IR satellites – current NWP impact and future considerations

Fiona Smith

NOAA Infrared Sounder Workshop, Dec 2021
## Model configurations

<table>
<thead>
<tr>
<th></th>
<th>Global (ACCESS-G3 and GE3)</th>
<th>City (ACCESS-C3 and CE3)</th>
<th>Tropical Cyclone (ACCESS-TC3)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Deterministic</strong></td>
<td>N1024 (12 km), L70 00, 06, 12, 18 UTC</td>
<td>1.5 km, L80 6 domains Hourly</td>
<td>4 km, L80, Up to 3 relocatable domains 00, 12 UTC</td>
</tr>
<tr>
<td><strong>Ensemble</strong></td>
<td>N400 (36 km), L70 18 members (plus lagging) 00, 06, 12, 18 UTC</td>
<td>2.2 km, L80 12 members (plus lagging) 00, 06, 12, 18 UTC*</td>
<td></td>
</tr>
<tr>
<td><strong>Data assimilation</strong></td>
<td>T-3 :T+3 window Hybrid 4D-Var (N144 + N320)</td>
<td>C3: Hourly cycling 4D-Var</td>
<td>T-3:T+2 window 4D-Var</td>
</tr>
<tr>
<td><strong>Bias Correction</strong></td>
<td>VarBC, with static scan bias correction</td>
<td>Uses VarBC coefficients from G3</td>
<td>Uses VarBC coefficients from G3</td>
</tr>
<tr>
<td><strong>Soil moisture analysis</strong></td>
<td>EKF analysis of screen temperature &amp; humidity and ASCAT soil moisture</td>
<td>Uses Soil moisture analysis from G3</td>
<td>Uses Soil moisture analysis from G3</td>
</tr>
</tbody>
</table>
ACCESS NWP "APS3" Systems (operational since 2019)

ACCESS-G3 (12 km) and GE3 (36 km)
ACCESS-TC3 (4 km): up to 3 relocatable domains
ACCESS-C3 (1.5 km) and CE3 (2.2 km): 7 domains
## Observation usage

<table>
<thead>
<tr>
<th>Type</th>
<th>Instrumentation</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiance</td>
<td>AHI CSR</td>
<td>G3 only</td>
</tr>
<tr>
<td></td>
<td>AIRS</td>
<td>G3 only</td>
</tr>
<tr>
<td></td>
<td>AMSR-2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ATMS (S-NPP, NOAA-20) – Global, Local</td>
<td></td>
</tr>
<tr>
<td></td>
<td>AMSU-A/MHS (Metop-B,C, NOAA-15,18,19) – Global, DBNet, Local</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CrIS (S-NPP, NOAA-20) – Global, Local</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IASI (Metop-B,C) – Global, Local</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SSMI/S</td>
<td>G3 only</td>
</tr>
<tr>
<td>GNSS</td>
<td>GNSS-RO (TerraSAR-X, Metop-B,C, FY3-C,D)</td>
<td>G3 only</td>
</tr>
<tr>
<td></td>
<td>Ground-based integrated WV</td>
<td>Australian stations only</td>
</tr>
<tr>
<td>AMV</td>
<td>AHI (JMA Winds and local winds)</td>
<td>10-min winds in C3</td>
</tr>
<tr>
<td></td>
<td>GOES-16,17</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Meteosat-8,11</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MODIS</td>
<td></td>
</tr>
<tr>
<td>Surface winds</td>
<td>ASCAT (Metop-B,C)</td>
<td>Coastal winds in C3</td>
</tr>
<tr>
<td>Aircraft</td>
<td>AIREPS, AMDAR</td>
<td></td>
</tr>
<tr>
<td>Surface</td>
<td>BUOY, METAR, SHIP, SYNOP (BUFR where available)</td>
<td>G3 and TC3 only</td>
</tr>
<tr>
<td>Sonde</td>
<td>PILOT, TEMP, WINPRO, BUFR Sonde where available</td>
<td></td>
</tr>
<tr>
<td>Radar</td>
<td>Doppler Radar Winds</td>
<td>C3 only</td>
</tr>
</tbody>
</table>
FSO observing systems impact
Australian Region +24 hour forecast error norm

- Unfortunately, old results
- IASI dominates forecast skill in our system
- Note we are not using AIRS at the moment
- Note this slide is prior to use of NOAA-20; expect CrIS impact to be greater in 2021

