# The 'ideal' collection of data sets for space weather forecasting

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# How to improve space weather forecasting?
# 10 stages

| Stage | Terresterial weather forecasting |
|---|---|
| 1 | Impact stage: prehistory |
| 2 | “Sky signs”: e.g. approaching thunderstorms |
| 3 | Instrument-based: 17th century |
| 4 | Synoptic systems of storms |
| 5 | Telegraph: 1850s |

| Stage | Terresterial weather forecasting |
|---|---|
| 6 | Modelling: 2nd half 19th century<br>Still subjective |
| 7 | Polar front theory |
| 8 | Objective forecasting |
| 9 | Numerical predictions |
| 10 | Satellite and radar imagery<br>Real-time storm tracking |



based on Siscoe, G. (2006)

# How to improve space weather forecasting?
# 10 stages

| Stage | Space weather forecasting |
|---|---|
| 1 | Impact stage: disruptions telegraph mid 19th century |
| 2 | Relation auroras, sunspots to disturbances |
| 3 | Magnetometer |
| 4 | Magnetic storms are global |
| 5 | Funding of forecast centers for radiocommunication |

| Stage | Space weather forecasting |
|---|---|
| 6 | First forecast rules: e.g. dynamics at active regions |
| 7 | First forecast rules |
| 8 | Operational objective forecast algorithms |
| 9 | Numerical predictions |
| 10 | Real-time tracking of solar wind: attempt by STEREO/HI |



based on Siscoe, G. (2006)

## How to improve space weather forecasting?

- Real-time observations
- More observational data
- Accurate numerical models

# Issues with real-time observations

- **Data gaps**
  - LASCO/C2, STEREO A/B, SDO/AIA, …
- **Latencies**
  - PROBA2, STEREO: up to 15h, LASCO/C2: several hours
- **Anomalies**
  - GOES, SDO
- **Lack of in situ measurements**
  - SOHO/CELIAS, ACE/SWEPAM and /MAG, WIND
  - STEREO/IMPACT A/B

# Instruments for long term observations

| Category | Current situation | Situation/suggestion for next decade(s) |
|---|---|---|
| Ground-based imager | GONG, BASS2000, KSO,... | Better combine observations from different sites |
| Ground-based radiospectrometer | E-Calisto network, RSTN, Culgoora,... | Realtime availability for space weather in standard format |

# Instruments for long term observations

| Category | Current situation | Situation/suggestion for next decade(s) |
|---|---|---|
| Magnetic imager | SDO/HMI | SDO/HMI, new spacecraft? |
| X-ray radiometer | GOES/XRS, PROBA2/LYRA | GOES/XRS, PROBA2/LYRA? |
| EUV imager | SDO/AIA, PROBA2/SWAP | SDO/AIA, PROBA2/SWAP? |
| Coronagraph | SOHO/LASCO (STEREO A/B) | new spacecraft?, PROBA3/ASPIICS: not for SW |
| In situ instrument | ACE/SWEPAM & MAG, WIND, SOHO/CELIAS (STEREO IMPACT A/B) | DISCOVR? Solar Orbiter: not for SW |
| Heliospheric imager | STEREO/HI | new spacecraft? |

## Status of tools/initiatives for space weather forecasting (non-exhaustive)

- **Solar event detection**:

  CACTus, SEEDS (CMEs), CorPITA (EIT, dimmings), SolarDemon (flares, EIT, dimmings), SoFast (flares),...

- **CME**:

  derive speed and direction of propagation via geometric models (e.g. STEREO CAT, Thernisien model,...)

- **Community efforts**:

  Space Weather Scoreboard for CME Arrival, SW email lists

# Status of numerical models

- Operational numerical models: **strongest boost** in performance
- Examples:
  - Flares: Automated Solar Activity Prediction (ASAP)
  - CMEs: ENLIL-WSA model, drag-based model
  - CME/Flares/SEP: MAG4

# Key factors to improve forecast performance: analogy with terresterial weather forecasting

| Terresterial weather | Applied to space weather |
|---|---|
| High resolution data | |
| More observations | |
| Tools and modelling | |

# Key factors to improve forecast performance: analogy with terresterial weather forecasting

| Terresterial weather | Applied to space weather |
|---|---|
| High resolution data | • Solar wind measurements:<br>– successor of ACE?<br>• Exploit innovative, efficient technologies:<br>– solar sail (cfr NanoSail-D),<br>– CubeSat (cfr QB50),<br>– IPS<br>• High resolution (coronagraphic) imaging data |
| More observations | |
| Tools and modelling | |

# Key factors to improve forecast performance: analogy with terresterial weather forecasting

| Terresterial weather | Applied to space weather |
|---|---|
| High resolution data | |
| More observations | • Small spacecraft for space weather<br>• Continuous observations, sustainable missions<br>• More and better coordinated ground-based observations around globe |
| Tools and modelling | |

