国家气象信息中心
National Meteorological Information Centre

国家气象科学数据中心
中国气象局气象数据中心

The 21th Workshop on High Performance Computing in Meteorology

Past, Present and Future of HPC at the CMA

Shuai Deng and many colleagues

National Meteorological Information Centre (NMIC)
China Meteorological Administration (CMA)

Who We Are

We‘re a team from **the Advanced Computing Division,** National Meteorological Information Centre (NMIC) of China Meteorological Administration (CMA).

The main responsibility includes :

- Develop HPC systems capacity
- Develop HPC-Supportive platforms
- Maintain system operations
- Track cutting-edge tech

CONTENTS

- The Evolution of HPC at the CMA
- HPC-Supportive Platforms
- Track Cutting-edge Tech

The Evolution of HPC

Modern weather forecasting is a comprehensive system encompassing meteorological observation, information infrastructure, numerical models, analysis and forecasting, and meteorological services.

Meteorological Observation

China has basically established a comprehensive meteorological observation system.

Information Infrastructure

Established a robust foundation of data, platforms, and security support.

Numerical Models

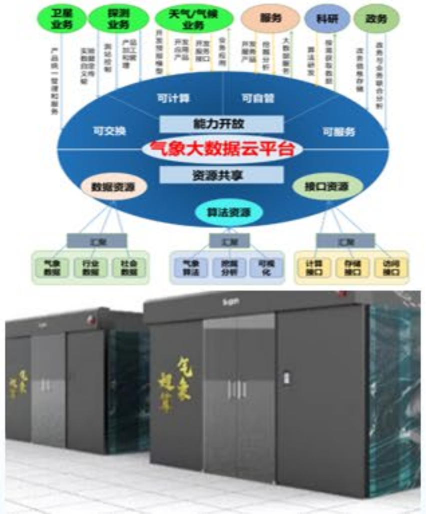
Established a comprehensive operational numerical forecasting system.

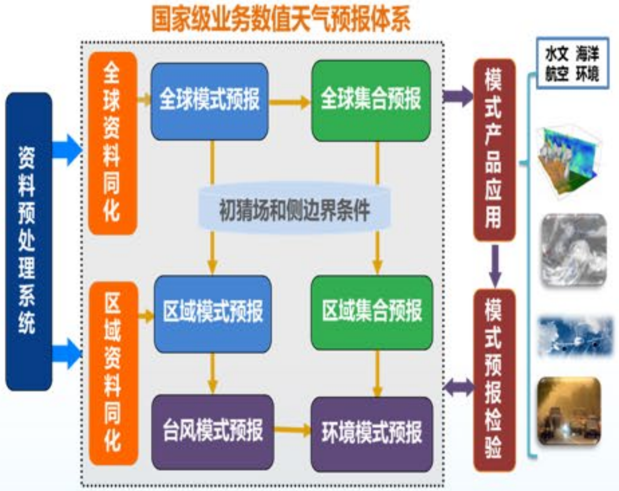
Analysis & Forecasting

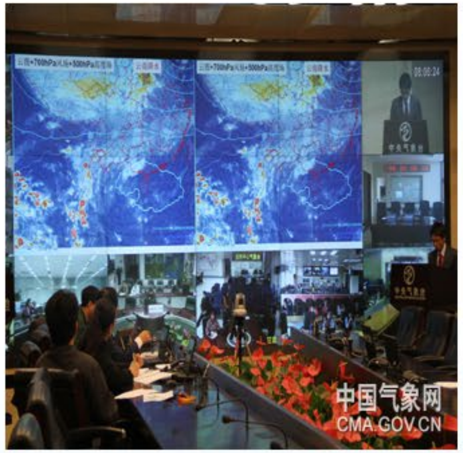
Forecast results are generated through forecasters' comprehensive analysis and forecast discussions.

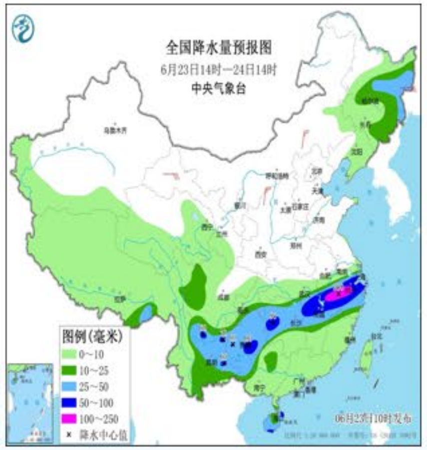
Meteorological Services

Provide a variety of meteorological services, including public services, industry services, and decision-making services.


卫星业务
探测业务
天气/气候业务
服务
科研
政务
可计算
可自管
可交换
可服务
能力开放
气象大数据云平台
资源共享
数据资源
接口资源
算法资源
汇聚
汇聚
汇聚
气象数据
行业数据
社会数据
气象算法
数据分析
可视化
计算接口
存储接口
访问接口

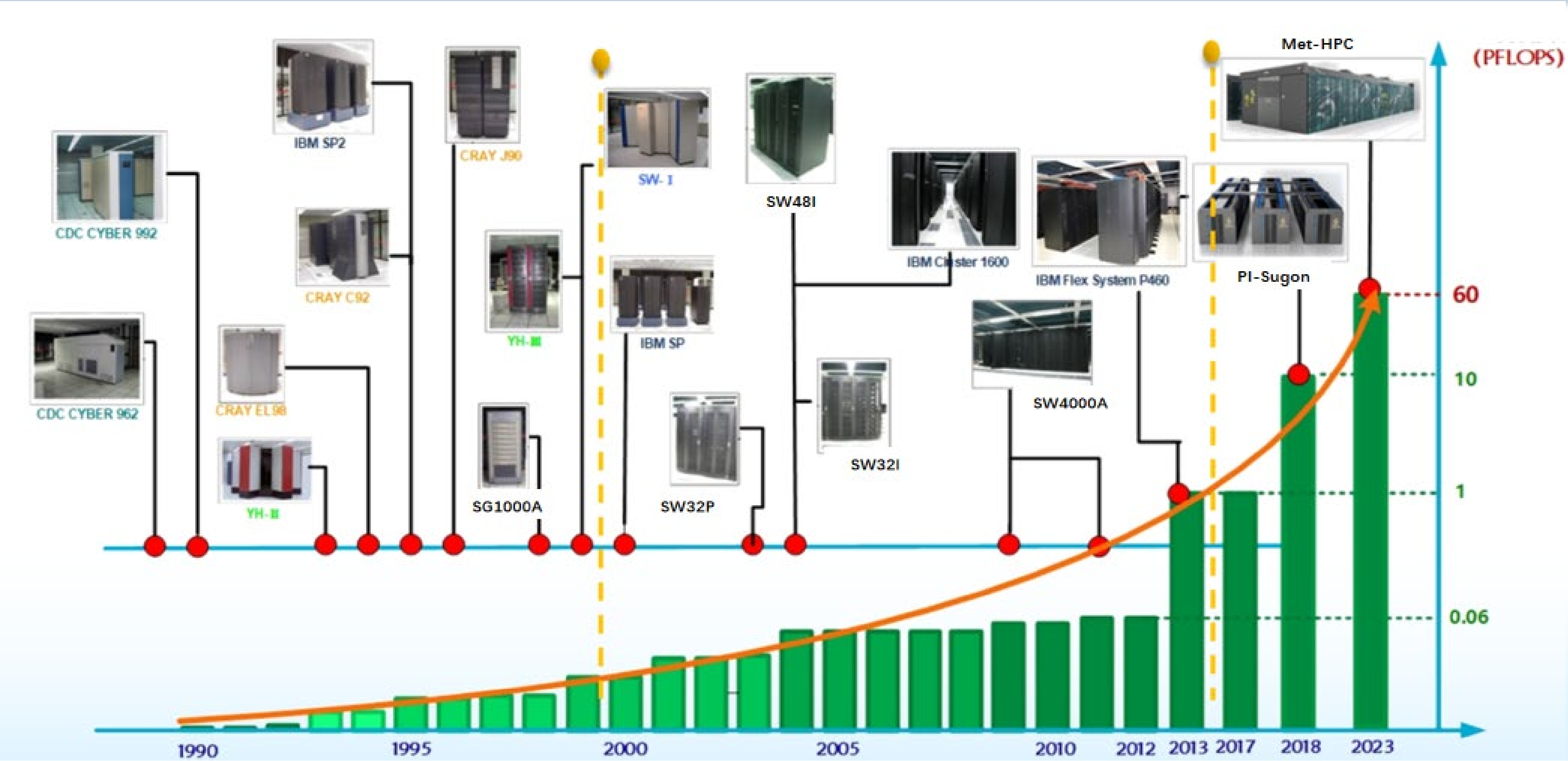

国家级业务数值天气预报体系
资料预处理系统
全球资料同化
全球模式预报
全球集合预报
初猜场和侧边界条件
区域资料同化
区域模式预报
区域集合预报
台风模式预报
环境模式预报
模式产品应用
模式预报检验
水文 海洋
航空 环境


中国气象网
CMA.GOV.CN


全国降水量预报图
6月23日14时—24日14时
中央气象台
图例(毫米)
0~10
10~25
25~50
50~100
100~250
× 降水中心值

The Evolution of HPC

The development of supercomputing at the China Meteorological Administration began in 1985, making it the earliest department in China to adopt supercomputing system.