Total 6-month FSO impact per observing system
Responses to SAT guidance memo

• Many of the comments in this presentation are in relation to the
  • Guidance Memo for Hyperspectral IR sounders written by the SAT team
• I've tried to keep the points general though
• It's not clear whether the memo is about the 'backbone'/'core' sounder capability or additional instruments in a smallsat constellation
  • In general, the Tier 1 proposal seems unambitious relative to current instruments
  • But if that will be mitigated by a constellation/rapid repeat, a lower specification instrument would probably still be useful.
Spectral, Radiometric and Spatial considerations

• These aspects of an instrument create a trade-off space. A perfect instrument would have
  • High spectral resolution, able to resolve absorption lines of chemical constituents free from contamination
  • Incredible radiometric accuracy and stability
  • A small footprint, commensurate with the vertical resolution of the instrument
• You can’t consider these items separately, although minimum performance requirements for each can be set
• The requirements for GEO and LEO instruments are clearly related, but are possibly prioritised differently.
  • Consider NEdT, footprint size and spectral resolution to be hygiene factors.
    • Set a minimum requirement for each
    • then consider the trade-offs separately for each platform and target application
    • then build the best instrument you can for the price
• LW vs SW argument is pertinent here as the instrument may be small
  • It is acknowledged that NWP centres have little experience of using the short-wave channels
    • More problematic RT (e.g. sun-glint, non-LTE)
    • Detectors are less sensitive so generally higher-noise
    • Cloud detection may be trickier
    • Errors are more highly correlated
  • Tier 3 (no MW band) is not really considered desirable even for temperature sounding
• Chemistry applications
  • Require LW band and LW end of the MW band (don't avoid the methane!)
  • High spectral resolution benefits chemistry more than NWP
• Short dwell-time limits the spatial resolution – noise performance trade-off space
  • Too high a spatial resolution may result in an unacceptable noise performance
  • In general, a low-noise instrument is preferable for NWP
• Consider IASI or CrIS to be a baseline instrument, not a stretch-target
• IASI and CrIS are great for NWP
• Spectral and radiometric performance may be somewhat mitigated by a constellation but this is hard to quantify
GEO considerations

• The requirement for full-disk will also limit the dwell time
• Smaller pixels are generally preferable in a GEO instrument, but we do not yet have experience of GEO sounders
  • Applications such as
    • generation of AMVs via emerging science
    • cloud characterisation
    • delivery of information in rapidly developing weather situations like TC
• Might there be future applications such as
  • bush-fire characterisation and smoke detection?
  • air quality event detection and impacts for particular chemical species

• In general, we would prefer a smaller footprint at the expense of spectral resolution for GEO
• Consider MTG-IRS to be a good baseline instrument
• The future is all-sky
  • Provision of heterogeneity information is important
    • A homogeneous cloud is much easier to forward-model
    • NWP Centres consistently request sub-pixel heterogeneity information is included in Hyperspectral IR BUFR products
      • See for example: IASI-NG Science Plan
      • See for example: ITSC DA/NWP Working Group Report 2021
  • The same can be said for surface-affected radiances.
    • Better homogeneity leads to an easier forward modelling process
    • With the advent of NEWP, we are likely to see more coupling of land surface models with atmospheric and ocean models. Surface-affected observations will become easier to use and more important.
Homogeneity requirements also lead to important considerations for footprint size

- A smaller footprint leads to a greater likelihood of finding a homogeneous scene
- Review of CrIS footprint size by ITSC NWP/DA WG in 2016 endorsed a proposal to reduce the size of footprints.
- See Wang et al., 2016 for one aspect of the analysis carried out.

Global model resolutions continue to get smaller

- Small grid boxes are no longer the preserve of limited area models

2 km is very good, maybe too good, but 50 km is too poor, given the vertical resolution of the information in an observation.

- The gap between 2km and 10km is quite large
Consider data dissemination mechanisms

• Future applications are likely to use more of the spectrum
  • Integration of chemistry transport models and strongly-coupled chemistry systems
  • Channel selections will be less and less relevant

• DBNet data usage
  • A large barrier to picking up DB-Net data is the lack of consistency with the global products.
  • Consider delivering global products in a way that allows a consistent DBNet product.
  • Centres value DBNet as a back-up to the global data supply but also because the **improved timeliness** means the observations are valuable for short cut-off forecast runs.