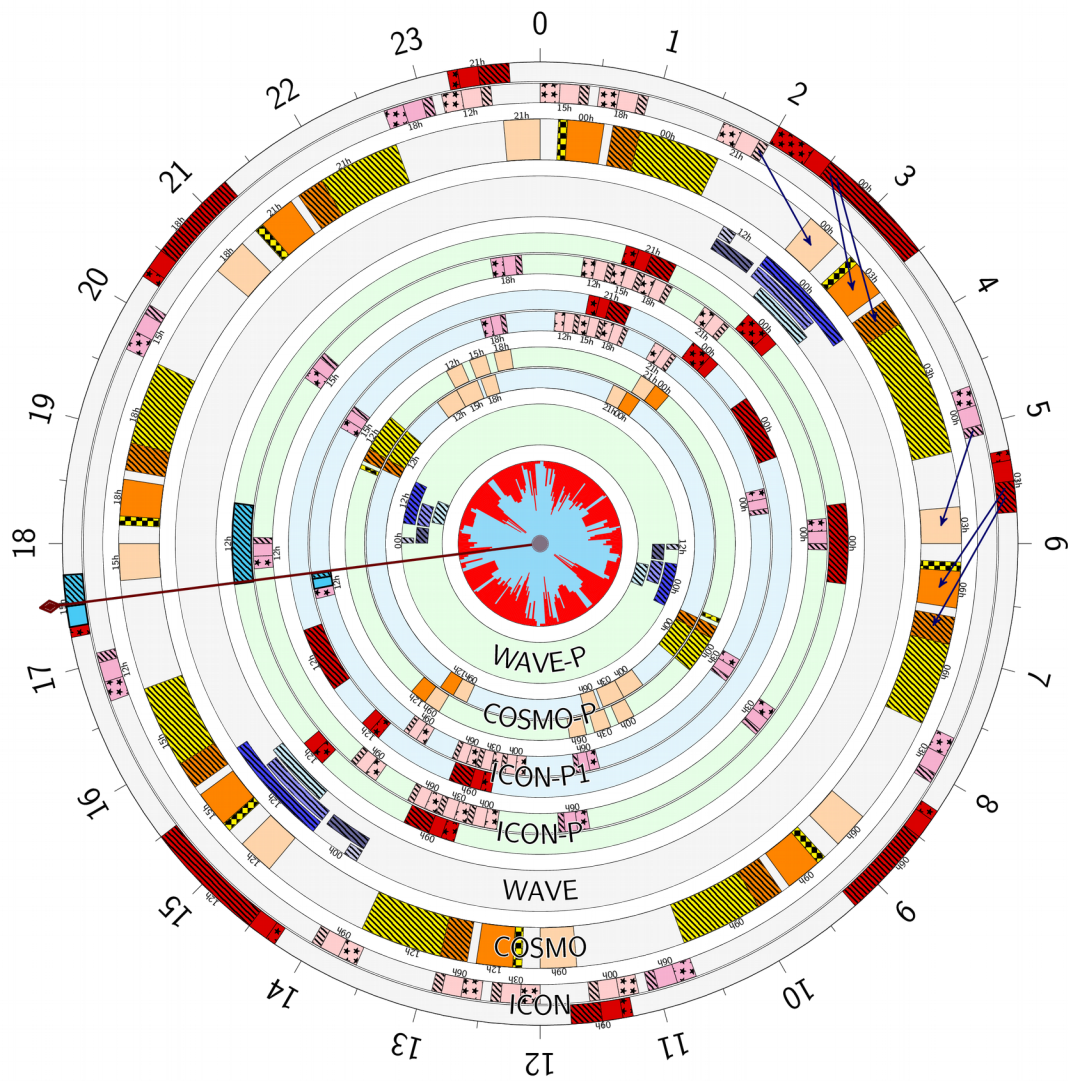


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# „Modell-Uhr“ - actual operational activity



Operational timetable of the DWD model suite

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- ICON, COSMO: forecast
- COSMO-DE-EPS: interpolation
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- main run
- pre-assimilation
- assimilation
- 00..23 real time [UTC]
- 00h, 03h, .. model time [UTC]
- P, P1 parallel suite

# Operational Schedule

	type	time [UTC] / interval	forecast time [h]	cut off time X + ??	ready time X + ??
ICON / ICON-EU	main forecast	00, 12	180	+ 2:14	+ 3:30
		06, 18	120	+ 2:14	+ 3:00
		03, 09, 15, 21	30	+ 2:14	+ 2:45
	pre-assimilation	3 hourly	3	+ 4:40	+ 5:05
	assimilation	00, 12	3	+ 11:10	+ 11:35
		03, 15	3	+ 9:00	+ 9:25
		06, 18	3	+ 6:30	+ 6:55
		09, 21	3	+ 4:35	+ 5:00
COSMO-DE	main forecast	00, 06, 09, 12, 15, 18, 21	27	+ 0:40	+ 0:55
		03	45	+ 0:40	+ 1:05
	assimilation	1 hourly (3h blocks)	1	+ 2:40...5:40 (0:15...3:15)	+ 3:00
COSMO-DE-EPS	main forecast	00, 06, 09, 12, 15, 18, 21	27	+ 0:55	+ 1:35
		03	45	+ 1:05	+ 2:10