The Evolution of HPC

Layout of CMA HPC System

- ➢ 4 subsystems located in Beijing
  - Pi-HPC : 2 subsytems
  - Met-HPC : 2 subsytems
- ➢ 1 subsytem located in Neimenggu
  - Met-HPC : 1 subsytem
- ➢ > 60PFlops

Neimenggu
Beijing

The Evolution of HPC

Pi HPC System

- **Located in Beijing, built in 2018**
- **Consists of 2 subsystems：** meteorological operational system and meteorological R&D system, backup for each other

- **Meteorological Operational System of Pi**：top rank 74 in TOP500(2018), Xeon Gold 6142 16C 2.6GHz, Infiniband EDR

- **Meteorological R&D System of Pi**：top rank 68 in TOP500(2018), Xeon Gold 6142 16C 2.6GHz, Infiniband EDR, NVIDIA Tesla P100

NMIC
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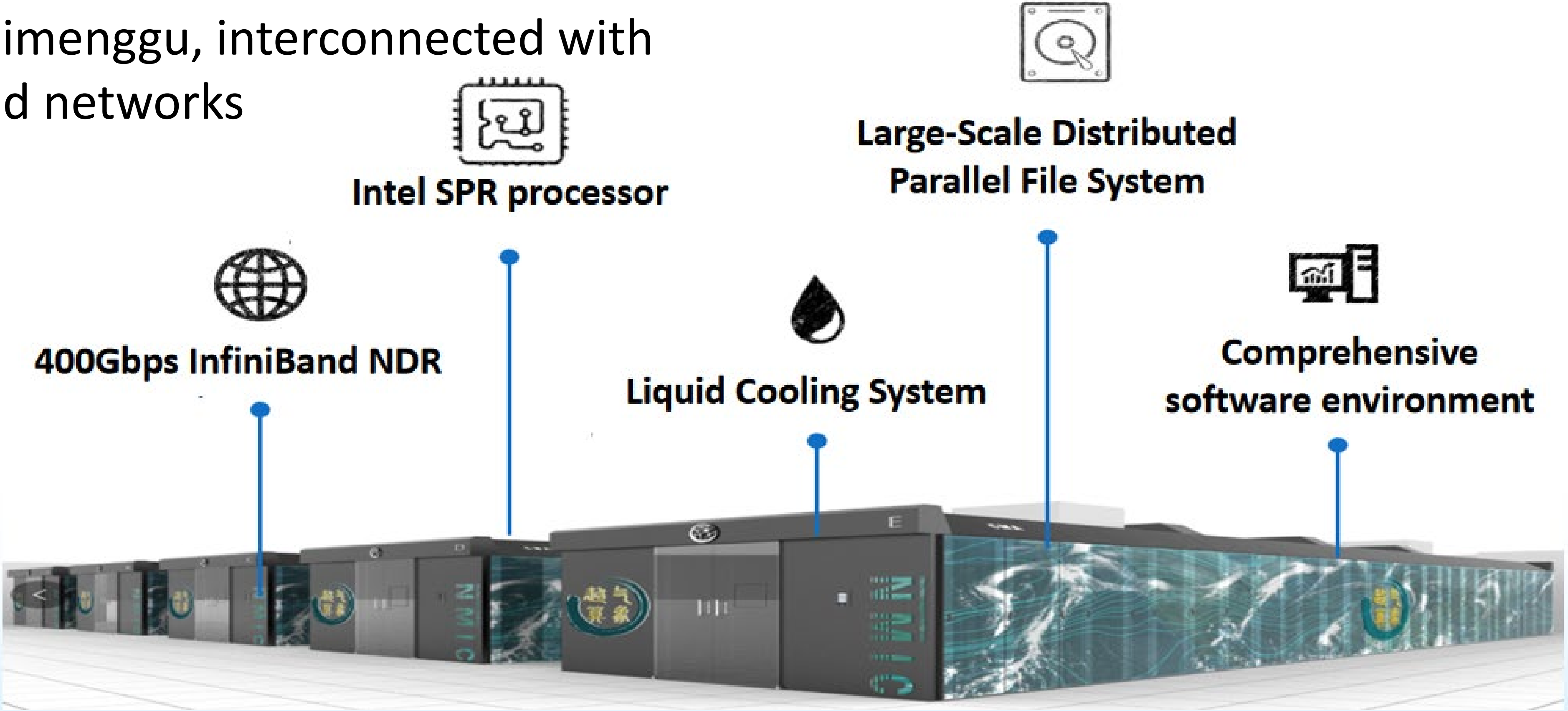
The Evolution of HPC

Met-HPC System

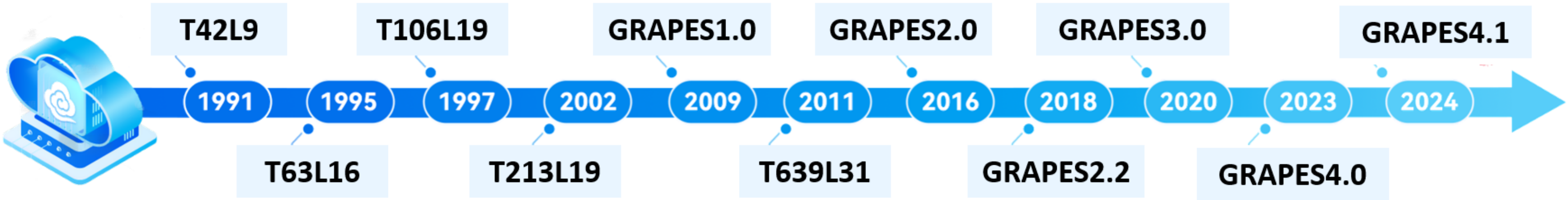
- **Named as Meteorological HPC system, built in 2023**
- **Consists of 3 subsystems :**
  operational system and R&D system in Beijing
  backup system in Neimenggu, interconnected with Beijing via high-speed networks