# Key factors to improve forecast performance: analogy with terresterial weather forecasting

| Terresterial weather | Applied to space weather |
|---|---|
| High resolution data | |
| More observations | |
| Tools and modelling | • Data assimilation<br>• Ensemble modelling<br>• Constant evaluation and feedback<br>• Operational implementation and integration |

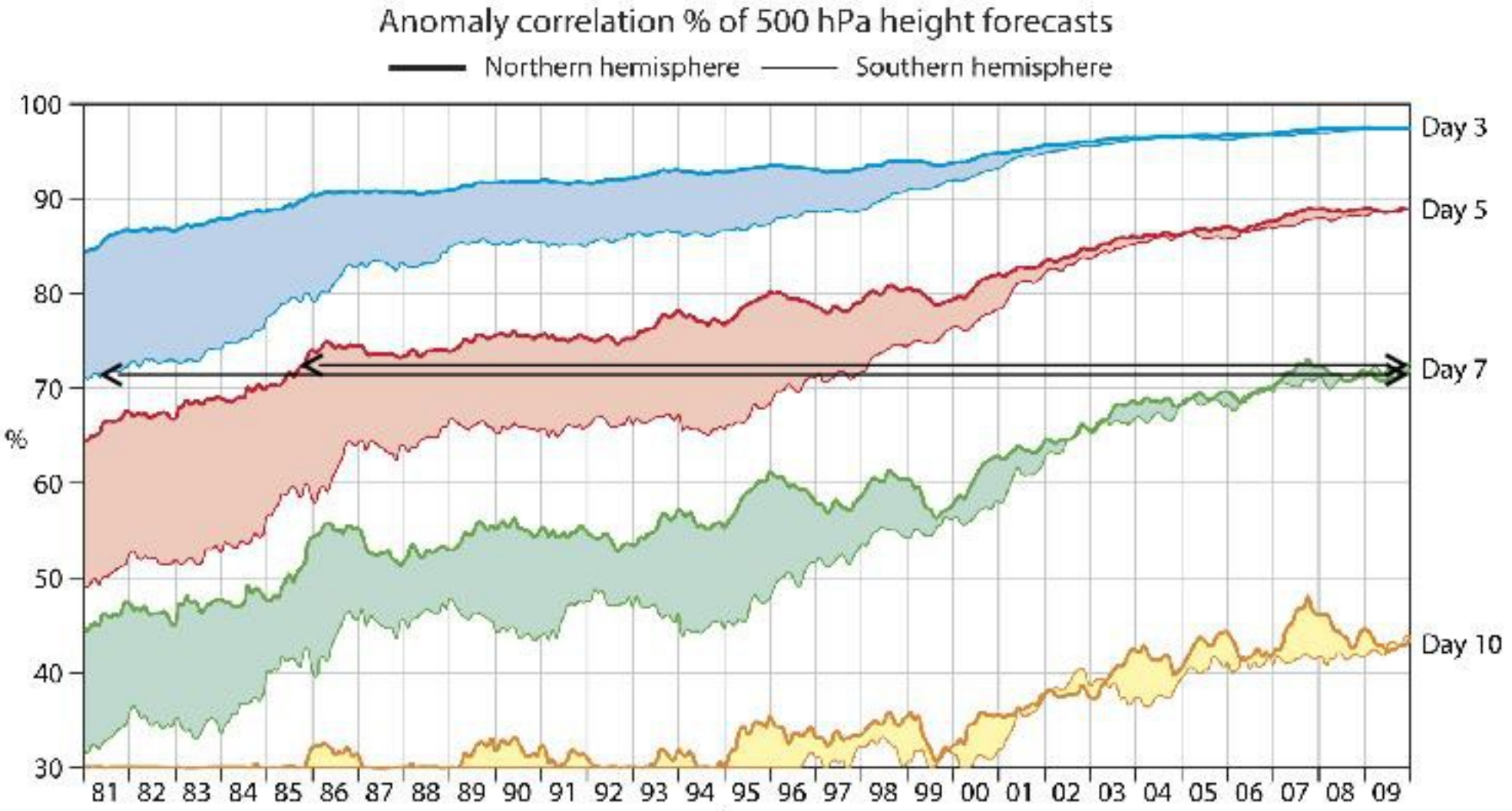
# Other key factors to stimulate evolutions in SW forecast

- **Data management**: combine data

Examples: helioviewer, latest event list (LMSAL), ...

- Make data **more quickly available**
- **Redundancy**
- **Networking** and intense collaboration between institutes
- **Incorporate** space weather at WMO (ISES)
- **Dissemination** and **teach** forecasting
- **Attract potential users**

# To improve forecast performance: investment during several decades






Source: ECMWF