# Operational Schedule

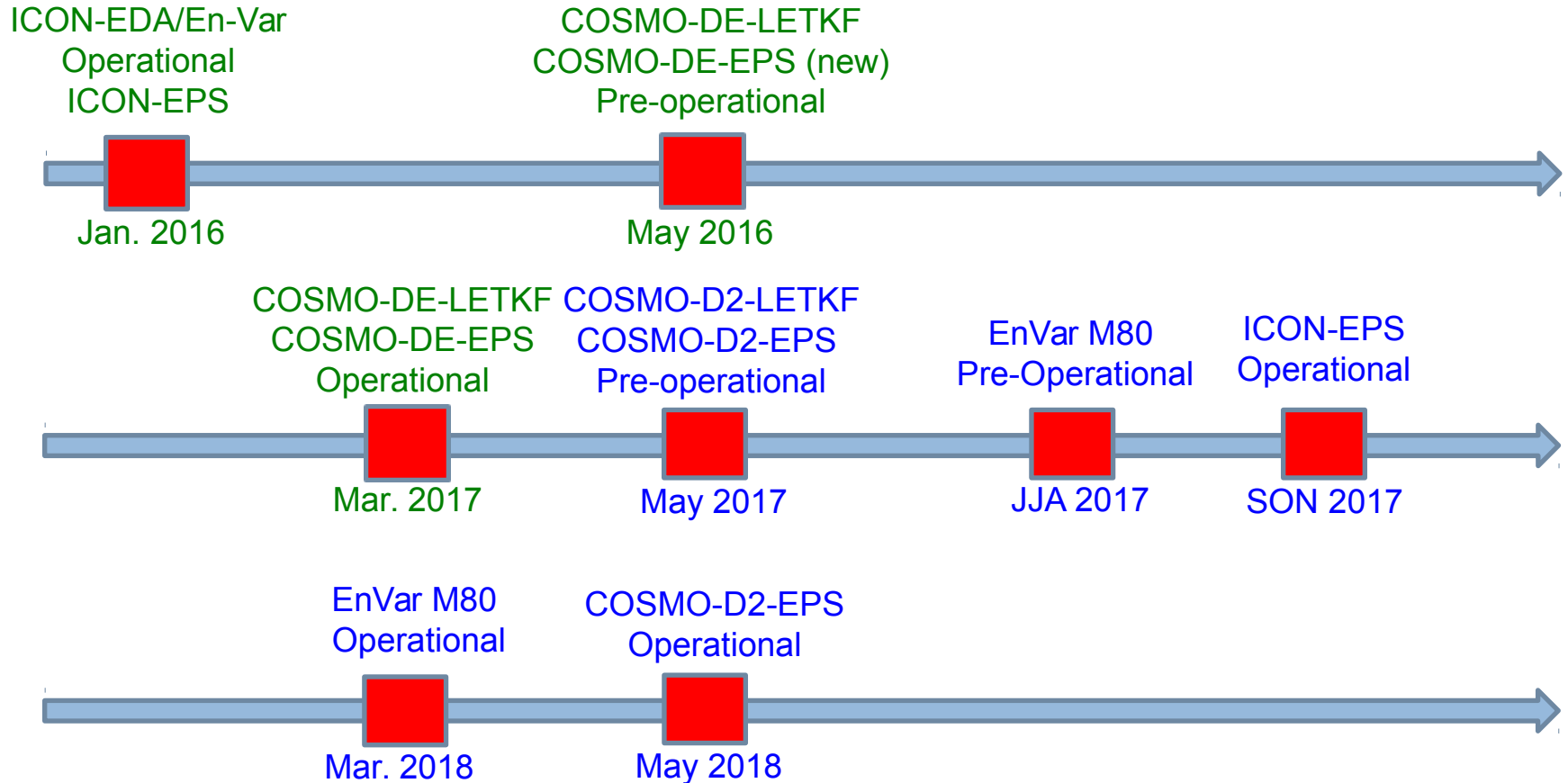
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- **COSMO-D2**
  - Regional Ensemble Data Assimilation (KENDA)
  - COSMO-D2-EPS
  
- **EnVar M80 (ICON)**
  - Ensemble Data Assimilation with 80 members
  - 40km (global) / 20km (ICON-EU nest)
  
- **ICON-Art**
  - Project “Perdus”: Dispersion of (Saharan) mineral dust
  - Data assimilation cycle (40km / 20km)
  - Volcanic ash forecast