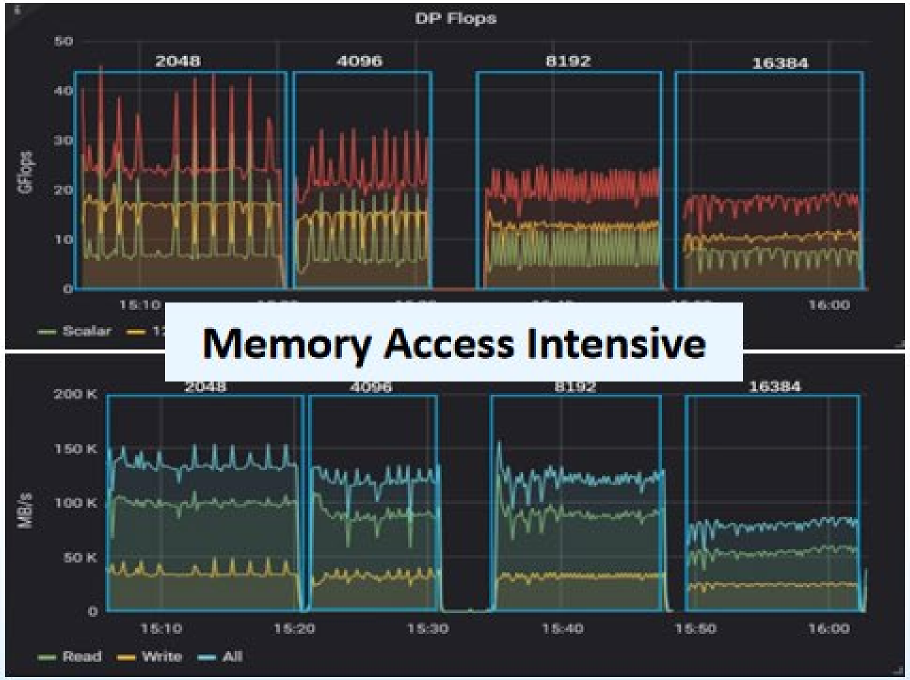
CMA Supercomputing Center

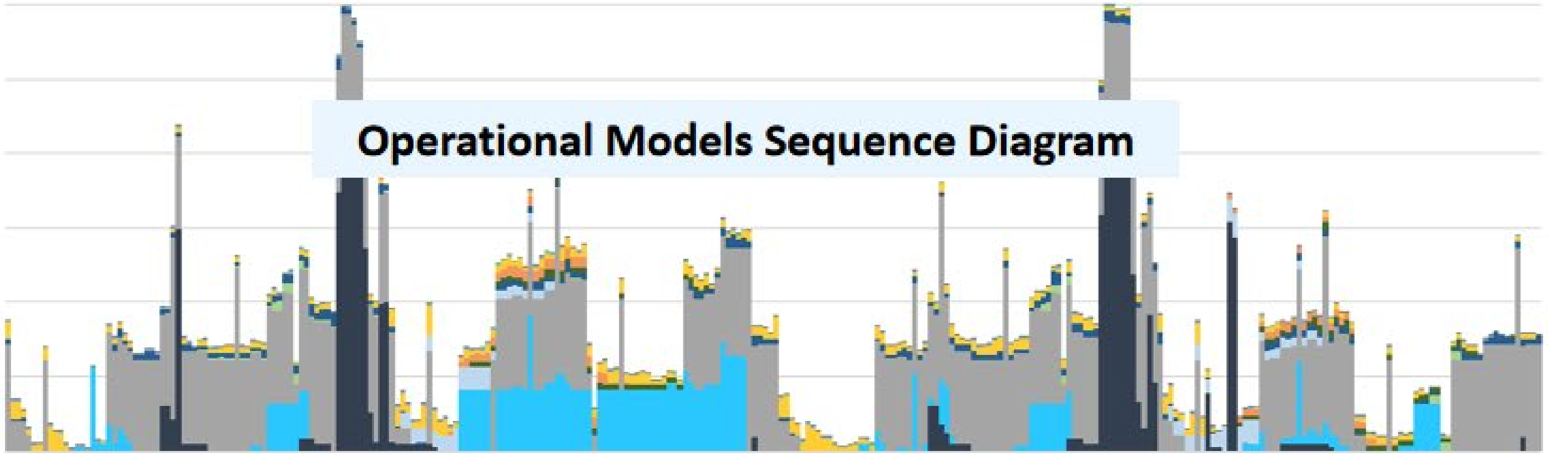

Large-Scale Distributed Parallel File System
Intel SPR processor
400Gbps InfiniBand NDR
Liquid Cooling System
Comprehensive software environment
NMIC

The Evolution of HPC

The iterative upgrades of supercomputing systems have propelled the rapid advancement of numerical forecasting operations.

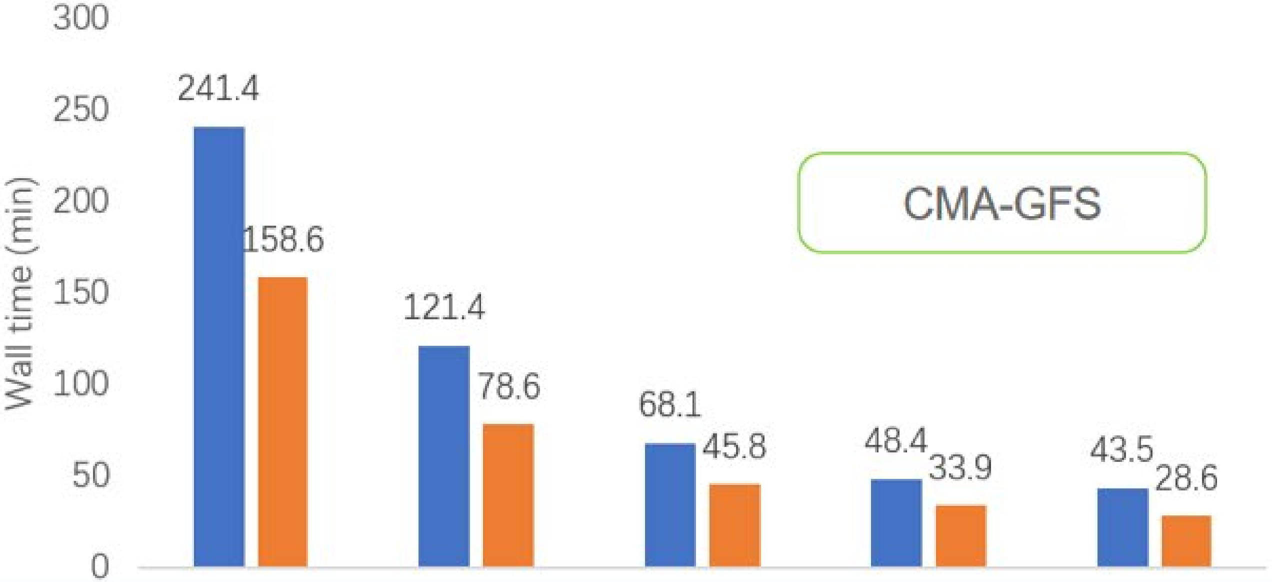

T42L9
T106L19
GRAPES1.0
GRAPES2.0
GRAPES3.0
GRAPES4.1
1991
1995
1997
2002
2009
2011
2016
2018
2020
2023
2024
T63L16
T213L19
T639L31
GRAPES2.2
GRAPES4.0

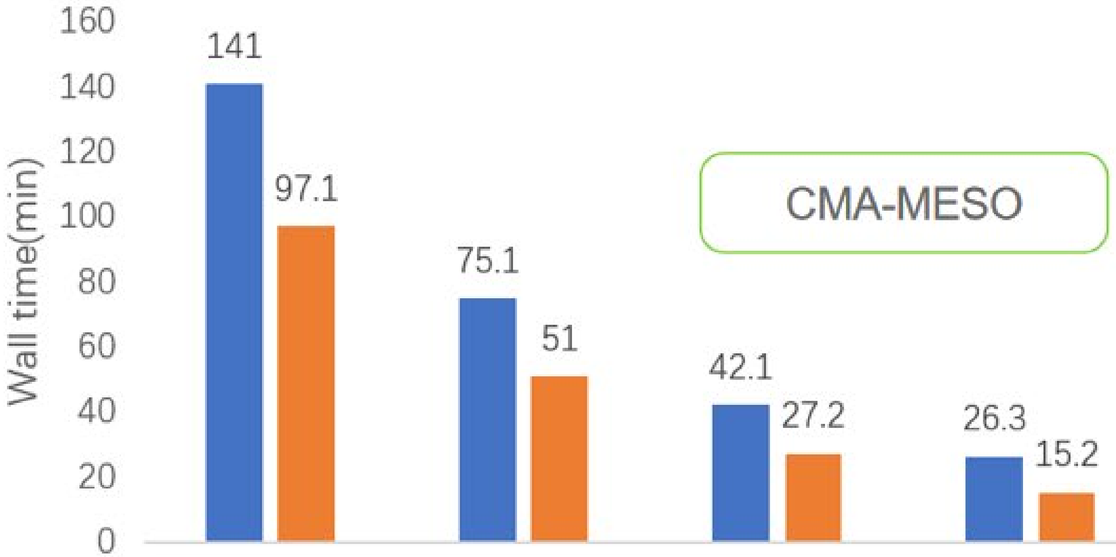




The Evolution of HPC

Test results for the scalability of the NWP models across different HPC systems.





