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Application of Multi-Source Fusion Real-Time Analysis Products in Weather Conferences in Qinghai Province

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Abstract: This paper focuses on the application of multi-source integrated real-time analysis products in Qinghai Province's weather discussions. Due to Qinghai's high-altitude location, complex terrain, and sparse observation stations, traditional data struggle to meet user application and scientific research demands. Through a "three-tier optimization" system tailored to Qinghai's characteristics, the integration of diverse data types plays a pivotal role in monitoring plateau blizzards and cold waves, issuing severe convective weather warnings, and serving Lake Qinghai and eastern agricultural regions during discussions, thereby supporting precise decision-making. The paper also identifies current challenges such as data gaps and timeliness, proposing improvements like adding observation stations and optimizing algorithms to enhance meteorological ecosystem services in Qinghai.

Keywords: Qinghai Province; Multi-source Fusion Real-time Analysis Product; Weather Forecast.

1. Introduction

Qinghai Province, located in the northeastern Qinghai-Tibet Plateau, features vast expanses and complex topography encompassing diverse landscapes including plateaus, basins, mountains, and river valleys [1]. Most areas exceed 3,000 meters in elevation, resulting in pronounced vertical climatic variations. This unique geography results in sparse meteorological observation sites across Qinghai. Concurrently, the warming and moistening of Northwest China due to global warming, coupled with the occurrence of La Niña and El Niño events, has made plateau weather and climate increasingly unpredictable [2]. Faced with challenges such as the rapid evolution of plateau weather systems and the sudden onset of severe weather events (e.g., blizzards, cold waves, severe convective storms, dust storms), traditional single-source observational data struggles to meet the demands of provincial-level weather conferences for comprehensive, precise real-time meteorological information. With the rapid advancement of meteorological observation systems, an increasing volume of data is being collected from ground-based automatic weather stations, radars, satellites, and other sources. Various industries urgently require rapidly updated, feature-rich, high-quality multi-source fusion real-time analysis products (referred to as real-time analysis products) [3]. By integrating data from ground automatic stations, plateau meteorological stations, satellite remote sensing, radar monitoring, and numerical forecast models, and through customized optimization tailored to Qinghai's plateau meteorological observation characteristics, these products generate high-precision meteorological element real-time fields adapted to the plateau environment. This provides critical technical support for Qinghai's weather consultation, effectively enhancing regional severe weather warning capabilities and ecological meteorological service levels.

2. Multi-source Data Fusion Technology Tailored to Qinghai's Geographic Characteristics

Meteorological observation data from Qinghai Province exhibits the characteristics of 'three excesses and three deficiencies': excessive gaps in remote areas, excessive errors in complex terrain and excessive interference from extreme weather; insufficient stations in plains; insufficient high-precision equipment; and insufficient continuous observation data. To address these challenges, the real-time analysis product uses a 'three-layer optimisation' fusion system. At the data preprocessing layer, the system focuses on resolving data gaps caused by low-temperature freezing damage at plateau stations. Spatiotemporal interpolation from neighbouring stations is utilised, and historical data from the same period is compared to fill observational gaps in uninhabited areas such as the Three Rivers Source Region and Kekexili. At the fusion algorithm layer, a physical parameterisation scheme for the plateau boundary layer is introduced to correct inversion biases in satellite remote sensing at high altitudes. At the product validation layer, observation data from national and regional stations in Qinghai are used to create an accuracy assessment model for the real-time analysis product. Missing data interpolation is also provided for multiple stations to ensure stable and efficient data support while continuously improving response speed [4]. This ensures that the fusion errors of elements such as air temperature, precipitation and wind speed meet the accuracy requirements for provincial-level weather discussions.

Furthermore, addressing Qinghai's ecological meteorological service needs, the operational analysis product specifically integrates specialized data such as remote sensing monitoring of pasture growth, glacier and snow cover extent, and lake water level changes. This research on "meteorology + ecology" integrated operational fields provides dedicated product support for consultation topics like ecological conservation in the Three Rivers Source National Park and governance of the Qinghai Lake basin. For

instance, during annual pasture growth season discussions, these products combine precipitation and temperature data to assist in assessing grassland carrying capacity, providing decision-making support for livestock production scheduling.

3. Core Application Scenarios of Real-Time Analysis Products in Qinghai Provincial Weather Consultations

3.1. Precise Monitoring and Early Warning of Plateau Blizzards and Cold Waves

Blizzards and cold waves are major winter hazards in Qinghai, and traditional single-point observations struggle to capture their large-scale movement processes. The multi-source fusion real-time analysis product integrates data from 1,000 ground automatic stations, next-generation weather radars, FY-4A satellite cloud imagery, and numerical forecast models to generate hourly snowfall and temperature fields with 1-kilometer resolution. This clearly depicts the movement paths of heavy snow centers and the advancement speed of cold air masses during cold waves. Additionally, these products enable real-time monitoring of snow depth distribution and precipitation phase distribution. By comparing with historical data for the same period, they assess the impact of snow accumulation on wintering pastures and protected agriculture, providing data support for formulating snow disaster relief plans during consultations.