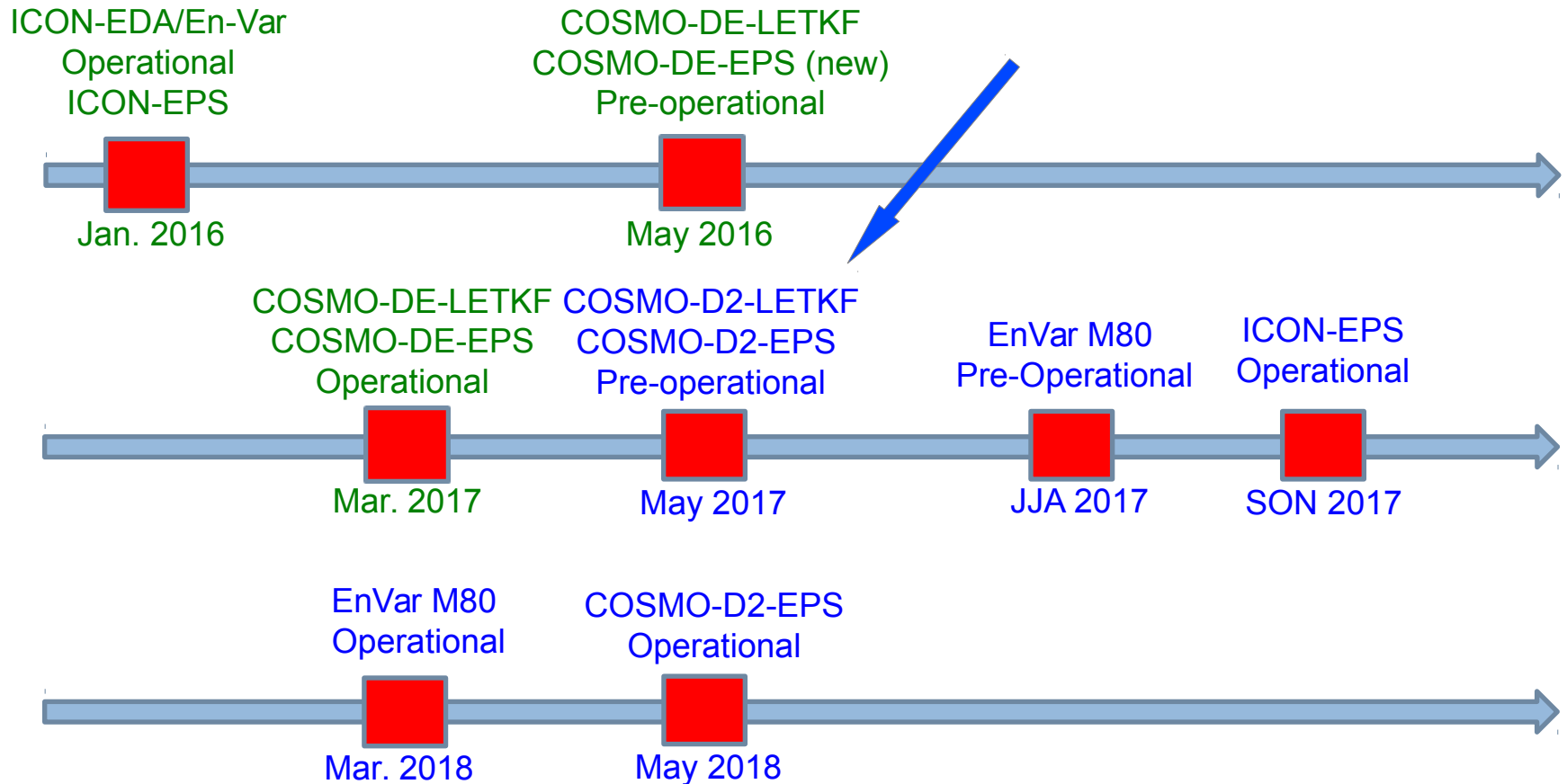
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# Schedule of larger NWP developments at DWD 2016 - 2018



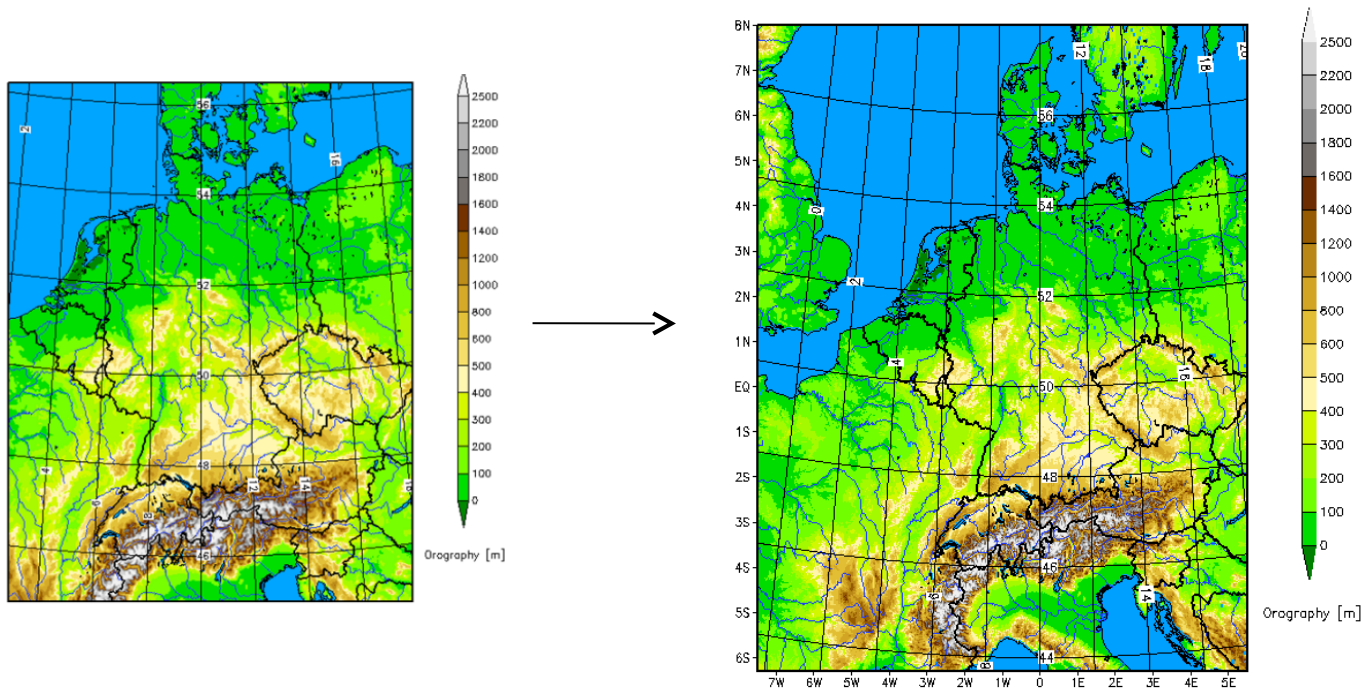
# Schedule of larger NWP developments at DWD 2016 - 2018