CONTENTS

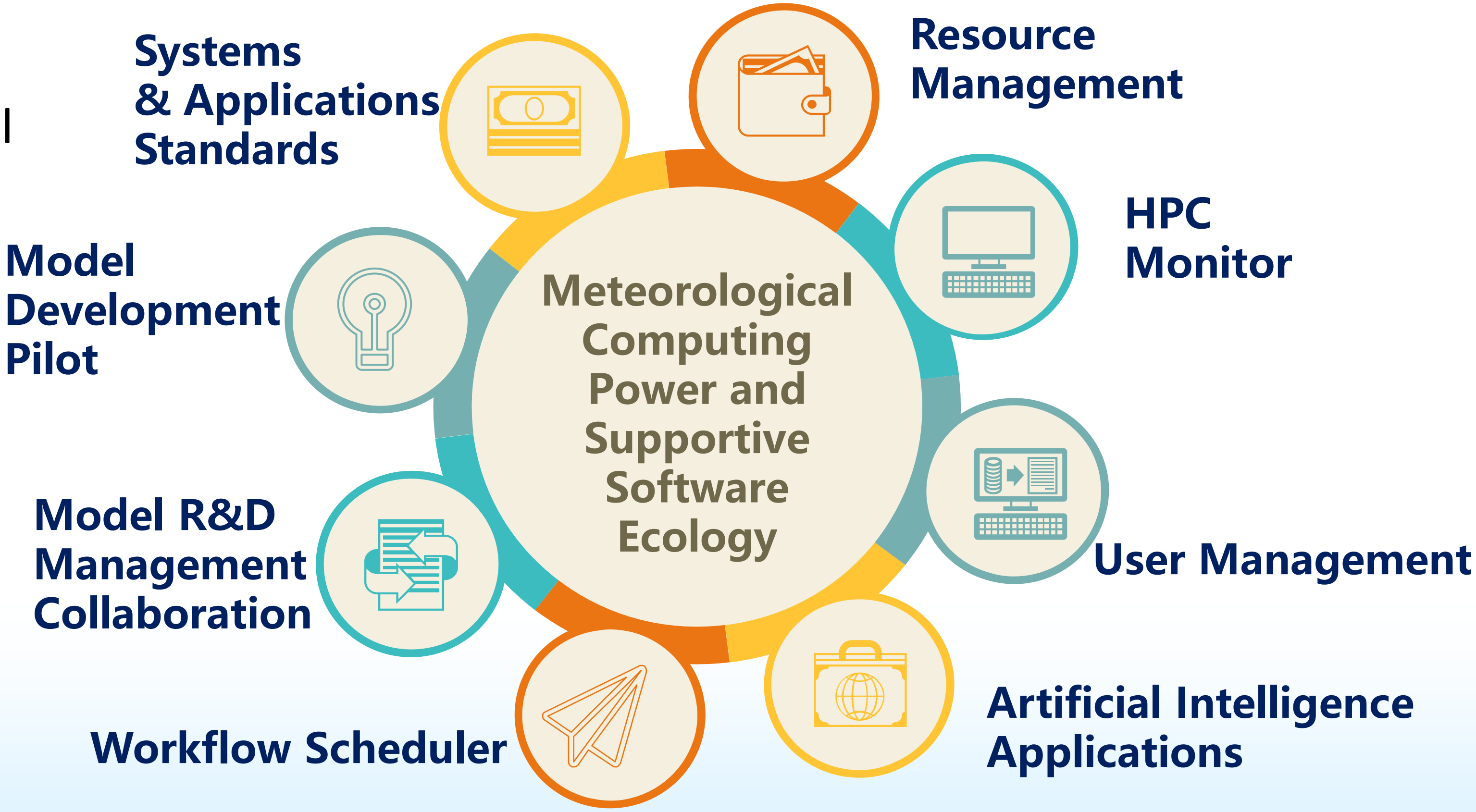
- The Evolution of HPC at the CMA
- HPC-Supportive Platforms
- Track Cutting-edge Tech

HPC-Supportive Platforms

Meteorological Computing Power and Supportive Software Ecology

Preliminarily established the application support software ecology of meteorological computing power resources.

- ✓ System operation and management
- ✓ Model operation
- ✓ Scientific research support


Systems & Applications Standards
Resource Management
HPC Monitor
Model Development Pilot
Meteorological Computing Power and Supportive Software Ecology
User Management
Model R&D Management Collaboration
Workflow Scheduler
Artificial Intelligence Applications

HPC-Supportive Platforms

Management Analysis of Computing Resource

HPC

Applications

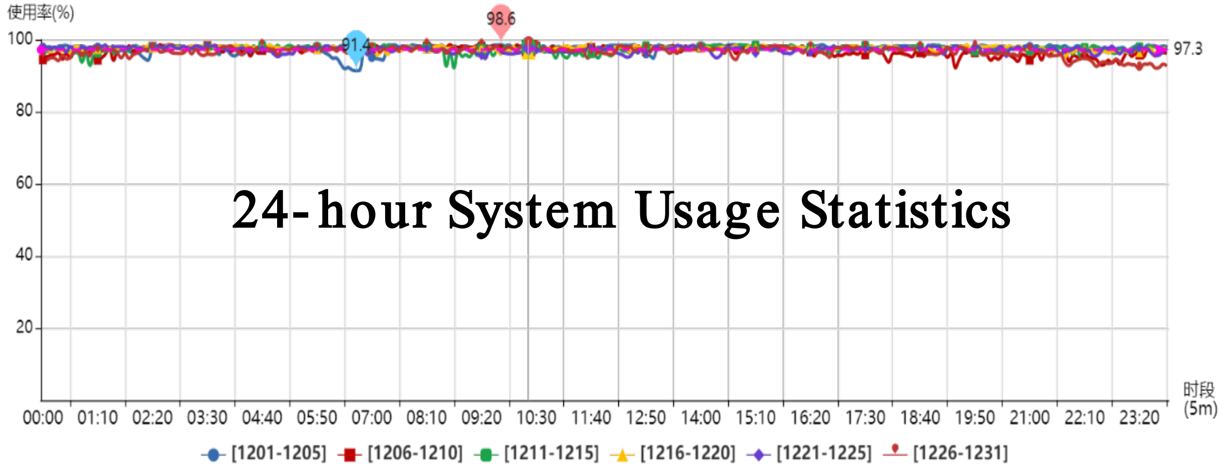
□ □□□

Multiple Resource Analysis

Costing

Monitor

Monthly Report



24-hour System Usage Statistics

Scientific management of supercomputing resources

Resource Allocation

Scheduling Strategy

Behavioral Monitoring

Optimization of Efficiency

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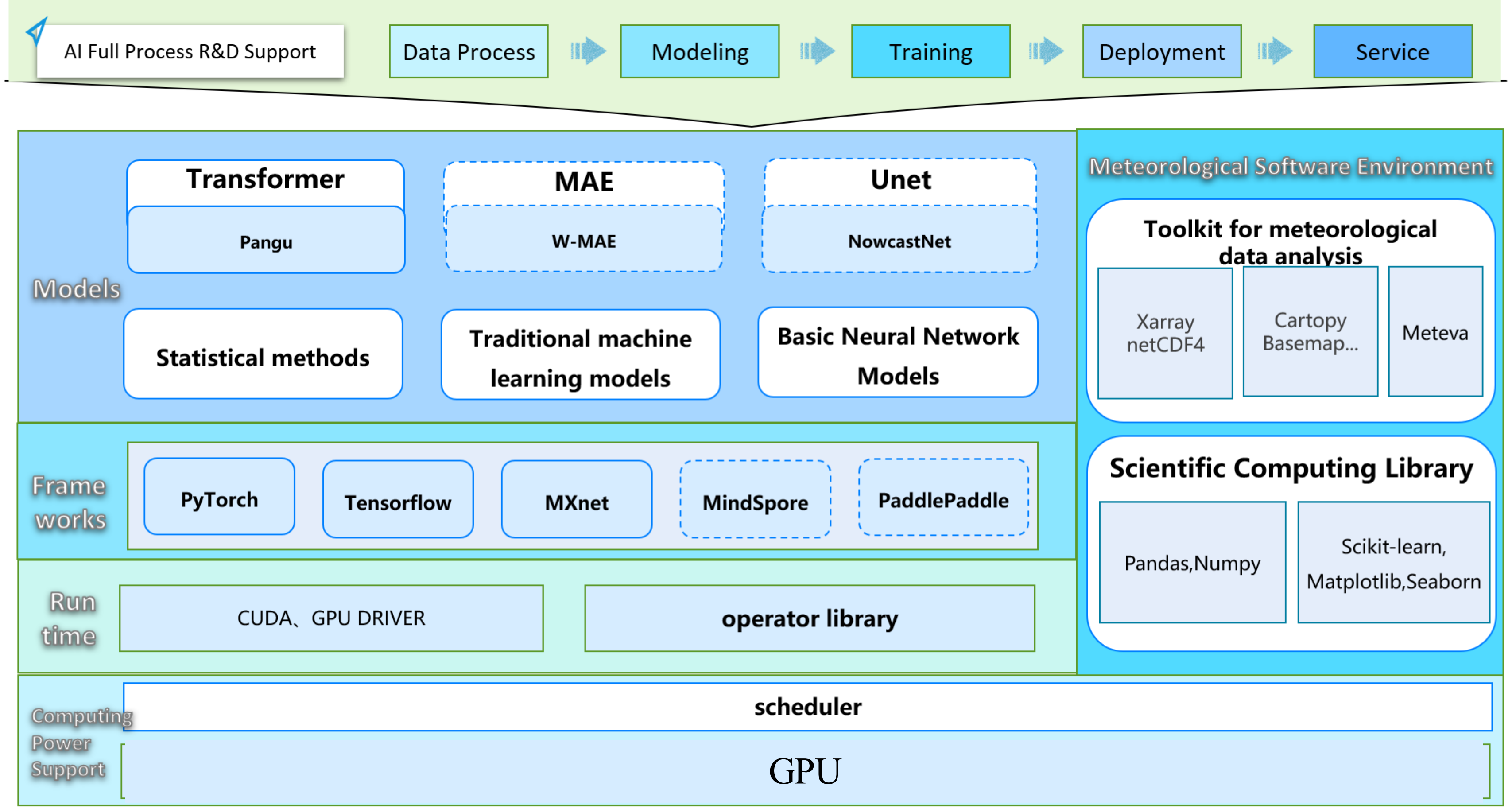
HPC-Supportive Platforms