During cold wave consultations, real-time analysis products provide province-wide 24-hour temperature drop distribution maps, with special annotations highlighting extreme low-temperature zones in southern Qinghai plateau regions like Yushu and Guoluo. By integrating upper-air sounding data with ground observations, these products analyze the thickness and intensity of temperature inversions during cold waves. This assists forecasters in determining the duration of low-temperature damage, providing precise basis for consultation decisions on livestock cold protection, power grid freeze prevention, and deicing measures.

3.2. Short-term and Immediate Warnings for Severe Convective Weather in the Three Rivers Source Region

As the source region of the Yangtze, Yellow, and Lancang Rivers, the Three Rivers Source Area features complex terrain and sparse observation stations. Severe convective weather events—such as intense short-duration precipitation and thunderstorm winds—occur suddenly with significant destructive power. The multi-source fusion real-time analysis product integrates "radar + satellite + ground station" data to build a severe convective weather identification model, enabling precise detection of small-scale convective systems during provincial weather consultations. Furthermore, for short-duration heavy rainfall in the Three Rivers Source Region, the analysis product integrates real-time soil moisture data to assess flood and debris flow risks. It generates three-dimensional fusion maps combining temperature, precipitation, and topography, aiding disaster impact assessments during consultations and providing scientific references for emergency management agencies to formulate rescue plans.

3.3. Fine-scale Meteorological Service Conferences for the Qinghai Lake Basin and Eastern Agricultural Areas

Lake effects in the Qinghai Lake basin and agricultural meteorological services for the eastern Huangshui River Valley are key topics in provincial weather consultations. Multi-source integrated real-time analysis products are being developed to address these specific needs: - For Qinghai Lake basin discussions, real-time analysis products will integrate lake surface temperature, wind speed, and water vapor flux data to analyze the lake effect's influence on precipitation in surrounding areas, serving tourism safety and fishery production scheduling around the lake. For Qinghai Lake ice melt discussions, specialized products will be developed: by integrating satellite-derived ice albedo data with ground-station air temperature observations, precise calculations of ice melt rates will predict complete ice breakup timing, providing critical references for bird migration monitoring and eco-tourism season planning. During spring planting season consultations in eastern agricultural zones (e.g., Xining, Haidong), real-time analysis products will integrate soil moisture conditions, accumulated temperature data, and crop growth models to generate agricultural meteorological suitability distribution maps. These maps will assess planting conditions for spring wheat and rapeseed, providing data support for formulating agricultural production recommendations during consultations.

4. Application Challenges and Optimization Directions

The application of multi-source fusion real-time analysis products in Qinghai's provincial weather consultations currently faces three challenges: First, observational data gaps persist in parts of the southern Qinghai Plateau (e.g., the core area of Kekexili), leading to reduced accuracy of analysis products in these regions. Second, low clouds and dust storms on the plateau significantly interfere with satellite remote sensing data, causing fusion errors in humidity, precipitation, and other parameters. Third, the update frequency of the analysis products (currently hourly) lags behind the real-time requirements of Qinghai's short-term weather discussions. Additionally, some grassroots forecasters lack sufficient understanding of the plateau-specific characteristics of these products, failing to fully leverage their technical advantages during discussions.

To address these issues, optimization should proceed on three fronts: First, accelerate the construction of Qinghai's "Smart Meteorology" observation network by adding unattended weather stations and millimeter-wave radars in the Three Rivers Source Region and southern Qinghai Plateau to fill data gaps. Second, develop specialized high-altitude fusion algorithms incorporating dust storm correction models and low-cloud identification techniques to reduce observational interference. Third, enhance product update timeliness by shortening data processing cycles through cloud computing to meet short-term consultation demands. Concurrently, strengthen forecaster training by implementing case-based teaching of real-time analysis products in plateau weather consultations to improve their application capabilities.

5. Conclusion

By integrating multi-type, multi-scale meteorological data, the multi-source fusion real-time analysis product effectively addresses operational challenges posed by Qinghai's plateau topography and sparse observations. It plays an irreplaceable role in monitoring and warning against hazardous weather such as blizzards, cold waves, and severe convective storms, as well as in ecological and agricultural meteorological service consultations. As Qinghai advances its "meteorological modernization" initiative, these multi-source integrated real-time analysis products will further optimize plateau-adaptive technologies, enhance spatiotemporal resolution and update timeliness. They will become core technical tools supporting plateau disaster prevention, ecological conservation, and agricultural production in provincial weather discussions, providing more robust meteorological support for Qinghai's development as an ecological civilization highland and a modern new Qinghai.

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