# COSMO-DE → COSMO-D2

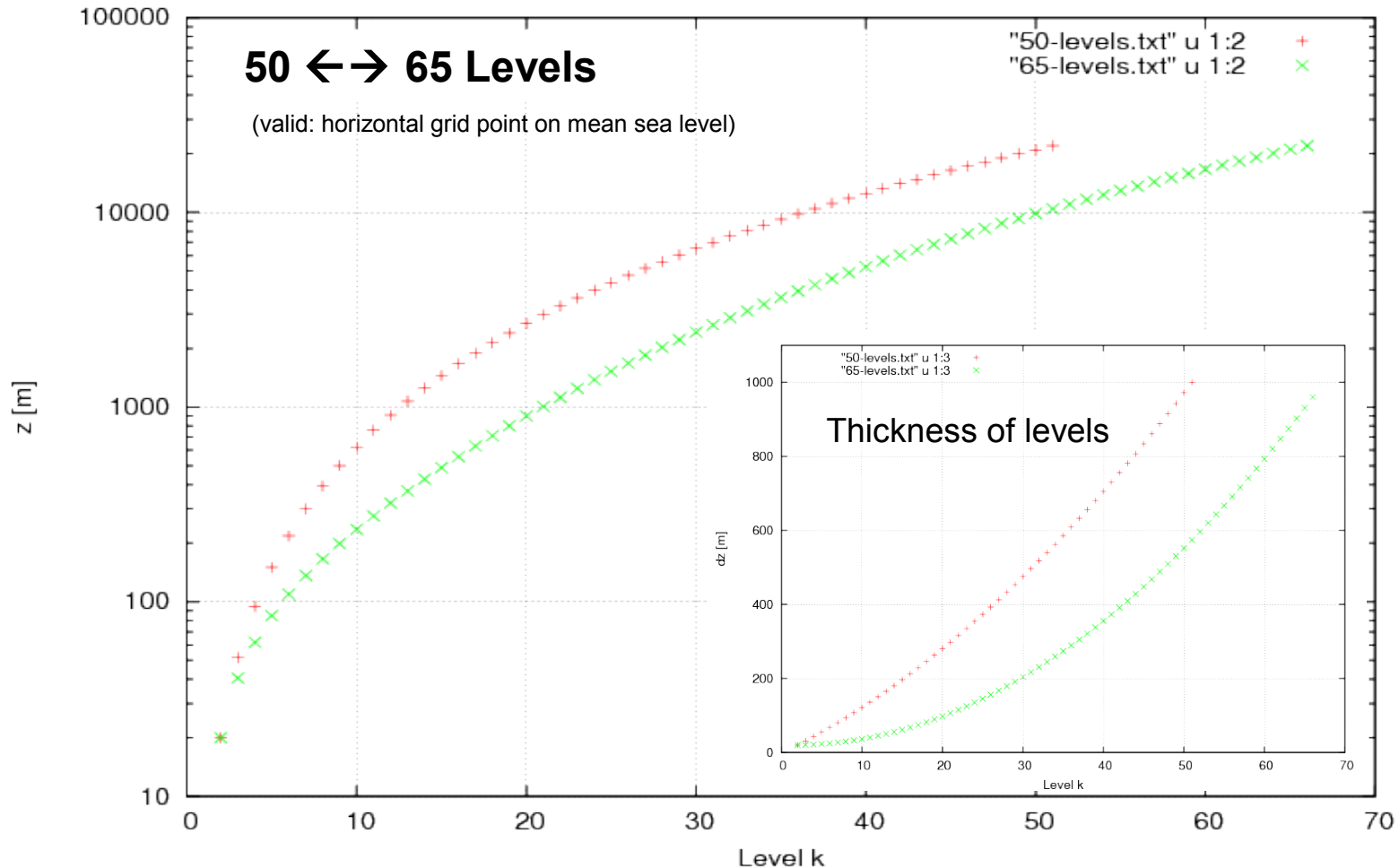
Horizontal resolution:	2.8 km	→	2.2 km
Grid points:	421 * 461	→	651 * 716
Vertical levels:	50	→	65
Model area:	10.5° * 11.5°	→	13° * 14.3°