AI Weather Support Platform



AI Full Process R&D Support

Data Process → Modeling → Training → Deployment → Service

Models

- **Transformer**
  - Pangu
- **MAE**
  - W-MAE
- **Unet**
  - NowcastNet
- **Statistical methods**
- **Traditional machine learning models**
- **Basic Neural Network Models**

Frame works

- **PyTorch**
- **Tensorflow**
- **MXnet**
- **MindSpore**
- **PaddlePaddle**

Run time

- CUDA、GPU DRIVER
- **operator library**

Computing Power Support

- **scheduler**
- GPU

Meteorological Software Environment

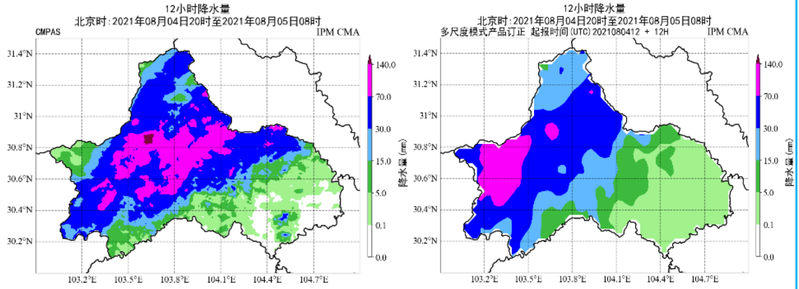
Toolkit for meteorological data analysis

- Xarray netCDF4
- Cartopy Basemap...
- Meteva

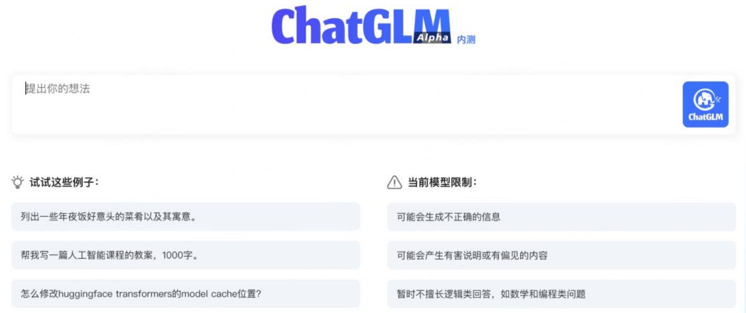
Scientific Computing Library

- Pandas,Numpy
- Scikit-learn, Matplotlib,Seaborn

Objectivized revision of precipitation products for multiscale numerical model forecasting


12小时降水量
北京时：2021年08月04日20时至2021年08月05日08时
CMPAS
IPM CMA
31.4°N
31.2°N
31°N
30.8°N
30.6°N
30.4°N
30.2°N
103.2°E
103.5°E
103.8°E
104.1°E
104.4°E
104.7°E
140.0
70.0
30.0
15.0
5.0
0.1
0.0
降水量 (mm)
12小时降水量
北京时：2021年08月04日20时至2021年08月05日08时
多尺度模式产品订正 起报时间 (UTC) 2021080412 + 12H
IPM CMA

Conducting Chat Smart Q&A Model Run Tests


ChatGLM Alpha 内测
ChatGLM

提出你的想法

试试这些例子：

- 列出一些年夜饭好意头的菜肴以及其寓意。
- 帮我写一篇人工智能课程的教案，1000字。
- 怎么修改huggingface transformers的model cache位置?

当前模型限制：

- 可能会生成不正确的信息
- 可能会产生有害说明或有偏见的内容
- 暂时不擅长逻辑类回答，如数学和编程类问题

HPC-Supportive Platforms

CMA AI FORCASTING SYSTEMS

CMA AI GLOBAL MEDIUM-TO-SHORT-TERM FORECASTING SYSTEM

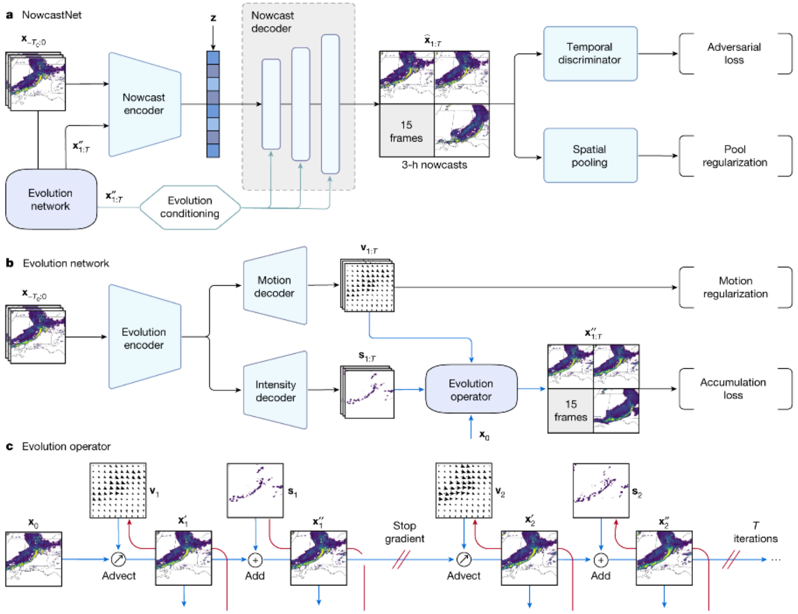
0-15days

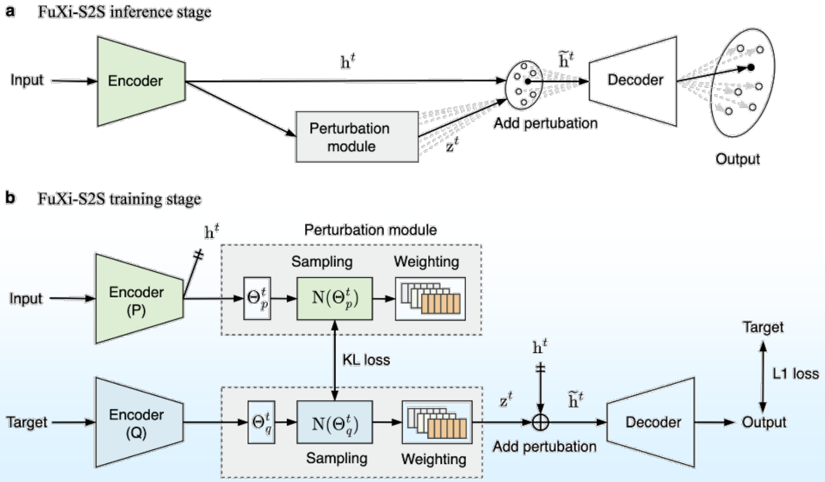
CMA AI NOWCASTING SYSTEM

0-3 Hours

CMA AI GLOBAL SUBSEASONAL-TO-SEASONAL PREDICTION SYSTEM

15-60 days


a NowcastNet
Nowcast encoder
Nowcast decoder
z
15 frames
3-h nowcasts
Temporal discriminator
Spatial pooling
Adversarial loss
Pool regularization
Evolution network
Evolution conditioning
b Evolution network
Evolution encoder
Motion decoder
Intensity decoder
Evolution operator
15 frames
Motion regularization
Accumulation loss
c Evolution operator
Advect
Add
Stop gradient
T iterations


a FuXi-S2S inference stage
Input
Encoder
Perturbation module
Add pertubation
Decoder
Output
b FuXi-S2S training stage
Encoder (P)
Encoder (Q)
Perturbation module
Sampling
Weighting
KL loss
Target
Add pertubation
Decoder
Output
L1 loss