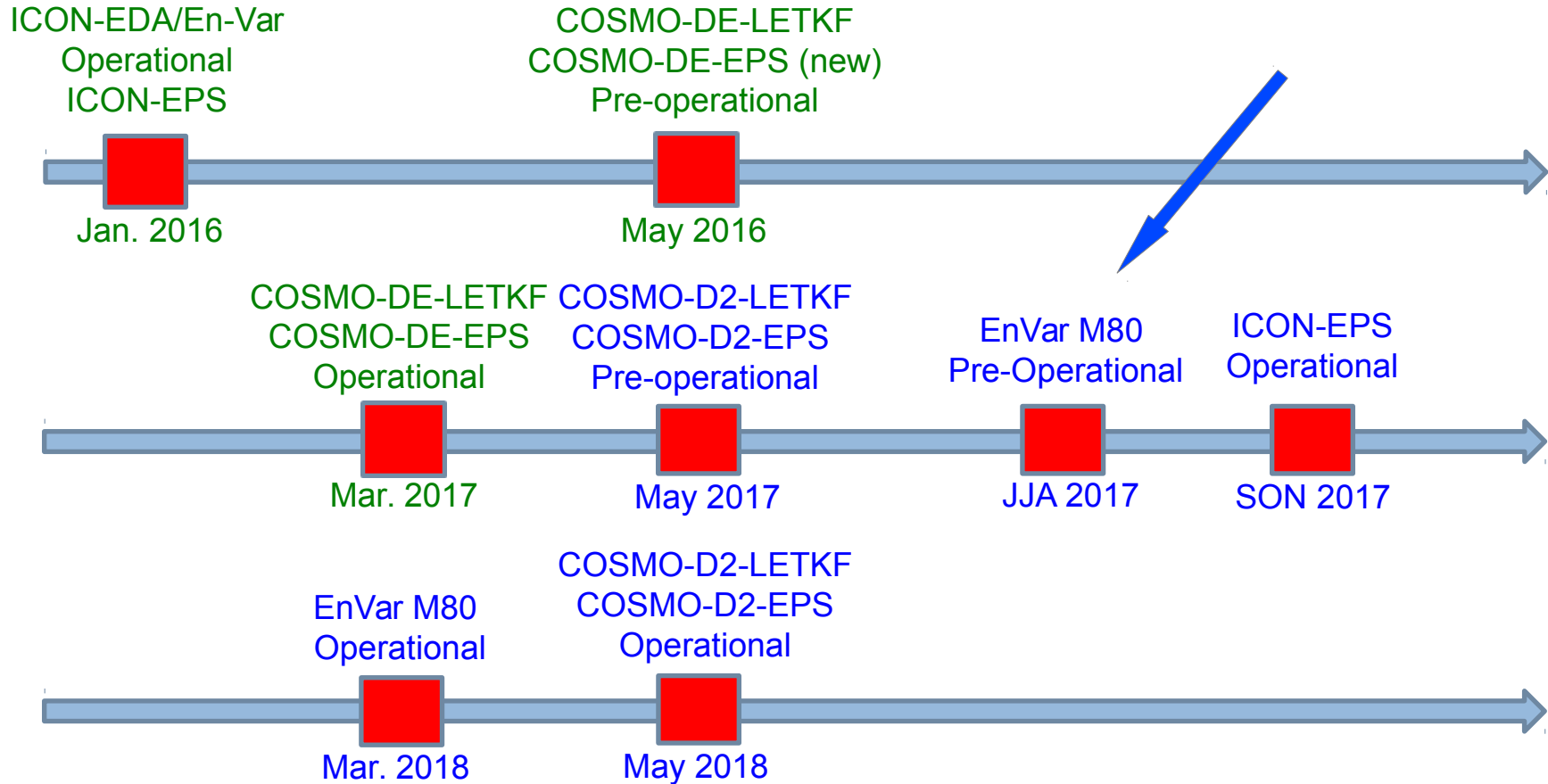
# COSMO-DE → COSMO-D2

New level distribution → better vertical resolution of boundary layer

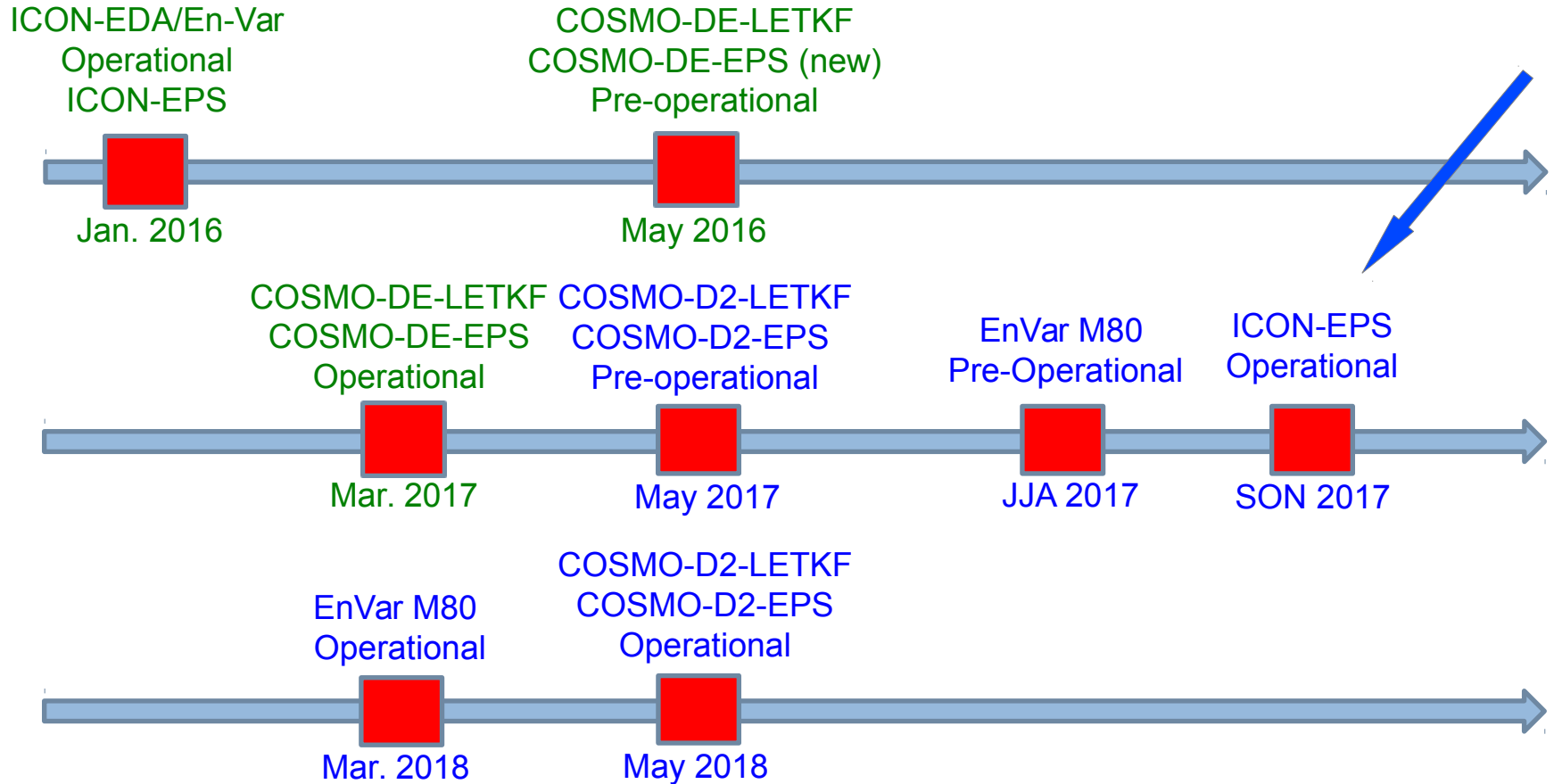
- goal: improve the triggering of convection



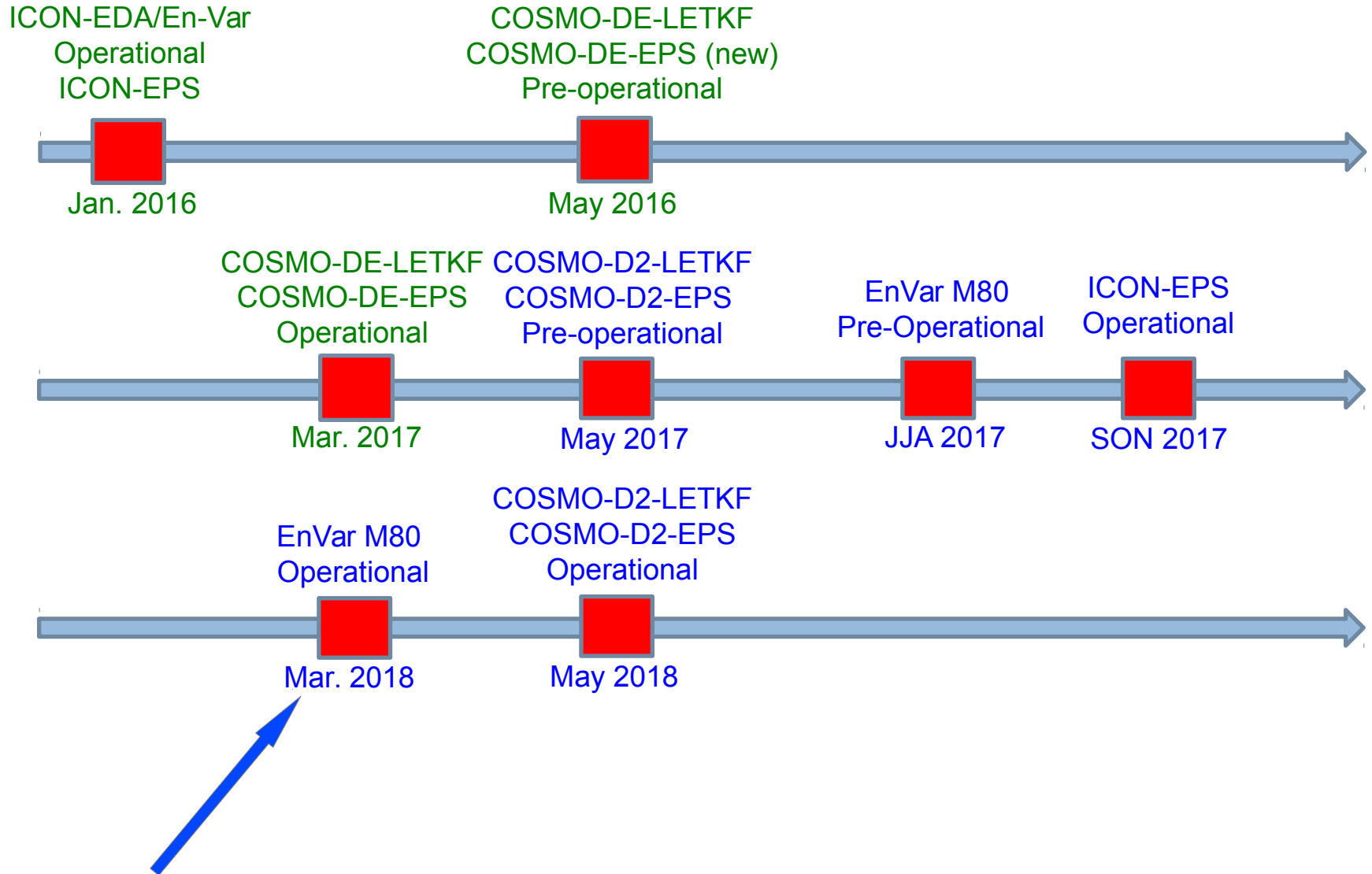
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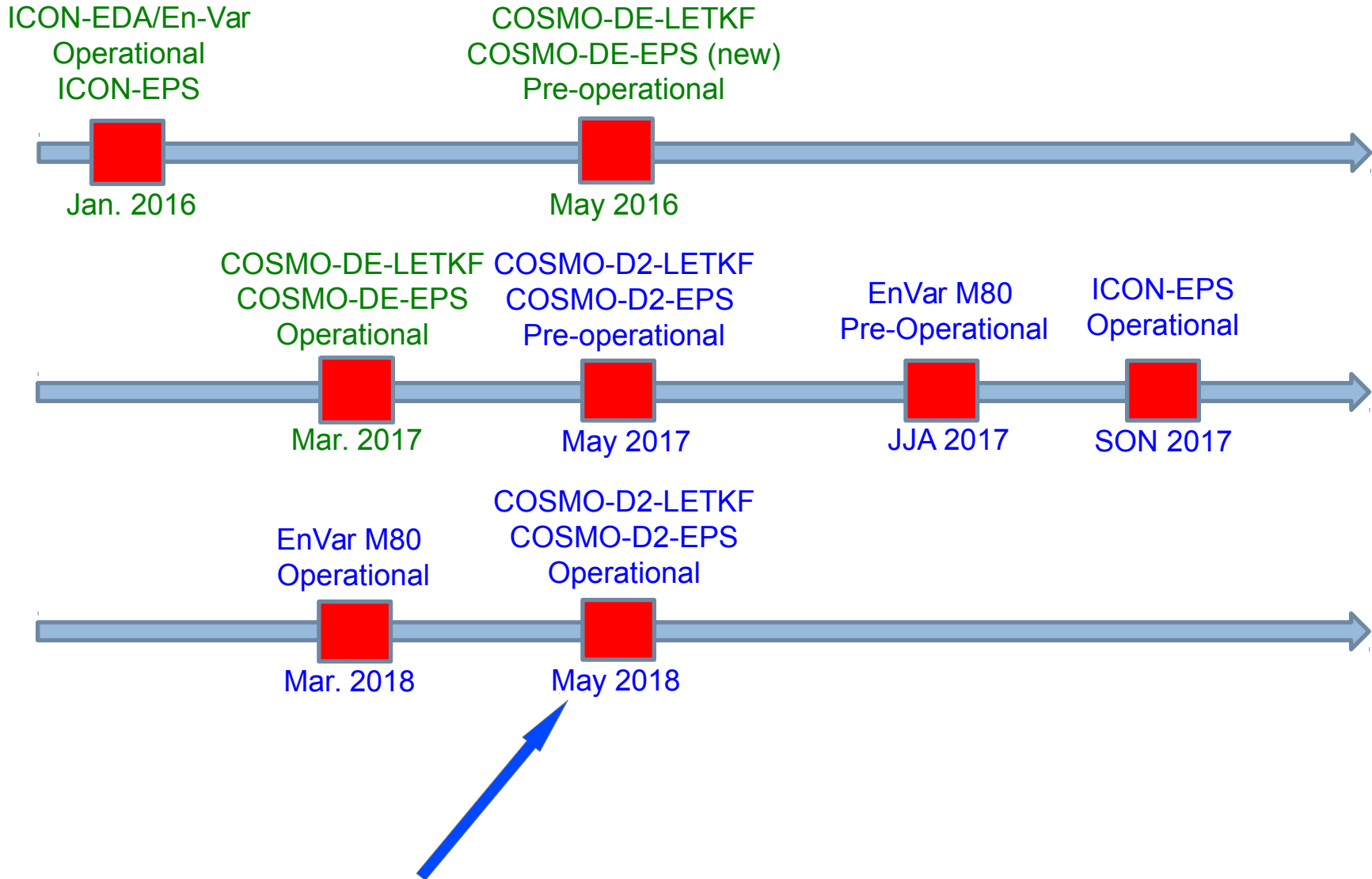
# Schedule of larger NWP developments at DWD 2016 - 2018