ZHANG, Y., LONG, M., CHEN, K. ET AL. SKILFUL NOWCASTING OF EXTREME PRECIPITATION WITH NOWCASTNET. NATURE 619, 526–532 (2023). HTTPS://DOI.ORG/10.1038/S41586-023-06184-4

CHEN, L., ZHONG, X., LI, H. ET AL. A MACHINE LEARNING MODEL THAT OUTPERFORMS CONVENTIONAL GLOBAL SUBSEASONAL FORECAST MODELS. NAT COMMUN 15, 6425 (2024). HTTPS://DOI.ORG/10.1038/S41467-024-50714-1

CONTENTS

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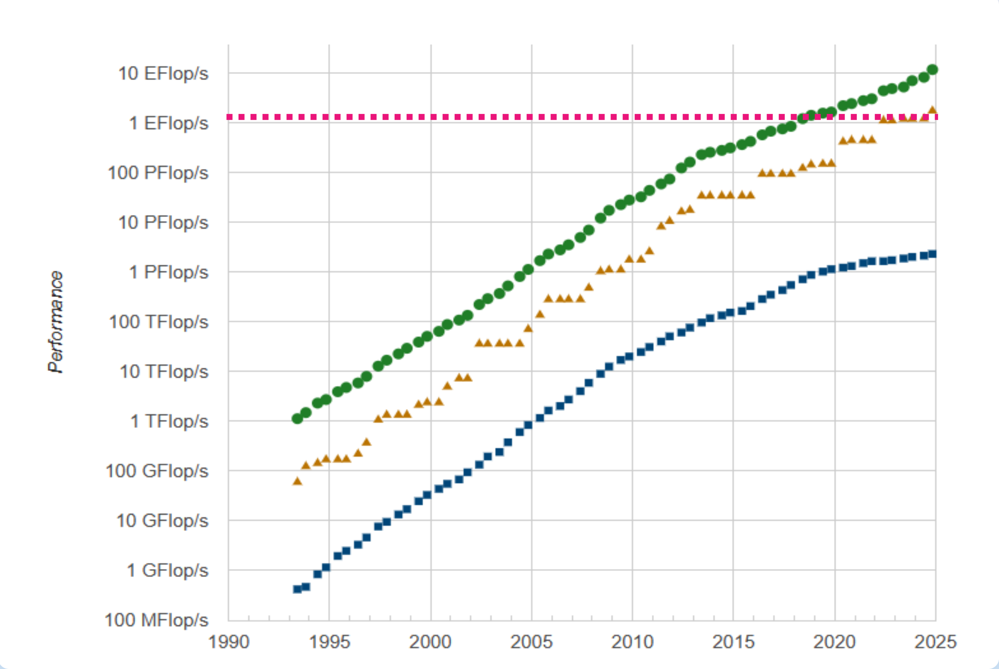
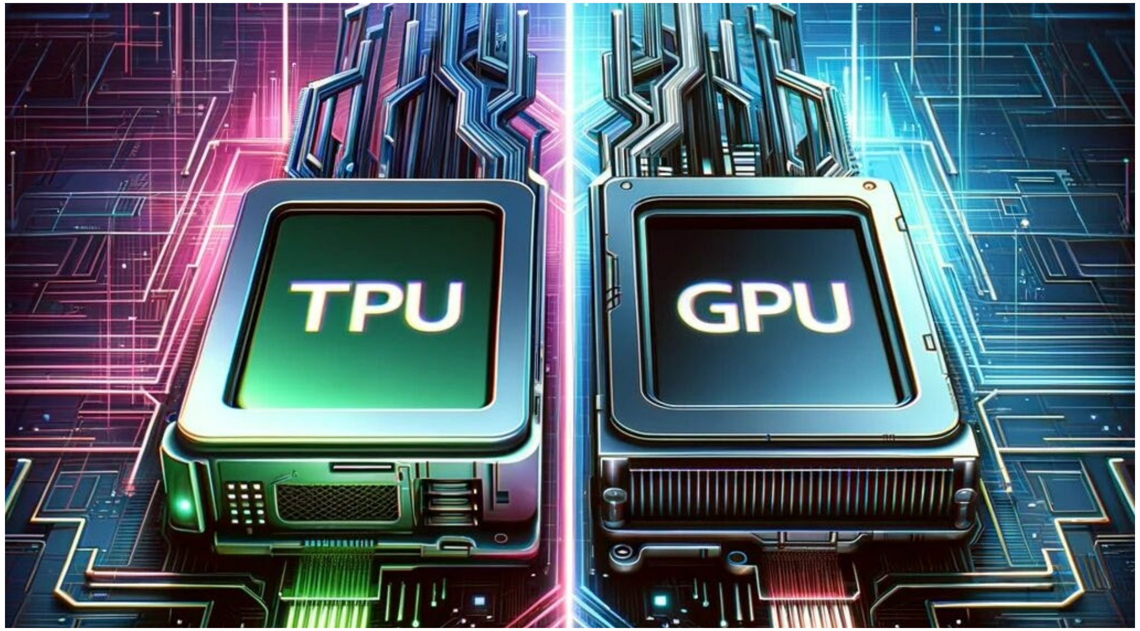
Track Cutting-edge Tech

In the post-Moore's Law era, processor performance growth has slowed, while the demand for computing power in high-performance computing and artificial intelligence continues to rise. Simultaneously, to further reduce system energy consumption and save costs, supercomputing systems are gradually evolving toward heterogeneous architectures, ushering in the exascale era.

The computational power of the world's supercomputing systems continues to advance, with the performance of the most advanced computer systems now exceeding exascale.

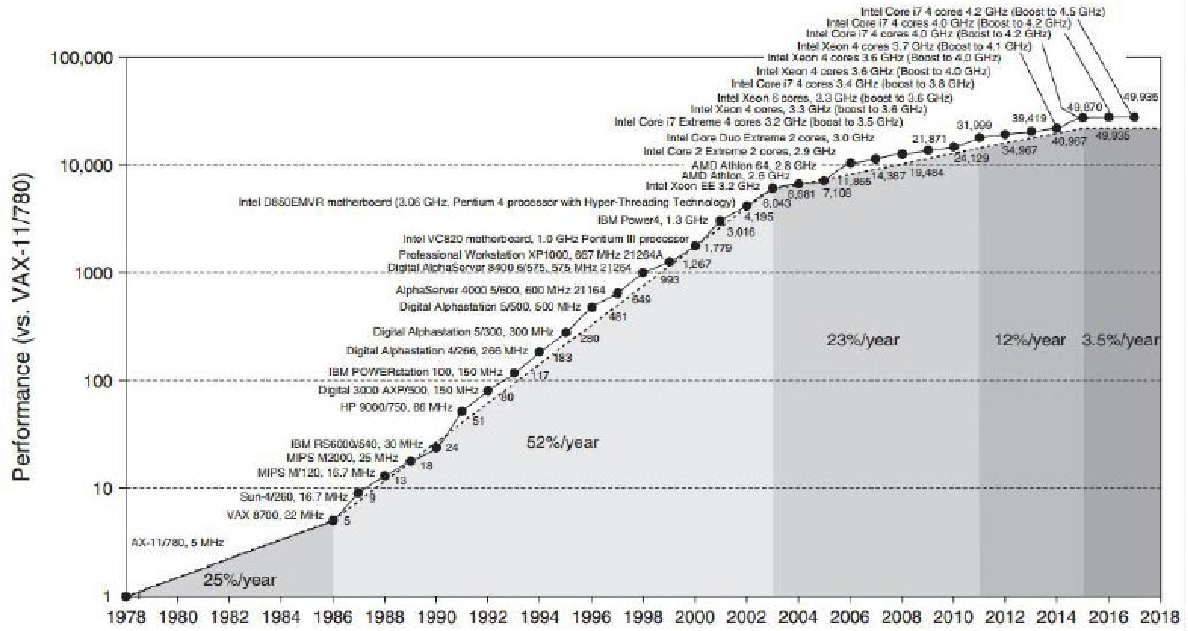


Supercomputing systems are gradually transitioning toward heterogeneous architectures that deliver high computational performance with low energy consumption.