# Schedule of larger NWP developments at DWD 2016 - 2018



# Schedule of larger NWP developments at DWD 2016 - 2018



# Some System Issues: now → 2018

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## Data handling

- Data amount (Routine + P-Suite)

COSMO	+ 12 TB/day
ICON	+ 8 TB/day

→ into archive system, excluding experiments !!!

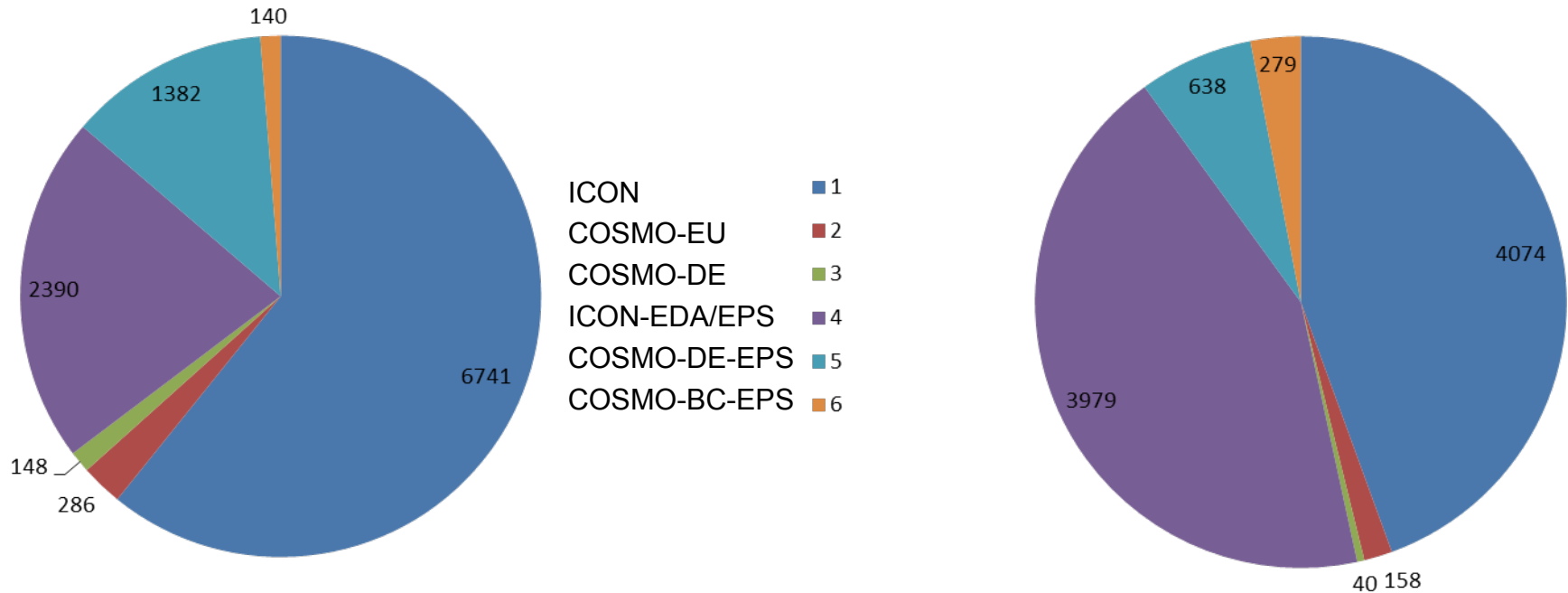
- Data transfer rate (HPC → database)

max.                    750 MB/s → 1500 MB/s

- What to do?

- increase the performance of datahandling system (network, I/O, ..)
- asynchronous data transfer
- data exchange from local disks, not database

# NWP data production (GByte / day)



**Operational NWP**  
**13334 GByte / day**

**Pre-operational NWP**  
**9168 GByte / day**



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## Job control

- Haswell / Broadwell

February 2017	COSMO	→	Haswell
	ICON	→	Broadwell
March 2017	COSMO	→	Haswell + Broadwell
(KENDA)	ICON	→	Broadwell

→ binary compatibility !!!

- ICON-EDA

EnVar40 → EnVar80

PBS: 80 Jobs immediately on HPC

→ Suspend / Resume

→ I/O: Data and Metadata

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- Haswell / Broadwell

February 2017	COSMO	→	Haswell
	ICON	→	Broadwell
March 2017	COSMO	→	Haswell + Broadwell
(KENDA)	ICON	→	Broadwell

→ binary compatibility !!!

- ICON-EDA

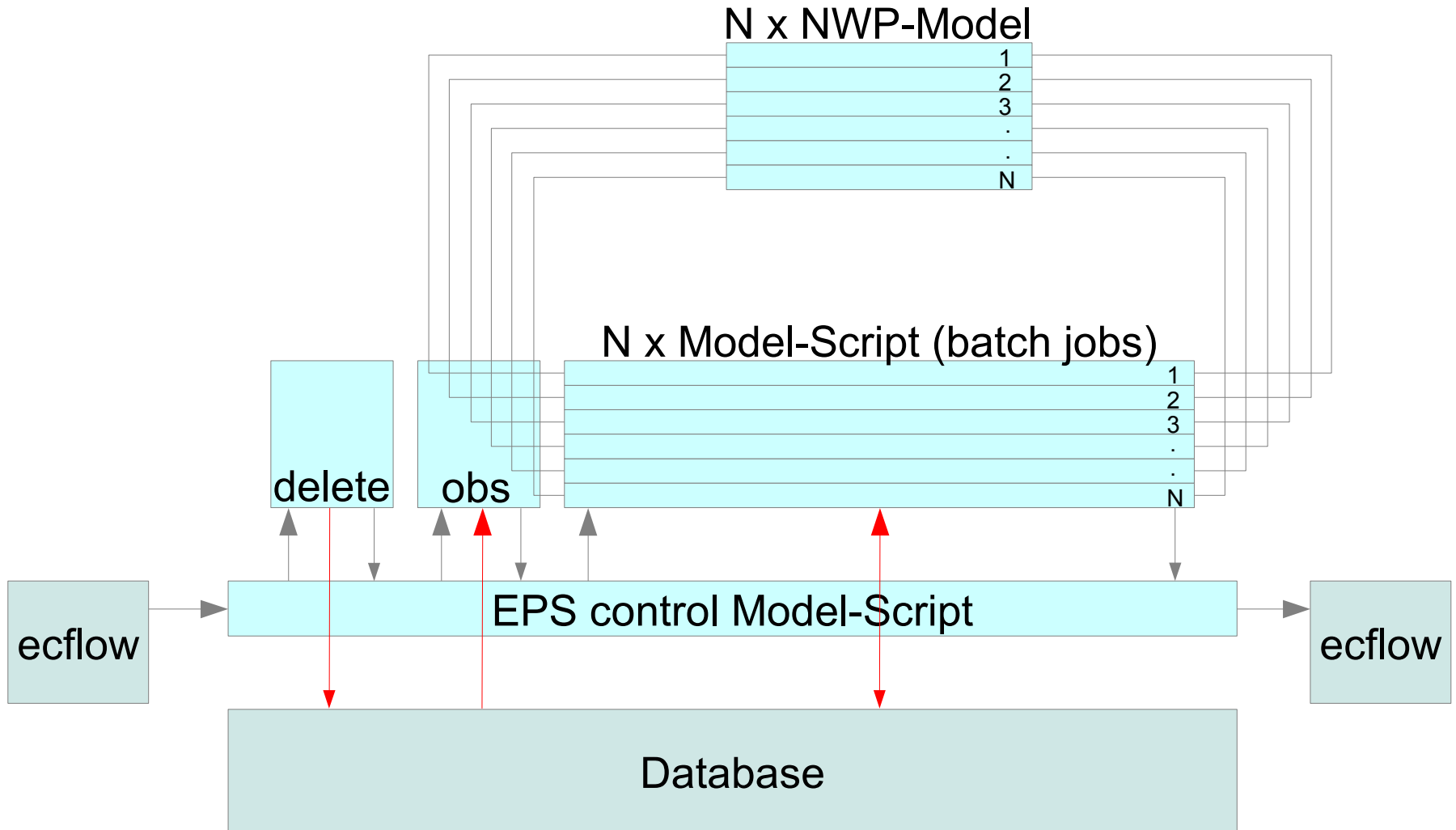
EnVar40 → EnVar80

PBS: 80 Jobs immediately on HPC

→ Suspend / Resume

→ I/O: Data and Metadata

# Operational Job Control - EPS



# Some System Issues: now → 2018

## Job control

- Haswell / Broadwell

February 2017	COSMO	→	Haswell
	ICON	→	Broadwell
March 2017	COSMO	→	Haswell + Broadwell
(KENDA)	ICON	→	Broadwell

→ binary compatibility

- ICON-EDA

EnVar40 → EnVar80

PBS: 80 Jobs immediately on HPC

→ Suspend / Resume

→ I/O: Data and Metadata



A large crowd of people is gathered at an outdoor event, likely a music festival, during a heavy rainstorm. Many individuals are wearing raincoats, ponchos, and hoods. The ground is muddy and reflective. The scene is filled with people of various ages and styles, some looking towards the camera and others engaged in conversation or walking. The overall atmosphere is one of a busy, weathered outdoor gathering.

**Thank you for your  
attention!**

**Any questions?**