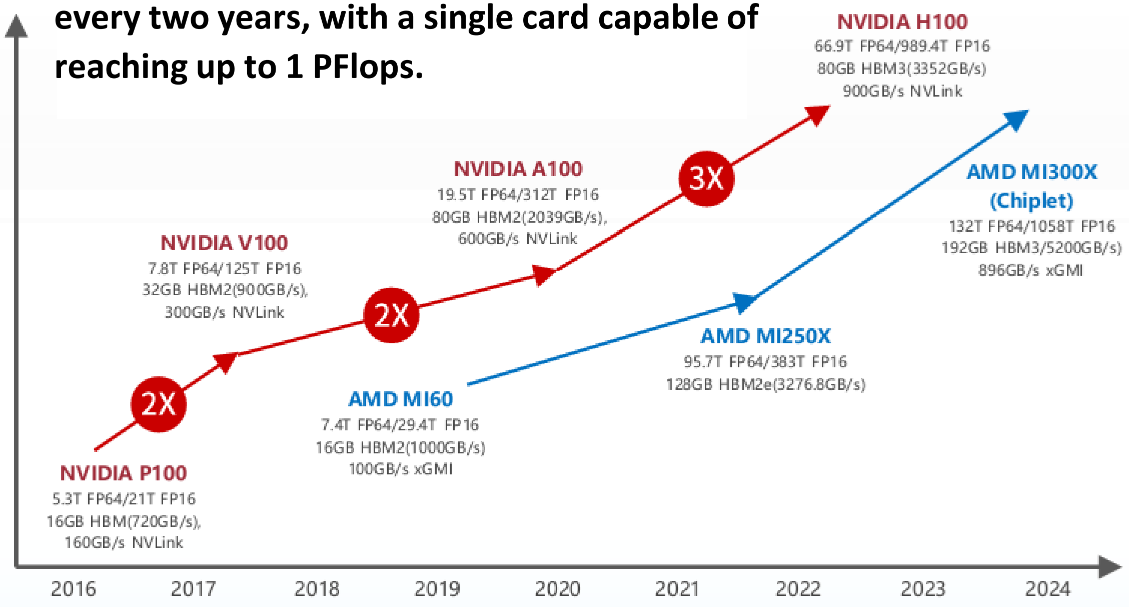


Track Cutting-edge Tech

The explosive growth of artificial intelligence models has triggered a surge in demand for GPU computing power. The development focus of computing power itself has begun shifting from pure CPUs toward GPUs, with the trend toward supercomputing intelligent-computing fusion emerging.



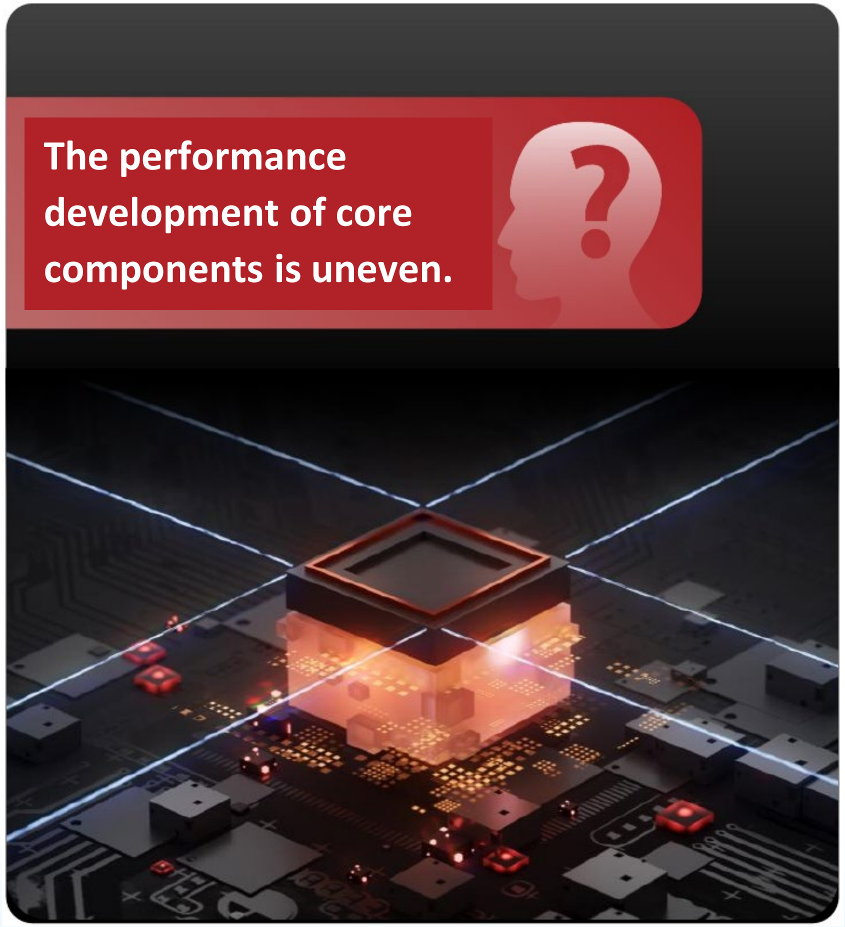
CPU performance gains have slowed down.



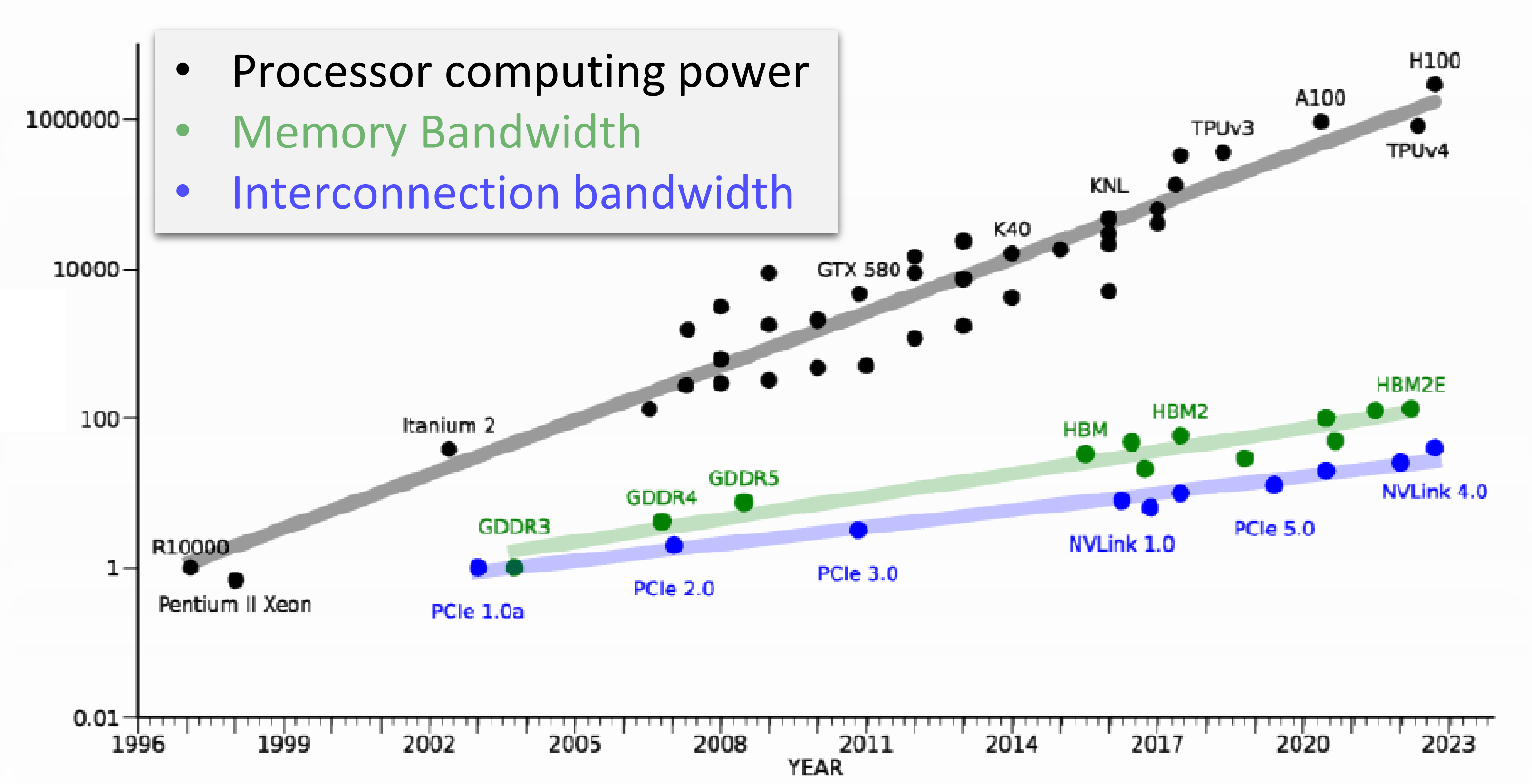
Peak performance is rapidly doubling roughly every two years, with a single card capable of reaching up to 1 PFlops.

GPU performance growth is accelerating.

Track Cutting-edge Tech

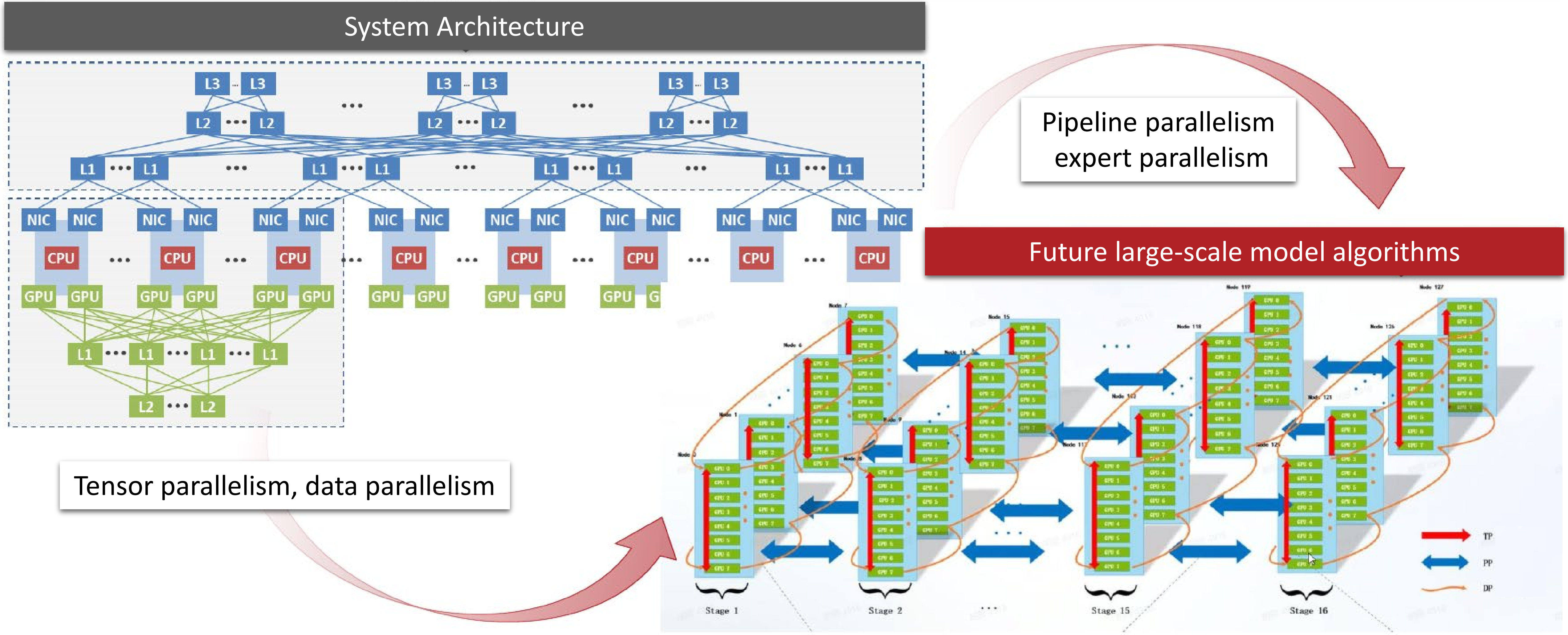


The performance development of core components is uneven.



Track Cutting-edge Tech

The supercomputing intelligence-computing fusion architecture must be highly compatible with the distributed algorithms of future large models.



System Architecture

Pipeline parallelism
expert parallelism

Future large-scale model algorithms

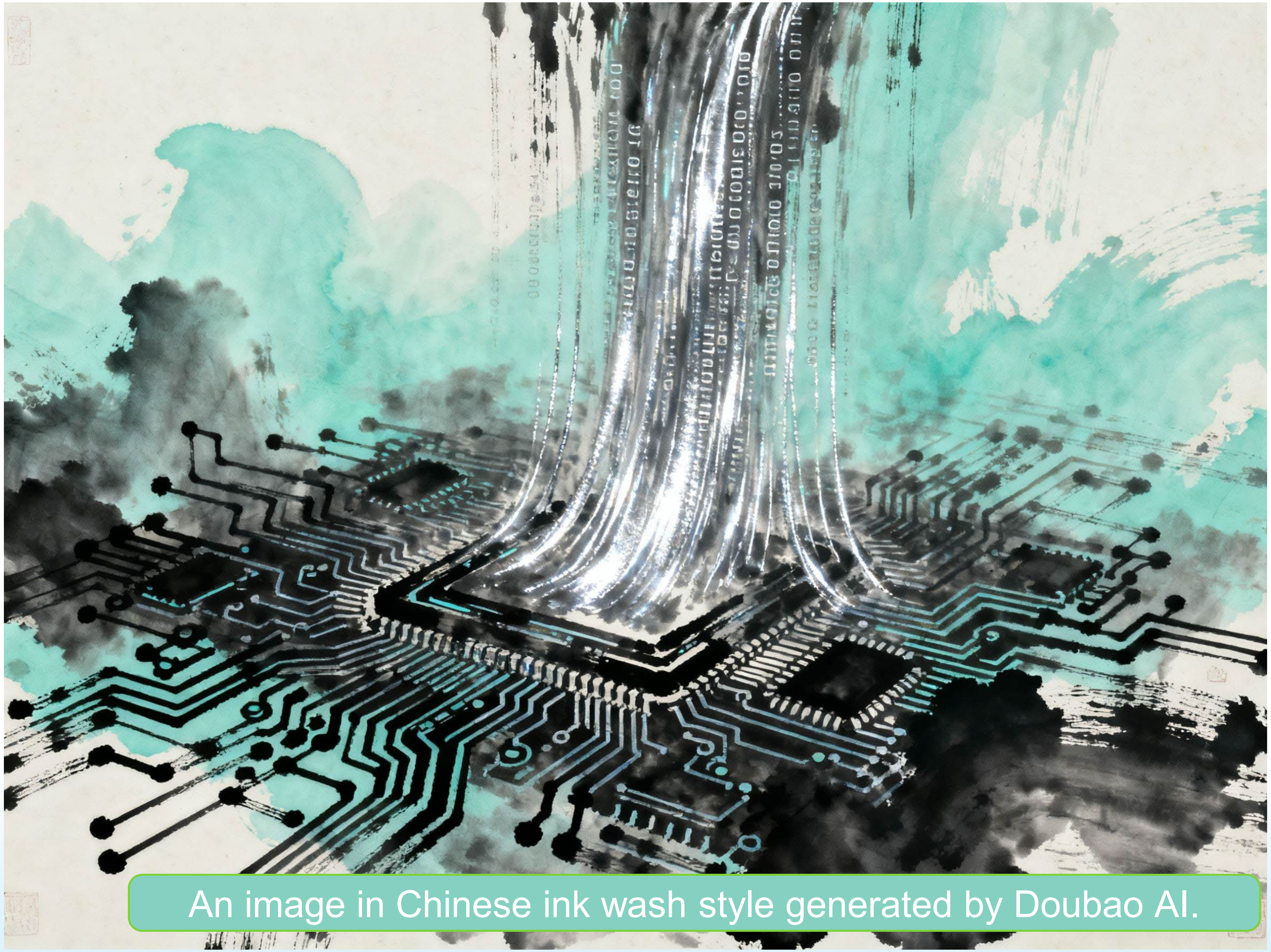
Tensor parallelism, data parallelism

L3
L2
L1
NIC
CPU
GPU
Node 7
Node 15
Node 119
Node 127
Node 6
Node 118
Node 126
Node 1
GPU 0
GPU 1
GPU 2
GPU 3
GPU 4
GPU 5
GPU 6
GPU 7
Stage 1
Stage 2
Stage 15
Stage 16
TP
PP
DP

THANKS

Thank You for Listenning!

Please contact me (dengshuai@cma.gov.cn) if you have any questions!



An image in Chinese ink wash style generated by Doubao AI.